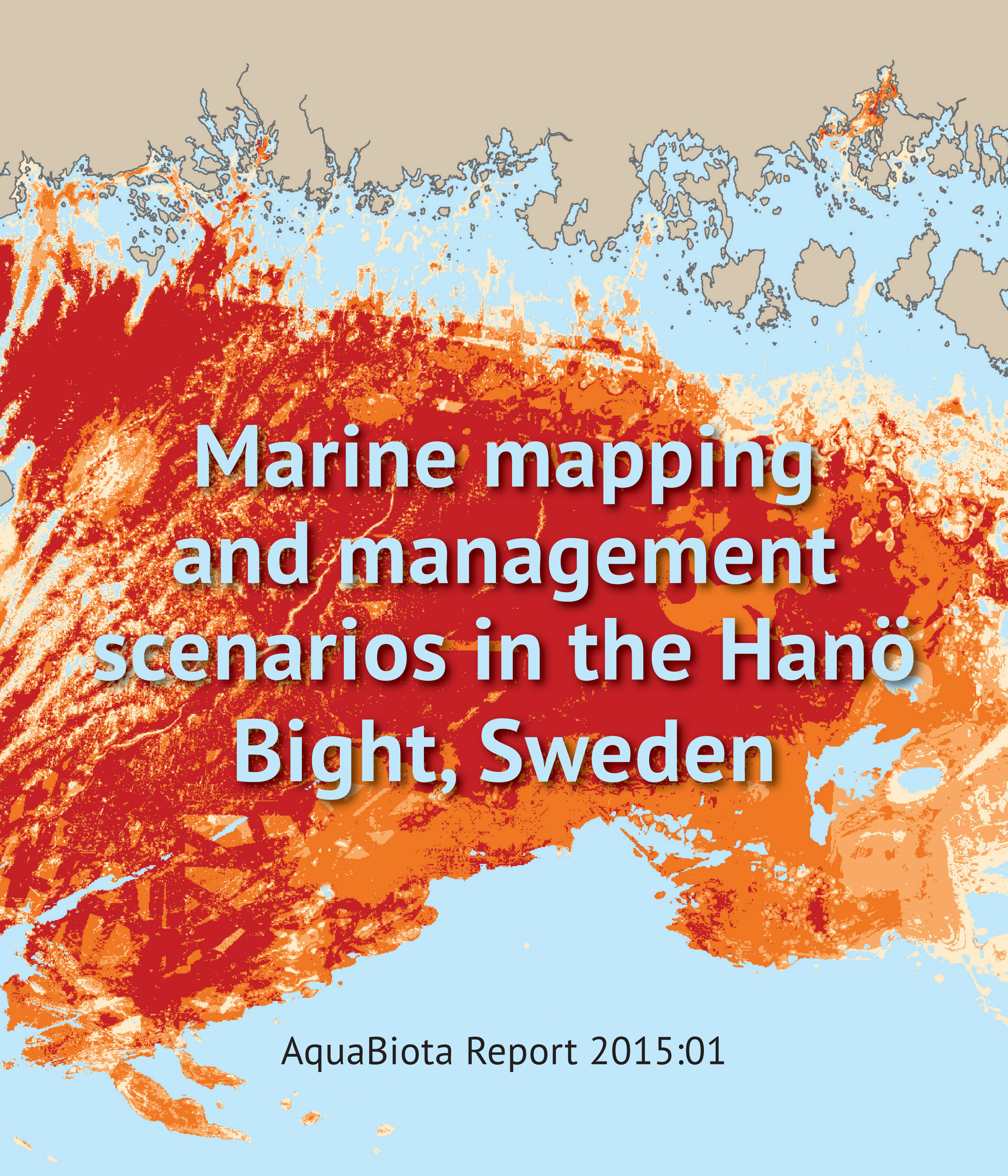

Marine mapping and management scenarios in the Hanö Bight, Sweden

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Cover image: Predicted abundance of the polychaetes *Marenzelleria* spp., based on inventory data from bottom grabs. See full map in Annex 2.

Summary

Knowledge about the presence and distribution of marine habitats is today requested by many sectors. In the 2000s, the demand has increased in line with efforts to protect the marine environment, with clear priority through national and international commitments. Within the county administration and the municipalities there is a great need for increased knowledge on the marine environment, both for regional and local coastal planning, and as a basis for supervision and decision making under the Environmental Code. Maps of the marine environment are of great importance for planning, protection and management, on both a national and an international scale. Further, identification of areas with high conservation values, knowledge on impacts of human activities and changes of eutrophication status on conservation values, and ocean zoning can all provide good basis for MSP.

Within the Life project MARMONI as well as the Swedish project "Biogeografisk uppföljning" (monitoring for the Habitats Directive), extensive field surveys of benthic flora and fauna, birds, juvenile fish, pelagic fish and plankton has been performed within Blekinge County and the Hanö Bight. Maps of benthic flora and fauna, fish and plankton have been created using spatial modeling. The surveys were performed with different methods such as aerial transects, drop-video, snorkeling, diving, bottom grabs, echo-sounding and small underwater detonations. Data from earlier surveys have also been compiled for use in the modeling.

In the spatial modeling, data about the physical environment and anthropogenic activities have been used as predictor variables in order to create models and predictions. Coherent maps were collected or created for the variables salinity, temperature, nutrients, chlorophyll, depth, different depth derivatives, Secchi-depth, wave exposure, potentially contaminated areas, proximity to densely populated areas and marine traffic.

In total, maps showing probability of presence are presented for 7 species or groups of vascular plants, 9 species or groups of algae, 19 taxa of benthic animals, 3 species of juvenile coastal fish and adult sticklebacks. Abundance-maps are presented for 3 groups of pelagic fish, jellyfish, 2 groups of zooplankton as well as 7 taxa of benthic animals. For several species and groups, maps showing probability of high cover or densities were also created. The total number of created maps is 81. All model results presented in this report are of good or excellent quality.

Additionally, conservation values have been identified assessed and mapped using a systematic approach based on years of experience as well as the well-established HELCOM underwater classification system and the scientific criteria for identifying ecologically or biologically significant marine areas in need of protection adopted by the Convention on Biological Diversity. Conservation values maps were produced based on benthic vegetation and animals, coastal fish recruitment areas, wintering waterbirds and seal haul-out sites.

Effects on the marine environment were tested through scenario analyses of the quantified effects of construction and operation of a marine wind park and changes of eutrophication status (measured as changes of Secchi-depth) on various conservation values. Further, structural equation modelling (SEM) was used to test fundamental ecosystem mechanistic pathways as well as the influence of important anthropogenic pressures on algae, rooted plants, and blue

mussels (*Mytilus edulis*) and the burrowing polychaete (*Marenzelleria* spp.) in a more holistic and ecosystem-like setting than had been done before.

To create a proposal for a network of marine protected areas, information on various conservation values and human interests were analysed with the decision support tool Marxan with Zones. Several ocean zoning maps were produced from three scenarios of protection targets.

The maps can be used directly in MSP, as a basis for consultation and strategic decisions concerning the location and design of the establishment of new operations or as a communication and visualization tool of conservation values. They also provide an indication of where it is appropriate to investigate the environmental impact more thoroughly during permit applications, such as EIA's. The spatially distributed field data and map layers of environmental parameters were essential to develop good model results and identify conservation values. But they are also strongly useful in themselves as information and for further analyses of the marine environment.

Spatial mapping of relevant marine conservation values are recommended for all EU member states, as a basis for MSP, and application of marine ecosystem based management in the Baltic Sea.

Contents

1 Background and aim

Extensive field surveys and modelling of marine biota have been conducted in Hanö Bight (which in this report also refer to the whole Blekinge County) in Sweden (Figure 1) within the EU LIFE+ project MARMONI (Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea) and the Swedish project "Biogeografisk uppföljning" (monitoring for the Habitats Directive). The field data and maps have further been used to identify areas with high conservation values, test scenarios of the impact of a fictive wind farm and for altered Secchi depth on various conservation values, and draft proposals on marine protected areas (MPAs) through a zoning process.

Knowledge about the distribution of marine habitats, biotopes and species are today requested by many sectors. The demand has increased as the marine environment has been given a clear priority in Sweden through national and international commitments during the 2000s. National environmental quality objectives, legislation and the introduction of the EU Water Framework Directive (WFD; Directive 2000/60/EC) and the Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC) have significantly increased the ambitions for conservation as well as demands for good ecological and environmental status in water bodies. Counties and municipalities have a strong need for increased knowledge of the marine environment for local coastal zone management (CZM) and marine spatial planning (MSP), as well as a knowledge base for permit matters according to the Swedish environmental code. The EU Maritime Spatial Planning Directive (MSPD; Directive 2014/89/EU) should be incorporated in the member states' national legislations by 2016 and marine plans shall be in place by 2021.

The MSFD was incorporated in Swedish legislation in 2010. The goal for Swedish management is that both the Baltic Sea and North Sea should have good environmental status (GES). The WFD demands that water bodies are classified and assessed and the marine maps may contribute to this. The status of the water bodies are not allowed to deteriorate and these statuses are valid as environmental targets. Permissions, approvals or exemptions may normally not be given for any new activities which contribute to the violation of an environmental target.

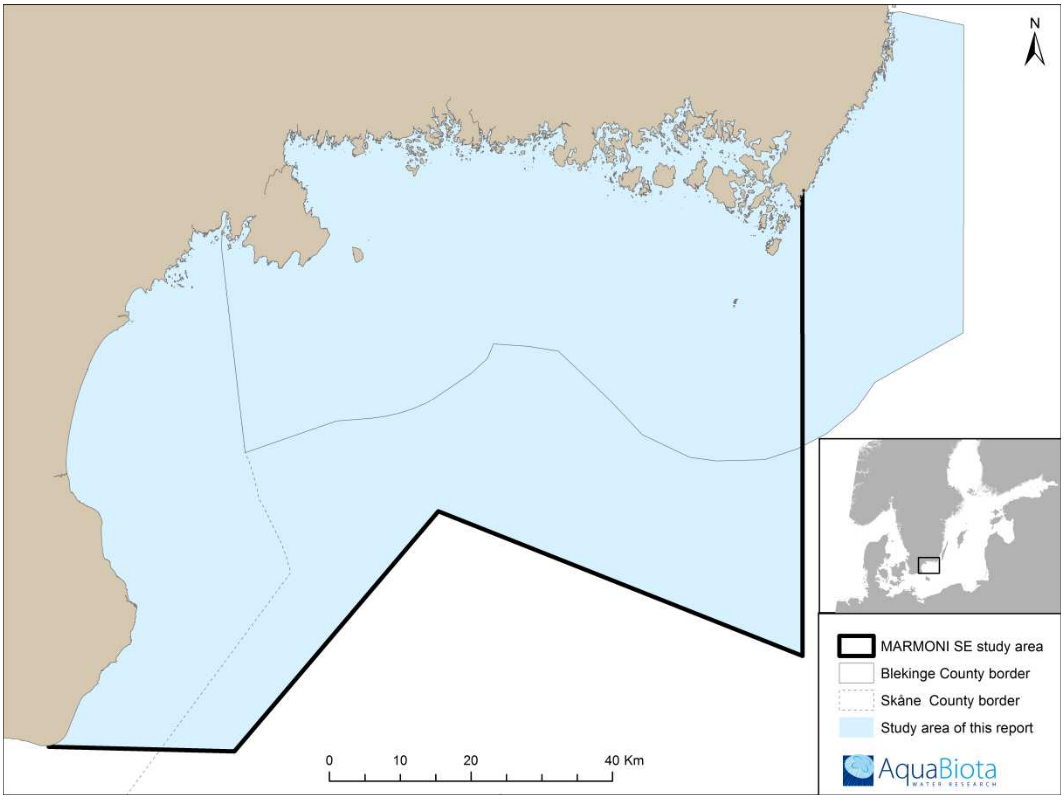

Figure 1. The areas encompassed by this report; the marine area of Blekinge County and the Swedish study area of the MARMONI-project.

1.1 Nature conservation and management

Planning, management and development of marine and coastal areas demand comprehensive and reliable spatial data describing the marine systems as well as their functions and values. Maps of the distribution of species and groups provide information for conservation value assessments and may be used in MSP, CZM, conservation plans as well as trials of development consents.

Knowledge of the distribution of habitats and biotopes on the seafloor is crucial for nature conservation and management. The maps on county level provide a broad overview of the distribution of species and groups. Together with maps of environmental variables which were created or compiled within this project, these maps provide a good overview of environments and biotopes in different coastal areas.

The Swedish Environmental Protection Agency (SEPA) (SEPA 2007a) lists certain criteria for selection and prioritization of marine areas worthy of protection where naturalness, representativity and biogeographical values, rarity, ecological and biological value, variation, threatened species, biotopes or biotope complexes as well as foraging, resting, reproduction and recruitment areas are considered. Other values are scientific values, international and economical values as well as social values. These maps are valuable in the assessment of such values.

The maps may also be used in the creation of a protection strategy for the marine environment based on ecologic landscape planning. They can contribute to decision making in many ways. For example identify where the needs for new protected areas are largest, answer if the currently protected areas are representative and if unique or rare biotopes and habitats are protected or not. Reasons for prioritization may be threat, vulnerability, size, connectivity, feasibility, etc. There are currently four marine reserves with a total area of 4149 ha in Blekinge County. Many protected areas are also included in Natura 2000, the European framework of areas protected according to Species and Habitats directive. Within these areas management plans describing values, habitats, status and threats should be established. The maps can also contribute to this. The Swedish environmental code points out large areas of the Blekinge coast and archipelago as national interest for nature conservation. As a principal rule, developments and other activities are allowed only in a way which has no significant effect on natural and cultural values in the area. Knowledge about the underwater environments in such areas is important.

Many people are interested in marine and aquatic environments but they are traditionally inaccessible and the questions are many.

A better knowledge of the location of biotopes and habitats on the seafloor also facilitates the production of information material and guidebooks describing the marine life. An interested and knowledgeable public is important for future nature management and conservation. Development of the tourism in the area is also of interest and the marine maps may provide a tool to guide and direct the visitors.

1.2 Decision support for planning

An important part of the counties' and municipalities' environmental and nature management work is the handling of consultations and applications for exemptions or permissions according to the Swedish environmental code for many different types of activities involving the marine environment.

Permission or consultation is needed for water resource management, measures in shoreline protection areas or for measures that may affect the natural environment such as construction works in water bodies, excavation, dredging, cables, fish farming etc. For many activities an environmental impact assessment is demanded. Where county administrative boards or municipalities are not decision-making authorities, pronouncements are written to SEPA or the environmental court. In addition there are questions from the public, companies and authorities regarding the marine and coastal environment. In all, this means that the county administrative board has a constant work of assessing the different activities' impact on the marine environment. A modelled habitat and biotope description and distribution of species and species groups in the underwater environment may facilitate this work. The maps are also useful in conservation value assessments which are in turn very useful in spatial planning.

1.3 Marine Spatial Planning in Sweden

Sweden is about to establish a system for MSP based on the ecosystem approach. The aim is to ensure a sustainable use of marine resources as well as to coordinate and prioritize interests spatially. Economic, social and ecological factors are important for this planning and spatial data (maps) are of great importance.

The national MSP in Sweden is coordinated by the Swedish Agency for Marine and Water Management (SwAM). The planning is divided within three large marine plans extending from one nautical mile from the baseline to the EEZ boundary. Within the territorial waters the marine plans overlap with the comprehensive plans of the coastal municipalities, which extend from the coastline to the boundary of Swedish territorial waters. Today we have a good knowledge of the distribution of nature types and species in the terrestrial environment. This knowledge has been achieved through comprehensive national surveys performed by authorities such as the Swedish Forest Agency, the Swedish Board of Agriculture, county administrative boards and municipalities. In contrary to this the knowledge of the marine environment is scarce and fragmented and coherent maps of biotopes and species distributions are largely missing. The mapping presented in this report is an important contribution to the filling of this knowledge gap.

In Sweden county wise mappings of marine biophysical elements were initiated in 2009 in Östergötland County. Since then six of Sweden's 14 coastal counties have been mapped in similar ways.

1.4 Decision support for restorations and other management measures

Aquatic and marine environments are often strongly affected by human activities wherefore restorations or other measures may be needed to restore or improve the status. The modelled maps may facilitate the work to direct these measures to appropriate locations. If a certain biotope or species is predicted in certain a location but is not found there in reality, the reason may be anthropogenic pressures.

1.5 Fisheries management

The knowledge of the spatial distribution of fish populations and marine habitats in different areas is important for the evaluation of the effect of the fisheries management. The maps may also facilitate the selection of fish monitoring locations and act as complementary information when making fishery management decisions.

1.6 Further surveys and monitoring programs

To prioritize and select areas for marine monitoring a baseline map is valuable. Maps of marine biotopes, species, conservation values and geophysical elements provide good baseline maps. These can be used for spatial distribution and selection of sampling stations. The maps also provide an opportunity to assess the representativity of selected monitoring stations for the entire coastal area, both for coastal areas included in the WFD monitoring and off-shore areas included in the MSFD monitoring.

1.7 The maps

The aim was to perform a comprehensive mapping of biophysical elements of the coastal environment and to identify areas with high conservation values for use in planning on county and municipality level and to provide basis information for MSP.

The mapping was performed with several techniques and several different institutions and experts were involved in the process. Extensive field surveys of biological elements were performed including waterbirds, fish, plankton and benthic vegetation and animals (Section 3). A large number of map layers of environmental variables were prepared, such as depth and depth derivates, different hydrografical chemical variables and wave exposure (Section 4). Coherent maps for the distribution and abundance of species and biotopes were created using spatial modelling (Sections 5 and 0) (except for waterbirds). Waterbird presenses were presented in dot distribution maps and polygon density analyses based on extensive seabird surveys (Section 3.5). The collected field data and modelled distribution maps were used for conservation value assassement and mapping (Section 7) as well as scenarios of effects of a fictive wind park (Section 8) and changes in Secchi-depth (Section 9). An ecosystem model of the benthic community was done (Section 10) as well as a Marxan with Zones-analysis (Section 11).

1.7.1 Resolution of species predictions and maps

A modelled distribution map of a species or biotope (i.e. spatial prediction) presents the probable distribution of a species or biotope. When working with modelling the balance between generalization and reliability should be decided through discussions between planners and modellers, in order to ensure that the spatial data have a resolution and quality adequate for planning needs. Further, the precision of the prediction depends on the resolution and quality of the environmental variables, the performance of the modelling and the characteristics of the species or biotope. A coarse resolution normally generates a prediction of higher quality, but a too coarse resolution will not be sufficient for management on county and municipality level. Predictions with too high spatial resolution and resulting low quality on the other hand are not desirable either. Therefore a trade-off between spatial resolution and quality of the prediction has to be done. Predictions were made in spatial resolutions from 10 to 1000 meters depending on modelled variable. Juvenile fish in coastal recruitment areas were predicted in 10 m resolution since these recruitment areas largely consist of small bays in a complex coastline. Predictions of benthic vegetation and animals were performed over considerably larger areas and therefore predicted in 25 m resolution due to limitations in computational power. A spatial resolution of 1000 m was used for pelagic fish and plankton since they were predicted in a larger and more homogenous offshore area.

2 Compilation of existing biological data

In addition to the data that was collected through field surveys within the MARMONI project, existing data from previously conducted marine biological surveys in Blekinge and Skåne County was compiled to be included in the modelling. The status of the data and the relevance for the project was assessed by AquaBiota before compilation. Insufficient data or data in the wrong format was removed. To maximize the efficiency of the field surveys within MARMONI these data were also used in a gap analysis before planning the field surveys.

Data used for vegetation modelling was compiled from drop-video, diving and snorkelling surveys. For zoobenthos modelling data was collected from different benthic surveys. The additional data used for modelling of fish (young of the year) comes from inventories using small underwater detonations in Blekinge County in 2008 and 2010.

Some processing was performed to facilitate the management of data, reduce the risk of overlap between stations or years, as well as to avoid over-representation of data in some areas.

3 Biological surveys

A wide array of field surveys were conducted within the project to collect data for spatial modelling of species and species groups and for mapping and assessing conservation values. Another important purpose of the field surveys was to collect data for testing of biodiversity indicators under development within the MARMONI project (Martin et al. 2015). For example, drop-video and diving data were used in the development of two indicators for phytobenthic communities, fish detonation data for the development of juvenile fish and hydroacoustic data for the development and testing of an indicator for herring spawning grounds.

Several of the field surveys were performed with new methods or with existing methods used in new ways or for new purposes (read more in Wijkmark et al. 2015). Two examples are the combination of drop-video and a simplified grab method and the use of hydroacoustics for surveys of plankton and jellyfish. A new method for dive surveys of phytobenthic species was also tested.

3.1 Vegetation

This section describes the basic data for benthic plant species and mussels collected within the MARMONI-project during July and August 2011 and 2012. The data set has been included in the modelling of vegetation-covered bottoms.

3.1.1 Drop-video surveys

Drop-video is mainly used for surveying substrate and sessile species. A video camera is lowered down from the boat and the inventory taker determines the bottom substrate, identify species and assess their degree of coverage (%) by looking at a screen in the boat. Drop-video is a cost effective method for collecting statistically independent data points that are well suited for modelling. Assuming that inventory stations are distributed randomly, a dataset that is representative for inventoried area is obtained. The disadvantage of this method is that it is not possible to identify as many species as in for example diving transects. Some species, such as filamentous algae, are difficult to distinguish on this scale, and it is also more likely to miss small-sized species or species with low coverage. Further, fouling, poor visibility or loose lying algae can complicate the inventory.

During 2011 and 2012 benthic plants and animals were surveyed with drop-video (Isaeus 2010). The inventoried area was approximately 5×5 meters per station. In total, data was collected from 1 038 stations within the Hanö Bight modelling area (Figure 2). 732 stations were within Blekinge County. Stations were placed randomly, and stratified according to a wave exposure layer (see Section 4.3) and depth retrieved from nautical charts. A balanced dataset was obtained by dividing the depth and wave exposure into classes and make sure that all combinations of these classes were equally represented. The reason for this weighted randomization was to get a dataset that represented the different marine environments within the County. All drop video data was transferred into the database MarTrans.

The drop-video inventories were generally combined with bottom grabs on soft bottoms (Section 3.2). The bottom grabber was also used to collect vegetation samples for verification of species on hard substrate bottoms.

3.1.2 Snorkelling in association with drop-video surveys

Some stations close to land was inventoried by snorkelling from the beach (Figure 2). This applied particularly to stations at very shallow coastlines. A total of 30 stations in the Hanö Bight study area were surveyed by snorkelling and all of these were located within Skåne County. As far as possible, the snorkelling was carried out in accordance with the drop-video method with respect to the surface inventoried and inventory methods.

3.1.3 Diving transects

In June 2011, 17 diving transects at six sites in the Blekinge archipelago were performed. The aim was to compare two diving survey methods (inventory of a 50x50 cm square, and free estimates in sections) and to give the inventory takers good knowledge of the species in the area before the drop-video inventories, which took place at exactly the same stations in August that year. In order to avoid duplication and to get comparable data, only the drop-video data was used in the modelling.

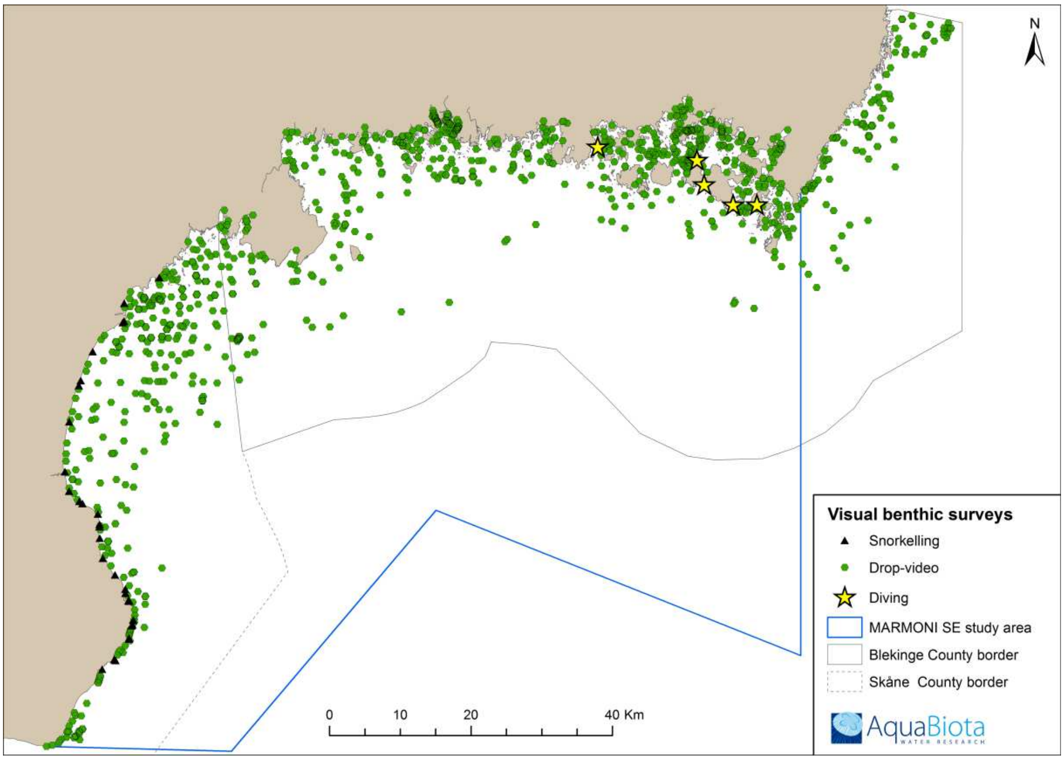

Figure 2. Surveyed drop-video, snorkeling and diving stations within the MARMONI-project during 2011 and 2012. Note that six dive stations were visited, and that two of the stations overlap in the map (second dot from the west).

3.1.4 Species that have not been modelled

Most species which occur frequently in the inventory data has been modelled with good results and predicted maps of these are presented in Section 5.3.4, as well as in Annex 2. Species that occur less frequently in the inventory data (for example, less common species or species that are more difficult to discover with the inventory methods used) can, however rarely be modelled. Examples of such species are stoneworts (Charophyceae), small filamentous algae and some vascular plants.

3.2 Zoobenthos

Soft bottom fauna, i.e. animals that live in and on soft soils were sampled with a bottom sediment grab sampler of Van Veen-type (sampling area 0.025 m^2) in accordance with existing methodology (Näslund 2011a). The method is suitable for the collection of numerous grabs for mapping purposes, and is especially adapted for use in combination with drop-video. The survey was conducted in combination with the drop-video investigation described above at stations with soft substrate, since drop-video cannot be used for the inventory of species living in the sediments. Sieving was performed on the boat with a 1 mm sieve and the catch was counted and species determined directly. For large quantities, the number of individuals was estimated.

In total, 491 bottom grabs were conducted in the Hanö Bight, with 398 grabs within Blekinge County (Figure 4). Species names used in this report follows the World Register of Marine Species (2013).

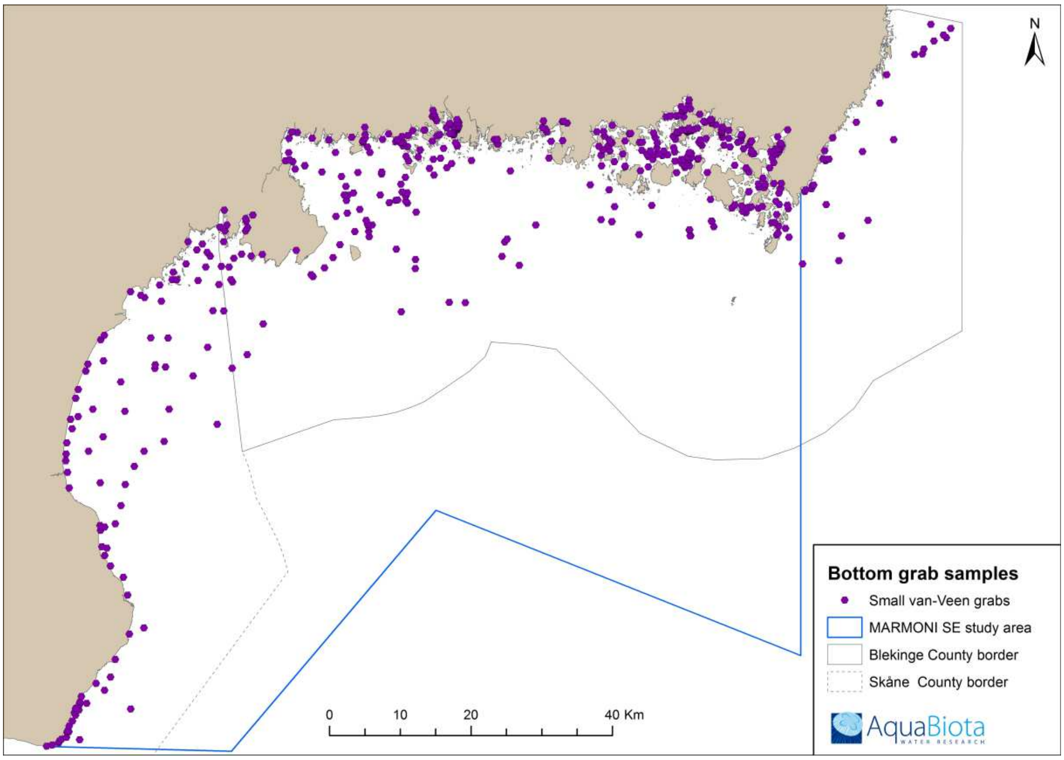

Figure 3. Bottom grab samples within the study area in the Hanö Bight.

3.3 Young of the year fish in coastal recruitment areas

Young of the year (YOY) fish in coastal recruitment areas were inventoried during late summer (August or the first part of September) with small underwater detonations (Table 1). This active sampling method, which is non-destructive with respect to other biota than fish, is used by Scandinavian fish researchers to obtain point abundance samples in heterogeneous environments where other methods such as beach-seines, small trawls, and drop-samplers are difficult to use (Snickars et al. 2007). The method captures all species with gas-filled cavities within approximately a 5-m radius of the detonation and yields representative length distributions of fish between 3 and 20 cm total length (unpublished data).

Sample points were randomly distributed between the shoreline and six meters depth within selected areas (Table 1). Temperature and water samples for turbidity analysis were taken at each sampling point. Sampling of juvenile fish was performed by detonating the explosives at a depth of about one meter. At shallow depths, the aim was to detonate the explosive charge at half the water depth. The detonation point was marked with a float, after which floating fish were collected from the boat and sunken fish by snorkelling. The snorkeler also noted presence and coverage of macro vegetation, the amount of filamentous algae and substrate. Juvenile fish inventories are described in detail in Lindahl et al. 2014.

Table 1. Number of detonations per year and area for the survey of young-of-the-year fish. The inventories between 2011 and 2013 were conducted within the MARMONI-project.

Area	Year	Number of detonations
Tosteberga - Landöbukten	2011	13
Valjeviken	2010	10
Valjeviken	2011	10
Valjeviken	2012	11
Valjeviken	2013	12
Sölvesborgsviken	2010	6
Sölvesborgsviken	2011	7
Sölvesborgsviken	2012	9
Sölvesborgsviken	2013	17
Pukaviksbukten	2010	28
Eriksberg - Ronneby	2008	23
Eriksberg - Ronneby	2010	38
Eriksberg - Ronneby	2011	7
Eriksberg - Ronneby	2012	29
Eriksberg - Ronneby	2013	53
Bredasund	2012	7
Listerby - Karlskrona	2010	42
Listerby - Karlskrona	2012	20
Listerby - Karlskrona	2013	41
Hallarumsviken	2010	17
Hallarumsviken	2011	5
Hallarumsviken	2012	20
Hallarumsviken	2013	16
Gåsefjärden – Torhamn's archipelago	2008	19
Gåsefjärden – Torhamn's archipelago	2010	21
Gåsefjärden – Torhamn's archipelago	2011	9
Gåsefjärden – Torhamn's archipelago	2012	41
Gåsefjärden – Torhamn's archipelago	2013	19
Sibbaboda - Kristianopel	2012	12
Sibbaboda - Kristianopel	2013	33

3.4 Pelagic fish and plankton

Vertical mobile hydroacoustics (with a taransducer(s) mounted on a towed body at the side of the ship) was used to study pelagic organisms. The study was conducted on four occasions between the 20th and 25th of August 2012 (Figure 4, Table 2). The surveys were conducted at night (at least one hour after sunset and one hour before sunrise), when pelagic organisms are more uniformly distributed in the water mass, and therefore measurement error is lower at night compared to the day when fish often aggregate in schools and are patchier distributed.

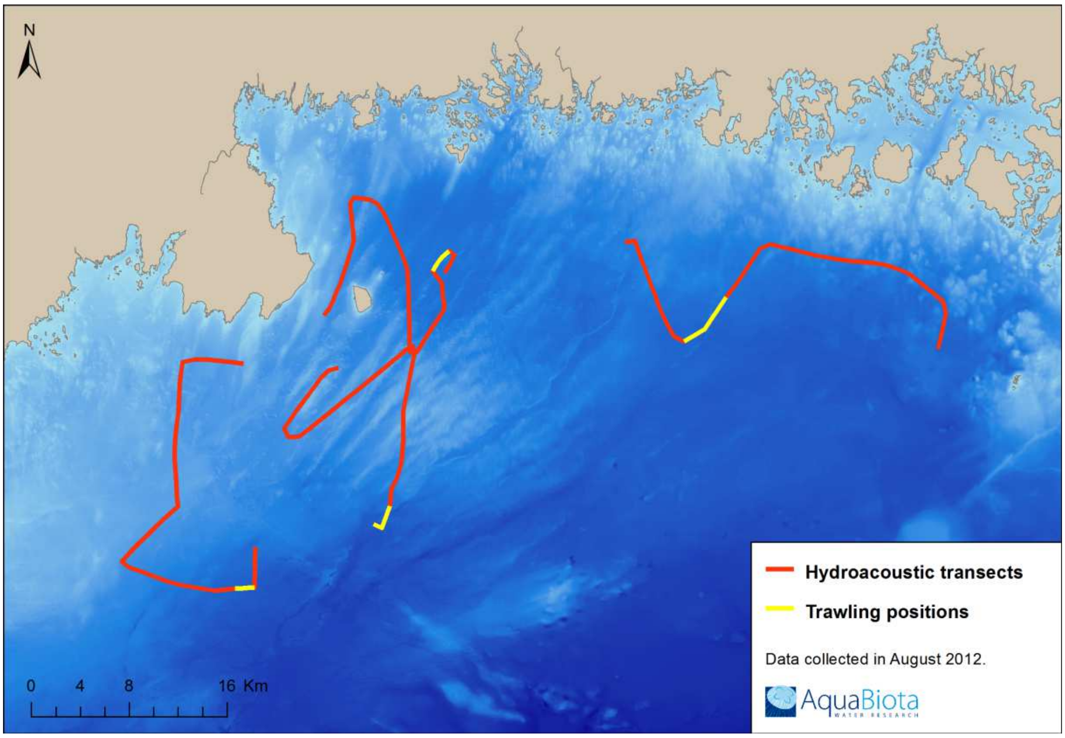

Figure 4. Hydroacoustic transects during the survey in August 2012 in the Hanö bight study area.

Table 2. Hydroacoustic transects in Blekinge in August 2012.

Occasions	Date start	Time start	Date stop	Time stop	Length (km)
1	2012-08-20	22:37	2012-08-21	04:47	37.7
2	2012-08-21	22:13	2012-08-22	04:47	34.8
3	2012-08-24	21:49	2012-08-25	04:46	35.5
4	2012-08-25	22:25	2012-08-26	04:48	31.7

A multi-frequency hydroacoustic system (MFHAS) consisting of 70, 120, 200 and 710 kHz echosounders (Simrad EY60) (for description see Table 3**Fel! Ogiltig självreferens i bokmärke.**) was used for surveys. The echesounders and transducers were calibrated according to the manufacturer's recommendations and applicable standards (Foote 1982, Foote et al. 1987). Survey was conducted from a commercial fishing boat "Nimrod" (18 m long) with transducers mounted on a so-called "Tow-body", which was towedabout two meters out on the starboard in about one meter depth.

Table 3. Specifications of the hydroacoustic system with multi-frequency (MFHAS) used in the studies

Frequency (kHz)	Transducer model	Transducer type	Pulse lenght (ms)	Bandwidth (kHz)
70	ES70-7c	Split beam	0.512	4.69
120	ES120-7c	Split beam	0.512	5.56
200	200-7F	Single beam	0.512	5.97
710	710-36	Single beam	0.512	6.23

In order to relate hydroacoastic data to fish size and species composition biological sampling in form of pelagic trawling was made once during each study night (Table 2). Trawling was made in direct connection to hydroacouastic transect. Trawling depth determined according to vertical fish distribution from echosounder and it was controlled in real time with attached depth sensor (Simrad PI38). During the trawling ship was mowing at 2-3 knot speed. In order to even catch small fish and larvae codend mesh size of the trawl was 6 mm (knot to knot). The catch was determined to species. Fish length was measured and each length group weighed. Water temperature and salinity depth profiles (CTD - conductivity, temperature and salinity; SD-204, Sensor Data AS, Bergen, Norway) were taken before or after the trawling.

Hydroacoustic data were processed and analysed by Sonar5-Pro Version 6.0.2 (Balk and Lindem 2012). In order to analyse different groups of the pelagic organism in acoustical data, first they have to be identified, and if possible (and necessary) separated from each other. Sonar 5 contains a module for multi-frequency analysis with several functions. In general, echoes from the different organisms depending on their size, body shape, inclusion of gas in the body has different strength at different frequencies. Therefore, frequency response curves of diverse organism groups are dissimilar (Figure 5). For example echoes of swim-bladdered fish are well “seen” on all frequencies, but they are stronger on lower frequencies. They are also are strongest in comparison to other groups, and have to be removed/separated from data if weaker echoes from other organisms are of interest.

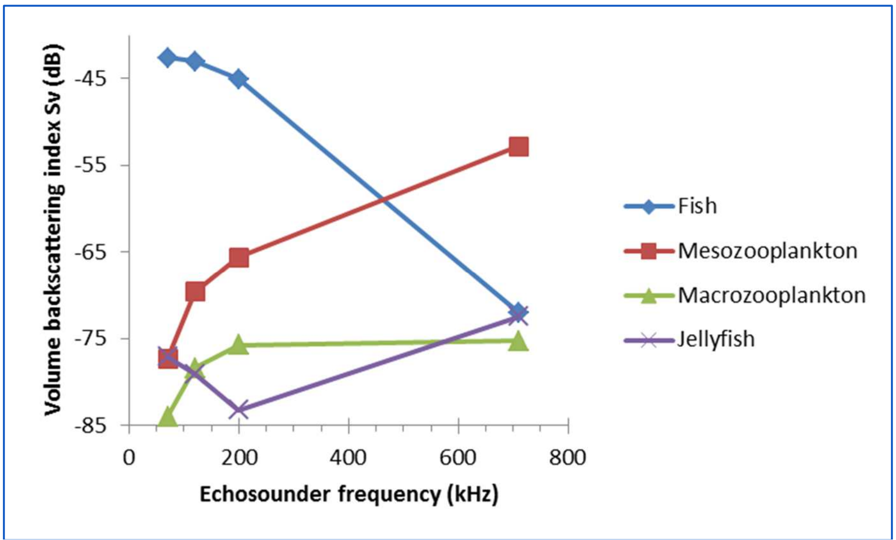

Figure 5. Frequency response curves of different pelagic organisms.

3.4.1 Fish

Acoustical data analysis methods of fish are well established. Fish analysis was performed from 70 kHz acoustic data. Fish density and distribution were analysed after fish echoes from the hydroacoustic data had been divided into four size groups based on the results from trawling. Fish length (L, mm) was calculated from acoustical target strength (TS, dB) following relationship (Didrikas and Hansson 2004):

$$TS = 25.5 \log (L/10) - 73.6$$

The data from trawling was used to interpret fish densities of different length classes along the acoustic transects. Pelagic species dominated the trawl catches. Small fish (2-6 cm) consisted mainly of stickleback, young of the year herring and/or sprat. Medium-sized fish (7-13 cm) were represented mainly by sprat, and large fish (14.5 to 25 cm) consisted mainly of adult herring. Large fish> 51 cm occurred sparingly in the acoustic data, and no fish of this size were caught in the trawl. Based on knowledge of the species composition of this type of habitat it can be assumed that echoes in this size class corresponds to fish-eating predatory fish such as cod, salmon or sea trout.

3.4.2 Other organisms

Fish echoes (with a swim bladder) are much stronger than echoes from other organisms at most frequencies. Therefore, the fish echoes must be separated/removed from further analysis, which was carried out using a masking tool in Sonar 5. The underlying concept of this tool is to identify and remove unwanted acoustic echoes from one frequency echogram and apply it as a mask to the other simultaneously recorded echogram(s) of same water volume, but at another acoustic frequency(s). Fish are best “seen” at lower frequencies; therefore 70 kHz echogram was used to do this. After masking “fish free” echograms of all frequencies, further analysis were made using a frequency response threshholding tool, which makes it possible to identify echoes based on their frequency response signature (see Figure 5).

3.4.2.1 Mesozooplankton

This group includes zooplankton with a size of 0.2-2 mm, dominated by large rotifers, cladocera, copepods and different larva of animals which are planktonic during certain developmental stages (meroplanktonic). Echoes of zooplankton-like organisms get stronger with increasing frequency (Figure 5). Therefore, data from the highest frequency (710 kHz) is most suitable to analyse mesozooplankton. Three frequencies with a rule where volume backscattering strength (S_v) was 120<200<710 kHz and noise gap (NG) of 3 dB were used for thresholding in order identify mesozooplankton echoes. 710 kHz echogram was used to output and store these data.

3.4.2.2 Macrozooplankton

This group is zooplankton with a size of > 2 mm that drift with water currents or swim slowly. Macrozooplankton consists mainly of opossum shrimps (Mysida) and fish larvae. The fish larvae hydroacoustic characteristics are similar to that of opossum shrimp only before metamorphosis, i.e. before they develop a swim bladder (for those species that have one). The shapes of the frequency response curves of meso- and macrozooplankton are quite similar at lower frequencies, but the macrozooplankton curve is not as steep between 200 and 710 kHz as of mesozooplankton (Figure 5). Therefore these zooplankton groups could be separated with a rule where the volume backscattering strength (Sv) was 200<710 kHz, and the noise gap (NG) of 1 dB. 200 kHz data was used for output.

3.4.2.3 Jellyfish

Jellyfish are also considered as zooplankton because they live freely in the water mass and drift with currents or swim slowly. In the Baltic Sea, this group is mainly represented by the moon jellyfish Aurelia aurita, which normally has a diameter of 10-15 cm as an adult. Jellyfish sometimes occur in very large numbers during late summer or early autumn, when they can form large aggregations. The frequency response curve of jellyfish has a rather unique shape with a pronounced dip at intermediate frequencies (200 and/or 120 kHz), while at the low and high frequency backscattering is typically higher (Figure 5). Three frequencies with a rule where the volume backscattering strength (Sv) was 70>200<710 kHz, and a noise gap (NG) of 3 dB were used to identify jellyfish echoes. 70 kHz echogram was used for output and storage of data. Later, these data were analysed using segments (approx. 1 km) and mean Sv used to model spatial distribution of each organism group separately.

3.5 Birds

The ornithological studies within the MARMONI-project were originally planned to cover the offshore seaducks (mainly the Long-tailed Duck) in the Hanö Bight. The wintering waterbirds in the inshore parts of the area (the archipelago and open coast) have been counted since 1967 as a part of the International Waterfowl Counts (IWC) coordinated by Wetlands International (Nilsson 2008). This data set has been used within the MARMONI-project to calculate indicators relating to wintering birds. These winter counts are a part of the national bird monitoring program.

During the development of bird indicators it was clear that indicators should also be developed to include the breeding waterbirds. There were no such time series available from Sweden for this work so the field work within the MARMONI-project was extended to cover the test of methods for a monitoring program of the breeding waterbirds in the archipelago. Thus, in 2011 censuses of breeding waterbirds were undertaken in three study areas in the Hanö Bight. The studies also included the productivity of Eiders in two of the study areas and an aerial survey of breeding Mute Swans in the archipelago.

Aerial surveys in the Hanö Bight were also part of other studies on seaducks organized by SEPA, which produced data that could be used in MARMONI, so resources could be made free for the items added to the project after the application was sent in.

In the present report I will cover the bird projects undertaken within the MARMONI-project. I will also include data from the IWC in the region to describe the wintering waterbird populations in the inshore areas, which form the basis for the development of “the wintering waterbird indicator”.

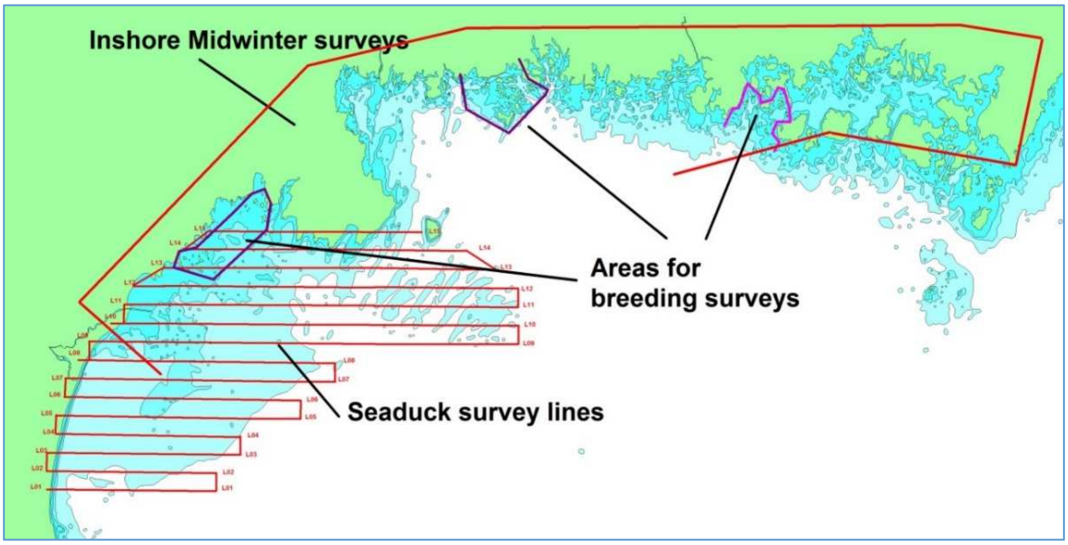

Figure 6. Study areas for the waterbird studies undertaken in the Hanö Bight within the MARMONI-project. For detailed maps of the areas used for breeding surveys see Figure 7 - Figure 8.

3.5.1 Inventory method – breeding birds

The breeding waterbirds were surveyed in three different areas, each covering a group of small islands and skerries in the archipelago (Figure 7 - Figure 8). The areas were covered with boat in late April to establish the number of pairs on the different islands. Waterbirds were counted in all three study areas, whereas gulls were only surveyed in the western area (L001- L003 in Figure 7). On the island Vållholmen (L002 in Figure 7) nests were also counted by searching the island by foot on three occasions during the spring. In the two easterly areas a second survey was undertaken in early June to check for the production of young in the Eider. For the ducks the total number of pairs was established on the basis of the total counts of birds in pairs plus groups of males numbering 1-3 males.

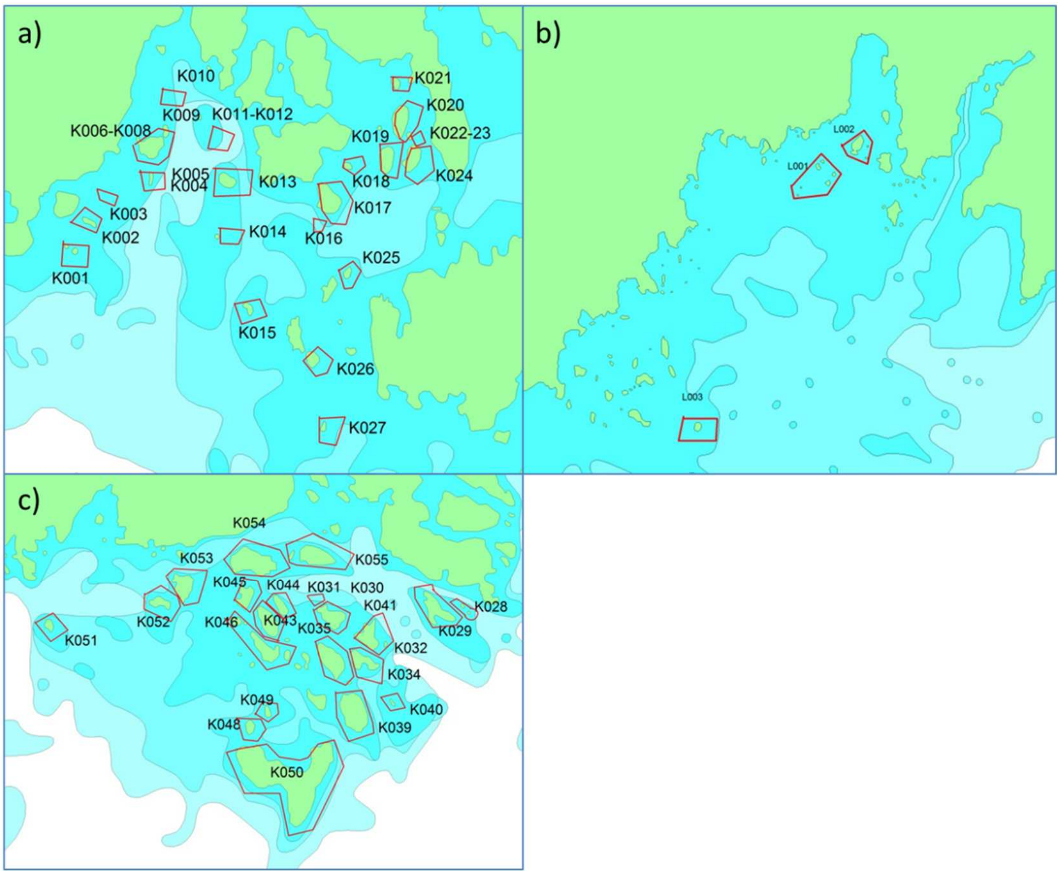

Figure 7. Map of the census area for breeding waterbirds a) Lindö – Hasslö, b) NE Scania and c) SE Karlshamn. Islands and skerries covered are marked on the map and assigned an area code. Different shades of blue indicate water depth <6, 6-10 and 10 – 20 m (lightest).

3.5.2 Inventory method – wintering birds

The international waterfowl counts (IWC) have been undertaken in Sweden every winter since the start in 1967 (Nilsson 2008). After the first years, when the program was established, more or less complete counts have been obtained from the area since 1969.

After a few years the entire Swedish coast was divided into counting units for the IWC. Each sector covered was counted from the ground by voluntary observers. In 1987 the system was standardized and a number of reference areas were established. These areas have then been covered in the same way each year.

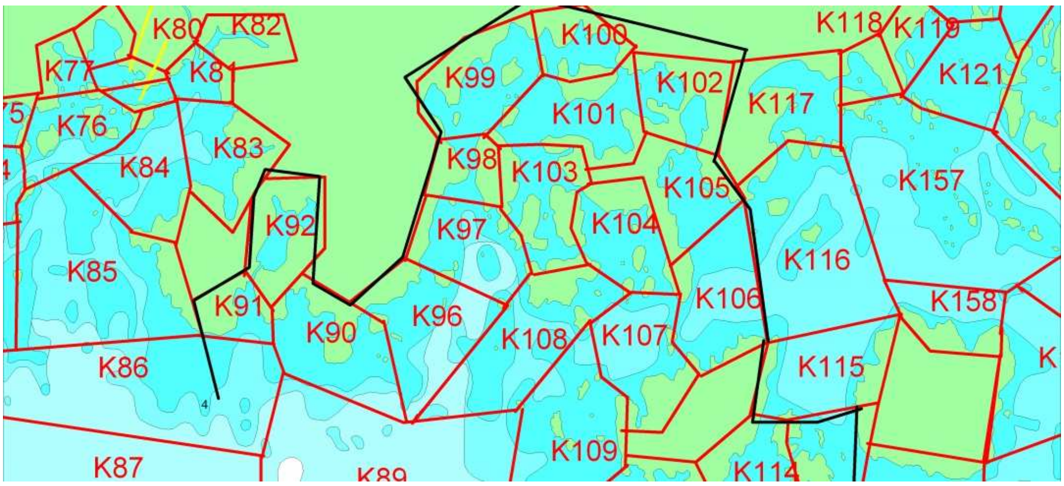

Figure 8. Map of the archipelago between Ronneby and Karlskrona as an example of the division into counting sectors used at the international waterfowl counts (IWC) in Sweden.

The main aim for the counts was to produce data for calculation of annual indices to follow the population development of the different species on a national and international level. To get a control of how well the different waterbirds were covered country-wide surveys were undertaken on some occasions, last time was 2004 (Nilsson 2008). These counts were made by a combination of ground counts and aerial surveys (Figure 9). Offshore areas were not covered in this program but special studies were undertaken in 2007 -2011 (Nilsson 2012).

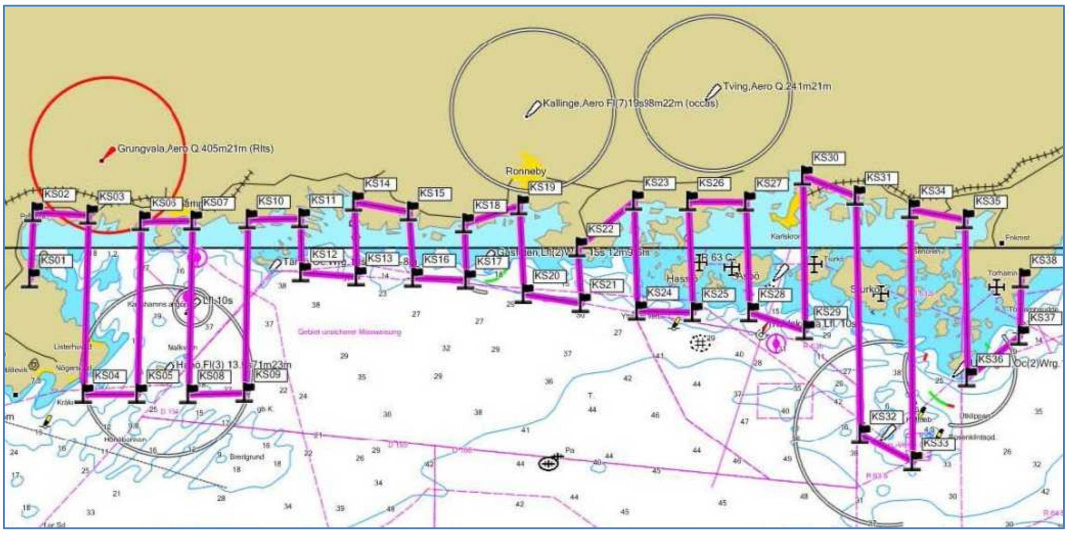

Figure 9. Survey lines in the archipelago of Blekinge used in 2012.

The offshore areas in the Hanö Bight were covered with aerial surveys along line transects on seven occasions between 2007 and 2011. The counts were made from an airplane (Figure 10) flying at 180 km/h at an altitude of 50 – 70m. Survey lines were separated by 2 km. Counts were made by two observers covering each side of the plane. Waterbirds were counted in a survey belt extending 200 m on each side of the aircraft. All observations were noted continuously for later transformation to a data base. Navigation was based on a GPS in the aircraft and the actual track was registered on a separate GPS.

Figure 10. A high-winged CESSNA 337 skymaster was used for the surveys, giving good visibility for the observers.

The counts were registered every ten seconds, meaning that each segment of the transect in the database was around 350 m depending on actual flying speed (wind factor). There was a blind angel below the aircraft so the effective area covered was 320 m. To obtain an estimate of the number of birds in an area correction factors were used to compensate for the coverage. For further information on methods etc. see Nilsson (2012).

As a complement to the ground counts in the archipelago two aerial surveys were undertaken there in March 2012. The same method as in the offshore areas was used, but survey lines were separated by 4 km. More surveys were planned but could not be done due to ice conditions in the archipelago.

In this report annual indices have been calculated for the more important species as chain-indices, using the standard method from the Swedish IWC (Nilsson 2008). For sites counted two consecutive years the total in year 2 has been calculated as per cent of the total for year 1. This primary percentages have then been recalculated in relation to the base year = 100. The series of primary indices so obtained have then been normalized so that the mean index for a species over the survey period is 100. For further details see Nilsson (2008).

