BALANCE Interim Report No. 24

Towards a representative MPA network in the Baltic Sea

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Towards a Representative Network of Marine Protected Areas in the Baltic Sea	24
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0 EXECUTIVE SUMMARY

The importance of establishing representative and ecologically coherent networks of Marine Protected Areas (MPAs) has been emphasized by many governments, scientists and by international agreements e.g. the Convention on Biological Diversity. Regional agreements within HELCOM and EU directives further state the importance of establishing an ecologically coherent network of marine protected areas in the Baltic Sea. A successful implementation of these agreements and directives require a systematic approach.

In this report we develop a systematic and coherent approach for identifying MPAs in the Baltic Sea and provide the basis for a plan of action. Prior approaches have largely been done on an ad-hoc, site by site basis without regional coordination. A systematic approach for planning in the marine environment are now well developed and widely recognized. This provides a transparent, scientifically credible and efficient framework for the planning of MPA networks to meet the conservation criteria and management objectives. This report provides the first steps towards development of a regional systematic approach to MPA site selection in the Baltic Sea.

The computer based decision support tool MARXAN was used to demonstrate the selection of a network of MPAs including representation of all benthic marine landscapes in the Baltic Sea and some selected species and habitats. A benthic environment classification model was used to identify the benthic marine landscapes with the assumption that a representation of these landscapes would capture the full range of biodiversity in the Baltic Sea, Kattegat and Skagerrak, on a broad scale.

To support MPA decision making in the Baltic Sea, we provide several different scenarios where we vary the target levels and whether or not existing MPAs are included in the network design. Three uniform representation target scenarios were explored to illustrate different levels of conservation ambition; minimum 20 percent, 10 percent and 30 percent representation of all benthic marine landscapes. Specific targets were set for representation of specific species and habitats. The selected sites represent a minimum quantity of all conservation features at the minimum area required and fulfil a range of criteria for spatial arrangement, such as site suitability and complementarity. We primarily identified MPAs that would complement existing MPAs already designated under the Habitats Directive.

We also examined how efficient the existing MPAs were at meeting the management objectives and what would be required to extend this existing network to meet the conservation targets. 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 about three times the existing sites. The total coverage of selected <u>and</u> existing sites in this scenario was equivalent to approximately 30 percent of the entire Baltic Sea water surface. However this coverage is based on the specific analysis criteria applied in this assessment and as other criteria are added the results will change.

All of the scenarios help inform decision making, and the scenario with minimum 20 percent representation target that includes existing MPAs is likely the most informative for envisioning a network of Baltic Sea MPAs (Figure 1). The result presented should be seen as a first step in a continuously improving and iterative MPA-planning process, aiming towards a coherent, well managed network of sites representing the whole range of marine biodiversity in the Baltic Sea.

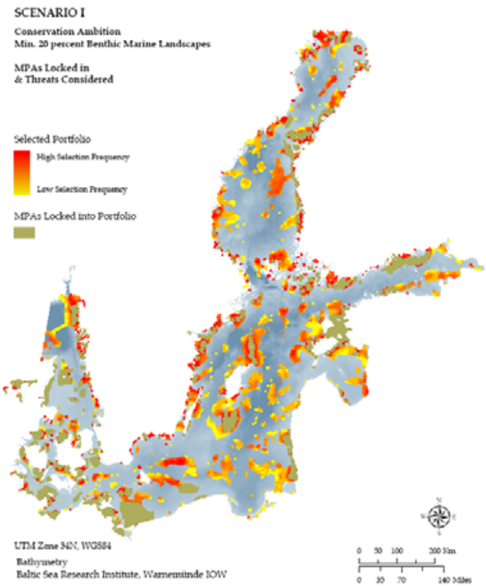

Figure 1. 20 percent representation target that includes existing MPAs.

We have also in a case study in the Swedish Archipelago - Åland - Archipelago Sea area, illustrated how the regional broad scale assessment can be improved with access to more biodiversity data, such as marine Natura 2000 habitats and fish recruitment areas.

We could conclude that it is possible to apply a broad scale systematic approach in the Baltic Sea region. If the aim is to establish a representative network in the region, 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. Using decision support tools such as MARXAN secure an efficient process and increase the likelihood that the selected network make efficient use of available resources and satisfy the whole range of ecological and socio-economic targets. A systematic approach to selecting a representative network of sites is a key component in a broad scale ecosystem based spatial planning process in the Baltic Sea.

It is important to keep in mind that the MPA-planning process involves many more steps than the initial site selection, e.g. negotiations with stakeholders and experts and development of a management and zoning plan. Planning for marine protected areas should be viewed as an adaptive process, allowing for continuous improvement in both method and outcome.

1 INTRODUCTION

Marine Protected Areas (MPAs) are increasingly accepted as a tool for conserving marine biodiversity. The importance of establishing representative and coherent networks of MPAs, aimed at protecting the full range of habitats and species in a region, have been underlined by a number of international conventions and agreements e.g. the World Summit for Sustainable Development (WSSD) and the Convention on Biological Diversity (CBD). The establishment of MPA networks in the Baltic Sea has primarily been guided and governed by the EU Habitats (1992) and Birds Directive (1979) and HELCOMs recommendation 15/5 including the HELCOM guidelines for designating marine and coastal Baltic Sea Protected Areas (2003) and the HELCOM-OSPAR Ministerial Declaration (2003). All these agreements state the importance of establishing an *ecologically coherent* network of marine protected areas in the Baltic Sea.

A systematic approach to site selection has been recommended by conservation experts as it maximises the chance of creating MPA networks that meet the conservation criteria and objectives, ensures a transparent and defensible process while making efficient use of available resources (Leslie et al. 2003, Margules & Pressey 2000). Despite this, a regional systematic approach to site selection has so far been lacking in the Baltic Sea, and in many other parts of the world. The 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. More sites have also been designated in coastal areas than offshore. Most of the marine sites designated in the Baltic Sea also have a terrestrial component such as important bird or seal skerries. These sites have rarely been selected primarily based on marine biodiversity values below the sea surface.

The aim of this report is to introduce a regional, systematic, transparent and ecologically based approach to select and protect a representative network of sites in the Baltic Sea. We have introduced and tested an approach to select a network of marine protected areas 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[1]. One of the main principles has been to build on already existing MPAs by selecting new sites that complement already designated sites under the EU Habitats Directive.

The computer based decision support tool MARXAN (version 1.8.6: Ball & Possingham, 2000) was used to demonstrate the selection of a representative network or portfolio of marine protected areas in the Baltic Sea. Decision support tools are helpful in a systematic site selection process since consideration of large amounts of spatial data and an enormous number of possible combinations of sites often is required, a task that

[1] Marine landscapes are a broad scale characterisation of the marine environment using physical parameters such as salinity, available light and sediments. For more information please see chapter 5.2 or Al-Hamdani & Reker 2007.

is virtually impossible without computer support. Having been used successfully in other parts of the world, this introduces and tests MARXAN in the Baltic Sea context.

It is important to underline that the MPA-planning process involves more steps than just identifying and selecting candidate sites for protection e.g. negotiations with stake-holders, development of management and zoning plans. **The result presented here should therefore be seen as a first step in an iterative and continuously improving process towards identifying and protecting a network of sites representing the whole range of marine biodiversity in the Baltic Sea.**

Finally, the Baltic Sea countries all share the responsibility of protecting and managing the Baltic Sea biodiversity. The Baltic Sea ecosystem must be protected through a joint approach, where all countries share the responsibility for action. Political agreements on the overall principles and objectives are essential for a successful approach to protecting the Baltic Sea ecosystems.

Table 1. Definition of terms.

Conservation features	The biodiversity elements that should be represented in the net-work, e.g. marine landscapes, habitats and species.
Coarse filter features	Conservation features expected to capture the full range of biodi-versity in the study area by representing broad scale ecological units, such as benthic marine landscapes.
Fine filter features	Conservation features that may not be represented by using coarse filter features alone e.g. specific species or habitats.
Conservation targets	The amount or proportion of the range of each of the conserva-tion features to be represented in the network
Planning Unit	A subdivision of the planning area to be considered for inclusion in the network or portfolio of sites.
Portfolio	A term used to describe a collection of planning units making up a network of sites. MARXAN is used to identify portfolios that to-gether meet all conservation targets.
Stratifying Units	Large spatial units that represent areas or regions that may be biologically distinct, or that enable the stratification of the network across political boundaries or geographic ranges.
Suitability Surface	A map representing the relative suitability of areas across the study area for positioning a protected area. This may represent a proxy for threat or for economic loss or any factor that may be relevant to the suitability of a site for the designation of an MPA.

2 EXISTING NETWORKS OF PROTECTED AREAS IN THE BALTIC SEA

This section briefly describes the existing Baltic Sea MPA networks and how they have been included/considered in the site selection process. Both these protected area networks aim towards being ecologically coherent.

The Baltic Sea Protected Area network (BSPAs) is based on HELCOM Recommendation 15/5 (2003). The network aims to protect areas with high biodiversity, habitats of endemic, rare or threatened species and communities, habitats of migratory species, and rare, unique, or representative geological or geomorphological structures or processes. The BSPA network consists to date (HELCOM HABITAT 9, 2007) of 78 Notified and Designated BSPAs, 14 proposed BSPAs (by Rec. 15/5), and 13 sites proposed through expert consultation (Skov & Hägerhäll, 1998). The sites are only protected by the contracting parties' national legislation. Management plans have been implemented for some of the 78 sites, but several sites either lack a plan, or have a plan 'under preparation'. Many designated BSPAs overlap with Natura 2000 sites and the BALANCE site selection exercise has therefore not included the BSPA network, but focused on the Natura 2000 network.

The European Union (EU) is committed under the Convention on Biological Diversity (CBD) to protect and, if necessary, restore biodiversity in all Member States. This commitment is implemented, in part, by the EU Habitats and Birds Directives (EC Habitats Directive, 1992; EC Birds Directive 1979). The two directives together form a commitment to a network of sites called Natura 2000, designed to protect specific species and habitats in Europe.

The Natura 2000 network is a key component in the EU's efforts to conserve biodiversity. It is made up of protected areas designed to maintain or restore important habitats and species at a favourable conservation status. Fully implemented, the Natura 2000 network is to span the entire EU to create an ecologically coherent system of representative sites on land and at sea. However, due to the insufficient number of marine habitats identified in Annex 1 of the Habitats Directive it is unlikely that this goal will be reached in the near future.

Special Areas of Conservation (SACs) designated under the Habitats Directive aim to protect habitats listed in the Annex I of the Habitats Directive and habitats of importance for species listed in the Annex II, whereas Special Protected Areas of Conservation (SPAs) designated under the Birds Directive on the other hand, aim to protect the European avian fauna (species listed in Annex 1 of the Birds Directive), especially its breeding, feeding, resting and moulting areas.

The EU Biodiversity Action Plan states that a complete network of SPAs should be established by 2008. Management priorities and necessary conservation measures for SPAs should be established by 2012. The SAC network should be designated by 2012 (marine sites) and management and conservation measures should be established by 2012 (marine sites).

The main distinction between SACs and SPAs is that the Habitats Directive aim to protect the entire habitat from any actions that threaten the viability of the habitats and/or species for which the SAC has been designated, whereas the Birds Directive only aims at prohibiting actions which threaten viable populations of the listed bird species, but not necessarily the benthic environment. We have in this analysis primarily focused on coastal and marine sites designated under the Habitats Directive, since the overall aim of the site selection was adequate representation of all broad scale benthic habitats.

Russia and Norway are non-EU countries, not bound to the implementation of the Habitats and Birds Directive. Consequently, there are no designated Natura 2000 sites in their waters. There are, however, corresponding initiatives to establish marine protected areas such as the Emerald Network, which is the equivalent of Natura 2000 in non-EU European countries. These have not, however, been taken into account in this assessment.

2.1 Current representation status of the Natura 2000 network

An assessment of the Baltic Sea Natura 2000 network completed within the BALANCE project revealed several gaps in representation of benthic marine landscapes and also in the distribution of sites geographically (Piekäinen & Korpinen, 2007).

Approximately 7 percent of the Baltic Sea (including the Baltic Sea, Kattegat and Skagerrak) is designated to the Natura 2000 network under the Habitats Directive, representing approximately 11 percent of the territorial waters and 3 percent of the Exclusive Economic Zone, EEZ. The territorial waters, out to 12 nm from the coast, was used as a proxy for coastal waters and offshore waters were represented by the area outside the territorial waters out to the outer boundary of the EEZ. The territorial waters are generally much better represented than areas offshore.

Altogether, 60 benthic marine landscape types were identified in the Baltic Sea (for more details on benthic marine landscape mapping see Chapter 5.2 and Al-Hamdani & Reker, 2007). The proportion of each of the landscape types that were covered by Natura 2000 sites was calculated using GIS. The data only allowed the analysis to be completed on a very coarse scale. This should be kept in mind when interpreting the results.

To a large extent, there is a lack of solid scientific evidence for how large a proportion of a landscape, habitat or species is needed to ensure viable populations of all species into the future. Nevertheless, many scientific reports suggest that about **20** percent is the minimum level of protection required for each habitat to ensure long term population viability. There are also a number of international conventions and agreements supporting the same minimum level of protection. For example, the European Commission use a minimum of **20** percent (for non-priority habitats) and more than **60** percent (for priority habitats) of each habitat as a guiding principle for sufficient protection when evaluating the EU-member states contribution to the Natura 2000 network (see Chapter 4.2). Based on this, a representation of at least 20 percent of each benthic marine landscape was considered the minimum level of representation when evaluating the Natura 2000 SAC and SPA networks. The assessment was done using uniform representation levels, however it can be discussed whether such an assessment should be done using specific levels set individually for each landscape, based on some measure of distribution and abundance or threat to the individual features.

The proportionate representation of landscapes were categorized according to five levels; bad <10 percent, poor 10-20 percent, moderate 20-30 percent, good 30-60 percent and high 60-100 percent. Less than one third (19/60) of the marine landscapes were found to be in quantities of over 20 percent of its distribution being within designated SACs. The corresponding figure for all Natura 2000 sites (SACs and SPAs) is 23/60, i.e. only a slight improvement. (Table 2). It is important to keep in mind that a habitat listed in Annex 1 to the Habitats Directive is not by default protected if present within a SPA, and that habitats not mentioned within the Habitats Directive is not by default protected even if present within either a SAC or SPA. In this analysis, however, it was assumed that all habitats present within a marine protected area are protected.

The major part of the designated Natura 2000 sites (**SACs**) cover benthic landscapes with bottom substrate dominated by **sand (15%)**, **hard bottom (12%)** and **bedrock (12%)**, whereas there is much less coverage of benthic landscapes where **mud or hard clay** are the dominant bottom substrates (**approx. 3%**). In summary, none of the sediment categories are represented to more than 20 percent and most of them are represented to less than 10 percent. Figure 2 shows an example taken from the Kattegat.

Generally, most designated sites are established in the euphotic zone. SACs protects only 4 percent of the benthic landscape types occurring in the non-photic zone. This coincides with the geographical distribution of sites being dominated by coastal areas. The same trend is seen independently of bottom substrate type or salinity category.

Moreover, the majority of all SCAs and SPAs in the Baltic Sea territorial water (77% or 692 out of 900) are smaller than 1000 hectares, which, according to HELCOM (recommendation 15/5) is the minimum required area for a coastal site.

This assessment shows that the current Natura 2000 network in the Baltic Sea does not fully represent the existing biodiversity in the region. A regional, integrated and systematic approach to select and protect a representative network of sites in the Baltic Sea should be applied to fill the identified gaps.

Table 2. The proportion of each of the marine landscape types were categorized according to five representation levels; Bad <10 percent, Poor 10-20 percent, Moderate 20-30 percent, Good 30-60 percent and High 60-100 percent.

Representation	Number of landscape types within Natura 2000 SACs	Number of landscape types within Natura 2000 SACs+SPA s
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

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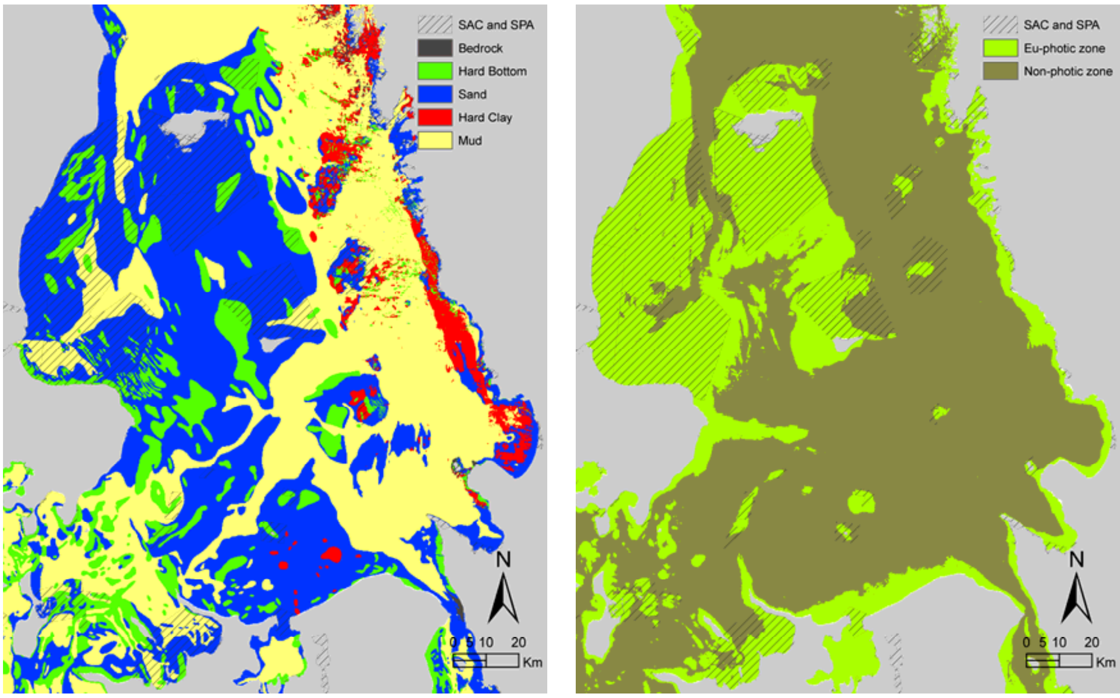

Figure 2 a) The map shows the Kattegat area between Denmark and Sweden. A large proportion of the designated area (striped) occur in benthic landscapes with bottom dominated by sand, (blue), whereas designated area in benthic landscapes dominated by mud (yellow) are very rare. b) Generally most of the designated area (striped) occurs in benthic landscapes in the photic zone (green) whereas landscapes in the non-photic zone are much less covered (brown). This coincides with the geographical distribution of sites being dominated by coastal areas in the territorial waters.

3 PRINCIPLES AND CRITERIA FOR SITE SELECTION

The overall objective of the network of marine protected areas selected during this analysis is to protect the biodiversity and ecosystems in the Baltic Sea region. This is in line with the EU Habitats and Birds directives and HELCOMs recommendation 15/5 on Baltic Sea Protected Areas. Management of natural resources, e.g. increasing the catch of commercial fish species, is therefore not considered as the primary objective. Protection of spawning grounds and nursery areas for fish has e.g. been shown to have a positive impact on populations of commercial fish species (Roberts et al. 2000).

The network of selected sites should ultimately represent adequate quantities of the whole range of marine species, habitats and ecological processes in the Baltic Sea Region and ensure sufficient representation in each of the sub-regions where they occur. The network should also build on existing networks of marine protected areas, take socio-economic interests into account and minimise the impact on conflicting interests and select sites of adequate size in relation to the broad regional scale analysis.

Representation in its simplest form means '*protecting some of everything*', in this case ensuring that all marine landscapes, habitats, species and ecological functions in the region are adequately protected. Representation can be seen as insurance in situations with lack of knowledge about the exact distribution of species and habitats. By protecting a representative and accurate share of the marine area, also unknown biodiversity will most probably be covered.

3.1 Conservation features

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. Ideally, an assessment should include data to ensure that all biodiversity is represented. However, mapping of every population, species and habitat type as well as the interactions associated with them, is impossible. Therefore the use of coarse filter conservation features that act as surrogates for the broader biodiversity are a main component in this analysis. 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. The "fine filter" is expected to ensure inclusion of 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" (Beck et al., 2003) e.g. threatened, rare or declining species or habitats.

A draft list of conservation features representative for the Baltic Sea was identified at an initial stage of the analysis, based on a literature review, relevant political frameworks, experiences from similar projects in other parts of the world and a workshop with representatives from partners in the BALANCE project. A questionnaire was also sent out to a group of experts and relevant authorities in the Baltic Sea region to get input on the proposed conservation criteria. The aim was to develop criteria based on both scientific knowledge and expertise, as well as on political frameworks, conventions and recommendations. For a complete list of all the conservation features originally listed, see

Appendix 1, Table 4 and also to the BALANCE Interim Report No. 2 '*Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea a strategy*' (Andersson & Liman, 2006).

The original list of conservation features was revised during the project, on the basis of spatial data availability and access. Only species and habitats for which there were access to reliable and coherent spatial information covering the entire Baltic Sea region could be 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. The conservation features to be represented in the selected network are listed below.

