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Seamless Maps and Management of the Bothnian Bay SEAmBOTH - Final report

SEAmBOTH
Seamless Bothnian Bay

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Summary

The SEAmBOTH project (Seamless Maps and Management of the Bothnian Bay) was a collaboration (2017-2020) project between Sweden and Finland and included partners from Parks and Wildlife Finland (Metsähallitus), County Administrative Board of Norrbotten (Länsstyrelsen Norrbotten), Geological Survey of Sweden (SGU), Geological Survey of Finland (GTK), Finnish Environmental Institute (SYKE), Centre for Economic Development, Transport and the Environment in Northern Ostrobothnia and Lapland (ELY centers POP and LAP). The main funders of the project were Interreg Nord, Swedish Agency for Marine and Water Management (SWAM) and Lapin liitto.

The project had a focus on sustainable management of the northern Bothnian Bay, as well as increasing the knowledge of the marine environment and promoting collaboration across the border. The main goal of the project was to ensure the conservation of the habitats, ecosystems, and biodiversity of the Bothnian Bay, through efficient planning, sufficient knowledge, and management of the area. The end products of the project (e.g. marine maps, species identification guides and workshop reports) are intended for use by environmental agencies, the general public, and any other organization that may need them.

The project area was the northernmost part of the Bothnian Bay (which is itself the northernmost part of the Baltic sea). It reaches from Luleå, Sweden, to the south of Oulu, Finland.

Bothnian Bay is a unique marine area characterized by low salinity levels, brackish waters, and a unique mix of freshwater and marine species, with ice cover half year-round. Before the start of the SEAmBOTH project, the amount of available data of the seafloor, species and habitats were low, making assessment of e.g. biodiversity and conservation status difficult. The marine area of the Bothnian Bay is divided by the border between Sweden and Finland and is therefore a shared responsibility of both countries.

The northern Bothnian Bay is characterized by freshwater runoff from several large rivers causing low salinity levels (~1–3 PSU). Rivers are also a main source of humus, phosphorus and nitrogen in the area. The humic content of water is quite high, but turbidity and the amount of suspended solids is low outside the river estuaries. Although several large rivers flow into the northern Bothnian Bay, highly influencing the area, the nutrient levels are quite low, reflecting mainly oligotrophic conditions.

The SEAmBOTH project used satellite observations (EO, Earth Observation) to detect spatial and temporal changes in the water quality in the area of the Bothnian Bay. It was found that water quality parameters such as turbidity and CDOM could be estimated well in the Bothnian Bay using Sentinel-2 satellite observations. The water quality estimates provided by high resolution instruments are especially valuable in coastal regions, whereas moderate resolution instruments can cover open sea areas with more frequent coverage. With Sentinel-3 satellite OLCI data, examples of Chl-a time series with good correspondence with station sampling were shown at many of the investigated stations. However, the best performing Chl-a algorithm (MPH) was not developed for areas with low Chl-a concentration and extreme aCDOM (brown/humic) waters and over stations with this combination of water type, the performance was not convincing. Dedicated development of an algorithm to estimate Chl-a in high aCDOM waters is a task for future research and development projects.

The in-situ dataset collected during SEAmBOTH was a valuable resource for the algorithm testing and development. However, development of water quality algorithms over dark water types requires long time series before a sufficient level of confidence in the results can be reached. It is therefore recommended that water quality sampling is kept at high level in this northern region of the Baltic Sea, and that the sampling follows the optical protocols developed and utilized during the project. In addition to determining the in-situ concentrations of Chl-a, CDOM and turbidity, it is also important in the future to collect more data on the inherent optical properties of the water. Getting improved information about the water depth in coastal areas is also important. During the project, a number of algorithms were analysed, which continuously will be updated. Thus, it would be valuable to repeat the analyses with additional data and new versions at a later date. Usually, at least 25–30 match-ups between satellite and in situ data are required, to derive the uncertainties statistically. Hopefully, this can be accomplished in a follow-up project on the Bothnian Bay.

To understand the marine ecosystems, it is key knowledge to understand and map the seafloor abiotic environment which the ecosystems build on. Geological knowledge helps us understand the past and the present environment and is a vital piece of information when attempting to understand how the environment may look in the future. The existing charts and geological maps in the northern Bothnian Bay have generally been old, patchy, and coarse. To improve this knowledge, the focus of the geological mapping activities in the SEAmBOTH project was two-fold: ship-based mapping of selected "pilot" areas in high resolution with state-of-the-art survey techniques, as well as spatial modelling for the larger project area. The pilot areas were selected to provide valuable maps and knowledge of important areas, but they also allowed alignment and comparison of mapping techniques between Finland and Sweden, as well as provided a window of good data to compare with all other maps.

The seafloor in the region is relatively shallow with a mean depth of 19 meters, and deepest areas around 125 meters. The geologically young sea area, in large shaped by the last ice age, is full of structurally complex features. Canyons or canyon-like seabed features are the most striking broad scale geomorphological features noted. These canyons are probably ancient river channels, which formed when the water level was significantly lower than today. Examples of fine scale geological/geomorphic features discovered were erosional hard clay structures. These structures consist of a very compact clay, and they can create complex reef like structures. Features related to sediment transport (e.g. ripples), have also been observed in the area.

The canyons and deeper parts are mainly filled with soft clay and mud while the shallower and wave exposed areas above 30 meters are often covered with a mix of sand, gravel and rocks. However, modern mud accumulation seems to mainly occur in the water depths shallower than 40 meters. Scattered occurrences of small hard clay features seem fairly common, though challenging to map due to their small area coverage and patchy occurrence. Hardbottom such as rocks and large boulders is estimated to cover about 10 % of the area and is mainly found in the shallow areas where it is the dominating substrate type above 10 meters water depth in wave exposed regions.

Elevated concentrations of harmful substances, such as cadmium (Cd), lead (Pb), zinc (Zn) and mercury (Hg) were recorded in the seabed sediments.

Regarding the new seabed maps created in this project, where both manual and modelling methods have been tested, it was found that they all provide valuable information and aspects of the seabed environment. Fine scale substrate models and the thematic interpreted substrate maps show similar patterns, however the substrate models capture much variations within the thematic classes as well as soft transitions, indicating that even very detailed thematic maps (1:25000) are still significant simplifications of the true seascape complexity in many areas.

Data and information on the biotic marine environment of the northern Bothnian Bay was collected through biological inventories. In total, data was collected from over 23 000 sampling sites around the area. Focus was on macrophytes, but a few benthic macro fauna surveys were also conducted. The collection and mapping were done using VELMU methods. According to HELCOM, there are around 289 different macro species living in the Bothnian Bay, not including birds. In the SEAmBOTH project, 167 species of macrophytes were encountered.