3.5.3 Result – breeding birds

The breeding bird fauna of the three study areas is shown in Table 4. Gulls and terns were only included in the western study areas, whereas Anatidae were surveyed in all three areas. The western area had large colonies of Herring gull, a species also occurring in the eastern areas where it was not surveyed.

Table 4. Number of pairs of different species estimated to breed in the three study areas in the Blekinge archipelago in 2011.

Species	NE Scania	Karlshamn archipelago	Lindö – Hasslö
Mallard *Anas platyrhynchos*	20	25	52
Goldeneye *Bucephala clangula*	0	5	1
Eider *Somateria mollissima*	652	325	249
Red-breasted Merganser *Mergus serrator*	0	12	3
Goosander *Mergus merganser*	0	26	18
Shelduck *Tadorna tadorna*	0	13	21
Greylag Goose *Anser anser*	16	83	141
Canada Goose *Branta canadensis*	4	21	34
Barnacle Goose *Branta leucopsis*	154	3	7
Mute Swan *Cygnus olor*	12	22	15
Herring Gull *Larus argentatus*	847	NOT COUNTED	
Black-backed Gull *Larus marinus*	1		
Caspian Tern *Hydropogne tschegrava*			

Eiders dominated markedly in all three areas. Some islands also had good populations of breeding geese, especially the Greylag Goose but the Barnacle Goose had established a strong colony on one of the islands in the western study area. The Cormorant was not surveyed in 2011, but there is an important colony on Lägerholmen in the western area which had 702 pairs in 2009 and 498 in 2012.

The productivity of Eiders was low in the Blekinge archipelago with 1.o and 1.1 respectively for the two areas there (Table 5).

Table 5. Number of females and young counted in the two study areas in the Blekinge archipelago in June 2011.

Area	Females	Young	Young/Female
SE Karlshamn	562	553	1,0
Lindö-Hasslö	297	322	1,1

At an aerial survey in April 2011 170 stationary pairs (territories) of Mute Swans were located. 29 of these birds were seen on a nest and others had started with the nest. The survey was actually too early for a swan survey, but it was undertaken in connection with other surveys in the general area.

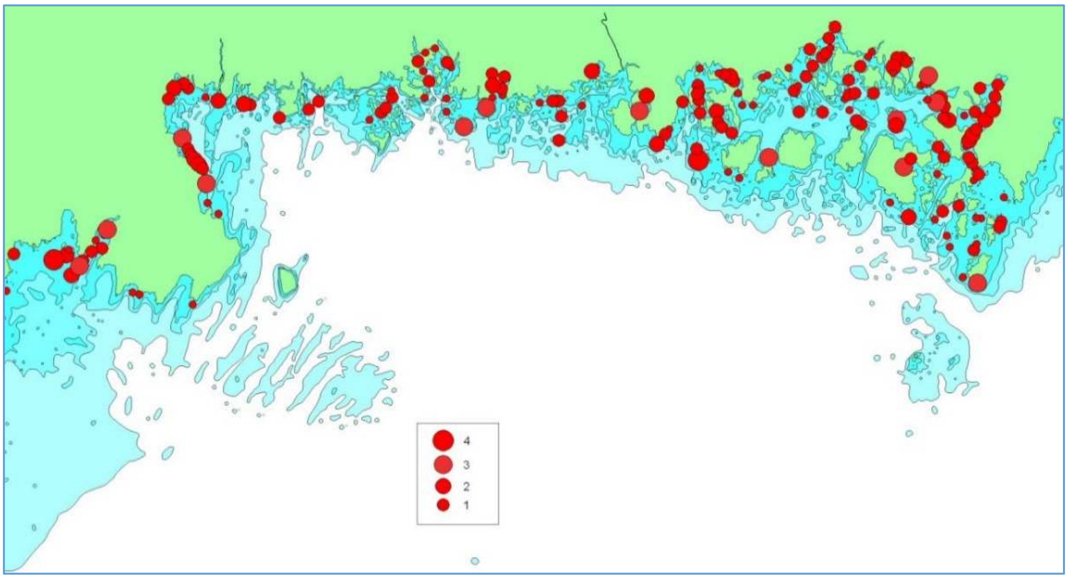

Figure 11. Distribution of breeding pairs of Mute Swan Cygnus olor in the Blekinge archipelago at an aerial survey in the of spring of 2011.

3.5.4 Result – wintering birds

The wintering waterbird fauna in the offshore areas of the Hanö Bight is markedly dominated by the Long-tailed Duck (Table 6). Normally Common Scoter and Velvet Scoter are to be found here in moderate numbers, but in 2007 and 2008 large numbers of especially the Common Scoter were found here.

Table 6. Estimated totals for Long-tailed Duck Clangula hyemalis, Common Scoter *Melanitta nigra* and Velvet Scoter *Melanitta fusca* at aerial surveys in the Hanö Bight 2007 – 2012.

	Long-tailed Duck	Common Scoter	Velvet Scoter
2007-03-04	23044	13500	3175
2008-12-07	8888	12981	138
2009-01-17	14381	463	44
2009-02-27	17075	63	288
2009-03-14	6231	1125	0
2011-01-30	7088	238	331
2012-02-13	6813	256	50

In addition to the three seaduck species mentioned, staging flocks of Eiders can be found in these areas during migration periods. Red-breasted mergansers are also sometimes found in the outer areas of the Hanö Bight but in small numbers. In addition small numbers of other species have been seen at the aerial surveys in the area (Table 7). Several of these were seen close to the shore at the end of the transects. The transect counts are not representative for the presense of these species in the area.

Table 7. Number counted waterbirds of various species during aerial surveys in the Hanö Bight 2007-2012.

	2007-03-04	2008-12-07	2009-01-17	2009-02-27	2009-03-14	2009-05-04	2011-01-30	2012-03-12
Blackthroated Diver *Gavia arctica*	20	1	0	2	0	0	1	4
Red-throated Diver *Gavia stellata*	0	0	1	0	0	0	0	0
***Gavia* sp.**	0	2	0	6	0	0	0	0
Great Crested Grebe *Podiceps cris-tatus*	236	0	1	0	1	0	0	1
Slavonian Grebe *Podiceps auritus*	0	4	0	0	0	0	0	0
Great Cormorant *Phalacrocorax carbo*	88	44	63	63	52	27	33	26
Tufted Duck *Aythya fuligula*	2	0	500	1000	0	0	0	0
Goldeneye *Bucephala clangula*	692	105	53	607	52	0	370	110
Long-tailed Duck *Clangula hyemalis*	5242	1622	2301	2732	1077	1	1374	1090
Velvet Scoter *Melanitta fusca*	340	22	7	10	0	0	28	8
Common Scoter *Melanitta nigra*	1312	2277	424	46	180	20	18	41
***Melanitta* sp.**	1089	0	0	0	0	0	45	0
Eider *Somateria mollissima*	174	34	0	36	420	257	2	402
Red-brested Merganser *Mergus ser-rator*	45	119	8	117	9	3	18	35
Goosander *Mergus merganser*	498	0	14	22	8	2	77	23
Smew *Mergus albellus*	0	0	0	30	0	0	0	8
Guillemot *Uria aalgae*	6	1	0	0	0	2	0	0

The long-tailed ducks are found over large parts of the Hanö Bight out to a depth of about 20m. Large flocks are often seen at a considerable distance from the shore as exemplified in the map in Figure 11, (for more maps see Annex 2). When comparing these maps a marked variation between different counts is apparent. Outside the main areas covered in offshore the Hanö Bight smaller numbers of long-tailed ducks are also found in the outer parts of the Blekinge archipelago but the total here is small. Small numbers are also found in Puka-viksbukten and along the coast of Scania south of the main area. These coastal areas only have small flocks of long-tailed ducks.

The Velvet Scoter and the Common Scoter are to be found in more or less the same areas as the long-tailed ducks. In general the larger flocks of these species are found somewhat more to the sea than flocks of the long-tailed ducks.

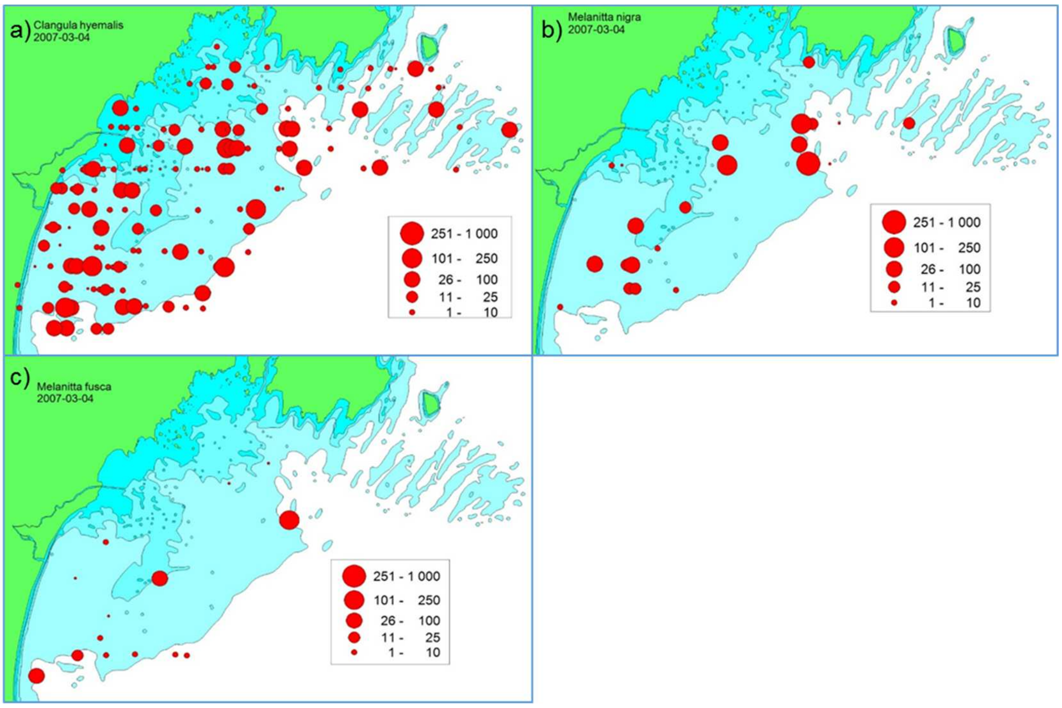

Figure 12. Example of the distribution of a) long-tailed ducks *Clangula hyemalis*, b) Common Scoter *Melanitta nigra* and c) Velvet Scoter *Melanitta fusca* in the Hanö Bight, 2007-03-04.

In 2007, the first year in the new series of aerial surveys, the number of long-tailed ducks in the area was estimated to 23000, but in 2009 the total was only 2009 to be lower still in 2011 and 2012, close to 7000. Based on field work in the area during the 1960s and 1970s (Nilsson 1972a, 1980), the wintering population of long-tailed ducks in the area was estimated to be around 25000.

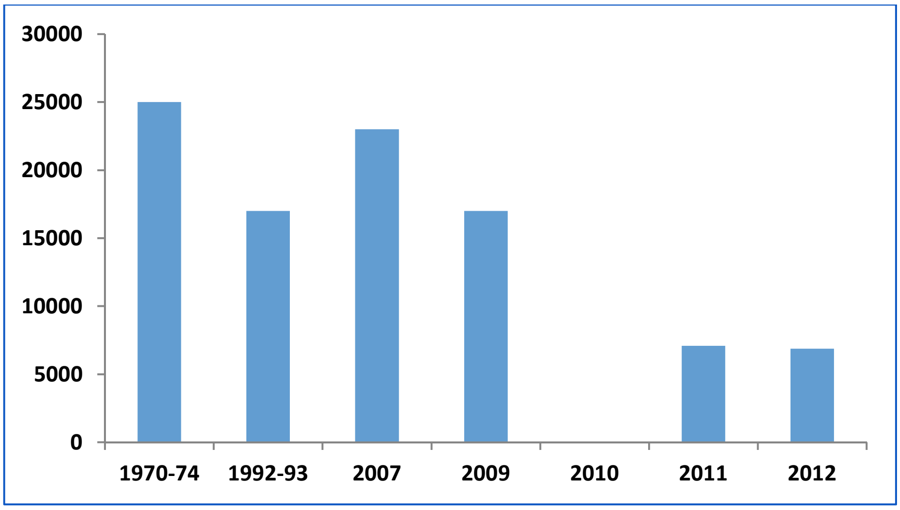

Figure 13. Estimated total of wintering long-tailed ducks Clangula hyemalis in different years.

The density of long-tailed ducks in 2007 was estimated to be about $30/km^2$ for the water area out to a depth of about 20m compared to 10/km2 at the latest surveys (Figure 14). Densities on the main offshore banks for the species are normally considerably higher.

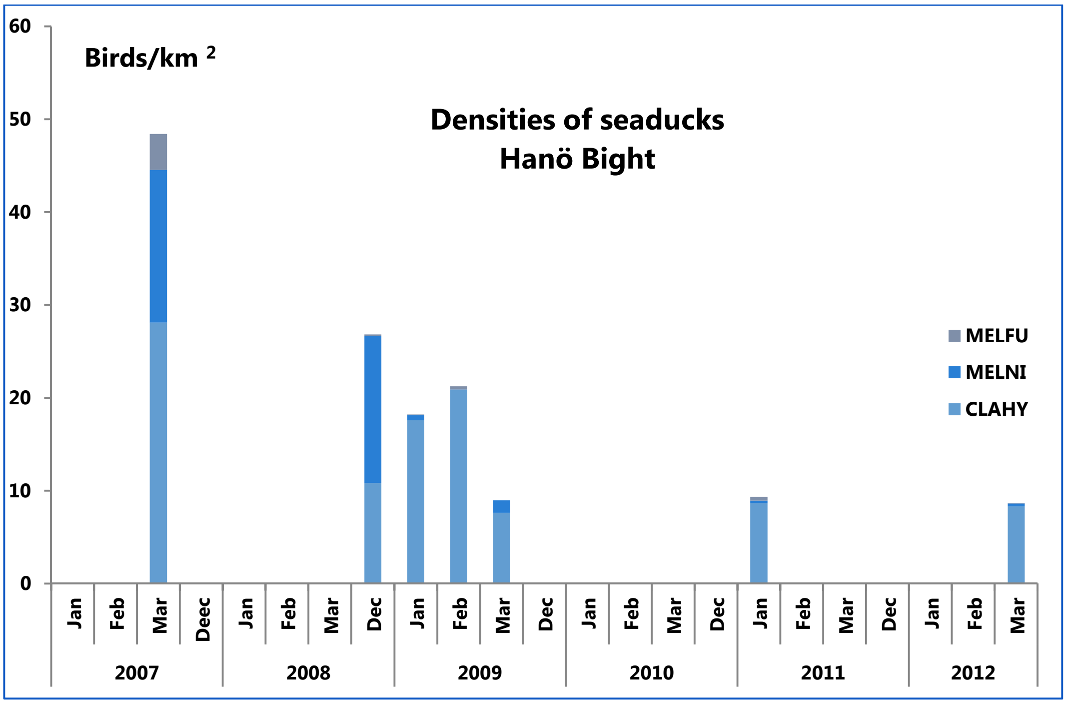

Figure 14. Densities for the three seaduck species Long-tailed Duck Clangula hyemalis (CLAHY), Common Scoter Melanitta nigra (MELNI) and Velvet Scoter Melanitta fusca (MELFU) 2007 – 2012.

The numbers of waterbirds of different species counted in the inshore areas of the northern part of the Hanö Bight (study area shown in Figure 9) during the MARMONI period are to be found in Table 8. Even if the counts do not cover the entire area (parts concealed behind islands could not always be covered) it gives a good indication of the importance of the area for the different species. As stated above the counts were organized to produce data for the calculation of annual indices and not total counts. A comparison between the annual ground counts and the last country wide survey for the area in 2004 showed a good agreement.

Table 8. Numbers counted in the inner parts of the Hanö Bight (Åhus – Torhamn, Figure 15) during the winters 2010 – 2013.

Species	2010	2011	2012	2013
Black-throated Diver *Gavia arctica*	1	1	10	11
Red-throated Diver *Gavia stellata*	1	0	1	2
Great Crested Grebe *Podiceps cristatus*	270	182	479	205
Red-necked Grebe *Podiceps griseigena*	3	4	0	3
Slavonian Grebe *Podiceps auritus*	1	1	7	3
Little Grebe *Tachybaptes ruficollis*	70	9	13	15
Cormorant Phalacrocorax carbo	303	296	950	383
Heron *Ardea cinerea*	22	2	21	11
Mallard *Anas platyrhynchos*	7403	7446	15251	8784
Teal *Anas crecca*	6	8	364	12
Wigeon *Anas penelope*	1	0	65	2
Pintail *Anas acuta*	0	0	1	2
Gadwall *Anas strepera*	43	6	92	18
Scaup *Aythya marila*	980	333	403	510

Tufted Duck *Aythya fuligula*	29611	8228	47280	43236
Pochard *Aythya ferina*	1112	627	1397	1396
Goldeneye *Bucephala clangula*	2779	2824	3469	3532
Long-tailed Duck *Clangula hyemalis*	88	78	169	68
Velvet Scoter *Melanitta fusca*	6	1	0	1
Common Scoter *Melanitta nigra*	4	6	45	4
Eider *Somateria mollissima*	24	5	11	19
Red-breasted Merganser *Mergus serrator*	187	960	727	342
Goosander *Mergus merganser*	760	520	683	900
Smew *Mergus albellus*	1547	1221	953	1627
Whooper Swan *Cygnus cygnus*	240	139	183	166
Bewick Swan *Cygnus bewickii*	0	0	0	1
Mute Swan *Cygnus olor*	1602	1577	1530	1193
Coot *Fulica atra*	10753	1694	5361	3270
Common Guillemot *Uria aalgae*	1	0	0	1
Black Guillemot *Cepphus grylle*	0	0	1	2
Razorbill *Alca torda*	0	0	0	2

Proper seaducks are only found in small numbers during the counts in the archipelago. In the western parts of Blekinge there were some flocks of long-tailed ducks also relatively inshore but off the main part of the archipelago only small groups of long-tailed ducks were found. According to special surveys done here (for other projects) during the MARMONI period between 100 and 300 long-tailed ducks were estimated here.

The most common species in the inshore waters was the Tufted Duck with a total count of between 45000 and 50000 for the MARMONI period. Other species that were common in the counts were the Mallard, Coot, Goldeneye, Pochard, Smew and Mute Swan. The Smew and the Pochard are of special interest here as the archipelagos of Blekinge has a large proportion of the national wintering population for these two species.

The number of wintering waterbirds in inshore the Hanö Bight showed a marked variation between years, which will be especially apparent below when the annual indices for important species during the period 1987 – 2011 is presented. However, large variation was also found during the MARMONI-years, which included two cold winters 2010 and 2011. Even 2012 and 2013 had some ice-periods that blocked the possibility to do aerial surveys of the inner parts of the archipelago.

The archipelago of Blekinge (as also the northeast parts of Scania) is used by large numbers of waterbirds during migration periods in autumn and spring. There are no censuses made during these parts of the year with the exception of two aerial surveys in the archipelago of Blekinge (Figure 15) in 2012, when large numbers of staging Goldeneyes and Tufted Ducks were found (Table 9).

Table 9. Estimated totals for some waterbird species in the Blekinge archipelago (Figure 15) at two surveys in 2012.

Species	2012-03-06	2012-03-12
Red-throated Diver *Gavia stellata*	0	12
Great Crested Grebe *Podiceps cristus*	60	0
Cormorant *Phalacrocorax carbo*	1668	1548
Mallard *Anas platyrhynchos*	7800	8136
Wigeon *Anas penelope*	24	0
Tufted Duck *Aythya fuligula*	60600	58608
Goldeneye *Bucephala clangula*	18612	7716
Long-tailed Duck *Clangula hyemalis*	984	252
Eider *Somateria mollissima*	300	6108
Red-breasted merganser *Mergus serra-tor*	264	60
Goosander *Mergus merganser*	3468	5148
Smew *Mergus albellus*	1164	504
Shelduck *Tadorna tadorna*	324	564
Whooper Swan *Cygnus cygnus*	0	72
Mute Swan *Cygnus olor*	5040	3324

The distribution of more common wintering waterbirds in the Blekinge part of the area is exemplified by a series of maps (Annex 2) for 2012, which was a fairly normal winter at least compared to the other winters of the period. Most species were spread over the entire archipelago, but there was a marked dominance for the eastern part of the area with the exception of Sölvesborgsviken in the west which together with the parts in Scania (Valjeviken) has relatively high numbers of a number of species such as the Tufted Duck, Goldeneye and Smew.

Even if the diving ducks are spread over the entire archipelago, the largest flocks of Tufted Duck are to be found in the shallow parts between Gö and Karlskrona (Figure 15). Another diving duck showing the same pattern is the Pochard, whereas the Goldeneyes are more spread over the entire area. Also the Smew, which has its main Swedish wintering ground in Blekinge archipelago, shows a concentration to this area. The two herbivores Coot and Mute Swan are also found in largest numbers in the eastern part of the archipelago with its shallow areas.

The concentration of many species of waterbirds to the eastern part of the Blekinge archipelago is related to the presense of large shallow areas with rich food resources in the form of benthic vegetation and a rich benthic fauna in shallow waters. This concentration to the east is mostly seen during mild and normal winters as these areas are the first to freeze during cold period making the waterbirds to move to areas further out at sea close to the ice edge.

There was also a marked concentration of waterbirds to the eastern part of the archipelago area at the censuses during early spring in 2012 as seen in the overall map in Figure 15 (for species maps see Annex 2).

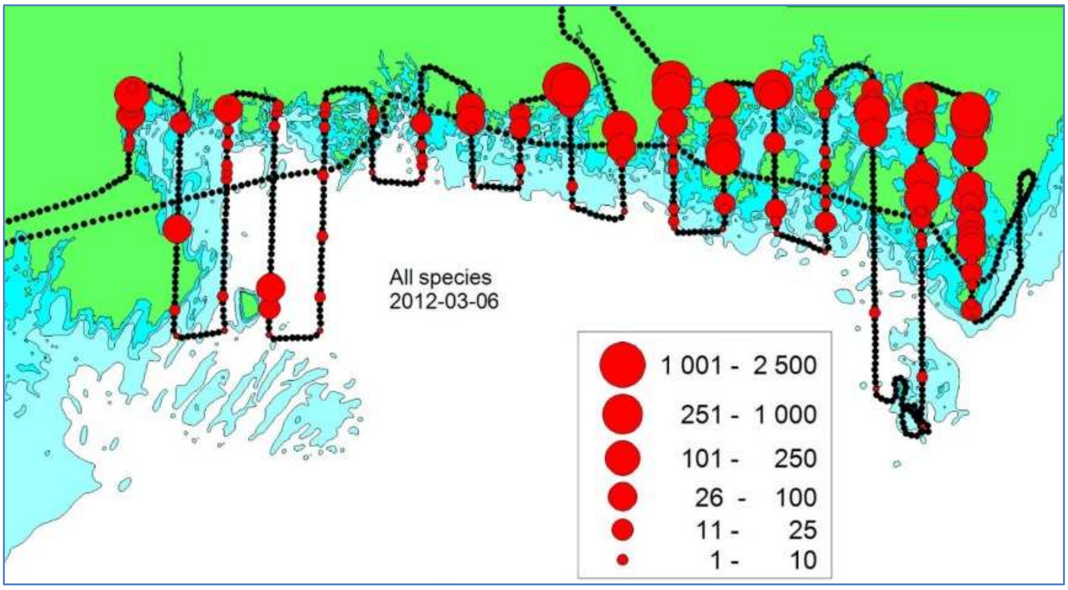

Figure 15. Distribution for all waterbird flocks seen at aerial surveys in the archipelago of Blekinge 2012-03-06. The black dot-lines visualize the aerial survey route. For further maps from these counts see Annex 2.

As stated above the number of wintering waterbirds show marked variation between years which to a large extent can be related to the hardness of the winter. This is clearly a factor to take into account when evaluating the indices. The starting year of the series of counts used for the index calculations presented here, 1987, was a very cold winter which followed a series of cold winters in 1979, 1982 and 1985. After 1987 we had a series of very mild winters but the period considered here ended with the two cold winters 2010 and 2011.

Generally, the total number of wintering waterbirds has increased markedly in the inshore parts of the Hanö Bight during the study period (also before that period). Eight out of 15 species trends shown in Figure 16 -Figure 17 (summarized in Table 10) showed markedly increasing trends, compared to six species showing fluctuations around a more or less stable level. The only species with a decreasing trend is the Long-tailed Duck, but the totals counted from the shore are small. However the same tendency is found for the offshore areas in recent years.

Table 10. Trend analysis of various waterbird species in the inner waters of the Hanö Bight 1987 – 2011.

Species	25 year mean	Trend	R2
Mallart *Anas platyrhynchos*	7775	Increase	0,25
Tufted Duck *Aythya fuligula*	32420	Increase	0,50
Pochard *Aythya ferina*	1325	Fluctuating	0,06
Scaup *Aythya marila*	279	Increase	0,38
Goldeneye *Bucephala clangula*	2926	Fluctuating	0,03
Long-tailed Duck *Clangula hyemalis*	306	Decreasing	0,54
Eider *Somateria mollissima*	26	Fluctuating	0,01
Red-breasted merganser *Mergus serrator*	450	Increase	0,57
Goosander *Mergus merganser*	1086	Fluctuating	0,00
Smew *Mergus albellus*	750	Increase	0,61
Whooper Swan *Cygnus cygnus*	241	Increase	0,15
Mute Swan *Cygnus olor*	1527	Increase	0,22
Coot *Fulica atra*	5596	Fluctuating	0,04
Cormorant *Phalacrocorax carbo*	734	Fluctuating	0,04
Great Crested Grebe *Podiceps cristatus*	309	Increase	0,55

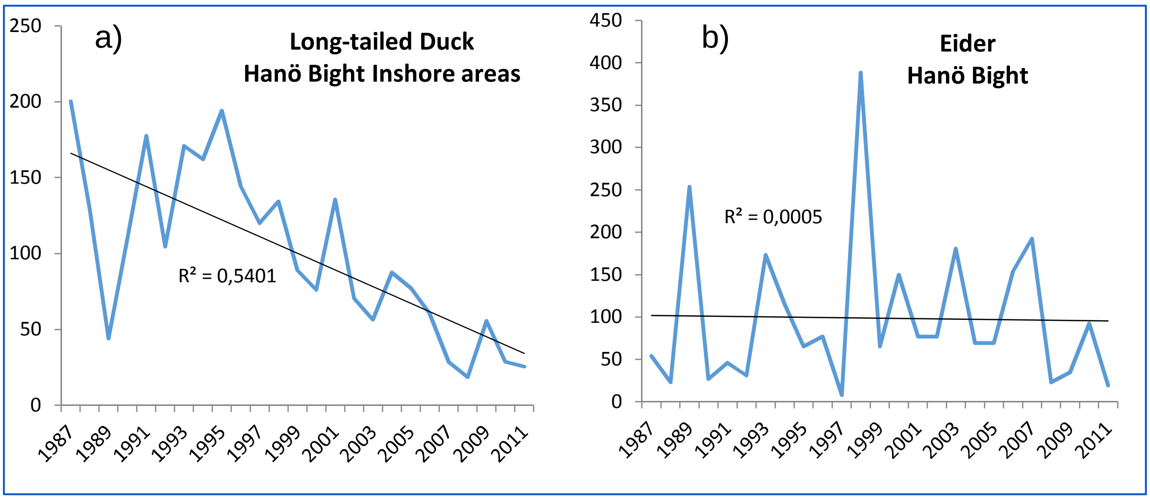

Figure 16. Midwinter indices 1987-2011 for a) Long-tailed Duck Clangula hyemalis in the inshore parts of the Hanö Bight, and b) Eider Somateria mollissima.

3.5.5 The importance of the Hanö Bight for waterbirds

It is clear from the above that the Hanö Bight has a rich and varied waterfowl community especially in the shallow bays in the archipelago of Blekinge and in the northeastern parts of the coast of Scania. When these areas are free from ice they are used by large numbers of waterbirds which also applies to the autumn and spring staging periods. Except for some studies in the Blekinge archipelago all censuses have been undertaken during midwinter in connection with the IWC, but in the early seventies counts were made in some archipelago areas during the entire season, showing the importance of the archipelago areas also during the migration periods (Nilsson 1972b, 1978). This also applies to the are-as in the neighboring parts of Scania even if no regular counts have been made here.

Some species fulfills the international criteria for an important waterbird area with the regular presense of more than 1 % of the flyway population or more than 20000 individuals (Wetlands International 2013). In the first years of the study and also earlier, the offshore areas of the Hanö Bight was used by more than 20000 long-tailed ducks, thus qualifying for international importance but in the later years numbers have been much lower

The overall total for the Long-tailed Duck population in the Baltic has shown a marked decrease in recent decades. The Baltic population was estimated to be around 4.2 million in 1992/93 and decreased to 1.4 million in 2007 – 2009 (Nilsson 2012). During the same period the Swedish wintering population decreased from 1.4 to 0.5 million. From a national perspective the Hanö Bight is still to be regarded as an important area for the species. Until the last few years the overall decrease noted in the main offshore areas in the Baltic were not seen here (Nilsson 1980, 2012).

The other seaducks were normally found in small numbers only, but in 2007 and 2008 important concentrations of especially the Common Scoter and to some extent the Velvet Scoter were found in the offshore areas of the Hanö Bight, but in other years only very small numbers were counted in these areas.

Two species were found to have internationally important wintering populations in the area, the Tufted Duck and the Smew, where the criteria are 12000 individuals and 400 individuals, respectively. Such concentrations are regular in the central part of the Blekinge archipelago between Kuggeboda and Hasslö, where the large shallow areas with rich food supplies are important for these two species. Nationally important concentrations of Pochards are also found here. Nationally important concentrations of waterbirds are found in other parts of the study area during the winter, but there are no national criteria on which to base an evaluation.

The country-wide surveys undertaken at intervals, last time 2004 (Nilsson 2008) make it possible to set the area into a national perspective. In this evaluation I concentrate on a comparison between the archipelago areas of Blekinge and not the smaller parts with more open coast in the western parts of the study area.

The Tufted Duck is the most common species in the archipelago in the winter and in the last country-wide survey 14 % of the national total was found here (Table 11). In some winters the number of Tufted Duck can be much higher with more than 25% of the national wintering population. However, as was seen in the analysis of the annual indices there is a marked fluctuation in the number of wintering waterbirds in the area between years. Other species with a high proportion of the national total counted in the Blekinge archipelago are Smew, Pochard and Coot, with more than 50 % of the national total concentrated to a few flocks in the archipelago.

Table 11. The total number of counted waterbirds of various species in Blekinge archipelago in Sweden at the last nationwide inventory in January 2004 (see Nilsson 2008).

Species	Blekinge total	National total	% in Blekinge
Black-throated Diver *Gavia arctica*	1	114	1
Red-throated Diver *Gavia stellata*	1	30	3
Great crested Grebe *Podiceps cristatus*	438	4294	10
Rednecked Grebe *Podiceps griseigena*	1	35	3
Slavonian Grebe *Podiceps auritus*	2	75	3
Little Grebe *Tachybaptes ruficollis*	3	95	3
Cormorant *Phalacrocorax carbo*	836	11709	7
Heron *Ardea cinerea*	45	495	9
Mallard *Anas platyrhyncos*	5019	77755	6
Teal *Anas crecca*	59	315	19
Wigeon *Anas penelope*	5	5562	+
Scaup *Aythya marila*	338	3153	11
Tufted Duck *Aythya fuligula*	32435	224949	14
Pochard *Aythya ferina*	1359	2660	51
Goldeneye *Bucephala clangula*	2410	71872	3
Long-tailed Duck *Clangula hyemalis**	46	-----	+
Velvet Scoter *Melanitta fusca**	1	-----	+
Common Scoter *Melanitta nigra**	1	-----	+
Eider *Somateria mollissima**	9	48955	+
Red-breasted merganser *Mergus serra-tor*	261	5334	5
Goosander *Mergus merganser*	983	18004	5
Smew *Mergus albellus*	1017	3716	27
Shelduck *Tadorna tadorna*	1	20	5
Mute Swan *Cygnus olor*	2773	31138	9
Whooper Swan *Cygnus cygnus*	250	1485	17
Coot *Fulica atra*	4108	15597	26

*** = Offshore areas of the Baltic were not included in 2004**

3.5.6 Birds as indicators of environmental status in marine areas

In the development of indicators for the status of the marine environment the winter counts from the IWC have been used to develop an indicator for wintering waterbirds, which is now included in the set of indicators both for the HELCOM and OSPAR regions within the area covered by the MSFD. For this indicator we have used the count data from 1991 as this was the first year when the entire Baltic could be surveyed. In the development of the indicator we have used trends for different species based on the trends in the indices. These have then been combined in functional groups but also to a common wintering waterbird indicator.

In this report regional indices for the different waterbird species for the years 1987 – 2011 was presented. The starting year was chosen as the first year with the standardized coverage of the reference areas. Based on these species indices an overall index (or indicator) for all included waterbird species in the Hanö Bight and also for the different functional groups has been calculated. General questions relating to the calculation of the bird indicator will not be discussed here as this will be treated elsewhere (Martin et al. 2015). The discussion will be restricted to the local use of the indicator for an area like the Hanö Bight.

All species for which indices for the Hanö Bight were calculated showed a positive trend or fluctuations around a steady level (Figure 17) with one exception, the Long-tailed Duck. This species is not wintering in the inshore areas in any larger numbers, but it has shown a significantly decreasing trend during the period. The same trend was also found for the south coast of Scania (Nilsson 2012) and as shown above there has been a marked decrease in numbers in the offshore parts of the Hanö Bight from 2007 to 2011 and 2012.

The overall index (=wintering waterbird indicator) for all waterbird species in the inshore parts of the Hanö Bight also shows a significantly increasing trend over the study period as is also the case for the three functional groups (Figure 17). The increase is most marked for the fish-eaters and the herbivores.

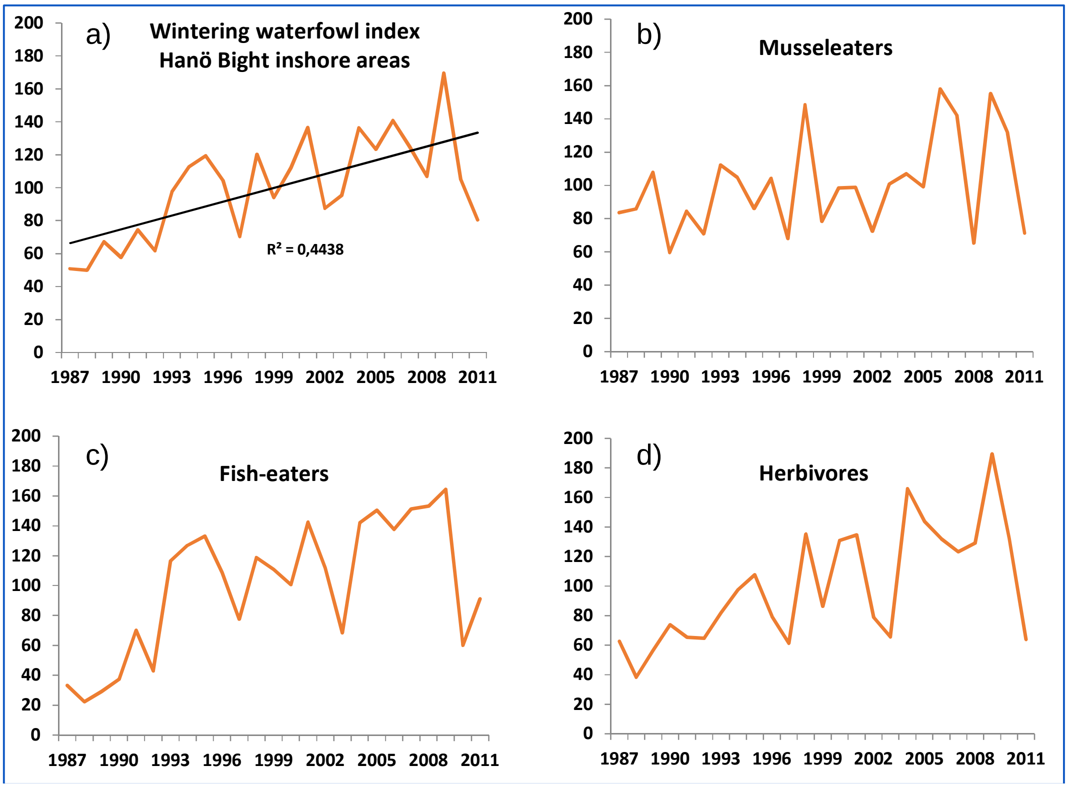

Figure 17. Combined midwinter index for a) the more important species, b) mussle-eating species, c) fish-eating species and d) herbivores in the inshore areas of the Hanö Bight 1987-2011.

One problem with the use of these indices, either for the separate species or combined, as an indicator of the status of marine environment in a restricted area like the Hanö Bight is that the number of wintering birds in the area is not only dependent on the local situation in the area but also related to climate factors such as the hardness of the winter. During the last few decades we have experienced a trend towards more and more mild winters, which will affect the distribution of the waterbirds and also their trends. This shift in the winter distribution and numbers in the Baltic has recently been established for three important species of wintering diving ducks (Lehikoinen et al. 2013).

These factors make it more difficult to use the winter bird indices as an indicator on the local level. For the evaluation of the status of the environment on a larger scale, like the whole Baltic this is not a big problem and methods are being developed to compensate for climate in the calculation of the indices for the Baltic and the indicator (Martin et al. 2015).

When evaluating the trends for wintering waterbirds it must be kept in mind that an increasing trend is not necessarily an indication of a good environmental status even if the indices have been compensated for climate change. Increases in a mussel feeding species like the tufted duck can be due to an increase in the favorite food the blue mussel, but that can be an effect of eutrophication (Nilsson 1972a).

4 Environmental variables

This section describes how environmental variables such as depth and depth derivatives, hydrographic layers, wave exposure, Secchi depth, bottom substrate and anthropogenic layers like potentially polluted areas and marine commercial traffic has been developed for the marine area of Blekinge and the Hanö Bight. Annex 1 presents all maps in their entirety.

4.1 Depth and depth derivatives

4.1.1 Depth

A continuous depth grid for Skåne and Blekinge County and the entire Hanö Bight study area was created from point format depth data. Depth data divided into squares (21 pieces plus four in the economic zone; Figure 18) for Skåne and Blekinge was delivered from the Swedish Maritime Administration.

The depth data is based on hydrographic surveys carried out at different times and with different methodologies why point density varies within the area. Examples of various methods used to collect digital depth data are singel and multibeam echosounding and digitized depth curves. The highest resolution depth data is gained from multibeam. Areas measured by this method were delivered in five meter resolution. In addition to point data from the Swedish Maritime Administration the property map's shoreline converted into points with a point every ten meters was also used.

To convert point data into a continuous depth grid in 10-meter resolution, a semi-variogram model for interpolation was used. During the interpolation, the search was performed in ten points (at least two) and eight directions. Root-mean-square-error, average standard error, standard error, and standardized root-mean-square-error was recorded for each square.

In three squares in Blekinge (1, 2 and 4), a random sample of 10% (5% in grid 4) of points were made. In these squares, the interpolated depth was compared with the measured depth. The results were then plotted to give a geographical image of the defect.

The interpolated frames were finally joined to a continuous depth grid in a 10 m resolution raster format (Figure 19).

For some areas along the coast of Blekinge, the depth and depth derivatives are presented in 100 m resolution due to secrecy restrictions. However, the data with the highest resolution (10 m) has always been used in the species predictions.

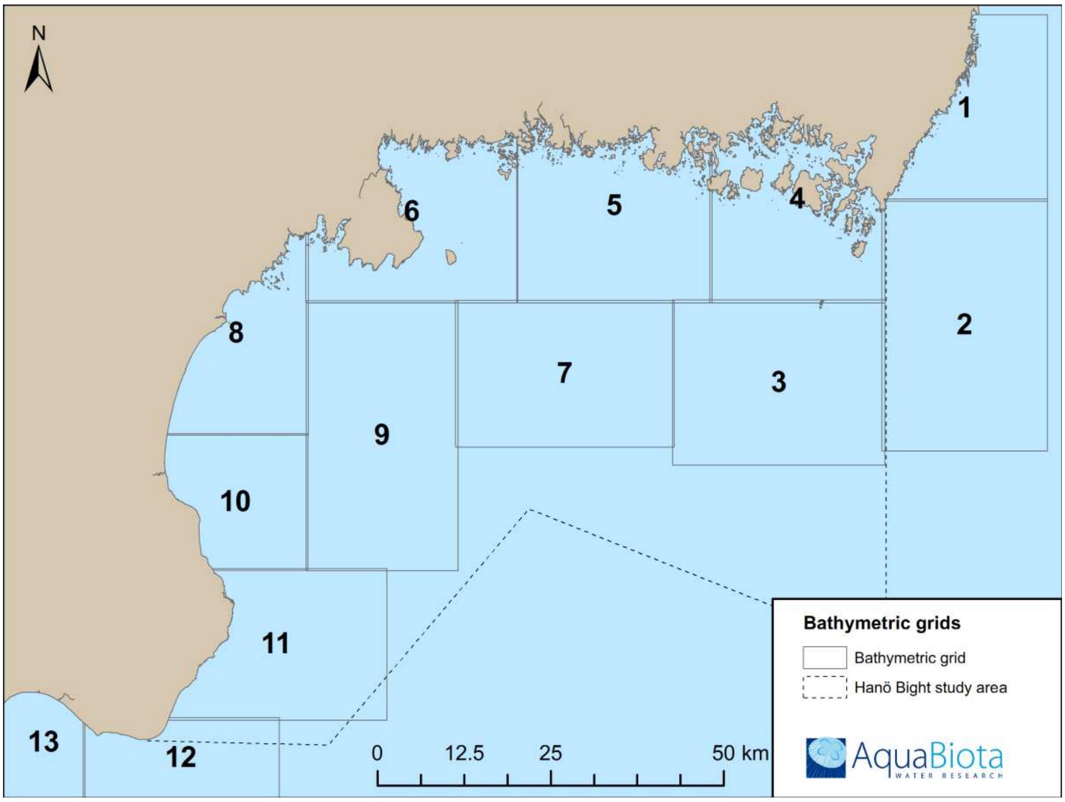

Figure 18. Depth data delivered in squares from the Swedish Maritime Administration.

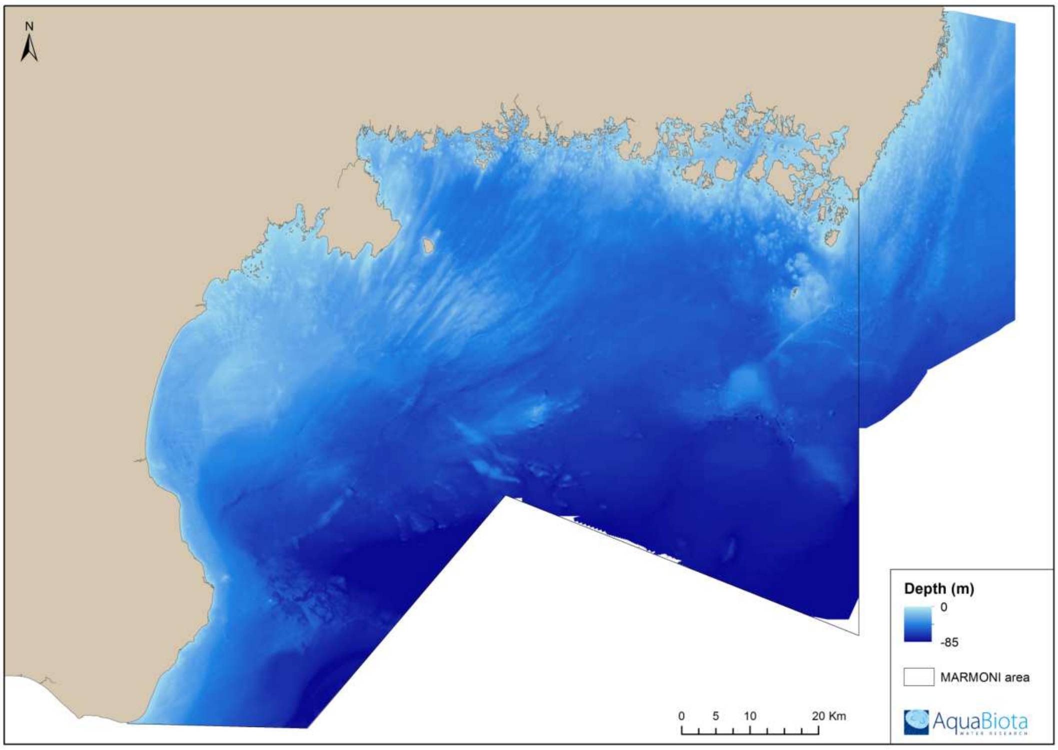

Figure 19. Interpolated depth grid created from depth data from the Swedish Maritime Administration depth database.

4.1.2 Slope, aspect, curvature and landforms

Grids describing the bottom slope, aspect and curvature were calculated based on the interpolated depth grid in 10 m resolution. A detailed and accurate depth grid is a basic condition for the usefulness of these derivatives, because they are very sensitive to both the resolution and errors in the depth map. The slope is calculated by taking the difference in depth from one raster grid to another, and is given in degrees where zero degrees describes a completely horizontal surface and 90 degrees a vertical surface. The aspect describes the bottom slope angle in degrees from 0 to 360. Curvature is a description of how the depth of each point in the map relate to the average depth within a radius of 200 m, and provides a snapshot of relative heights and sinks. Positive values indicate heights and negative values sinks. The depth grid was also classed into nine different landforms in the GIS software SAGA. The method was performed according to Wilson and Gallant (2000). Maps of the bottom slope and curvature of the Hanö Bight are shown in Figure 20 andFigure 21.

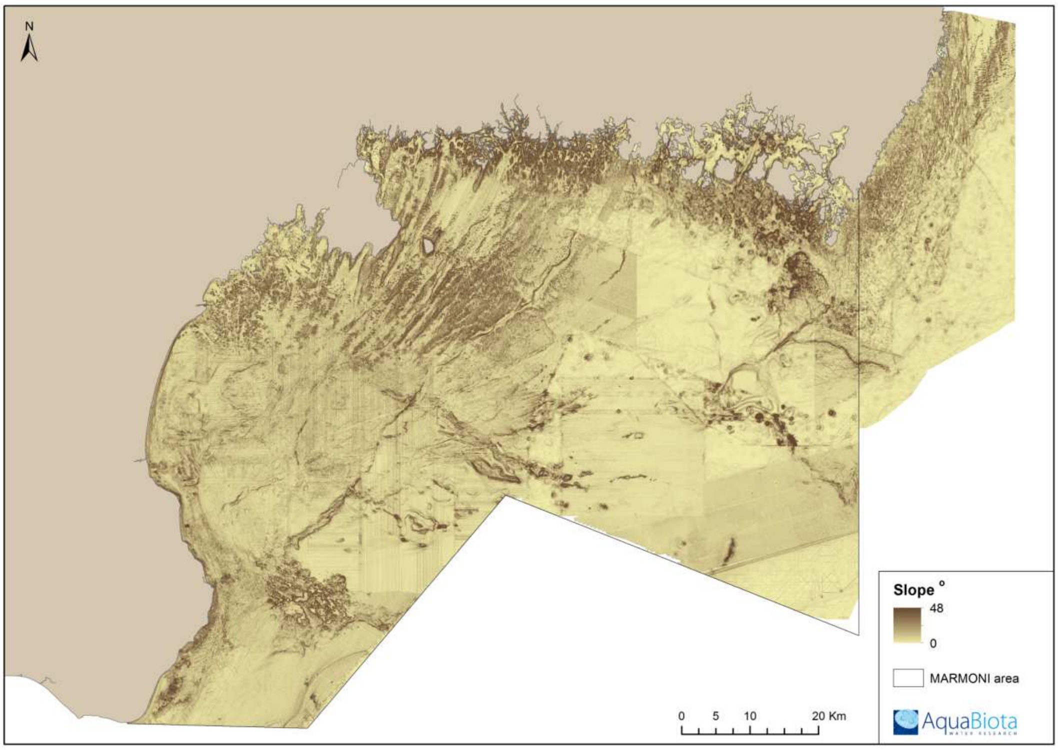

Figure 20. Slope based on the interpolated depth grid. Zero degrees denotes a horizontal surface and 90 degrees a vertical surface.

Figure 21. Curvature based on the interpolated depth grid. Negative values illustrate sinks and positive values illustrate hills.

4.1.3 Depth information density

The interpolated depth map has different detail levels and accuracy in different areas, since the points containing depth information are unevenly distributed in the area. This also applies for the depth derivatives. The reliability of a prediction, especially where the depth and/or depth derivatives plays a significant role as predictor variables, is also affected by depth data point density. To visualize areas with depth data uncertainties in the predictions a density map for depth information was created. Areas with a density of less than 1 000 points per km^2 are classified in this map as areas with sparse depth information. Point density was calculated for the same squares as depth data was delivered in (Section 4.1.1). To avoid false low density values in areas close to shore and narrow bays (due to lack of depth information on land) the point density map was corrected using a layer for proportion of land per km^2.

4.2 Hydrographical and chemical variables

A series of physical and chemical variables were created as a basis for the spatial modelling based on two types of modelled data. Data from the coastal basin model HOME Water was compiled for coastal areas for bottom and surface values of temperature and salinity, near bottom values of oxygen, total nitrogen and phosphorous and integrated chlorophyll values for the water column. Comprehensive county maps were prepared for temperature and salinity at the surface or bottom with the addition of data from the hydrodynamic model HIROMB.

4.2.1 Data

Data was provided as daily values for the years 2005-2010 from two different types of models, HOME Water and HIROMB, both created and implemented at SMHI.

HOME Water is a model system that connects several models for land, lakes, rivers and coastal waters (Marmefelt et al. 2007). In the so-called coastal model averages for smaller basins with fine vertical resolution are calculated. The basin extent varies and follows the classification of water bodies according to Swedish waters archives (SVAR). For the coastal waters of Blekinge, HOME data was obtained as daily profiles of temperature, salinity, chlorophyll-a, oxygen, total phosphorus and total nitrogen in a total of 37 bodies of water (basins), see Figure 22.

HIROMB is a three-dimensional ocean circulation model used operationally at SMHI for the Baltic Sea, Skagerrak and Kattegat and parts of the North Sea (Funkquist and Kleine 2007).

Data for temperature and salinity was retrieved from HIROMB as daily profiles with varying vertical resolution in a total of 134 model nodes in the marine area of Blekinge County. The distance between nodes (model resolution) was three nautical miles (about 5.5 km), see Figure 22.

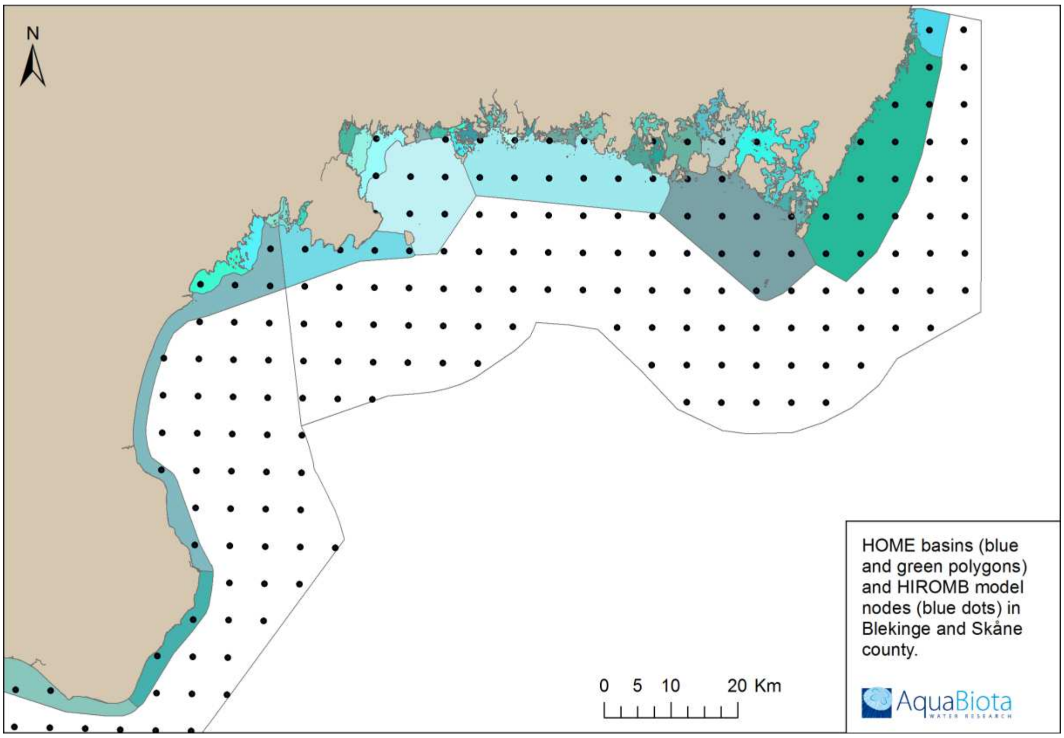

Figure 22. The data coverage for the two hydrographic models used. Points show the model nodes in the HIROMB model while colored polygons show the sub-basins in the HOME Water model. Data were obtained as day profiles in each node (HIROMB), respectively sub-basin (HOME).

Comprehensive grids in 10 meter resolution were compiled for surface values based on the values at 0.5 m depth in each day profile. The HOME data grids were thus based on one profile per HOME basin, and the HIROMB grids on one profile per model node. The corresponding grid for near-bottom values were created by matching the variable value to the bottom depth of each separate grid cell. All parts were then joined to comprehensive layers for the two respective models using ESRI ArcGIS function Mosaic to New Raster according to the *blend* method.

4.2.2 Results

Based on the expected contribution to the species and habitat modelling one or more statistical quantities were calculated for each variable, such as the mean and minimum and maximum values over the entire period (2005-2010). As a more representative value for the minimum conditions than individual outliers, the 10 percentile of all daily values was used rather than the absolute minimum. Similarly, the estimated 90th percentile of all the monthly values was used as the value of maximum conditions.

Based on data from the HOME Water model a total of 19 grids were compiled; mean, minimum and maximum values at the surface and near the bottom for temperature and salinity; mean, minimum and maximum values integrated for the whole water column for chlorophyll-a; mean and minimum values at the bottom for oxygen levels, and mean values at the bottom for total phosphorus and total nitrogen (Table 12 and Figure 23). Data from the HIROMB model was compiled in a total of four grids; means at the surface and bottom for temperature and minimum values at the surface and bottom for salinity (Figure 24). Figures in higher resolution can be found in Annex 1.

All raster grids displayed here (Table 12) are free to distribute in 10 m resolution according to the Swedish Maritime Administration (reference 13-02136).

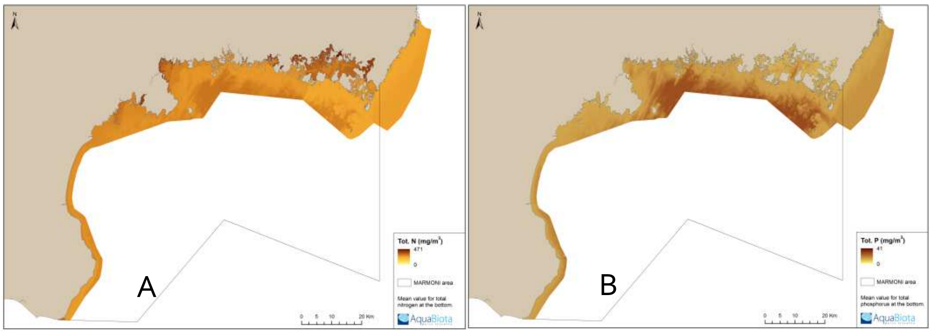

Figure 23. (A) Mean value for total nitrogen at the bottom and (2) mean value for total phosphorus at the bottom from the HOME model.