Coarse filter features:

The **benthic marine landscapes**, mapped within the BALANCE project, were the primary conservation feature for which the portfolios presented in this report have been selected. The modelling of benthic marine landscapes is based on 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. (For more details on benthic marine landscape mapping see Chapter 5.2.1 and Al-Hamdani & Reker, 2007)

Fine filter features:

The original list of fine filter conservation features was heavily revised based on data availability. The fine filter conservation features for which the network/portfolios of sites presented in this report have been selected are:
Cold water corals (*Lophelia pertusa, Paramuricea placomus, Primnoa resedaeformis)*
Areas of importance for sea birds *(Important Bird Areas, IBA)*
Haul out sites for Grey Seal (*Halichoerus grypus*)

3.2 Conservation targets

How large a proportion of the distribution of each conservation feature is needed to offer adequate protection and to ensure long term viability? In other words, what conservation targets should a representative network of MPAs aim towards? There is limited knowledge and support to be found in scientific literature with regard to how much of a certain habitat or species should be protected to ensure sufficient protection. However, some examples do exist in both scientific and grey literature.

According to scientific recommendations, **30-50 percent** (Airamé et al., 2003) or **20-50 percent** (Saldek Nowlis & Friedlander, 2005) **of each habitat** should be protected to ensure viability of populations. In a review of over 30 studies addressing the question of how much of a sea area should be protected, Roberts & Hawkins (2000) found that the estimates ranged from **10** to **80 percent** of the sea area. The majority of these 30 studies were from a fisheries perspective, seeking to find how much of a *sea area* should be protected to maximize fish catches. The answer varied depending on the characteristics (e.g. mobility or vulnerability to fishing) of the species considered. In the case of highly migratory species, such as cod, the reserve should even include 80 percent of the fishing grounds (Lipcius et al., 2005). The potential size of the stock or population of Baltic Cod is directly linked to the size of the habitat available for spawning or rather the volume of water mass with higher than 11 psu and more than 2 mgO_2/l (Nielsen & Kvaavik 2007).

In summary, it seems that many scientific reports suggest that **20 percent of each habitat** should be protected to ensure long term population viability. There are also a number of international conventions and agreements supporting the same minimum level of protection:

- The World Parks Congress in Durban 2003 recommended that "*marine protected area networks should be extensive and include strictly protected areas that amount to at least **20-30 percent of each habitat***" (IUCN, 2003).

- U.S. National Research Council in their report on marine protected areas (NRC 2001) supports the idea that **20 percent of each habitat** needs to be protected in order to provide at least some degree of support for fisheries and biodiversity.

- The European Commission use **20 percent** and **60 percent** (for priority habitats) coverage of **each habitat** type as a guiding principle for sufficient protection when evaluating the EU member states contribution to the Natura 2000 network.

The Convention of Biological Diversity recommended that at least **10 percent of each of the world's ecological regions** should be effectively conserved, to ensure conservation of the biological diversity of ecosystems, habitats and biomes.

Within this analysis, 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 will probably increase if the targets also are in line with the political agreements listed above. We have therefore tried to incorporate both these aspects into our 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 sites will still partly support some species and ecosystems.

The conservation targets for this analysis are listed below.

Conservation targets; coarse filter features:

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

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

Conservation targets; fine filter features:

Individual targets were set for each of the fine filter conservation features according to the following:
Important Bird Areas: The IBAs were given uniform targets following the same target scenarios as the coarse filter features (20, 10 and 30 percent).
Grey Seal: In accordance with the guiding principles in the Habitats Directive a representation target for the Grey Seal haul out sites was set to 60 percent in all scenarios.
Cold water corals: Cold water corals are very rare with few occurrences only in the 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. However, a lower target of 60 percent was set for dead reef structures.

3.3 Other principles

Apart from setting conservation targets based on minimum representation, criteria for spatial representation in the region were also set to guarantee that the network of sites fulfil some basic principles. The principles are summarized below and further described in the following text.

Other principles for the network:

1. All existing protected areas should be included in the selected network/portfolio of sites. Complementary sites should be added to the already designated Natura 2000 sites.
2. All conservation features should be represented to their targets within each political unit (exclusive economic zone) and each ecologically different sub-region.
3. Socio-economic factors and the suitability of sites should be taken into account during the site selection process. The conservation targets should be met with a minimum impact on other interests and consider the relative suitability of potential conservation sites.
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.

1. All existing protected areas should be included in the selected network/portfolio of sites

One of the principles for the site selection was to build on the existing protected areas and select complementary sites until the existing and selected sites together meet the defined conservation targets. Adequate representation of all broad scale benthic habitats was the overall aim of the site selection, and therefore it was most reasonable to primarily consider including the coastal and marine sites designated under the Habitats Directive.

However, a separate scenario with all existing Natura 2000 sites (SAC and SPA sites) included has also been considered. This particular scenario is of interest since expanding and/or strengthening the protection of the SPAs by designating them also as SACs is politically more likely to be achieved, than designating new sites without any previous protection status.

2. All conservation features should be represented and targets met throughout the entire region where the feature occurs

The portfolios were selected from conservation features stratified in line with ecologically different sub-regions to ensure sufficient representation of all conservation features across their natural range of variation. An even distribution of sites across non-Baltic Sea countries was also ensured by using stratification in line with political boundaries, i.e. the countries' exclusive economic zones. This stratification ensures that conservation features are each fully represented both within each political unit and within each ecologically different sub-region.

Ecological Stratification Units:

The Baltic Sea is naturally divided into different water basins separated by shallow thresholds and the distribution of biodiversity is strongly dependent on the salinity gradient from the Bothnian Bay to Skagerrak. The ecological differences between these sub-regions were taken into account by ensuring that all conservation features were stratified accordingly. All fine filter features were stratified in line with six sub-regions (the Bothnian Bay, the Bothnian Sea, The Baltic Sea, The Gulf of Finland, Kattegat, and Skagerrak). The benthic marine landscapes were not stratified since they already have a salinity component ensuring stratification in line with the major salinity shifts.

Stratification of targets will also ensure 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 community level and variation in ecosystems as well as distribute the sites to spread risk (Beck et al., 2003). Stratification was also used to guide the distribution of sites spatially, i.e. between political units, such as national boundaries.

Political Stratification Units:

All conservation features were stratified by the exclusive economic zones to ensure that selected sites were distributed evenly between countries in the region. This was considered important for political reasons. The Baltic Sea is shared by nine countries and protection of the marine biodiversity should therefore also be a shared responsibility between all countries.

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

A network of marine protected areas must meet the minimum biodiversity conservation objectives, but to be realistic and accepted by stakeholders it is also important to consider the relative suitability of potential conservation sites.

This aspect should be included during the site selection process. A "suitability map" was therefore created and used in the analysis to guide the selection of sites away from areas less suitable for conservation, and towards areas offering equal conservation values in a more suitable environment.

Suitable areas could be where there is low political or social pressure or threat to biodiversity. Unsuitable areas can be, for example, areas with a high level of threat, management practicality or high conflicting interest from other sectors. 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.

The original list of socio-economic activities to be incorporated into the analysis was, revised during the project, on the basis of spatial data availability, access and quality. For a complete list of all the socio-economic activities originally listed, see Appendix 1, Table 5 and also to BALANCE Interim Report No 2 (Andersson & Liman, 2006).

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

The selection of portfolios aims to be as efficient as possible in terms of the area selected. However, a portfolio being maximised 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 portfolio. Therefore the selected portfolios all have relatively large patches of selected units.

In summary, this section has described the criteria (conservation features, targets and other network principles) for a broad scale representative network in the Baltic Sea, as defined by the BALANCE project.

4 MARXAN; A SITE SELECTION TOOL

This section briefly describes the decision support tool used to demonstrate the selection of a broad scale representative network fulfilling the criteria described above.

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. It is designed to help automate the planning process so that a team of planners can offer many different conservation plan scenarios. It can be used to offer planning scenarios that are alternatives to pre-conceived patterns of protected area networks. It can also be used to offer alternatives and solutions where the input of local stakeholders is highly valued and a compromise with prospects for achievable results is sought.

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. A pattern of priority sites, known as a portfolio, that satisfy explicit quantitative biodiversity targets can be identified that are of the most suitable areas. Suitable areas could be where there is low political or social pressure or threat to biodiversity, or where resources necessary to implement conservation strategies or threat abatement are forecast to be lower, or any measure appropriate for the locality.

MARXAN has been utilised 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 Selecting Conservation Areas

MARXAN uses a 'simulated annealing' optimization algorithm to evaluate biodiversity conservation features, targets and suitability factors in a spatial context under different alternative scenarios to identify portfolios of sites to be considered in terms of conservation. Suitability of individual sites can be evaluated in locally appropriate ways such as using a measure of threat or conflicting interests from other sectors, or management practicality. Many potential portfolios are assessed according to how efficiently they meet representation, suitability and spatial targets such as connectivity and site replication. This flexibility allows expert knowledge to be utilized where a suite of efficient portfolios that all meet all targets are possible. It also makes it possible to take other interests into account in the site selection process. To allow a comparison between candidate areas, the area of interest is subdivided into smaller spatial units known as 'planning units'. They are parts of the landscape that are analyzed as the potential building blocks of an expanded system of protected areas or areas of conservation priority. Planning units can be natural, administrative or arbitrary sub divisions of the landscape. They differ widely in size between studies and within regions, dependant mostly on scale of analysis and data resolution. The design of planning units considers many factors including the following outlined by Pressey & Logan (1998) that are relevant to this programme:

The size of the planning unit relative to the scale of the underlying features (e.g. planning units that are much larger than underlying fragments of conservation feature can mask the size, shape and extent of fragmentation; planning units that are very small relative to the conservation features will mostly be homogeneous, i.e. small and large patches of habitat will be indistinguishable).

The number of planning units that can be handled by the analysis computer in a time that is reasonable for the intended process (e.g. calculation of conservation feature area within planning units, clustering tests etc). A limit of 20,000 is recommended although 40,000 have been used, but incurs an extended running time).

The size of planning units in relation to the reliability of mapping (e.g. larger planning units could be needed where the locations of the conservation features to be represented are imprecise or where the boundaries of planning units are known to be inaccurate).

The ability of regular grids or hexagons to show per unit area values for criteria such as richness of unprotected conservation features.

Size and shape related considerations such as edge effects, viability of populations and management overheads in the resulting reserves.

Inputs to MARXAN are created from GIS data and are in the form of the area or number of occurrences of biodiversity conservation features within each planning unit, the quantitative conservation target (area, length or number of occurrences) for each conservation feature, the suitability score of each planning unit and the planning unit boundary lengths. The boundary lengths are included in the analysis to allow the selection of planning units clustered into conservation areas. Planning units with a higher suitability would be favoured for selection when biodiversity conservation feature values and clustering implications are similar.

Other user inputs to the analysis include:

- The number of iterations or spatial portfolio configurations to be assessed during each run of the algorithm.
- The number of independent runs of the algorithm.
- The conservation feature penalty factor, (CFPF) is a weight or multiplicative factor which can be put on each conservation feature to determine the relative importance of reaching all targets specified for this feature e.g. if it is more, less or equally important to meet the target for one marine landscape than another.
- A parameter known as the 'boundary length modifier' (BLM) that determines the level of clustering of planning units into conservation areas to improve spatial cohesion of the portfolio.

A low value of BLM will result in widely dispersed and fragmented planning units within the portfolio and conversely a high value of BLM will increase the clustering of the planning units into larger conservation areas, but may result in a higher number of planning units required to meet the targets. The management efficiency, ecological cohesion and connectivity of the portfolio, however, may be greatly increased

The analyses are based on many independent runs of the algorithm, each of millions of iterations. Many levels of BLM can be evaluated and the final value that offers an appropriate balance between ecological coherence and efficiency is carried forward to further analysis.

4.2 The MARXAN Algorithm

MARXAN implements a 'simulated annealing' site optimization algorithm (Ball & Possingham, 2000). In order to design an optimal reserve network, each planning unit is examined for the values it contains. The features (conservation features and a measure of suitability) within one planning unit may be valuable alone but may not be the best choice overall, depending on the distribution and replication of those features in the wider area.

The algorithm attempts to minimize portfolio total 'cost' whilst meeting conservation targets in a spatially compact network of sites or portfolio. This set of objectives constitutes the 'objective cost function':

Total Cost = Planning Unit Suitability Scores + Conservation Feature Penalties + Boundary Length

where 'Total Cost' is the objective (to be minimized), 'Planning Unit Suitability' is a cost assigned to each planning unit, 'Conservation Feature Penalties' are costs imposed for failing to meet biodiversity representation targets, and 'Boundary Length' is a cost determined by the total outer boundary length of the planning units in the portfolio.

During the run of the algorithm, an initial portfolio of planning units is selected and the total cost calculated. In an attempt to reduce the total cost and improve the efficiency of the portfolio, planning units are then added and removed and the total cost re-evaluated through multiple iterations, as follows:

1. A portfolio of planning units is selected at random

2. A planning unit is swapped in or out of the portfolio

3. The change in the total cost is measured

4. The change is accepted if it improves the score

5. Randomly, a change is accepted if it lowers the score, with decreasing frequency through the run of the algorithm

6. Steps 1-5 are repeated millions of times to produce a portfolio

7. Steps 1-6 are repeated hundreds of times

Attempts are made to minimize the total portfolio cost by selecting the fewest planning units with the lowest total unit cost that are needed to meet all biodiversity targets, and by selecting planning units that are clustered together rather than dispersed (thus reducing outer boundary length). Early in the procedure, changes in the portfolio that do not improve efficiency can be made in order to allow the possibility of finding a more efficient overall portfolio. The requirement to accept only those changes that improve efficiency becomes stricter as the algorithm progresses through the set of iterations. Many runs of the algorithm are used to find the most efficient portfolio and to calculate a measure of flexibility (often referred to as summed solution or irreplaceability). MARXAN summed solution is the number of times a particular planning unit is chosen and offers a measure of the flexibility of including of each planning unit in an efficient portfolio that meets all targets.

Alternative scenarios can be evaluated by varying the inputs to the total cost function. The impact of the boundary length cost factor, for example, can be increased or decreased depending on the assumed importance of a spatially cohesive portfolio of sites using the BLM.

4.3 Planning Criteria

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 or even climate change. Dividing the study area by stratifying units ensures this spread of sites and can increase the likelihood of including a greater diversity within the conservation feature in the portfolio by representing it over a larger geographic range. Stratifying units can also include a political component if this is required.

Areas of special interest can be guaranteed to be included in the portfolio. These areas can be ‘locked in’ to the portfolio before the algorithm is run. These may be areas such as existing protected areas or other areas that are particularly important to include.

There are often many more candidate planning units available than needed to meet representation targets. Some locations will be inflexible (or irreplaceable), but for the majority there is some flexibility in which areas are selected to represent each conservation feature. After a portfolio has been selected, planning units can be swapped with units that will provide a similar contribution to the targets, identified by complimentary GIS tools. This aspect can be very useful in a forum where negotiation over which areas are to be selected is occurring, as the consequences of choosing or not choosing a particular candidate area can be explored.

5 SITE SELECTION METHODOLOGY

This chapter describes in detail the methods and data layers used to select portfolios representing a minimum of 20 percent (recommended ambition), 10 percent (lower ambition) and 30 percent (higher ambition) of the benthic marine landscapes.

The delineation and stratification of the study area and the sources of data on the distribution of conservation features and socio-economic factors and the methods used to create a suitability map are also described. Finally, a description of the preparation of input files to MARXAN and an example of a basic calibration of the major input parameter values is presented.

5.1 Study Area and Stratification

The study area was defined as the Baltic Sea region including the Baltic Sea, Kattegat and Skagerrak. The marine area is delineated by a 1:250 000 coastline. The study area was divided into sub-regions defining the ecological and political stratification units (Figure 3).

A data set from HELCOM defining the 18 sub-regions in the HELCOM marine area, the Baltic Sea and Kattegat was used to form the five ecological regions (the Baltic Proper, the Bothnian Bay, the Bothnian Sea, the Gulf of Finland, and Kattegat). The 18 sub-regions were merged according to Figure 1, Appendix 1 to form regions in line with the major thresholds causing the major shifts in salinity. The boundaries delineating the sub-regions were transferred from the original data set coastline to the study area coastline. Skagerrak, which is outside the HELCOM marine area, was defined as the remaining part of the study area. The five ecological stratification units were used to stratify the fine filter conservation features. The benthic marine landscape types were not stratified as they already included a salinity component, which gave approximately the same stratification.

A data set defining the approximate exclusive economic zones for the nine countries) in the region (Finland, Sweden, Russia, Estonia, Latvia, Lithuania, Poland, Germany and Denmark) was used to stratify all conservation features in line with political boundaries.

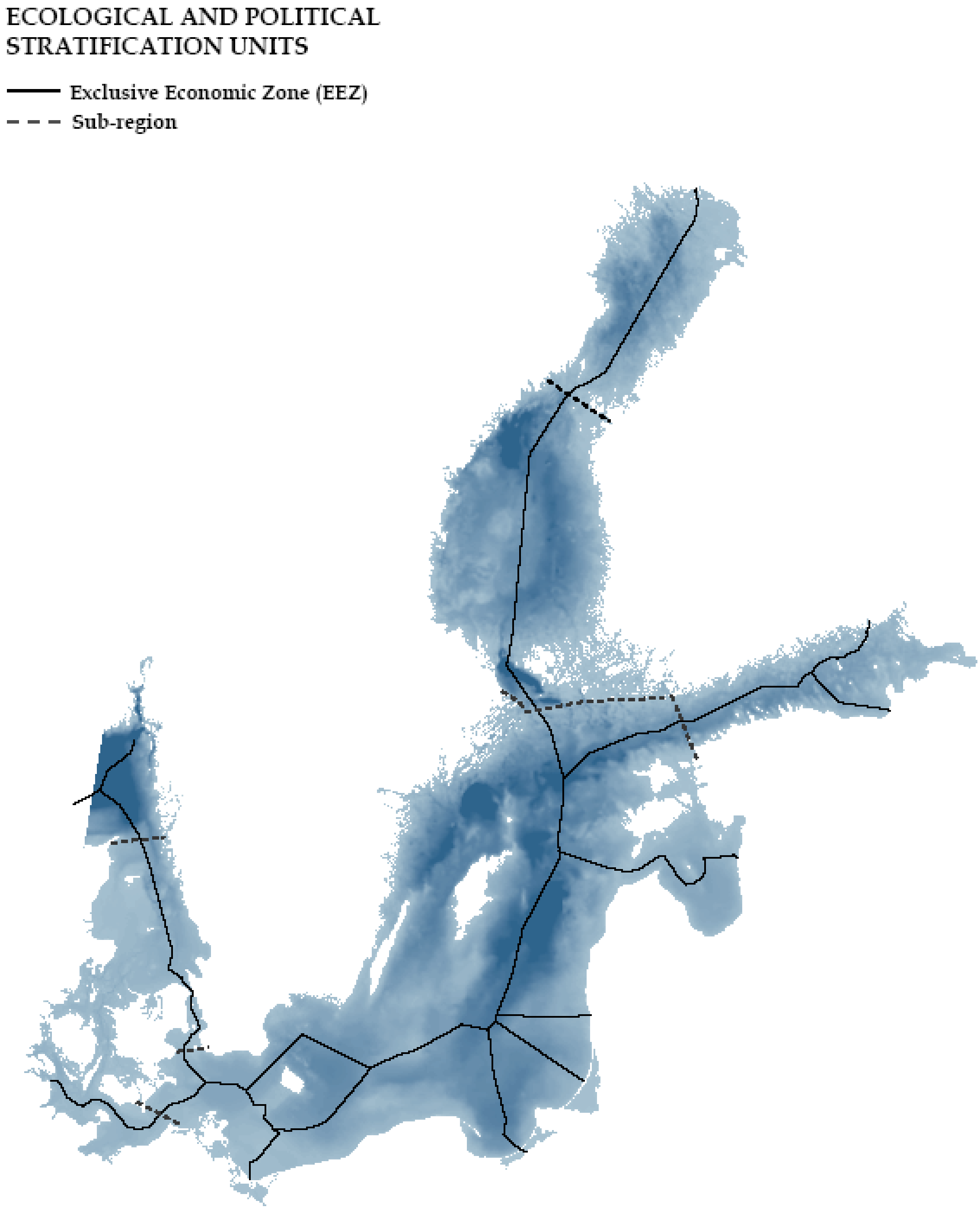

Figure 3. A political stratification following the Baltic Sea countries' exclusive economic zones in the region (Finland, Sweden, Russia, Estonia, Latvia, Lithuania, Poland, Germany and Denmark) was used to stratify all conservation features (map to the left). Also an ecological stratification using the six major bio-geographical units (the Baltic Proper, the Bothnian Bay, the Bothnian Sea, the Gulf of Finland, Kattegat and Skagerrak) was used to stratify the fine filter conservation features (map to the right). The benthic marine landscape types were not stratified

5.2 Spatial Data Management

GIS data containing information of the area or number of occurrences of coarse and fine filter biodiversity conservation features and socio-economic features has to the most part been provided by the BALANCE project partners, with the exception of certain layers. The projection system used for the analysis was WGS 84 UTM 34N. The data preparation was done using ArcGIS 9, ArcView 3 and the extension CLUZ.