Overall the species, and number of species, found in Sweden and Finland were relatively similar. The main differences in number of species were found amongst the water mosses and algae. Several species (alien invasive, native and threatened) were also discovered for the first time in the project area. The project contributed especially in increasing the knowledge of water mosses in the northern Bothnian Bay. Now the area is known to host 23 identified water moss species altogether.

During the project a comparison between two benthic macro fauna methods was conducted outside of Hailuoto island, Finland. The benthic macro fauna sampling methods and classification indexes differ namely between Finland and Sweden in coastal areas. On the Finnish side, sampling has been done with Ekman sampler, while on the Swedish side, van Veen sampler is used. In Finland, the Brackish water Benthic Index (BBI) is used in benthic macro fauna status assessment, whereas the Benthic Quality Index (BQI) is applied in Sweden. Results from the study showed significant differences in e.g. species richness between the methods and depending upon which classification index was used, the final status of benthic macro fauna in the coastal area came out differently.

Part of the SEAmBOTH project included investigation of the Natura 2000 habitat definitions of Sweden and Finland and applying them in the unique habitats of the northern Bothnian Bay. River estuaries were studied in detail and the mudflat habitats were drawn on a map in Finland. HELCOM Underwater Biotopes (HUB) were also mapped within the project area.

There are many human activities and pressures that are affecting the marine areas of the Bothnian Bay. To name a few, coastal construction, industry, marine traffic, and tourism. All have varying effects on the environment and cause different levels of pressure on marine nature. Eutrophication and climate change are both having a strong impact on the Bothnian Bay as well, but they are difficult to try to mitigate locally. In the SEAmBOTH project, there was a focus on local pressures causing physical loss and disturbance. A map of combined human pressures was made in the project area with the help of an expert workshop focusing on regional human pressures.

Overall, 112 ecological models were developed for the SEAmBOTH project area. Models relied on over 23,000 sites where species inventories have taken place, and 23 environmental layers, which describe physical, chemical and geological parameters of marine waters. Ecological models, together with the human pressure models, acted as input data for Zonation, a spatial prioritization tool, where with the help of MOSAIC framework, nature values were defined for the whole area. Most important nature value areas were river estuaries, shallow bays, and offshore islands with limited disturbance and pressure from human activities. As high as 96 % of the nature values are located in the 10 % of the total SEAmBOTH area, which suggests that nature values are rather highly concentrated.

Moreover, that 10 % holds also 57 % of the human pressures. This implies that nature values are burdened by various pressures resulting from human activities degrading the ecosystem state, such as small-scale dredging and harbour activity.

During the project, maps of the marine environment were produced along with environmental data. To make the information as available as possible to end-users, activities of the project were specifically directed towards receiving feedback from them and holding a dialog with stakeholders. Workshops and meetings were, for example, arranged with various stakeholders and other potential end-users.

Effective communication can play a vital role in efforts to gain support and understanding for the project and for the management and mapping of the seas. One of the project's main objectives was to facilitate open communication with the authorities and organizations involved in planning and management, as well as corporations and contractors, who could benefit from the project results, and nature conservation organizations. Additionally, the project strived to inform and educate members of the general public living in the project area, in order to spark interest about sea related issues and create a change in attitude towards protecting the Bothnian Bay.

Results of the project, such as collected data and maps, can be found in national marine databases, for example at the Swedish Meteorological and Hydrological Institute, Geological Survey of Sweden, VELMU data base, LajiGIS, www.laji.fi and at TARKKA map portal in Finland. Reports and the species guidebooks developed during the project are available at the SEAmBOTH webpage, www.seamboth.com and the links can also be found in chapter 12.1.

There are still many areas left to map on both the Finnish and the Swedish sides. Of particular interest are the river estuaries. The study of fluctuating water levels and how they affect the species in the area would also be an interesting area of study. Areas affected by human activities can be investigated to better assess zone loss and the level of disturbances from different activities. In both countries it would be important to know more about the northern distribution of the beetle Macroplea pubipennis. In Sweden, it would be important to learn more about the distribution of habitat's directive species and other threatened macrophyte species. The need to develop benthic macro fauna classification in the Bothnian Bay remains, but as sampling methods are now similar in Finland and Sweden, developments towards a common approach can be accomplished easier. The connection between substrate and seabed features with infauna and fish is an area that can be improved and may help us expand the understanding and definition of nature values within the Bothnian Bay. Submarine canyons are key areas for understanding the transfer of detrital sediments (including e.g. harmful substances) from the coastal areas to the deep basins and their related biological and physicochemical processes should be studied further. Overall, survey technologies of the sea floor need to be more efficient to be able to cover larger areas with high quality data. A promising way is to combine remote sensing data from the air (Lidar, aerial surveys and satellites) and ship-based surveys which are completed by above, on and below water drones. This could significantly help reduce the carbon footprint of seabed surveys, as well as improving cost to data quality ratios. In the future, possibilities of EO to be integrated with ecological modelling, should also be thoroughly investigated. Satellite-derived bathymetry, turbidity, and temperature are just few examples, which would improve the accuracy of species distribution models.

There is a lot more work to be done in the northern Bothnian Bay. The project has shown how important the collaboration between countries and organisations is, but there are many more areas to potentially expand the collaboration in. While a lot of data has been collected in the Bothnian Bay, it is important to keep up the field inventories. Bothnian Bay is very different to the rest of the Baltic Sea, so we have had to adapt common methods in mapping and inventory for it. While it has been difficult, it has led to new techniques being developed for these different areas. As climate change alters the environment, it is hard to exactly know what the effects will be, so the knowledge we have gathered during this project is crucial for the continued well-being of the underwater nature of the northern Bothnian Bay.