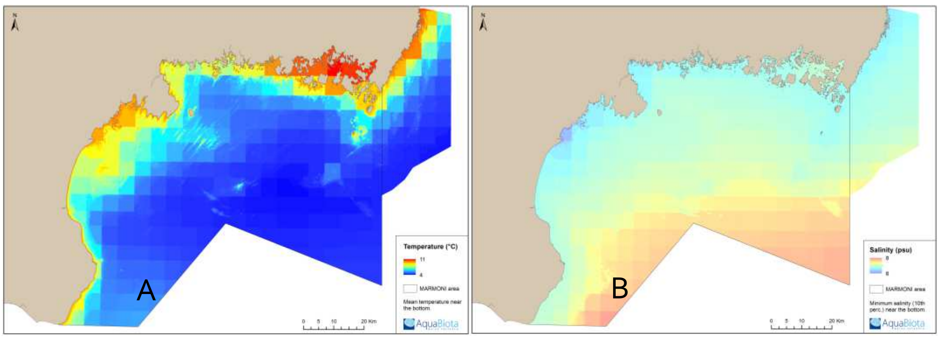

Figure 24. (A) Mean temperature at the bottom and (2) minimum salinity (10th percentile) at the bottom from the HIROMB model.

Table 12. Available layers for the physical and chemical characteristics for Blekinge County. Because the coastal model was limited to only coastal areas, and HIROMB's coverage is somewhat limited near the coast the county-wide grids were created as a composite of the two data sets.

Variable	Grid extent	Data source	Level	Statistical quantity
Temperature	Coastal area	HOME	Surface. bottom	10-perc, mean, 90-perc
Salinity	Coastal area	HOME	Surface. bottom	10-perc, mean, 90-perc
Chlorophyll-a	Coastal area	HOME	Integrated	10-perc, mean, 90-perc
Oxygen level	Coastal area	HOME	Bottom	10-perc, mean
Total phosphorous	Coastal area	HOME	Bottom	Mean value
Total nitrogen	Coastal area	HOME	Bottom	Mean value
Temperature	The whole county	HIROMB+ HOME	Surface. bottom	Mean value
Salinity	The whole county	HIROMB+ HOME	Surface. bottom	10-perc

4.3 Wave exposure

Wave exposure refers to the spatial pattern of wave action degree that structures the shoreline species composition (Lewis 1964). Although the direction of waves and energy constantly varies the pattern for wave exposure is largely unchanged over time. This becomes most evident in island environments where the benthic community is completely different in sheltered and exposed environments. The undulations are strongest at the surface and decreases with depth, which means that the shallow, often plant-dominated habitats are most affected. The wave motions affect the species distribution both directly and indirectly. Direct effects occur for example when plants are removed by physical force by wave action or when good water circulation is created for filtration species. Indirect effects occur when loose sediments are removed or divided into different grain sizes. In these cases the hard substrata is exposed to the attachment of algae and animals. In other areas sand and other loose sediments are accumulated, creating habitats for rooted plants and burrowing animals. Species may be specialized and only occur with some degree of wave action, or have different shapes or sizes as a result of the degree of wave action. An example of the latter is bladderwrack which is tall and has many vesicles in protected environments, while it has a short body and may completely lack vesicles in environments with high wave exposure.

4.3.1 Calculating wave exposure

Since the wave activity constantly varies the degree of wave exposure is difficult to measure in the field. Therefore, it’s normally estimated with a calculation method. There are several cartographical methods to choose from, and each one has its pros and cons. In this project the method Simplified Wave Model (SWM, Isæus 2004) has been used (Figure 25). The method called simplified because it does not account for how the water depth affects the wave properties. The calculated wave exposure at the surface can be converted into wave exposure at the bottom with the help of a comprehensive depth grid, but without any consideration to the impact on wave characteristics by the bathymetry. The advantages of the SWM method are that it can be used in high resolution and that it provides an ecologically relevant picture of wave exposure patterns in island areas (see Eriksson et al. 2004, Bekkby et al. 2008, Sandman et al. 2008).

Since the wave exposure for different areas are based on wind data from different stations there will be an overlap between areas where the values differ slightly. SWM was calculated along the coasts and hence SWM values from the open sea are missing. To cover all of the study area in the Hanö Bight SWM grids (25 m resolution) was merged with wave exposure grids from the EU - SEAMAP (about 335 m resolution). SWM values> 500 000 in this layer consists of significant wave height that has been created by DHI (DHI 2010) and then converted into the SWM (Wijkmark and Isaeus 2010).

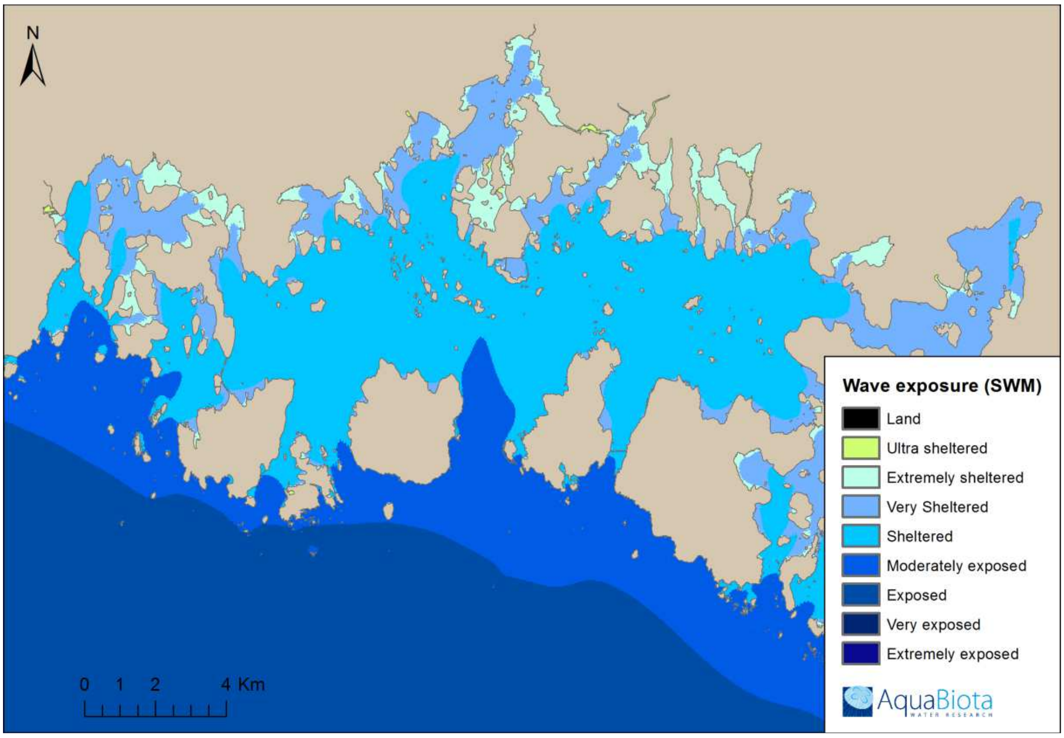

Figure 25. Wave exposure (SWM). A snapshot from Blekinge archipelago shows different environments from ultra-sheltered to exposed.

4.4 Secchi depth

Benthic vascular plants and algae are affected by the amount of light that reaches down through the water column. The amount of light is in turn affected by the depth and water transparency, i.e. Secchi depth. A regression analysis between a satellite image and a large number of field measurements was used to create a high-resolution map of Blekinge and the Hanö Bight (Philipson et al. 2013). Similar methods have also sometimes been used, for example in Södermanland County (Florén et al. 2012), for combining different types of satellite imagery. The Secchi depth is also affected by the level of nutrients in the water (since nutrients affect the amount of vegetation in the water column, which affects the water transparency). This means that a Secchi depth map could also indicate the degree of eutrophication.

Satellite data used is from Landsat TM with an EO-sensor with a resolution of approximately 30 m. The southern parts of the Secchi depth image from 2010-08-10 (description in Philipson et al. 2013) contains some clouds and cloud banks covering parts of the surface. These were cut out from the satellite image whereupon a median filtering was performed to eliminate noise. Thereafter, an interpolation was made to fill the gaps with the surrounding values, which gave a comprehensive Secchi depth map (Figure 26).

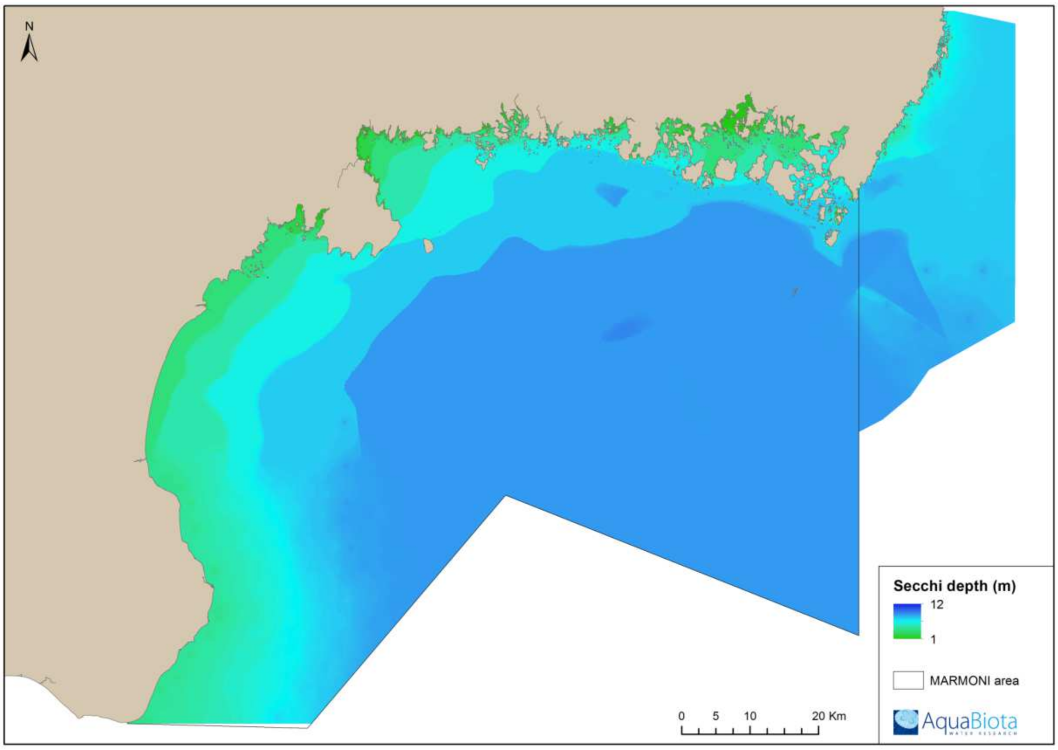

Figure 26. Secchi depth from satellite data after median filtration and interpolation.

4.5 Bottom substrate

The Geological Survey of Sweden (SGU) has on behalf of the Swedish Environmental Protection Agency produced modelled continuous bottom substrate maps of investigated Swedish marine areas. These maps show the bottom substrate divided into nine classes and are based on marine geological map databases and on surface bottom observations classified according to the EUNIS system (now called the HUB system) (Hallberg et al. 2010). In the south coast areas of Blekinge County a more detailed inventory of the uppermost surface substrate has been developed.

5 Habitat modelling

5.1 Modelling

This section describes the basic principles of the modelling process and procedure for selection of the modelling methodology for modelling of species.

5.1.1 The modelling process

Modelling is a broad term that can include everything from simple causal relationship to advanced computer calculations. In this context it refers to spatial statistical modelling, which aims to model the spatial distribution of a species, a substrate class, a habitat or other response variable based on empirical data. Sometimes this technique also called habitat modelling, which is really only one of several possible applications. Changes in this distribution over time are not modelled here, but also such applications are possible.

5.2 Step 1 – Model

5.2.1 Model development

The modelling process is shown in Figure 27. In the first step, the statistic relation between response variable (e.g. cover of a species or the presence of a substrate) and the predictors (environmental variables) at the surveyed stations. Some predictors such as depth can be measured during the survey of the response variable. Other predictors such as wave exposure or potentially polluted areas are difficult to measure during the biological field surveys. Values for these are instead extracted from coherent raster layers. A raster is a map consisting of a large number of smaller cells (usually squares). Each cell has a single value. The raster resolution should be equivalent to the spatial resolution of the patterns that the model should describe. Only predictors that are likely to affect the distribution of the response should be included in the modelling. Most modelling methods provide one or a few variable importance measures that describe the importance of each predictor in the model.

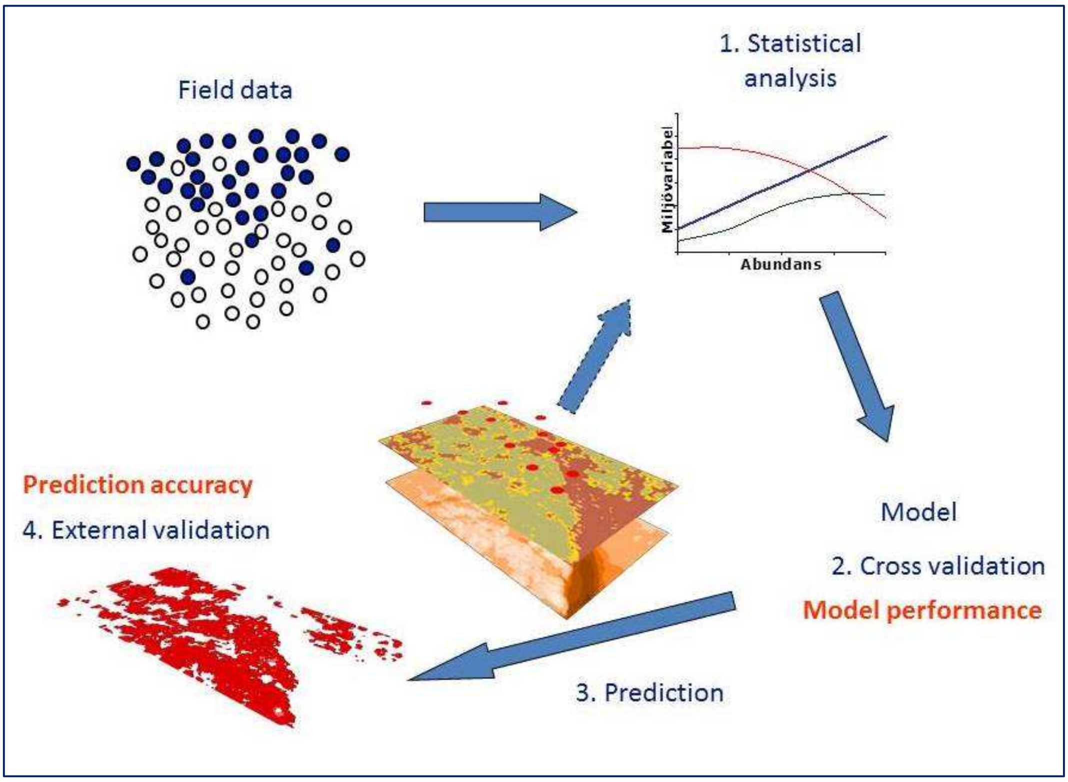

Figure 27. Principles of the modelling process (valid for all models in this project, both GAM and rF models).

Predictors were chosen based on distribution and ecology of each modelled response variable (species or group). E.g. hydrographic predictors from the HIROMB model were used for response variables that occur in offshore areas while hydrographic variables from the HOME model were used for response variables with a coastal distribution. The HIROMB model covers both offshore and coastal areas while the HOME model only covers coastal areas but includes a wider range of variables than the HIROMB model.

Since marine species are normally limited by low salinity and limnic species are limited by high salinity, different predictor layers for salinity were used for these. E.g. a layer describing the salinity 10 percentile at the seafloor was used for macroalgae while the salinity 90 percentile at the seafloor was used for vascular plants.

The modelling method used for most species and groups (vegetation, zoobenthos and juvenile fish in coastal recruitment areas) in this project was randomForest (rF), a classification algorithm in which a large number of classification trees are built to provide a common classifier (Breiman 2001; Cutler et al. 2007). The algorithm starts by the extraction of a large number (e.g. 500 depending on number of trees selected) of randomly selected bootstrap-samples from the data set. A typical bootstrap sample includes about 63 % of the original observations at least once. The observations not included in the bootstrap-sample are called "out-of-bag observations". A classification tree is fitted for each bootstrap-sample but only a small number of predictors are used at each split in the tree (e.g. the square root of the number of predictors included in the model). Each classification tree predicts the out-of-bag observations (i.e. the observations not included in the construction of the tree). The predicted class for an observation is calculated be majority vote of the out-of-bag observations for that observation. Each tree in randomForest is heavily fitted to the data set.

One advantage of this method is that several correlated predictors may be included in the same model. The method uses all predictors available but predictors with small classifying ability have small or negligible importance in the model. RandomForest-modelling was performed with the tool randomForest (Breiman and Cutler 2012) in the software R (R 2010).

The method Generalized Additive Modelling (GAM) (Hastie and Tibshirani 1986) was used for modelling of pelagic fish, zoo plankton and jellyfish. In GAM, non-parametric response curves are fitted. The selected number of degrees of freedom determines how sharp turns that is allowed on the response curves. GAM-modelling was performed with the tool MGCV (Wood and Augustin 2002, Wood 2006) in the software R (R 2010).

5.2.2 Evaluation of model quality

In randomForest models accuracy and error rate is calculated for each observation of the out-of-bag observations. Mean values of all observations are used as accuracy measures. Since the out-of-bag observations for each tree isn't included in the fitting of the tree, these can be regarded as a type of cross-validation. The error rate presents the proportion wrongly predicted observations among the out-of-bag observations. This is calculated for all observations and used as a description of the internal classifying capacity of the model. It is presented in this report as the OOB-error in per cent.

Internal validation of presence/absence models created with GAM was performed by calculation of AUC on the data set used in the fitting of the model. The classifying capability of the model is presented by a value 0 and 1.

5.3 Step 2 - Prediction

5.3.1 Prediction development

During the second step, the model is applied on raster layers of all included predictors in order to create a spatial prediction of the response. During the calculation of the prediction, the model is run for each raster cell. In each cell the value of the predictor variable is used in the model and the expected value of the response variable (e.g. the probability of presense of a species or group) is calculated. The result is a new raster, a spatial prediction presenting the predicted distribution of the response variable in GIS format (digital map). When predicting a presence/absence model the result is a predicted map of the probability of presense of the response variable between 0 and 1 in each cell. Prediction of an abundance model (e.g. cover or number of individuals) results in a map showing the predicted abundance of the response variable in each cell.

Any deficiencies in the predictor raster layers will be transferred to the predicted map and decrease its quality. Predictors with comparably high importance in the model will contribute with more of its deficiencies to the predicted map. It is therefore very important that the most important predictor layers are of high quality.

Sharp edges and other distinct shapes in important predictor layers will often appear clearly also in the predicted maps. Sometimes these shapes are real such as a steep slope or a dredged sea-lane. They may also be results of coarse resolution or generalizations such as the classification of seabed substrate into a number of distinct classes with sharp boundaries.

5.3.2 Evaluation of the prediction quality

In order to assess the quality of a model, a validation with external data should be performed. This means that predicted values are compared with independent field data that has not been involved in the modelling process. Presence/absence models (models for the probability of presense of the response) are best evaluated by the measure AUC (Area Under Curve, see AUC fact box). Abundance models are often assessed by a correlation coefficient (e.g. COR, r2 or RMSE). Low AUC- or COR-values indicate that the model quality is poor and that the model should not be used in prediction. Low number of observations or that important predictors are missing are Common reasons for poor modelling results. The model may also be over fitted. An over fitted model has not only been fitted to the variation in the included predictors but also to a variation caused by other factors or random. Too many degrees of freedom and too many predictor variables increase the risk for over fitted models in modelling methods such as GAM. Over fitting leads to high AUC value in the internal model validation but often a low AUC value in the external validation.

By external validation, the entire modelling process is validated, i.e. both the model and the predictor layers. External validation is the only way to detect weaknesses in the predictor rasters. It is also more likely to find errors caused by over fitting or uneven data distribution with external validation than with internal validation. The only drawback with external validation is that parts of the data have to be withheld from the modelling process and saved for the external validation (example in Table 13). This may be considered a high price when field data is scarce and predictions without external validation are often presented, also in scientific literature. All validation values presented in this report (AUC, R2 etc.) are based on data withheld from the modelling process, i.e. external or split validation.

5.3.3 MapAUC

The AUC-value depends on the characteristics of the validation data set, i.e. in what areas the validation of the prediction is performed. The use of many validation observations outside the potential distribution area may lead to high AUC-values also with a quite poor prediction since most models can classify absences far outside the range of species correctly. If most of the validation observations are located outside the potential distribution area of the species, the AUC value will most likely be misleading.

For evaluation of predictions, the AUC-value has been used in a strict way in this report. Validation data sets were selected according to the depth distribution of each species. Stations located more than 20 % shallower or deeper than the depth distribution of the species in the dataset were removed from the validation data set. This means that for a species occurring between 1 and 5 meters depth, the validation data set was restricted to observations between 0.5 and 5.5 meters depth. This validation method has been developed by AquaBiota. The main advantages is that it provides a stricter and more correct evaluation of the quality of the prediction since only areas relevant for the predicted response are included. Differences in quality between different modelled areas (e.g. counties) are more comparable since differences in depth distribution of species and bathymetric conditions have are less likely to affect the AUC-value. In order to include the uncertainty of the bathymetric grid, the validation was performed on the interpolated bathymetric grid instead of field measurements of depth. This AUC value is here termed mapAUC. In cases where AUC was calculated as above but with field depth, the term splitAUC is used.

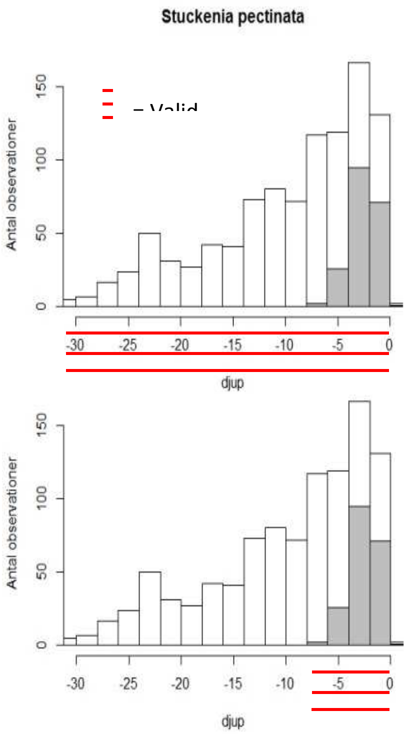

Figure 28. Principle for selection of validation data with AUC and mapAUC. The grey fields indicate presence of a species (Stuckenia pectinata as an example). The model is built with data from the entire depth interval. Upper figure: Prediction validated in the entire depth interval and an AUC value is calculated. Lower figure: Prediction validated in 1.2 * depth interval wherein a mapAUC is calculated.

Table 13. Example from some models for vegetation and blue mussels with number of stations (observations) used in the modelling process and external validation and the depth distribution of the species in the modelling data set. Observe that number of stations in the modelling data set depends on the number of presences in the data since the modelling dataset is balanced to 50 % prevalence.

Modelled species/group	Hydro-graphic model	Number of stations in modelling and validation	Species/group depth distribution in modelling data	Depth range validation data
High vascular plants	HOME	mod: 1268, val: 391	0 - 8.5	0 - 9.8
Fennel pondweed ***Stuckenia pectinata***	HOME	mod: 1006, val: 393	0.1 - 8.5	0 - 9.8
Hornwort ***Ceratophyllum demersum***	HOME	mod: 174, val: 350	0 - 5.2	0 - 5.9
Eurasian watermilfoil ***Myriophyllum spicatum***	HOME	mod: 552, val: 395	0 - 8.5	0 - 9.9
Perennial macroalgae	HIROMB	mod: 1202, val: 503	0 - 36	0 - 42.7
Chorda filum	HIROMB	mod: 538, val: 455	0 - 14.1	0 - 16.5
Toothed wrack ***Fucus serratus***	HIROMB	mod: 118, val: 409	0.6 - 11.9	0 - 13.7
Bladderwrack ***Fucus vesiculosus***	HIROMB	mod: 592, val: 385	0 - 7.6	0 - 8.8
Furcellaria lumbricalis	HIROMB	mod: 556, val: 497	0.3 - 27	0 - 31.6
Blue mussel ***Mytilus edulis***	HIROMB	mod: 956, val: 503	0 - 41	0 - 47.6

The method randomForest predicts the dominating class in the data set better than the other classes and the fewer observations of a class in the data set in relation to other classes, the worse it is predicted (e.g. Yao et al. 2013). Most species and groups occur in less than 50 % of the visited stations. In order to enhance the predictive ability for presence, the data sets were balanced. This was performed by a random removal of absence observations until the modelling data sets were balanced. Thus, the difference in predictive capacity between the classes was decreased.

Fact box AUC

AUC (Area Under Curve) is a quality measure for a model or prediction. The AUC value 1 means that all presences and absences are correct according to the validation data. An AUC value of 0.5 means that the result is totally random.

At present there is no consensus on how AUC-values should be interpreted in habitat modelling. One recommendation has been to use the scale presented here (AUC) (Hosmer & Lemeshow 2000). With the new standardized measure mapAUC, values should be adjusted since mapAUC generally gets 0.1 units lower than corresponding AUC calculated on the entire depth range and field depth.

AUC	Quality	mapAUC	Quality
0.9-1.0	Excellent	0.8-1.0	Excellent
0.8-0.9	Good	0.7-0.8	Good
0.7-0.8	Intermediate	0.6-0.7	Intermediate
0.5-0.7	Poor	0.5-0.6	Poor

5.3.4 Sensitivity, Specificity och Cut-off

Sensitivity and specificity are calculated by predicting on the entire dataset (including modelling and validation data). Sensitivity indicates the model's capacity of classifying presences and specificity indicates the model's capacity of classifying absences. To calculate these two measures, the predicted probabilities are divided into two classes, presence and absence. If the cut-off in this classification is too low, the model is likely to classify all observed presences as presences which give a high sensitivity value. With a too low cut-off the model will however also classify most absences as presences. In this project, cut-off values were calculated in order to maximize the model's classifying capacity of both presences and absences during the modelling process (Figure 29). The cut-off value for each response has been used in the probability maps to show where a species is likely to occur and not occur. The map legends state how often a species was observed during the field surveys for the predicted classes low probability of presense (under cut-off) as well as high and very high probability of presense (50 % of raster cells over the cut-off value with lowest and highest probability values respectively).

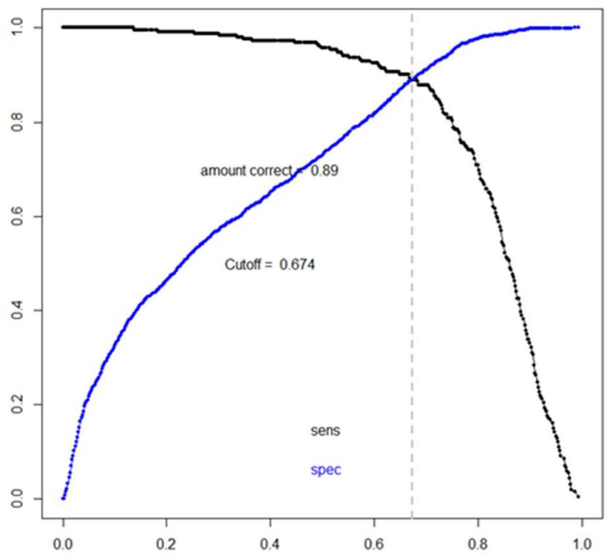

Figure 29. In this model for 10% cover of bladderwrack (*Fucus vesiculosus*) a cut-off of 0.674 was selected to maximize both sensitivity and specificity. The model classes 89 % of the presences and 89 % of the absences in the field data correctly.

5.3.5 Revised probability maps

Interpretation of the unprocessed predictions (probability maps in raster format) can be precarious. The probability maps were therefore processed to better suite management needs.

For each map the cut-off value from the modelling results (see above) was used to delimit areas with low probability of presense from areas with higher probability values. Areas with probability values above cut-off were divided into two classes of equal area, high and very high probability of presense. The map legends state how often a species was observed during the field surveys for each class to facilitate the interpretation of the predicted maps.

5.3.6 Spatial uncertainty of predictions

MapAUC, sensitivity and specificity provide good measures of the general quality of the predictions but the measures provide no information about the spatial variation of the quality within the predictions. It is therefore not possible to determine where the prediction is more reliable and where it is less reliable. Since the prediction quality is largely dependent on the predictors included in the model, an uncertainty map for bathymetry (depth information) was created. Depth and/or depth derivatives were important predictors in most models (Table 14 – Table 20). The uncertainty layer was created from density of depth measurements used in the creation of the bathymetric grid and depth derivatives. The creation of this layer is described in detail in Section 4.1.

6 Species predictions and maps

This section describes the results from the spatial modelling of species and groups in the Hanö Bight. The results are divided into subsections depending on data sets used in the modelling.

6.1 Vegetation and blue mussels

Vegetation and blue mussels (*Mytilus edulis*) were modelled with the method randomForest (rF) according to the descriptions in Sections 5.1 and 5.3.

6.1.1 Modelling data

Vegetation and blue mussels were modelled with field data collected with drop-video, snorkelling and diving (Sections 3.1 and 2). The distribution of macroalgae and blue mussels were modelled with hydrographical predictors from the HIROMB model which covers both coastal and off-shore areas. For these species a data set of 2009 stations in total were used. Since vascular plants are restricted to coastal areas, hydrographic predictors from the HOME-model (coastal basins) were used. Therefore only biological field data from the area covered be the HOME-model were included. A data set of 1843 stations was used in the modelling of vascular plants.

6.1.2 Modelling results for vegetation and blue mussels

This section describes the modelling results for vascular plants, macroalgae and blue mussels. Blue mussels are included here since they were modelled using the same data set as the vegetation models. A number of the modelled species are described in more detail in this section and examples of predicted maps are provided. Annex 2 provides all predicted maps.

All predictions were externally validated and all predictions of vascular plants and blue mussels in this report are of good or excellent quality (mapAUC >0.7). In total 31 predictions for species and groups of vegetation and blue mussel were created.

Beside the validation process all predictions were also manually assessed by personnel with good ecological knowledge and unrealistic predictions were rejected. All predictions presented here were regarded realistic in the sense that the general distribution in the map as a whole was likely. Deviations may occur within certain areas, often due to the quality and resolution of the predictors used in the model. This is discussed in Section 6.3. For some species and groups, predictions for the probability of higher cover were also created. In addition to >0 % (i.e. presence) predictions were also created for ≥10%, ≥25% and ≥50% cover. This was mainly performed for species of high ecological importance but the selection was also restricted by the prevalence of higher cover and validation results. Modelling results are provided in Table 14 and Table 15.

Vascular plants and macroalgae often piece out each other on shallow photic bottoms where vascular plants (having roots) grow on soft substrates such as mud and sand and macroalgae (having holdfasts) grow on hard stable substrates such as rocks and boulders. Macroalgae are therefore more common in exposed environments and outer archipelagos where hard substrates are common while vascular plants are most common in inner archipelagos and bays where the soft substrates aren’t removed by water movements. Common eelgrass (*Zostera marina*) is a vascular plant which often occurs in more exposed environments than other vascular plants. The most exposed sandy bottoms however normally lack vegetation, at least in the shallowest part where the wave action is strongest.

The large sized brownalgae bladderwrack (*Fucus vesiculosus*) and toothed wrack (*Fucus serratus*) are large habitat building macroalgae. Both species grow on hard substrates but the bladderwrack normally grows shallower and in more sheltered environments than the toothed wrack (Figure 30 and Figure 31). The model predicts high probability of presence of bladderwrack on hard substrates along the shores in most of Blekinge archipelago and Pukaviksbukten. An exception is the inner and mid archipelago around Karlskrona where lower probabilities are predicted (Figure 30). Along the Blekinge east coast only smaller and more scattered areas of high probabilities are predicted. The toothed wrack is mainly predicted further off the coast, deeper and in more exposed environments. It is rarely found in the inner archipelago or in sheltered bays and inlets.

Redalgae are generally common in exposed environments and are found at comparably large depths. Several of these species are predicted over large areas of seabed in the Hanö Bight. One example is *Furcellaria lumbricalis* (Figure 32) which is a common species in the area. Filamentous redalgae are very common over wide areas where they often occur together with blue mussels. The blue mussel is distributed over the entire modelled area and high probabilities of presense are predicted over large parts of the offshore areas as well as along exposed shorelines and outer archipelagos (Figure 34). Lowest probability of presense id predicted in sheltered bays and on soft substrates.

Common eelgrass (Figure 33) often forms underwater meadows on soft photic bottoms, often also in more exposed environments than other vascular plants. High probabilities of presense of eelgrass are predicted over rather large areas in Blekinge archipelago and Möllefjorden. High probabilities are also predicted along the east coast, but not in as large and coherent areas as in Blekinge archipelago and Möllefjorden.

Other common high vascular plants in the area are the pondweeds *Stuckenia pectinata* and *Potamogeton perfoliatus* as well as Eurasian watermilfoil (*Myriophyllum spicatum*). High vascular plants were also predicted together as a group both for presence and higher cover. One example is Figure 35 which provides probability of at least 10 % cover of high vascular plants.

Chlorophyll *a* and phosphorus were important predictors in most vascular plant models. The response was normally negatively affected by higher concentrations of chlorophyll *a* (more phytoplankton) and higher phosphorus levels. Phosphorus is often regarded a limiting factor for phytoplankton in our lakes, watercourses and coastal waters. Secchi-depth was an important predictor in many macroalgae models. The response was normally positively affected by large Secchi-depth.

Many species of filamentous macroalgae also grow as epiphytes on vascular plants or other macroalgae. Epiphytic algae were not modelled in this project.

Table 14. Modelling results for vascular plants. These species were modelled with hydrographic predictors from the HOME model. The table lists the four most important predictors for each model (of totally 14 predictors per model). PFO is a layer of distance to potentially polluted areas. OOB-error is a measure of the model's internal fit and mapAUC is a measure of the quality of the predicted map.

Modelled species/group	Model internal fit (OOB-error, %)	Map quality (mapAUC)	Four most important predictors (environmental variables)
High vascular plants	15	0.87	Secchi-depth, wave exposure, salinity at seabed, tot. nitrogen
At least 10 % cover of high vascular plants	23	0.80	depth, wave exposure, tot. phosphorus, chl a
At least 25 % cover of high vascular plants	26	0.79	depth, wave exposure, chl a, tot. phosphorus
Fennel pondweed *Stuckenia pectinata*	16	0.86	depth, wave exposure, chl a, tot. phosphorus
At least 10 % cover of *Stuckenia pectinata*	21	0.77	depth, wave exposure, chl a, tot. phosphorus
At least 25 % cover of *Stuckenia pectinata*	26	0.79	depth, wave exposure, chl a, salinity at seabed
Hornwort *Ceratophyllum demersum*	22	0.81	wave exposure, depth, tot. phosphorus, substrate
Eurasian watermilfoil *Myriophyllum spicatum*	20	0.86	wave exposure, depth, chl a, tot. phosphorus
At least 10 % cover of Eurasian watermilfoil *Myriophyllum spicatum*	18	0.88	depth, substrate, wave exposure, commercial traffic
Eelgrass *Zostera marina*	23	0.81	depth, wave exposure, tot. phosphorus, chl a
At least 10 % cover of eelgrass *Zostera marina*	26	0.86	depth, wave exposure, tot. phosphorus, chl a
Ditch grasses *Ruppia* spp.	22	0.76	wave exposure, depth, chl a, tot. phosphorus
Horned pondweed Zannichellia palustris	26	0.76	wave exposure, chl a, tot. phosphorus, oxygen at seabed

Table 15. Modelling results for macroalgae and blue mussel. These were modelled with hydrographic predictors from the HIROMB model. The table lists the four most important predictors for each model (of totally 11 predictors per model). PFO is a layer of distance to potentially polluted areas. OOB-error is a measure of the model's internal fit and mapAUC is a measure of the quality of the predicted map.

Modelled species/group	Model internal fit (OOB-error, %)	Map quality (mapAUC)	Four most important predictors (environmental variables)
Perennial macroalgae	24	0.83	wave exposure, depth, substrate, salinity at seabed
Chorda filum	24	0.74	depth, wave exposure, commercial traffic, Secchi-depth
Toothed wrack ***Fucus serratus***	15	0.82	wave exposure, curvature, depth, temp. at seabed
Bladderwrack ***Fucus vesiculosus***	26	0.74	depth, wave exposure, salinity at seabed, PFO
At least 10 % cover of bladderwrack ***Fucus vesiculosus***	25	0.79	depth, wave exposure, salinity at seabed, PFO
At least 25 % cover of bladderwrack ***Fucus vesiculosus***	24	0.80	depth, wave exposure, salinity at seabed, curvature
Ectocarpus siliculosus* and *Pylaiella littoralis	25	0.77	substrate, PFO, slope, Secchi-depth
Perennial redalgae	21	0.93	wave exposure, substrate, salinity at seabed, depth
Furcellaria lumbricalis	16	0.90	wave exposure, substrate, depth, Secchi-depth
At least 10 % cover of ***Furcellaria lumbricalis***	15	0.93	wave exposure, substrate, depth, PFO
At least 25 % cover of ***Furcellaria lumbricalis***	15	0.94	wave exposure, substrate, PFO, depth
Coccothylus* and *Phyllophora	23	0.90	substrate, Secchi-depth, wave exposure, temp. at seabed
Filamentous redalgae	15	0.95	wave exposure, substrate, Secchi-depth, depth
Blue mussel ***Mytilus edulis***	16	0.91	depth, wave exposure, curvature, temp. at seabed
At least 10 % cover of blue mussel ***Mytilus edulis***	13	0.94	wave exposure, depth, substrate, PFO
At least 25 % cover of blue mussel ***Mytilus edulis***	10	0.95	depth, wave exposure, substrate, temp. at seabed

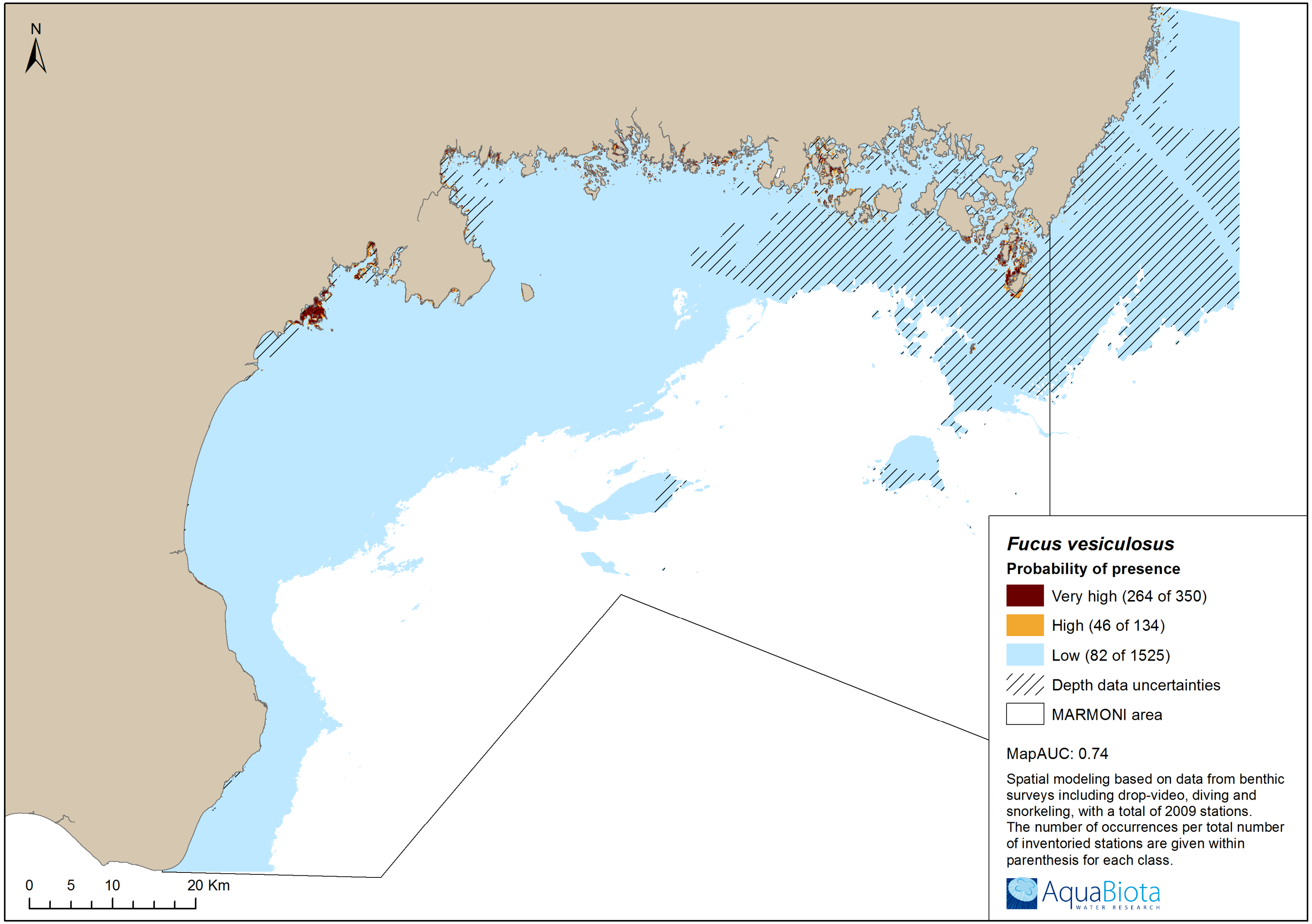

Figure 30. Predicted probability of presence of bladderwrack (*Fucus vesiculosus*).

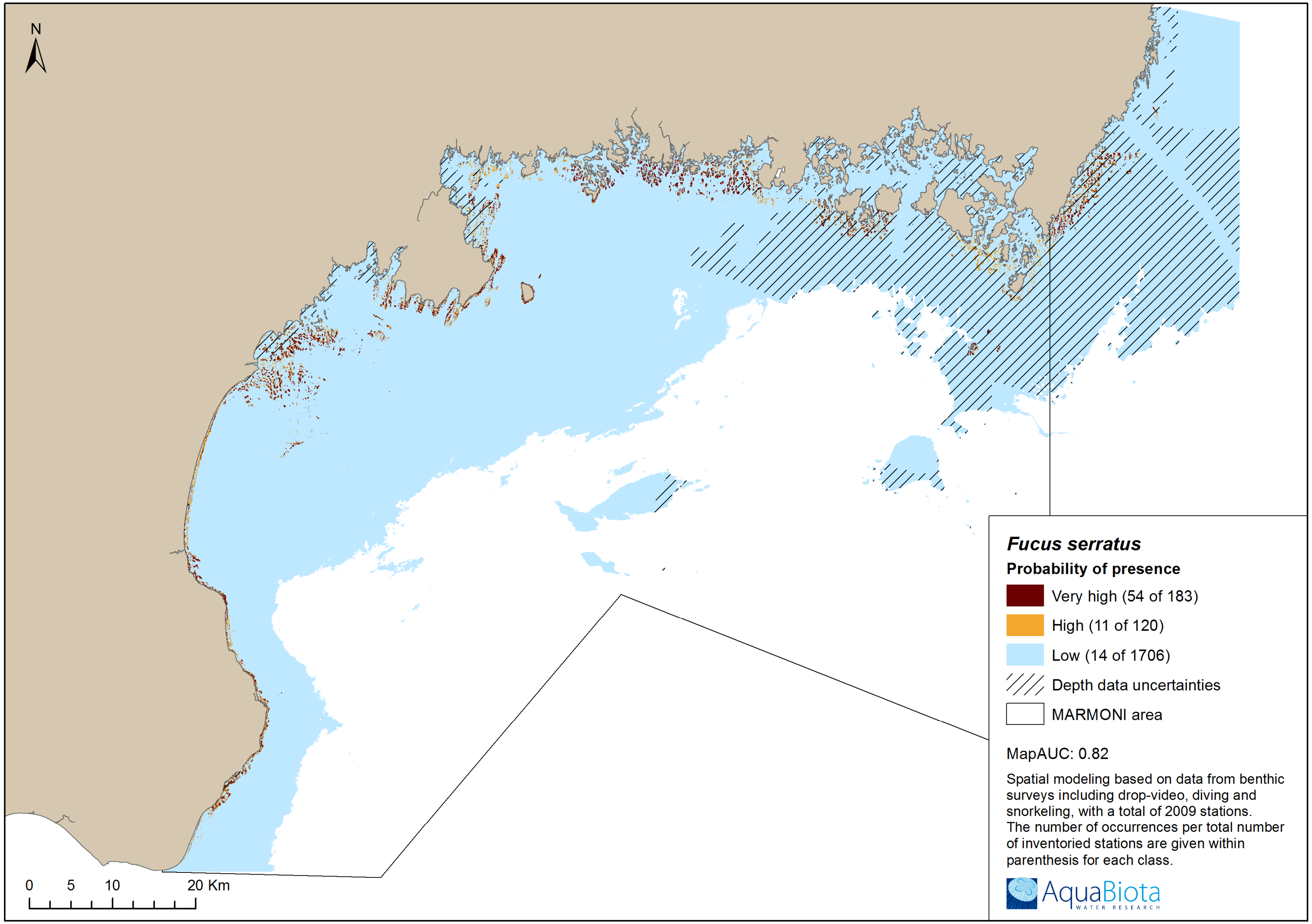

Figure 31. Predicted probability of presence of toothed wrack (*Fucus serratus*).

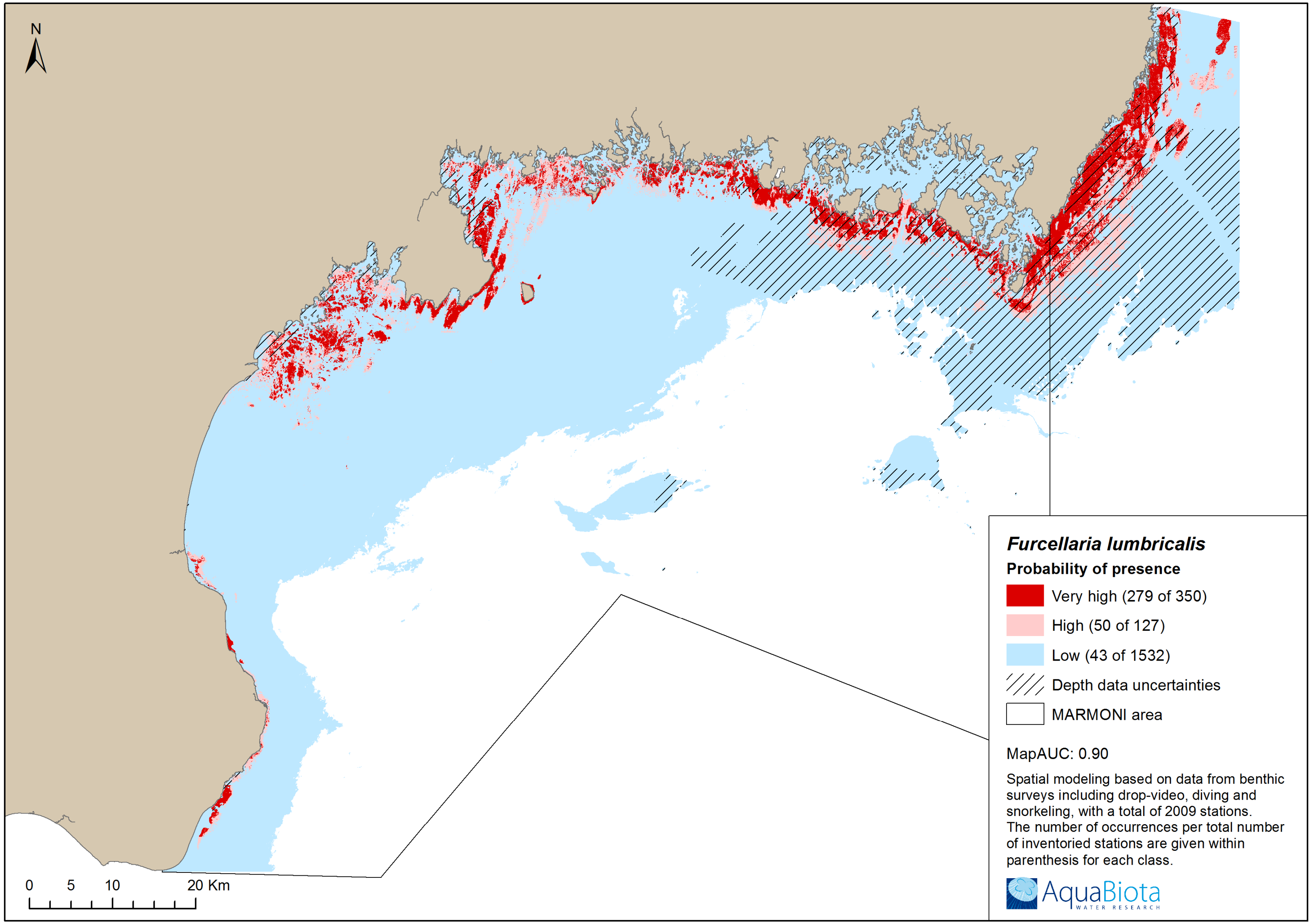

Figure 32. Predicted probability of presence of the red algae *Furcellaria lumbricalis*.

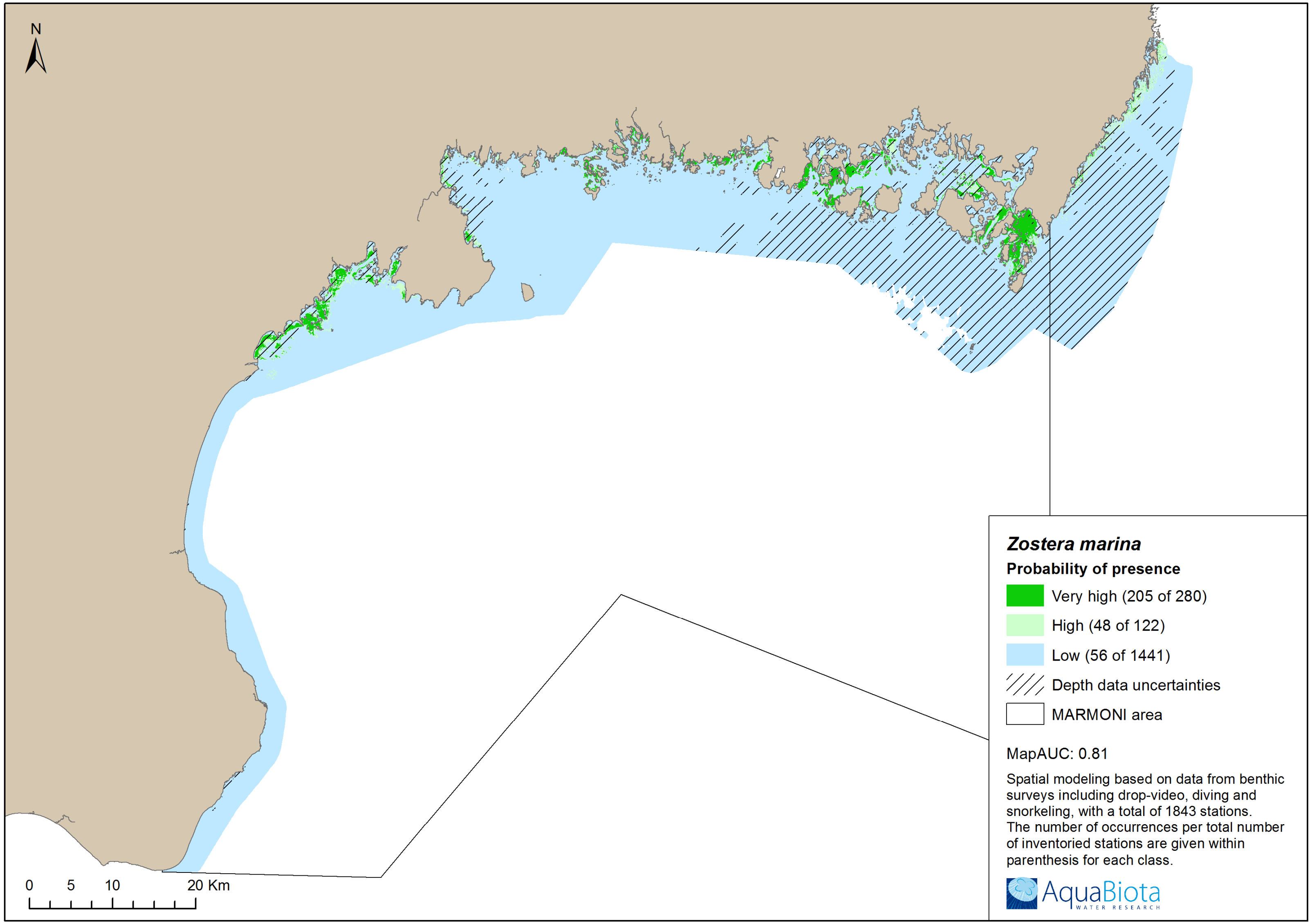

Figure 33. Predicted probability of presence of common eelgrass (*Zostera marina*).

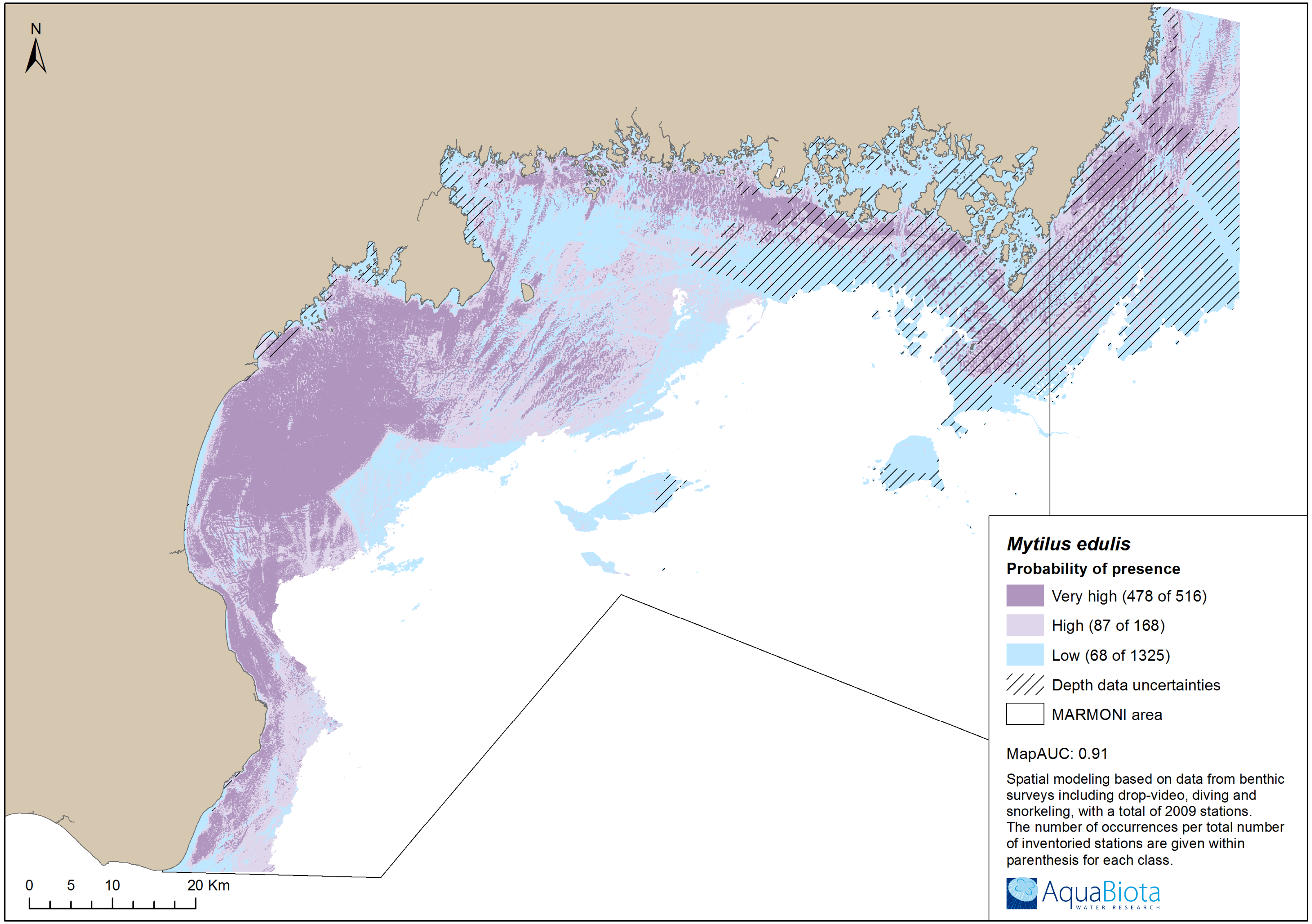

Figure 34. Predicted probability of presence of blue mussel (*Mytilus edulis*).