The criteria for including a data set in the analysis were the following:

1. The spatial data should be a complete, coherent coverage of the entire study area.

2. The data set should include information on both presence and absence of the conservation features. Presence only data, for example, was largely not used in the analysis. Absence may, in these types of datasets, be caused by the area not being a suitable habitat or it may be a false absence due to a lack of sampling.

3. The dataset should be of 'sufficient' quality. A dataset describing potential spawning areas for the Baltic Cod, *Gadus morhua* can be mentioned as an example. The data described sites where the physical conditions such as salinity, depth, temperature etc were favorable for cod spawning, but did not include information on whether the areas were actually used as spawning grounds, for example, due to oxygen depletion. An attempt was made to find a Baltic Sea wide data set describing areas with extensive oxygen depletion, but no such data could be made available until very late in the project. It was therefore decided, during one of the BALANCE workshops, to exclude the Baltic Cod data layer from this analysis, due to insufficient quality.

The original list of conservation features and socio-economic activities to be incorporated into the analysis was, as mentioned before, revised during the project, on the basis of spatial data availability, access and quality. The data layers used in the analysis are described below. For a complete list of all the conservation features and socio-economic activities originally listed, see Appendix 1, Table 4 and 5 and BALANCE Interim Report No. 2 (Andersson & Liman, 2006).

5.2.1 Coarse filter conservation features- Benthic Marine Landscape maps

Benthic marine landscapes have recently been mapped (Al-Hamdani & Reker, 2007). They provide a broad-scale spatial overview of the diversity of the benthic environment illustrating the distribution and quantity of ecologically relevant entities of the seafloor (Figure 4). Surface sediment (five categories), sea floor salinity (six categories) and depth zonation (two categories) were combined in an overlay analysis that resulted in 60 marine landscape types (Table 3).

Some benthic marine landscapes are very widely spread, while others cover very limited areas. In summary, it can be said that 8 of the 60 benthic marine landscapes identified cover the majority of the seabed, while 40 landscapes cover less than 1 percent and 12 landscapes cover between 1 and 2 percent of the total seabed area.

It is important to note that this mapping only takes into account the benthic environment and therefore can not predict the distribution of species such as pelagic fish, marine mammals etc. For a more detailed description of the marine landscape approach, justification of chosen environmental factors and ecological relevance of the defined subcategories, see the BALANCE Interim Report No. 10 '*Towards marine landscapes in the Baltic Sea*' (Al-Hamdani & Reker, 2007).

Table 3. Surface sediment (five categories), sea floor salinity (six categories) and depth zonation (two categories) were used to form the 60 benthic marine landscapes.	
Surface Sediment	Hard bottom that includes bedrock (crystalline and sedimentary) and bedrock covered with boulders. Hard bottom composite that includes complex, patchy hard surface and coarse sand (sometimes also clay) to boulders). Sand including fine to coarse sand (with gravel exposures). Hard clay sometimes/often/possibly exposed or covered with a thin layer of sand/gravel. Mud including gyttja-clay to gyttja-silt.
Sea Floor Salinity	Oligohaline 0 – 5 psu Oligohaline 5-7.5 psu Mesohaline 7.5-11psu Mesohaline 11-18 psu Polyhaline 18-30 psu Euhaline >30 psu
Depth zonation	Photic depth – euphotic zone (defined as were 1% surface irradiance reaches the seafloor) Below the photic depth- non photic zone

5.2.2 *Fine filter conservation features data*

A data set from an annual inventory of Grey Seal (*Halichoerus grypus*) in Finnish, Estonian, Swedish and Russian waters was used to describe the distribution of haul out sites in the Baltic Sea. Many of the hauls out sites inventoried also occasionally contain Harbour Seal (*Phoca vitulina*).

Occurrences of living and dead Cold Water Corals of the species *Lophelia pertusa, Paramuricea placomus, Primnoa resedaeformis* were used to represent the sites hosting the major populations of coral in Skagerrak, which is the only sub-region within the study area boundaries where corals occur.

Important Bird Areas (IBAs) are sites identified by Birdlife International as important wintering, feeding and breeding areas in the Baltic Sea, Kattegat and Skagerrak. Several of these areas have also been designated as SPAs.

Existing Natura 2000 sites

Polygons defining the outer boundaries of sites designated according to the Natura 2000 Habitats and Birds Directive were compiled from the authorities in each of the EU-member states Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden.

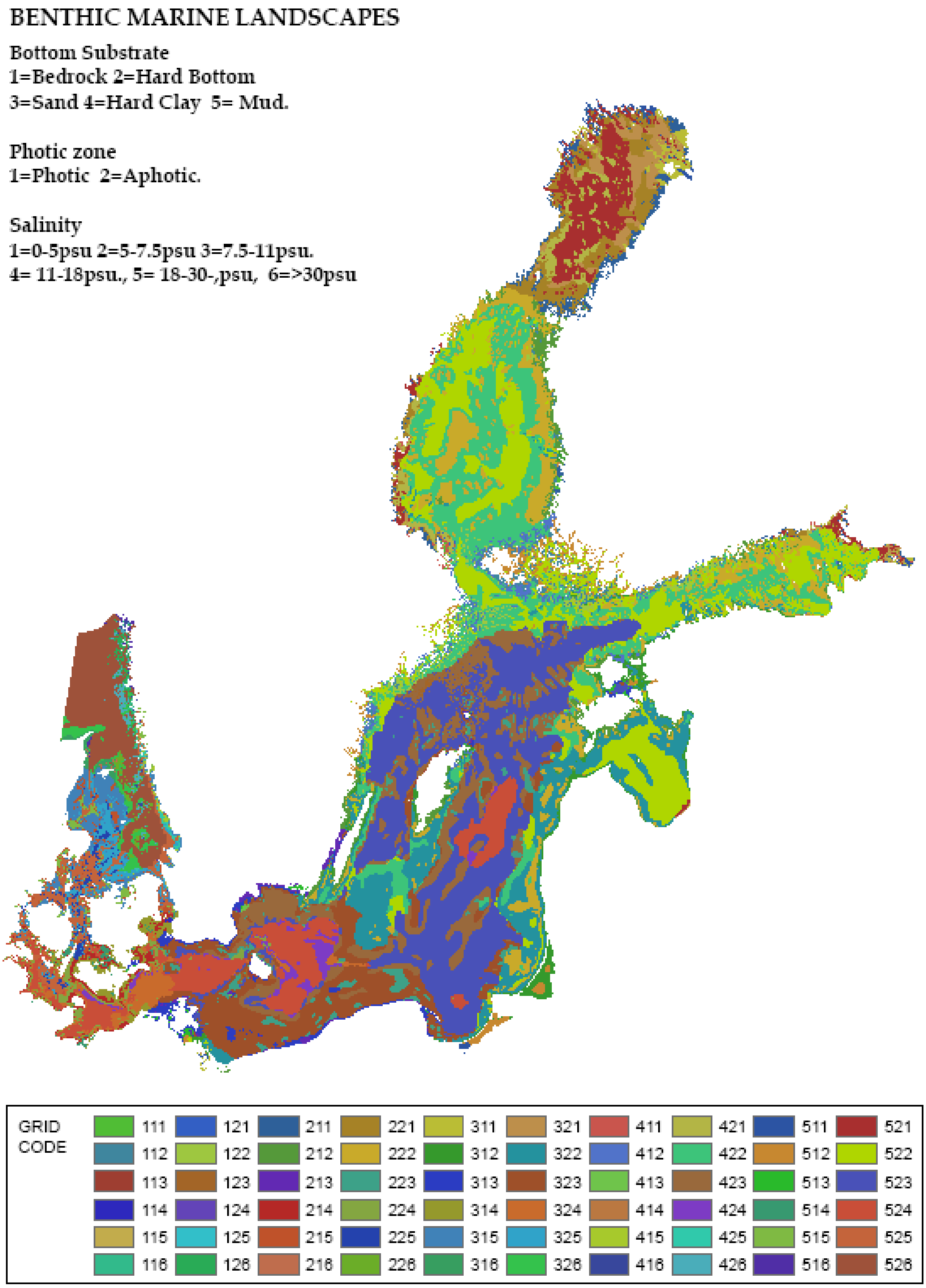

Figure 4. Benthic marine landscapes in the Baltic Sea.

Table 4. Fine filter features data included in the analysis.		
Grey Seal *Halichoerus grypus*	Haul Out Sites Central Coordinates	Annual inventory/monitoring of Grey Seal at haul out sites in Sweden, Finland, Russia and Estonia. Data source: Swedish Museum of Natural History, Finnish Environmental Institute, Baltic Fund for Nature Russia, Estonian Fund for Nature.
Sea Bird Species	Important Bird Areas, IBA (Wintering, Feeding and Breeding Areas)	Areas identified by Birdlife International as "Important Coastal and Marine Bird Areas in the Baltic Sea". Data source: Birdlife International
Cold Water Corals *Lophelia pertusa* *Paramuricea placomus* *Primnoa resedaeformis*	Living and Dead Reefs/Occurrences Central Coordinates	Data source: Gothenburg University, Tjärnö Marine Biological Laboratory.

Socio-Economic Data

The spatial data that were incorporated into the suitability map (described in detail below) included those on harbours, oil terminals, major shipping lanes, areas with increased risk for oil related accidents and human population density. The spatial data sets are all of low resolution with regional coverage (Table 5).

Table 5. Socio Economic spatial data used to create the suitability map.		
Oil terminals	Central coordinate	Main oil terminals and their volumes 1997, 2000-2002 (over 3 Million tons/year) Data Source: HELCOM MARIS, 2004
Harbours	Central coordinate	Harbours with commercial traffic Data Source: HELCOM MARIS, 2004
Potential Ship Accident Areas	Polygon	Areas of high accident risk estimated by VTT Technical Research Center of Finland. Data Source: HELCOM MARIS, 2004
Major Shipping Lanes, (cargo traffic)	Polyline	Total traffic (excluding ferries) year 2000 Data Source: HELCOM MARIS, 2004
Recommended Shipping Routes	Polyline	Shipping lanes/Secure shipping lanes in the Baltic Sea. Data Source: http://www.gis.lst.se
Human Population Density	Grid 5*5km	Population Density for Baltic Sea drainage basin region. Data Acquisition 1989-1993 Data Source: GRID-Arendal

Suitability Map

A map describing a measure of relative suitability of sites for designation as a protected area was created for use in selecting a portfolio of protected areas following a distance method used in previous site selection projects described by Huggins (2004). Factors affecting suitability were those that were seen to pose a threat to the biodiversity or to the successful implementation of a protected area e.g. strong conflicting interests. No direct evidence for a causal effect is inferred, the map was used to influence the selection of areas that appear to be more favourable. The intensity and distance from the activity were considered.

Distance of influence
All activities were assumed to have influence at an approximate distance from the actual central coordinate/approximate area where the activity occurred and that the strength of the influence decreases with distance from the activity. The assumption was that areas close to a certain threat are less suitable as an MPA than an area further away. The reason behind this assumption is that all the threat factors included are threats caused by large scale human activities that will probably not be restricted as a response to protection. The distance of influence of all considered threats was categorized as: Point specific (-25 m), Short distance (-1000m), Intermediate distance (-10 000 m) or Long distance effect (-10 km)

A threat categorized as '**point specific'** (-25 m) is assumed to have a negative effect on its immediate surroundings. These threats affect the suitability of their surroundings simply by their physical presence. None of the threats fit into this category, mainly due to the fact that all the threats incorporated into the suitability map were broad scale data sets describing threats operating on a scale far above 25 m.

Harbours and areas with population density up to 3000 persons per 25 square kilometer were categorized as having a '**short distance'** effect (-1000m), Threats in this category influence the suitability of a site through e.g. noise and to some extent export chemical pollutants, particles etc at a more local scale.

Threats categorized as having an '**intermediate distance'** effect (-10 000m) are mainly sources of chemical pollutants, spread by currents at a local to regional scale. Here, represented by oil terminals, oil risk related areas, major shipping lanes and major cities. Shipping lanes were primarily put into this category due to the spatial insecurity of the data. The data set does not reflect the actual shipping lanes but indicates the approximate regions where there is intense traffic. By assigning a rather high distance of influence, a large area around the lines was captured as an area with a high degree of conflict.

None of the threats fit into the last category, '**long distance**' effect (-10 km) threats. Threats in this category could be sources of chemical pollutants potentially transported a long way by currents. It could also be threats to very rare features.

The distance of influence was decided during discussions with partners in the BALANCE project. A more thorough evaluation of the threats posed by the listed factors would be a most valuable input to further improve the accuracy of the values used.

Relative threat score
The suitability map was designed to capture human activities at different levels of intensities. The relative score aims to indicate the <u>relative level</u> of threat the activity poses to its surrounding environment or to the successful implementation of a protected area.

Each of the threats were assigned a <u>relative score</u> ranging from 1 to 5, depending on the intensity of the threat i.e. how severe or threatening the activity could potentially be for the surrounding marine habitats and species, and so how suitable the area is for long term protection of the marine biodiversity (Table 6). This relative scoring is only a way to put a weight on how unsuitable an activity makes an area relative to the intensity of other activities.

Threats categorized as **1** on the relative scale were assumed to pose more or less '**insignificant threats'** to there surroundings. Areas with a low human population density (up to 200 persons/25 km^2) were assigned this category. Sparsely populated areas can be a source of conflict for MPA establishment but should not be always avoided.

Less sparsely populated areas, (up to 3000 persons/25 km^2) and shipping lanes trafficked by up to 700 ships per year were put into **category 2** assumed to pose a **'low level threat**' due to chemical pollutants, physical damage of habitats and noise pollution. However, MPA establishment in these areas should not always be avoided.

More extensively trafficked shipping lanes (used by up to 14000 ships/year) and oil related accident areas in the "moderate risk" category were assumed to fit into level **3**, i.e. pose a '**moderate level threat**'. Improving shipping safety in these highly trafficked regions would make the site more suitable for MPA establishment, but in present state these sites do not qualify as candidates for MPA designation if other more suitable sites are available.

Harbours with commercial traffic, oil accident related areas in the high risk level were put in **category 4** posing a '**high threat**'. The increased risk of oil discharge makes the site highly unsuitable for MPA designation and should if other more suitable sites exist, be avoided.

Oil terminals and areas of very high risk for oil related accidents were put in **category 5**, assumed to pose a "**severe threat**" to biodiversity in case of an oil discharge. Sites where the risk for severe oil pollution is high are not suitable for MPA designation.

Table 6. Socio Economic factors incorporated into the suitability map and the assigned approximate distance of influence and relative suitability scores on a scale 1-5, with 5 indicating the most severe threat.

Suitability factor	Unit of Measurement	Distance (m)	Relative suitability (1-5)
Harbours with commercial traffic	presence/absence	0-1000	4
Oil terminals	presence/absence	0-10 000	5
Oil risk related areas; Moderate risk	Fulfil argument: 1,3,5,7,10,11*	0-10 000	3
High risk	Fulfil arguments: 1,7, 10, 11, 2, 4, 6, 14, 3, 5, 8, 9, 13, 12*	0-10 000	4
Very high risk	Fulfil arguments: 1,2,3, 4,5,6,7,8,10,11,12,13,14,15*	0-10 000	5
Major shipping lanes, cargo traffic	1-700 ships/year	0-10 000	2
	701-14000 ships/year	0-10 000	3
	14001- ships/year	0-10 000	4
Population density	10-200 persons / 5*5km	0-1000	1
	201-3000 persons / 5*5km	0-1000	2
	3001-11500 persons/ 5*5km	0-10 000	3

For a complete listing of the arguments used to categorize the oil risk, related areas see Appendix 1, Table 3. The relative threat scoring was, like the distance of influence, decided based on a discussion with the BALANCE project partners. A more thorough evaluation of the threats associated with the listed factors would be a valuable input to further develop the relative scores used.

Suitability Map

1. Grids for each activity were created and the distances from each activity in the map were calculated in a distance grid. Different grids were calculated for each intensity class of each of the activities. The distance numbers are then inversed, giving the position of the activity the maximum score and decreasing the score with increasing distance, from the centre of the activity to zero at the maximum distance from the activity.

2. The resulting distance grids, one grid per activity and per intensity level, were multiplied by the assigned, activity specific intensity level.

3. The grids were then combined into one grid where each cell contained the maximum threat value found in each point (Figure 5).

The surface is summarized by planning unit, assigning each planning unit a cost. The planning unit cost can be used in MARXAN to steer planning unit selection away from unsuitable areas (high planning units cost) and favor more suitable areas (planning units with a lower cost), when biodiversity values, cluster implications etc are similar.

5.2.3 MARXAN Input

Data can be prepared in a GIS and are later converted/transformed to MARXAN input files in text format. Four files include the required input to MARXAN containing information on 1) planning units status, i.e. whether planning units are locked in, earmarked or available 2) each planning units conservation value (area or number of occurrences of conservation features) and cost/suitability value associated with selection of each planning unit 3) the boundary length of all planning units, and 4) the conservation target for each conservation feature and the penalty associated with not fulfilling the defined targets. A brief description of the major steps taken is given below.

Planning Units

The study area was divided into approximately **45500 hexagonal planning units.** Each full size unit was 1039 hectares in size. The planning units are the smallest units into which the conservation features are split. Hexagons have a larger number of edges and so are better than other shapes such as squares for forming clusters of planning units. The size was designed based on the underlying conservation feature distribution data. The planning units must reflect the spatial arrangement of the features in addition to the factors mentioned in Chapter 4.1. If the units are too small, the information concerning places where several conservation features occur together and information about whether the conservation features are in large or small fragmented patches, is lost, as the information tends towards being presence/ absence data.

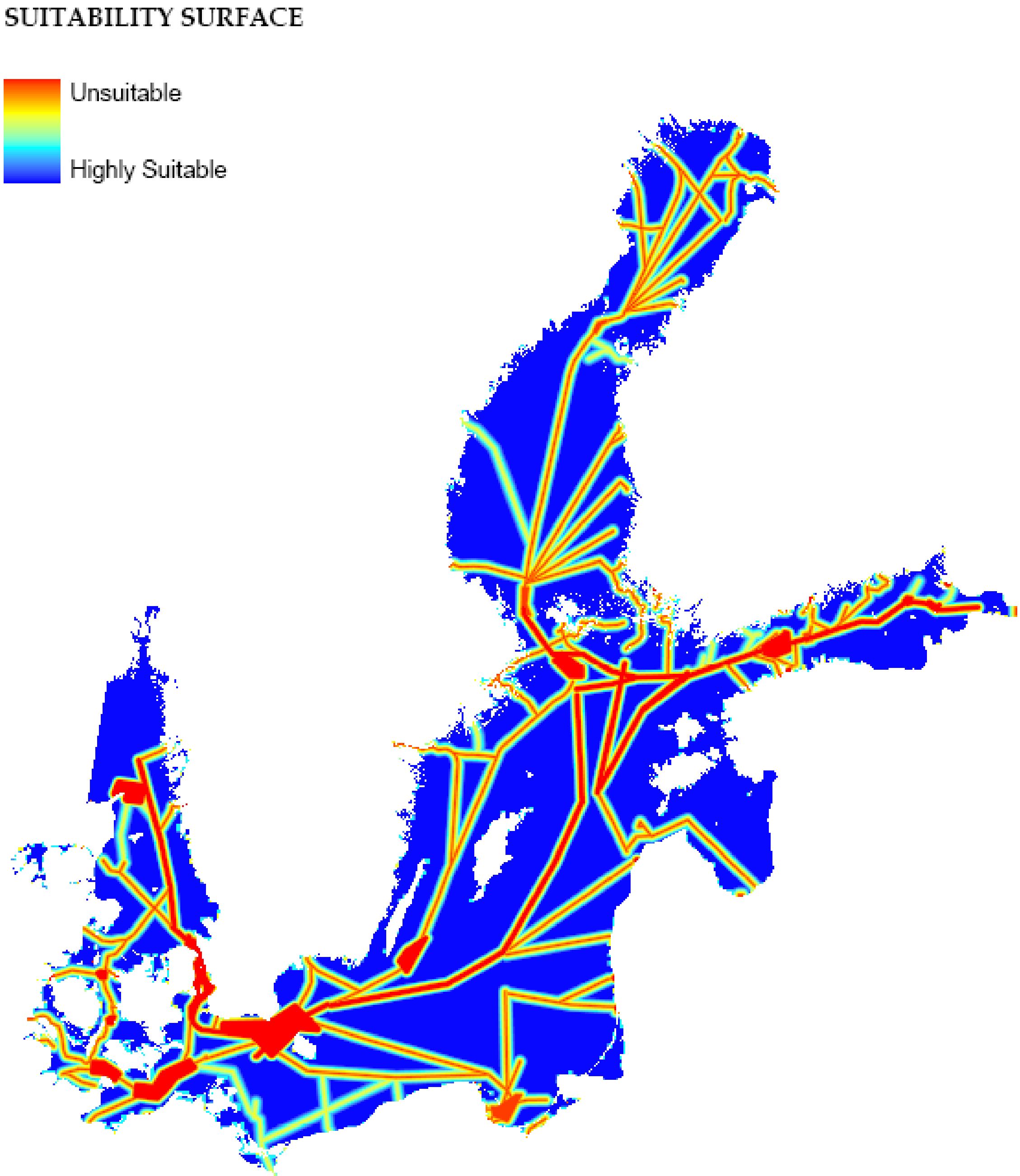

Figure 5. Suitability Surface created using distance grids. Values in the map represent relative suitability for MPA-designation, ranging from 'unsuitable value (red) to 'highly suitable value (dark blue). Broad scale data on harbours, oil terminals, major shipping lanes, areas with increased risk for oil related accidents and human population density were included.