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Acronyms

aCDOM	Absorption by Coloured Dissolved Organic Matter
C2RCC	Case-2 Regional Coast Colour satellite data processor
CBD	Convention on Biological Diversity
CDOM	Coloured Dissolved Organic Matter
Chl-a	Concentration of Chlorophyll-a
EBSA	Ecologically or Biologically Significant Marine Areas
EMMA	Ekologisesti Merkittävät Merialueet, Ecologically Significant Marine Areas (Finland)
EMODnet	The European Marine Observation and Data Network
EO	Earth Observation
GIS	Geographical Information Systems
GTK	Geological Survey of Finland
HELCOM	Baltic Marine Environment Protection Commission
HUB	HELCOM Underwater Biotopes
IOPs	Inherent Optical Properties
MBES	Multibeam Echosounder
MPA	Marine Protected Area
MPH	Maximum Peak Height
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
OLCI	Ocean and Land Colour Imager
S2	Sentinel-2 satellite
S3	Sentinel-3 satellite
SSS	Side-scan sonar
SWAM	Swedish Agency for Marine and Water Management
SYKE	Finnish Environment Institute
VELMU	The Finnish Inventory Program for the Underwater Marine Environment
WFD	Water Framework Directive

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Foreword

The Bothnian Bay is a unique marine environment in the north of the Baltic Sea. As the Bothnian Bay sits between Sweden and Finland, it is a shared responsibility of the two countries. It is a largely unstudied area of the Baltic Sea, with little known about the species living there or the geology of the seabed. Because of this lack of knowledge, as well as the lack of collaboration and networking between the organizations working on marine related issues across the neighbour countries, the SEAmBOTH project was started. The project used a variety of techniques, including mapping and field inventories, with the aim of getting a better understanding, as well as improving the sustainable management, of the area. Some of these methods included biological surveys of river estuaries and shallow coastal areas via wading and drop videos, to identify plants and animals, as well as using aerial satellites and sonar to map the seafloor. Over the course of three years the project has produced several maps on the geological and biological habitats, human pressures and nature values, raised public awareness, and contributed to the future protection of the biological and geological diversity and ecosystem services of the northern Bothnian Bay.

One of the most important outcomes has been the collaboration and co-operation of a new network of partners around the marine conservation issues in the northern Bothnian Bay. We hope this collaboration will continue even after the project has ended because together, we are looking after the common sea for future generations. A good example of the seamless sea is the cover photo - this photo is from the Torneå river estuary and we are walking from the Finnish side to the water and the island in front is already in Sweden. So, we in the photo are in fact in the Seamless Bothnian Bay!

We want to express our deepest gratitude towards our sponsors Interreg Nord, Swedish Agency for Marine and Water Management and Lapin liitto for funding this project.

In Oulu, 28th April 2020

Essi Keskinen, Metsähallitus, Project coordinator, on behalf of all project partners

1. Introduction

1.1. Project background

The Bothnian Bay is a unique marine area characterized by low salinity levels, brackish water, and a unique mix of freshwater and marine species. In addition, it is an area where the land uplift rate is high (up to 1 cm/year). But before this project there was not sufficient data about the species or habitat distribution to assess the marine biological diversity and conservation status of the area. The marine area of the Bothnian Bay is divided by a human constructed border; thus, it is a shared responsibility for both Sweden and Finland. However, the natural processes in the sea and the marine species that live there do not follow any borders. Therefore, cooperation between the two countries is needed to ensure the protection and conservation of this important marine environment.

The SEAmBOTH (Seamless Maps and Management of the northern Bothnian Bay) project was a transboundary project between Finland and Sweden funded by the EU-financing program, Interreg Nord, and by national partners, Lapin liitto (Finland), and the Swedish Agency for Marine and Water Management (SWAM, Sweden). The project focused on the sustainable management of the northern Bothnian Bay, while increasing knowledge of the marine environment and promoting collaborations across the Swedish and Finnish borders.

This report is the result of a three-year collaboration among Finnish and Swedish partners: Parks and Wildlife Finland (Metsähallitus), County Administrative Board of Norrbotten (Länsstyrelsen), Geological Survey of Sweden (SGU), Geological Survey of Finland (GTK), Finnish Environmental Institute (SYKE), Centre for Economic Development, Transport and the Environment in Northern Ostrobothnia and Lapland (ELY centers POP and LAP). The project ran from the beginning of May 2017 to the end of April 2020.

The main goal of the project was to ensure the conservation of the habitats, ecosystems, and biodiversity of the Bothnian Bay, through efficient planning, sufficient knowledge, and management of the area. The project focused on biological habitat mapping, as well as geological mapping and remote sensing. One of the aims of the project was to provide full coverage maps showing spatial distribution of high nature values, such as sensitive habitats and species, as well as human pressures in the project area. Another aim of the project was to harmonize methods and definitions in order to develop more efficient methods and guidelines for future use. Additionally, the project aimed to communicate often with the general public, raising awareness and increasing knowledge about the marine environment.

The project focused on fulfilling national and international obligations. Finland and Sweden have committed themselves to protecting the biological diversity and ecosystem services through the Convention of Biological Diversity (CBD) and the Helsinki Commission (HELCOM). Moreover, the project followed policies put in place by existing EU legislation, namely the Marine Strategy Framework Directive (2008/56/EC), the Water Framework Directive (2000/60/EC), the Habitats Directive (CD92/43/EEC), and the Maritime Spatial Planning Directive (2014/89/EU).

End products of the project (maps, models, and species data) are intended for environmental agencies and other authorities, as well as the general public, who can use them to make ecologically sustainable decisions. Resulting maps and data are published and distributed via platforms for GIS-data (Finnish VELMU-map service, Itämeri.fi, LajiGIS, laji.fi, Geodatakatalogen, SMHI Svenskt Havsarkiv, Länskarta Norrbotten, GTK's Hakku portal, and SGU's websites etc.) The results can then be utilized by all levels in marine management to further maintain and improve the ecological status of the Bothnian Bay.

1.2. Project area

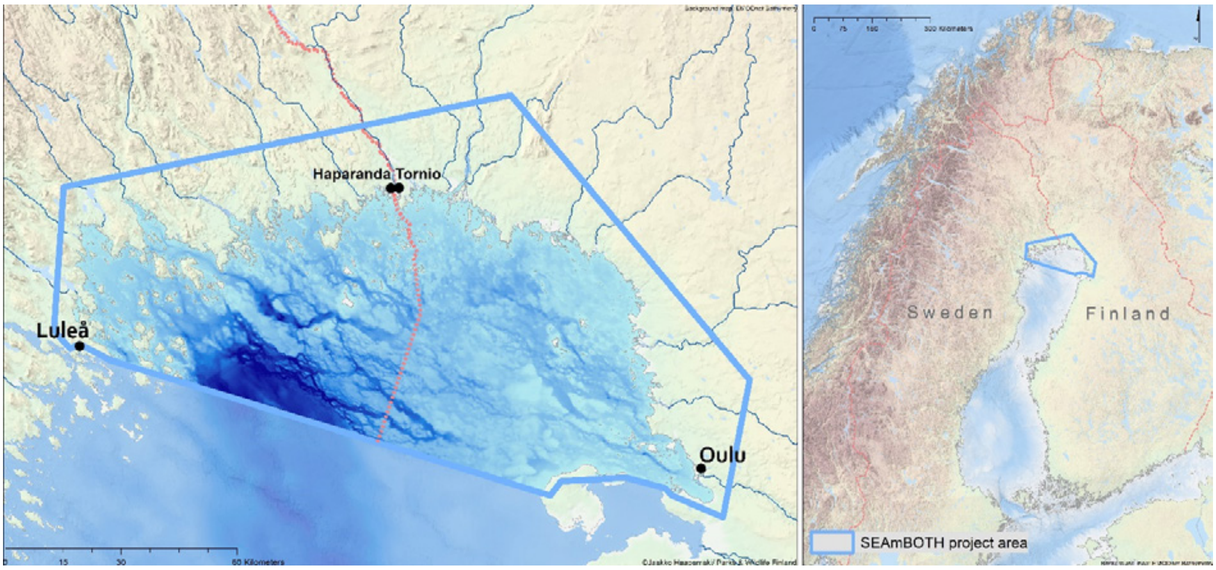

Figure 1. SEAmBOTH project area in the northernmost Baltic Sea. Map by Jaakko Haapamäki, Metsähallitus.