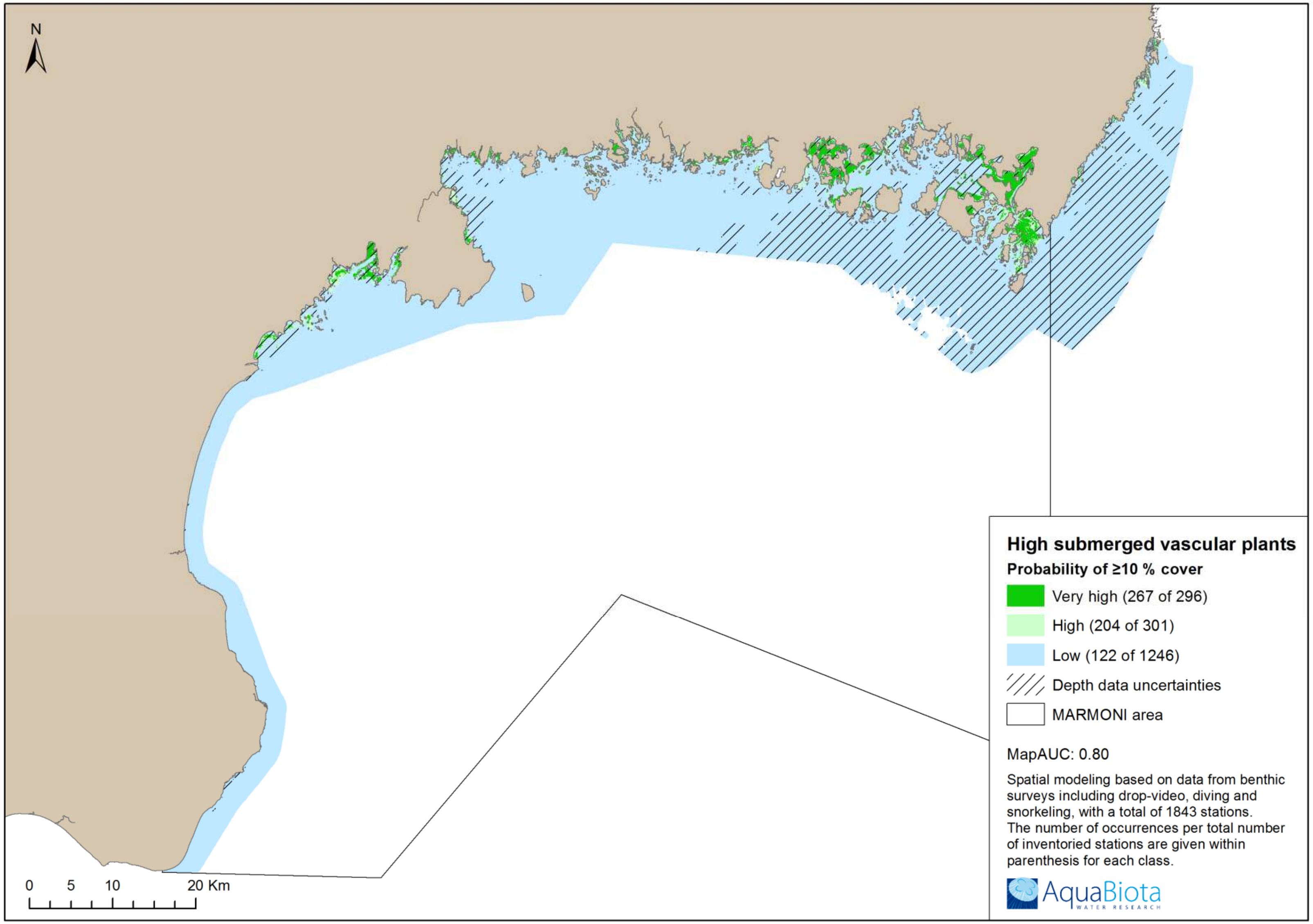

Figure 35. Predicted probability of over 10 % cover of high submerged vascular plants.

6.2 Zoobentos

Animals living in or on soft bottoms were modelled with the method random-Forest (rF) according to the descriptions in Sections 5.2 and 5.3.

6.2.1 Modelling data

Zoobenthos were modelled with biological field data collected with benthic grabs (small and large Van-Veen grabs, see Section 3.2 and 2 for information). A number of drop-video stations were also included in the modelling (Section 3.1.1). A dataset of 831 stations was used, of which 491 were collected during the project with small Van-Veen grabs (0.025 m^2) and 161 were compiled from other surveys with large Van-Veen grabs (0.1m^2). Remaining stations are drop-video stations which were included in the modelling as absence stations for other seabed types (e.g. rock and boulders). Zoobenthos species and group were modelled with hydrographical predictors from the HIROMB model which includes both coastal and offshore areas.

6.2.2 Modelling result for zoobentos

This section describes the results of the modelling of zoobenthos species and groups. A selection of predicted maps is provided in Figure 36 – Figure 42. All predicted maps are provided in Annex 2.

All zoobenthos predictions provided in this report are of excellent quality (mapAUC >0.8). In total 247 presence/absence models and 68 abundance models were created. Predictions were created for all models that passed the validation, which resulted in 16 predictions for probability of presence, 14 predictions for probability of ≥100, 300 or 500 individuals per m^2 as well as eight abundance models and a model for taxa per m^2.

Two maps for filtering capacity (L per day*m^2) were also created, one for filtering capacity on soft bottoms and another for filtering capacity on hard bottoms.

All predictions were validated with external data and manually quality assessed by personnel with good ecological knowledge. All modelling results are provided in Table 16 to Table 19 below.

Table 16. Modelling results for presence/absence models for zoobenthos species and groups.

Modelled taxa	Response	Model internal fit (OOB-error, %)	Map quality (mapAUC)	Four most important predictors (environmental variables)
Asellus aquaticus	presence	14	0.87	land forms, curvature, wave exposure, depth
Bathyporeia pilosa	presence	16	0.93	substrate, tot. nitrogen, oxygen at seabed, chl a
Bylgides sarsi	presence	16	0.81	depth, oxygen at seabed, tot. phosphorus, PFO
***Cerastoderma* spp.**	presence	13	0.87	wave exposure, depth, slope, temp. at seabed
Chironomidae	presence	26	0.88	chl a, wave exposure, oxygen at seabed, temp. at seabed
Halicryptus spinulosus	presence	12	0.82	depth, land forms, commercial traffic, oxygen at seabed
Hediste diversicolor	presence	23	0.80	wave exposure, PFO, slope, depth
Hydrobiidae	presence	25	0.83	slope, depth, chl a, land forms
Macoma balthica	presence	19	0.94	land forms, wave exposure, curvature, depth
***Marenzelleria* spp.**	presence	22	0.85	depth, commercial traffic, land forms, substrate
Monoporeia affinis* and *Pontoporeia femorata	presence	16	0.87	depth, land forms, commercial traffic, curvature
Monoporeia affinis	presence	16	0.90	depth, curvature, land forms, oxygen at seabed
Oligochaeta	presence	25	0.81	depth, slope, tot. phosphorus, curvature
Pontoporeia femorata	presence	15	0.86	depth, commercial traffic, tot. phosphorus, Secchi-depth
Saduria entomon	presence	20	0.80	depth, slope, curvature, dense housing
Spionidae	presence	19	0.90	commercial traffic, substrate, depth, oxygen at seabed

Table 17. Modelling results for presence of high abundances of zoobenthos species and groups.

Modelled taxa	Response	Model internal fit (OOB-error, %)	Map quality (mapAUC)	Four most important predictors (environmental variables)
Bathyporeia pilosa	*≥100 individuals/m²*	18	0.96	temp. at surface, substrate, salinity at seabed, Secchi-depth
Cerastoderma spp.	*≥100 individuals/m²*	8	0.81	wave exposure, depth, chl a, tot. phosphorus
Chironomidae	*≥100 individuals/m²*	22	0.81	wave exposure, chl a, substrate, nitrogen at seabed
Corophium volutator	*≥100 individuals/m²*	10	0.80	depth, land forms, wave exposure, tot. phosphorus
Diastylis rathkei	*≥100 individuals/m²*	17	0.83	depth, wave exposure, tot. phosphorus, salinity at seabed
Hediste diversicolor	*≥100 individuals/m²*	23	0.81	wave exposure, chl a, substrate, depth
Macoma balthica	*≥100 individuals/m²*	23	0.89	land forms, wave exposure, depth, curvature
Marenzelleria spp.	*≥100 individuals/m²*	22	0.82	land forms, kurvatur, slope, oxygen at seabed
Monoporeia affinis* and *Pontoporeia femorata	*≥100 individuals/m²*	15	0.88	depth, kurvatur, land forms, oxygen at seabed
Monoporeia affinis	*≥100 individuals/m²*	15	0.86	depth, oxygen at seabed, slope, tot. phosphorus
Monoporeia affinis* and *Pontoporeia femorata	*≥300 individuals/m²*	21	0.94	depth, marine traffic, slope, PFO
***Marenzelleria* spp.**	*≥300 individuals/m²*	23	0.91	depth, tot. phosphorus, land forms, substrate
Spionidae	*≥500 individuals/m²*	29	0.83	depth, tot. phosphorus, oxygen at seabed, temp. at seabed
Macoma balthica	*≥500 individuals/m²*	30	0.82	chl a, oxygen at seabed, slope, temp. at surface

Table 18. Modelling results for abundance models (individuals per m²) for zoobenthos and models for taxa per m².

Modelled taxa	Response	R^2 (on final map, not transformed)	R^2 test	Four most important predictors (environmental variables)
Macoma balthica	number of individuals /m²	0.39	0.62	land forms, curvature, wave exposure, depth
***Marenzelleria* spp.**	number of individuals /m²	0.47	0.53	depth, bottom substrate, commercial traffic, land forms
Pontoporeia femorata	number of individuals /m²	0.53	0.45	depth, oxygen at seabed, wave exposure, Secchi-depth
***Cerastoderma* spp.**	number of individuals /m²	0.35	0.28	depth, urban areas, temp. at seabed, oxygen at seabed
Monoporeia affinis & Pontoporeia femorata	number of individuals /m²	0.40	0.25	depth, tot. nitrogen, chl a, Secchi-depth
Chironomidae	number of individuals /m²	0.34	0.63	wave exposure, chl a, depth, tot. nitrogen
Hydrobiidae	number of individuals /m²	0.40	0.46	depth, curvature, temp. at seabed, tot. phosphorus
Total number of individuals (all species)	number of individuals /m²	0.60	0.36	Secchi-depth, urban areas, wave exposure, chl a
Number of identified taxa	number of taxa /m²	0.32	0.25	depth, commercial traffic, oxygen at seabed, tot. nitrogen

Table 19. Modelling results for filtering capacity for hard and soft bottoms.

Modelled taxa	Response	R^2 (on final map, not transformed)	R^2 test	Four most important predictors (environmental variables)
Filtering kapacity, hard bottoms	L per day*m²	0.84	0.57	slope, PFO, wave exposure, depth
Filtering capacity, soft bottoms	L per day*m²	0.88	0.72	land forms, curvature, depth, wave exposure

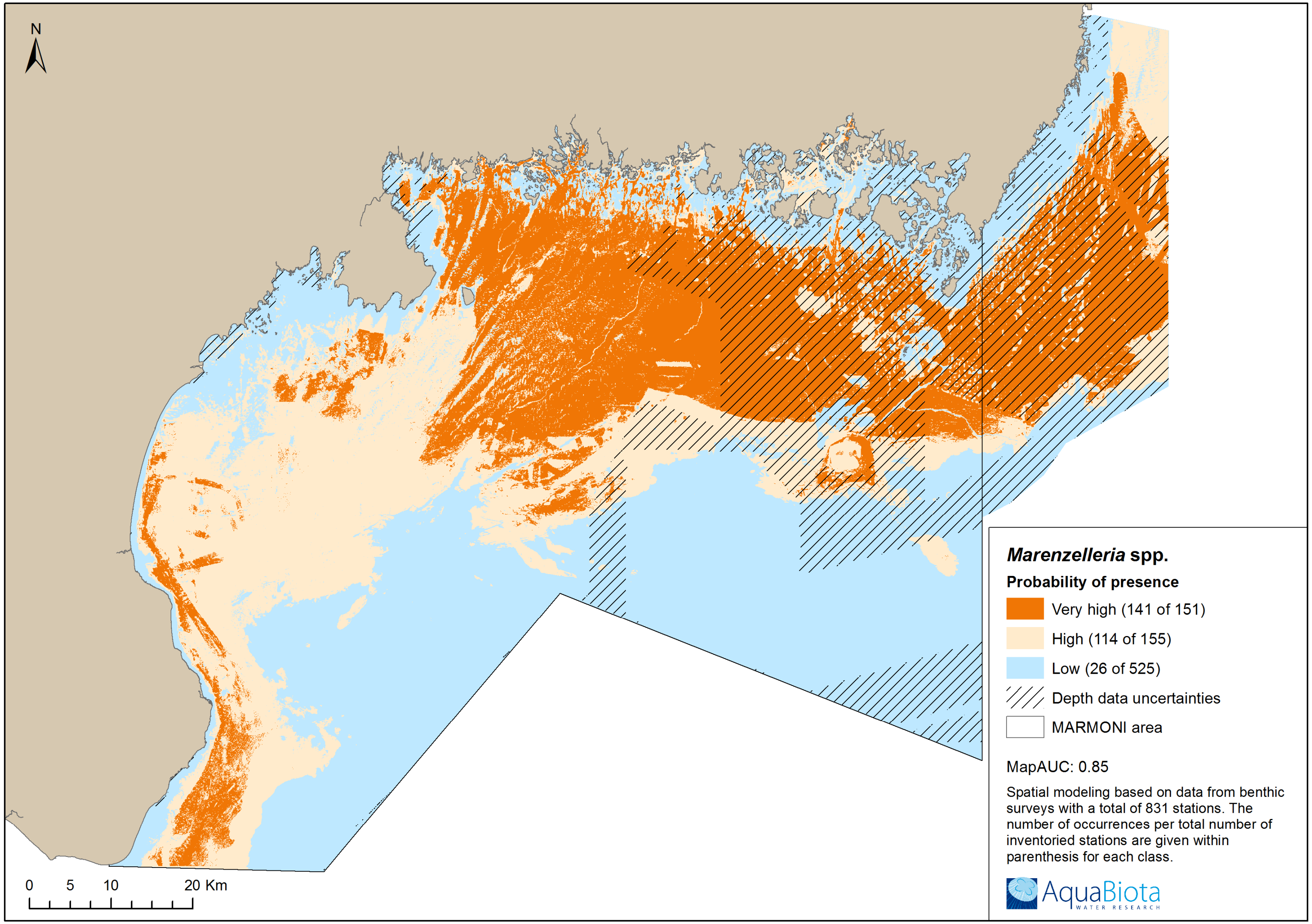

Figure 36. Predicted probability of presence of the polychaete *Marenzelleria* spp. These are ailien in Swedish waters.

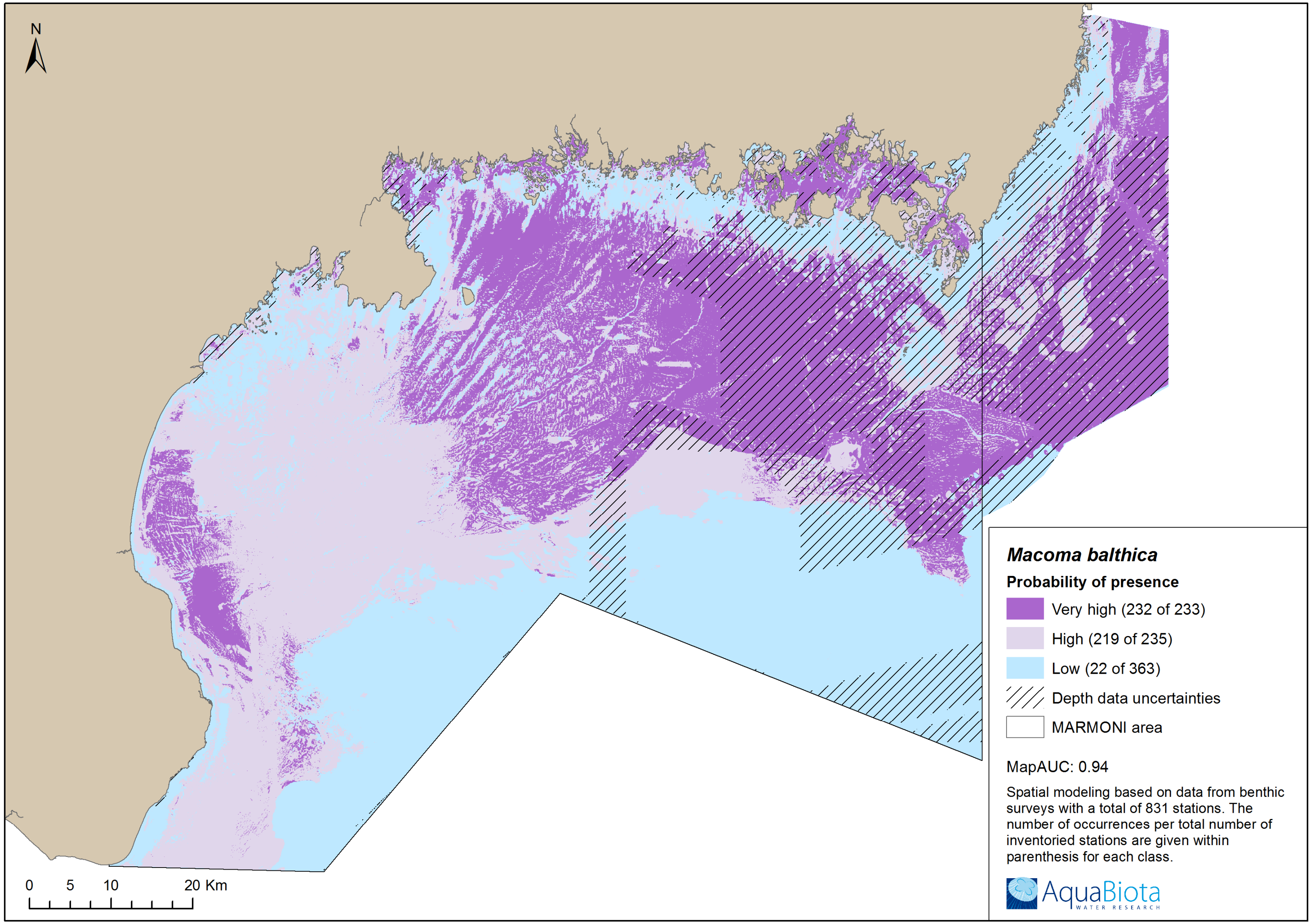

Figure 37. Predicted probability of presence of baltic clam (*Macoma baltica*).

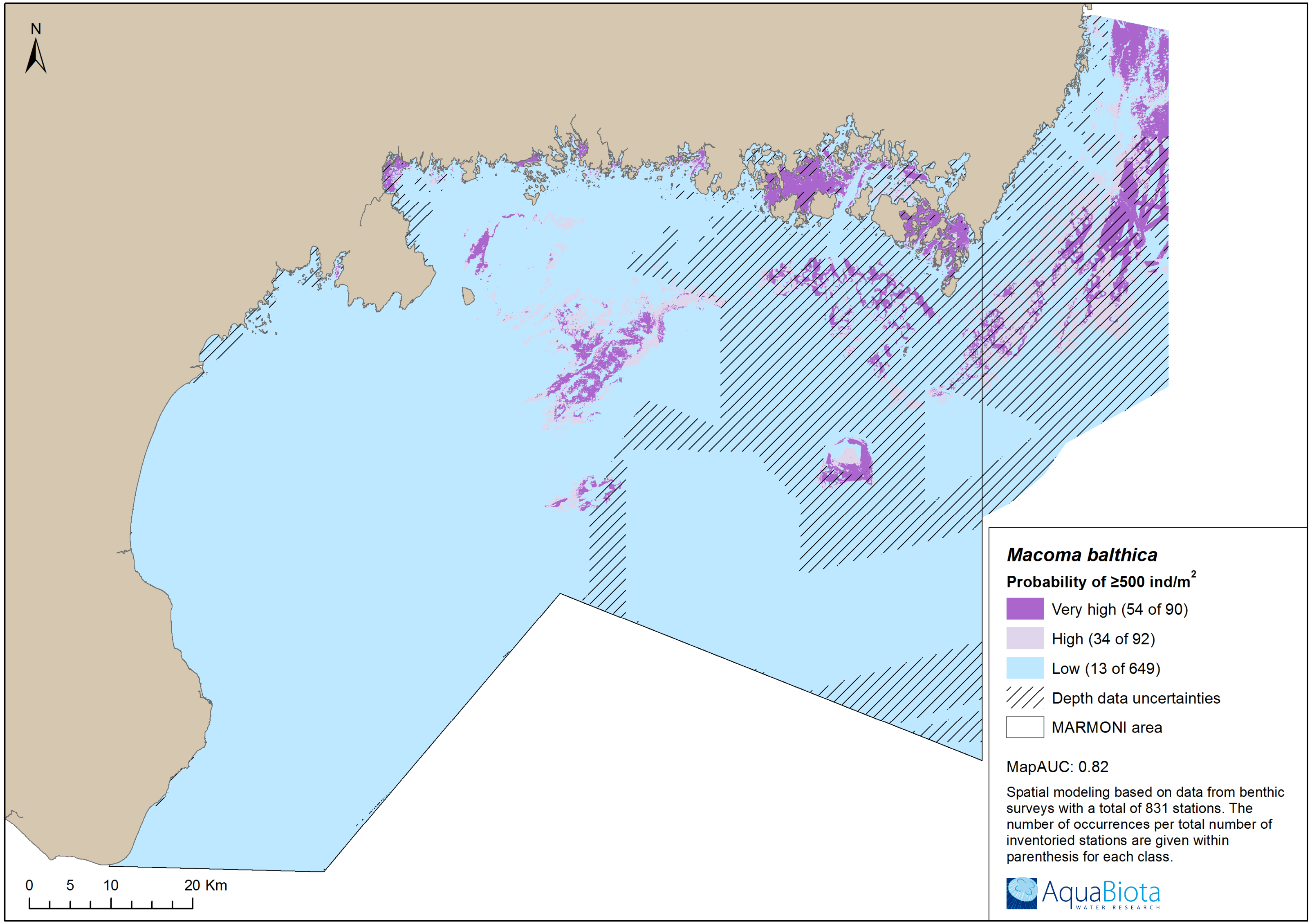

Figure 38. Predicted probability of over 500 individuals/m2 of baltic clam (*Macoma baltica*). This mussel is a very common species found virtually throughout the area. This map shows the areas with the highest densities.

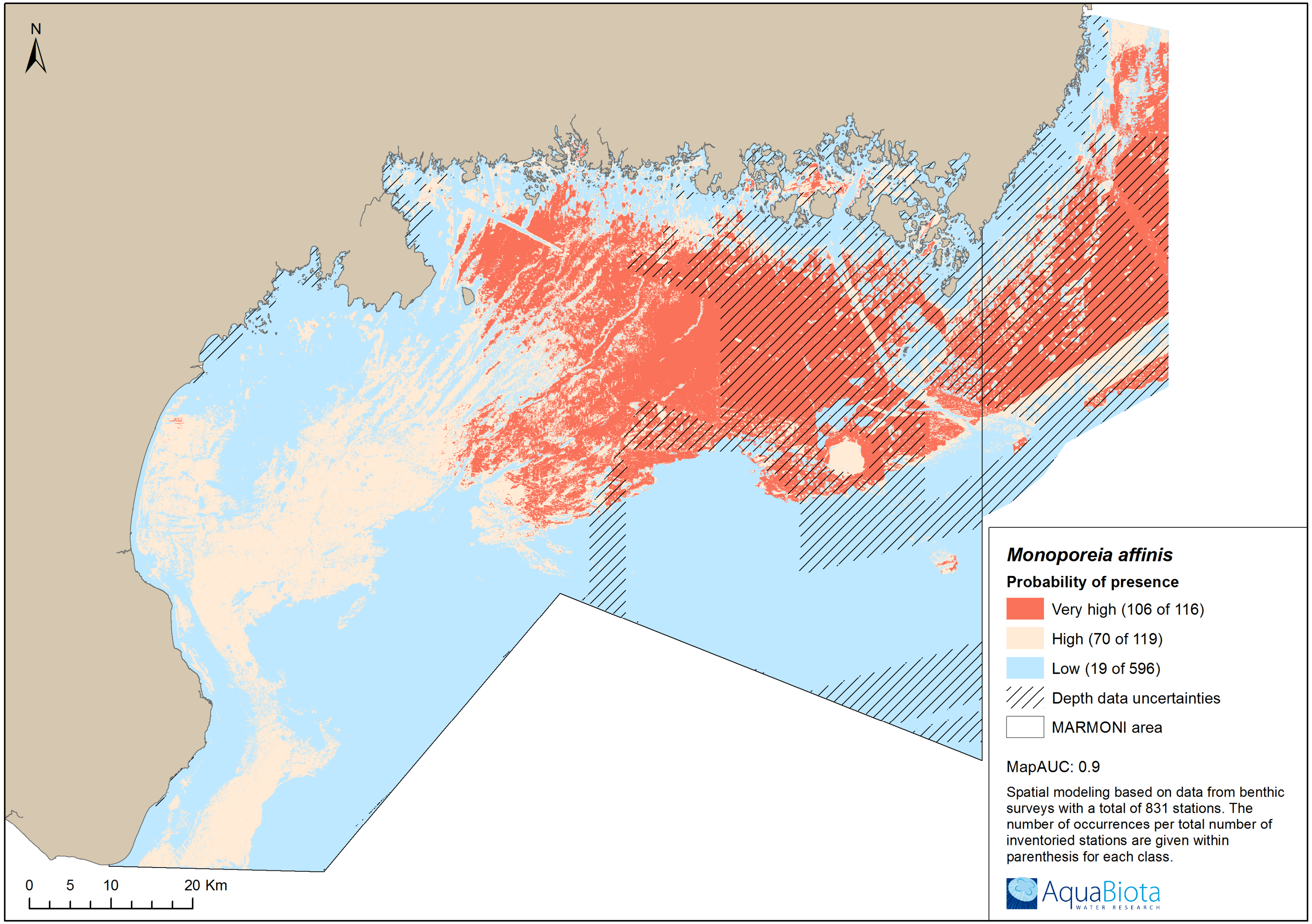

Figure 39. Predicted probability of presence of the arthropod *Monoporeia affinis*.

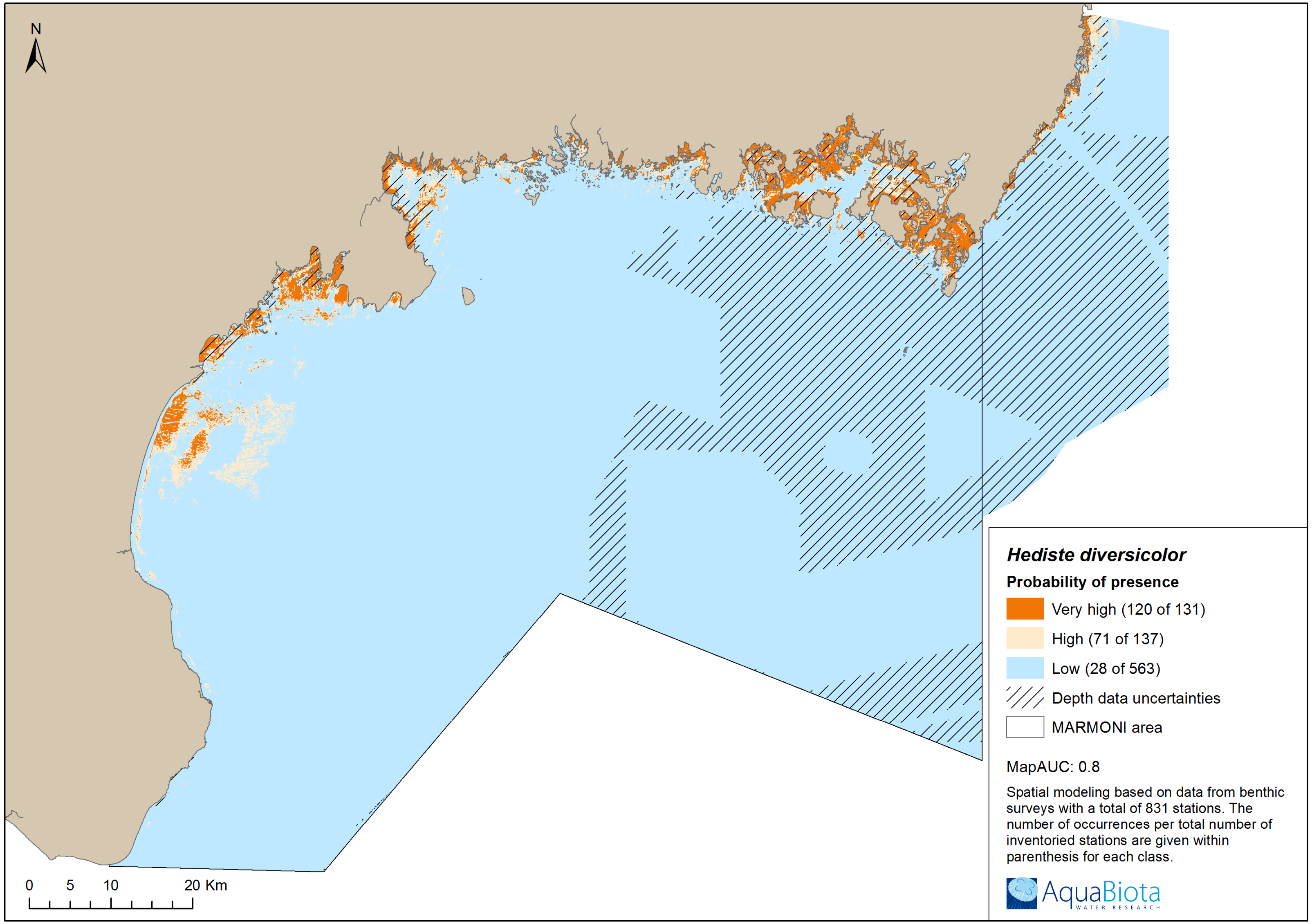

Figure 40. Predicted probability of presence of the polychaete *Hediste diversicolor*.

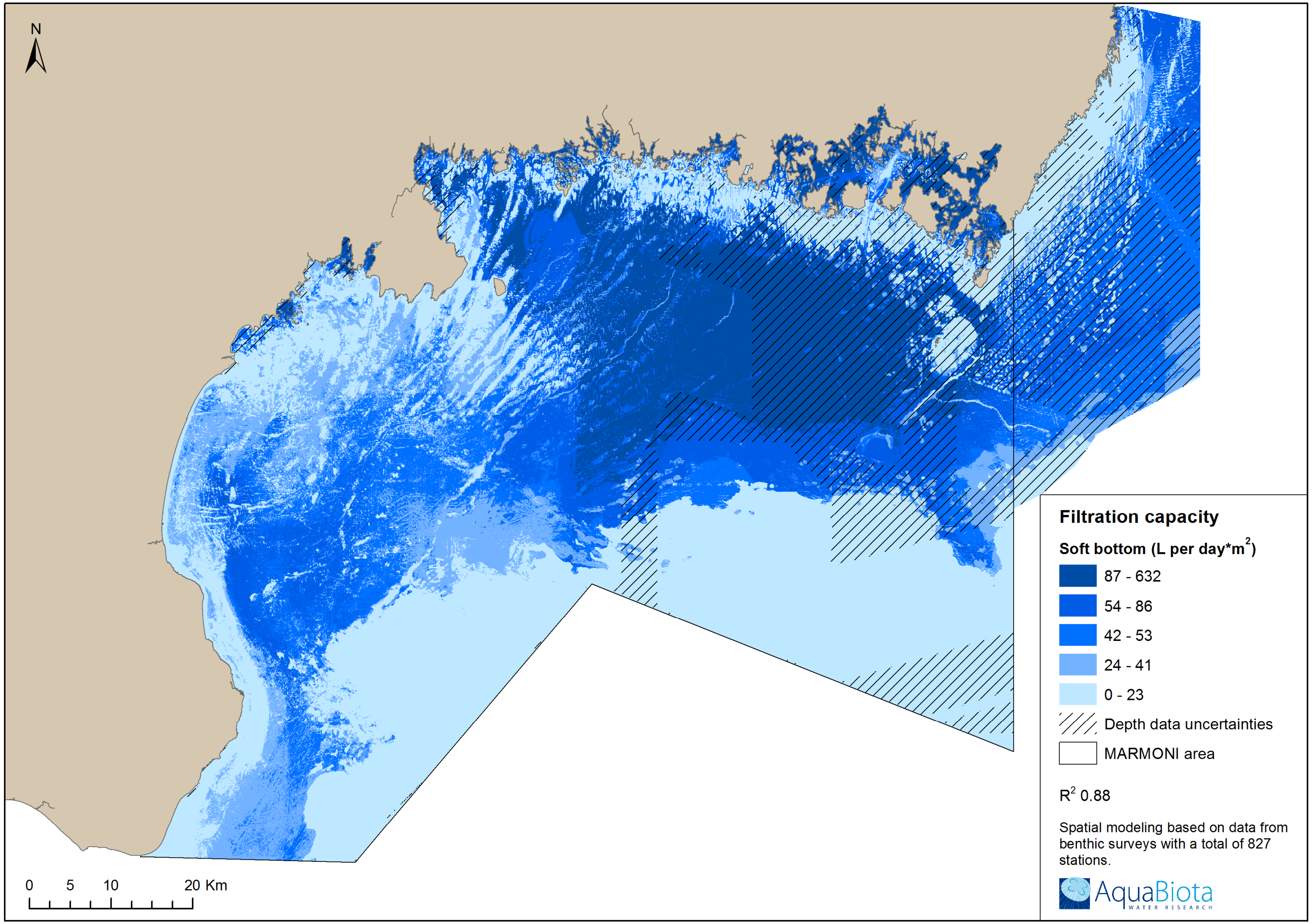

Figure 41. Predicted filtration capacity on soft bottom, based on inventory data from bottom grabs.

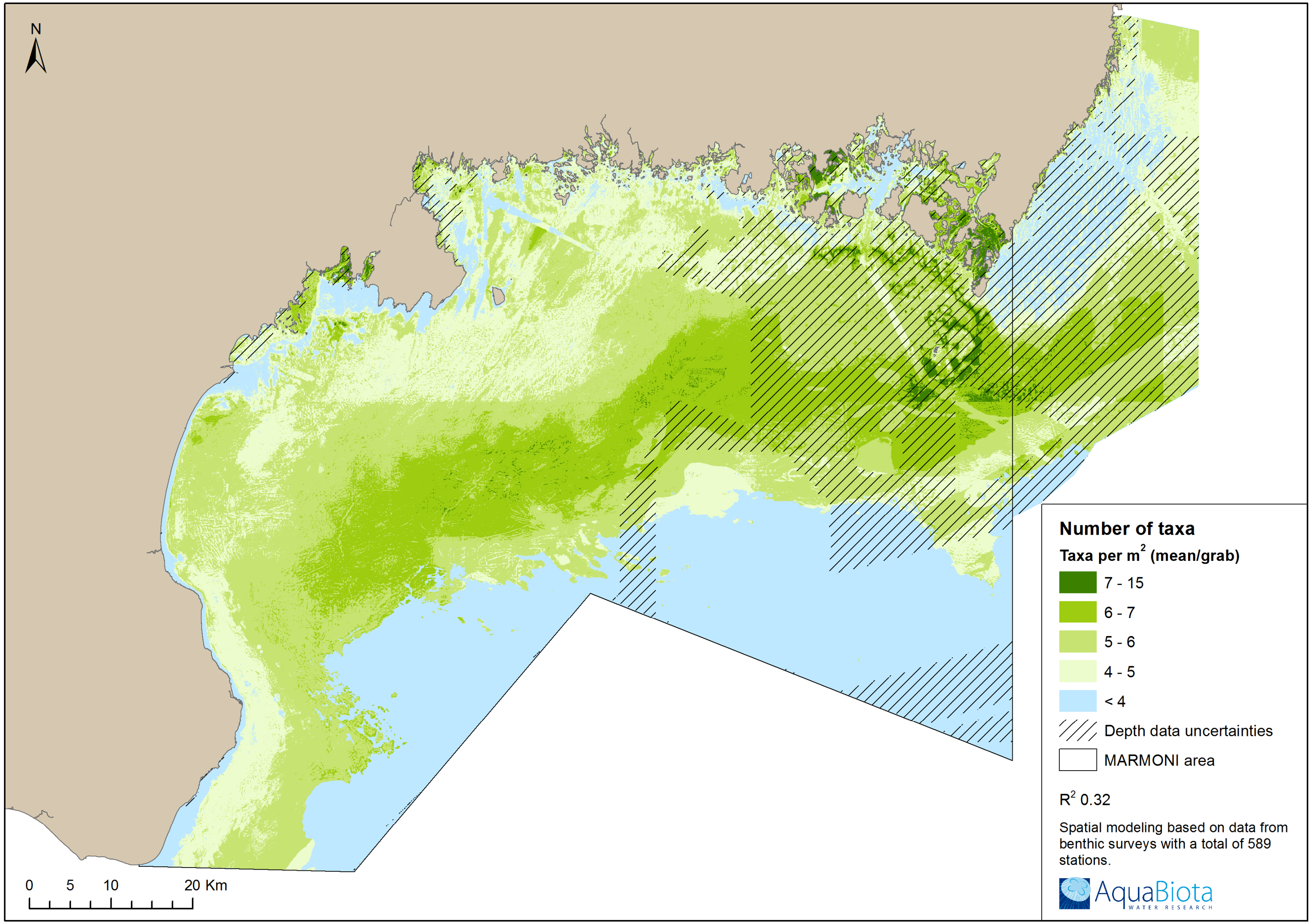

Figure 42. Predicted number of taxa, based on inventory data from bottom grabs.

6.1 Young of the year (YOY) fish in coastal recruitment areas

Young of the year fish in coastal recruitment areas were modelled with the method randomForest (rF) according to the descriptions in Section 5.1 and 5.3.

6.1.1 Modelling data

Field data from 402 stations collected with the method small underwater detonations (Section 3.3) were used in the modelling. 82 of the stations were reserved as validation data.

6.1.2 Result

Four of totally six modelled taxa passed the validation (splitAUC >0.7). These were: perch (*Percha fluviatilis*), roach (*Rutilus rutilus*), pike (*Esox lucius*) and sticklebacks (*Gasterosteus aculeatus* and *Pungitius pungitius*). The roach model was approved although the validation result was just below splitAUC 0.7. The validation measure mapAUCfull is calculated on the entire dataset (including stations used in the modelling) and gives normally higher scores than mapAUC. The predictions are limited to areas shallower than six meters since the field surveys were only performed shallower than 6 meters.

Table 20. Modelling results for young of the year fish in coastal recruitment areas.

Taxa	Model internal fit (OOB-error, %)	splitAUC	mapAUCfull	Four most important predictors (environmental variables)
Perch	24	0.74	0,83	wave exposure, surface salinity, substrate, river mouths
Sticklebacks	26	0.85	0,93	temperature, river mouths, substrate, surface salinity
Roach	25	0.69	0,87	depth, wave exposure, Secchi-depth, temperature
Pike	34	0.71	0,96	depth, slope, temperature, curvature

6.1.2.1 Pike

The spatial distribution of pike recruitment was mainly explained by wave exposure, depth, potentially polluted areas and distance to river mouths. Although similar life history characteristics result in spatially overlapping recruitment areas for perch, pike and roach (Sundblad et al. 2011) a difference was noted. Pike young of the year was not predicted close to river mouths (< ca 500 m). The peak was about 4 km distance and then decreasing with increasing distance. A similar pattern was observed for depth where the shallowest environments were avoided (ca <0.75 m) with peak at ca 3 m (while the perch model rather indicated an increasing preference with decreasing depth). The pike preferred environments with lower salinity and showed an overlap with high traffic intensity although these predictors were of low or negligible importance in the final map.

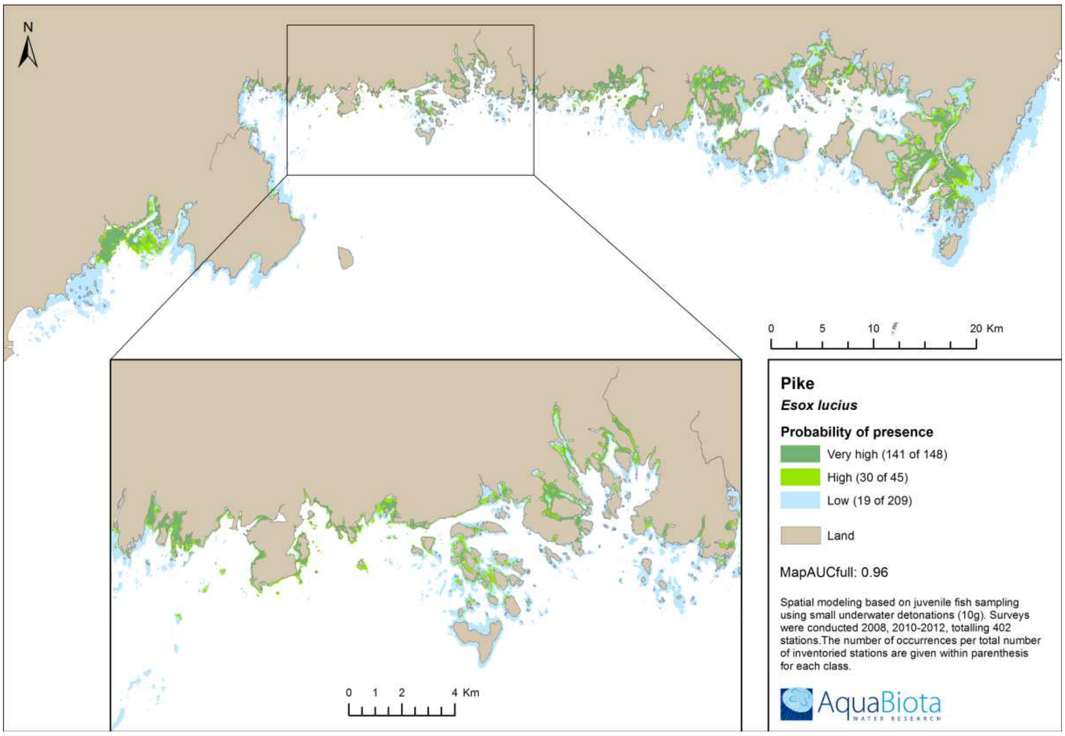

Figure 43. Predicted presence of pike young of the year. Observe that the measure mapAUCfull is calculated with values predicted on the entire dataset (i.e. both training data and validation data) and therefore result in higher validation values than a mapAUC (only based on withheld validation data) for the same map.

6.1.2.2 Perch

The spatial distribution of perch recruitment was mainly explained by wave exposure, salinity, substrate and distance to river mouths. According to the models perch recruitment areas were sheltered (<4-4.5 log(m^2/s)), shallow (<3 m) areas often close to river mouths (<2-3km) with low salinity and high temperature. These areas often coincided with human activities and pressures such as marine traffic and proximity to urban areas and potentially polluted areas.

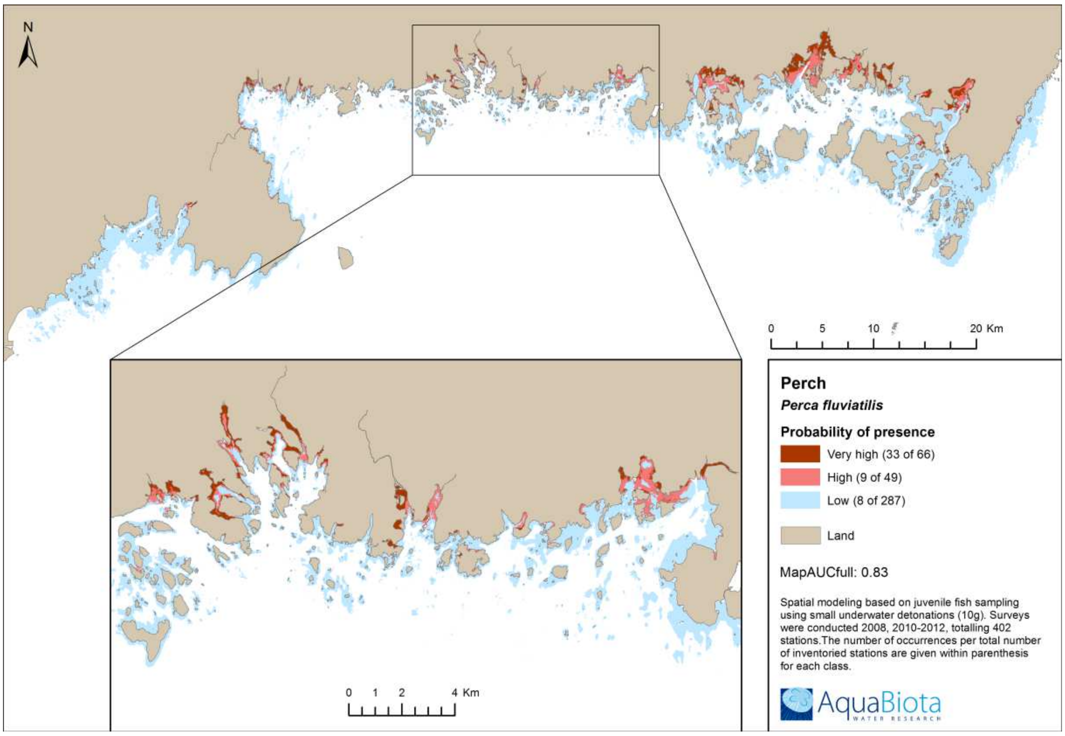

Figure 44. Predicted presence of perch young of the year. Observe that the measure mapAUCfull is calculated with values predicted on the entire dataset (i.e. both training data and validation data) and therefore result in higher validation values than a mapAUC (only based on withheld validation data) for the same map.

6.1.2.3 Roach

The spatial distribution of roach young of the year was similar to perch young of the year. Sheltered, shallow and warm environments close to river mouths with lower visibility were the most important variables.

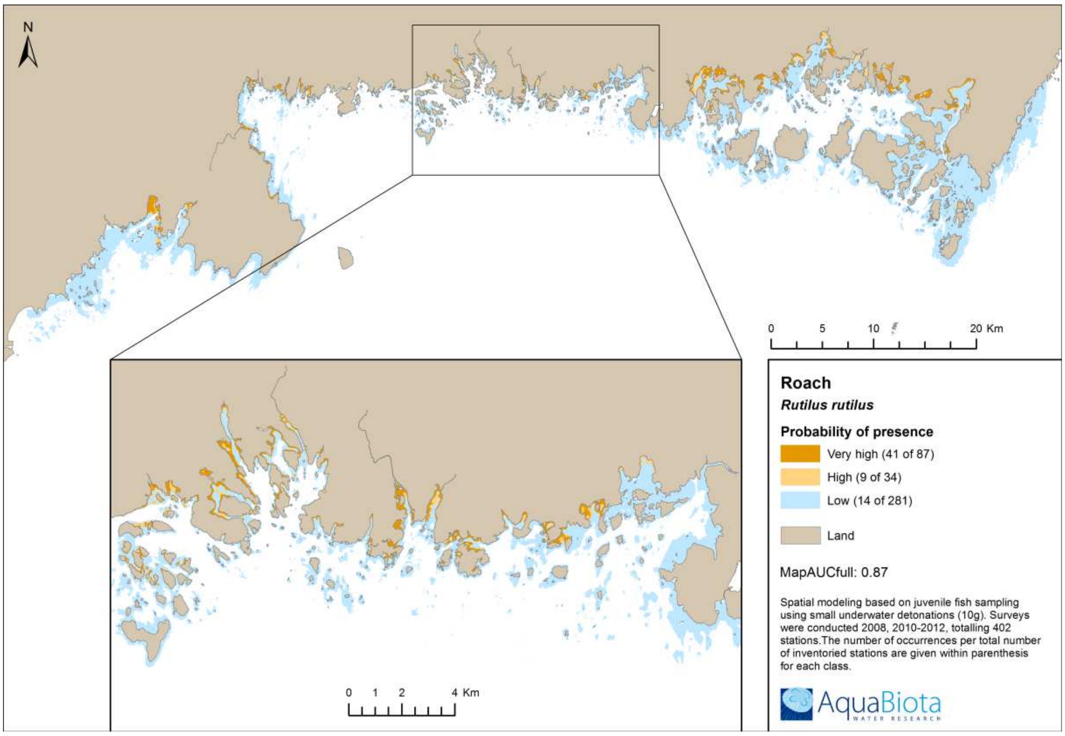

Figure 45. Predicted presence of roach young of the year. Observe that the measure mapAUCfull is calculated with values predicted on the entire dataset (i.e. both training data and validation data) and therefore result in higher validation values than a mapAUC (only based on withheld validation data) for the same map.

6.1.2.4 Sticklebacks

The distribution of sticklebacks within the interval 0-6 meters depth, was mainly explained by temperature, distance to river mouths, substrate, salinity and distance to potentially polluted areas. The response to temperature was positive. The response to river mouths was negative and the probability of presence of sticklebacks increased with increasing distance to river mouths. A similar pattern was observed for salinity with an increasing preference for higher salinity levels. In contrast to pike, perch and roach, sticklebacks were negatively correlated to muddy bottoms. In general sticklebacks occurred in environments where perch, pike and roach did not occur (Figure 46). Parts of the negative relation between presence of sticklebacks and the predators pike and perch is explained by the fact that the predators prey on sticklebacks.

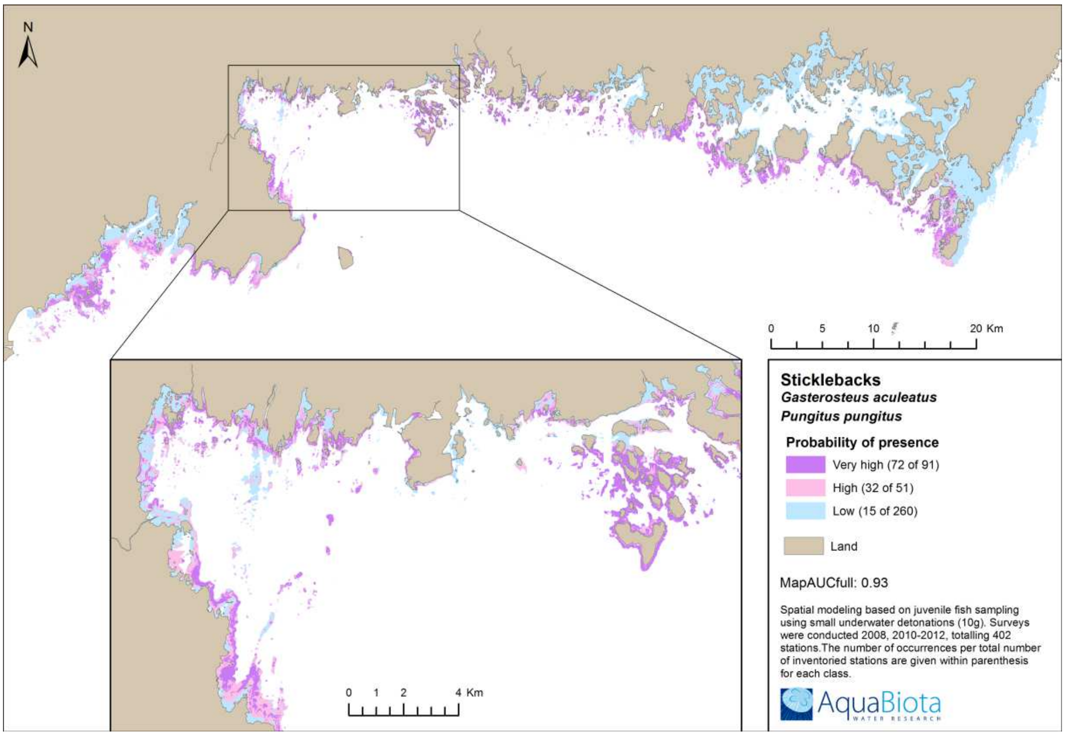

Figure 46. Predicted presence of sticklebacks. Observe that the measure mapAUCfull is calculated with values predicted on the entire dataset (i.e. both training data and validation data) and therefore result in higher validation values than a mapAUC (only based on withheld validation data) for the same map.

6.2 Pelagic fish and plankton

Pelagic fish and zooplankton were modelled with the method GAM according to descriptions in Sections 5.2 and 5.3.

6.2.1 Modelling data

To create models of pelagic fish and zooplankton, the hydroacoustic data described in Section 3.4 was used. Data from the acoustic transects were split into 172 sections with a length of 1 km each. Mean values per section were calculated. 15 % of the sections were withheld for validation while the remaining 85 % was used in the modelling.

6.2.2 Modelling result for pelagic fish and plankton

6.2.2.1 Pelagic fish size 2-6 cm

This size class is mainly represented by three-/ninespine stickleback and (YOY sprat and herring. Sand/common gobies and YOY smelt may also occur in this group and sometimes are observed in large numbers in coastal areas (Figure 47). Modelled higher abunces of this size fish were observed close to the coast as well as in the open eastern parts of the area which corresponds well with the biology of these species. Sticklebacks spawn at shallow littoral coastal areas between May and July. After the spawning, sticklebacks are often observed in large schools both at the open sea and coastal areas (e.g. Kullander and Delling 2012). Herring spawn between May and June on vegetation or hard bottoms normally up to 10 m depth of (Aneer 1989). In general YOY herring stay inshore (e.g. Axenrot and Hansson 2004). Sprat spawns at offshore pelagic areas between February and August (e.g. Kullander and Delling 2012). Sand- /common gobies normally live on soft bottoms at 20-40 m depth (Ehrenberg et al. 2005), but can be pelagic during night time (personal observations, Didrikas 2013).

Minimum surface salinity, mean water temperature at seabed, wave exposure and depth were the most important of totally six predictors in the model. The model explains 72.1% of the variation (R^2 0.7). Normalized root-mean square error in the prediction (NRMSE) was 0.092, which is in a level/below than observed values while modelling abundance of other species in the Baltic Sea (Bŭcas et al. 2013).

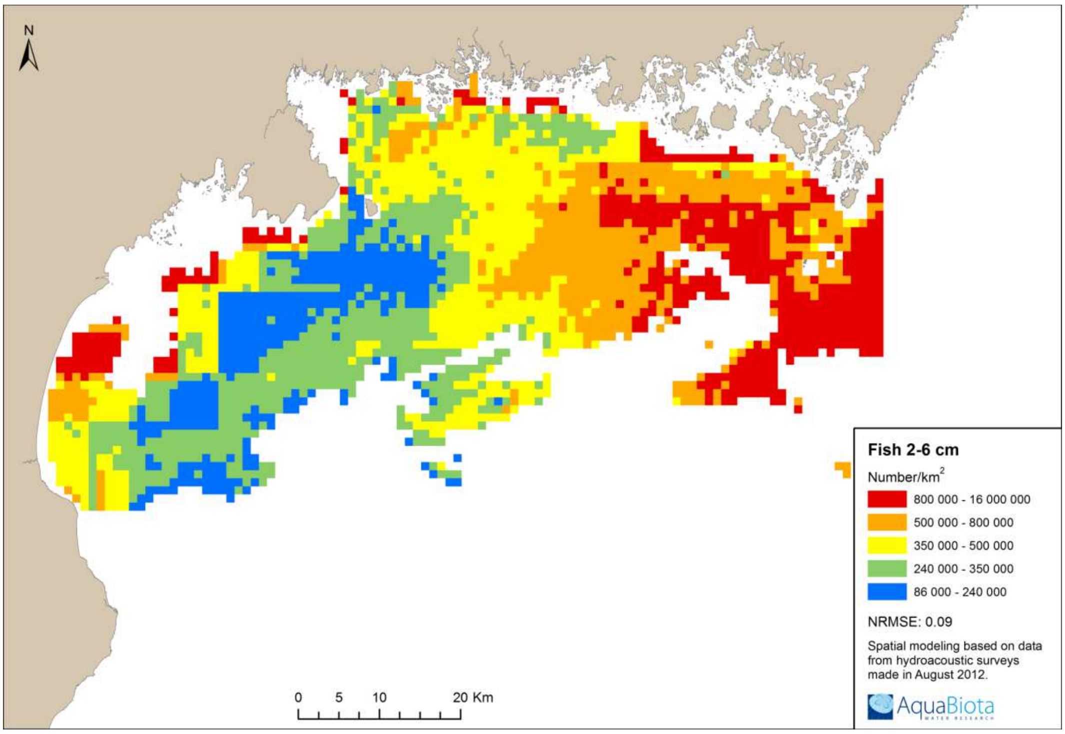

Figure 47. Predicted abundance of pelagic fish in size between 2 and 6 cm.