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Planning Unit Status

Since one of the aims of the site selection exercise was to add complementary sites to already designated Natura 2000 sites, these were "locked in" to the portfolio during analysis. Locked in sites are included in the initial portfolio and can not be removed. Sites below a certain size (<1000 ha) were earmarked, and not locked in, which means that they were included in the initial portfolio selected at the beginning of the algorithm run, but can be exchanged for other planning units during the run where equal conservation values could be found elsewhere at lower cost. Either because the boundary decreased or because suitability was higher. Earmarked units are, however, more likely than unmarked units to be included in the final portfolio.

Planning Unit Conservation Value and Cost

The GIS data (described in detail in Chapter 5. 2) containing information on the area or number of occurrences of conservation features were merged with the planning unit layer to form a dataset where each hexagon contained information about the quantity of features occurring within it. The conservation targets were calculated as percent of the total occurrence of the feature. The conservation targets were specified in area (hectares) or number of occurrences.

Each planning unit was given a base cost equal to its area. The planning units layer was clipped by the coastline, to ensure that the units along the coastline were not penalised for not having as much area of conservation features as full sized planning units, just because a part of the planning units contain land. The suitability map, described in detail in Chapter 5.2.2, was also merged with the planning units layer to add a measure of suitability to the area-base cost of each planning unit. The suitability values ranged from highly suitable (lower planning unit cost) to unsuitable (higher planning unit cost). Low cost units are favored over high cost units when biodiversity values, cluster implications etc are similar. The cost of individual planning units can therefore be used to steer the selection of sites away from unsuitable areas without affecting the target representation.

Boundary Length

The planning unit dataset was also used to calculate the boundary of each planning unit and the distance of the boundary between all adjoining pairs of planning units. The file is later used by MARXAN to calculate the total boundary length of a collection of planning units. Since units along the coastline were clipped by the coastline their outer boundaries were probably longer than the whole hexagonal unit itself. Including the outer boundary of those planning units would therefore make them less favourable to select. It was therefore decided to exclude the outer boundary of those units.

Conservation Targets and Penalty

The conservation targets were calculated as percent of the total occurrence of each feature. The conservation feature penalty values used were decided for each run separately, using the basic calibration method described below.

5.2.4 *MARXAN settings*

Three scenarios with the aim to select site portfolios representing <u>at least:</u> 20 percent (recommended minimum level), 10 percent (lower ambition) and 30 percent (higher ambition) of the benthic marine landscapes were run in MARXAN. The spatial configuration criteria were the same for all scenarios, i.e. adding complementary sites to the existing SACs using stratified features, including a measure of site suitability and aiming towards a relatively high level of clustering.

The major input parameter values; number of iterations, conservation feature penalty factor (CFPF-value) and boundary length modifier, (BLM) were decided using a basic calibration. An approach using the near optimising algorithm simulated annealing followed by iterative improvement was used for all runs. Each scenario was calculated separately, meaning that different parameter values were used in all scenarios. The calibration of the 20 percent scenario is presented below, as an example.

Number of iterations

The number of iterations determines how long the simulated annealing algorithm runs, and so how many times planning units are swapped in and out of the portfolio. The longer it runs, the more likely it is to give a more efficient portfolio/lower total cost of the portfolio (planning unit cost + boundary length + penalty). Quite a lot of iterations are needed, but since too many iterations potentially can be quite time consuming the amount of improvement might not be worth the extra computation time (Ball & Possingham, 2000).

A set up using the CFPF=10 000 and BLM=0 were used to do 100 runs using a) 500 000, b) 1 million, c) 2 million and d) 3 million iterations. The total portfolio costs for each of the 100 runs in all four settings a)-d) were plotted in the same graph (Figure 6).

A sufficient amount of iterations should not only produce portfolios with low total portfolio cost, but also produce equally good solutions, measured as the total cost of the portfolio, in all 100 runs. At the point of 2-3 million iterations, the total portfolio costs seem to stabilize and all 100 runs produce equally good portfolios. Due to analysis time constraints, 2 million iterations were chosen to be used for this particular analysis.

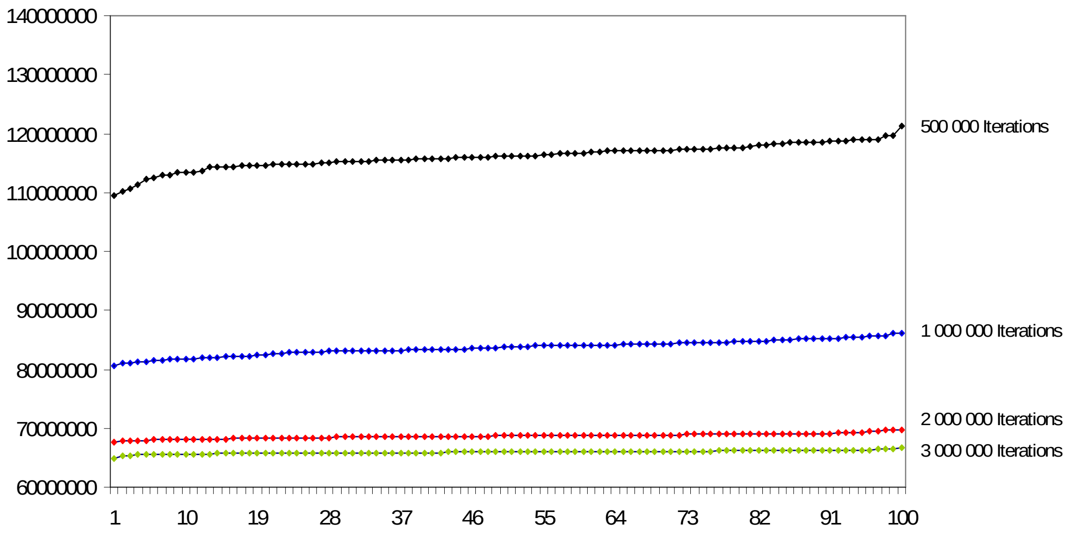


Figure 6. The total portfolio costs (y-axis) for a hundred runs of each of the four different number of iterations 500 000, 1 million, 2 million and 3 million iterations (x-axis).

Conservation Feature Penalty Factor, CFPF
The conservation features penalty factor, CFPF, is a weight or multiplicative factor put on each conservation feature to determine the relative importance of reaching all targets specified for this feature.

According to the MARXAN Manual (Ball & Possingham, 2000) "*there is no good theory at the moment about what level achieves what effect. Setting it higher than 1 will increase the motivation for the system to perfectly represent that conservation feature"*. But, to "*ensure that each conservation feature (which can meet its targets) meet its target it can sometimes be desirable to set the CFPF at a much greater value than one*'. It was therefore decided to test a range of different weights on reaching species targets using 100 runs and BLM=0 a) 10 000, b) 100, c) 10, and d) 1.1. The same CFPF-value was used for all features. All CFPF-values tested in this scenario produced portfolios fulfilling all targets. It was therefore decided to use the lowest possible value CFPF=1.1.

Boundary length modifier, BLM
The boundary length modifier (BLM) is, as mentioned earlier, a parameter used to determine the importance given to the boundary length relative to the total cost of the portfolio. If a value of 0 is given to BLM then the boundary length is not included in the objective function (Ball & Possingham 2000) and the larger the BLM value, the larger the penalty for many small planning unit clusters, i.e. it will cause the program to select large clusters of planning units. The boundary length can be measured in any unit. However, the boundary length unit is highly related to the range of BLM values having a significant effect on planning unit aggregation.

A range of BLM values (0, 1, 2, 2.5, 3, 6, 8 and 10) were tested using CFPF=1.1, 2 million iterations and 10 runs. The boundary length was measured in meters, whereas the area of each planning unit and the quantity of the conservation features within it was measured in hectares. The resulting portfolios were plotted in two graphs, one to illustrate the total number of selected planning units (Figure 7 a), and one to illustrate the total boundary length of the portfolio (Figure 7 b), as a result of increased BLM value. An increased BLM value also increases the total area of the portfolio and thereby the over representation of the minimum targets. This aspect was also taken into account when determining a suitable level of clustering. The results were also mapped and inspected visually (Figures 7 a-d). Using these parameters, a BLM-value of 2.5 gave a reasonable level of clustering given the broad scale objectives of this analysis. This level of clustering was also agreed upon at a workshop with BALANCE partners. Other values were used in the other scenarios.

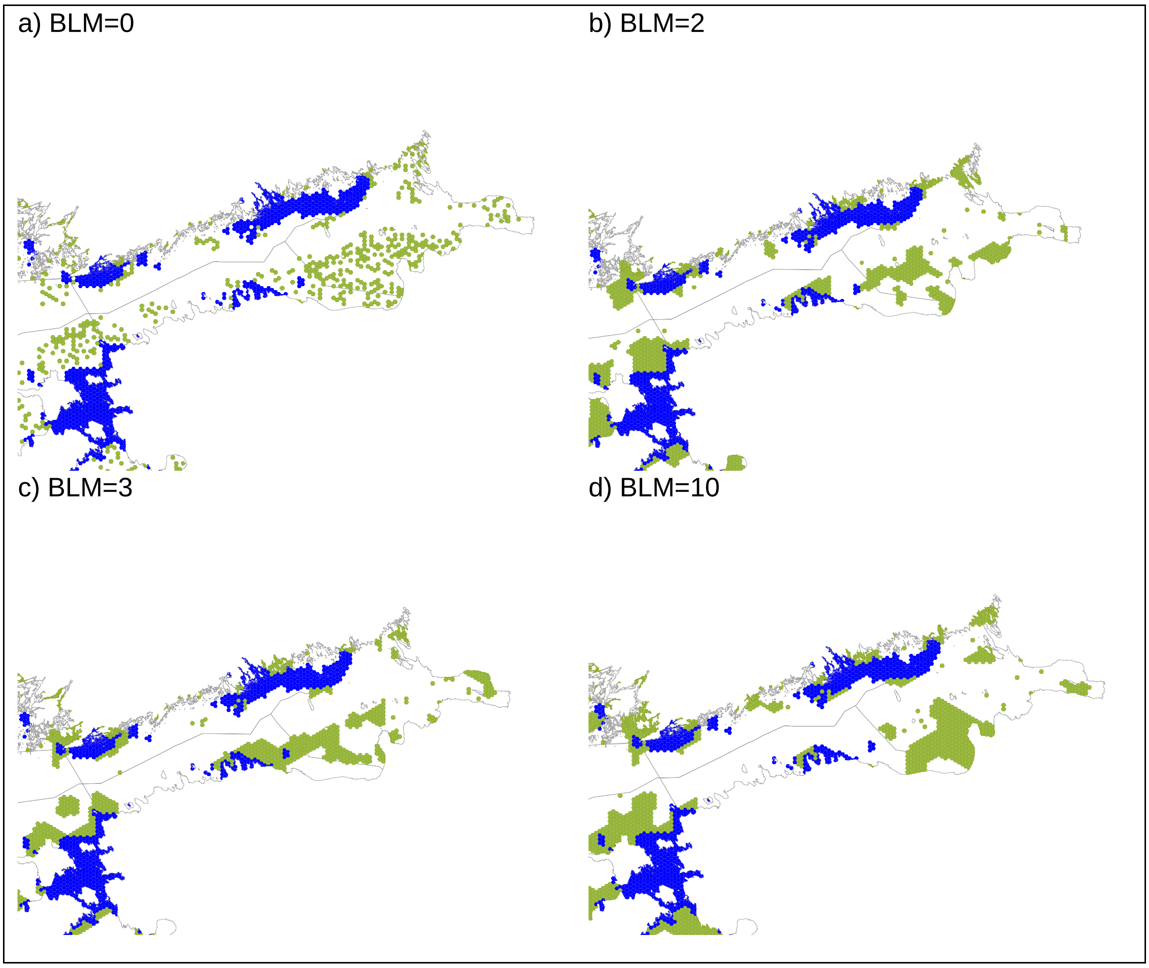
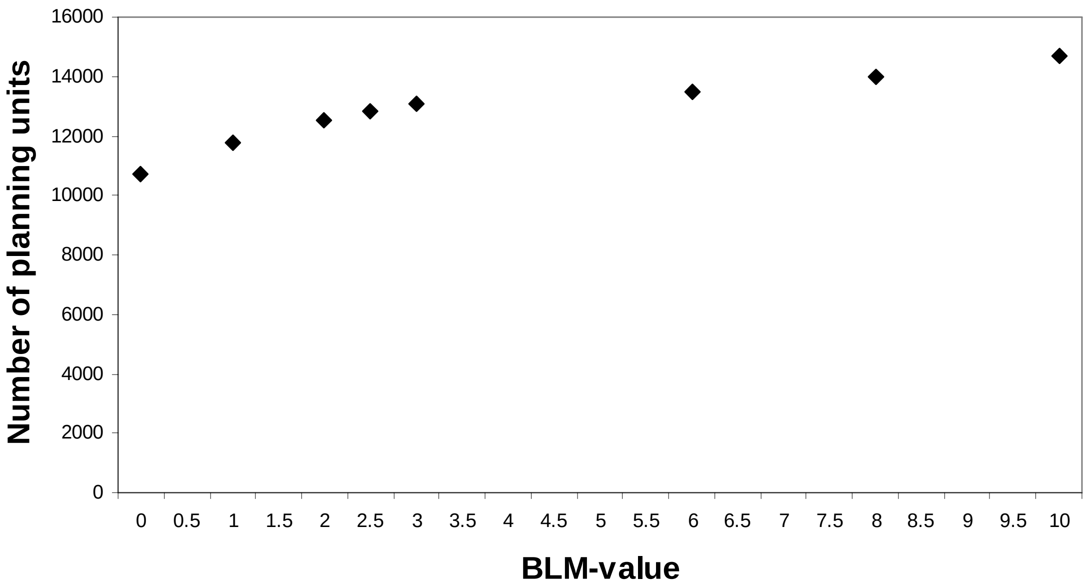


Figure 7. The maps show the selected units (green) and the locked in SACs (blue) in the Gulf of Finland area using BLM-values a) 0, b) 2, c) 3 and d) 10. As the boundary length modifier (BLM) increases, placing more weight on minimizing the overall portfolio perimeter rather than the portfolio area, the selected units form more spatially clustered sites. For this particular scenario a value of 2.5 was considered most appropriate.



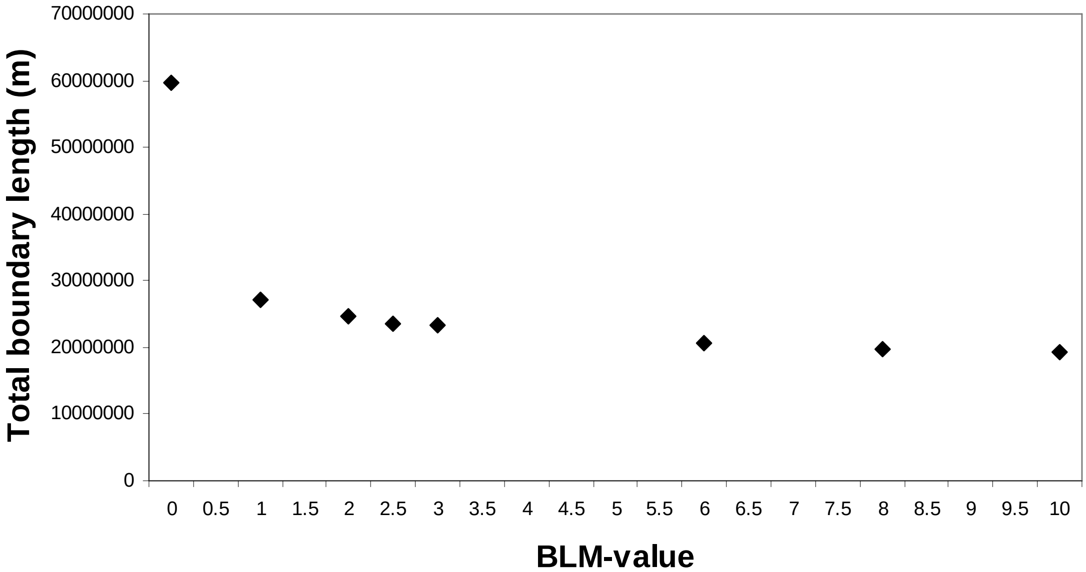


Figure 8. a) The total number of selected planning units (y-axis) using BLM-values, 0, 1, 2, 2.5, 3, 6, 8 and 10 (x-axis). b) The total boundary length in meter (y-axis)of the planning units selected using BLM-values, 0, 1, 2, 2.5,3, 6, 8 and 10.

6 MARXAN OUTPUT RESULT AND DISCUSSION

Development of the conservation portfolio can be supported by two outputs of the site selection program MARXAN called ‘best portfolio’ and ‘summed solution’. The *best portfolio* is the one portfolio selected during repeated runs of the algorithm that meets the conservation targets and objectives in the most efficient manner. Examples of the best portfolio for the three main scenarios are shown in Section 6.1. These examples illustrate the requirement of larger portfolios as the minimum representation targets are increased from 10 to 30 percent. Also included are the alternative 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 area locked in. These scenarios give an indication of how well the existing protected areas help meet the biodiversity conservation targets specified. An example of how the different spatial arrangement criteria defined affect the best portfolio in terms of representing the minimum defined targets is also presented in Chapter 6.3.

The *summed solution* is the number of times each planning unit was selected as part of a portfolio in the set of repeated independent runs of the algorithm and is a measure of the flexibility of including each planning unit when building an efficient portfolio. The summed solution for scenario I (the minimum 20 percent scenario) is presented in Chapter 6.2.

6.1 Best portfolio

The best portfolio is the run producing the lowest total score (cost of planning units + boundary length + penalty) out of all runs in that scenario. It is important to note that this is not the only solution meeting the specified ecological objective and analysis constraints, but rather the best portfolio in terms of efficiency. There are often many portfolios that are almost equally efficient, the best may be only marginally more efficient than the next best. It is therefore important to look at a number of efficient portfolios when interpreting the results. The most efficient runs of the three scenarios, (I) min. 20 percent (recommended minimum level), (II) min. 10 percent (lower ambition) and (III) min. 30 percent (higher ambition) representation are presented below in Figures 9, 10 and 11. These results aim to set out a starting point for a systematic selection of MPA candidates in the Baltic Sea and further insight to the extent of such a network. The results should be further developed through discussions with experts and stakeholders. More extensive data can be included and the network design criteria further improved. This is discussed further in Chapter 8 and 9.

The best portfolio for the minimum 20 percent representation (Scenario I), resulted in a portfolio consisting of 13034 planning units (4391 locked in and 8643 additionally selected) with a total area of slightly more than 11.5 million hectares or about 27 percent of the entire study area (Figure 9, Table 7). The 20 percent assessment was also run with both SACs and SPAs locked in (see Appendix 1, Figure 2). The best portfolio for this run resulted in a portfolio with a total area of 11.7 million hectares, i.e. only slightly less efficient then the scenario where only SACs were locked in. It should be pointed out that there is extensive spatial overlap between the SACs and SPAs. For this reason the performance of the two portfolios is not expected to differ much.