The project area is located in the northernmost part of the Bothnian Bay (part of the Baltic Sea, Fig. 1), including all marine areas, islands, and the Swedish and Finnish coastlines from Luleå, Sweden to the southern region of Oulu, Finland. The project area also includes the Bothnian Bay National Park, the Haparanda Skärgård National Park, and several Natura 2000 sites.

As the most northern part of the Baltic Sea, the Bothnian Bay is one of the largest brackish bodies of water in the world with no tides and an abundance of freshwater runoff from rivers causing low salinity levels. The Bothnian Bay differs from the rest of the Baltic Sea with its even lower salinity levels (~1–3 PSU), decreased nutrient load, harsh climate conditions, and short growing seasons; as well as extreme temperature and light variations (Andersen et al. 2017, Kautsky & Kautsky 2000, Korpinen et al. 2018, Virtanen et al. 2018). The Bothnian Bay is bordered by the north Kvarken sub-basin, which makes this area somewhat isolated from the rest of the Baltic Sea, resulting in less pollution coming from the southern waters (Korpinen et al. 2018, Virtanen et al. 2018). Rivers are usually a main source of humus, phosphorus, and nitrogen and contribute to the low salinity. Although several large rivers do flow into the northern Bothnian Bay, highly influencing the area, there is a lower nutrient load and less eutrophication than other parts of the Baltic Sea (Andersen et al. 2017, HELCOM 2018a, Korpinen et al. 2018). The Bothnian Bay is also an area with high geodiversity (Kaskela & Kotilainen 2017).

The unique make-up of the Bothnian Bay influences the biodiversity here, with species often adapted to extreme environmental factors. The low water visibility due to humus and the short growing season (up to 6 months of ice-cover every year) have led to less vegetation due to the limited amount of sunlight reaching the sea floor. The Bothnian Bay is a unique area in the Baltic Sea as it is the only sea area where phosphorus is the limiting nutrient and not nitrogen, as in other parts of the Baltic Sea. This means that the Bothnian Bay works effectively more like an oligotrophic lake than a eutrophicated sea (HELCOM 2018b). This also explains why there are so few blue green algal blooms in the Bothnian Bay.

The low salinity leads to a scarcity of marine species and more freshwater species being present, with a higher number of endemic macrophyte species. Moreover, there is an absence of specific species that are characteristic and important (key stone species) to other parts of the Baltic Sea such as Fucus spp. and the blue mussel, Mytilus trossulus (HELCOM 2018b, Kautsky & Kautsky 2000). Larger water mosses such like Fontinalis spp. have at least partly taken the ecological function of Fucus spp. as the larger macrophytes on hard sea floors.

In November 2018, the northern Bothnian Bay was chosen by the Convention of Biological Diversity (CBD) as one of nine Ecologically or Biologically Significant Marine Areas (EBSA) in the Baltic Sea (Fig. 2). EBSAs "are geographically or oceanographically discrete areas that provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics "(CBD 2008). Sites are chosen based on seven CBD criteria, including rarity, importance, fragility, and diversity.

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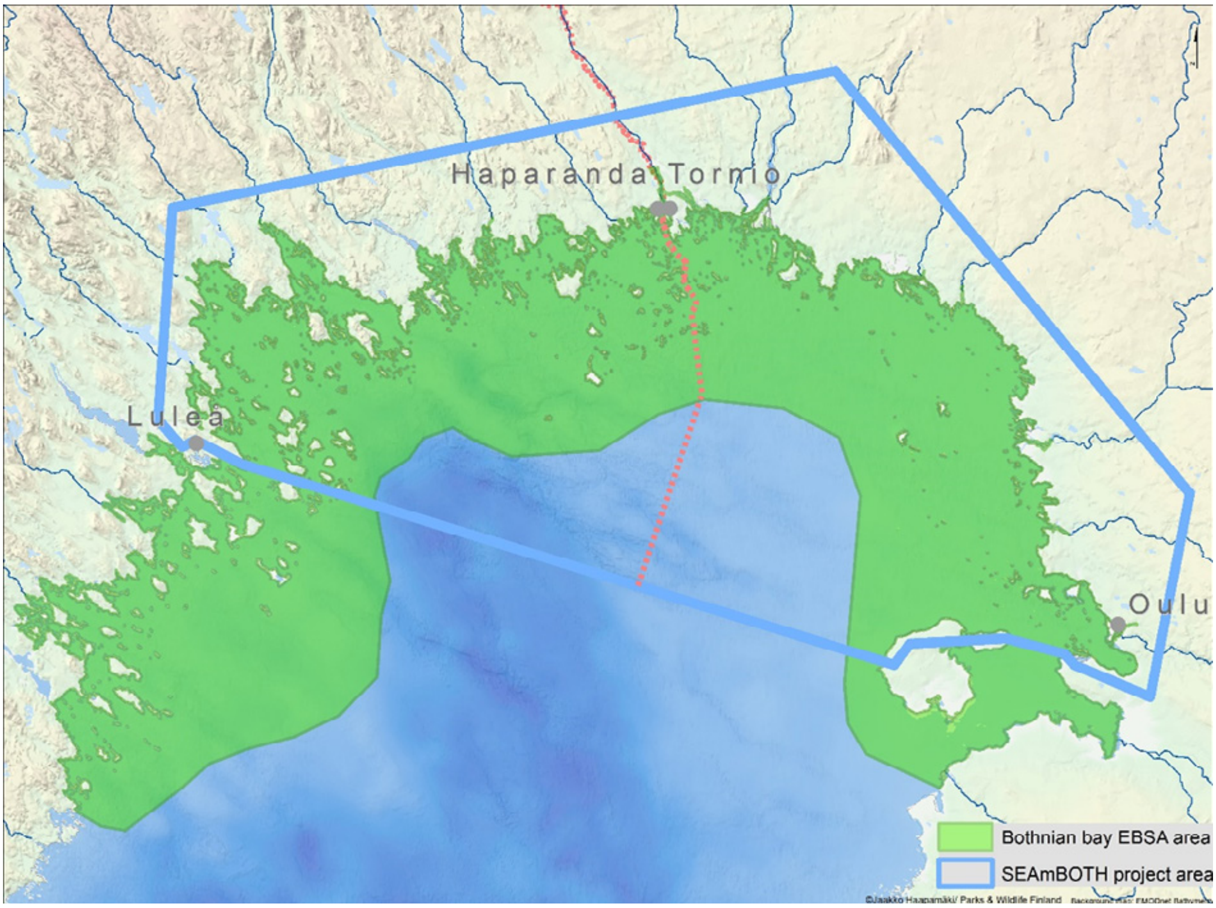