6.2.2.2 Pelagic fish size 7-13 cm

Fish in this size group are mainly represented by sprat, which normally lives pelagicaly in large schools but sometimes also observed coastaly (e.g. Kullander and Delling 2012). The largest modelled abundances of these fish were observed in the central and southwestern part of the Hanö Bight (Figure 48). Minimum surface salinity, water temperature at seabed, minimum salinity at seabed and depth were the most important predictors of the six predictors included in the model. The model explained 68.3% of the variance (R^2 0.651). NRMSE was 0.126 which is in a level/below than observed values while modelling abundance of other species in the Baltic Sea (Bŭcas et al. 2013).

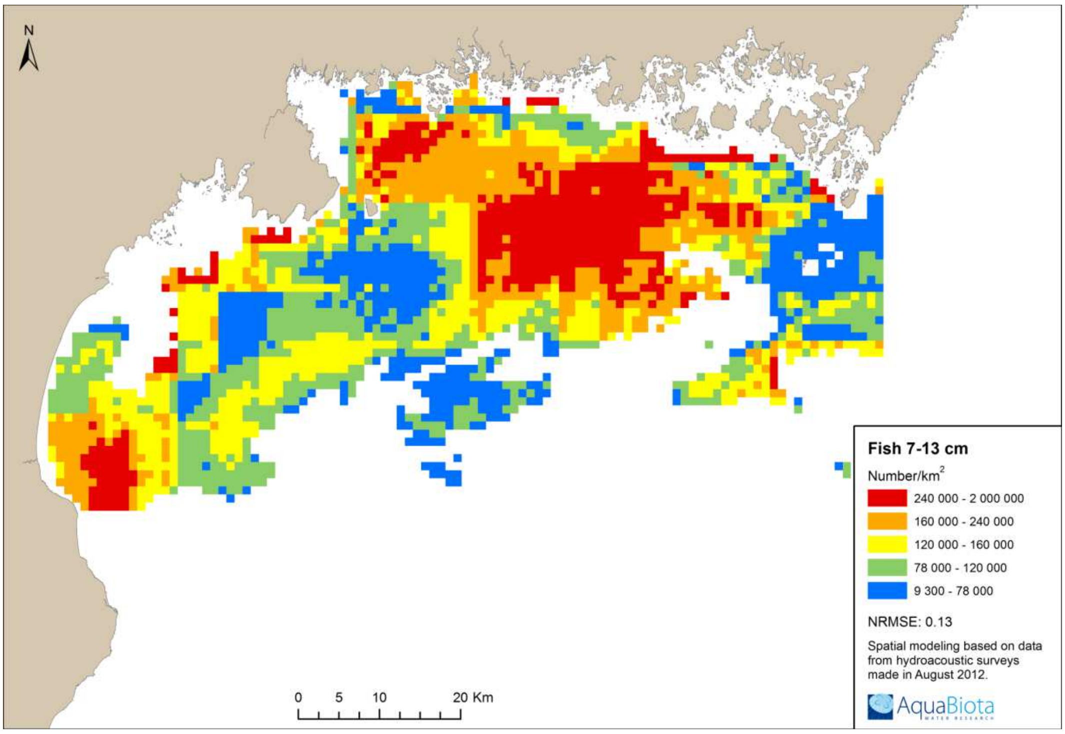

Figure 48. Predicted abundance of pelagic fish in size between 7 and 13 cm.

6.2.2.1 Pelagic fish size 14.5-25 cm

Fish of this size int his area were mainly adult herring. The model predicted highest abundance in the open centra-/eastern part of the Hanö Bight (Figure 49). This is cosnistenst with the biology of the species. After the spawning in shallow (0-10 m; Aneer 1989) coastal areas in May and June, adult herring concentrates at deeper often off-shore waters (Axenrot and Hansson 2004). Minimum surface salinity and minimum salinity at seabed, depth and slope were the most important of five predictors included in the model. The model explains 63.1% of the the variance (R^2 0.599). NRMSE was 0.143, which is in a level/below than observed values while modelling abundance of other species in the Baltic Sea (Bŭcas et al. 2013).

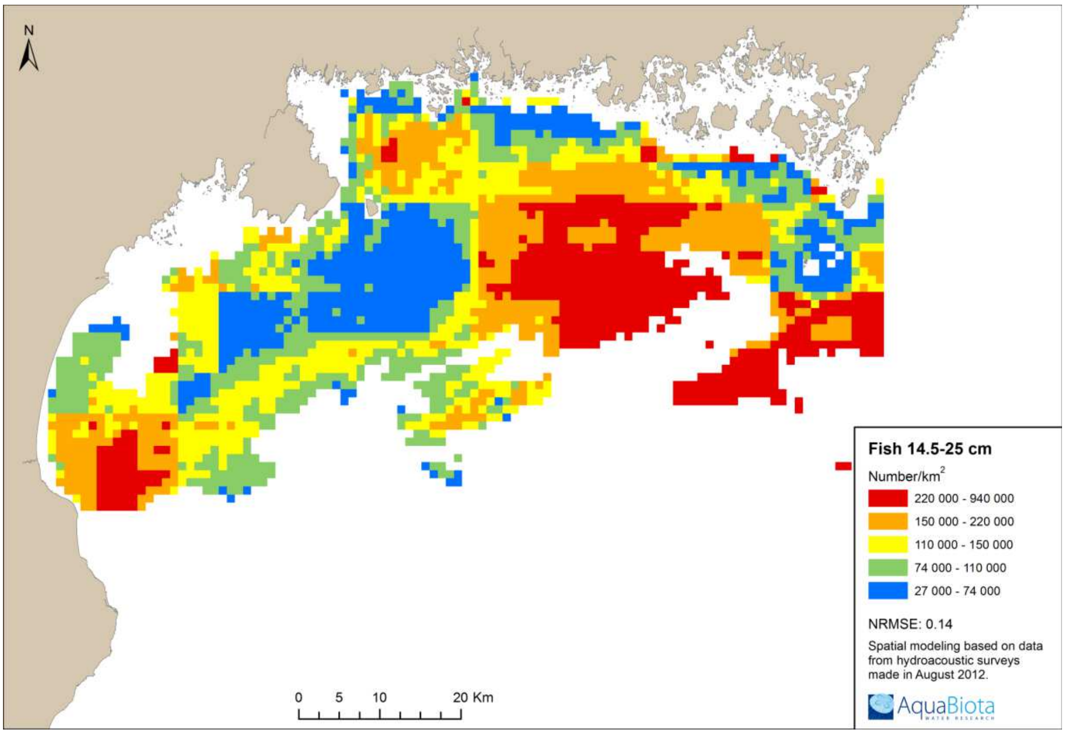

Figure 49. Predicted abundance of pelagic fish in sizes between 14.5 and 25 cm.

6.2.2.2 Pelagic fish 39-80,5 com

Fish of this size are represented by piscivorous predators such as cod, salmon and sea-trout. However, observations of this fish size were rather scarce hydroacoustic survey data. Threfore, spatial distribution of these fish was modelled as presence/absence. Highest probability of presence of these fish was predicted at offshore deeper areas (Figure 50). Curvature, mean temperature at seabed, depth and minimum surface salinity were the most important of five predictors included in the model. The model explained 25.4% of the variance and mapAUC was 0.809.

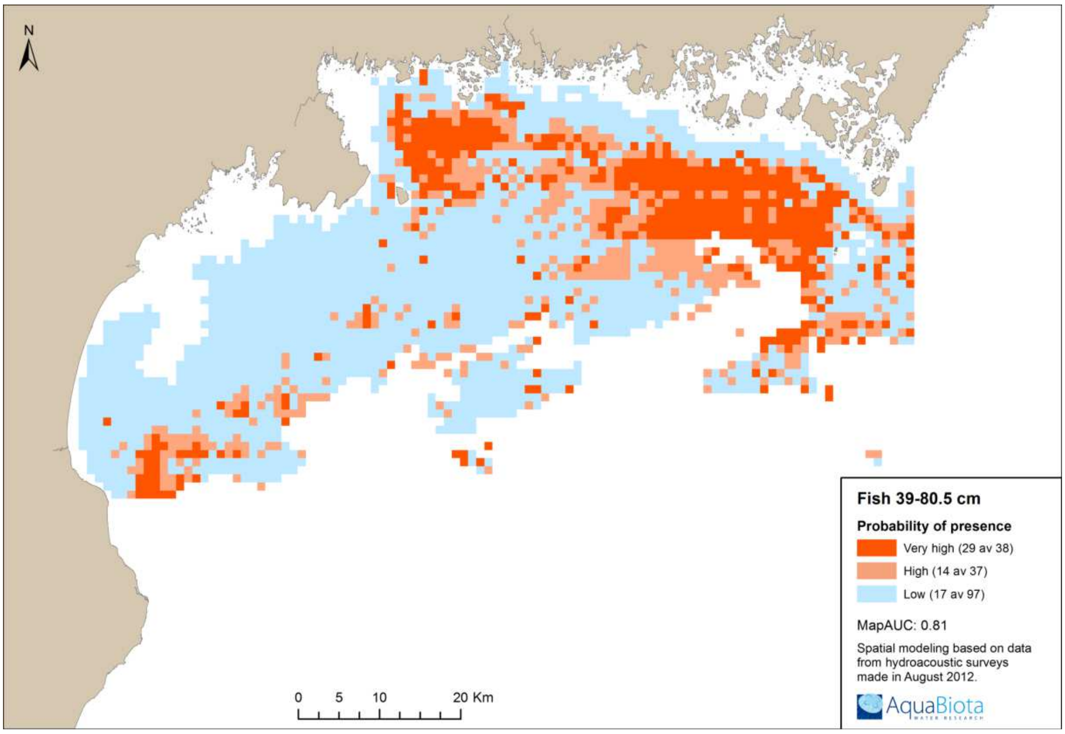

Figure 50. Predicted probability of presence of pelagic fish in sizes between 39 and 80.5 cm.

6.2.2.3 Mesozooplankton

Mesozooplankton are mid size (0.2-2 mm) zooplankton represented by large rotifers, cladocers, copepods and different larvae of species with certain planktonic life stages (meroplankton). These aqnimals drift with currents or swim slowly in the water. Their distribution in the water mass is often driven by natural stratification (e.g. a thermocline). These organisms play a key role in the food web of pelagic ecosystem. They are an important food source for herring and sprat as well as for early life stages of most other fish species. The model predicted highest abundances of mesozooplankton along the coast and in the the central part of the Hanö Bight (Figure 51). Mean temperature at seafloor, mean surface temperature, Secchi-depth and minimum salinity at seafloor were the most important of the four predictors included in the model. The model explained 37.8% of the variance (R2 0.336). NRMSE was 0.113 which is in a level/below than observed values while modelling abundance of other species in the Baltic Sea (Bŭcas et al. 2013).

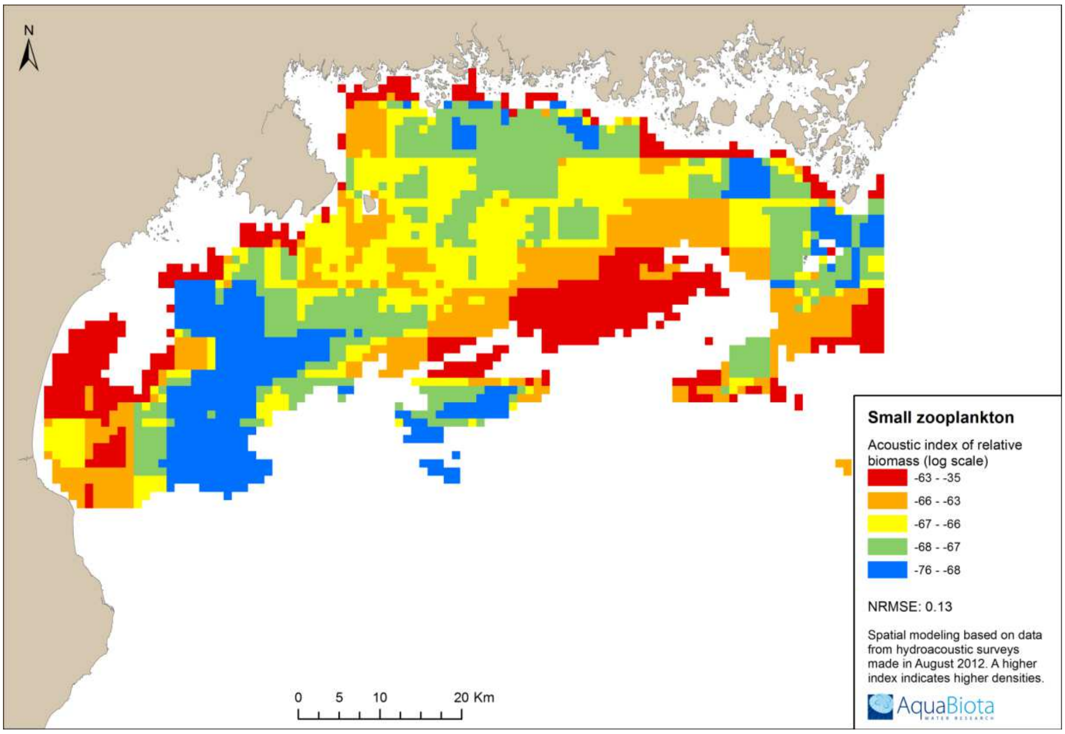

Figure 51. Predicted abundance of meso zooplankton.

6.2.2.4 Macrozooplankton

Macrozooplankton are planktonic animals larger than > 2 mm. This group is dominated by mysids. Some species are coastal, such as *Praunus flexuosus,* while other, such as *Neomysis integer,* spends parts of their lives in coastal areas and later live pelagialy. Other, such as *Mysis mixta* and *Mysis relicta* are pelagic during their entire life cycle (Ogonowski 2012). Pelagic species are normally sensitive to light and spend daytime close to the seafloor at depths > 20 m (bathypelagic; Mauchline 1980). During night, at least some individuals migrate vertically (Ogonowski 2012) upwards in the water column. These species are an important food source for pelagic fish during autumn and winter (e.g. Aneer 1980). The model predicted highest abundance of these organisms along the Hanö Bight coasts (Figure 52). Depth, minimum salinity at the seafloor, slope and wave exposure were the most important of five predictors included in the model. The model explains 52.7% of the variance (R2 0.501). NRMSE was 0.155 which is in a level/below than observed values while modelling abundance of other species in the Baltic Sea (Bŭcas et al. 2013).

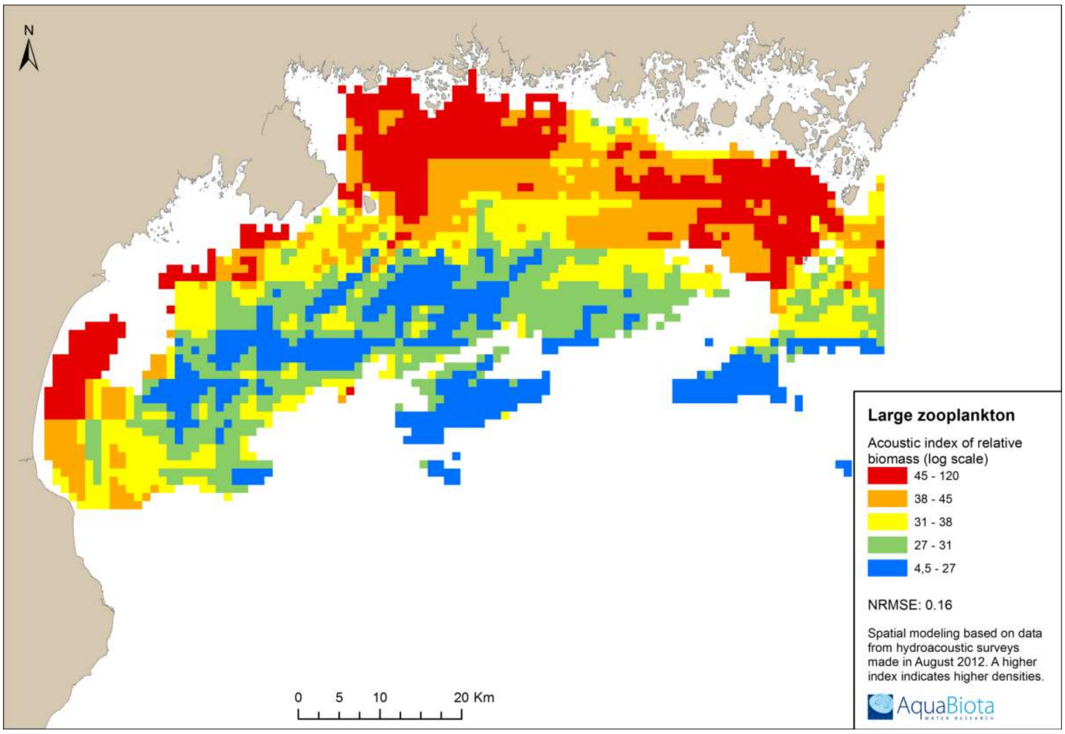

Figure 52. Predicted abundance of macrozooplankton.

6.2.2.5 Jellyfish

Biologicaly jellyfish are also considered as a zooplankton as they live pelagicaly in the water mass where they drift with the currents or swim slowly. In the Baltic Sea this group is dominated by the moon jellyfish *Aurelia aurita*, which normally reaches a diameter of 10-15 cm as adults. Moon jellyfish sometimes occur in very large numbers during late summer - early autumn. Modeled abundance of jellyfish showed in a rather pathcy pattern with higher densities in the central and eastern parts of the Hanö Bight (Figure 53). Mean surface temperature, depth, minimum surface salinity and wave exposure were the most important of five predictors included in the model. The model explains 62.1% of the variance (R^2 0.589). NRMSE was 0.167, which is in a level/below than observed values while modelling abundance of other species in the Baltic Sea (Bŭcas et al. 2013).

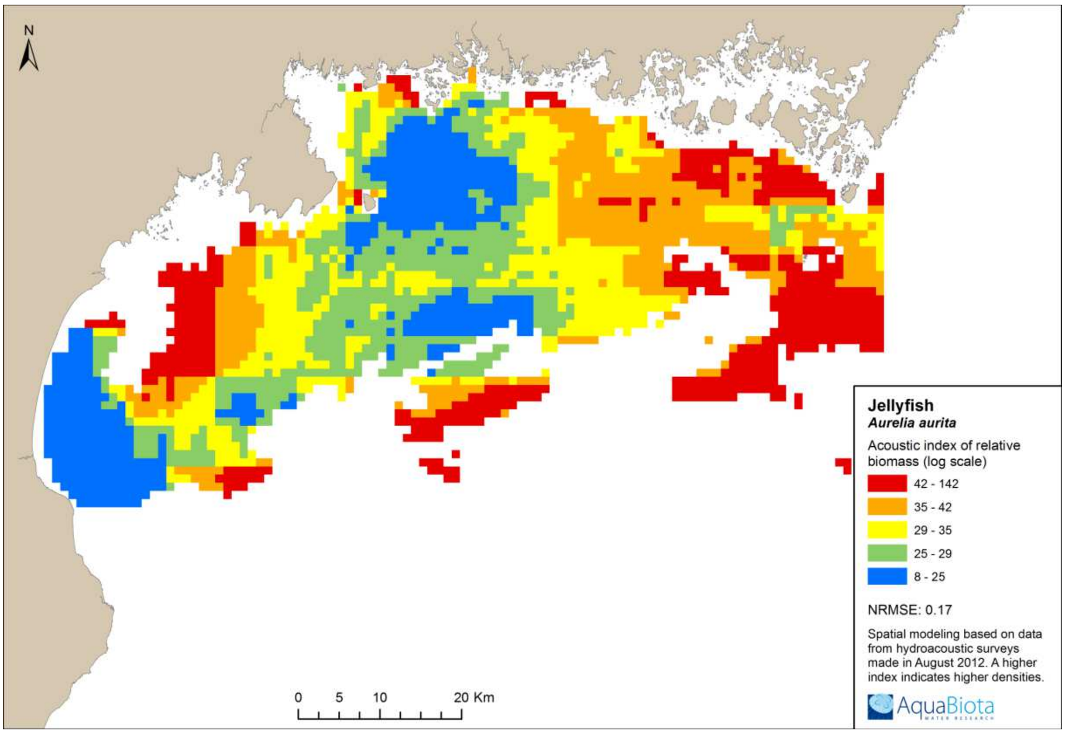

Figure 53. Predicted abundance of moon jellyfish.

6.3 Discussion

This marine mapping based on field surveys and spatial modelling is very extensive. A large number of coherent maps of highly different organisms including fish, vegetation, benthic invertebrates and plankton were created through spatial modelling. Furthermore, maps from a large number of surveys of wintering and breeding birds were created. A group which was not mapped in this project is marine mammals.

The maps and surveys include many different Natura 2000-habitats such as 1110 sandbanks which are slightly covered by sea water all the time, 1170 reefs, 1160 large shallow inlets and bays and 1620 Boreal Baltic islets and small islands. The maps may therefore provide a valuable base-line material for further more detailed studies of specific habitats or biotopes. The maps of species and groups were also used in the mapping of conservation values presented in this report.

The predicted maps cover different areas of Blekinge and the Hanö Bight depending on the areas covered by the GIS-layers of environmental variables included as predictors in the models, and also depending on what environments that were surveyed during the biological surveys. The aim was to only predict maps in environments represented in the biological survey data. Validations by withheld data and visual inspections of each map were further measures to secure reliable predictions. This means that the quality of each predicted map is good to excellent in the map as a whole. The quality however varies spatially within each map. This spatial variation is difficult to display entirely in the maps. Areas with coarse depth data can however be regarded as less certain than areas more detailed depth data, in particular for predictions where depth- or depth derivatives are of high importance in the model. Areas with coarse depth data are therefore visualized as striped regions in predictions of benthic species.

Straight or in other ways seemingly artificial shapes or patterns can be seen in some predicted maps. These occur when environmental variable layers with coarse resolution are important predictors in a model. Examples of such environmental layers are hydrographic variables from the HIROMB-model. A few maps were discarded during the visual inspection despite good validation results. This was done since parts of the predictions were considered unrealistic. It is important to understand that the models don't include 100 per cent of all possible factors that may affect the distribution or abundance of the modelled species. Most environmental layers used as predictors were also created through modelling, interpolation from point samples or similar. Since the included predictors have different importance in different models, local contradictions may occur between e.g. a modelled probability of presense of a species and modelled probability of high abundance of the same species. Such differences may depend on that presence and abundance of a species are partly regulated by different environmental factors. Local special conditions in certain areas may lead to local errors if the included environmental variables don't include these local special conditions. On the other hand absence of a species in an area where it is predicted with high probability may also indicate a local disturbance in the environment.

Since vegetation, i.e. macroalgae and vascular plants are heavily dependent on light availability; their distribution is often limited by a combination of depth and water transparency (here represented by the predictor Secchi depth). Uncertainty in depth information may therefore be regarded as particularly important for these groups. Higher concentrations of nutrients in the water can affect the benthic vegetation in a negative way since it often leads to an increase in phytoplankton and following lower transparency. Indications of this relation were seen in both vascular plants and macro algae models. Chlorophyll *a* and Secchi-depth were often important predictors. The proportions of nutrients with natural and anthropogenic origin could however not be separated. Both presence and abundance of macroalgae normally increased with increasing distance from potentially polluted areas. This should however be interpreted with some caution since many macroalgae species are naturally more common in outer more exposed areas with hard substrates where the distance to potentially polluted areas normally is higher than in inner areas.

Modelled zoobenthos species belong to different taxonomic groups of both marine and freshwater origin. These animals are represented by anything from insect larvae to mussels and polychaetes and their ecology and behaviour differ greatly. Since these species normally don’t depend on light availability for their survival they may occur much deeper than the vegetation. Important limiting factors for these animals may instead be oxygen concentration, salinity and food availability or other factors. Seabed substrate is also of crucial importance to most of these species. Uncertainty in depth information is of some importance also in these species models, but not nearly as important as in vegetation models. Although depth and/or depth derivatives may be important in models of species occurring on widespread deep bottoms, a lower density of depth measurements has a rather small importance since these environments are more homogenous and since there are no significant changes occur in the environment if the depth changes a meter or so.

In addition to species and groups, filtering capacities for hard and soft bottoms were also modelled. These maps contribute with valuable spatial information of an important ecosystem service and demonstrate how functions and ecosystem services can be mapped.

Young of the year fish were surveyed in coastal recruitment areas such as shallow bays with dense vegetation. These species were therefore only predicted in such coastal environments at a maximum depth of six meters. The restricted distribution and heterogenic environment motivates a high spatial resolution, wherefore these maps were predicted in 10 m resolution. The results of these models are interesting from several aspects. They are often affected by human activities and recruitment problems are known for perch and pike along the east coast of Blekinge. These species are also of public interest and are important for recreational fishing and tourism. Except from the east coast, the results show a very good recruitment of pike in most locations.

Pelagic fish, zooplankton and jellyfish were surveyed using multi frequency hydroacoustics in order to cover most important groups of pelagic organisms. This is a cost-effective survey method have mainly been used for fish surveys over large areas, but it can be also used for plankton. Fish species and size composition were determined from pelagic trawl catches, which was performed during the acoustic survey zooplankton and jellyfish acoustic data were collected using other frequencies than pelagic fish. Plankton and jellyfish acosutic data could not be verified since biological sampling of these organisms wasn’t performed. However, frequency responses extracted from the hydroacoustic dataset were specific for these organisms and have been described earlier (Brierley et al. 1998, 2004, Korneliussen and Ona 2002). Threfore, the prediction maps of these groups should be used with some caution. Hydroacoustic methods for surveying zooplankton and jellyfish are still being developed. Today zooplankton are surveyed by vertical netting in a small number of locations. The spatial and temporal distribution of zooplankton is very variable, which strongly limits our understanding of the distribution and abundances of these species. Jellyfish are not included in any monitoring at all, but could be identified with multi-frequency acoustics. Future developments of multi-frequency technique may offer a cost-efficient method for monitoring of zooplankton and jellyfish with high spatial resolution. Jellyfish have in many places been seen as potential threats to fish recruitment and fish food availability. With a higher temporal resolution surveys like these, could provide a more complete understanding of how different pelagic organism groups interact and the mechanisms that regulate their distribution.

7 Conservation value assessment and mapping

The conservation value assessment has largely followed the methodology developed within the SUPERB-project (Wikström et al. 2013), a survey of Swedish offshore banks in 2007-2008 (SEPA 2010a) and the Swedish Environmental Protection Agency's project Marine modelling in Östergötland (MMÖG) (Carlström et al. 2010). In parallel with this project the same method was also used in the SEPA-project Marine Modelling in Stockholm and Södermanland (MMSS) (Nyström Sandman et al. 2013a and 2013b), which enabled exchanges of experience between projects. The method is mainly designed for regional mapping of conservation values; valuation of biotopes and habitats that can be mapped on a regional scale. How well the method works depends primarily on whether enough biotope and habitat maps can be produced for the study area, as well as on whether the data availability supports a quantitative (in addition to a qualitative) assessment of conservation values of each biotope and habitat based on the chosen criteria. Ideally, the choice of criteria and the valuation is made in collaboration between specialists and managers with good knowledge of local relations.

The conservation value assessment of this project was done in several stages, where the first stage of the process was to identify what could be assessed (here divided into different categories). The next step was to select a number of conservation value criteria to use as the basis for valuation within each category. Existing biological components (in this case, species and habitats) are identified and assessed according to the criteria selected.

The conservation values were then mapped spatially using map layers of species and species groups or places important for life-history stages of species (Section 6 and 5.3.4). The maps were merged by category and to a combined map (see Section 7.4).

7.1 Categories

The five different categories used in the conservation value assessment was benthic "**vegetation**" (i.e. macrophytes), "**zoobenthos**", "**coastal fish recruitment areas**", "**wintering areas for waterbirds**", and "**haul-out sites for marine mammals**".

7.2 Criteria and measures of conservation value

The conservation value assessment was based on recommendations and guidelines for the valuation of marine environments by the Convention on Biological Diversity (CBD)[1] (CBD 2008). The criteria were chosen from CBD's guidelines based on (1) if they were perceived as important for assessing the conservation value of Swedish marine areas and (2) if it was possible to determine from available data (Table 21).

[1] The guidelines are designed by an international group of experts and is used for the valuation of the marine environment in, for example, Norway and the Azores (CBD 2009). The recommended criteria are largely the same as those recommended in other conventions and organisations both internationally (e.g. OSPAR Convention for the protection of the marine environment of the north-east Atlantic; OSPAR 2008) and nationally (e.g. SEPA guidelines; SEPA 2007a), which shows that there is a general consensus on what constitutes valuable marine environments.

7.2.1 Recommended criteria

CBD's recommendations and guidelines for assessment of the marine environment include a set of scientific criteria for identifying ecologically and biologically significant marine areas in need of protection (CBD 2008). Bold type denotes the criteria used in this report.

CBD's criteria to identify ecologically and biologically significant marine areas in need of protection:

- **Uniqueness or rarity**
- **Special importance for life-history stages of species**
- **Importance for threatened, endangered or declining species and/or biotopes**
- Vulnerability, fragility, sensitivity, or slow recovery
- Biological productivity
- **Biological diversity**
- Naturalness

7.2.2 Chosen criterions

Most of the CBD criteria to identify ecologically and biologically significant marine areas were used, but some exceptions were made. Three of the criteria from the CBD list were excluded from the conservation value assessment: vulnerability, biological productivity and naturalness. It proved to be difficult to make an assessment of overall vulnerability without reference to specific threats. A full analysis of vulnerabilities should take into account the vulnerability of a given species, or group of species, which can differ greatly between different threats or interference, but such an analysis, has not been made in this project. Productivity data could not be developed within the project – it has been judged to be difficult to estimate in these environments. Naturalness was difficult to evaluate because of the lack of historical information.

Ecological function, on the other hand, is a criterion that has been added. The criterion was introduced because it describes a holistic perspective and was judged to be important for the assessment of conservation values.

Table 21. Description of the criteria used for the conservation values assessment.

Criterion	Definition
Uniqueness or rarity	Area contains unique/rare species, biotopes or geomorphological features
Importance for life-history stages	Areas that are required as a reproductive/foraging/residence area for a population to survive and thrive
Endangered/declining species or biotopes	Area containing habitat or life-history important areas of endangered/declining species or biotopes
Biological diversity	Area containing a high diversity of species or biotopes
Ecological function	Area containing large area or density of important species/biotopes

The two categories vegetation and zoobenthos were evaluated based on the criterions **uniqueness or rarity**, **endangered/declining species or biotopes**,

biological diversity and **ecological function**. The criterion **importance for life-history stages** was only relevant to the categories of the mobile species; coastal fish recruitment areas, wintering areas for waterbirds and haul-out sites for marine mammals. The criterion **endangered/declining species or biotopes** was used for all categories, when possible (Table 2).

Table 22. Criteria used for assessing conservation values within each category.

Category \ Criterion	Uniqueness or rarity	Importance for life-history stages	Endangered/ declining species or biotopes	Biological diversity	Ecological function
Vegetation	x		x	x	x
Zoobenthos	x		x	x	x
Coastal fish recruitment areas		x	x		
Wintering areas for waterbirds		x	x		
Haul-out sites for marine mammals		x	x		

The first two categories (vegetation and zoobenthos) assess conservation values which are not only of value to the category's own organisms (for example by creating habitat and food for other organisms or by making the water clearer through filtering). The latter three categories (coastal fish recruitment areas, wintering areas for waterbirds and haul-out sites for marine mammals) assess conservation values in order to investigate which biotopes have high natural value for the category's own organism group. In other words, conservation values which fish, birds and mammals have for other organisms are not evaluated here (Table 22).

During the work with conservation value assessment it has been important that, as far as possible, the work is based on actual data rather than subjective judgments. This has limited the ability to cover all aspects of conservation in many cases. For example, it has not been possible to make a conservation value assessment for groups of organism not examined in the area. Furthermore, conservation values associated with marine mammals are poorly covered because they are not tested within the project.

7.3 Valuation

Each biotope or species was assigned a value of several criteria according to Table 22. As far as possible the conservation value assessments were based on empirical data, e.g., data from surveys with drop-video and grab samplings was used for vegetation and zoobenthos as the basis for the criteria: Uniqueness or Rarity and Biological Diversity. A three-point scale was then used; high conservation value (10), lower value (1) and no specific value (0). Please note that it is not a continuous scale from 0 to 10. The aim was to distinguish high and low conservation value so that high values would be reserved for prioritized biotopes and species. The thresholds between high and low conservation were set after each category. Since these thresholds are subjective they can be discussed. To settle on chosen thresholds, discussions were held with other researchers and with the relevant authorities.

The conservation values for the various criteria were added up to a total value for each biotope/species. The total value for each biotope/species was not allowed to be higher than 10. Thus, to obtain the highest conservation value for a biotope or species, it is sufficient to receive value 10 for one of the evaluation criteria.

7.3.1 Vegetation and Zoobenthos

The criteria used for conservation value assessment of vegetation (i.e. macrophytes) and zoobenthos were: **uniqueness or rarity**, **endangered/declining species or biotopes, biological diversity** and **ecological function** (see Table 22).

Maps of the predicted presence of vegetation and zoobenthos were used together with assessed conservation values to map biotopes conservation value spatially. These distribution maps are predictions that have been developed using statistical modelling (see Section 5).

7.3.1.1 Biotope Classification of Field Data

Inventory data on vegetation and zoobenthos (drop video and grabs) were classified according to the biotope classification system HELCOM Underwater Biotope and Habitat Classification (HELCOM HUB)[2] (HELCOM 2013a).

A hierarchical system (a so-called "key") is used to determine the different biotopes. Within the system there are six separate levels (Table 23). At Level 1 biotopes in the Baltic Sea and biotopes of corresponding marine areas are separated. At Level 2 biotopes in the photic and aphotic zones are divided. Level 3 divides biotopes on the substrate type and Level 4 on the community structure. The communities are further divided at Level 5 according to their characteristics. Level 6 is a finer division depending on the predominant species or groups of species (see Table 23).

[2] The system has been developed to provide a common understanding of the Baltic Sea biotopes and communities and are based on the best available biological data. HUB largely follows the European habitat classification system EUNIS and is developed in collaboration with national experts from all Baltic Sea countries; e.g. the SEPA, the Swedish Species Information Centre, Stockholm University, AquaBiota Water Research and Alleco Oy et al. have participated in this process. By using tens of thousands of data points from the sea area, the biotopes have been defined based on their community structure along different environmental gradients. HELCOM HUB is a hierarchical system based on substrate type and defines 328 underwater biotopes and ten biotope complexes.

Table 23. Classification levels of benthic biotopes according to *HELCOM Underwater Biotope and habitat classification.*

Class	Description
Level 1. Region	• The system is only available for the Baltic Sea
Level 2. Vertical zones	• Photic zone
	• Aphotic zone
Level 3. Substrate	• Dominating (≥ 90 % coverage) substrate type
	• Mixed sediment
Level 4. Community structure	• ≥10 % coverage of epifauna or vegetation
	• 0> <10 % coverage of epifauna or vegetation
	• Macroinfauna present
	• No vegetation or macrofauna present
Level 5. Characteristic community	• ≥10 % coverage of a specific taxonomic group
	• Select the dominant taxa/taxons from a group
	• Mixed community
	• No macroscopic community
Level 6. Dominating taxa	• ≥50 % biomass/biovolume of specified taxa

Each inventory unit was classified separately, if possible, to HUB Level 6, based on coverage rates or abundances of substrates, species and depths recorded at the site. Biotopes were also grouped at Levels 5 and 6 regardless of substrate type and vertical zone. This means that biotopes, which are characterized by the same species on different substrates or depths, were treated as the same biotope in the conservation value assessment. The reason for this treatment is because the map data used for estimating the spatial extent of biotopes do not distinguish between different substrates or vertical zones.

At Level 4, in the HUB system, epibenthic species (animal and plants that live above ground) prevail over infauna (animals that live in the bottom sediments). This means that it only takes a few epibenthic individuals to be the ones determining the biotope classification of the site. Since it was considered interesting to identify conservation values based on both epibenthic species as well as infauna, they were classified separately, given that more than one biotope classification were enabled at the same location provided that they belonged to either epibenthic species or infauna. Thus to avoid any underestimation of infauna biotopes, a slight deviation from the original HUB system was made.

Moreover, some modifications were also made in the classification of the epibenthic biotopes. At Level 6, classification should be based on biomass/biovolumes, but since only the coverage degree and abundance were available from the drop video and grab data that was used instead. However for infauna species wet weight per species were calculated (Näslund 2011b), making it possible to convert abundance to biomass.

In some cases it was not possible to classify species from drop video data as accurately as required for the HUB system. e.g. at Level 5 it is required to distinguish between perennial and annual vegetation (e.g. filamentous red algae species) which was not always possible. In these cases classification was only possible to Level 4. Epiphytic species (species that grow on other species) were excluded from the assessment.

7.3.1.2 Valuation

All biotopes which were recorded reliably with the underwater drop-video (i.e. all benthic vegetation biotopes excluding those dominated by emergent vegetation and soft crustose algae) were assessed according to the four criteria mentioned above - Uniqueness or rarity, Biological diversity, Endangered/declining species or biotopes and Ecological function (see Table 21). All biotopes were evaluated at Level 5 of the HUB classification system (since not all could be classified to Level 6). The biotopes which could be classified all the way to Level 6 were also evaluated at that level.

Uniqueness or rarity and **biological diversity** were evaluated at their relative frequency of presense in the study area, given that the biotopes may be unique or non-unique on a larger (global, Baltic Sea) level or a smaller (local) level. Even if a regional perspective was chosen in this analysis, this can be supplemented in the future when data of other spatial scales are available.

The Uniqueness or rarity of the biotopes was evaluated according to relative frequency of presense in the data. A mean value of presense frequency for each biotope in four different depths (0-5; 5-10; 10-20; >20), relative to the area of respective depth, was employed since shallower marine areas were overrepresented in the inventory data (Section 3.1.1). A biotope's relative presense rate of 0.1% or less of the surface was given value 10 and relative frequency of presense of more than 0.1% but less than 1% of the surface was given a value of 1. All biotopes with a presense rate of more than 1% were given the value 0.

The biological diversity of biotopes was assessed as mean species richness (number of species) of benthic vegetation and zoobenthos, based on drop video and grab inventories. This provides a rough measure of species richness because the taxonomic resolution in video inventories is relatively low. Comparisons of species richness measured by diving and underwater video has shown a connection between the two inventory methods and that video inventory can separate low from high diversity (Gullström et al. 2014), indicating that the species diversity measured by underwater video at least gives the relative differences in diversity between stations.

At stations with a mixture of hard and sedimentary substrates, only species associated with the biotope and the substrate as the station had been classified into were counted. E.g. if the station was designated as a blue mussel biotope only species which are linked to hard substrates were enrolled to the measure of diversity. For biotopes containing a mixture of hard and sedimentary substrates all epi-benthic vegetational species were included in the evaluation of biological diversity. An average presense of species per biotope higher the ninetieth percentile (P_{90}) was giving a conservation value of 10. A species number higher than the seventy-fifth percentile (P_{75}) but lower then (P_{90}) were given a value of 1. Remaining biotopes were giving the value 0.

Endangered/declining species or biotopes were assessed for benthic vegetation and zoobenthos after HELCOM's Red List of Baltic Sea biotopes, which assess the status of threats on the Baltic Sea scale (HELCOM 2013b). Biotopes that have been assessed to be near threatened or vulnerable were given a conservation value of 1 and those assessed to be threatened, endangered or critically endangered were giving the value 10.

Ecological function has been identified as an important criterion (Wikström et al. 2013), but it was difficult to find data to support an evaluation for this criterion. Therefore expert judgment was used to evaluate each biotope type. The expert judgments were based on four functions: food availability, habitats for other species, primary production and filtration. All biotopes were regarded as executors of at least one of these functions. Thus all biotopes were given at least a value of 1, e.g. every species of vegetation are primary producers. Only those biotopes that were considered irreplaceable from an ecosystem perspective were given value 10 in the conservation value assessment. Examples of such biotopes are blue mussel biotopes (which have a high filtration and are an important food source) and biotopes dominated by large plants (which creates an important biotope for many other species, such as fish).

7.3.2 Coastal fish recruitment areas

Conservation value assessment for coastal fish recruitment areas was evaluated by the criteria **importance for life-history stages** and **endangered/declining species or biotopes**. Spatial data for perch, pike, roach and stickleback were available in the Hanö Bight through the modelled maps of coastal fish recruitment areas (Section 6.1). The maps are based on both prevalence data collected in the field and data on which biotopes the fish thrive in.

All coastal fish recruitment areas were given a conservation value of 10 because of their **importance for life-history stages**. An exception was made for sticklebacks since they can have a negative impact through trophic cascades on the quality of biotopes important for the recruitment of predatory fish (Sieben et al. 2011). Nursery grounds for sticklebacks were therefore given the value 0.

The threat level against the fish species were verified on the Swedish Red List (The Swedish Species Information Centre, SLU 2010) and the Red List of the International Union for Conservation of Nature (IUCN 2014). However, none of the species were named on any of the lists and all evaluated fish species were therefore given the value 0 for the criterion **endangered/declining species or biotopes**.

7.3.3 Wintering areas for waterbirds

Conservation value assessment for wintering areas for waterbirds was based on the criteria **importance for life-history stages** and **endangered/declining species or biotopes**.

To identify **important areas for life-history stages** in the Hanö Bight for coastal waterbirds, results from midwinter inventories were used from the national environmental monitoring (Nilsson 2008), and data collected within this MARMONI project (Section 3.5). The midwinter inventories of coastal waterbirds were analysed by a number of inventory units (polygons of different shapes and size) which were merged to a number of areas for analysis (Figure 54).

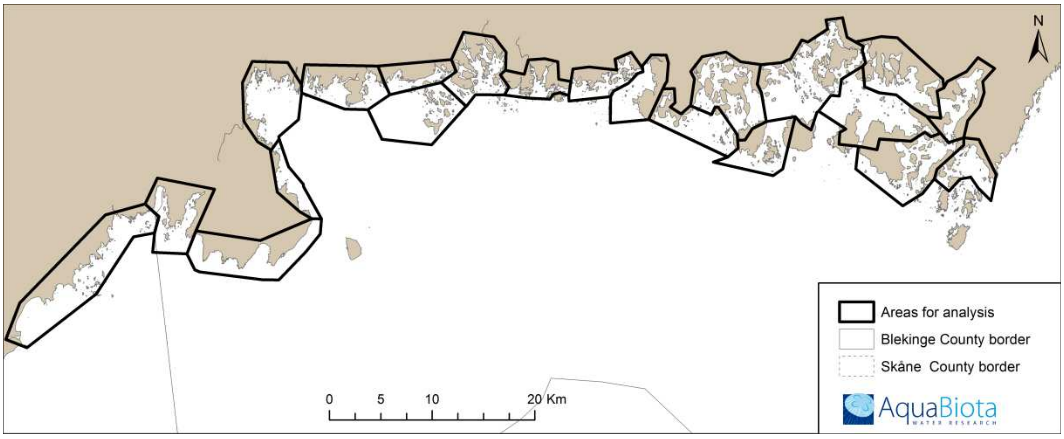

Figure 54. Areas used for analysis of coastal waterbirds. The areas were created by merging inventory units used for midwinter inventories of coastal waterbirds.

Subsequently, an average of the total number of coastal seabirds in each area was compared. The average values were calculated on the basis of a ten year period (2004-2013) where all waterbirds were counted in one day in mid-January. The time period was chosen to cover the inter-annual variability and to illustrate the current situation of the waterbirds in the area. For a more detailed description of the method see Annex 4.

Each area (polygon) was given a separate value based on the result of the survey. It is not easy to determine thresholds for high/low conservation values, since there is no widespread acceptance of what denotes important areas for coastal birds at present – neither regionally nor nationally. The Ramsar Convention has however identified criteria for regular internationally important concentrations of waterbirds (RAMSAR 1971). The convention agenda states that an area should be considered internationally important if it is regularly used by 1% of a population within each "flyway"[3] or a total of 20 000 individuals or more.

Areas visited by an average of less than 2 000 birds were given a conservation value of 0; areas with an average of more than 2 000 birds, but less than 10 000, were given a value of 1; and an average of more than 10 000 birds a value of 10.

To identify areas importance for life-history stages for offshore waterbirds, represented here by the long-tailed duck (*Clangula hyemalis*) were data used from national inventories of marine diving ducks in the Hanö Bight which occurred on a few occasions 2007-2011. These data were used to identify areas of concentrations of long-tailed ducks in the outer parts of the Hanö Bight. These winter inventory data were used to calculate the average density in a number of projected concentration areas (Figure 54). For a more detailed description of the method see Annex 4. Areas with an average density of over 20 individuals/km^2, but less than 75 were given the conservation value 1 and areas with an average density of over 75 individuals/km^2 were given the conservation value 10.

As for fish and marine mammals, input to the valuation of the criterion **endangered/declining species or biotopes** was picked from the Swedish Red List (The Swedish Species Information Centre, SLU 2010) and the Red List of the International Union for Conservation of Nature (IUCN 2014). For obvious reasons, this criterion can only be eligible for species and not coastal seabirds as a whole. Species that were classified as near-threatened or vulnerable in any of these lists

[3] BirdLife International terms the main migration routes between breeding grounds in the north and winter quarters further south for "flyways".

were given the value 1 and those classified as threatened, endangered or critically endangered were given the value 10 where the species is found in high concentrations (i.e. those considered internationally important areas for the species or that there are more than 75 individuals/km^2). In areas where concentrations were slightly lower, i.e. medium high concentrations (more than 20 individuals/km^2, but fewer than 75 individuals/km^2) were given conservation value 1 even if the species was classified as threatened, endangered or critically endangered.

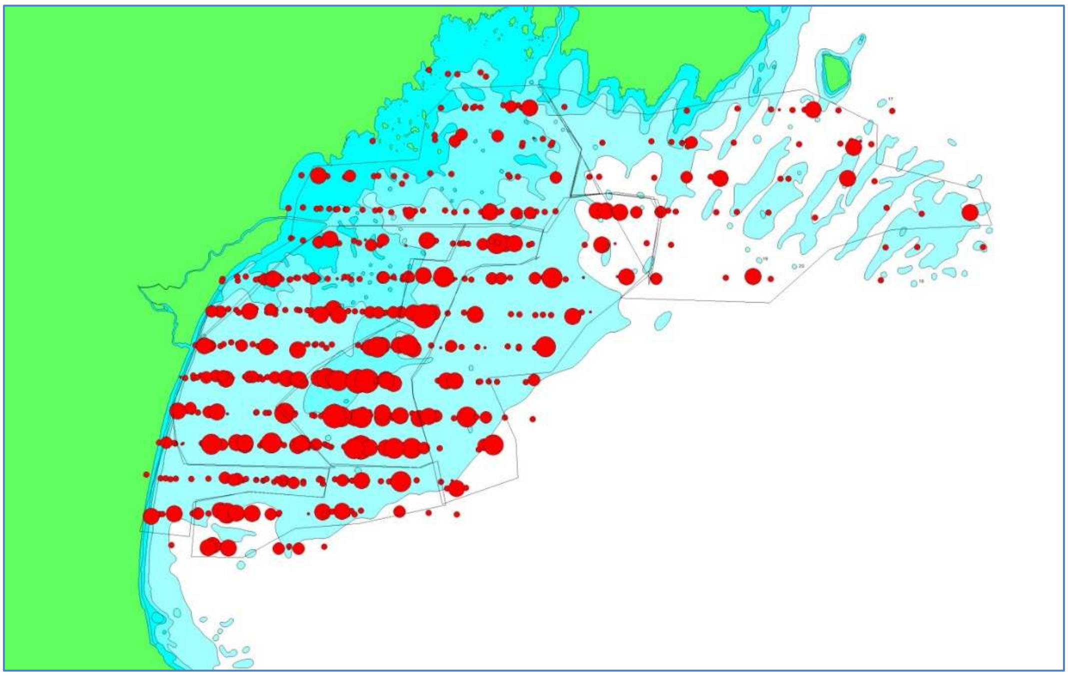

Figure 55. Inventory area for long-tailed ducks and borders between different estimated concentration areas. The dots visualize flocks of birds compiled from all surveys (Section 3.5.2).

7.3.4 Haul-out sites for marine mammals

Conservation value assessment for haul-out sites for marine mammals was based on the criteria **importance for life-history stages** and **endangered/declining species or biotopes**.

At present available data on marine mammals are insufficient to make a proper assessment. Annual inventories of seals are made on land, as well as in the surrounding water, at known locations of harbour seals (*Phoca vitulina*) and grey seal (*Halichoerus grypus*) by the Swedish Natural History Museum. The counts are made in a period of two weeks in late May or early June, when the largest proportion of the population is located on land. Based on these data, specific restriction zones are defined by the Swedish Natural History Museum and presented in the "Marine Geographical Biology Calendar" of the Swedish Armed Forces (Swedish Armed Forces 2012). The restricted areas correspond to the major haul-out sites of seals during moulting and giving birth. This primarily takes place in April-June for grey seals and May-July for harbour seals. These counts have been used to identify areas of high values for seals, i.e. for the criterion **importance for life-history stages**. There is currently no consolidated spatial information about the underwater environments that are of particular importance for the seals. Harbour porpoise (*Phocoena phocoena*) in the Baltic Sea have been inventoried in the EU LIFE+ project SAMBAH (Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise), but the results of this were not available at the time of analysis.

As for birds and fish, input to the valuation of the criterion **endangered/declining species or biotopes** was, picked from the Swedish Red List (The Swedish Species Information Centre, SLU 2010) and the Red List of the International Union for Conservation of Nature (IUCN 2014). Species that were classified to be near-threatened or vulnerable in any of these lists were given the value 1 and those classified as threatened, endangered or critically endangered were given the value 10.

7.4 Compilation of mapped conservation values

All map data in vector format were converted to grid format to facilitate when various elements were put together in a foreseeable conservation value map.

The first step was to merge assessed values for the different criteria for each respective category (i.e. benthic "vegetation", "zoobenthos", "coastal fish recruitment areas", "wintering areas for waterbirds", and "haul-out sites for marine mammals") based on the highest conservation value occurring in each grid cell of the map. In other words, if more than one biotope is covered in the same grid cell the conservation values of the biotope are not summarized. Thus avoiding those areas with multiple overlapping map layers were given a higher value solely due to more than one biotope in the grid. An exception to this was made for seals since experts in the field considered areas used by both grey and harbour seals particularly important.

However, when a combined conservation value map was made, the values of the different categories were summarized and merged in each grid cell. This was done to clarify which areas are important for several groups of organisms and to create a more multi-faceted picture.

7.5 Results

7.5.1 Benthic vegetation

The criteria used for conservation value assessment of benthic vegetation (i.e. macrophytes) were: **uniqueness or rarity**, **endangered/declining species or biotopes**, **biological diversity** and **ecological function** (see Table 22).

By using drop video, twelve biotopes of benthic vegetation (macrophytes) were identified at Level 6 in HELCOM's biotope classification system HUB (HELCOM 2013a) and four biotopes at Level 5 in the Hanö Bight (which in this report also refers to the whole of Blekinge County) (Table 24).

At Level 6 (in the HELCOME HUB biotope classification system), the biotopes *Myriophyllum spicatum*; Charles; filamentous annual algae; and *Chorda filum* and/or *Halosiphon tomentosus* were covering areas less than 0.1% of the surface. They were all given the conservation value 10 for the criterion **uniqueness or rarity** (Table 24). The biotope filamentous perennial algae were the most common biotope at Level 6 and were therefore given the conservation value 0. All other biotopes at Level 6 were given the conservation value 1 (Table 24).

At Level 5, the biotopes dominated by stable aggregations of unattached perennial vegetation and annual algae were more rare (and therefore given the conservation value 1) than the biotopes dominated by submerged rooted plants and perennial algae (which were given the conservation value 0). No biotope at Level 5 was given the highest conservation value (10) (Table 24).

The biotopes of Charales and *Zostera marina* have been classified as near-threatened on the HELCOM Red List of Baltic Sea biotopes (HELCOME 2013b). Consequently they were given the conservation value 1 for the criterion **Endangered/declining species or biotopes**. Other biotopes at Level 6 and all biotopes classified at Level 5 (in the HELCOME HUB biotope classification system) (Table 24), were all given the conservation value 0 of this criterion (Table 24).

At Level 6, the biotope with the highest **biological diversity** was filamentous annual algae and was the biotope at that level which had the highest species richness with an average of five species per station and was thus given the highest conservation value, i.e. 10 (Table 24). The biotopes: *Ceratophyllum demersum*; *Myriphyllum spicatum*; and the biotope with non-filamentous perennial corticated red algae had particularly low average number of species per station. These biotopes and the biotopes dominated by *Potamogeton perfoliatus* and/or *Stuckenia pectinate*; Charales; *Zanichellia* spp. and/or *Ruppia* spp.; *Zostera marina*; and *Chorda filum* and/or *Halosiphon tomentosus* were all given the conservation value of 0. The remaining three biotopes at Level 6: *Fucus* spp.; Filamentous perennial algae; and unattached *Fucus* spp. had an average species richness between 3.9 and 4.2 and were given the conservation value of 1 (Table 24).

At Level 5, the biotope of annual algae (which include the sub-biotope filamentous annual algae of Level 6) had the highest species richness (4.9) of that level and were given the conservation value of 10 concerning biological diversity. The biotope of perennial algae was given the conservation value of 1 due to its average value of 3.9 species. The other two biotopes at Level 5 were given the conservation value 0 (Table 24).

Of the biotopes classified at Level 5, the submerged rooted plant biotope (theire structure creates an important biotope for many other organisms) was given the conservation value of 10 (the highest) for the criterion **ecological function**. Upon further breakdown of biotopes into a finer scale (i.e. from Level 5 to Level 6), all submerged rooted plants except the biotope *Zanichellia* spp. and/or *Ruppia* spp. (i.e. *Potamogeton perfoliatus* and/or *Stuckenia pectinate*; *Myriophyllum spicatum*; Charales and *Zostera marina*) were also given the conservation value of 10. Further, at Level 6 the biotope *Fucus* spp. was also given the high conservation value of 10 for the same reason – that it creates a favourable environment for many other organisms. All other biotopes (at both Level 5 and 6) were given the value 1 (Table 24).

The values of the different criteria were weighted together according to Section 7.3 and a comprehensive conservation value was given each biotope (Table 24). To produce conservation value maps over the area, the overall conservation value for each biotope were used together with the predicted maps over species coverage that were modelled (Section 6).

Table 24 specifies which maps were used for each biotope. Matched predicted-maps were lacking for three of the biotopes at Level 6 and for two of the biotopes at Level 5. Further, for some biotopes the species predicted in the maps were not entirely consistent with the species in the biotope. The spatial mapping of conservation values based on vegetation biotopes is therefore not complete.

The comprehensive map over conservation values on vegetation biotopes is shown in Figure 56. The maps show that the highest conservation values are found in the shallow hard bottom areas and along the beaches. These areas get high conservation values primarily due to the biotopes of submerged rooted plants: *Potamogeton perfoliatus* and/or *Stuckenia pectinate*; *Myriophyllum spicatum*; and *Zostera marina*, *Chorda filum* and/or *Halosiphon tomentosus* and *Fucus* spp. Areas with lower natural values, situated outside the nearest coast line are mainly dominated by the non-filamentous perennial corticated red algae and by the filamentous perennial algae.

Table 24. Conservation value assessments of benthic vegetation (macrophytes) biotopes in the Hanö Bight. The biotopes at Level 6 are listed under the corresponding biotope at Level 5 (bold type). The species mentioned are the typical species found in the area. The valuation is compatible with HELCOM classification system.