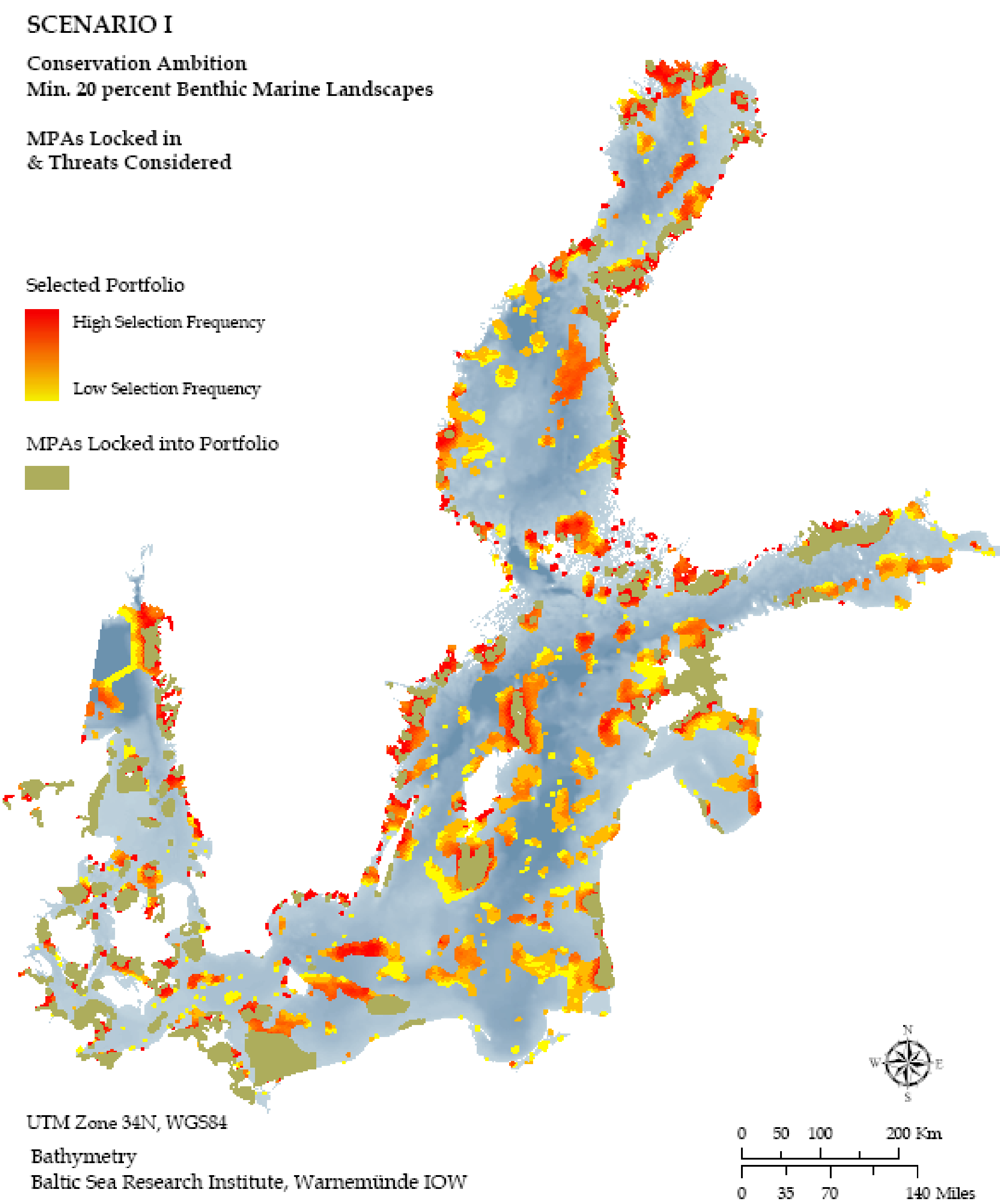


Figure 9. SCENARIO I MIN. 20 PERCENT REPRESENTATION (RECOMMENDED).
MARXAN "best portfolio" with the selection frequency of each unit during 100 runs. The portfolio represents a minimum of 20% of all benthic marine landscapes and IBAs, 60% of all Grey Seal haul out sites, 100% of all Cold Water Coral occurrences (60% of the dead structures). The portfolio adds complementary sites to 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 targets. All targets were met.

Furthermore, scenario I was run without any existing protected areas locked in (see Appendix 1, Figure 3). The aim of this was to get an indication of how well the existing protected areas help meet the biodiversity conservation targets specified. In this scenario the algorithm is allowed to select planning units in the existing protected areas under the same conditions as all other planning units, e.g. spatial efficiency in representing biodiversity targets and site suitability. This scenario resulted in an improved site selection efficiency where the same targets were represented using 8990 planning units with a total area of slightly more than 8.7 million hectares or 20 percent of the study area (compared to 27 percent in scenario I). Altogether or 20 percent of the planning area were selected in the no protected areas fixed scenario. These results indicate that selecting a portfolio of sites representing 20 percent of the benthic marine landscapes becomes less efficient if complementary sites are added to the existing protected area network then if all sites are selected from scratch. Despite this, it is still highly recommended from a political point of view to continue develop the existing network of sites to adequately represent the whole range of biodiversity.

The "best portfolio" for the minimum 10 percent representation (Scenario II) resulted in a portfolio of 8645 planning units (4391 locked in and 4254 additionally selected) with a total area of 7.3 million hectares or 17 percent of the planning area (Table 6). When the minimum representation target is as low as 10 percent, many of the targets are already fulfilled and/or overrepresented in the locked in sites. The selection of additional sites therefore becomes less efficient then if sites were to be selected from scratch. Intuitively, we would expect the performance of the protected areas fixed scenario to improve as representation targets increase.

This is illustrated in **the best portfolio for the minimum 30 percent representation (Scenario III)** which resulted in a set of sites consisting of 15719 planning units (4391 locked in and 11328 additionally selected) with a total area of slightly more than 14.4 million hectares or 33 percent of the planning area (Table 7). This result is also in line with the expected increase in portfolio size when representation targets are increased.

Table 7. The number of planning units selected, and the corresponding area in all presented scenarios.

SACs locked in	***Total nr. of pu's***	***Total Area selected***		***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%*

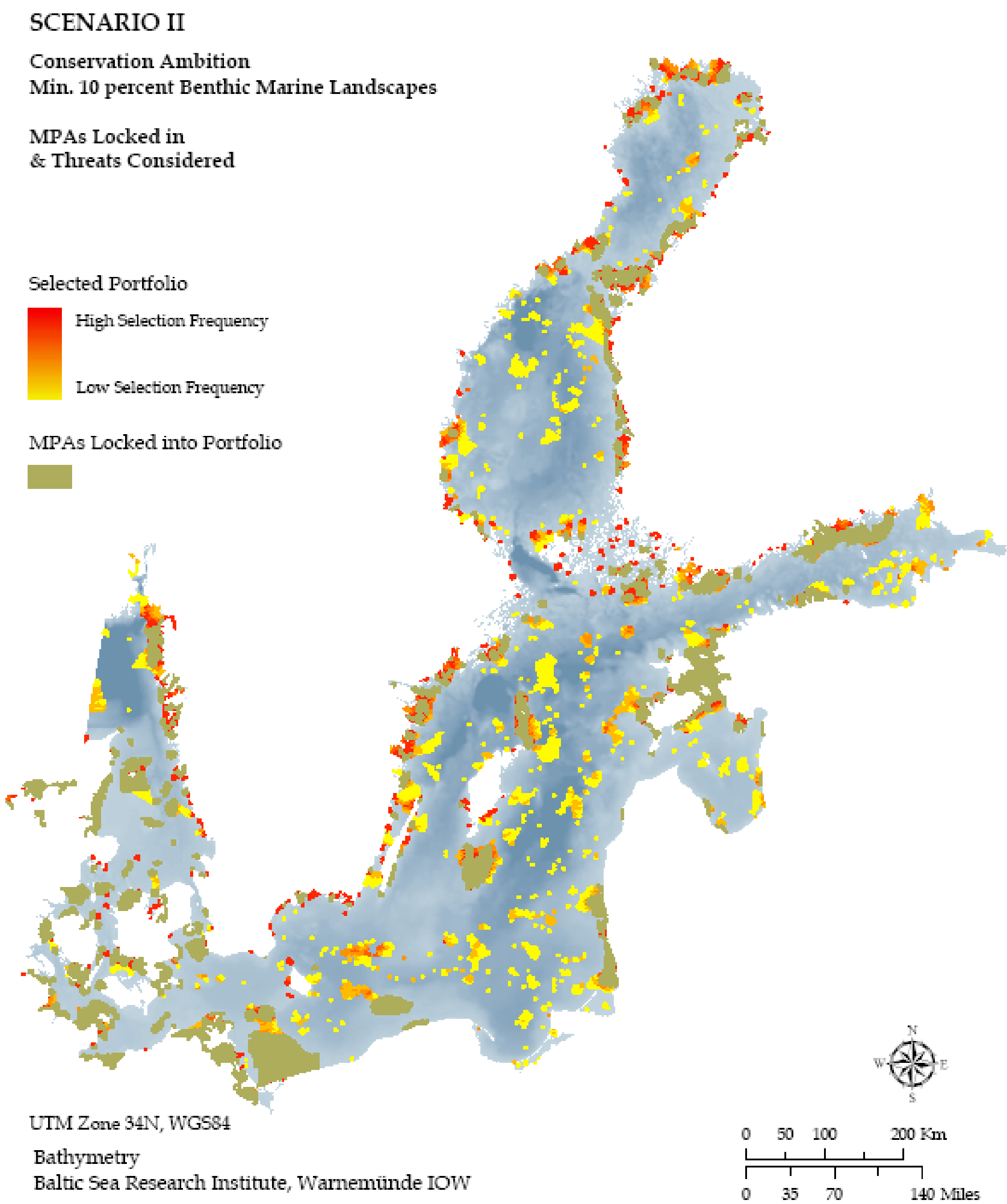


Figure 10. SCENARIO II MIN. 10 PERCENT REPRESENTATION (LOWER AMBITION). MARXAN "best portfolio" with the selection frequency of each unit during 100 runs. The portfolio represents a minimum of 10% of all benthic marine landscapes and IBAs, 60% of all Grey Seal haul out sites, 100% of all Cold Water Coral occurrences (60% of the dead structures). The portfolio adds complementary sites to SACs, using BLM=1, 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 100 for all targets. All targets were met.

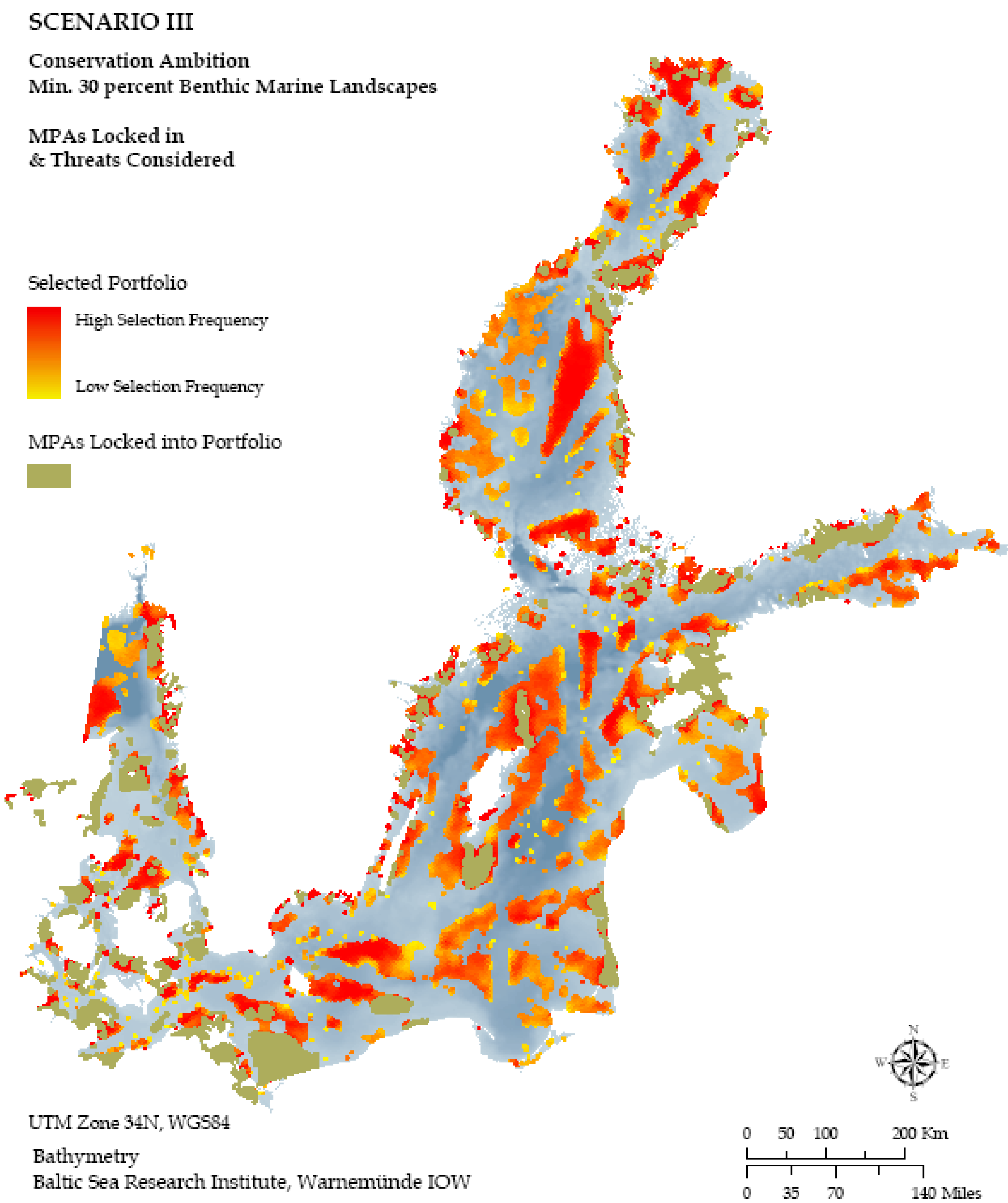


Figure 11. SCENARIO III MIN. 30 PERCENT REPRESENTATION (HIGHER AMBITION). MARXAN "best portfolio" with the selection frequency of each unit during 100 runs. The portfolio represents a minimum of 30% of all benthic marine landscapes and IBAs, 60% of all Grey Seal haul out sites, 100% of all Cold Water Coral occurrences (60% of the dead structures). The portfolio adds complementary sites to SACs, using BLM=1.5, 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 100 for all targets. All targets were met.

All minimum targets were met in all the presented scenarios (≥ 100 percent). Several features were also overrepresented 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 overrepresentation of features is due to criteria for spatial arrangement of the portfolio. E.g. the best portfolio for the minimum 20 percent representation scenario corresponded to about 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.

6.2 Summed Solution

There are often many portfolios that are almost equally efficient, the best may be only marginally more efficient than the next best. In other words, there is not only one solution, but alternative ways to meet the same conservation targets. The summed solution (often termed irreplaceability) therefore, gives a measure of the flexibility of including each planning unit in an efficient portfolio.

The summed solution is the number of times each planning unit was selected as part of a portfolio in the set of repeated independent runs of the algorithm. It measures the priority of a planning unit to achieving targets efficiently and indicates the flexibility available for including that unit in a portfolio or swapping it with one that provides similar biodiversity distribution in an area that fits with the other selected units more easily. If a planning unit is selected in all or many runs (low flexibility or high irreplaceability), it may include biologically rich areas or areas that contain a large proportion of one or several biodiversity conservation features and thereby contribute to meeting many of the conservation targets or could contain reasonable amounts of biodiversity conservation features in a planning unit with a high suitability score. The flexibility of the unit can, therefore, be used to identify core areas that are more likely to be necessary for inclusion in the protected area network and also to guide the iterative process of site selection. Areas with higher flexibility are often interpreted as areas with low importance. These areas are not less important, as the inclusion of many of these areas in the portfolio may be necessary to meet the representation targets, it is the choice of which of these to choose to make the representation that is more flexible. These areas can be seen as lower in priority, although many must be included in the portfolio in order for the targets to be met.

One of the strengths of MARXAN is 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. However, in this analysis it appears as if though there is a quite high flexibility in reaching targets, which is mainly due to the fact that there are few overlapping conservation features.

The following conclusions can be drawn based on the summed solution for scenario I (Figure 12): Planning units with a high selection frequency are mainly in areas close to locked in protected areas (SACs). Unsuitable sites, e.g. those with an “irremovable” threat or strong conflicting interests like shipping lanes and harbours are avoided and have a low selection frequency.

It is important to note that since a coarse filter conservation feature covering the entire study area (like the benthic marine landscapes) 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 map is the main factor determining spatial selection. This can quite clearly be seen when comparing the summed solution map from scenario I with the suitability surface, where areas which have been considered unsuitable, very often have a very low selection frequency. If more species information were 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. This has e.g. been shown in the case study presented in Chapter 8.

An example below illustrates, using performance measures, how two of the parameters; the BLM-value and locked in sites, affect the final portfolio in terms of over-representation of conservation targets.

6.3 Spatial Arrangement Criteria Evaluation

Four principles or spatial arrangement criteria were defined for the portfolios (see Chapter 3.3). All these affect the site selection process, either by steering the selection away from or towards sites (the site suitability map), or in terms of portfolio efficiency, over-representation of features etc (locking in protected areas and increased BLM-value/cluster level). For example, the results above show that a large amount of the frequently selected planning units are located close to permanently locked in areas. This is mostly a consequence of two factors, namely the high flexibility of many of the planning units (that the conservation targets can be fulfilled by selecting planning units in several different locations in the region) and the relatively high weight put on minimizing the total boundary length of the portfolio. Adding units next to locked in units is an efficient way of meeting the conservation targets with only a small increase in the total boundary length of the portfolio.

The effect of the spatial arrangement criteria on solution efficiency is not obvious from the figures. The example below illustrates, using performance measures, how two of the parameters; the BLM-value and locked in sites, affect the final portfolio in terms of over-representation of conservation features. The percent overrepresentation was calculated as follows: the area selected of each landscape type was added up and divided by the total area required for a minimum representation of 20 percent of all the landscape types. The '20 percent representation' scenario (locked in SACs, BLM=2.5) resulted in 'an overrepresentation of the overall benthic marine landscapes features with 30 percent.

Running the same scenario without clustering constraints, BLM=0, gave an overrepresentation of 13 percent, whereas the same scenario, BLM=2,5 without locking in SACs, resulted in an overrepresentation of 5 percent. Excluding both criteria resulted in less than 1 percent overrepresentation of the benthic marine landscapes. On the basis of this, it can be concluded that the locked in areas and the cluster level/BLM-value, to a large extent, can explain the overrepresentation of the conservation features over the minimum targets. Of these factors the level of BLM appears to have the largest influence (Table 8).

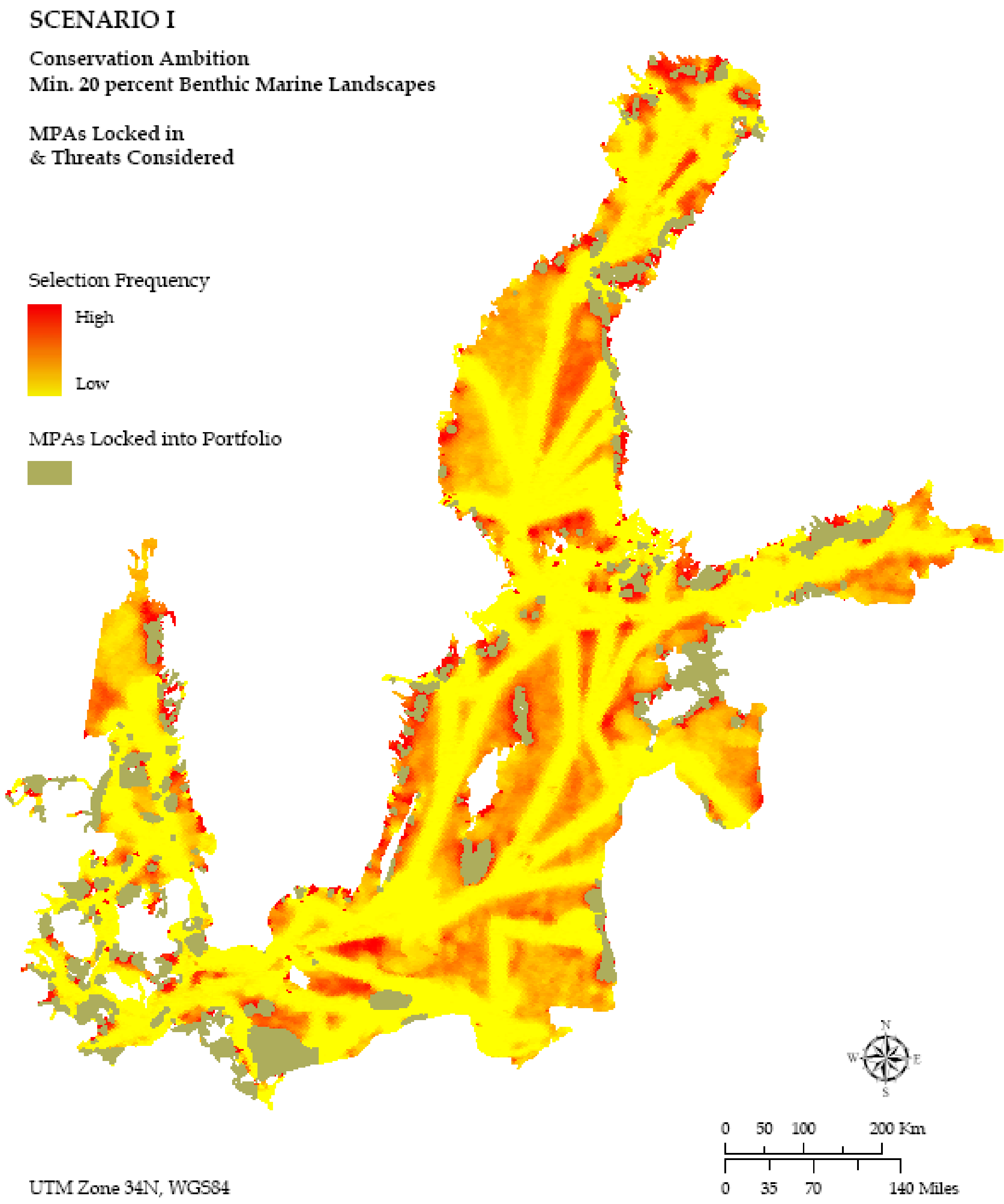


Figure 12. SCENARIO I SUMMED SOLUTION. MARXAN "summed solution" representing a minimum of 20% of all benthic marine landscapes and IBAs, 60% of all Grey Seal haul out sites, 100% of all Cold Water Coral occurrences (60% of the dead structures). Only units with a selection frequency above 60 are shown on the map. The portfolio adds complementary sites to 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 targets.