Figure 2. The Bothnian Bay EBSA -area and the SEAmBOTH project area. Map by Jaakko Haapamäki, Metsähallitus.

As stated in the report, the northern Bothnian Bay was appointed as an EBSA because of its uniqueness due to several Natura 2000 habitats, spawning areas, and occurrence of the rare beetle, Macroplea pubipennis. The area is also highly important for critical life stages of the ringed seal (Pusa hispida), several anadromous fish, and migrating birds, as well as hosting a number of threatened species of plants (e.g. Hippuris tetraphylla, Alisma wahlenbergii, and Chara braunii) (CBD 2018).

1.3. History of mapping the underwater northern Bothnian Bay

The Bothnian Bay has not been studied for as long, or in as much detail, as the southern parts of the Baltic Sea. In Finland, the Krunnit archipelago, which is a private nature conservation area and part of the Perämeren saaret Natura 2000 area, was a focal point for marine studies in the Bothnian Bay. It was during the 1970s and 1980s International Biological Program IBP (1964–1974) when the Oulu university field station in Ulkokrunni island was in busy use. The first Bothnian Bay symposium was held in Oulu, Finland, 27th-28th November 1974 (Valtonen 1974) and a busy research period of about two decades followed. After that, scientific work on underwater marine nature ceased for a long time, except for some national monitoring programs and monitoring for industry.

In 1991, in a nominated Bothnian Bay year, physico-chemical and biological studies were conducted on both sides of the Bothnian Bay in order to get an integrated status assessment of the Bothnian Bay. Ecological studies were focused on food web and mechanisms controlling it.

The Bothnian Bay Life project (2001–2005) aimed to improve co-operation and information exchange on environmental issues between regional and municipal authorities and industries around the Bothnian Bay. Environmental information database, water quality, and ecosystem model for three coastal areas, best available technology information exchange system for metal industry and action plan for the Bothnian Bay were produced.

The Bothnian Bay national park was established in 1991 in Finland and, for the management plan purposes, a two-year survey of underwater nature (flora and fauna) was conducted in 1993–1994 (Leinikki & Oulasvirta 1995).

In Finland, mapping of habitats and species started in a high volume again in 2007 when the national underwater mapping program VELMU was initiated (VELMU, 2020). The aim of VELMU was to produce species and habitat distribution data to be used in nature conservation and management plans. So far, VELMU has collected information from hundreds of thousands of biological, geological, and abiotic sampling points along the whole coast of Finland.

On the Swedish side, the underwater environment of the northern Bothnian Bay has been very sparsely investigated. A couple of studies were conducted during the 90's (Foberg & Kautsky, 1991; Forsberg & Pekkari, 1999; Kautsky & Foberg, 1999). The Baltic water-plantain (Alisma wahlenbergii) has however been of interest for botanists with several inventories and reports having been conducted in search of it, from the first time it was found on the Swedish side in the Bothnian Bay in 1998 in Haparanda (Hammarsjö & Zethraeus, 1998) and up until today (for example Zethraeus, 2000, 2003 & 2007).

The island Haparanda Sandskär became a nature reserve in 1965. In 1982 the reserve expanded to include some surrounding islands and was followed by an inventory of its nature (Landström, 1983). In 1995 the islands became a part of the newly established Haparanda National Park.

2. Geology

2.1. Background

The focus of this project was to map and understand the marine and coastal ecosystems, including human caused pressures. Benthic species require certain substrates to survive and thrive, and the seascape which is shaped by geological processes provide shelter and habitat for the benthic fauna, fish, and marine mammals. In addition, environmental pollutants are mainly found in areas with recent accumulation of fine sediments. It is therefore key knowledge to also understand and map the seafloor abiotic environment which the ecosystems build on. Geological knowledge helps us understand the past and the present environment and is a vital piece of information when attempting to understand how the environment may look in the future. The existing charts and geological maps in the northern Bothnian Bay have generally been old, patchy, and coarse.

To improve this knowledge the focus of the geological mapping activities was two-fold: ship-based mapping of selected "pilot" areas in high resolution with state-of-the-art survey techniques, as well as spatial modelling for the larger SEAmBOTH area. The pilot areas were selected to provide valuable maps and knowledge of important areas, but they also allowed us to align and compare our mapping techniques between Finland and Sweden, as well as providing a window of good data to compare with all other maps.

In short, the high-resolution maps in the pilot areas give us a glimpse of what we do not know or understand in other areas, especially the deeper waters (>5m), which are not possible to map using aerial based remote sensing. Hence models building on such data will have limited ability to predict ecological values in the deeper waters below the detection for such systems. Geological models of the whole SEAmBOTH area are designed to take advantage of both existing data and the new data collected in the project but are also limited by quality as well as spatial and thematic resolution. This data includes geological data collected during the biological surveys was developed to help improve the biological modelling of species and habitats.

2.1.1. Geological history

Bedrock

The Bothnian Bay is located in a depression of the Fennoscandian Shield. The bedrock is similar on the coasts of Sweden and Finland and it consists of basement rocks formed during the Precambrian period. In the southern and south-eastern part of SEAmBOTH area, the crystalline bedrock is covered by sedimentary rocks (Koistinen et al., 2001), which were deposited in the Ectasian period approximately 1.4 to 1.2 billion years ago.

Similar sedimentary rocks are also found from various places, including the district around Oulu, the Muhos formation, the Bothnian Sea seabed, and in the Satakunta region of western Finland. These sedimentary rocks are sometimes covered by younger Ediacarian sedimentary rocks (circa 635 million years ago). Corresponding Ediacarian sedimentary rocks are found almost everywhere in the southern Gulf of Finland. Interestingly, throughout the deposition of the Ectasian sediments, Fennoscandia and also SEAmBOTH area was located near the equator.