Biotope / Dominating species (based on inventory data)	Uniqueness or rarity	Endangered biotopes	Biological diversity	Ecological function	Comprehensive conservation value	Predicted maps of benthic vegetation used for the mapping of conservation values
Submerged rooted plants	**0**	**0**	**0**	**10**	**10**	Not mapped
Potamogeton perfoliatus* and/or *Stuckenia pectinata	1	0	0	10	10	≥ 25 % coverage of *Stuckenia pectinata*
***Zanichellia* spp. and/or *Ruppia* spp.**	1	0	0	1	2	Combination of > 0 % coverage of *Zannichellia palustrisand* and > 0 % coverage of *Ruppia* spp.
Myriophyllum spicatum	10	0	0	10	10	≥ 10 % coverage of *Myriophyllum spicatum*
Charales (*Charophyceae, Chara aspera, Chara baltica, Chara canescens, Chara horrida, Tolypella nidifica*)	10	1	0	10	10	No predicted map was applicable
Zostera marina	1	1	0	10	10	≥ 10 % coverage of *Zostera marina*
Perennial algae	**0**	**0**	**1**	**1**	**2**	Not mapped
***Fucus* spp. (*Fucus vesiculosus* and/or *Fucus serratus*)**	1	0	1	10	10	Combination of ≥ 25 % coverage of *Fucus vesiculosus* and > 0 % coverage of *Fucus serratus*
Non-filamentous perennial corticated red algae (*Chordaria flagelliformis* and *Furcellaria lumbricalis*)	1	0	0	1	2	≥ 25 % coverage of *Furcellaria lumbricalis*
Filamentous perennial algae (*Cladophora rupestris, cf. Battersia arctica, Batterisa plumigera, Ceramium virgatum, Polysiphonia elongata, Polysiphonia fucoides, Rhodomela confervoides*)	0	0	1	1	2	Combination of > 0 % coverage of filamentous perennial algae (excluding *Fucus* spp.)
Stable aggregations of unattached perennial vegetation	**1**	**0**	**0**	**1**	**2**	Not mapped
***Fucus* spp.**	1	0	1	1	3	No predicted map was applicable
Annual algae	**1**	**0**	**10**	**1**	**10**	Not mapped
Filamentous annual algae (*Aglaothamnion* sp., *Ceramium tenuicorne, Chaetomorpha* spp., *Cladophora glomerata, Cladostephus spongiosus, Dictyosiphon foeniculaceus, Stictyosiphon tortilis, Ectocarpus, Pylaiella, Elachista fucicola, Monostroma balticum, Polysiphonia fibrillosa, Spirogyra, Ulva* spp.)	10	0	10	1	10	No predicted map was applicable
Chorda filum* and/or *Halosiphon tomentosus	10	0	0	1	10	> 0 % coverage of *Chorda filum*

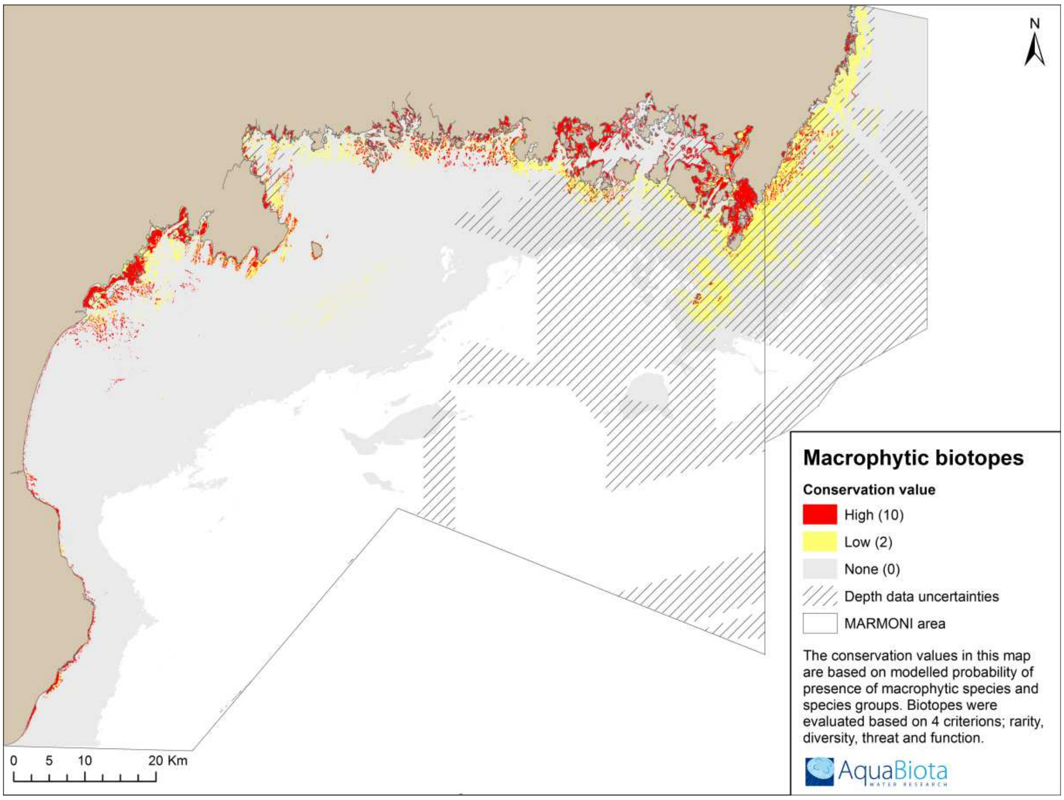

Figure 56. Conservation values, estimated on predicted coverage of benthic vegetation in the Hanö Bight.

7.5.2 Zoobenthos

The criteria used for conservation value assessment of zoobenthos were: **uniqueness or rarity**, **endangered/declining species or biotopes**, **biological diversity** and **ecological function** (see Table 22).

According to the HELCOME HUB biotope classification system, thirteen biotopes of zoobenthos on Level 6, and five on Level 5, were identified in the Hanö Bight (Table 25).

No biotope was given the conservation value of 10 for the criterion of **uniqueness or rarity**, but several biotopes at Level 6 were within the range (see section 7.3.1.2) for the conservation value 1. These biotopes were *Cerastoderma* spp., *Mya arenaria*; multiple infaunal bivalve species; *Monoporeia affinis* and/or *Pontoporeia femorata*; *Corophium* spp.; *Bathyporeia pilosa*; and *Chironomidae*. At Level 5, the biotopes that were given conservation value 1 were infaunal crustaceans and infaunal insect larvae. The other biotopes not mentioned were given the conservation value 0 for the criterion uniqueness or rarity.

The infaunal bivalve biotope *Astarte* spp. (Level 6) is classified as endangered in the HELCOME Red List of biotopes in the Baltic Sea (HELCOM 2013 b) and was thus given the conservation value of 10 for the criterion **endangered/declining species or biotopes**. In the same list, the infaunal crustacean biotope *Monoporeia affinis and/or Pontoporeia femorata* (Level 6) were classified as near-threatened and were thus given the conservation value of 1. The other biotopes were given the value 0 for this criterion.

At Level 6, species richness peaked for biotopes dominated by *Cerastoderma* spp. and dominated by multiple infaunal bivalve species (with respective mean of 5.1 and 5.3 species per sample). These habitats were given conservation value

10 for the criterion of **biological diversity**. The crustacean-biotope *Corophium* spp., with an average of 4.4 species per sample was given the conservation value 1. The remaining habitats at Level 6 were given conservation value 0.

The biotope at Level 5, with infaunal insect larvae was given the conservation value 10 because of its high average of species (5.1 species per sample), while the biotope with infaunal bivalves was given the conservation value 1 due to its average number of 4.2 species per sample. The other four biotopes at Level 5 were given the value 0 for the criterion of biological diversity.

The epibenthic bivalve biotopes (at both Levels 6 and 5) were given the conservation value 10 for the criterion of **ecological function** since they are considered irreplaceable. This is partly because they have a significantly higher filtration capacity than other biotopes in the area (Kautsky 1981, Rönnbäck et al. 2007, Lemmens et al. 1996, Prins et al. 1995) and partly because they are an important food source for other organisms. All other biotopes were given the conservation value 1 for this criterion.

The values of the different criteria were weighted together according to Section 7.3 and a comprehensive conservation value was given to each biotope (Table 25). To produce conservation value maps over the area, the overall conservation value for each biotope was used together with the predicted maps over species coverage that were modelled (Section 6). Table 25 specifies which maps were used for each biotope. Matched predicted-maps were lacking for three of the biotopes at Level 6 and for one of the biotopes at Level 5. Further, for some biotopes the species predicted in the maps was not entirely consistent with the species in the biotope. The spatial mapping of conservation values based on zoobenthos biotopes is therefore not complete.

The comprehensive map over conservation values on biotopes of zoobenthos is shown in Figure 57. The maps show that the highest conservation values are primarily localized in the deeper areas with some distance from the coast and in the Karlskrona archipelago areas. These areas get high conservation values primarily due to the biotopes of the epibenthic bivalve *Mytilus edulis* and the infaunal bivalve *Cerastoderma* spp.

Table 25. Conservation value assessments for biotopes of zoobenthos in the Hanö Bight. The biotopes at Level 6 are listed under the corresponding biotope at Level 5 (bold type). The species mentioned are the typical species found in the area. The valuation is compatible with HELCOM classification system.

Biotope / Dominating species (based on inventory data)	Uniqueness or rarity	Endangered biotopes	Biological diversity	Ecological function	Weighted conservation value	Predicted maps of zoobenthos used for the mapping of conservation values
Epibenthic bivalves	**0**	**0**	**0**	**10**	**10**	Not mapped
Mytilidae (*Mytilus edulis*)	0	0	0	10	10	≥ 25 % coverage of *Mytilus edulis*
Epibenthic cnidarians	**0**	**0**	**0**	**1**	**1**	Not mapped
Infaunal bivalves	**0**	**0**	**1**	**1**	**2**	Not mapped
Macoma balthica	0	0	0	1	1	≥500 individuals/m^2 of *Macoma balthica*
Cerastoderma spp.	1	0	10	1	10	≥100 individuals/m^2 of *Cerastoderma*
Mya arenaria	1	0	0	1	2	No predicted map was applicable
Astarte spp.	0	10	0	1	10	No predicted map was applicable
Multiple infaunal bivalve species (*Cerastoderma* spp., *Mya arenaria, Astarte borealis, Arctica islandica, Macoma baltica*)	1	0	10	1	10	No predicted map was applicable
Infaunal polychaetes	**0**	**0**	**0**	**1**	**1**	Not mapped
Marenzelleria spp.	0	0	0	1	1	≥300 individuals/m^2 of *Marenzelleria* spp.
Multiple infaunal polychaete species (*Marenzelleria* spp., *Hediste diversecolor*)	0	0	0	1	1	Combination of ≥300 individuals/m^2 of *Marenzelleria* spp. and ≥100 individuals/m^2 of *Hediste diversecolor*
Infaunal crustaceans	**1**	**0**	**0**	**1**	**2**	Not mapped
Monoporeia affinis and/or *Pontoporeia femorata*	1	1	0	1	1	≥300 individuals/m^2 of *Monoporeia affinis/Pontoporeia femorata*
Corophium spp.	1	0	1	1	3	≥100 individuals/m^2 of *Corophium volutator*
Bathyporeia pilosa	1	0	0	1	2	≥100 individuals/m^2 of *Bathyporeia pilosa*
Infaunal insect larvae	**1**	**0**	**10**	**1**	**10**	Not mapped
Chironomidae	1	0	0	1	2	≥100 individuals/m^2 of *Chironomidae*

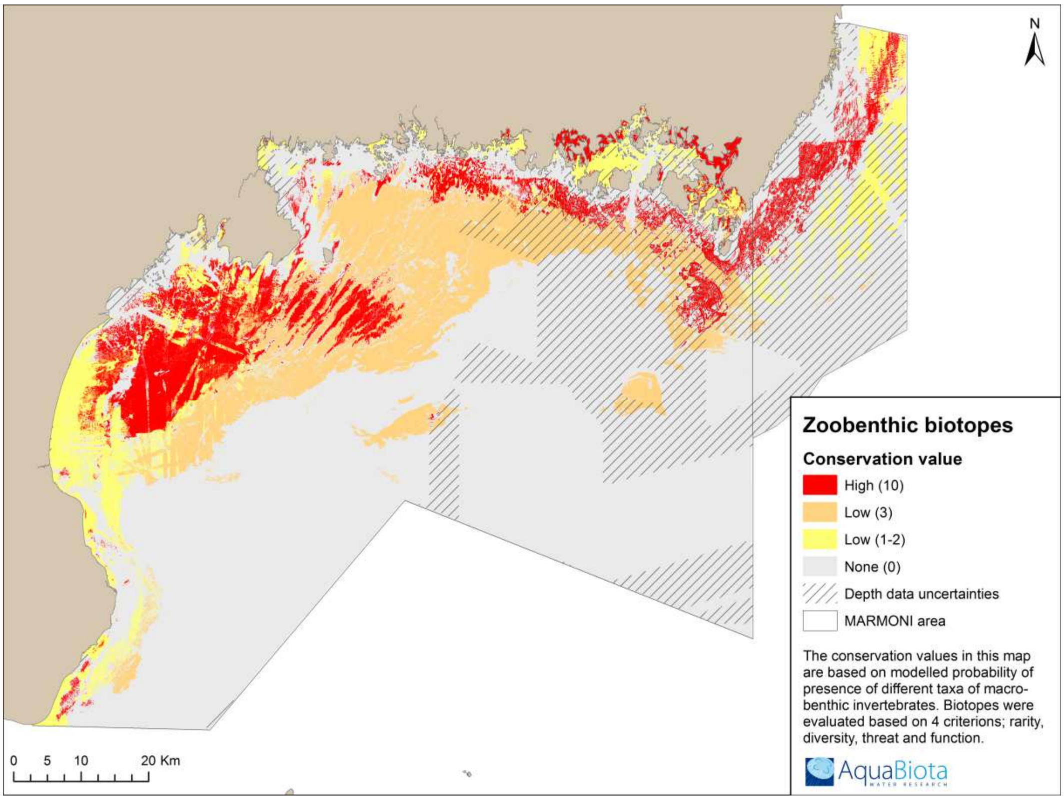

Figure 57. Conservation values, estimated on predicted coverage of zoobenthos in the Hanö Bight.

7.5.3 Coastal fish recruitment areas

Conservation value assessment for coastal fish recruitment areas was evaluated by the criteria **importance for life-history stages** and **endangered/declining species or biotopes** (see Table 22).

Areas of **importance for life-history stages** for the fish species perch (*Perca fluviatilis*), pike (*Esox lucius*) and roach (*Rutilus rutilus*) in the Hanö Bight are mainly located in shallow protected environments along the coast of Blekinge County and the south coast of Bromölla (Figure 58). The predicted coverage of roach and perch shows a preference for sheltered, shallow and warm environments close to the mouths of streams, where the water transparency is often lower. Pike on the other hand was predicted to be located at a slightly larger distance from stream mouths and at slightly greater depths. As described in Section 7.3.2 all coastal fish recruitment areas were given the conservation value 10 just because they are important for fish life-history stages.

None of the species that were predicted were given any conservation value for the criterion **endangered/declining species or biotopes** as no threats were listed in the Swedish Red List (The Swedish Species Information Centre, SLU 2010) or the Red List of the International Union for Conservation of Nature (IUCN 2014).

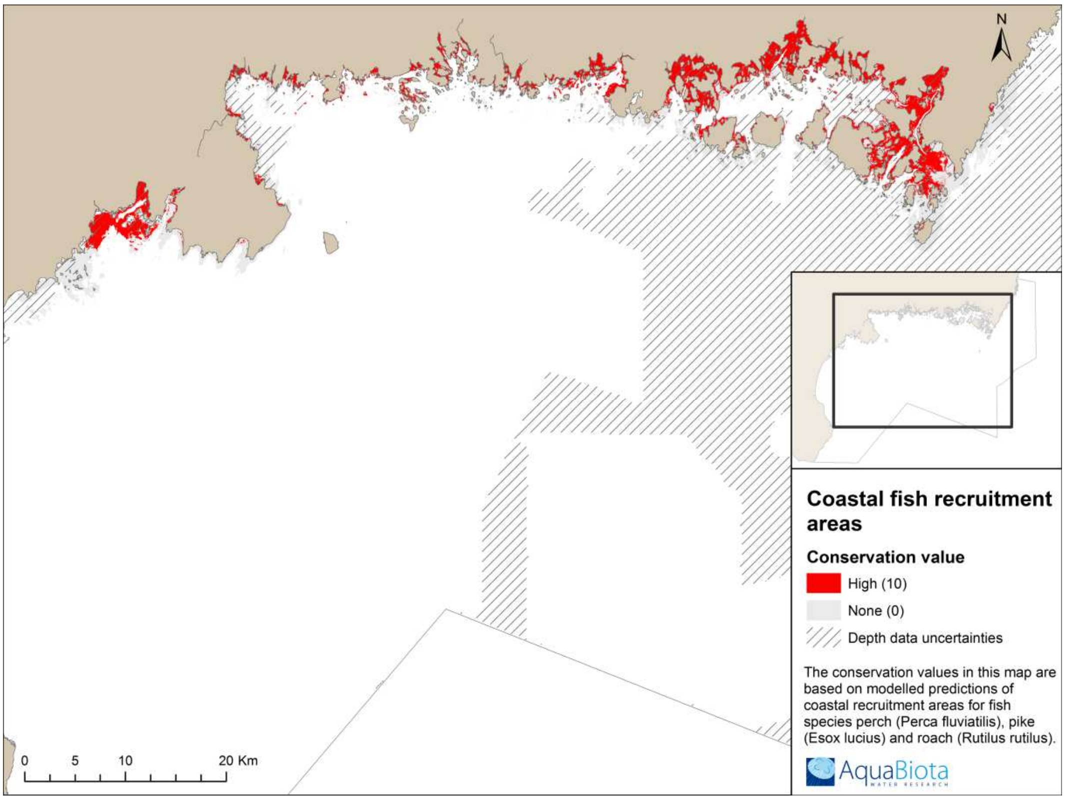

Figure 58. Conservation values based on coastal recruitment areas for perch, pike and roach.

7.5.4 Wintering areas for waterbirds

Conservation value assessment for wintering areas for waterbirds was based on the criteria **importance for life-history stages** and **endangered/declining species or biotopes** (see Table 22).

The highest conservation value (10) with respect to **importance for life-history stages** for wintering areas in the Hanö Bight was given to Listerby and Nättraby's archipelago area (Figure 59) due to its high abundances of coastal waterbirds (more than 10 000 individuals). At the same area regular internationally important concentrations of tufted duck (*Aythya fuligula*) and smew (*Mergellus albellus*) are to be found. Lower (i.e. medium high) concentrations of waterbirds (more than 2 000 individuals, but fewer than 10 000 individuals) are found along the coast from Jämjö in the east to Åhus in the west and were given the conservation value 1 (Table 26).

The conservation value 10 (for the criterion of areas of importance for life-history stages) was given to an area due to its high concentration of more than 75 individuals/km^2 of the offshore long-tailed duck (i.e. the southernmost area was given the value 10 in Figure 59). This area coincides well with the concentration area set during the boat inventories during the late 1960s (Nilsson 1972a, see also Nilsson 2012). Long-tailed ducks appear in medium high concentration (i.e. more than 20 individuals/km^2, but lower than 75 individuals/km^2) around the high concentration area and were thus given the conservation value 1. However the long-tailed duck does occur all across the offshore areas of the Hanö Bight to a depth of about 20 m but shows a significant variation in its coverage between different inventories (Section 3.5, Nilsson 2012).

The criterion **endangered/declining species or biotopes** could not be assessed for the group of coastal waterbirds as these are estimated for several species simultaneously. Regular internationally important areas for the tufted duck and the smew were given the conservation value 1 because smew is classified as near-threatened in the Swedish Red List (SLU 2010). In the same list, the long-tailed duck is classed as critically endangered and in the IUCN Red list as vulnerable. Therefore the area with high concentrations of the species (i.e. the area assessed as internationally important area for the long-tailed duck and with more than 75 individuals/km^2) was given the conservation value 10. Around the area of high concentration, areas with slightly lower concentration i.e. medium high concentrations (more than 20 but fewer than 75 individuals/km2), were given the conservation value 1 due to the lower concentrations.

Table 26. Valuation of important waterbird areas in the Hanö Bight.

	Endangered species	Importance for life-history stages	Weighted conservation value
Areas with medium high concentrations of coastal waterbirds	-	1	1
Areas with high concentrations of coastal waterbirds	-	10	10
Regular internationally important concentrations of tufted duck (*Aythya fuligula*) and smew (*Mergellus albellus*)	1	10	10
Areas with medium high concentrations of long-tailed duck (*Clangula hyemalis*)	1	1	2
Areas with high concentrations of long-tailed duck (*Clangula hyemalis*)	10	10	10

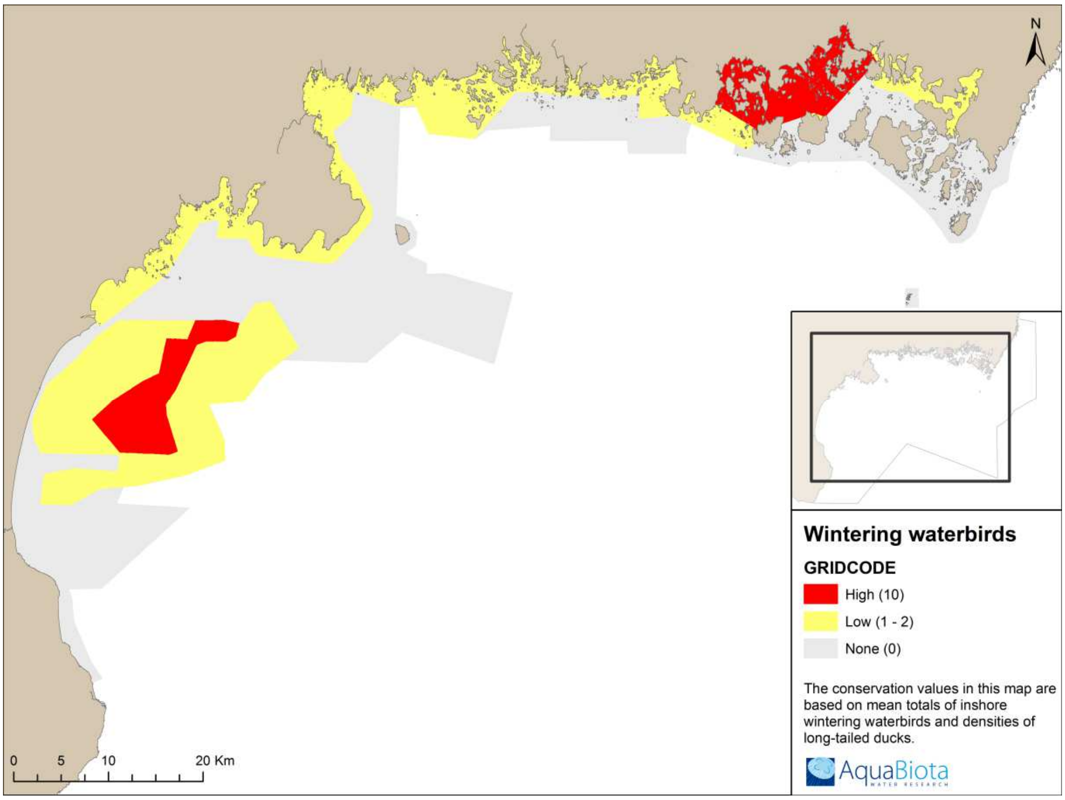

Figure 59. Conservation values assessed in Hanö Bight based on concentrations of wintering waterbirds.

7.5.5 Haul-out sites for marine mammals

Conservation value assessment for haul-out sites for marine mammals was based on the criteria **importance for life-history stages** and **endangered/declining species or biotopes** (Table 22).

Haul-out sites for the two seal species harbour seal (*Phoca vitulina*) and gray seal (*Halichoerus grypus*) were given the conservation value 10 for the criterion **importance for life-history stages** (Table 27).

The Baltic Sea population of harbour seal is classified as vulnerable in the Swedish Red List (SLU 2010). Therefore designated areas for harbour seal were given the conservation value 1 for the criterion **endangered/declining species or biotopes**.

The knowledge about haul-out sites for porpoises (*Phocoena phocoena*) in the Baltic Sea was low at the time for analysis. Therefore neither the criterion importance for life-history stages nor the criterion endangered/declining species or biotopes could be evaluated. However for the latter criterion, areas of importance for porpoises would have been given the conservation value 1 since the population in the Baltic Sea is classified as vulnerable in the Swedish Red List (SLU 2010).

Restricted areas were used as a basis to designate areas of high conservation value for seals. These are located at "Utklipporna", where both seal species occur, and in two areas on the east coast of Blekinge County where the harbour seal occurs (Figure 60).

Table 27. Valuation of marine mammals (i.e. seals) in the Hanö Bight.

	Endangered species	Importance for life-history stages	Weighted conservation value
Harbour seal (*Phoca vitulina*)	1	10	10
Gray seal (*Halichoerus grypus*)	0	10	10

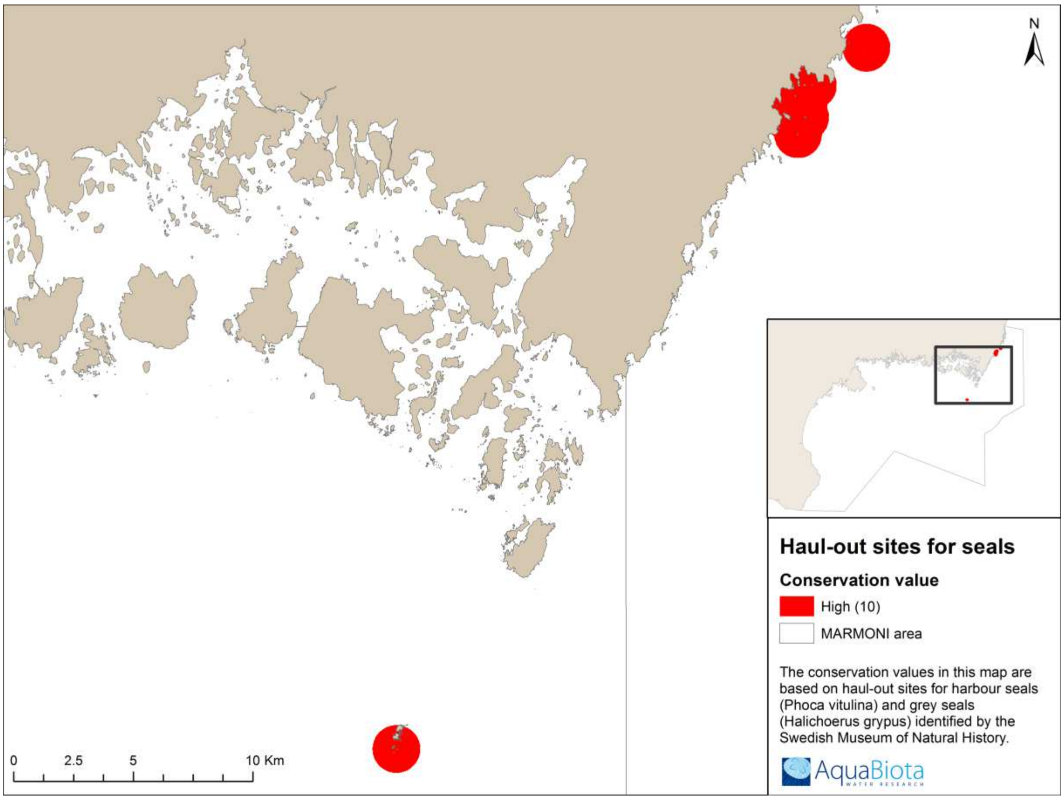

Figure 60. Conservation values in Hanö Bight based on restricted areas for gray and harbor seals designated by the Swedish Natural History Museum.

7.5.6 Compilation of mapped conservation values

The combined conservation value map (Figure 61) shows high conservation values in large parts of the area. The highest values are found in shallow areas (about 0-25 m). Conservation values above 10 indicate areas where conservation values from various categories overlap. A larger area which has been assigned high conservation values (between 16 and 25) is found in the sea area outside Åhus harbour. The high conservation values in this area are mainly based on biotopes of zoobenthos (blue mussels and Marenzelleria spp.) and long-tailed ducks. Furthermore, high conservation values (from multiple categories) are identified along much of the coastline. The highest values are found in Blekinge inner archipelago and at Utklippan. High conservation values for all categories, except marine mammals, are found in the bays of Karlskrona archipelago.

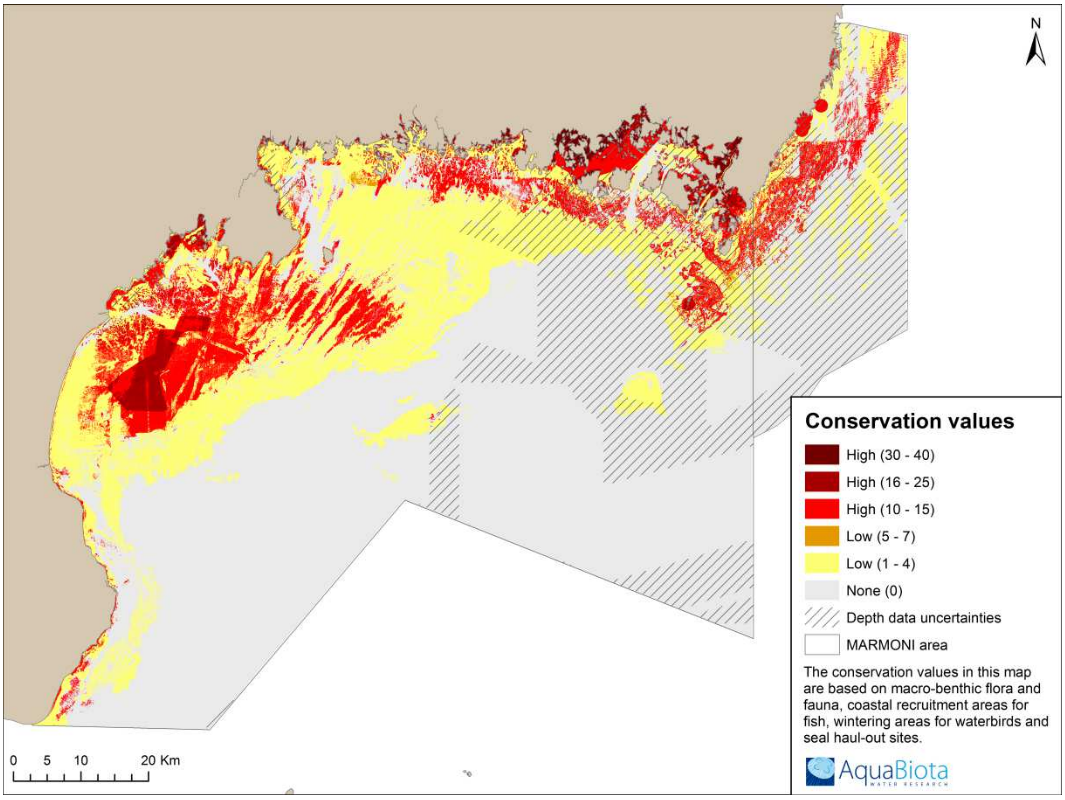

Figure 61. Conservation values in Hanö Bight and Blekinge County, based on densities of wintering waterbirds, important areas of importance for grey and harbour seals and predicted occurrences of coastal fish recruitment areas, benthic vegetation and zoobenthos.

7.6 Discussion

The mapping of conservation values contributes with valuable information on various nature values in the Hanö Bight and Blekinge County. Many biotopes and habitats have been identified and shown to harbour high conservation values. The information can be used directly as a basis for planning and communications during consultations etc.

However, it is important to note that these maps over conservation values do not include everything that is of value for the marine environment. At the start of this project the classification system HUB (HELCOM Underwater Biotope and habitat classification) was not fully developed. Neither the data nor the mapping (field work and modelling) were therefore performed in an optimal manner for this purpose, making it necessary for some data modification during classification. Moreover it was not possible to map some biotopes for this reason. This is of special concern regarding the more rare biotopes and species which are difficult to distinguish with drop video. Now when the classification system is ready, a greater effort can be focused on rare and/or endangered biotopes and habitats. Verification in field of unusual biotopes should also be made after modeling since these biotopes are not adequately examined by randomly scattered stations. Offshore fish recruitment areas, important feeding areas for adult fish and other pelagic organism groups, as well as breeding areas for birds, are also lacking in this conservation value assessment. This shortcoming obviously affects the final result as these may be worthy of protection.

The method presented here is intended for regional mapping of conservation values. For a successful result, it is crucial that a sufficient number of biotope and habitat maps can be produced for an area and that data are available for an objective valuation of the criteria chosen for each biotope. Furthermore, it is also preferable if the choice of criteria and its evaluations is made in collaboration between specialists and managers with good knowledge of local conditions.

The evaluation of the different biotopes and habitats is not entirely unproblematic. For example it is good to be aware of that a species, which itself is the fundament of a biotope, may be relatively common in the inventory data, but rare as a biotope since it then needs to fulfil certain requirements (e.g. ≥ 50 % coverage). Further, the biotopes dominated (≥ 50 % coverage) by filamentous annual algae and *Chorda filum* and/or *Halosiphon tomentosus* were given the conservation value 10 for the criterion uniqueness or rarity, which might be explained by the HUB classification hierarchiology rather than different species' actual coverage. These biotopes are given lower priority than e.g. perennial vegetation in the classification system, meaning that the whenever the coverage of a perennial group is at least 10 % the area is defined as that biotope, regardless of the amount of annual algae. The cover of filamentous annual algae is also highly dependent on the season, being highest early in the summer. The inventory data is however collected in August, when the filamentous annual algae are only occurring in high numbers in very shallow areas (mainly 0-0.5 meters). This could further effect the evaluation of the uniqueness or rarity criterion. The biotope dominated by filamentous annual algae also had the highest species richness of the vegetational biotopes which also could be influenced by the same classification hierarchiology. It is possible that the filamentous annual algae species only were high in numbers where the perennial algae were absent or sparse. Further is shallow areas often linked to high diversity in macro-vegetation. The majority of the biotope dominated by filamentous annual algae was found on mixed bottoms which have an advantage in the diversity evaluation (see Section 7.3.1.2). Additionally, since the biotope only occurred in a few stations the confidence of the evaluation of the diversity is somewhat low, since it is based on few data samples. This raises the question of whether the HUB classification system provides a good representation of the biotopes with lower rank in the classification system.

There are also many other potential ecological functions that can be used in conservation value assessment, which have not been evaluated in this example. To mention a few examples, vegetation affects water movement and binds sediments while zoobenthos mix sediments and clean sandy beaches. The results are also dependent on the assessment's spatial scale. Some biotopes can have a locally important ecological function (for example in a bay) but not if you consider the whole of Hanö Bight. In other words, the results of conservation value assessment can differ based on the ecological functions chosen and on what scale they are assessed. It is therefore particularly important to think through these choices before a conservation value assessment is made.

Conservation value assessment focuses on species, biotopes and habitats that are important to ensure the sustainability of ecosystems and the maintenance of biodiversity. In future analyses, it may also be interesting to add ecosystem services as a criterion. However, this is a complex issue and most likely needs to be based on expert judgments.

Important recruitment areas for fish are largely based on different vegetation biotopes that are favourable for fish reproduction. When these conservation values are added to the ones of benthic vegetation biotopes, there is a risk of unwanted duplication of conservation values. However, in this present study it was considered important not to miss if an area was both of importance due to vegetation as well as for fish recruitment since the latter also considers factors such as temperature and water current conditions.

It can be discussed whether large contiguous areas of a biotope should be given a higher value than a smaller area. Moreover, how the different values within each category are weighted together can also be discussed. Under current methodology, the maximum value for each category is set to 10. If more biotopes are added to the assay, an area theoretically reaches this maximum value more easily, making it more difficult to see differences in conservation values between areas and reduces the ability to prioritize which areas are most important to protect.

The mapping of conservation values for wintering waterbirds was made with a potential complementary approach to assess biodiversity values. The value of each individual object (in this case polygons) was assessed. This approach allows for a more detailed mapping of natural values, where the value can vary for the same biotope or habitat in different locations. At the same time, more extensive field investigations are required and are only possible to perform these in smaller areas of for a limited number of biotopes/habitats.

We recommend that spatial mapping of relevant marine conservation values is made by all Baltic countries, as a basis for marine planning and implementation of an ecosystem-based management. Currently, marine conservation values are defined and mapped in various ways in different areas, which makes comparisons between areas and overall assessments difficult. We acknowledge a need for common principles for marine conservation value assessment and mapping.

8 Scenario: Quantification of effects of a fictive wind park on some marine conservation values

In this scenario GIS tools and spatial conservation value layers from different sources were used to demonstrate how effects of construction and operation of a marine wind park can be quantified for a number of conservation values.

8.1 Scenario description

In this scenario impacts from a fictive wind park placed at Kiviksbredan (a shallow area in the Hanö Bight) are quantified for a number of conservation values in the area. The fictive wind park consists of 37 wind mills placed with 700 meters distance between each mill. The wind park area is 19.2 km2 and the depth varies between 4.5 and 17 meters. Around 40 % of the bottoms within the wind park are sandy and the rest are a mix of mainly coarse sand, gravel and stones.

There are several different construction types and methods for construction of marine wind parks. Two common methods are monopile and gravity foundations. A monopile is a pile which is drilled or piled into the bottom while a gravity foundation is a concrete caisson which is placed on the bottom and normally surrounded by an erosion protection of stones and boulders. Dredging is normally performed during construction with gravity foundations. In reality, cables are also laid both within the park and between the park and the mainland. These cables are not considered in this scenario.

8.2 Analysis method

Information which only states whether or not a conservation value is sensitive to a certain activity or is likely to be affected by a planned activity has a very limited usefulness. In order to assess the consequences of an activity, the effects must be quantified. This scenario demonstrates how expected effects can easily and effectively be quantified through GIS-analyses.

In order to perform this kind of analysis the following is needed:

- Maps of conservation values
- Information on how the conservation values are affected by the activities
- Maps of the planned activity

Here maps over conservation values created from spatial modelling, field surveys and expert opinion have been used and effects on conservation values from activities have been taken from literature. A fictive wind park was drawn in GIS (described in the section above).

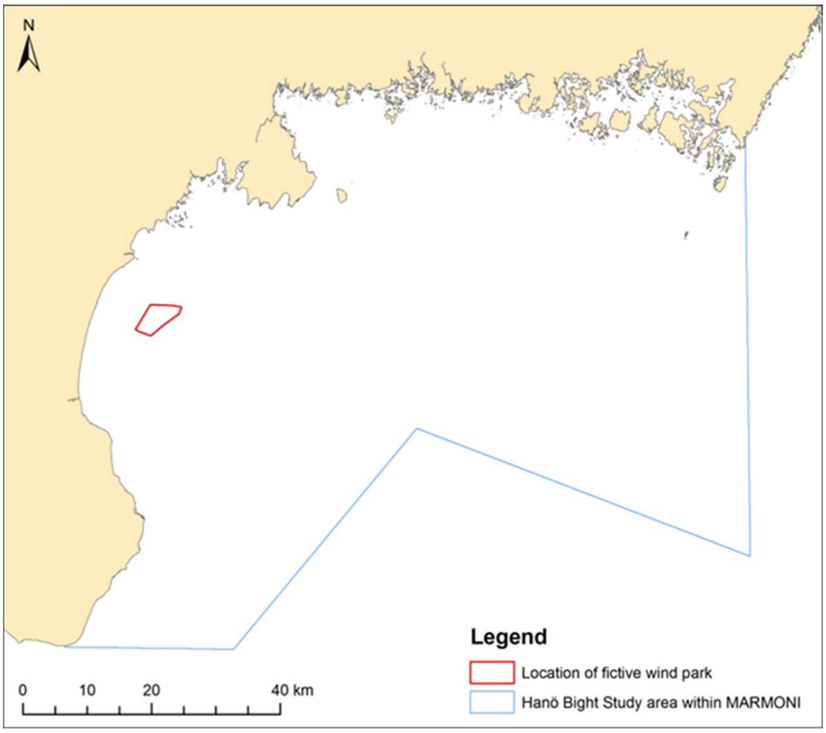

Figure 62. The Swedish study area the Hanö Bight and the location of the fictive wind park at the bank Kiviksbredan

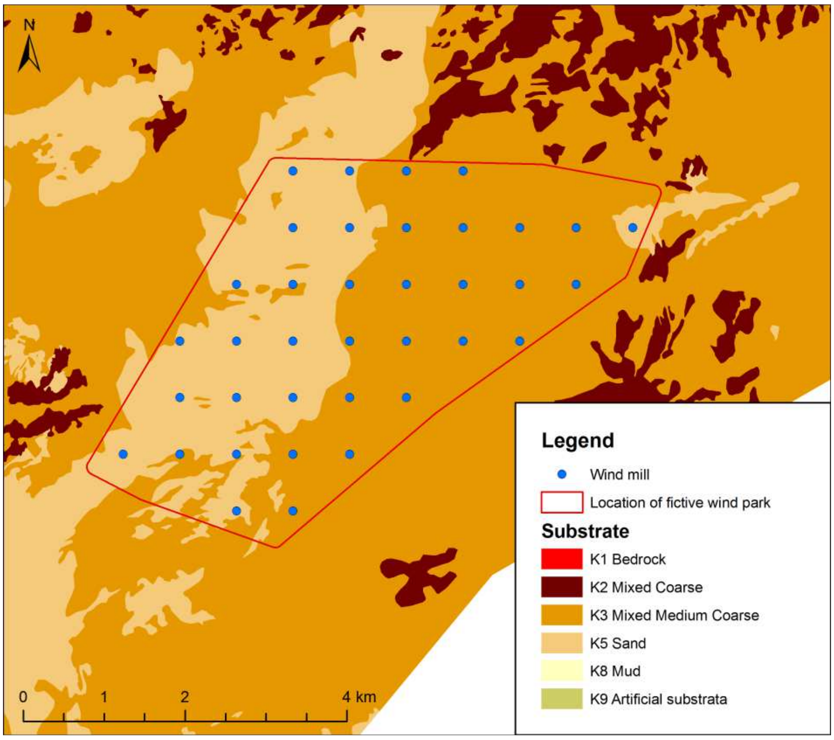

Figure 63. The locations of the wind mills in the fictive wind park and seafloor substrates in the area.

8.1 Conservation values in the area

Of mapped conservation values in the Hanö Bight, the following were chosen for the scenario: long-tailed duck, high cover of blue-mussels, perennial macroalgae, harbour porpoise and grey seal (Table 28). The long-tailed duck and, mussels and algae were selected since good GIS maps exist. The mammals were included since both species are known to occur in the entire Hanö Bight. (Detections from the SAMBAH-project show that harbour porpoises occur in the Hanö Bight, including the Kiviksbredan area and the grey seal is a common and often observed species in the entire area). Fish were not included in the analysis since there are no maps for the Kiviksbredan area.

Table 28. Conservation values in the area and total area as well as area within the wind park. *For harbour porpoise and grey seal conservation value maps are not used in this scenario. These species are expected to occur in the entire area.

Conservation value	Area in the entire study area (km2)	Area within the fictive wind park (km2)	% of total area of the cons. value in the Hanö Bight within the fictive wind park
Long-tailed duck, high densities	274.40	0.40	0.15
Long-tailed duck, high-est densities	73.96	18.83	25.47
Blue mussel	523.45	10.68	2.04
Perennial macroalgae	225.16	0.05	0.02
Harbour porpoise*	6338.86	19.25	0.30
Grey seal*	6338.86	19.25	0.30

8.1.1 Long-tailed duck

Kiviksbredan is the most important area for the long-tailed duck in the Hanö Bight. The conservation value map for the long-tailed duck is based on inventories performed in wintertime. The map presents bird-density in two classes (high and low).

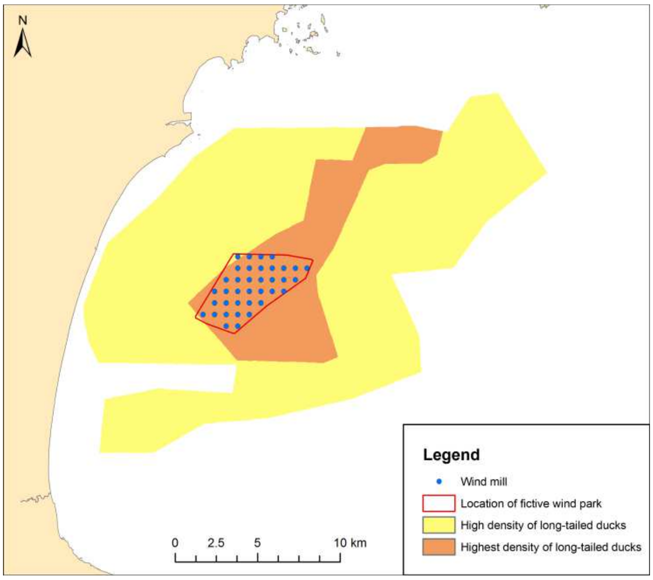

Figure 64. Important areas for long-tailed duck in the area coincide with the fictive wind park at Kiviksbredan.

8.1.1 Blue mussels and perennial macroalgae

The conservation value map for blue mussels was created through spatial modelling and points out bottoms with high density of blue mussels (at least 25 % cover). The conservation value map for macroalgae was also created through spatial modelling. The map identifies bottom with high probability of presence of perennial macroalgae.

High cover of blue mussels occurs over most of the bottoms with coarse mixed substrate but is largely missing on the sandy bottoms. Perennial macroalgae are much more sparse in the area and restricted to a few minor shallow coarse mixed bottoms.

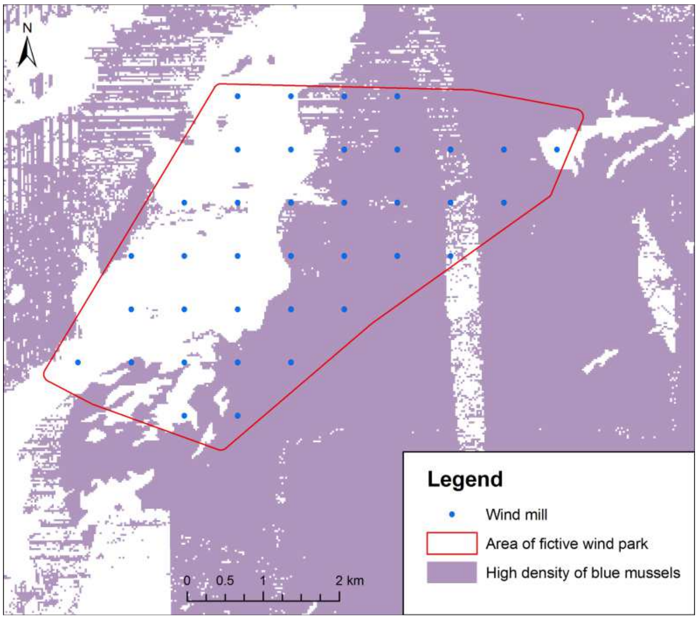

Figure 65. High cover of blue mussel in the fictive wind park.

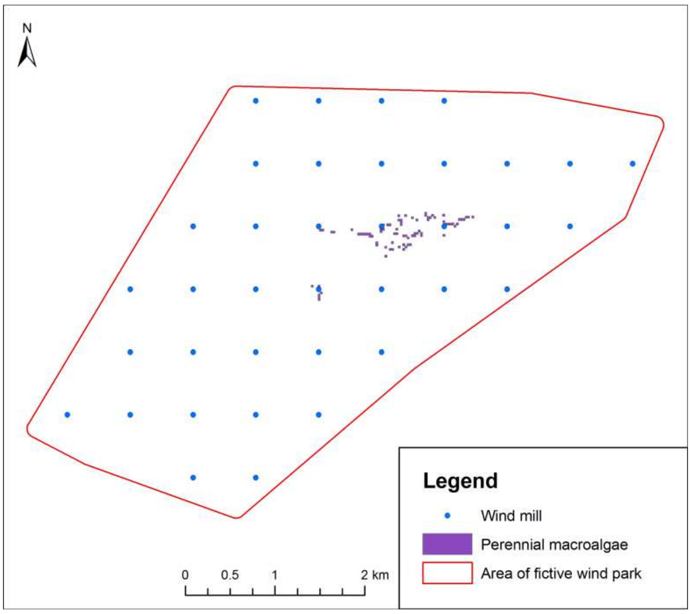

Figure 66. Perennial macroalgae within the fictive wind park. Conservation value from modelled presence of perennial macroalgae.

8.1.1 Harbour porpoise and grey seal

Since harbour porpoise were detected in many places in the Hanö Bight, including the area around Kiviksbredan, also these were included in the analysis. The conservation value map for grey seals only includes known haul-out places (on land). Since the species is known to forage in the entire area, also the grey seal is included in this analysis.

8.2 Results

Impacts on the conservation values are different during the construction phase and operation phase. Therefore the impact has been quantified separately for these phases. Relevant phases and construction methods were analysed for each conservation value.

8.2.1 Long-tailed duck

Long-tailed ducks detect the wind park visually and are known to avoid wind parks. The species don't occur at all inside wind parks and occurs only sparsely in a 2000 m radius around these (Nilsson and Green 2011; Petersen et al. 2006). A wind park on Kiviksbredan would therefore most likely have a large negative impact on long-tailed duck in the area. Over 50 % of the most important area for long-tailed in the Hanö Bight would be affected. About 25 % of the area would be inaccessible to the species and about 27 % would be affected by lower densities.

Foundation type and construction method are of less importance for the long-tailed duck and have therefore not been analysed for this species. Impact during construction phase is the same during the operation phase, i.e. avoidance of objects in the area.

Table 29. Effects on long-tailed duck during operation of the wind park.

	Unavailable area during operation (km²)	Area unavailable (%)	Area with lower density during operation (km²)	Area with lower density (%)
Long-tailed duck, high density	0.40	0.15	19.61	7.14
Long-tailed duck, highest density	18.83	25.47	19.70	26.63

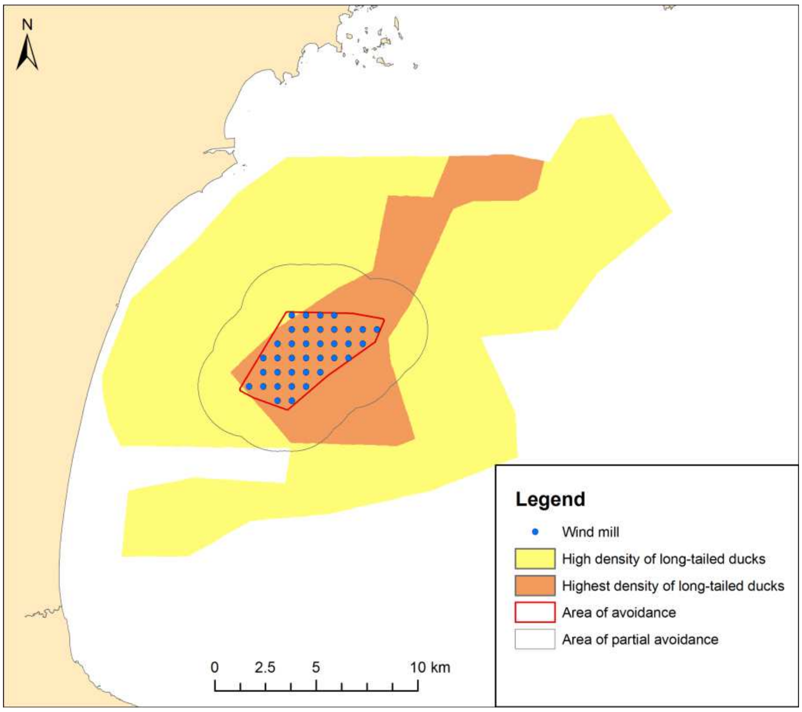

Figure 67. Areas with expected impact on long-tailed duck.

8.2.1 Blue mussels and perennial macroalgae

Hard bottom species like blue mussels and perennial macroalgae are manly affected by loss and addition of hard substrates. These species are therefore more affected by gravity foundations than by monopoles since gravity foundations with surrounding erosion protection cover a larger seafloor area than monopiles. During the construction phase and a period after this, available area will decrease for these species, but during the operation phase, the foundations and stones and boulders of the erosion protections will instead provide hard substrates for blue mussels and macroalgae. On the sandy bottoms this means addition of new available substrate for mainly blue mussels (this species occurs in high density on most coarse substrates in the area). Macroalgae will probably also occupy some of these new hard substrates.

For these conservation values, impact was calculated for both construction and operation phases. Impact is calculated for the alternative gravity foundations with surrounding erosion protection, which would mean largest impact on the conservation values (both loss of existing substrates and addition of new substrates).

The natural value blue mussels and to some extent also perennial macroalgae can therefore be expected to increase in the area after construction of a wind park, especially if gravity foundations with large erosions protections are used.

Table 30. Temporary loss of conservation values blue mussels and perennial macroalgae during construction of the wind park. Recolonization is expected at almost the entire lost area after the construction phase. The table was calculated with the construction alternative gravity foundations and 650 m2 erosion protections and therefore provides maximum values.

Species	Area temporary loss during the construction phase (km^2)	Amount temporary loss within the wind park during the construction phase (%)	Amount temporary loss within the entire study in the Hanö Bight during the construction (%)
Blue mussels	0.014	0.127	0.003
Perennial macroalgae	0.0002	0.412	0.00009

Table 31. Potential increase of the natural values blue mussels and perennial macroalgae as an effect of the addition of new substrates as a result of the construction of the wind park. The table was calculated with the construction alternative gravity foundations and 650 m2 erosion protections and therefore provides maximum values.

	Area with potentially new substrate (km^2)	Potential increase of cons. value within the wind park (%)	Potential increase of cons. value within the Hanö Bight (%)
Blue mussels	0.01	0.096	0.002
Perennial macroalgae	0.01	20.073	0.005

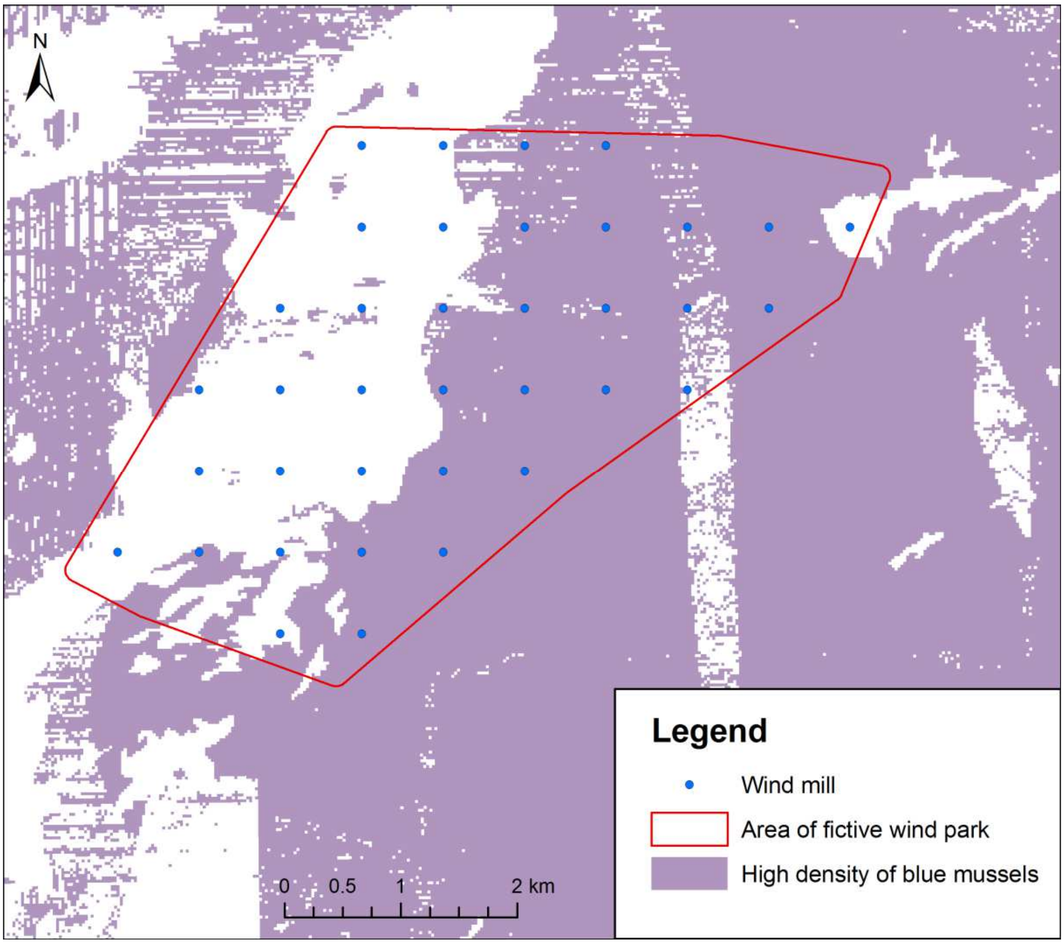

Figure 68. The benthic conservation values blue mussels and perennial macroalgae as well as areas that are lost during the construction phase. The example shows the alternative gravity foundations which is the alternative that occupies largest seafloor area.