Table 8. Example illustrating how two of the spatial arrangement criteria parameters, BLM-value and locked in sites affect the final portfolio in terms of representing the conservation features over the minimum targets.

Scenario	**BLM-value**	**Locked in areas**	**Overrepresentation of feature**
Original scenario (Scenario I)	BLM=2.5	SACs locked in	30%
No sites locked in	BLM=2.5	No sites locked in	13%
Removing the weight on clustering the planning units	BLM=0	SACs locked in	5%
No sites locked in <u>and</u> removing the weight on planning units clustering	BLM=0	No sites locked in	<1%

7 RANGE OF APPLICABILITY

When interpreting the results of the assessment it is important to be aware of the quality and limitations of the underlying data layers. This chapter briefly describes the gaps and limitations of the data available for this assessment.

7.1 Data gaps and limitations

Ideally, an assessment should include data to ensure that all biodiversity in the region is represented. However, mapping of every population, species and habitat types as well as the interactions between them, is impossible. Therefore the use of coarse filter conservation features that act as surrogates for the broader biodiversity are a main component in this analysis. The best data sets available for the BALANCE project covering the entire region and being of sufficient quality have been used to perform this site selection. However, there are several limitations in the data sets, related to accuracy, resolution, data compilation method etc. These are outlined below:

7.1.1 Coarse filter data layers

There are certain inherited limitations to the mapped benthic marine landscape layer, which must be taken into account when interpreting the results of the site selection. The main limitations of the maps include low and or varying resolution of the input data sets. The resolution of the substrate raw data ranges from 1: 100 000 in some coastal areas to 1: 1000 000 in some off shore areas. The salinity regimes have also been modelled using a low resolution, (sea floor salinity regimes grid size 7.5*7.5 km, and depth zonation models 600*600 m). For a complete listing of the limitations of the marine landscape layer see the separate BALANCE interim report 'Towards marine landscapes in the Baltic Sea '(Al-Hamdani & Reker, 2007).

The marine landscapes map with 60 benthic marine landscapes was created using a 200*200m grid, which does not reflect the resolution of the coarsest input data layers. However, an attempt to compensate for this was done by using large size planning units, approximately 1000 hectares (2 km sides).

7.1.2 Fine filter data layers

The Important Bird Areas (IBA) represents an extensive inventory and a solid data set. The database includes information about which species occur in which areas etc, unfortunately this information was not possible to take into account within the scope of this project. However, the main problem we have struggled with is the apparent lack of coherent digital information on the marine species and habitats in the region. The fine filter features which are included in the analysis therefore have a disproportionate influence on the selected portfolios. The stratification in line with exclusive economic zones, however, allows the possibility of including more data sets, since targets are reached in each of the strata separately. Including data layers with coverage on a national level is therefore possible in the current setting. However, the ambition of this project has been a uniform approach to site selection using data coherent over the entire region.

More specific habitat and species data, such as species specific recruitment areas for coastal fish species and Natura 2000 habitat types have been incorporated in the case study carried out in the Swedish Archipelago-Åland- Archipelago Sea area (see Chapter 8)

7.1.3 Socio-Economic data layers

The socio-economic data used to steer the selection away from areas less suitable for conservation or areas with high conflicting interest are all very broad scale, partly spatially very insecure data sets, this is especially so for the shipping routes. Information on the actual shipping routes in the Baltic Sea (Automatic Information System, AIS-data) was not available to the BALANCE project and therefore the recommended routes map was used as a proxy. The data set used is very simplified and only reflects the shipping routes in a very coarse manner. However, to compensate for the spatial insecurity these lines were buffered to steer away from quite extensive areas around these lines. The population size data is also very broad scale. Other human activity indicators such as housing frequency along the coastline would perhaps give a better indication of human density and its potential impact on the coastal areas. However, a coherent data set does not exist for the entire area. Perhaps the main gap in the suitability surface is the lack of data on fisheries, which is a factor of major importance in the region. No coherent data layer on a relevant scale could be identified and included in the analysis.

8 CASE STUDIES - A BALTIC ARCHIPELAGO AREA

Two case studies were also carried out at a finer scale in a trans-boundary area located in the vast archipelago region that stretches from the Swedish Archipelago over via Åland to the Finnish Archipelago Sea. The archipelago area with its tens of thousands of islands is topologically and geologically very heterogeneous, and the habitat patches are therefore usually small, with a very complex mix of soft-and hard bottom substrate (Lindberg et al., 2006)

The pilot area has been focus for other activities in the BALANCE project such as modelling of Natura 2000 habitats and fish recruitment areas. The pilot area has also been a case study area for development of a framework for management and zoning of the marine environment. More specific data was therefore available in this area as compared to most other parts of the Baltic Sea.

8.1 Current representation status

The Natura 2000 SAC networks representation status, with respect to the marine Natura 2000 habitats and fish recruitment areas, was assessed in a trans-boundary area located in the vast archipelago region that stretches from the Swedish Archipelago over via Åland to the Finnish Archipelago Sea (Piekäinen & Korpinen, 2007). The assessment showed that none of the six Habitats Directive Annex 1 habitats present in the area are adequately represented within the network of MPAs, e.g. fulfilling the minimum requirement of 20 percent representation or 60 percent representation in the case of priority habitats (*Estuaries 2.8%, Coastal lagoons 15.4%, Large shallow inlets and bays 7.9%, Reefs 4.6%, Esker islands 16.1% and Boreal Baltic narrow inlets 7.4%*). Note that only the marine (underwater) parts of the habitats were assessed.

The study area for the fish habitat assessment was somewhat larger than the study area for the Natura 2000 habitat assessment. Despite this, the protection level of all essential fish habitats is well below the 20 percent minimum representation level (*Pearch 3.8%, Pike 4.6%, Roach 5.0% and Pike pearch 3.5%*). Poor representation of some of the essential fish habitats that are often also important habitats for fish, such as shallow vegetated habitats (e.g. *Estuaries, Large shallow inlets and bays, Coastal lagoons etc)* can be related to the poor representation of the Natura 2000 habitats.

Conservation features and targets
The case study conservation features include, apart from the benthic marine landscapes also several of the modeled habitat maps produced within the BALANCE project e.g. marine Natura 2000 Annex 1 habitats and recruitment areas for a number of coastal fish species.

Conservation targets for representation of features in the case study area was set using the same framework as used in the landscape scale assessment, i.e. consistency with scientific recommendations and political documents especially the EU Habitats Directive (see Chapter 3.2). The conservation features to be represented in the network are listed below.

Coarse filter features:
Benthic Marine Landscapes: The distribution of benthic marine landscapes mapped within the BALANCE project (Al-Hamdani & Reker, 2007) was used as a coarse filter aiming to capture the broad scale variation in the pilot area. Altogether, 60 benthic marine landscapes were identified in the entire Baltic Sea region, whereas only 18 types occur in pilot area 3. The dominating benthic marine landscape types are non-photic mud in 5-7.5 psu covering 24 percent and non-photic hard clay in 5-7.5 psu covering 27 percent of the pilot area.

Conservation targets
Scenario A: Minimum **10 percent** representation target for representation of all benthic marine landscapes.
Scenario B: Minimum **20 percent** representation target for representation of all benthic marine landscapes.

Fine filter features:
The fine filter features in this assessment include:

Natura 2000 habitats: The distribution of marine habitats listed in Annex 1 to the Habitats Directive were also mapped within the BALANCE project (Dinesen et al., 2007) Altogether six habitats were included in the assessment; Estuaries (1130), Coastal lagoons (1150), Large shallow inlets and bays (1160), Reefs (1170), Esker islands (1610) and Boreal Baltic islets and small islands (1620). The habitat Sub-littoral sandbanks (1110) and Boreal Baltic narrow inlets (1650) were only mapped on the Swedish side of the pilot area and could therefore not be included in the assessment. Only the marine (underwater) parts of the habitats were included in the assessment.

It should be kept in mind that the maps used are based on predictive modelling and may therefore not display the real distribution patterns of the Natura 2000 habitats. The maps used in this assessment are an earlier version of the maps presented in Dinesen et al. (2007) and are therefore somewhat different.

Essential Fish Habitats: The predicted distribution of recruitment areas for four coastal fish species was also mapped within the BALANCE project (Bergström et al., 2007); The fish habitats included in the assessment were; spawning habitats for perch (*Perca fluviatilis*) and nursery habitats for pike (*Esox lucius*), roach (*Rutilus rutilus*), pike pearch (*Sander lucioperca*).

Areas predicted to have high heterogeneity was used to indicate areas with potential ecological "hot spots". The predicted benthic heterogeneity was also mapped within the BALANCE project (Snickars, M & Pitkänen, T., 2007). Only areas in the category "very high heterogeneity" were included in the assessment. It is widely acknowledged that heterogeneous environments normally support more species than homogenous ones.

Areas of importance for sea birds (Important Bird Areas, IBAs.) These sites were included in the assessment as indicators of important wintering, feeding and breeding habitats for many bird species

Grey Seal (*Halichoerus grypus*), which is a species listed in the Habitats and Species directive was also included in the assessment. Many of the haul out sites also occasionally also contains Harbour Seal (*Phoca vitulina*).

Conservation targets
Targets for representation of all fine filter features were set in line with the 20 percent and 60 percent (for priority habitats and species) coverage which is used as a guiding principle for sufficient protection when evaluating the EU-member states contribution to the Natura 2000 network. The representation target for Natura 2000 habitats, fish recruitment areas, heterogeneous areas and important bird areas were therefore set to at least **20 percent**. The only priority habitat and species included in this assessment was the habitat Coastal lagoons (1150) and the species Grey Seal, which were assigned a minimum **60 percent** representation target. Conservation targets for fine filter features representation were the same in both scenario A and B.

The total quantities of each of the conservation features in pilot area 3 as well as quantity of the features needed to fulfil the 10 and 20 percent conservation targets are summarized in Appendix 2, Table 1 and 2).

Other principles

Partly the same framework for determining criteria for the spatial configuration of the network as used in the landscape scale assessment was also used when determining principles for the pilot area assessment. However, the selected planning unit clusters were smaller due to the finer scale objective of the exercise.

Input and settings for the pilot area analysis was created using largely the same criteria, assumptions and methods as described for the landscape scale assessment. The major input parameter values; number of iterations, conservation feature penalty factor (CFPF-value) and boundary length modifier, (BLM) were decided using the same basic calibration as for the landscape scale assessment (see Chapter 5.2).

The spatial data that were incorporated into the suitability map (Figure 13) included those on harbours, shipping lanes near shore and off shore, potential ship accident areas and population density. Three data sets were new to the pilot area assessment, harbours, near shore shipping lanes and population density at commune level. These more high resolution data sets replaced the broad scale regional data on harbours, shipping lanes and population density used in the landscape scale assessment.

The intensity and distance from the activity considered are consistent with those specified in the landscape assessment, apart from a few adjustments of the figures related to those activities where data with better resolution replaced broad scale data i.e. harbours, near shore shipping lanes and population density (see Appendix 2, Table 3).

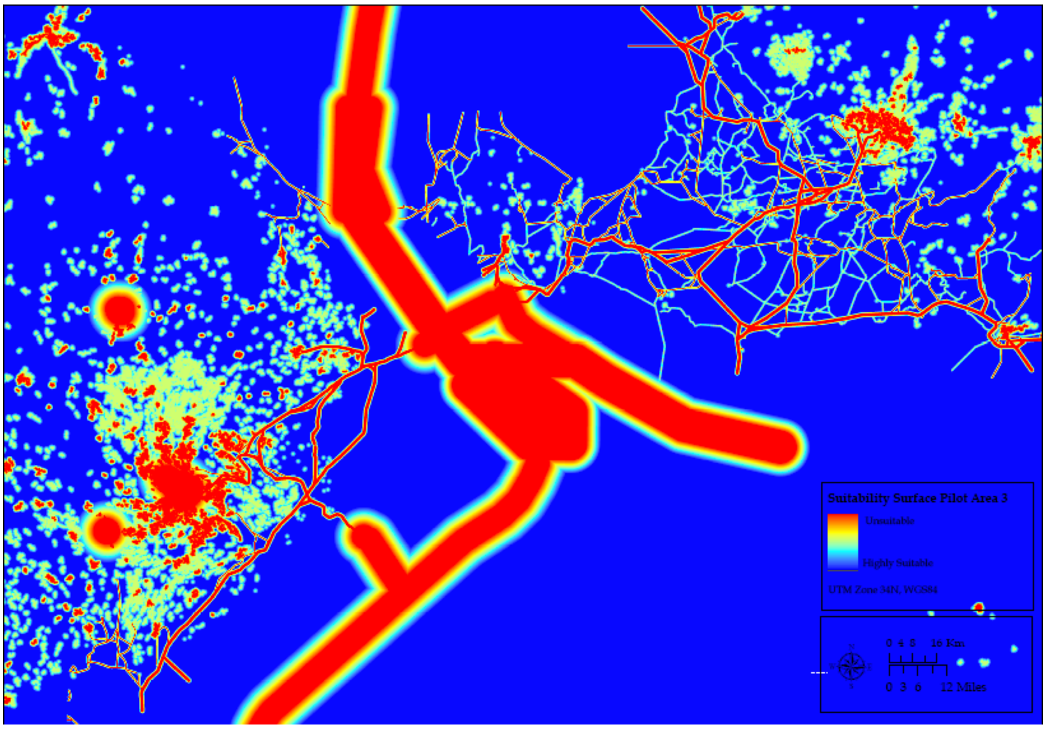


Figure 13. Suitability Surface created using distance grids. Values in the map represent relative suitability for MPA-designation, ranging from 'highly suitable value' (blue) to 'unsuitable value' (red). Broad scale data on major shipping lanes off shore, areas with increased risk for oil related accidents and population density were included along with higher resolution data on small vessel harbours and near shore shipping

lanes in the archipelago area.

8.2 Case Study 1

The aim of the first case study was to show how the regional assessment could be improved with access to coherent maps on e.g. Natura 2000 Annex I habitats and other fine filter conservation features.

8.2.1 Methods

The study area was delineated by a coastline with an approximate resolution of 1:20 000. The north-south delineation of the area was determined by the coverage of all the input data layers

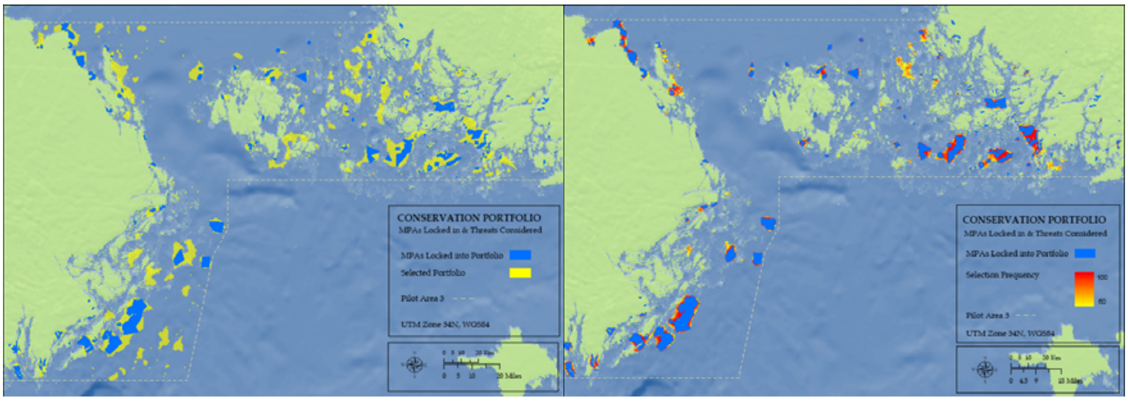
- The study area was divided into approximately 44 000 hexagonal planning units, each full size unit was 65 hectares in size. The planning unit layer was clipped by the coastline and each planning unit was given a base cost equal to its area. The pilot area suitability map, described above was used to add a measure of suitability to the area-base cost of each planning unit.

- Already designated Natura 2000 SACs were locked in to the portfolio during analysis. SACs that were less than 20 hectares in size were "earmarked" rather than locked in. Only the marine part of the sites were taken into account.

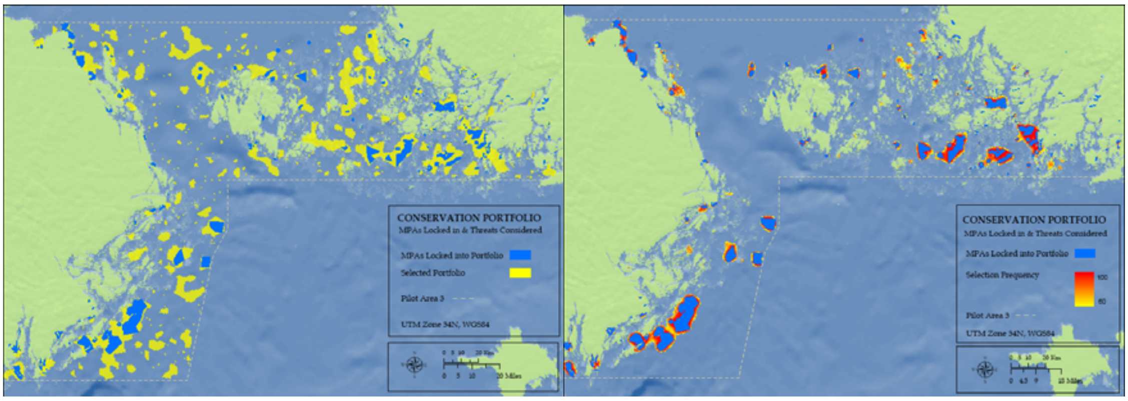
Examples of the best portfolio and summed solution for the case study 1 scenarios are shown below.

8.2.2 Result and Discussion

The best portfolio for the minimum 10 percent representation (Scenario A), resulted in a portfolio consisting of 5390 planning units (1940 locked in and 3450 additionally selected) with a total area of approximately 286 thousand hectares or 12.6 percent of the entire study area (Figure 14a). The best portfolio for the minimum 20 percent representation (Scenario B), resulted in a portfolio consisting of 8101 planning units (1940 locked in and 6161 additionally selected) with a total area of approximately 460 thousand hectares or 20 percent of the entire study area (Figure 14b).



a) SCENARIO A. MIN. 10 PERCENT REPRESENTATION (LOWER AMBITION)



b) SCENARIO B. 20 PERCENT REPRESENTATION (RECOMMENDED AMBITION)

Figure 14. Map on the left: MARXAN "best portfolio" Map on the right MARXAN "summed solution" The portfolios represent a minimum of 10% (scenario A) and 20% (scenario B) respectively of all benthic marine landscapes. A minimum of 20 % of each of the Marine Natura 2000 habitats: Estuaries (1130), Large shallow inlets and bays (1160), Reefs (1170), Esker islands (1610), Boreal Baltic islets and small islands (1620,) 60% of Natura 2000 priority habitat: Coastal lagoons (1150). A minimum of 20 % of each of the Essential Fish Habitats: spawning habitats for peach, nursery habitats for pike, roach, pike pearch. 60% of the Natura 2000 priority species: Grey Seal Haul Out sites and 20% of the important bird areas. The portfolio adds complementary sites to 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 targets. All targets were met

There is a high selection frequency in areas close to locked in protected areas (SACs). Planning units with a high selection frequency are also in both assessments mainly in coastal areas where many conservation features overlap. Whereas planning units with a low selection frequency are in the offshore areas, where the selection of planning units is more flexible due to the lack of overlap between conservation features. Most of the fine filter features e.g. coastal Natura 2000 habitats and fish recruitment areas occur in the near shore areas, whereas there are few overlapping features in the off shore areas.

This case study, carried out at a finer scale using more data layers, has aimed at illustrating how access to more data can improve the basis for selecting representative sites on a regional scale. One important conclusion is that regional coherent maps of the coastal and marine Natura 2000 habitats, habitat forming species such as bladder wrack, eelgrass and blue mussel and other species would vastly improve the basis for selection of a network of MPAs representing the whole range of biodiversity in the Baltic Sea.

8.3 Case Study 2

The aim of the second case study was to assess one of the portfolios selected in the regional assessment (Best portfolio, Scenario C; Recommended minimum 20 percent area coverage of all benthic marine landscapes). The selected sites were assessed with regard to how well the broad scale representation of benthic marine landscapes had captured some of the fine filter features mapped in the pilot area (i.e. Natura 2000 habitats, Fish recruitment areas).

Additional sites were then added to the sites selected in the regional assessment, until all conservation targets for features not included at the regional scale were met (i.e. Natura 2000 habitats, Fish recruitment areas).

8.3.1 Methods

The study area was delineated by a coastline with an approximate resolution of 1:20 000. The north-south delineation of the area was determined by the coverage of all the input data layers

- The study area was divided into approximately 44 000 hexagonal planning units, each full size unit was 65 hectares in size. The planning unit layer was clipped by the coastline and each planning unit was given a base cost equal to its area. The pilot area suitability map, described above was used to add a measure of suitability to the area-base cost of each planning unit.