Quaternary Glaciations

During the Quaternary, the past ~2.58 million years, the Baltic Sea has undergone several glacial erosion and sediment accumulation periods (e.g., Mangerud et al., 1996; Hughes et al., 2016). During the Weichselian glaciation, the Baltic Sea basin experienced several glacial and ice-free periods with changing water level (e.g., Nenonen, 1995; Houmark-Nielsen and Kjær, 2003; Houmark-Nielsen, 2007; Salonen et al., 2007; Lunkka et al., 2016). The entire Baltic Sea basin was covered by up to 3 km thick ice sheet during the last glacial maximum, around 20,000 years ago (Svendsen et al., 2004). The Bothnian Bay was deglaciated ~10,000 years ago (Stroeven et al., 2016). The Bothnian Bay is geologically very young, it is the youngest part of the Baltic Sea, and one of the youngest sea areas of our planet.

The post-glacial evolution of the Bothnian Bay

The melting of the ice sheets triggered local glacio-isostatic adjustment, which is still taking place in the Baltic Sea today. In the Bothnian Bay the land uplift rate is up to 1 cm/year (Ekman, 1996; Lidberg et al., 2010; Kakkuri, 2012). If the current sea level rise is taken into account, the land uplift rate (relative to sea level) is smaller (7 – 9 mm/v) (Poutanen and Steffen, 2014). Relatively rapid isostatic uplift has dramatically altered the hypsography/bathymetry of the Bothnian Bay since the last deglaciation. Just after the latest deglaciation the Gulf of Bothnia was more than 200 m deeper than today (Berglund, 2012). It is estimated that today, in the Gulf of Bothnia, the land rises from the sea by about 700 hectares per year (Poutanen and Steffen, 2014).

Over the last 8000 years, due to the land uplift, the Baltic Sea area has decreased by ~ 30%, and the Baltic Sea water volume has declined by ~ 47% (e.g. Meyer and Harff, 2005). In the Bothnian Bay, these changes have been relatively even higher due to faster land uplift.

Over the past thousands of years, large areas of the seabed in the Bothnian Bay, and especially in SEAmBOTH area, have been subjected to potential erosion (wave erosion) (Kaskela and Kotilainen, 2017). This is particularly the case on the Finnish coast, where the coastal area is shallow, and the seabed is deepening gently towards the west.

The SEAmBOTH study area was deglaciated during the Ancylus Lake phase, thus the area was a part of the large freshwater lake. The brackish water phase, the Litorina Sea, started when the global sea level rose and resulted in saline water incursion via Danish Straits into the Baltic Sea basin (Björck, 1995; Andrén et al., 2000; Moros et al., 2002; Witkowski et al., 2005). The onset of the brackish water phase occurred later in the Bothnian Bay than in the southern Baltic Sea. The brackish water conditions occurred in the Bothnian Bay around 7000 years ago onwards (e.g. Häusler et al., 2017), and probably also in the SEAmBOTH area.

The SEAmBOTH area has experienced significant environmental changes after the ice age; its sea level/shoreline, bathymetry, water volume, salinity, sea surface temperature, primary production, and seabed hypoxia have changed abundantly. The ongoing land uplift modifies the seabed and the coast slowly, but steadily. The seabed is under a constant change.

2.2. Methods

2.2.1. Field surveys

The geological surveys at the study area were executed in the summer of 2017 (GTK) and 2018 and 2019 (GTK and SGU). The aim was to provide full-coverage bathymetry and seabed substrate data from key (pilot) areas, as well as samples and underwater images of the seafloor.

Seafloor geological information was obtained using various acoustic-seismic investigation and sediment sampling methods. Acoustic-seismic data and sediment cores were collected onboard the Finnish research vessel (RV) Geomari, the survey boat Gridi, and the Swedish survey vessel (SV) Ocean Surveyor and the launch SV Ugglan. The vessels and their survey systems were continuously positioned using GPS. GTK and SGU used similar but slightly different survey systems as described below.

2.2.1.1. Acoustic survey GTK

The acoustic-seismic surveys by GTK were run at around 5 knots of speed along predetermined transect lines and using DGPS (Differential Global Positioning System) to position the survey data. Before starting the survey, sound velocity in the water column was measured in each study area. The sound velocity and temperature profiles of the water column were measured using a Reson SVP 15T profiler. Acoustic-seismic surveys of key areas included multibeam echo sounding (Kongsberg Geoswath 4) (Atlas FS20-200 2017–2018, Kongsberg Geoswath 4), sub bottom profiling (echo sounding) (Pinger/MeriData MD 28 kHz and Chirp/Massa TR-61A 3.5–8 kHz transmitters), side scan sonar (Klein System 3000, 100/500 kHz) imaging, and single-channel seismic profiling (Electro Magnetic implosion type sound source, ELMA, 250–1300 Hz, depth resolution of ±2 m) (Fig. 3). These instruments were operated simultaneously. Acoustic profiles and side-scan sonar data were collected and recorded digitally using a MDCS software package (Oy Meridata Finland Ltd).