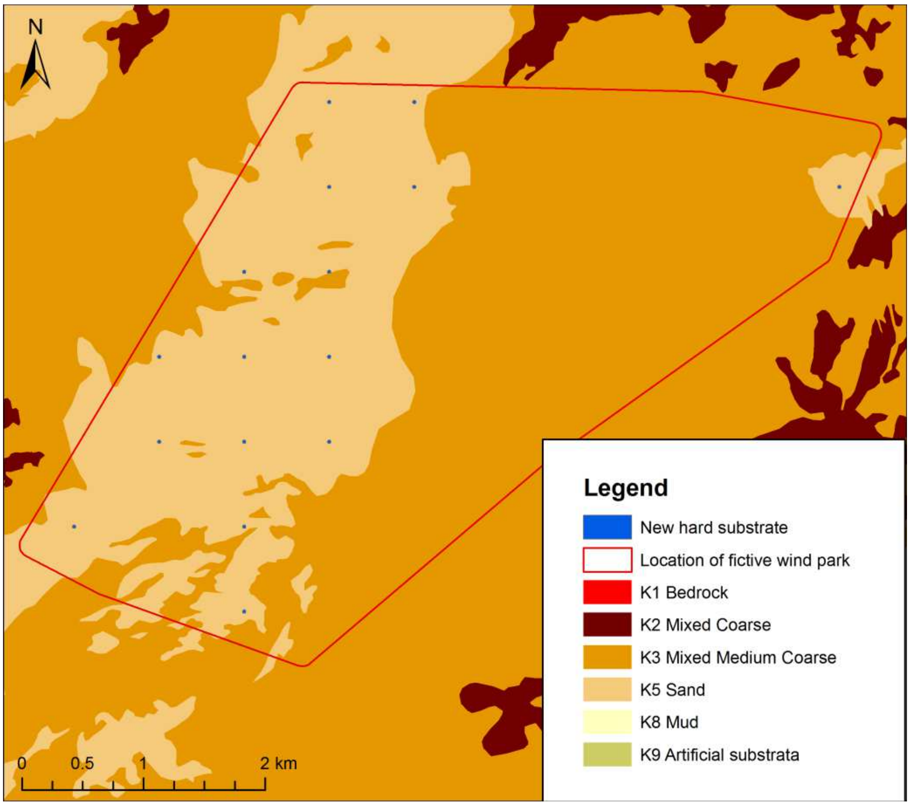

Figure 69. New hard substrate available to blue mussels and macroalgae if gravity foundations and 650 m2 erosion protections are constructed.

8.2.1 Harbour porpoise and grey seal

The most important pressure from wind farms affecting marine mammals such as harbour porpoise and grey seal is noise during the construction phase. The noise levels during operation are much lower. These are mainly caused by vibrations in the submerged part of the tower (Enhus et al. 2012).

During construction work for the alternatives monopiles and gravity foundations different construction methods are used. Monopiles are often piled into the bottom and dredging is a common practice during construction work with gravity foundations. Pile-driving produces strong sound impulses that can be heard from long distances under the water while dredging produces a considerably weaker continuous noise.

Noise from pile-driving can cause severe physical injuries on marine mammals. In this scenario the impact area is calculated using the distance where the behaviour is affected (i.e. avoidance of the area).

Expected effects of the alternatives pile-driving and dredging were analysed. Effects on grey seal are calculated as effects on seals in the water (largest impact area). Grey seals are likely to be affected by pile-driving up to a distance of 2500 m and by dredging up to a distance of 100 m (Enhus et al. 2012). Harbour porpoise detect noise from pile driving over large distances and effects on the behaviour can be expected on as large distances as 50 km (Dähne et al. 2013). No information on behavioural effects from dredging on harbour porpoise was found. Other whales may by affected at distances of about 100 m (Enhus et al. 2012). Due to this uncertainty, a distance of 1000 m was not to underestimate the impact area.

Effects on seals and harbour porpoises during operation of wind parks are more uncertain and difficult to estimate. Literature data provide different answers, both that harbour porpoises may occur in larger densities around structures like oil rigs and artificial reefs but also that they can detect sounds from a wind park on rather long distances (Enhus et al. 2012). Effects could therefore not be quantified.

Table 32. Impact on grey seal and harbour porpoise during construction of the wind park. Pile-driving and dredging are two commonly performed activities during construction work, where pile-driving is a likely method during construction work with monopoles and dredging is a likely method during construction work with gravity foundations. *The entire study area counts as natural value for harbour porpoise and grey seal since these species occur in the entire area.

Species	Impact area during pile-driving (km^2)	Amount of entire cons. value * within the Hanö Bight affected by pile-driving (%)	Impact area during dredging (km^2)	Amount of entire cons. value * within the Hanö Bight affected by dredging (%)	Impact area during operation phase
Harbour porpoise	3858.81	60.88	32.21	0.51	unknown
Grey seal	73.85	1.17	1.16	0.02	unknown

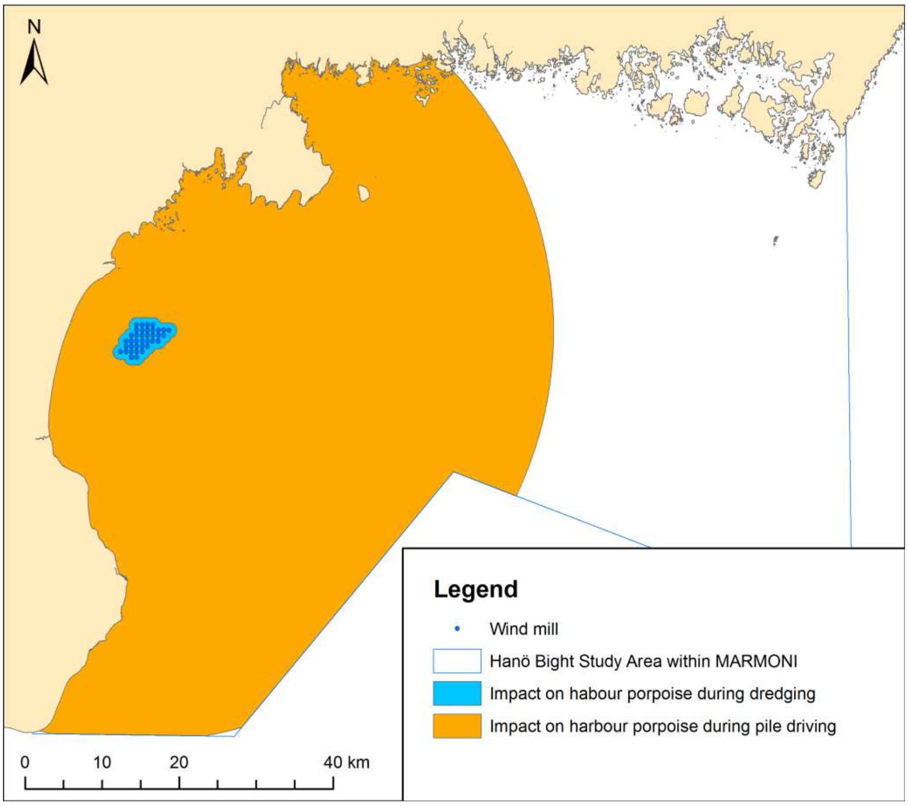

Figure 70. Area which will likely be avoided by harbour porpoise during construction work with pile-driving and dredging respectively.

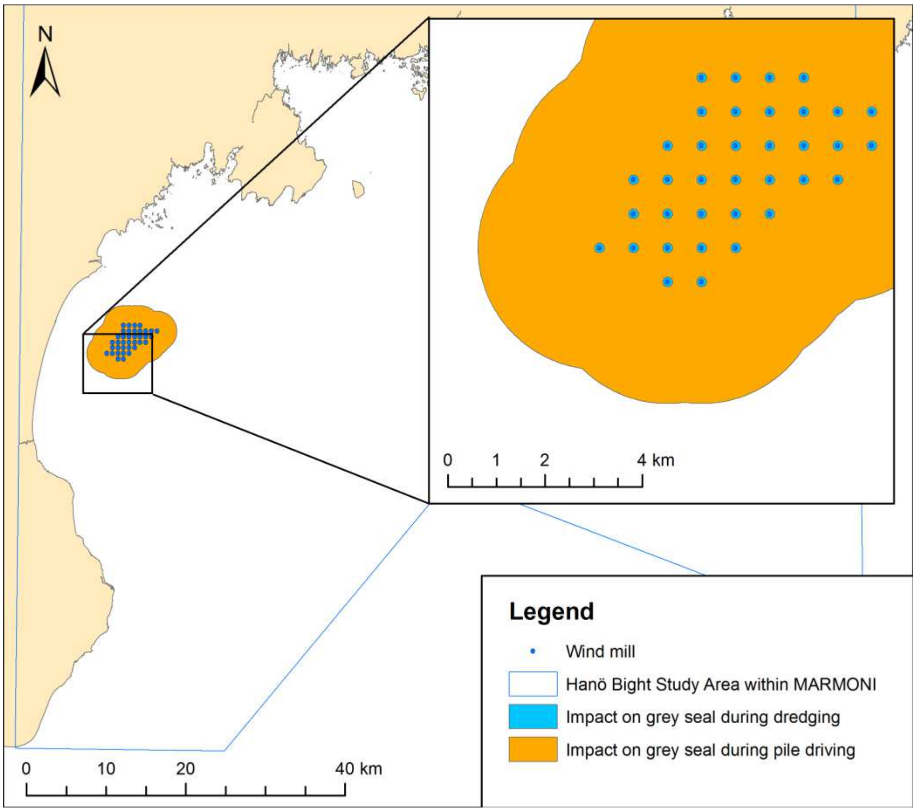

Figure 71. Area which will likely be avoided by grey seal during construction work with pile-driving and dredging respectively.

8.1 Discussion

This scenario highlights the importance of quantification of expected impact on conservation values in the area (contrary to just pointing out which conservations values that are likely to be impacted). By quantification of effects of an activity, the severity of these effects on the conservation values in the area can be assessed.

The scenario shows that the impact on long-tailed duck in the study area would be very severe with the location selected. It also shows that the impact on the benthic conservation values blue mussel and macroalgae would be negligible (less than 0.01 % of these conservation values are likely to be affected within the study area).

The analyses also illustrates the importance of construction method and foundation type for the impact on marine mammals during the construction phase where effects on harbour porpoise could be expected over more than half the study area during pile driving. This area is more than 30 times larger than the area affected if dredging would be performed instead.

Analyses if these kinds are powerful and relatively fast. Effects on fish and effects due to sediment spread were not included, but the same kinds of analyses with quantification of such effects are also possible by the use of models for sediment spread. Such an analysis is presented in Didrikas and Wijkmark 2009.

9 Scenario: Secchi depth changes in the Hanö Bight – quantification of effects on bladderwrack

In this scenario, GIS-tools and spatial environmental variables are used to quantify effects of changed Secchi depth on bladderwrack (Fucus vesiculosus) along the south coast and archipelago of Blekinge County. The size of the analysed area is 1241 km2 (land excluded). The area is located in the northern part of the study area the Hanö Bight within MARMONI.

9.1 Scenario description

An attempt is made to quantify the effects of increased Secchi depth along the south coast of Blekinge County and archipelago as well as a coastal area in the northeast of Skåne County.

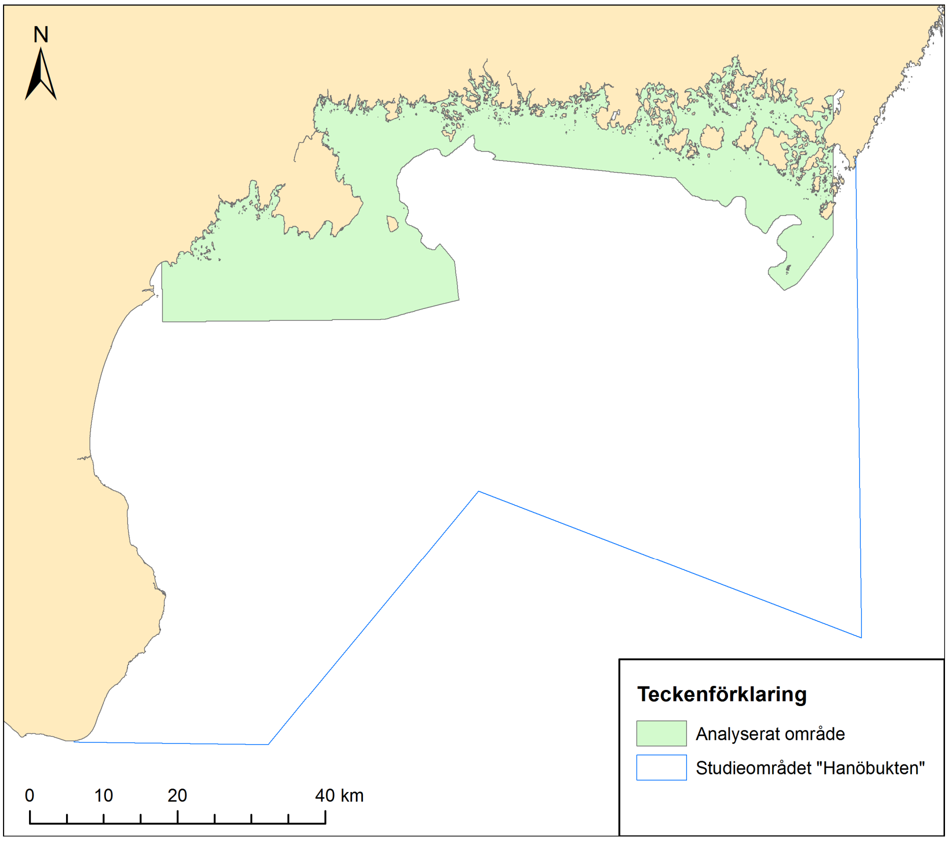

Figure 72. The Swedish study area in the MARMONI-project, "The Hanö Bight" and the analyzed area along the south coast and archipelago of Blekinge and northeastern Skåne (in green).

Scenarios were created for Secchi depth changes according to the target- and reference levels in HELCOM Baltic Sea Action Plan, BSAP (HELCOM 2007). A zero-alternative (here referred to as Business As Usual, BAU) was also calculated. This alternative illustrates the expected situation in 2021 if no measures are taken.

Expected changes of Secchi depth in the area follow Bergström et al. (2013), table 1.

Table 33. Expected changes of Secchi depth in the Baltic Proper until 2021 according to Bergström et al. (2013).

Scenario	Change
BAU	10 % decrease*
BSAP target level	11 % increase
BSAP Reference level	48 % increase

** This value was calculated for Stockholm Archipelago but was here applied to the Hanö Bight.*

9.1 Analysis method

The maximum possible distribution of bladderwrack along the south coast and archipelago of Blekinge County was retrieved through a GIS-analysis in ESRI ArcMap 10. Maximum and minimum values for wave exposure at the bottom and minimum values for light at the bottom was calculated for presence of bladderwrack as well as bladderwrack belts (at least 25 % cover of bladderwrack). A dataset including 1496 stations collected with drop-video, diving and snorkelling from the area was compiled from several inventories (Section 3.1).

Light at the bottom was calculated from a modelled Secchi depth grid in 100 m resolution (Sundblad and Bergström 2011). The model is based on mean Secchi depth for the summer months between 2000 and 2010. From this layer, GIS-layers where created for 10 % decrease of Secchi depth as well as 11 and 48 % increases of Secchi depth.

To calculate light at the seafloor from the layers created, the following equation was used:

$$\frac{I_z}{I_0} = e^{-kz}$$

Where: Iz is light intensity at the seafloor, I0 is the light intensity at the surface and k is "light attenuation koefficient" which is 1,7/the Secchi depth in meters and z id the depth in meters. Depth values were retrieved from an interpolated depth-grid in 10 meters resolution (Section 4.1.1).

Wave exposure at the seafloor was calculated from SWM (Simplified Wave Model, Isaeus 2004) in 25 m resolution and the depth grid in 10 m resolution. The calculation method follows Bekkby et al. (2008).

In order to calculate maximum seafloor area available to bladderwrack, GIS-layers in 10 m resolution were created and restricted to the maximum and minimum values for wave-exposure at the seafloor as well as light at the seafloor, for presence of bladderwrack and bladderwrack belts.

Finally, areas with soft substrates were deleted in order to not overestimate the maximum distribution of bladderwrack. This was performed with a polygon-layer with seafloor substrate classes created by SGU (Geological Survey of Sweden) in 2010 and 2012. The creation of such layers is described in Hallberg et al. (2010).

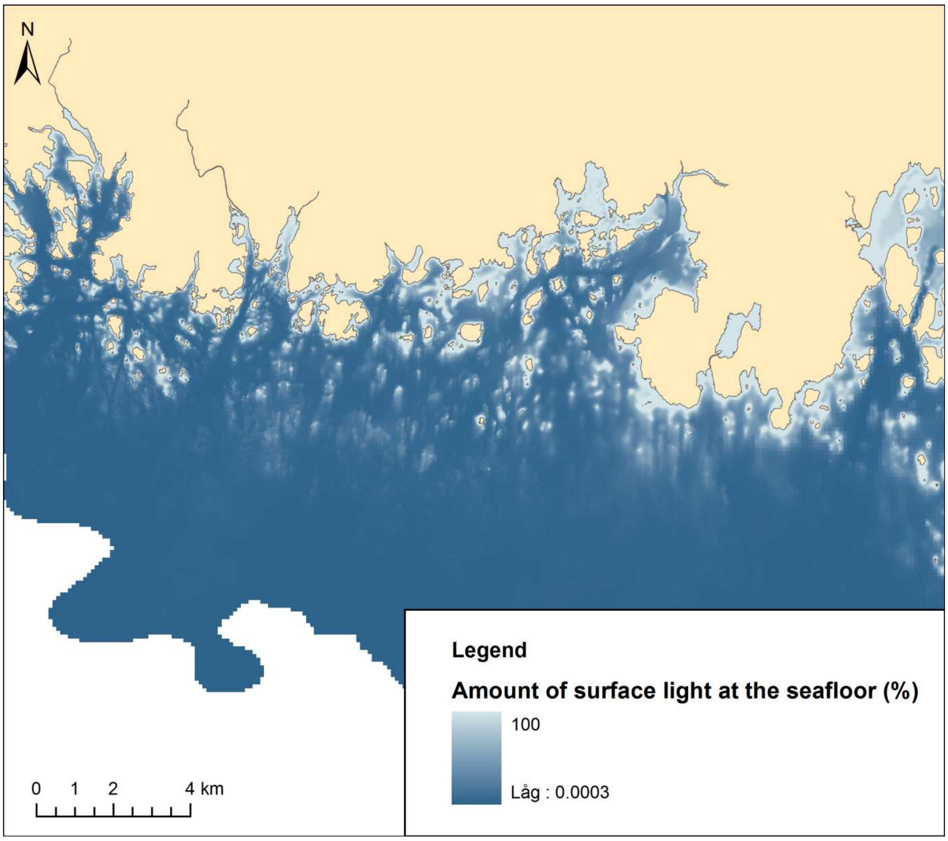

Figure 73. Section of the GIS-layer for percent the light at the surface that reach the seafloor. The map shows summer mean values between 2000 and 2010.

9.1 Results

Increases in Secchi depth according to the target-level for HELCOM BSAP would according to these calculations lead to ca 14 % increase in seafloor area available to bladderwrack and bladderwrack belts while the "business as usual"-alternative would lead to 12 and 13 percent decreased areas available to bladderwrack and bladderwrack belts, respectively.

The largest difference from the present situation is represented be the HELCOM BSAP reference value for Secchi depth. This value would correspond to ca 61 and 63 % larger available seafloor area for bladderwrack and bladderwrack belts, respectively in the area.

Table 34. Area and percent change in seafloor area available to bladderwrack and bladderwrack belts at present situation as well as the three calculated scenarios.

Scenario	Area (km^2) available to bladderwrack	Change (%) of area available to bladderwrack	Area (km^2) available to bladderwrack belts	Change (%) of area available to bladderwrack belts
Present situation	202		162	
BAU	177	- 12	142	- 13
BSAP target level	229	+ 14	186	+ 14
BSAP reference level	325	+ 61	264	+ 63

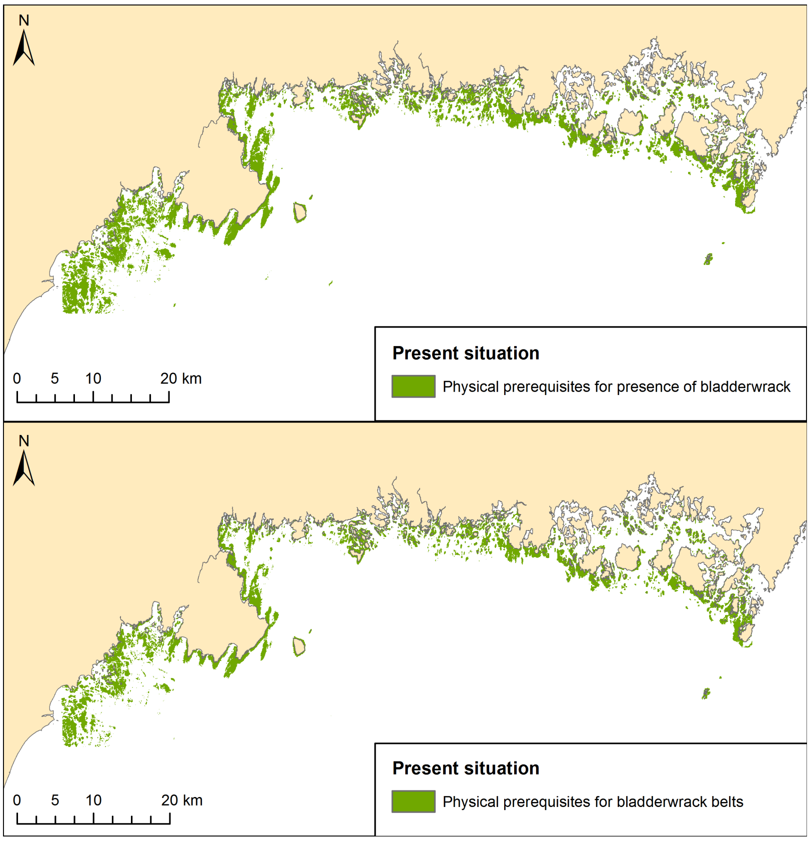

Figure 74. Calculated areas available to bladderwrack (upper) and bladderwrack belts (lower) at present summer Secchi depth (mean 2000-2010).

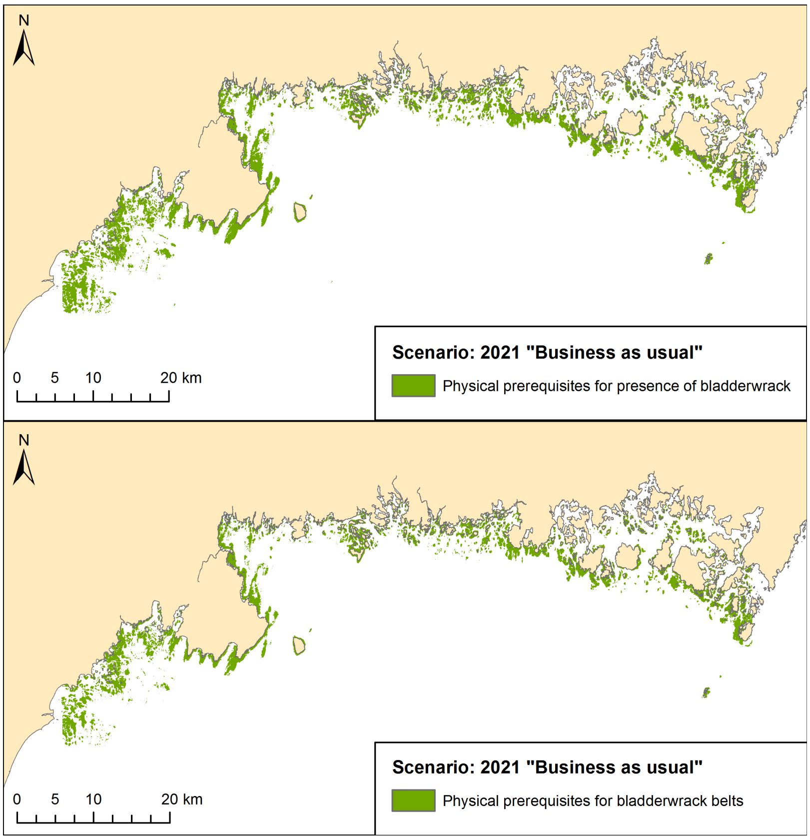

Figure 75. Calculated areas available to bladderwrack (upper) and bladderwrack belts (lower) in the scenario where no measures are taken (Business As Usual, BAU).

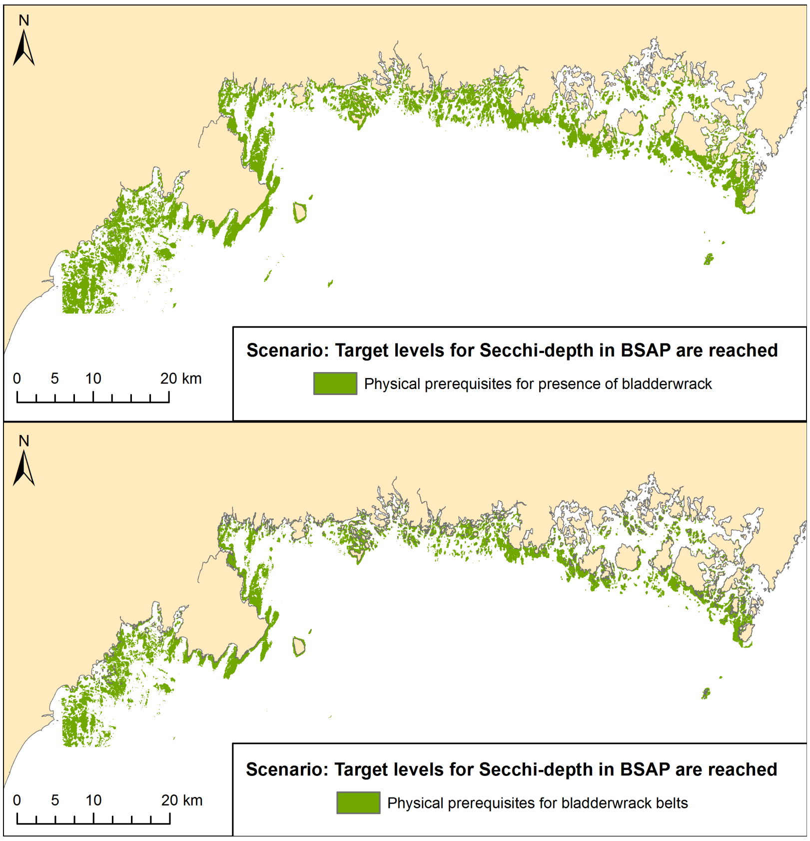

Figure 76. Calculated areas available to bladderwrack (upper) and bladderwrack belts (lower) in the scenario where the target level for HELCOM BSAP in the Baltic Proper is reached.

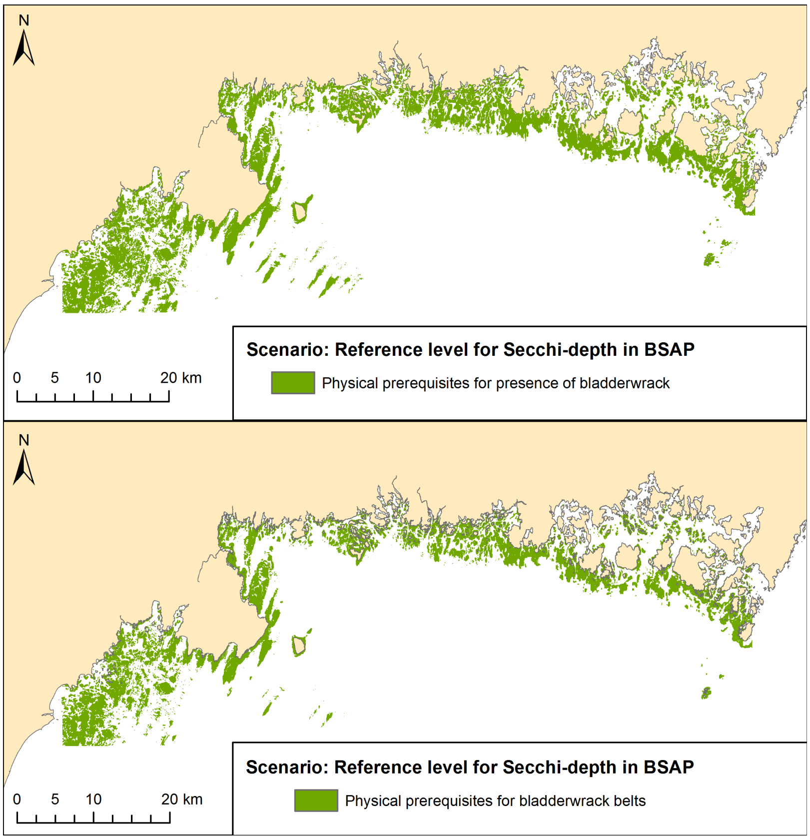

Figure 77. Calculated areas available to bladderwrack (upper) and bladderwrack belts (lower) in the scenario for reference levels of HELCOM BSAP.

9.1 Discussion

The results are based on changes applied to modelled and generalized layers but provide hints on the effects of changed Secchi depth on bladderwrack in this area. Areas from this type of calculations do not correspond to the actual area covered by bladderwrack. The figures rather correspond to the seafloor area which lies within the physical demands of the species in this area with regard to seafloor substrate, wave exposure and light. The actual area covered by the species is most likely considerably smaller since the distribution is also limited by biological factors such as interspecific competition as well as other physical and chemical variables that were not included in this analysis. Distribution outside the physical boundaries presented in these scenarios is however unlikely (except occasional presense).

10 An ecosystem model of the benthic community in the Hanö Bight

10.1 Introduction

Many problems in ecology require an understanding of the relationships between variables; how they interact with each other, their relative importance and the responses that they induce. Partly, such relationships can be tested using classical statistical techniques such as analysis of variance (ANOVA) or multiple regression. However, interactions among and between species and the environment are naturally complex involving indirect effects and feedback loops which are difficult to investigate using traditional techniques.

Structural equation modelling (SEM) on the other hand is a multivariate technique that allows complex causal relationships to be interpreted from observed correlations between traits or groups of organisms and provides a means to test hypotheses on preconceived mechanistic pathways. It also provides a means to test theory in relation to varying spatial scales. This is a valuable trait because it allows us to test causal relationships that may have been derived from small scale experimental studies and apply them in a broader spatial context. Furthermore, SEMs are particularly well suited to large-scale community or population data sets and are very intuitive in terms of how we often conceive our study systems. The use of so called "latent variables" also enables immeasurable, more abstract variables to be incorporated in the model (e.g. "human impact" in Fig. 1); making it a very useful tool for communicating complex ecological relationships to e.g. competent authorities and management.

The aim of this study was twofold: first, we wanted to test the ecological relevance and the relative importance of the independent variables being used as input for the benthic indicators (see Martin et al. 2015) by using a more holistic approach that includes relationships across trophic levels and different types of communities. Second, we wanted to test our current theoretical understanding of ecosystem linkages and apply them on a larger spatial scale.

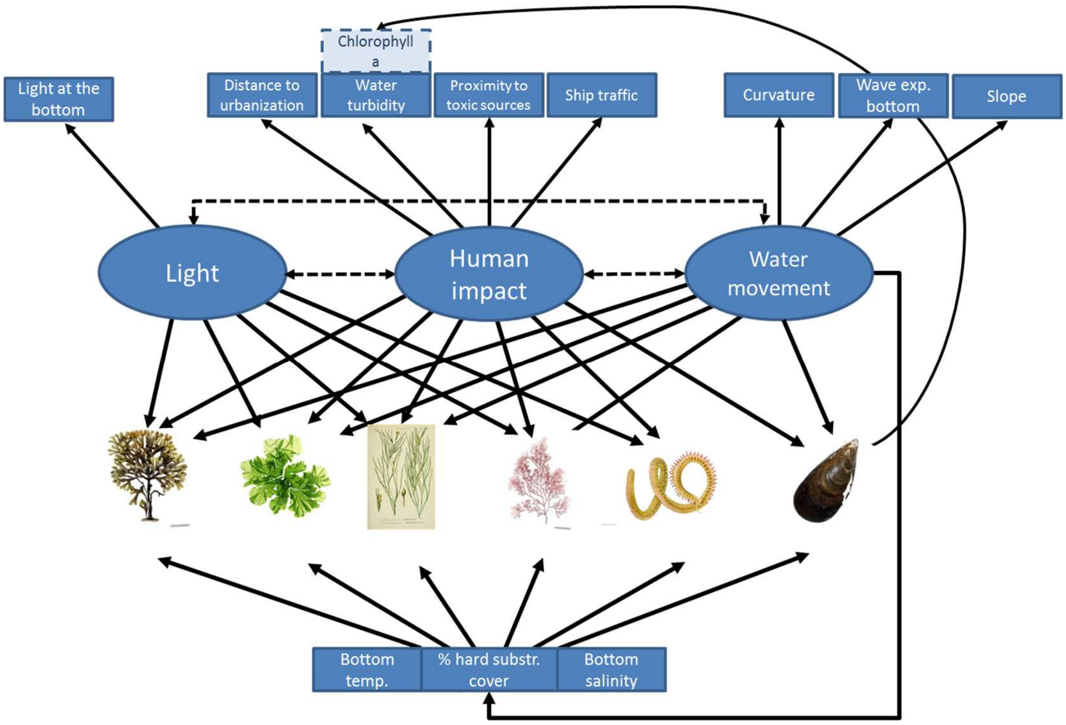

Figure 78. The figure illustrates the initial, saturated conceptual model including all ecologically relevant linkages from which nested conceptual models were constructed. "Chlorophyll a" (light blue rectangle) was used in models without "Water turbidity" due to too high intercorrelation. Ovals represent latent variables and rectangles, measured variables. Response variables are depicted by images and are as follows from the left: brown algae, green algae, rooted aquatic plants, red algae, a polychaete worm (*Marenzelleria sp.*) and blue mussels (*Mytilus edulis*).

10.2 Methods

To model the benthic community in the Hanö bight we used abundance data of representative taxonomic groups measured as percent coverage of brown, green and red algae, rooted aquatic plants, and blue mussels (*Mytilus edulis*) while the density of a burrowing polychaete (*Marenzelleria sp.*) was expressed as number of individuals per m^2 (sediment samples).

We used a range of ecologically relevant variables as input to the model (Table 1). In cases where abundances were modelled to be used for the indicators (e.g. red algae and blue mussel cover), we used the variables that contributed the most in explaining the variance of those models (Table 35). All variables were log-transformed (log+0.1) to linearize relationships. Measured variables with a correlation higher than 0.4 or a variance infliction factor (VIF) higher than 2.5 where not used simultaneously in any model to prevent multicollinearity problems.

A series of conceptual ecosystem models were constructed using combinations of variables (Figure 79 and Table 35) and theoretically anchored relationships were constructed and evaluated according to standard criteria, i.e. $\chi 2$ p-value, comparative fit index (CFI) and standardized root mean square residual (SRMR). Model fit was considered poor if either of the criteria were below the threshold; 0.95 for CFI, 0.08 for SRMR and 0.05 for $\chi 2$ p-value (Schreiber et al. 2006). Insignificant manifest variables, i.e. variables that formed the latent constructs were sequentially removed to improve the fit. All modelling was performed in R (R

Development Core Team 2010) using the lavaan package v. 0.5-14 (Rosseel 2012).

Table 35. Variables used as input in the SEM

Predictor variable	Measured data?
Total cover of red algae	Yes
Mean bottom salinity 10th percentile	No
Mean bottom temperature 10th percentile	No
Curvature	No
Slope	No
Proximity to urban areas	Yes
Ship traffic index	Yes
Wave exposure at the bottom	No
Distance to environmentally hazardous areas	Yes
% hard bottom	Yes
Total cover of blue mussels	Yes
Total cover of green algae	Yes
Total cover of brown algae	Yes
Secchi depth (reversed to mean turbidity)	Yes
Mean chlorophyll a concentration	No
Marenzelleria density in the sediment	Yes
Total cover of submerged vascular plants	Yes
Light intensity at the bottom	No

10.3 Results and Discussion

The most parsimonious model with the best fit explained red algae abundance well (r^2 = 0.70) while variance explained was lower for the other groups (r^2 = 0.23-0.42) except for green algae where r^2 was very low (0.09). However, the exclusion of green algae from the model resulted in a generally worse fit implying the inclusion of green algae is in spite of the low degree of explained variance. The reason for this poor fit could be explained by sparse green algae cover in the study area.

Available light at the bottom had a strong effect on all plants but the effect on red algae was relatively weak (Figure 80). The availability of suitable substrate (soft sediment for vascular plants and *Marenzelleria*, hard substrate for algae and blue mussels) was generally very important, especially for red algae, blue mussels and vascular plants. The amount of hard substrate was in turn mediated by the latent variable “water movement” that contained both curvature and bottom wave exposure. This makes sense since both of these factors are probable to affect the magnitude of water being displaced along the bottom; thereby preventing fine sediment accumulation. “Water movement” also had a direct, negative effect on *Mytilus* abundance. Most mussels in the study area were found at intermediate depths of about 15-20 meters in the outer coastal areas (Figure 34) with decreasing abundances at shallower depths. High water movements at these shallow depths could prevent the permanent establishment of communities through abrasion (Keegan et al. 2013), which would explain the observed patterns. Abrasion or limited settling abilities due to strong water movement could also affect algal communities. This relationship was however not found. One explanation could be a limited spatial distribution of algae in relation to the “water movement” parameters. A weak gradient in abundances probably made it difficult for the model to pick up such patterns.

Light had a strong effect on *Marenzelleria* densities. This effect was however spurious as there is no biological reason for light to be of importance. A more plausible explanation is that "light" in this particular case represents both substrate and food availability in contrast to "% hard substrate" that merely is a substrate indicator. Since "light at the bottom" is a function of both Secchi depth and depth itself, it acts as a proxy for sediment and particulate organic matter accumulation, which further is supported by the fact that there was a positive effect of "water turbidity" (the inverse of Secchi depth) on *Marenzelleria* density. With *Marenzelleria* being a deposit feeder, it is actually not surprising that a proxy for substrate and food availability had such a large influence in the model.

Human pressures approximated by "water turbidity" and "environmentally hazardous areas" only showed linkages to red algae (-), blue mussels (-) and *Marenzelleria* (+) (Figure 80). The positive influence of human impact on *Marenzelleria* may seem counterintuitive at first but both observational and experimental data suggest that *Marenzelleria* has an especially high tolerance to polluted sediments (Granberg et al. 2008, Florén et al. 2012) as well as bottom hypoxia (Schiedek 1997, Norkko et al. 2012). In fact, removing "human impact" from the model resulted in substantially worse fit (Figure 81). The exclusion of anthropogenic pressures did however not change the parameter estimates very much (Figure 80 andFigure 81); indicating that the overall model is robust and that the effect of "human impact" is reliable, not being an artefact of collateral correlations with other variables such as wave exposure or depth.

Mytilus on the other hand, was affected negatively by "human impact" which could be attributed to its sensitivity to a range of chemicals of anthropogenic origin. For instance, it is known that several pesticides and antifouling copper compounds prevent byssus thread formation, thereby preventing mussels to adhere to the substrate (Roberts 1975, Davenport and Redpath 1984).

10.4 Concluding remarks

The robust contribution of "human impact" on *Marenzelleria* density is interesting because it gives weight to previous data on the correlations between *Marenzelleria* presence and environmental pressures such as nutrient loads and environmentally harmful point sources (Hedman et al. 2008, Florén et al. 2012). Those studies however, were either small scale experiments or purely data-driven single species models with a predictive more than mechanistic purpose.

The significance of input variables was also very similar between the SEM and the random forest (RF) models used to predict the spatial cover of biota, even though completely different approaches were used (

Table 14). While the RF models ignored the actual biological or environmental drivers behind the distribution of biota, the SEM incorporated information from multiple sources and integrated it in a mechanism-driven framework.

By the use of a relatively large and comprehensive data set with good spatial coverage we have been able to test fundamental mechanistic pathways as well as the influence of important anthropogenic pressures in a more holistic and ecosystem-like setting than before. The application of this model to other geographical areas could provide valuable information on the generality of these pathways.

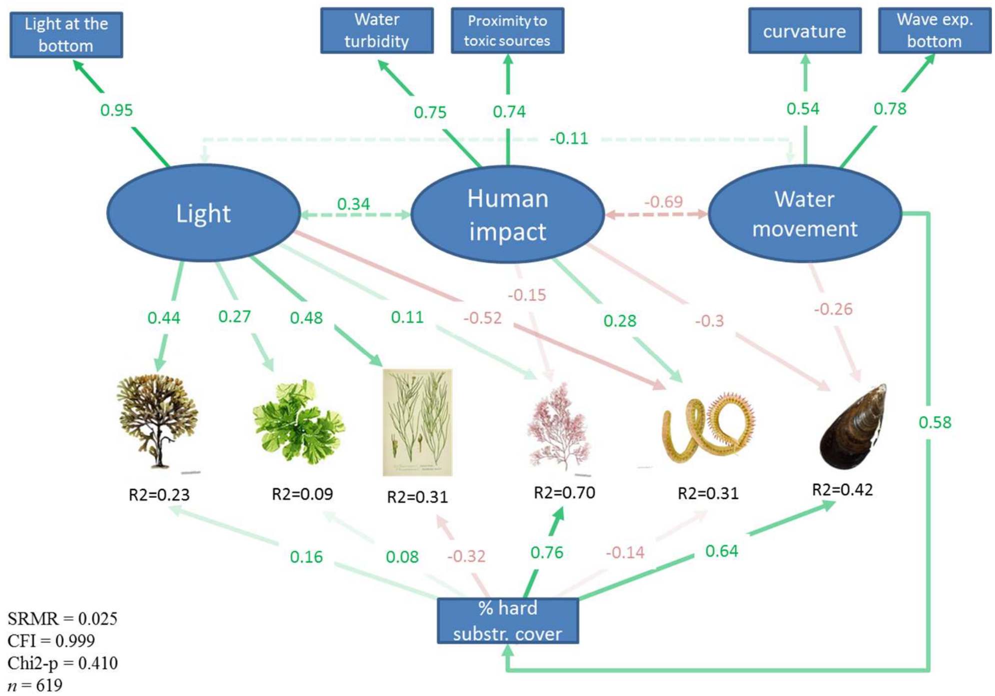

Figure 79. SEM-model depicting significant pathways and correlations between environmental variables, anthropogenic pressures and the benthic community in the Hanö bight. Ovals represent latent variables and rectangles, measured variables. Response variables are depicted by images and are as follows: (from the left) brown algae, green algae, rooted aquatic plants, red algae, a polychaete worm (*Marenzelleria sp.*) and blue mussels (*Mytilus edulis*). The color intensity of the arrows corresponds to the relative strength of the relationship. Numbers show the standardized estimates. Green arrows = positive relationship and red arrows = negative relationship. Double-headed, dashed arrows indicate a correlation without causation. Single headed arrows imply causal relationships. Residual correlations between response variables are not shown for simplicity.

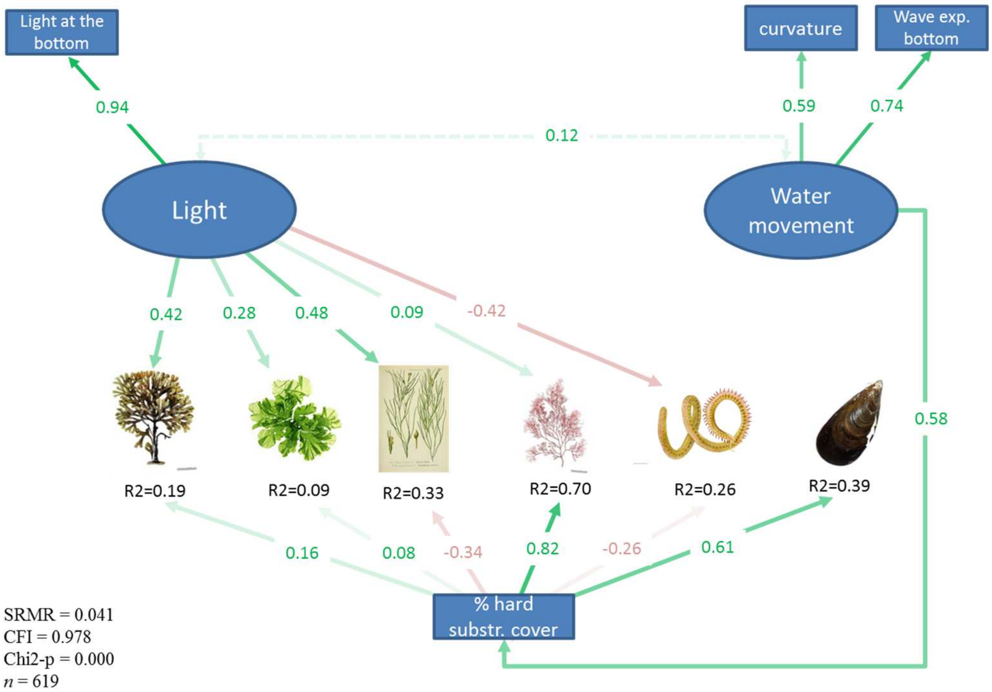

Figure 80. SEM model as in Fig.1 but without the influence of "human impact". Little change in the parameter estimates indicates a robust model and partitioning of variances (no multi-collinearity problems).

11 Ocean zoning

Ocean zoning is a spatial separation of regulatory measures, which are used to implement spatial marine plans. By dividing an area into zones one specifies the human use which is permitted in all parts of the area (Agardy 2010). Spatial planners can use zoning to integrate the planning of different activities and interests, such as aquaculture, wind farms, fishing and conservation of natural values.

The decision support tool Marxan with Zones (version 2.01.) (Watts et al. 2009) was used to create a proposal for a network of marine protection areas in the Hanö Bight tailored to national marine planning in Sweden. The study area (Figure 81) was limited against the coastline according to the area used for national MSP in Sweden, i.e. a nautical mil off the baseline (Prop. 2013/14: 186).

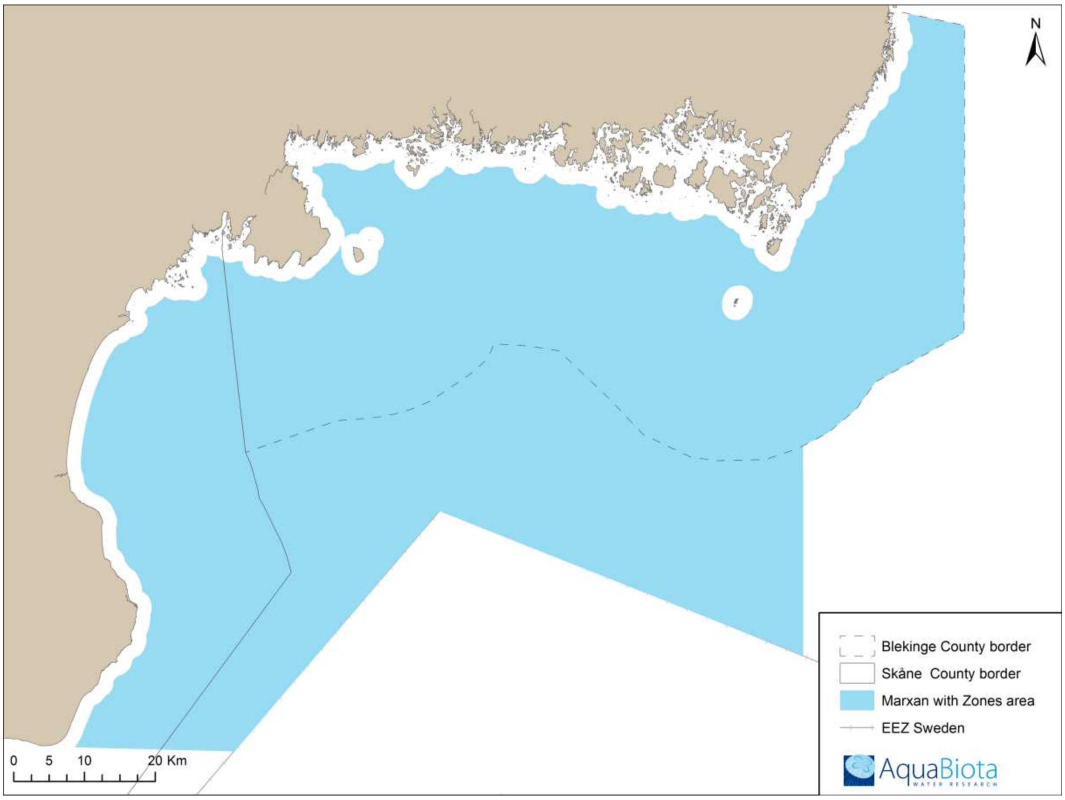

Figure 81. The area in which a Marxan with Zones analysis have been performed. The white coastal area represents the coastal area one nautical mile outside the Swedish baseline and is not included in the analysis.

11.1 Method

11.1.1 Marxan with Zones

Marxan with Zones is an analytical software used to weigh various interests against each other in a spatial perspective in the most effective way possible. The software's algorithm strives to achieve targets for spatial protection while minimizing conflicts between the protection and various interests for use of the area, resulting in a basis for spatial planning (Watts et al. 2009). For this to be possible the conservation values must be identified spatially and their needs for protection, i.e. their protection target, must be quantified. A target could, for example, be that 30 % of an important biotope's distribution area is within a protection zone. Based on a planning strategy from what and how these values should be protected, the user defines a number of zones and objectives for these. It may e.g. be a zone with the goal of creating undisturbed environments for some species or designate space to protect the natural environment and promote outdoor activities. Additional, spatial data is needed to describe the activities that are considered to be in conflict with the zone objectives. The level of conflict is also established by the user. Marxan with Zones then creates a zone configuration that (hopefully) achieves the targets for protection while minimizing the sum of conflicts.

All Marxan with Zones analyses were done using Zonae Cognito (Version 1.74) (Segan et al. 2011). Detailed explanations on how Marxan with Zones and Zonae Cognito works, has been provided by Watts et al. (2009) and Segan et al. (2011). In order to ensure stable and logical analyses each scenario is calibrated individually according to Ardron et al. (2010).

11.1.2 Spatial resolution

The analysis is run on a grid of hexagons (even if the input data have higher resolution), each of which constitutes an individual analysis unit. The size of hexagons was set to 3 km^2, which was considered appropriate for MSP at Swedish national level[4].

11.1.3 Conservation values and targets for protection

The zoning was designed as a suggestion of MPAs for the conservation values that were mapped in the study area, i.e. toothed wrack (*Fucus serratus*), red alaga *Furcellaria lumbricalis*, red algae species *Coccotylus truncates/Phyllophora pseudoceranoides*, blue mussel (*Mytilus Edulis*), baltic clam (*Macoma Baltica*), polychaete species *Marenzelleria* spp., as well as crustaceans *Monoporeia affinis/Pontoporeia femorata* and *Bathyporeia* spp. as well as two concentration areas for wintering long-tailed ducks of 20 respectively 75 individuals/km^2 (Section 5) (see Table 36 and Annex 3). A focus on species rather than species groups (such as perennial red algae) was chosen to escape the duplication of species that was included in several species maps.

The analysis was done in three scenarios with different protection targets, expressed as precentage, for the conservation values (Table 36). In scenario 1 and 2 all conservation values were given identical protection targets within each scenario, of 10 % vs. 20 %. In scenario 3 the conservation values were given individual protection targets. The protection target of 20 % from Scenario 2 was retained for toothed wrack and red seaweed, while the red algae were lowered to 10 %. The latter's species distribution maps (red algae) were predicted with lower probability than any other vegetation (Section 6.1) and were therefore given a somewhat lower protection targets to compensate for uncertainties in the prediction. The red algae species were not identified as a biotope in the conservation value assessment (Section 7.5.1), because it was never dominant in any individual survey station. Also the blue mussels were assigned a protection target of 10 %. The species is of great importance to the marine ecosystem of the area (Section 7.5.2), but occurs at the same time over a large area (Figure 34). The other invertebrate benthic fauna was assigned protection targets of 5 %, except *Marenzelleria* spp., which was assigned a value of 2 %. The need for

[4] Discussed with representatives at the Swedish Agency for Marine and Water Management (SwAM).

spatial protection of the benthic animals the Hanö Bight area was not assessed as particularly large since the main threats to these species are likely to be diffuse effect of eutrophication and pollution, which are badly dealt with through spatial protection. *Marenzelleria* spp. has also been identified as one of the invasive species in the Baltic Sea that has had the greatest impact on the ecosystem (Ojaveer and Kotta 2014). The highest protection targets in Scenario 3 were assigned to the long-tailed duck because of its threat status and the fact that the Hanö Bight area is a nationally important area for the species (Nilsson 2011). The areas with high concentrations of long-tailed ducks were given a protection target of 100 % and the medium concentration areas a target of 20 % to create a buffer adjacent to the high concentration area.

All other settings in the analysis were equal for all three scenarios, except for those associated with the calibration of the assay.

Table 36. Conservation values for which proposals of spatial protection were developed as well as the established protection targets for three different scenarios. Protection targets are expressed as the percentage of the conservation values' total distribution within the study area.

Conservation value (map layer)	Protection target, scenario 1	Protection target, scenario 2	Protection target, scenario 3
High or very high predicted probability of presence of toothed wrack (*Fucus serratus*)	10 %	20 %	20 %
High or very high predicted probability of over 25 % cover of red algae *Furcellaria lumbricalis*	10 %	20 %	20 %
High predicted probability of presence of red algae species (*Coccotylus truncates / Phyllophora pseudoceranoides*)	10 %	20 %	10 %
High or very high predicted probability of over 25 % cover of blue mussels (*Mytilus edulis*)	10 %	20 %	10 %
High or very high predicted probability of over ≥ 500 individuals/m^2 of baltic clam (*Macoma balthica*)	10 %	20 %	5 %
High or very high predicted probability of over ≥ 300 individuals/m^2 of polychaete species Marenzelleria spp.	10 %	20 %	2 %
High or very high predicted probability of over ≥ 300 individuals/m^2 of crustaceans *Monoporeia affinis / Pontoporeia femorata*	10 %	20 %	5 %
High or very high predicted probability of over ≥ 100 individuals/m^2 of crustaceans *Bathyporeia* spp.	10 %	20 %	5 %
Medium concentration (at least 20 individuals/km^2) area of wintering long-tailed ducks (*Clangula hyemalis*)	10 %	20 %	20 %
High concentration (at least 75 individuals/km^2) area of wintering long-tailed ducks (*Clangula hyemalis*)	10 %	20 %	100 %

11.1.4 Human activities

The following describes the map layers of human activities that were included in the analysis.

11.1.4.1 Military

Large areas in the Hanö Bight are used as military firing ranges. There are also several military risk areas above marine water from the firing ranges on land, an explosive area under water and a smaller dumping area (Figure 82). Such activities may induce surface and underwater noise, seafloor contamination and physical seafloor disturbance. An investigation conducted in the Hanö Bight in 2013 couldn't show any contamination of the marine coastal organisms caused by firing ranges on land. It does however also conclude that more extensive researches of the effects of the firing ranges may be needed to make a full evaluation (SwAM 2013a).