- The sites selected in the regional assessment, which intersected pilot area 3, were selected. It was then estimated, using an overlay analysis in ArcGIS, how much of the total area coverage of the six assessed Natura 2000 habitats were inside the sites.

- The study area was divided into approximately 44 000 hexagonal planning units, each full size unit was 65 hectares in size. The planning unit layer was clipped by the coastline and each planning unit was given a base cost equal to its area. The pilot area suitability map, described above (in case study 1) was used to add a measure of suitability to the area-base cost of each planning unit.

- The sites selected in the regional assessment were locked in to the portfolio during analysis and additional, complementary sites were added until all targets for representation of fine filter features Natura 2000 habitats, fish recruitment areas and heterogeneous benthic habitats were met (i.e. all the features that were not included in the regional assessment).

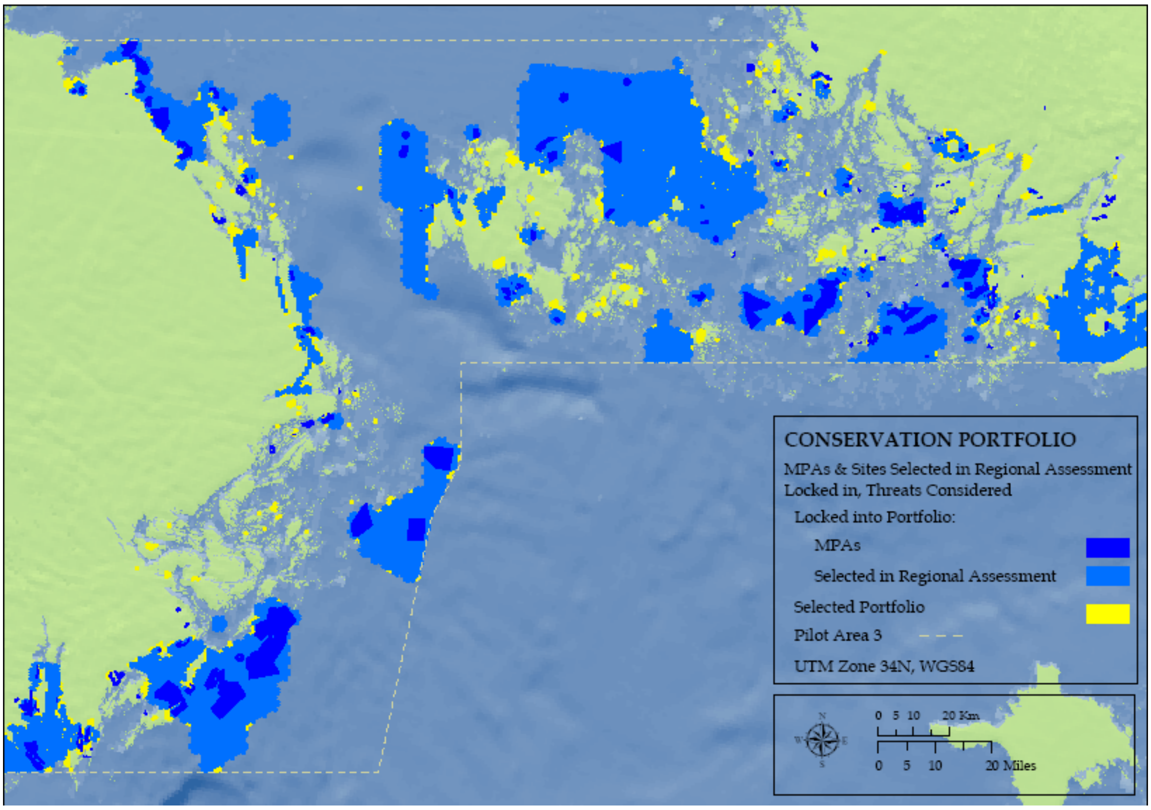
8.3.2 Results and discussion

The broad scale representative network captured more than 20 percent of five out of six assessed Natura 2000 habitats. (*Coastal lagoons 21%, Large shallow inlets and bays 23%, Reefs 33%, Esker islands 39%, Boreal Baltic islets and small islands 28%*). Only Estuaries (9%) were below the recommended 20 percent minimum level. However, it should be noted that coastal lagoons are a priority habitat with the target level set to 60 percent.

These results can at least indicate that representation of the broad scale variation of landscapes to a large extent also seem to capture the broad scale variation of several habitats, even though some gaps can be identified. The regional selection of sites was done using the marine landscape data mapped on a 1:250 0000 coastline, whereas the habitats were mapped using a much higher resolution (1:20 000). This can probably partly explain the lower coverage of the typical fine scale coastal habitats such as Coastal lagoons and Estuaries.

The regional broad scale representative network captured less than 20 percent of three out of four essential fish habitats (*Pearch 12%, Pike 14%, Roach 20% and Pike pearch 17%*).

The best portfolio for case study 2 scenario C, resulted in a portfolio consisting of 11651 planning units (10537 locked in and 1114 additionally selected) with a total area of approximately 630 thousand hectares or 28 percent of the entire study area (Figure 15).



SCENARIO C. 20 PERCENT REPRESENTATION (RECOMMENDED AMBITION)

Figure 15. MARXAN "best portfolio" representing a minimum of 20% (scenario C) of all benthic marine landscapes selected in the regional assessment and additional sites selected to ensure representation of 20 % of each of the Marine Natura 2000 habitats: Estuaries (1130), Large shallow inlets and bays (1160), Reefs (1170), Esker islands (1610), Boreal Baltic islets and small islands (1620,) 60% of Natura 2000 priority habitat: Coastal lagoons (1150), 20 % of each of the Fish Recruitment Areas: Spawning habitats for Perch, Nursery habitats for Pike, Roach, Pike pearch, 60% of the Natura 2000 priority species: Grey Seal Haul Out sites and 20% of the important bird areas.

The portfolio adds complementary sites to SACs and sites selected in the regional assessment (Scenario I), using BLM=0.1 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 targets. All targets were met.

In summary, more data layers vastly improve the analysis. However, it seems as if though the broad scale representative network at least to a certain extent captures the habitat variation. A broad scale representation of landscape types can therefore at least be a good starting-point for an analysis, which can be improved when more fine-filter data becomes available. Alternatively, the analysis can be done in two steps, which complement each other: A first regional selection of sites representing the broad scale variation and a second local scale analysis where complementary sites can be added which ensure representation of also the fine filter features.

9 CONCLUSIONS AND FURTHER RECOMMENDATIONS

This chapter will draw conclusions on the results of this analysis and discuss recommendations on how these results could be used to improve the existing Baltic Sea MPA network as well as recommendations on the further development of a systematic approach to selecting a representative network of protected areas.

9.1 A regional approach for implementation of international obligations

This analysis illustrate that it is possible to apply a **regional systematic approach** to site selection in the Baltic Sea. Such a systematic and ecologically based approach has for a long time been recommended by conservation experts and practitioners as it maximises the chance of creating MPA networks that meet the objectives, ensures a transparent, repeatable and objective process and makes efficient use of available resources. A regional, integrated and systematic approach is especially important in the Baltic Sea region where nine countries share the responsibility of protecting and managing the Baltic biodiversity. The marine ecosystems do not comply with political boundaries and can therefore not be managed without trans-national coordination. Since all the nine countries are bound to the same international agreements and conventions, a joint regional approach is the only reasonable way forward. Unfortunately, such an approach has, until now, been lacking in the Baltic Sea Region and the selection of protected areas has mainly been based on national processes and site-by-site selection.

To support MPA decision making in the Baltic Sea, this analysis provide several different scenarios where we vary the target levels and whether or not existing MPAs are included in the network design. Three uniform representation target scenarios were explored to illustrate different levels of conservation ambition; a minimum of 20 percent, 10 percent and 30 percent representation of all benthic marine landscapes. Specific targets were set for representation of specific species and habitats. The selected sites represent a minimum quantity of all conservation features at the minimum area required and fulfil a range of criteria for spatial arrangement, such as site suitability and complementarity.

We primarily identified MPAs that would complement existing MPAs already designated under the Habitats Directive. We also examined how efficient the existing MPAs were at meeting the conservation targets and what would be required to build out this existing system. All of the scenarios help inform decision making, and the scenario with 20 percent representation target that includes existing MPAs is likely the most informative for envisioning a network of Baltic Sea MPAs (Figure 9 and 12). The result presented should be seen as a first step in an iterative and continuously improving MPA-planning process, aiming towards a coherent, well managed network of sites representing the whole range of marine biodiversity in the Baltic Sea.

We have also in two case studies illustrated how the regional broad scale assessment can be improved through inclusion of more fine scale biodiversity data such as Natura 2000 Annex 1 habitats and essential fish habitats.

Based on the experiences from this project we believe that to be able to fully implement the international obligations, and designate a truly ecologically representative and coherent MPA network, there is a need to apply a regional holistic and integrated approach to site selection in the Baltic Sea region. If selecting a *representative network of sites* is the objective, which it is, 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. This method risks to miss 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 like MARXAN provides support to identify an efficient and comprehensive network that are driven by and satisfies a number of quantitative ecological and socio-economic goals.

The results presented in this report should be viewed as a first step towards a regional network of marine protected areas where the selection of sites is systematic and transparent, driven by quantitative conservation criteria as well as coordinated transnationally in the region. It is important to keep in mind that the MPA-planning process involves many more steps than the initial site selection, e.g. negotiations with stakeholders and experts and the development of management and zoning plans. Planning for marine protected areas should be viewed as an adaptive process, allowing for continuous improvement in both method and outcome.

Based on scientific literature, regional expert knowledge and political frameworks, a representation target of 20 percent was in this context considered the required minimum representation to secure long term sustainable populations and habitats. Beside this scenario, two other examples were presented illustrating a lower and a higher conservation ambition, of minimum 10 and 30 percent representation respectively.

Our analysis shows that the existing Natura 2000 network coverage does not sufficiently protect the minimum level 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 about three times the existing sites. The total coverage of selected and existing sites in this scenario was equivalent to approximately 30 percent of the entire Baltic Sea water surface. However, this coverage is based on the specific analysis criteria applied in this assessment and as other criteria are added the results will change.

It is important to note that the sites designated as SACs under the Habitats Directive only protect the habitats and species listed in the annexes to the directive. This means that although the existing sites cover also other habitats and species only those listed in the directive actually have legal protection that requires adequate management measures. The estimation of represented/protected benthic marine landscapes is therefore an overestimation of the actual protection. Consequently, since the current Habitats Directive only allow protection of certain habitats and species and not the full range of the Baltic Sea biodiversity it does not enable establishment of an ecologically coherent network of protected areas. If such a network is to be established under Natura 2000, more habitats and species have to be included in the directives.

The distribution of Natura 2000 habitats have so far only been modelled within restricted parts of the Baltic Sea (Dinesen et al., 2008) and a coherent coverage is still not available. It has therefore not been within the scope of this project to assess the representation/protection of Natura 2000 habitats, apart from a case study carried out a transboundary area located in the archipelago region that stretches from the Swedish Archipelago over via Åland to the Finnish Archipelago Sea. However, representing the broad scale variation of benthic environments (the marine landscapes) will most likely also at least to a certain extent capture representative quantities of the Natura 2000 habitats. This was i.e. shown in the assessment carried out in pilot area 3 (Case Study 2).

The landscape level analysis does not identify 'biodiversity hot spots' in the region, i.e. where several conservation features overlap and where conservation targets can be met in a limited area. This is mainly due to the fact that too few conservation features were included in the analysis. By including more detailed knowledge on the distribution of species and habitat, such areas could be identified and used to identify priority areas for conservation, as was shown in the case study. Such areas could e.g. be given priority in the site designation process, since several conservation targets can be met efficiently in limited areas. However, with respect to representing benthic landscapes, it could be concluded that there is a very high flexibility in selecting a broad scale representative MPA network. This means that by considering other user interests and including them in the site selection at an early stage, unnecessary conflicts can be minimised or avoided without compromising the broad scale conservation targets and objectives. With this type of analysis, where few coarse and fine filter features overlap, the most suitable sites (from an efficiency perspective) are often areas close to existing sites, heterogeneous areas (areas with high spatial variation of landscape types), sites with relatively low level of impact/threat and/or sites that meet multiple objectives.

9.2 Improving data availability

The ecological objectives originally defined for this site selection exercise (summarised in Andersson & Liman, 2006) stated that a representative network of marine protected areas in the Baltic Sea should adequately represent the full range of species, habitats and marine landscape types. Our aim throughout this exercise has been to follow that strategy and the ecological objectives originally stated as closely as possible. It is difficult, however, to consider ecological objectives for which there is very little or no data available. The access to spatial data is the key to being able to ensure full representation for all the stated targets. Therefore, the criteria for which this site selection is based upon had to be reconsidered, and instead aimed towards capturing an adequate amount of the full range of benthic marine landscapes as well as a few specific fine filter features.

Since compiling spatial data is generally a great challenge in an exercise such as this, it is worth to once again emphasise the need for further mapping and investigation of the marine environment. Highest priority should be put on coherent regional scale mapping of the Natura 2000 habitats and habitat forming species, such as blue mussel, bladder wrack, eel grass, kelp etc, but also on the quality of different habitats and landscapes, for example in terms of oxygen depletion. Without this information, political targets and goals can not be achieved and/or evaluated on an informed nor scientific basis.

Additional data sets with national coverage could be included in the analysis using the current political stratification by economic zone. It has not been done within this assessment, since the aim has been to accomplish a regional assessment. However, including more data is only covering one stratifying unit is possible. There will be no bias in the selection of sites as long as the data set is coherent in at least one stratifying unit, since representation targets are defined and fulfilled for each conservation feature in each stratifying unit separately.

Data availability has to be further improved to select a network representing the whole range of biodiversity in the Baltic Sea, and thereby to implement the political directives and international agreements.

9.3 Securing ecological coherence

In order to function as a network, marine protected areas (MPAs) need (1) to cover a proportion of all biotopes and habitats in the region, (2) to be of adequate size, shape and quality to support the protected features, (3) to be close enough to each other to ensure dispersal of species between the areas, and (4) to contain replicates of protected features to provide insurance against catastrophic events and to ensure natural variation of the feature. The four criteria (representation, adequacy, connectivity and replication) together form the concept of *ecological coherence* of protected areas.

However, in this analysis only representation, and to a certain extent, replication (via stratification and the clumping parameters used) has been considered. Technically, there are different ways to include the other coherence criteria into MARXAN. 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. A first step towards defining practical criteria for ecological coherence of MPA networks in the Baltic Sea has been taken by the BALANCE project. These criteria were also used in a first attempt to assess representativness, connectivity, adequacy and replication of the existing network (Piekäinen & Korpinen, 2007).

It is also highly recommended to consider habitat quality criteria when selecting sites for conservation. Habitats that are of good quality can support more viable and resilient populations. Oxygen depletion is probably the most important aspect 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. Vast areas dominated by soft substrates in the non-photic zones in Kattegat and the western Baltic Sea are influenced by oxygen deficiency (<2 mgO/l), e.g. 90 percent of the non-photic mud from 30 to 7.5 psu (Al-Hamdani & Reker, 2007).

Unfortunately a coherent and validated oxygen map for the whole Baltic Sea region was not available until at a very late stage in the project and could thereby not be included in this analysis. It is however highly recommended to be included in a further development of the approach.

Although this exercise has attempted to represent the full range of biodiversity in the Baltic Sea ecosystem, it has been strictly limited to representation of *marine* conservation features. As a long term target, it could be discussed if not a full holistic ecosystem approach should take into account the entire Baltic Sea catchment area, including terrestrial, freshwater and marine ecosystems to ensure full representation of all biodiversity features, their interactions and the complex ecological processes needed to sustain all habitats. Taking into account also the spatial and temporal dynamics of the ecosystems, such as i.e. climate change, land-uplift and ecological functions would further improve the approach.

9.4 Stakeholder involvement and socio-economic considerations

There are many different interests competing for space in the marine environment. Ideally, MPAs should be included in a broader marine spatial planning process, where the most suitable sites for nature conservation can be identified along with other uses such as fishing, military activities and tourism.

Taking socio-economic interests into account, e.g. by minimising the impact on conflicting interests, is a key factor for successful implementation and acceptance of the conservation plan. Decision support tools applied in a systematic conservation approach make this multiple objective approach possible by satisfying a number of ecological, social and economic goals simultaneously. A range of ecological and socio-economic considerations can be taken into account, already during the initial selection of conservation sites, to make sure that the most suitable sites from a socio-economic perspective are selected, e.g. areas with lower political or social pressure, or where resources necessary to implement conservation strategies and threat abatement are predicted to be lower, while at the same time achieve all conservation objectives.

However, it should be stressed that even though socio-economic aspects are taken into account during the initial selection of conservation sites, establishing a network of marine protected areas involve more steps than just selecting a set of candidate sites. Negotiation with stakeholders, revised selection of sites according to newly gained information and input, development of management and zoning plans etc. Therefore, the resulting portfolios of sites gained from an initial MARXAN run should always be seen as a first step in the process -a starting point for further negotiations.

Many alternative portfolios/solutions, all meeting conservation targets and objectives can be presented and the flexibility allow for stakeholder input and expert knowledge to be utilized to further guide the selection of conservation sites.

An approach using tools for ‘on screen conservation planning’ can be very useful in a forum for stakeholder and expert negotiations. The consequence of choosing or not choosing a particular candidate site can be explored interactively using GIS-tools. Individual planning units or sites in the initial portfolio can be swapped with units that contribute to targets in a similar way and thereby changing the spatial distribution of sites, without affecting the overall conservation target of the network.

The combination of decision support tools, such as MARXAN, expert opinion and stakeholder involvement is highly recommended. Including stakeholders and experts in the process also increase the probability of access to user interest data that can further improve the selection of sites and the final MPA network. Expert consultation allows for adjustment of selected sites according to administrative boundaries, which will contribute to a successful implementation of the conservation plan.

An important advantage of the approach presented in this report that it is repeatable and can easily be revised and rerun based on improved data availability and stakeholder consultation.

9.5 Importance of political support and regional action

Through this report, a first step has been taken towards a regional, strategic approach to systematic selection of conservation sites that could support implementation of the EU Habitats Directive, the HELCOM-OSPAR ministerial declaration as well as other regional and international conventions and agreements.

These agreements all require an ecosystem approach to protecting and managing the marine environment, which must directly or indirectly be based upon a broad scale characterisation of the marine environment. Based on the experiences from this project we believe that to be able to fully implement the international obligations mentioned above, and designate a truly representative and coherent network of protected areas, the approach must be holistic and integrated and span the entire Baltic Sea region. Protection of the Baltic Sea ecosystem must be a joint approach, where all countries share the responsibility for political action. Consequently, there should also be a fare distribution of protected areas between all countries. A single action from one country will be of limited use for the ecosystem if others do not follow. Political agreements on the overall principles and objectives are essential to a successful approach to protecting our ecosystems.

The BALANCE project has demonstrated that such a regional and strategic approach is possible in the Baltic Sea. We have introduced tools and methodologies and demonstrated the initial steps required for a regional selection of protected areas. We have also discussed the need for further mapping and investigation of the marine environment and outlined recommendations for a successful selection of conservation areas using a broad scale holistic approach. We hope that this report will inspire governments and stakeholders to participate in such a systematic conservation approach to implement international obligations.

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APPENDIX 1

HELCOM 18 Sub-region	Ecological Stratification Units
The Gulf of Gdansk The Gulf of Riga Eastern Gotland Basin Western Gotland Basin Southern Baltic Proper Northern BalticProper	Baltic Proper
Bothnian Bay The Quark	Bothnian Bay
Bothnian Sea Åland Sea Archipelago Sea	Bothnian Sea
Gulf of Finland	Gulf of Finland
Kattegat The Sound Litle Belt Great Belt Kiel Bay Bay of Mecklenburg	Kattegat

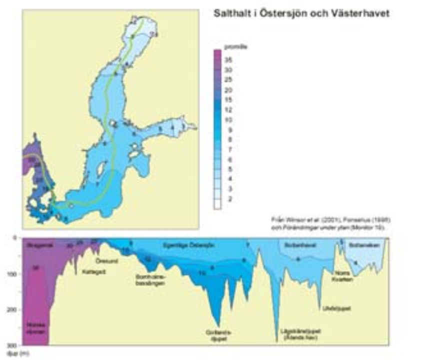

Figure 1. To the left; table summarizing the relation between sub-regions defined by HELCOM and the units used to stratify the fine filter conservation features. To the right; figure showing the salinity in the Baltic Sea, Kattegat and Skagerrak and the major thresholds (causing the major shifts in salinity regime). Source: Change Beneath the Surface, An In-Depth Look at Swedens Marine Environment. Monitor 19. 2005. Swedish Environment Protection Agency.

Table 1. Total quantity of fine filter conservation features included in the analysis. Quantity of the target needed to fulfill the minimum conservation target.