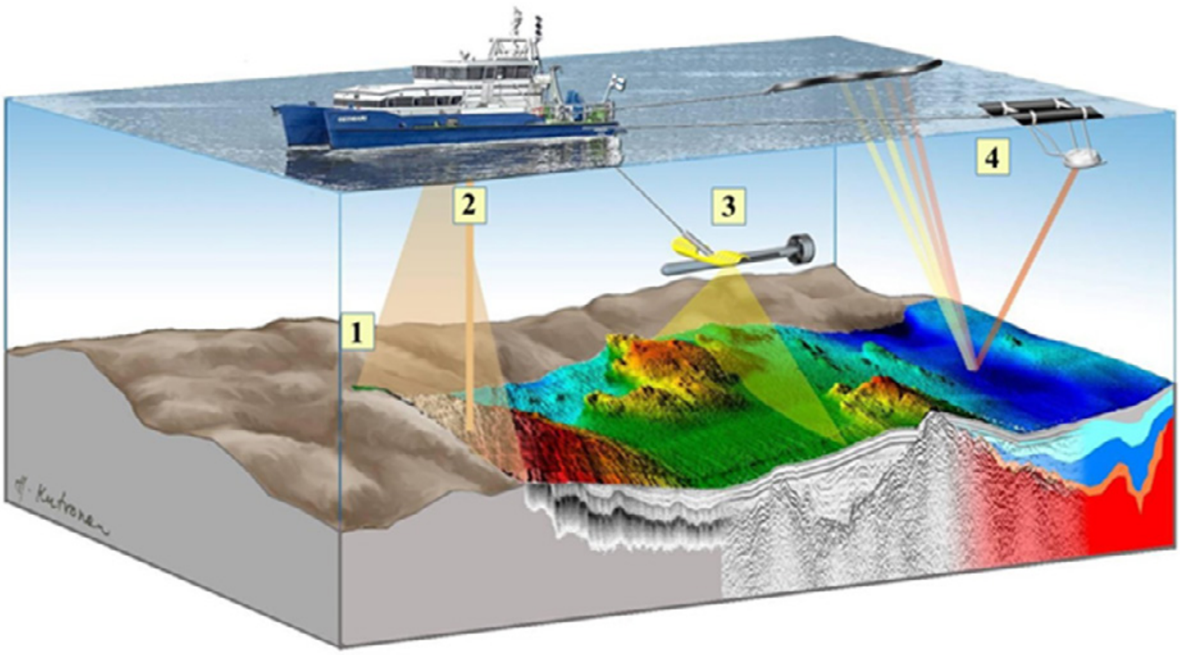

Figure 3. A schematic illustration of acoustic-seismic survey equipment onboard the research vessel Geomari. 1) multibeam echo sounder (Kongsberg Geoswath 4), 2) a sub bottom profiler (echo sounder) (Pinger/MeriData MD 28 kHz and Chirp/Massa TR-61A 3.5–8 kHz transmitters), 3) side scan sonar (Klein System 3000, 100/500 kHz), and 4) single-channel seismic profiler (Electro Magnetic implosion type sound source, ELMA, 250–1300 Hz). Figure by Harri Kutvonen, GTK.

2.2.1.2. Hydroacoustic survey SGU

The hydroacoustic surveys by SGU were conducted from both SV Ocean Surveyor and the small launch Ugglan, which has a similar survey system as the main ship. The surveys were run at 6–9 knots and following pre-planned survey lines for the SV Ocean Surveyor, but a more dynamic semi manual line plan for the small launch operating in shallow waters. Positioning was done by RTK (real time kinetics) GPS which has a high accuracy (in the order of centimetres) in xyz direction.

The survey instruments used on Ocean Surveyor were (Fig. 4): Multibeam echosounder: Kongsberg EM2040D, Subbottom Profiler: Kongsberg Topas 120 or IxBlue Echoes 3500, CTD sond: Midas SVX2 – combined with a secci depth disc for daily measurements, SVP: Valeport miniSVP. On the survey launch Ugglan, an interferometric sonar, Geoswath Plus, was used in 2018 and a multibeam echosounder, Kongsberg EM2040D, in 2019. Subbottom profiler used was a Kongsberg Topas 120, SVP a Valeport miniSVP. A boomer from Applied Acoustics was used in 2018. On the survey launch, the MBES and the SBP were interfering so in 2019 these instruments were not run simultaneously. The main differences between the two vessels aside from the slightly different sonar systems is that a moving vessel profiler was continuously logging temperature and sound velocity in the whole water column during surveys on Ocean Surveyor, while a manually operated profiler was used for the launch, resulting in fewer profiles to use for sound velocity corrections of the data.

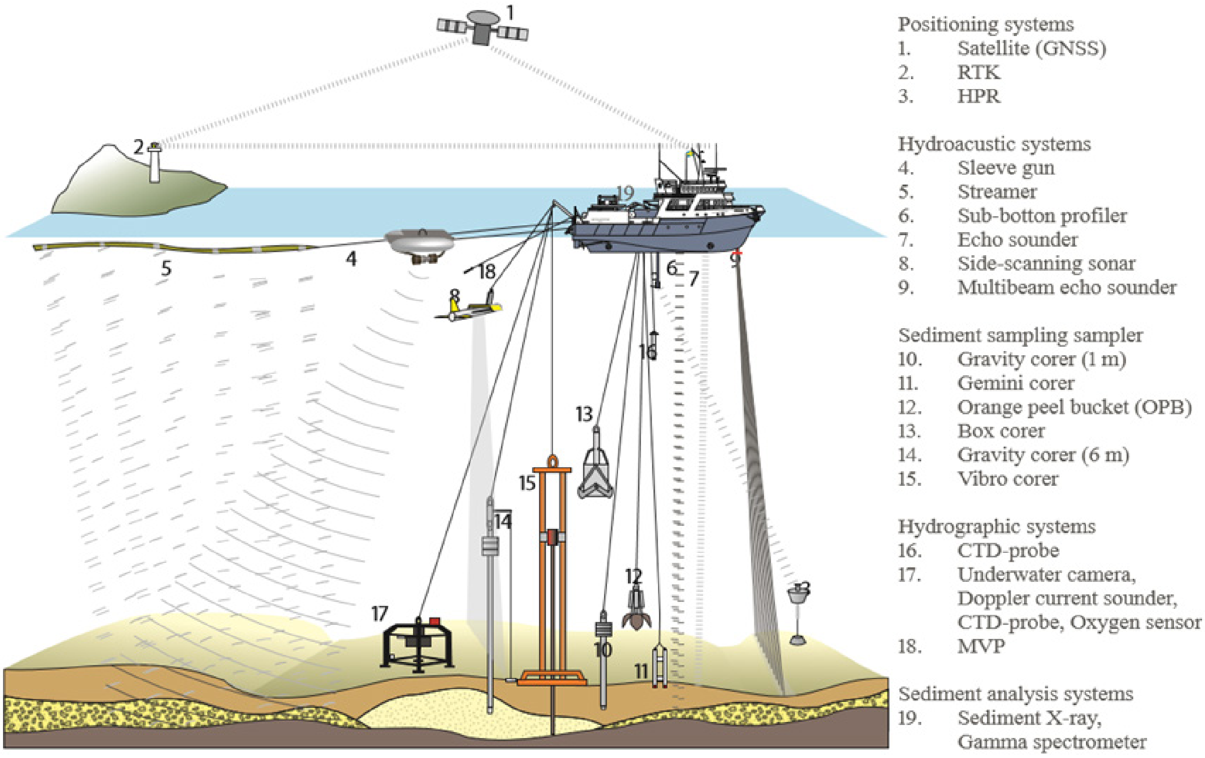

Figure 4. Schematic image of the survey and seabed sampling systems available on SV Ocean Surveyor. Figure by SGU.