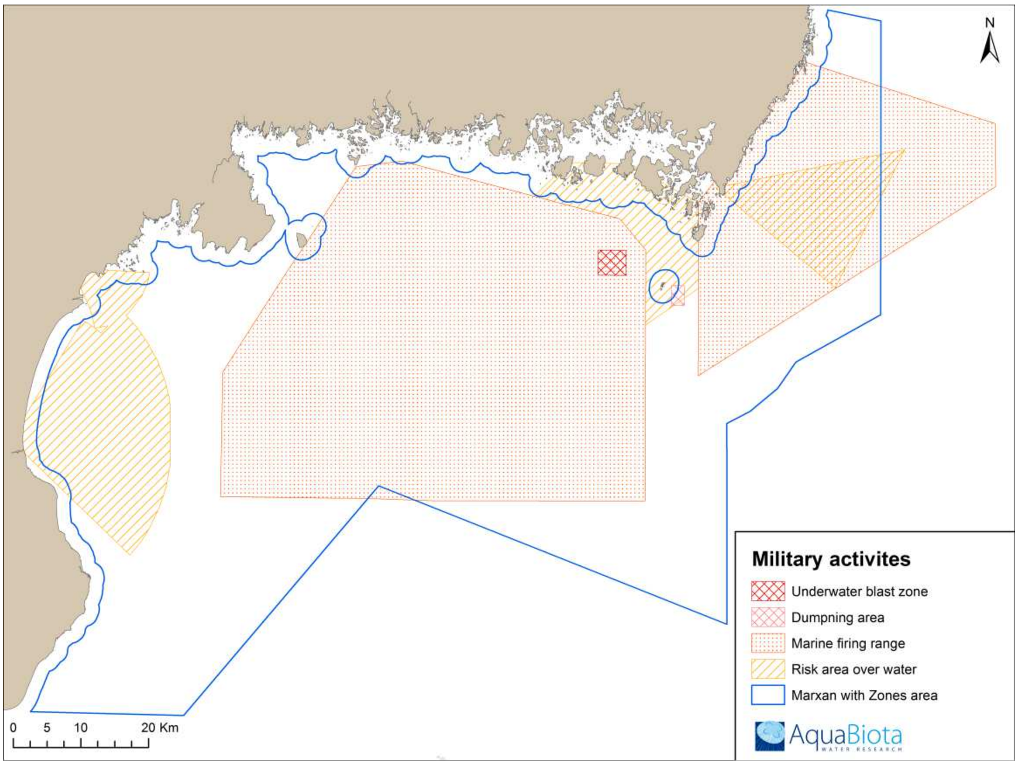

Figure 82. Areas designated for military activities in the Hanö Bight.

11.1.4.2 Shipping

Compiled vessel data and anchorage sites were available through a mapping of influencing factors on the marine environment (SEPA 2010b). The vessel data was based on density analyses of ship routes from Automatic Identification System (AIS) data and had been divided into five classes; (1) no or very sparse traffic, (2) moderate traffic, (3) frequent traffic, (4) dense traffic and (5) constant traffic (SEPA 2010b). The classes 3-5 were used separately in the analysis (Figure 83).

Marine traffic can cause seafloor disturbance and noise levels that effect marine life (Hildebrand 2009, Eriksson et al. 2004, Sandström et al. 2005, Sundblad and Bergström 2014, Popper et al. 2014). Oil spills are also a possible negative effect for marine life. Larsson (2006) argues that illegal oil spills is a substantial threat to the European long-tailed duck population. Only within the Baltic Sea, tens of thousands and in some years hundreds of thousands long-tailed ducks die each year by oil spills. Anchorage sites are often visited by more marine vessels than their nearby areas and are therefore also associated with the disturbances.

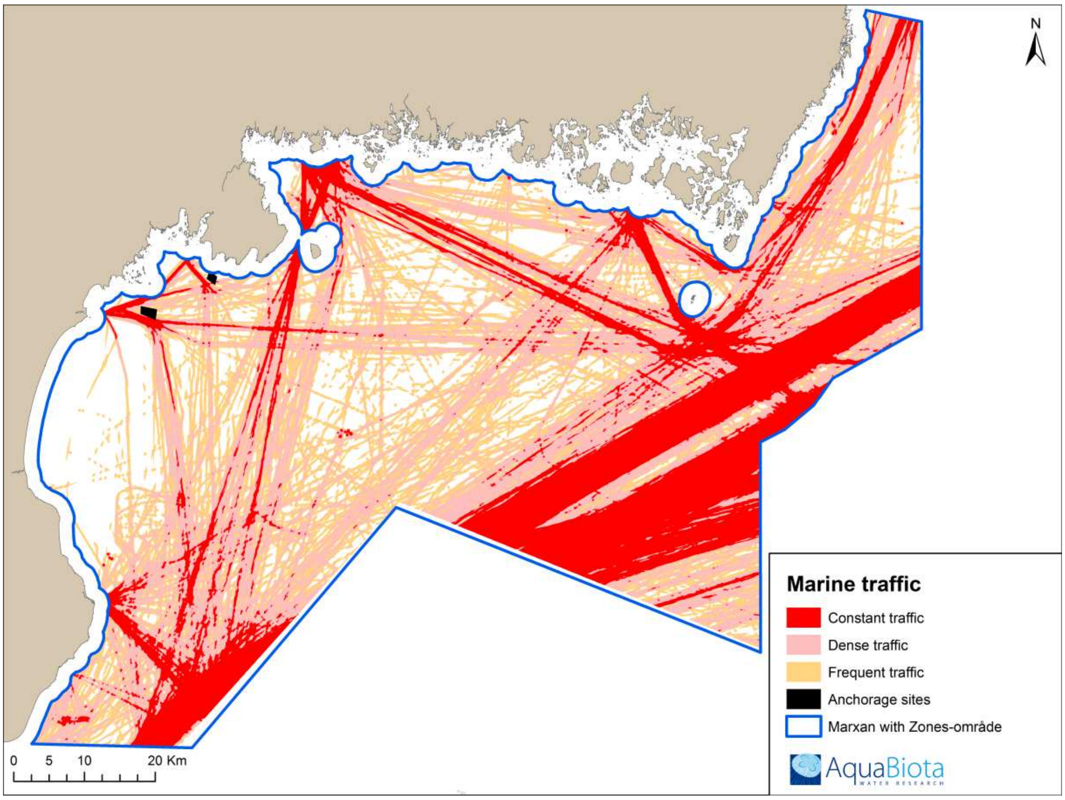

Figure 83. Marine traffic and anchorage sites. The map is based on data from a mapping of influencing factors on the marine environment (SEPA 2010b).

11.1.4.3 Wind farms

There is currently only one small wind farm established in the study area but may change significantly in the future. Permission is already granted for the construction of 30 wind turbines in in Kalmar Strait, and another 83 wind turbines south west Hanö Bight (Taggen). A construction of an additional 700 wind turbines (Blekinge Offshore) is currently undergoing review by the Land and Environment Court of Appeal. The wind farms' positions can be seen in Figure 84.

All existing and planned wind farms as well as those still undergoing permit matter were treated equally in the analysis. The map data is based on national interests for energy, since these correspond with the wind farms actual positions.

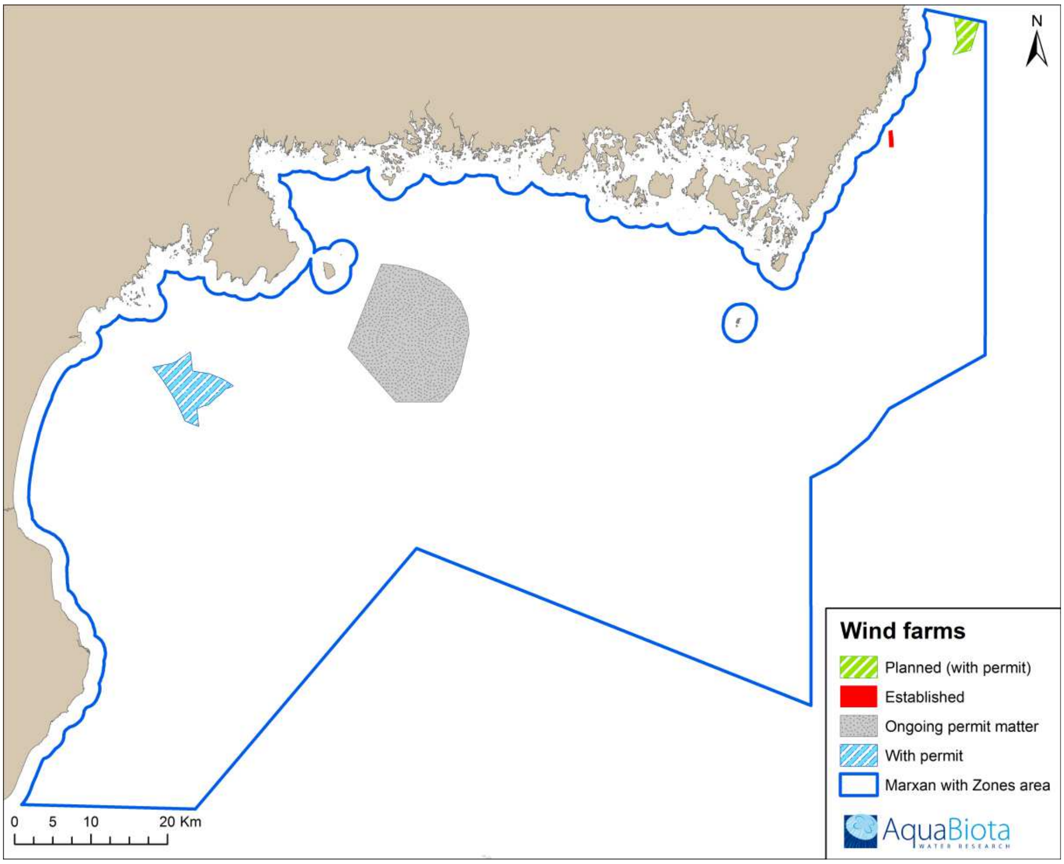

Figure 84. Wind farms in the Hanö Bight and Blekinge County.

11.1.4.4 Fishing

Map layers used for the description of the fishing industry in the study area was derived from a survey of VMS and logbook data for years 2007-2009 (SwAM 2013b). These layers describes catch in kg per year (average for 2007-2009) divided into different gear types (Figure 85). The lowest values (≥10% of the average catch) were removed to identify where it is most important to preserve the fishery, and where the pressure is the hardest. The limit was chosen by splitting the catch values into 32 natural breaks and visually examines the fishing stocks.

The impact of fishing on the conservation values included in this analysis varies between the different gear types. Bottom trawls make the most damage to the seafloor environments, although also other gear types with seafloor connection, such as yarn and fyke nets, can to some extent have negative effects (SwAM 2013b).

Bycatches of birds, fish and mammals is another negative impact of the fishing industry (Korpinen and Braeger 2003, Österblom et al. 2002, Lunneryd et al. 2004). In the Baltic, gillnet fishing is the fishing method where most birds accidentally get caught. The long-tailed duck is a species that is often reported as bycatch and which can be caught in significant quantities in relation to its population size (SwAM 2013b, Larsson 2006).

Just like other marine traffic, fishing vessels also generates over- and underwater noise that can interfere with marine life.

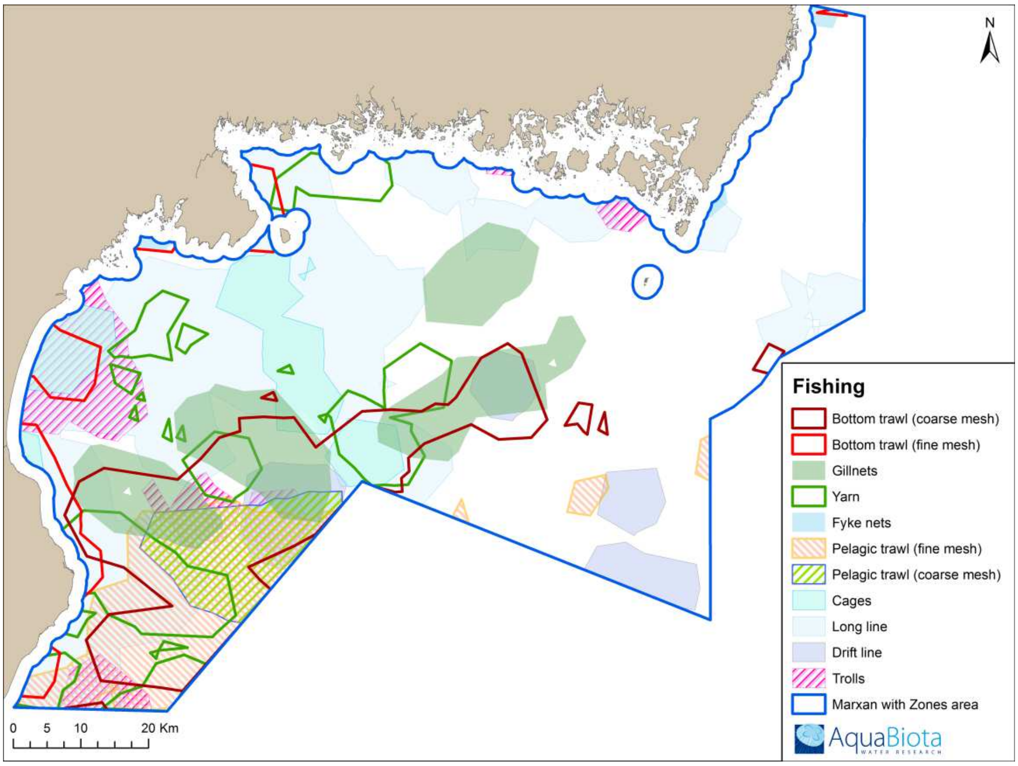

Figure 85. Fishing activities based on the mean landing data between year 2007 and 2009 and VMS positions (SEPA 2013b).

11.1.4.5 Areas of national interest

Several areas in the Hanö Bight have been identified as areas of national interest for commercial offshore fishing, harbours, maritime activities, outdoor activities and highly exploited coasts (Figure 86). There are also areas of national interest for energy, but since these are included as representatives for actual planned or present wind farms (Section 11.1.4.3), they were not doubled in the analysis. Designated areas of national interests give priority support to municipalities and County administrative Boards in decisions on land use changes.

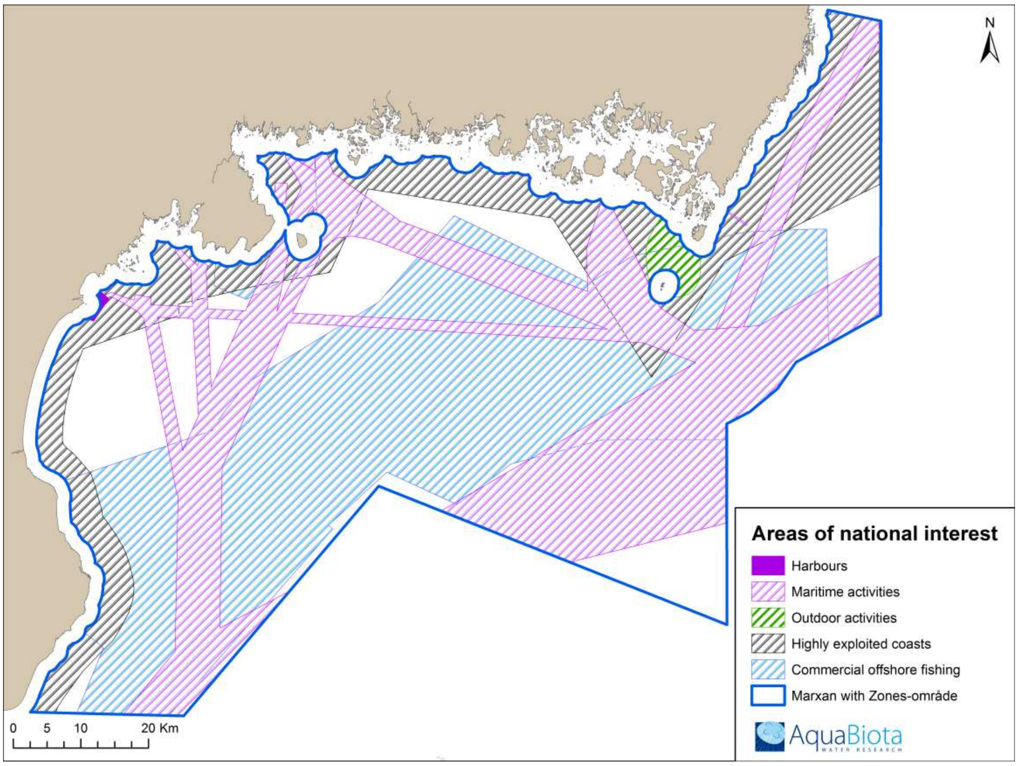

Figure 86. Areas of national interest.

11.1.5 Zones

A three-point scale was used for marine protection zones; moderate, medium and strict protection. The objective of the strict protection zone was to designate areas with minimal disturbance from human activities. The zone for a medium level of protection was primarily focused on preventing seafloor disturbance and the zone with moderate protection aimed to prevent heavy seafloor disturbance. In the moderate protection zone modest variants of seafloor disturbance was allowed. In addition to the three protected zones there was a zone for the areas not covered by any spatial protection.

The level of conflict between the activities and the objectives of the zones were defined on a relative scale (Table 37). These values were used as a basis for limiting the selection of a zone in areas where a conflicting the activity is conducted, also called penalty values. E.g. military blast zones under water have a high level of conflict and limitation value in all three protection zones (Table 37). This means that other areas will be chosen as MPAs, provided that the other areas are sufficient to achieve the protection targets for the conservation values and that they are not associated with even higher limitations.

The level (percentage) that each zone contributes to the protections targets for each conservation value is defined based on the zone objectives and limitations of activities (

Table 38). A proportion of 50 % means that a twice as large area needs to be protected compared a proportion of 100 % to achieve the same level of protection.

To create a buffer adjacent to the higher levels of protection a penalty value as used for various zones to be adjacent to one another. The fee was designed in such a way so that Marxan with Zones was guided toward aggregating the planning units (hexagons) of the same zone together as well as striving toward placing zones close to each other in the protective scale (none, moderate, medium and strict protection) adjacent to each other.

Table 37. The level of conflict between human activities and objectives of protection zones used as a basis for limiting the selection of a zone in areas where a conflicting the activity is conducted. The conflict / limitation is specified in a color scale, where dark blue means "high conflict / high limit" and white means "no conflict / no limit."

	Activity	No protection	Moderate protection	Medium protection	Strict protection
Military	Underwater blast zone				
	Military dumping area				
	Marine firing range (marine)				
	Risk area over water				
Shipping	Anchoring sites				
	Constant traffic				
	Dense traffic				
	Frequent traffic				
	Wind farms				
Fishing	Bottom trawl (coarse mesh)				
	Bottom trawl (fine mesh)				
	Gillnets				
	Yarn				
	Fyke nets				
	Pelagic trawl (fine mesh)				
	Pelagic trawl (coarse mesh)				
	Cages				
	Long Line				
	Drift lines				
	Trolls				
Areas of national interest	Commercial offshore fishing				
	Harbours				
	Maritime activities				
	Outdoor activities				
	Highly exploited coasts				

Table 38. The level (percentage) that each zone contributes to the protections targets for each conservation value is defined based on the zone objectives and limitations of activities. A proportion of 50 % means that a twice as large area needs to be protected compared a proportion of 100 % to achieve the same level of protection.

Conservation value (map layer)	No protection	Moderate protection	Medium protection	Strict protection
High or very high predicted probability of presence of toothed wrack (*Fucus serratus*)	0 %	20 %	50 %	100 %
High or very high predicted probability of over 25 % cover of red algae (*Furcellaria lumbricalis*)	0 %	20 %	50 %	100 %
High predicted probability of presence of red algae species (*Coccotylus truncates / Phyllophora pseudoceranoides*)	0 %	20 %	50 %	100 %
High or very high predicted probability of over 25 % cover of blue mussels (*Mytilus edulis*)	0 %	20 %	50 %	100 %
High or very high predicted probability of over ≥ 500 individuals/m^2 of baltic clam (*Macoma balthica*)	0 %	20 %	50 %	100 %
High or very high predicted probability of over ≥ 300 individuals/m^2 of polychaete species Marenzelleria spp.	0 %	20 %	50 %	100 %
High or very high predicted probability of over ≥ 300 individuals/m^2 of crustaceans *Monoporeia affinis / Pontoporeia femorata*	0 %	20 %	50 %	100 %
High or very high predicted probability of over ≥ 100 individuals/m^2 of crustaceans *Bathyporeia* spp.	0 %	20 %	50 %	100 %
Medium concentration (at least 20 individuals/km2) area of wintering long-tailed ducks (*Clangula hyemalis*)	0 %	20 %	50 %	100 %
High concentration (at least 75 individuals/km2) area of wintering long-tailed ducks (*Clangula hyemalis*)	0 %	0 %	0 %	100 %

11.1.6 Presentation of results

Marxan with Zones's algorithm uses a random stepwise parameter which generally includes multiple runs in each analysis, all of which generates a single zone configuration (Grantham et al. 2013, Watts et al. 2009). Every zone configuration is given different evaluation scores, such as effectiveness and levels of conflict. This results in a wide array of information that is presentable many different ways. The sum of the penalty values given for loss of effectiveness, conflict, unwanted zone neighbouring and/or poorly aggregated planning units, also referred to as the run's evaluation score, can be used to determine which execution is most optimal, i.e. meeting the protection targets while minimizing conflicts. It is recommended to not only consider the zone configuration with the best (i.e. lowest) evaluation score, since it may not be practically feasible. There may be several other runs with similar evaluation scores which are easier to implement (Ardron et al. 2010). The zone configuration with the best evaluation score and one designed based on the modal value in each planning unit of the 10 configurations with the best evaluation score is presented for each scenario. Additionally a suggestion for MPA candidates was created from the modal value in each planning unit of the zone configurations with the best evaluation score for each scenario, i.e. the three scenarios were merged into one map.

It may also be interesting to look at the planning units that often are chosen as part of a good solution based on all or several runs in an analysis, further referred to as selection frequency. This can be used to assess how useful a planning unit is to create an effective zone configuration in a given scenario, which in turn can facilitate prioritization. However, it is important to emphasize that it does not correspond to a zone configuration that meets the criteria for a given scenario, but is more intended as additional information (Ardron et al. 2010). Moreover, generally all runs in an analysis contribute equally to the selection frequency. Highly efficient solutions in which all targets are met contribute equally to inadequate solutions in which all targets have not been met. This means that the planning units often selected are not necessarily a part of the most effective solutions (Fischer and Church 2005, Ardron et al. 2010). To avoid this, the selection frequency is only presented for the 10 runs with the best evaluation scores.

11.2 Results

All three scenario analyses used to create proposals for a network of marine protection areas national MSP in Sweden resulted in zone configurations that met their protection targets. When comparing the area chosen for each protection zone within the configurations with the best evaluation scores it's noted that the largest area of protection is mainly chosen to the moderate protection zone in all three scenarios (Table 39). In scenario 1 a total of about 11.6 % of the entire study area is assigned to a protection zone (9 % in the moderate protection zone and 1 % each for the medium and strict protection zones) in order to reach its targets for nature protection. Scenario 2 (protection targets of 20 % for all conservation values) is the scenario in which the largest areas have been assigned to spatial protection (approximately 17.6 % of the study area). In the zone configuration resulting from scenario 2 the protection is somewhat more evenly divided between the three protection zones. About 11 % is assigned to the moderate protection zone, 5 % to the medium protection zone and about 2 % to the strict protection zone. To reach the individually set protection targets in scenario 3 only 7 % of the study area needed to be assigned to a protection zone.

The level (zone) and amount (%) of spatial protection assigned to each conservation value per scenario is presented in Table 40. The amount of protection is expressed as percentage of each conservation values' spatial distribution; hence it's not possible to compare the area assigned to different conservation values based on this information. The division of conservation values within the zones is partly based on meeting protection targets set for each conservation value (Table 36). However, it is also based on overlaps between conservation values. As example, the protection targets set for the high concentrations of long-tailed ducks in scenario 2 was 20 %, which is met in the strict protection zone. But the zones moderate and medium protection is also assigned space within the conservation values' distribution area in order to meet targets set for other overlapping conservation values, giving the long-tailed ducks extra protection "for free".

The spatial distribution of zones in the runs with the best evaluation scores is quite different between the three scenarios (Figure 87). Briefly viewed, it is about the same areas proposed for protection, but the size and type of the zones differ. In scenario 1 the strict protection zone is dispersed in single planning units, while in scenario 2 it is more aggregated. In Scenario 3 is the strict protection zone is almost entirely placed in the high concentration area of long-tailed ducks (compare Figure 87 and Figure 15 in Annex 3). The selection frequency of the zones in the 10 runs with the best evaluation score (moderate protection; Figure 88, medium protection; Figure 89 and strict protection; Figure 90) follows similar spatial patterns.

The merged (modal value) zone configurations from each scenario are presented in Figure 91. The zones are a bit more evenly distributed, but still with some planning units assigned to protection zones without adjencent neighbours of the same or other levels of spatial protection.

Table 39. Zone distribution (%) of the configurations with the best evaluation score per scenario.

Zone	Scenario 1	Scenario 2	Scenario 3
Strict protection	1 %	2 %	2 %
Medium protection	1 %	5 %	1 %
Moderate protection	9 %	11 %	4 %
No protection	88 %	82 %	93 %

Table 40. The proportion (%) of each conservation value which occurs in the four different zones for three scenarios of Marxan with Zones analyses.

	Scenario 1				Scenario 2				Scenario 3			
Conservation value (map layer)	None	Moderate	Medium	Strict	None	Moderate	Medium	Strict	None	Moderate	Medium	Strict
High or very high predicted probability of presence of toothed wrack (*Fucus serratus*)	67 %	18 %	10 %	5 %	52 %	14 %	12 %	22 %	71 %	5 %	8 %	15 %
High or very high predicted probability of over 25 % cover of red algae (*Furcellaria lumbricalis*)	70 %	22 %	5 %	3 %	72 %	9 %	1 %	18 %	69 %	3 %	17 %	11 %
High predicted probability of presence of red algae species (*Coccotylus truncates / Phyllophora pseudoceranoides*)	74 %	16 %	7 %	3 %	54 %	22 %	16 %	7 %	77 %	13 %	6 %	4 %
High or very high predicted probability of over 25 % cover of blue mussels (*Mytilus edulis*)	75 %	16 %	3 %	5 %	57 %	21 %	13 %	9 %	75 %	4 %	2 %	18 %
High or very high predicted probability of over ≥ 500 individuals/m^2 of baltic clam (*Macoma balthica*)	65 %	30 %	2 %	3 %	44 %	35 %	16 %	5 %	85 %	12 %	0 %	3 %
High or very high predicted probability of over ≥ 300 individuals/m^2 of polychaete species Marenzelleria spp.	65 %	27 %	4 %	3 %	47 %	29 %	18 %	6 %	80 %	12 %	2 %	6 %
High or very high predicted probability of over ≥ 300 individuals/m^2 of crustaceans *Monoporeia affinis / Pontoporeia femorata*	66 %	28 %	4 %	3 %	46 %	32 %	17 %	5 %	84 %	13 %	1 %	2 %
High or very high predicted probability of over ≥ 100 individuals/m^2 of crustaceans *Bathyporeia* spp.	73 %	16 %	8 %	3 %	66 %	5 %	21 %	8 %	94 %	0 %	0 %	5 %
Medium concentration (at least 20 individuals/km^2) area of wintering long-tailed ducks (*Clangula hyemalis*)	64 %	21 %	5 %	10 %	48 %	19 %	13 %	20 %	73 %	6 %	1 %	20 %
High concentration (at least 75 individuals/km^2) area of wintering long-tailed ducks (*Clangula hyemalis*)	58 %	32 %	0 %	10 %	46 %	18 %	16 %	20 %	0 %	0 %	0 %	100 %

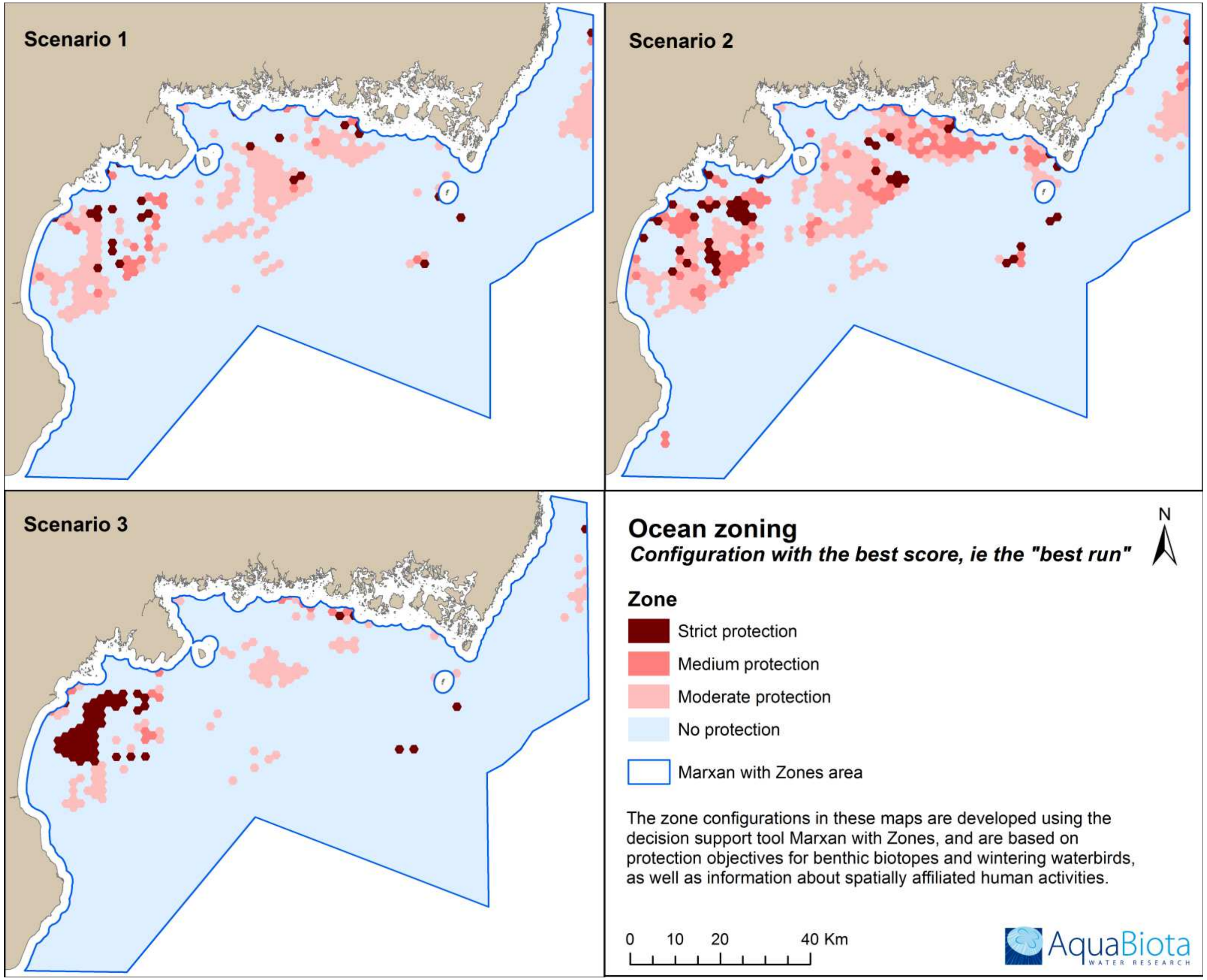

Figure 87. Zonation created through Marxan with Zones; runs with the best evaluation scores of three scenarios.

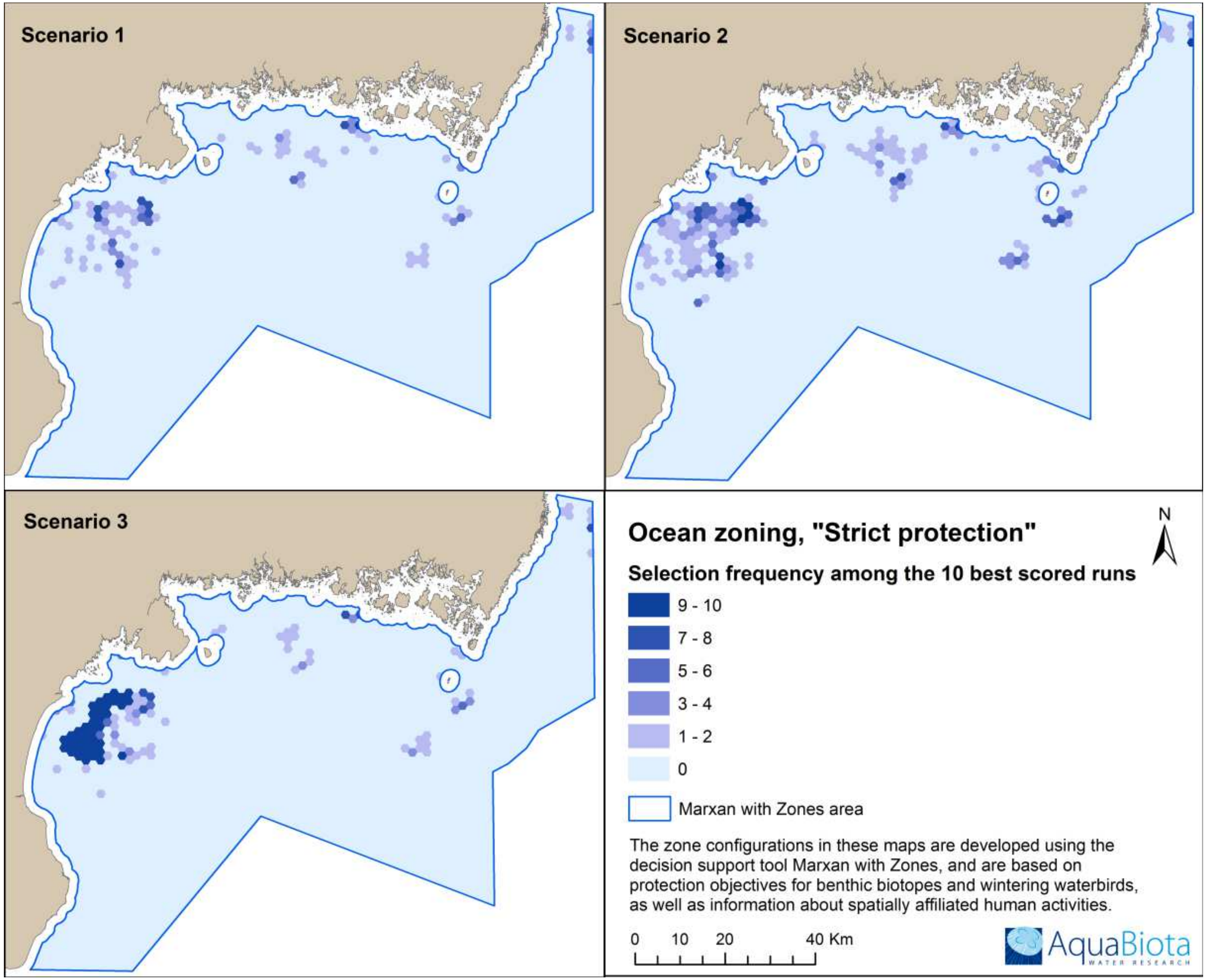

Figure 88. Zonation created through Marxan with Zones; selection frequency of the 10 runs with the best evaluation scores of three scenarios for the zone "Strict protection".

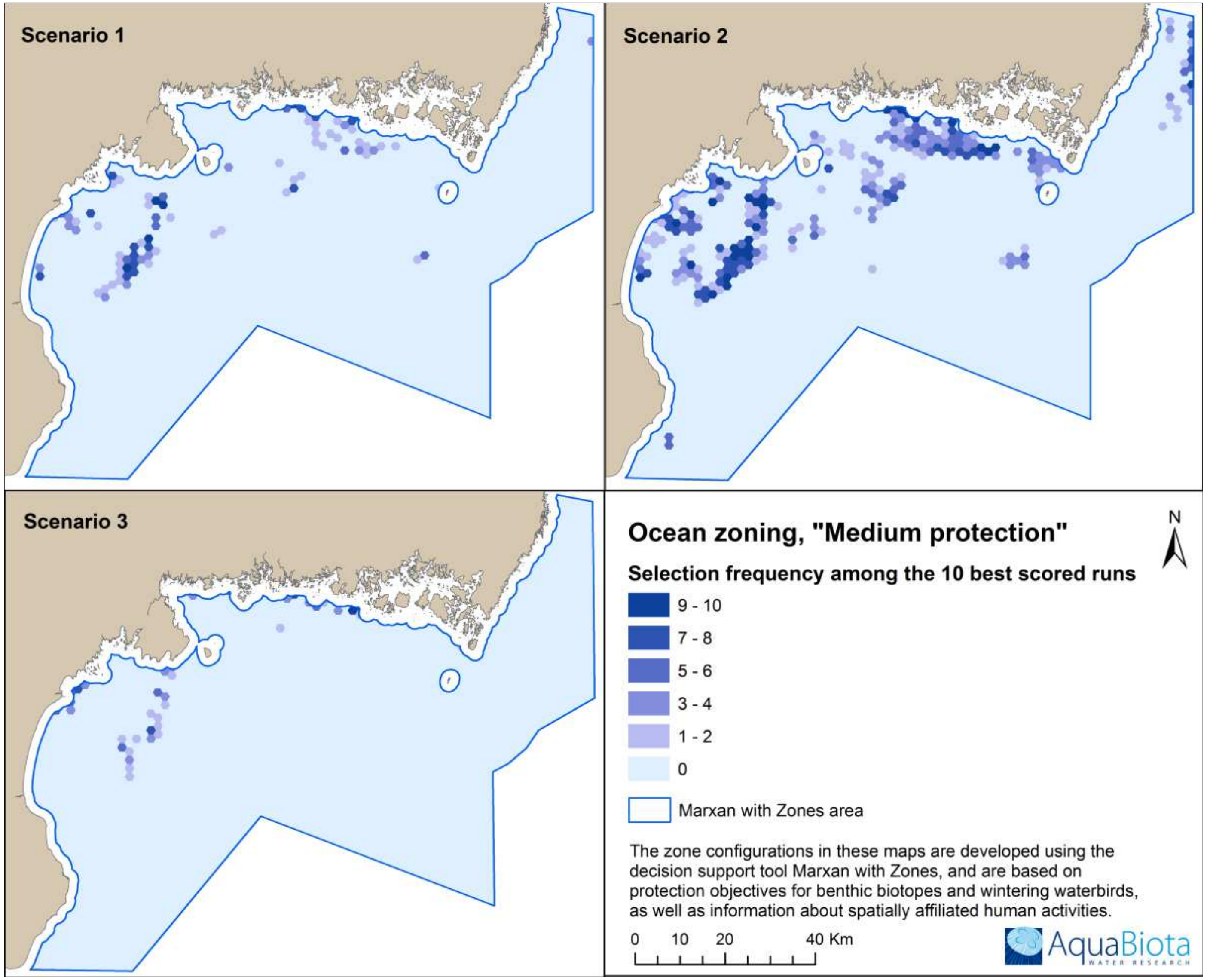

Figure 89. Zonation created through Marxan with Zones; selection frequency of the 10 runs with the best evaluation scores of three scenarios for the zone "Medium protection".

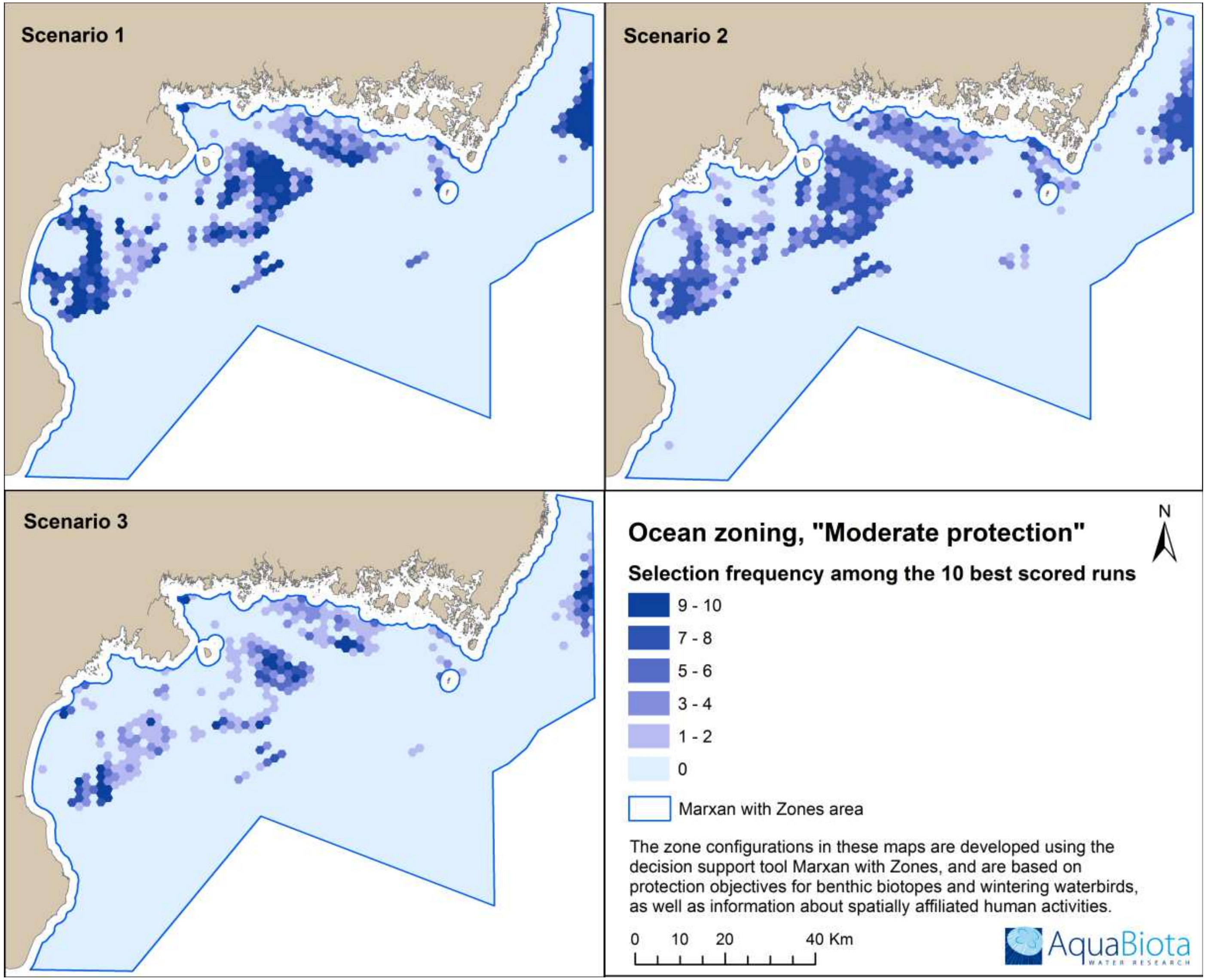

Figure 90. Zonation created through Marxan with Zones; selection frequency of the 10 runs with the best evaluation scores of three scenarios for the zone "Moderate protection".

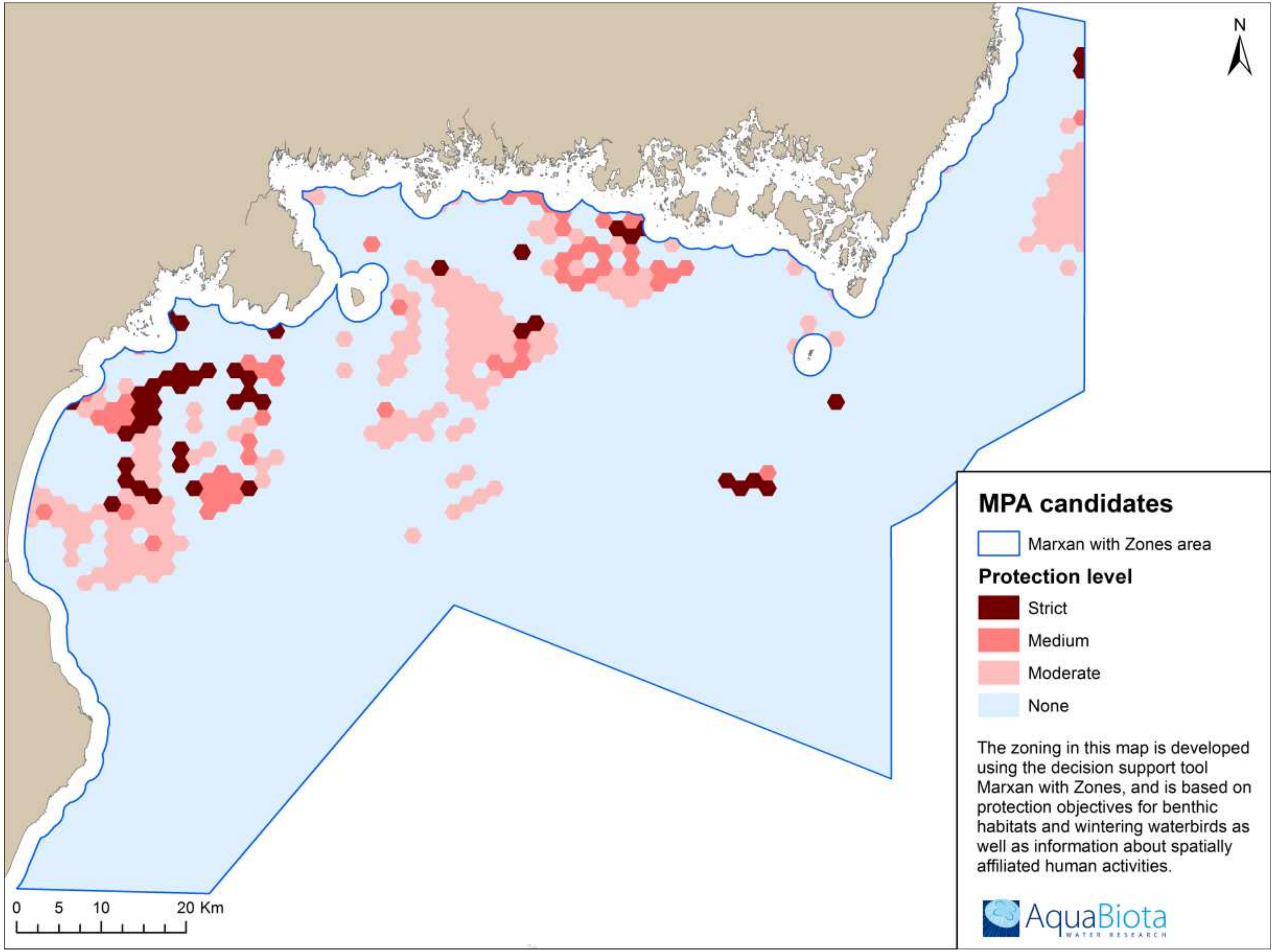

Figure 91. Suggestion for MPA candidates was created from the modal value of the zone configurations with the best evaluation score for three scenario in Marxan with Zones analyses.

11.3 Discussion

Marxan with Zones has proven to be an effective tool for managing, compiling and analysing information from a large number of spatially described natural and human-induced impacts in a structured way. The maps developed have provided several potential zoning opportunities and can serve as a good basis for MSP. Furthermore, it can be used for prioritization between areas considered for protection or identification of new MPAs. All scenarios resulted in MPAs within the municipalities' planning areas because many of the conservation values are located there. This result emphasizes the importance of coordination between the municipalities' and the national MSP in the areas where they overlap.

In the comparison of the runs with the best evaluation scores of the three scenarios, it's noted that in scenario 1, MPAs are proposed for an approximate total of 11.6 % of the study area, which is more than twice as much than the total area of the protection targets in the given scenario (Section 11.1.3 and Section 11.2). Even in scenarios 2 and 3 much larger areas are suggested as MPAs than the total area of the protection targets set in each scenario. This means that it in all scenarios it was more effective to avoid serious conflicts by assigning larger areas to a lower level of protection even though it contributes to less protection target fulfilment. The smallest spatial difference between total protection targets and analysis results was in Scenario 3, where a large part of the protection is concentrated on the strict protection zone to achieve the target of 100% protection of the high concentrations of long-tailed ducks. This area thus contributes to the protection of several other species (toothed wrack, red algae, blue mussels, *Marenzelleria* spp. and *Bathyporeia* spp.) predicted on the same surface as long-tailed ducks.

As already pointed out, the outcomes of Marxan with Zones is not a finalized zoning scheme for MSP, but more good basis for further discussions and specifications. The selection frequencies (Figure 88, Figure 89 and Figure 90) provide additional input to possible zone configurations, besides the best scored runs. It is recommended that all configurations be considered as possible solutions when assigning MPAs.

Today there are only small areas assigned as MPAs in the offshore areas included in the analysis; a nature reserve at Utklippan and a Baltic Sea Protected Area in Torhamns archipelago that extends out to Utklippan. The results of the Marxan with Zones analyses indicate a possible need for additional MPAs.

The amount of conservation values represented in this study is relatively comprehensive, although not all-embracing. Information about the distribution of areas important for life history stages of harbour porpoises and fish are examples of important information that was lacked. Further was the spatial data of benthic environments missing some valuable biotopes (Section 7.5). This might result in important conservation values being neglected in MSP processes.

There are some difficulties with assigning MPAs based on species-rich cells. If ranges of distribution of species, biotopes or habitat are used regardless of their abundance to identify MPAs that benefit multiple species, it might result in the protection of areas where many species occur randomly or in very small abundances, rather than core areas (Williams et al. 2014). It is therefore recommended that the layers used as conservation value maps in Marxan with Zones are describing core areas, rather than range of distribution. For the analyses in this study we used the maps of benthic species and species groups with the highest predicted presense available. However toothed wrack (*Fucus serratus*) and red algae (*Coccotylus truncates / Phyllophora pseudoceranoides*), had not been able to predict higher abundances than >0 % (see Section 6.1.2), meaning they equal ranges of distribution and not core areas. One should consequently be aware that there is room for further optimizing of the MPA design suggested in these scenarios.

As pointed out by Williams et al. (2014), the trade-offs and evaluations made when defining networks of protected areas, rather reflect targets of management objectives than mathematical solutions. Preferably scientific support could be used for such trade-offs. Knowledge about ecological thresholds, e.g. the minimum area needed for the survival of a species or the area of blue mussels needed to provide sufficient food for wintering long-tailed ducks could be useful to quantify protection targets in decision support tools such as Marxan with Zones. It would also be interesting to incorporate spatial thresholds for ensuring adequate ecosystem services to maintain an economically viable industry. Such information has not been available in this project.

It's not possible to ensure that conservation values get full protection from MPAs, no matter how well-placed they are. It is important that these regulations and management plans include the conservation values intended, the restrictions needed and that the plans are followed, avoiding paper-parks. It is further relevant to consider whether all conservation values need protection. In cases where pollutants and eutrophication are the greatest threats towards conservation values, perhaps other conservation measures are the main solution. Structured monitoring and evaluation of MPAs is also necessary to ensure that the protection is effective and that the conservation values are managed and preserved. Additionally, analyses and mapping of activities' effects on the conservation values are needed to improve the opportunities for effective conservation.

Temporal changes can also be problematic for spatial protection which is relatively static. Seasonal differences are not captured by Marxan with Zones, thus every analysis is equivalent with a snapshot or a yearly compilation. This can be partially dealt with by having seasonal regulatory measures of the zones, similar to today's bird sanctuaries.

Only one of CBD's required network properties and components, listed in their guidance for selecting a representative network of MPAs, is included in the analysis; ecologically and biologically significant areas (conservation values). However, CBD recommend four additional network properties and components to consider when designing spatial protection; representativity, connectivity, replicated ecological features and adequate and viable sites. Connectivity is e.g. an important factor for all migratory species, but cannot be included in a Marxan with Zones analysis. It is recommended that the zoning maps are reviewed with the other CBD network properties and components in mind and possibly adjusted for these afterwards in the further work on MPAs in the area.

An essential factor for effective management of conservation values is a reasonable level of human use of the marine environment outside protected areas (Day 2002). Further analysis of the economic impact of the proposed zoning schemes is therefore highly recommended. For a zoning scheme to contribute to the sustainable management, it must be based on something other than mere targets for conservation and conflict management. It should not be neglected that it may not be economically viable to manage activities according to a zone configuration exactly as it was suggested by a decision support tool. Issues relating to changes in fuel and time consumption as well as fishing catch levels as effects of relocating shipping routes and fishing grounds are usually relevant in a marine planning process.

12 Conclusions and recommendations

The extensive field surveys, map layers of a variety of environmental parameters, modelling and prediction of marine biota, conservation value assessment and mapping, scenario impact testing of a fictive wind farm and changes of eutrophication status (measured as changes of Secchi-depth) as well as the zoning process, has provided extensive high quality maps and information suitable as decision support for MSP and MPA network design. Many species, biotopes and habitats have been identified, mapped and shown to have large conservation values. However, it is important to note that the conservation values described throughout this report do not include all marine values of the area and needs to be supplemented to provide a full description.

The maps can be used directly in MSP, as a basis for consultation and strategic decisions concerning the location and design of the establishment of new operations or as a communication- and visualization tool of conservation values. They are however, not suitable for decision-making at site-specific permit applications, such as EIA's. In such cases they are better suited as an indication of where it is appropriate to investigate the environmental impact more thoroughly. The spatially distributed field data and map layers of environmental parameters were essential to develop adequate spatial ecosystem models. But they are also strongly useful in themselves as information and for further analyses of the marine environment.

Spatial mapping of relevant marine conservation values are recommended for all EU member states, as a basis for MSP, and application of marine ecosystem based management in the Baltic Sea. However, there is currently no established Baltic standard for assessment and mapping of marine conservation values. This means that it is done in many different ways, which makes comparisons between different areas and joint assessments of larger regions difficult. We see that it is very important that transparent and widely acknowledged criteria are used in conservation assessments. The methodology used in the Hanö Bight area for conservation value assessment and mapping is likely applicable for use across the Baltic Sea and is a good basis for developing a common standard/guidance. We have used a systematic approach based on years of experience as well as the well-established HUB classification system and the scientific criteria for identifying ecologically or biologically significant marine areas in need of protection adopted by the Convention on Biological Diversity (CBD 2008).

Quantification of the impact on conservation values of different activities and variations of the same activities contribute with valuable knowledge to environmental impact assessments, MSP and zoning of the marine environment. The scenario of effects of a fictive wind park highlights the importance of quantification of expected impact on conservation values in the area (contrary to just pointing out which conservations values that are likely to be impacted). By quantification of effects of an activity, the severity of these effects on the conservation values in the area can be assessed. Construction method and type of foundation for the production of wind power at sea has shown to have significant impacts on marine mammals during the construction phase. E.g. harbour porpoises are expected to be affected over an area that is more than 30 times greater during piling, than during dredging. This type of analysis nevertheless assumes that conservation value distributions are known, which again highlights the importance of inventory and mapping of the marine environment.

Scenario models of changes of eutrophication status (measured as changes of Secchi-depth) have provided hints on the effects of eutrophication on bladderwrack in this area. Areas from this type of calculations do not correspond to the actual area covered by a species, but rather correspond to the seafloor area which lies within the physical demands of the species in this area with regard to seafloor substrate, wave exposure and light. Areas where the effects of changes in Secchi-depth have been shown in the scenario could be suitable for monitoring as an indicator for changes in Secchi-depth. The results can also be used to identify areas that are robust against eutrophication and therefore might be prioritized when locating MPAs.

Marxan with Zones has proven to be an effective tool for managing, compiling and analysing information from a large number of spatially described natural and human-induced impacts in a structured way. The maps developed has provided several potential zoning opportunities and can serve as a good basis for MSP and provide input to municipal comprehensive plans. Furthermore, it can be used for prioritization between areas considered for protection or identification of new MPAs. Areas displayed in the combined zoning map (Figure 91) are good candidates for MPAs for waterbirds and macro-benthic biotopes in the study area. However, well-mapped conservation values and well-developed management plans are crucial to achieve relevant ocean zoning results.

Also the process leading up to conservation value maps or scenario results can in itselves be valuable. It's an opportunity to concretise management objectives, identify knowledge gaps and contribute to a common vision and understanding for both the maps and their area of use.

12.1 Recommendations

Mapping

- Comprehensive data on marine biodiversity and environmental variables is necessary to develop adequate spatial ecosystem models, which allows a spatially explicit mapping of ecological values at large scales.

Conservation values

- It is very important that transparent and widely acknowledged criteria are used in conservation valuation.

Scenario modelling

- Scenario models are both appropriate and recommended to be used in environmental impact assessments as well as in optimization of MPA placement to ensure adequate conservation value protection. Scenario models are also helpful in the identification of optimum locations for potential economic activities by providing quantified, spatially explicit impacts on valuable habitats and species.

Ecosystem based management

- High quality maps of all relevant conservation values is a prerequisite for an appropriate integration of ecosystem based management into spatial planning.

We recommend that spatial mapping of relevant marine conservation values are made by all member states, as a basis for MSP, and application of marine ecosystem based management in the Baltic Sea. The methodology used in the Hanö Bight area for conservation value assessment and mapping is likely applicable for use across the Baltic Sea and is a good basis for developing a common standard/guidance.

13 Acknowledgements

We would like to thank experts and national authorities for their kind participation in discussions and/or involvement in data collection and analysis.

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15 List of Annexes