Conservation Feature	**Unit**	**Total quantity of feature (Ha)**	**Target %**	**Quantity to meet target (Ha)**
Important Bird Areas	Area (Ha)	5310050	20, 10, 30	1062011, 531003, 1593015
Cold Water Corals Dead	presence	25	60	15
Grey Seal Haul Out Sites	presence	71	60	43

Table 2. Total quantity of coarse filter conservation features included in the analysis. Quantity of the target needed to fulfill the ten, twenty and thirty percent conservation targets.

Coarse filter conservation features **Benthic Marine Landscapes**	**Estimated Quantity of Fea-ture (Ha)**	**Quantity of Target 10%**	**Quantity of Target 20%**	**Quantity of Tar-get 30%**
Euphotic bedrock < 5 psu	19390	1939	3878	5817
Euphotic bedrock 5-7,5 psu	318480	31848	63696	95544
Euphotic bedrock 7,5-11 psu	17120	1712	3424	5136
Euphotic bedrock 11-18 psu	4852	485	971	1456
Euphotic bedrock 18-30 psu	6561	656	1312	1968
Euphotic bedrock >30 psu	17211	1721	3442	5163
Non-photic bedrock < 5 psu	10540	1054	2108	3163
Non-photic bedrock 5-7,5 psu	419175	41918	83836	125752
Non-photic bedrock 7,5-11 psu	94040	9404	18808	28212

Non-photic bedrock 11-18 psu	228	23	46	68
Non-photic bedrock 18-30 psu	3844	384	769	1153
Non-photic bedrock >30 psu	73415	7341	14683	22024
Euphotic hard bottom comp. < 5 psu	447358	44736	89472	134208
Euphotic hard bottom comp. 5-7,5 psu	682273	68227	136455	204682
Euphotic hard bottom comp. 7,5-11 psu	106612	10661	21322	31983
Euphotic hard bottom comp. 11-18 psu	221815	22182	44363	66545
Euphotic hard bottom comp. 18-30 psu	222752	22275	44550	66826
Euphotic hard bottom comp. >30 psu	11899	1190	2380	3570
Non-photic hard bottom comp. < 5 psu	1028097	102811	205619	308430
Non-photic hard bottom comp. 5-7,5 psu	2753536	275353	550706	826062
Non-photic hard bottom comp. 7,5-11 psu	384389	38440	76879	115316
Non-photic hard bottom comp. 11-18 psu	204157	20416	40831	61248
Non-photic hard bottom comp. 18-30 psu	167075	16708	33416	50122
Non-photic hard bottom comp. >30 psu	62693	6269	12539	18808
Euphotic sand < 5 psu	228847	22884	45769	68654
Euphotic sand 5-7,5 psu	552529	55253	110505	165759
Euphotic sand 7,5-11 psu	341971	34197	68395	102591
Euphotic sand 11-18 psu	298926	29892	59785	89678
Euphotic sand 18-30 psu	547423	54742	109485	164227
Euphotic sand >30 psu	77587	7758	15518	23276
Non-photic sand < 5 psu	581351	58135	116271	174405
Non-photic sand 5-7,5 psu	2655168	265517	531033	796552
Non-photic sand 7,5-11 psu	2419012	241901	483803	725703
Non-photic sand 11-18 psu	446164	44616	89233	133849
Non-photic sand 18-30 psu	361808	36180	72362	108542
Non-photic sand >30 psu	242465	24246	48493	72739
Euphotic hard clay < 5 psu	42794	4279	8558	12838
Euphotic hard clay 5-7,5 psu	276998	27700	55400	83100
Euphotic hard clay 7,5-11 psu	10515	1051	2103	3155
Euphotic hard clay 11-18 psu	1406	141	281	422
Euphotic hard clay 18-30 psu	18306	1831	3661	5492
Euphotic hard clay >30 psu	11112	1111	2222	3334
Non-photic hard clay < 5 psu	477009	47701	95402	143103
Non-photic hard clay 5-7,5 psu	4712949	471295	942589	1413884
Non-photic hard clay 7,5-11 psu	3052887	305288	610577	915866
Non-photic hard clay 11-18 psu	318192	31820	63638	95457
Non-photic hard clay 18-30 psu	36089	3609	7218	10827
Non-photic hard clay >30 psu	104332	10433	20865	31300
Euphotic mud < 5 psu	124894	12489	24979	37468
Euphotic mud 5-7,5 psu	462866	46287	92573	138861
Euphotic mud 7,5-11 psu	46081	4608	9215	13824
Euphotic mud 11-18 psu	71648	7165	14330	21494
Euphotic mud 18-30 psu	160570	16057	32114	48171
Euphotic mud >30 psu	25080	2508	5016	7524
Non-photic mud < 5 psu	1418177	141818	283635	425453
Non-photic mud 5-7,5 psu	4793063	479308	958611	1437921
Non-photic mud 7,5-11 psu	5863763	586375	1172752	1759130
Non-photic mud 11-18 psu	1969891	196989	393978	590969
Non-photic mud 18-30 psu	541346	54135	108269	162404
Non-photic mud >30 psu	1641986	164199	328397	492596

Table 3. Arguments used to rank sites with high risk for oil related accidents (Areas of high accident risk estimated by VTT Technical Research Center of Finland. Data Source: HELCOM MARIS, 2004).	
Arg1.	Tanker route diverges or merges with traffic flow
Arg2.	Heavy parallel traffic
Arg3.	Parallel traffic
Arg.4	Heavy oncoming traffic
Arg5.	Oncoming traffic
Arg6-7.	Crossing traffic
Arg8.	Traffic separation schemes inadequate or lacking,
Arg9.	Improper location of navigation mark
Arg10.	Narrow or/and restricted route
Arg11.	Contraventions of the Collision Regulations (not exercising prudent seamanship)
Arg12.	Lack of shore-based monitoring (e.g. VTS) and imposing sanctions against offending vessels
Arg13.	Fishing boats
Arg14.	Pleasure crafts

Table 4. Coarse and Fine filter features listed in BALANCE interim report No 2 "Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea" (Andersson & Liman 2006).

	Feature category	**Subcategories**
Coarse filter	Marine landscape representation	Benthic Marine Landscapes
	Habitat representation	Natura2000
		EUNIS
		Shoreline type
Fine filter	Species of special interest	Kelp belts (Laminaria sp.)
		Furcellaria belts (Fuecellaria lumbricalis)
		Bladder wrack belts (Fucus vesiculosus)
		Eelgrass beds (Zostera marina)
		Stoneworth beds (Charophyta)
		Blue mussel beds (Mytilus edulis)
		Horse mussel (Modiolus modiolus)
		Maerl beds (Phymatolithon calcareum)
		Oyster beds (Ostrea edulis)
		Lophelia reefs (Lophelia pertusa)
		Marine mammals
		Fish species
		Sea birds
	Special elements	Rare, unique, threatened and endangered species and habitats.
		Distinctive features (e.g. frontal systems, upwellings)

Table 5. Socio-Economic factors listed in BALANCE interim report No 2 “Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea” (Andersson & Liman 2006).	
Density of human population	Major shipping lanes
Cables and pipeline	Port facilities
Toxic levels	Oil transport
Nutrient levels	Fisheries
Military areas	Aqua-culture
Tourism density	Sand- and gravel extraction
Research sites	Dumping grounds (toxics, dredged material)
Reference sites	Wind farms (exisisting objects)
Cultural heritage sites	Other marine constructions
Ditched areas	Roads close to the shore line
Dredged areas	Noise levels
Artificial coastline	Marine Protected Areas

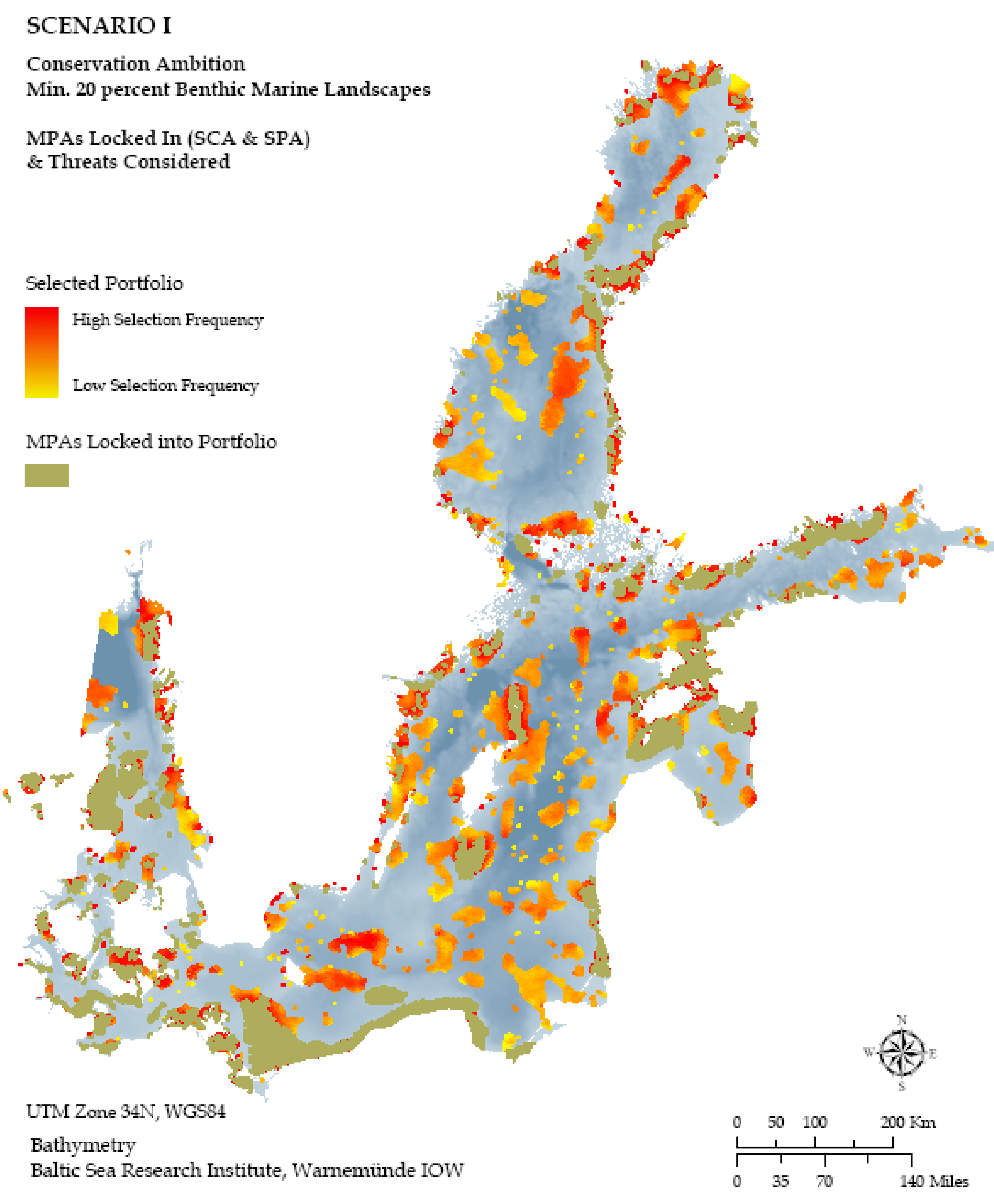

Figure 2. SCENARIO I MIN. 20 PERCENT REPRESENTATION (RECOMMENDED)
Both SACs and SPAs locked in. *MARXAN "best portfolio" with the selection frequency of each unit during 100 runs.*

The portfolio represents a minimum of 20% of all benthic marine landscapes and IBAs, 60% of all Grey Seal haul out sites, 100% of all Cold Water Coral occurrences (60% of the dead structures). The portfolio adds complementary sites to SACs and SPAs, 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 targets. All targets were met

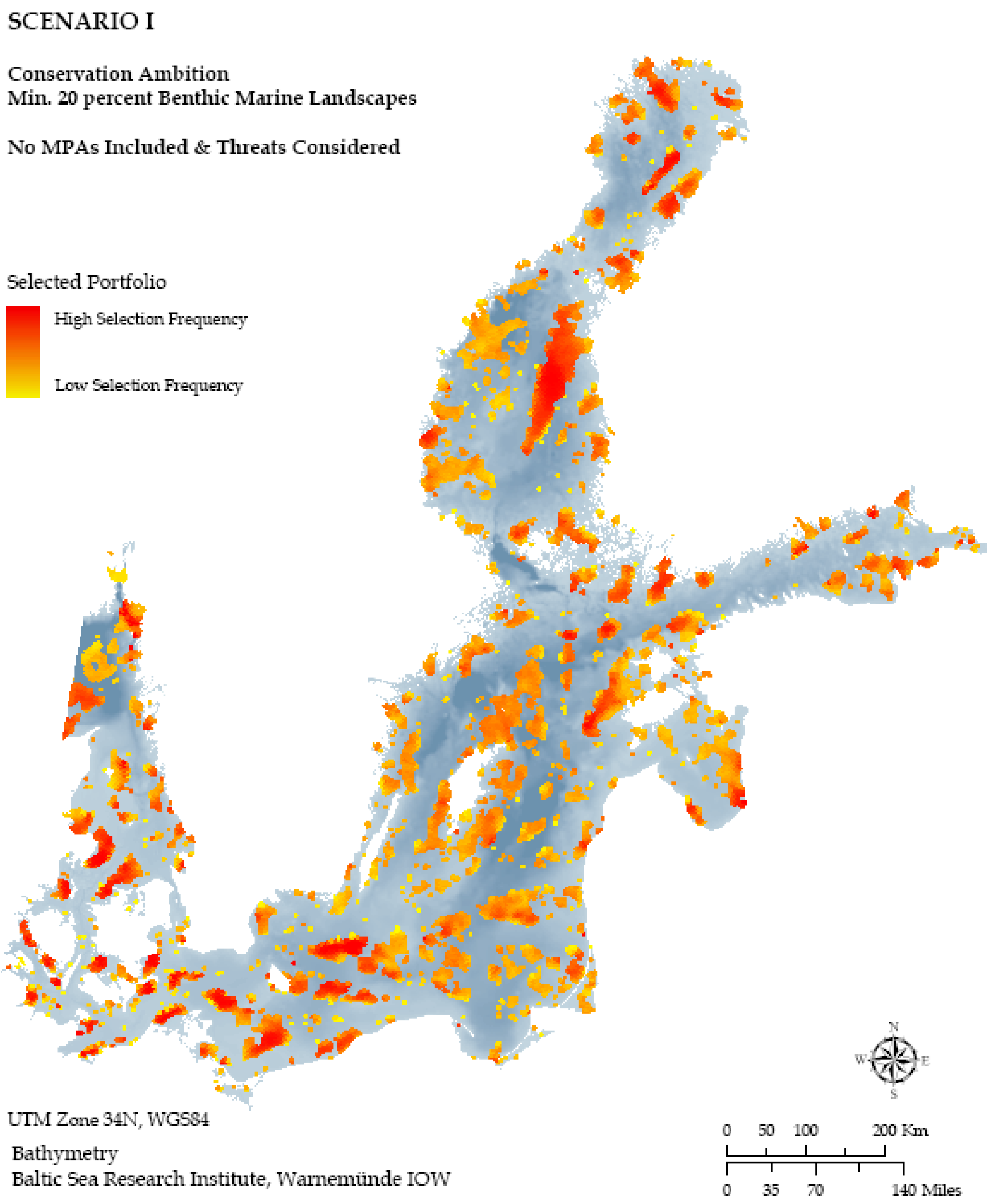

Figure 3. SCENARIO I MIN. 20 PERCENT REPRESENTATION (RECOMMENDED)
No previously protected areas locked in. MARXAN "best portfolio" with the selection frequency of each unit during 100 runs.

The portfolio represents a minimum of 20% of all benthic marine landscapes and IBAs, 60% of all Grey Seal haul out sites, 100% of all Cold Water Coral occurrences (60% of the dead structures). No existing MPAs were included in the portfolio. The portfolio does not include any permanently locked in areas. BLM=1, stratified targets and a measure of suitability were used. The selection was done using simulated annealing with iterative improvement using 2 million iterations in 100 runs and CFPF-value 100 for all targets.

APPENDIX 2

*Table 1. Total quantity of coarse filter features benthic marine landscape in **pilot area 3**. Quantity of the target needed to fulfill the ten and twenty percent conservation targets.*				
Grid code	**Benthic Marine Landscape**	**Estimated Quantity of feature (Ha)**	**Quantity of Target 10%**	**Quantity of Target 20%**
111	Bedrock, Photic, 0-5psu	5716.3	571.6	1143.3
112	Bedrock, Photic, 5-7.5psu	176012.7	17601.3	35202.5
121	Bedrock, Aphotic, 0-5psu	6917.2	691.7	1383.4
122	Bedrock, Aphotic, 5-7.5psu	175225.1	17522.5	35045.0
123	Bedrock, Aphotic, 7.5-11psu	12136.3	1213.6	2427.3
211	Hard Bottom, Photic, 0-5psu	23443.7	2344.4	4688.7
212	Hard Bottom, Photic, 5-7.5psu	1680.0	168.0	336.0
221	Hard Bottom, Aphotic, 0-5psu	15688.4	1568.8	3137.7
222	Hard Bottom, Aphotic, 5-7.5psu	13091.4	1309.1	2618.3
312	Sand, Photic, 5-7.5psu	4735.5	473.5	947.1
322	Sand, Aphotic, 5-7.5psu	4098.3	409.8	819.7
411	Hard Clay, Photic, 0-5psu	24267.8	2426.8	4853.6
412	Hard Clay, Photic, 5-7.5psu	132944.4	13294.4	26588.9
421	Hard Clay, Aphotic, 0-5psu	52039.4	5203.9	10407.9
422	Hard Clay, Aphotic, 5-7.5psu	573077.1	57307.7	114615.4
423	Hard Clay, Aphotic, 7.5-11psu	107981.7	10798.2	21596.3
512	Mud, Photic, 5-7.5psu	235940.2	23594.0	47188.0
522	Mud, Aphotic, 5-7.5psu	507896.3	50789.6	101579.3
523	Mud, Aphotic, 7.5-11psu	17851.2	1785.1	3570.2

Table 2. Total quantity of fine filter features in pilot area 3. Quantity of the target needed to fulfill the 10 and 20 percent conservation targets.			
Natura 2000 Annex 1 Habitats	**Estimated Quantity of feature (Ha)**	**Quantity of Target 10%**	**Quantity of Target 20%**
Estuaries (1130)	12268.6	1226.9	2453.7
Coastal lagoons (1150)	1598.7	159.9	319.7
Large shallow inlets and bays (1160)	36303.7	3630.4	7260.7
Reefs (1170)	36068.7	3606.9	7213.7
Esker islands (1610)	2958.9	295.9	591.8
Boreal Baltic islets and small islands (1620)	117681.0	11768.1	23536.2
Spawning habitats for perch	18165.6	1816.6	3633.1
Nursery habitats for pike	45911.7	4591.2	9182.3
Nursery habitats for roach	189302.7	18930.3	37860.5
Nursery habitats for pike pearch	105776.1	10577.6	21155.2
Important Bird Areas	258470.4	25847.0	51694.1
Heterogeneous areas	13132.6	1313.3	2626.5

*Table 3. Socio Economic factors incorporated into the **pilot area** suitability map and the assigned approximate distance of influence and relative suitability scores on a scale 1-5, with 5 indicating the most severe threat.*			
Suitability factor	**Unit of Measurement**	**Distance (m)**	**Relative suitability (1-5)**
Harbours	presence/ absence	0-1000	1
Shipping lanes,	channel depth 0-8 m	0-500	2
near shore	channel depth >8 m	0-1000	3
Shipping lanes off shore, cargo traffic	701-14000 ships/year	0-10 000	3
	14001- ships/year	0-10 000	4
Population density	0.4-8 persons / 100*100m	0-1000	1
	8.1-120 persons / 100*100m	0-1000	2
	120.1-580 persons / 100*100m	0-10 000	3
Oil risk related areas Moderate risk	Fulfill argument: 1,3,5,7,10,11*	0-10 000	3
High risk	Fulfil arguments: 1,7, 10, 11, 2, 4, 6, 14, 3, 5, 8, 9, 13, 12*	0-10 000	4

About the BALANCE project:

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

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

The **BALANCE Report Series** includes:

BALANCE Interim Report No. 1 Delineation of the BALANCE Pilot Areas
BALANCE Interim Report No. 2 Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea – an interim strategy
BALANCE Interim Report No. 3 Feasibility of hyperspectral remote sensing for mapping benthic macroalgal cover in turbid coastal waters of the Baltic Sea"
BALANCE Interim Report No. 4 Literature review of the "Blue Corridors" concept and its applicability to the Baltic Sea
BALANCE Interim Report No. 5 Evaluation of remote sensing methods as a tool to characterise shallow marine habitats I
BALANCE Interim Report No. 6 BALANCE Cruise Report – The Archipelago Sea
BALANCE Interim Report No. 7 BALANCE Cruise Report – The Kattegat
BALANCE Interim Report No. 8 BALANCE Stakeholder Communication Guide
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BALANCE Interim Report No. 10 Towards marine landscapes of the Baltic Sea
BALANCE Interim Report No. 11 Fish habitat modelling in a Baltic Sea archipelago region
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BALANCE Interim Report No. 32 Guidelines for harmonisation of marine data
BALANCE Interim Report No. 33 The BALANCE Conference

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