2.2.1.3. Seabed sampling GTK

Ground-truthing by sediment sampling and camera observations was performed from the research vessels. The seabed surface was also documented using underwater cameras. Selection of the most suitable sampling sites and sediment samplers (corers) was based on the preliminary interpretations of the acoustic data and the seabed inspection by an underwater video camera. Sediment cores were recovered using various samplers (corers) like box corer, a twin barrelled GEMAX gravity corer and Van Veen grab. The recovered sediment cores were photographed, documented and subsampled onboard. Sedimentological description and digital photography of sediment cores were made both through the plastic core liner (GEMAX corers only) and from the splitted and trimmed sediment surfaces. For the chemical and other analysis, the selected surface sediment cores were sliced into 1 cm thick subsamples onboard and packed in plastic bags. In addition, the lowermost ~5 cm were collected from each core (GEMAX corers only). The subsamples were stored refrigerated until laboratory analyses onshore.

2.2.1.4. Seabed sampling SGU

Similar to the GTK survey, SGU conducted seabed sampling and drop-camera observations in the pilot areas. Sampling locations were selected using a stratified random sampling design based on sonar mosaics and depth models from the acoustic survey, as well as some complementary expert locations and taking subbottom profiler data into account. The aim of the sample plan was to locate as many unique habitats and seafloor features as possible in the pilot areas.

All sampling and camera observations were run from Ocean Surveyor. Sampling gears were 0.1 m2 Van Veen sampler and Orange Peel Bucket or 1-meter gravity corer. Drop camera observations were made by a custom-made camera including a rotating full frame Canon 6D dslr camera (video and images), a GoPro 5 camera (video and images) as well as ctd, current and oxygen sensors (Fig. 5). The camera captured up to 15 m2 seafloor in high resolution, depending on water visibility, using a series of 20 images and a 360-sweep using an automated protocol.

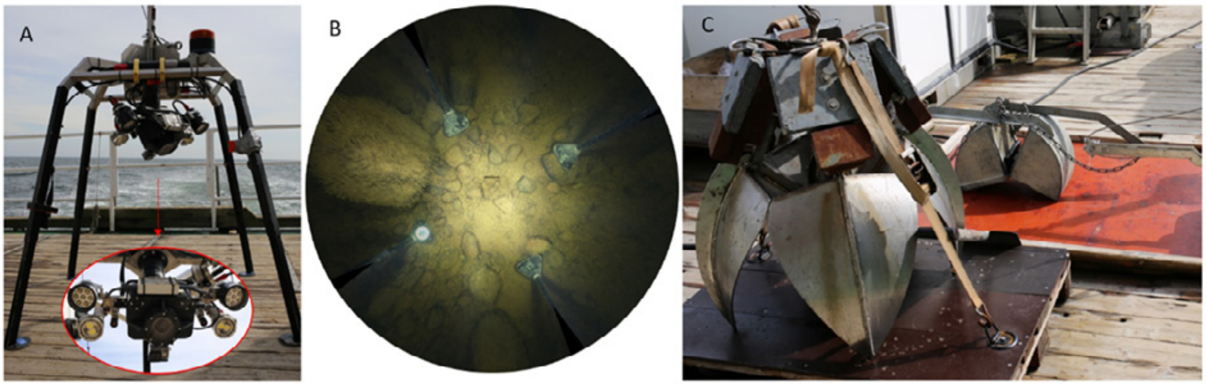

Figure 5. (A) SGUs Drop-camera system including lights, sensors (current, salinity, temperature, depth, oxygen), red lasers (30cm apart) and two cameras (Canon 6D, GoPro 5) on a 360 rotating mount; (B) example of high resolution photomosaic from the SEAmBOTH pilot area (16–20 images stitched into one mosaic); (C) Orange Peel Bucket and Van Veen sampler used for sediment grabs. Photos by SGU.

2.2.2. Field data processing

2.2.2.1. Bathymetric model

The Finnish multibeam bathymetric data was collected and processed with Hypack and visualized with Fledermaus software. Bathymetry models were interpolated from Multibeam echosounder (MBES) data (5 m point distance), raster size 25 m for the pilot study areas.

The bathymetric data collected by SGU in 2018 was processed in two different ways. The multibeam data from Ocean Surveyor was processed in Caris Hips and Sips 10 and then visualized with Fledermaus software, the interferometric side scan sonar data was processed using GS4, a GeoAcoustic/Kongsberg software, and then visualized with Fledermaus. The bathymetric data collected in 2019 was processed with Qimera and visualized with Fledermaus software. The same process and software were used for data collected from both vessels. The resolution of the data was 0.5 metres. A final data set was combined in ArcGIS where small holes in the grid were interpolated to produce a continuous surface.

2.2.2.2. Sonar mosaics

SGU made mosaics of the backscatter data from the interferometric side scan sonar and from the multibeam data. This processing was done with Fledermaus software (FMGT) for the multibeam data and Caris Hips and Sips 11 (sidescan editor) for the interferometric side scan sonar data. The resolution of the backscatter/sonar data was 0.5 metres. A final mosaic was combined in ENVI by mosaicking all backscatter/sonar mosaics (geotiff format) into one. The backscatter data from Ocean Surveyor was used as the reference data set (i.e. all mosaics where adjusted to match the EM 2040D backscatter data as close as possible in the combined final mosaic). At GTK, the side-scan sonar backscatter mosaics were done with a MDCS software.

2.2.2.3. Sediment samples and underwater observations

Each sediment sample recovered from the seabed was photographed and described by an expert geologist before putting into the database. A selection of samples was also sent to the lab for detailed grainsize analysis.

In SGUs case, the station data was further analysed in the following way: the underwater images were analysed using point intercept methods in CPCe (Coral Point Count with Excel extensions) software, extracting both geological information (substrate grainsizes and features such as ripple marks) and biological information, including observations of animals on and above the seafloor. The point intercept method followed the Swedish "visuella metoder" standard (which is still in draft mode) and runs 10 images from each site with 10 random points scattered across each image, making up 100 points / site. Both geologist and biologists were working with the data to verify each site. All interpreted point intercept data were combined into one dataset using R where an additional QC took place. In order to derive proportions of fine grain sizes from the stations (the point intercept method can only distinguish between sand and gravel, not between sand – silt fraction which is too fine to see in images), a final percent cover data set was produced by combining data from grain size lab analysis (only 30 stations had this data available). Experts interpreted data from samples and images to model the detailed grainsize fraction for all sample locations (same modelling framework as described in 2.2.4.1. Pilot area models but applied only on information from station data).

2.2.2.4. Environmental samples

Datings for the surface sediment cores and estimations of recent sedimentation rates are based on the 137Cs that could be used as a timemarker in the sediment column (e.g. Kankaanpää et. al 1997, Meili et al. 1998, Mattila et al. 2006, Ilus 2007, Zaborska et al. 2014, Moros et al. 2017). In undisturbed, non-bioturbated Baltic Sea sediments, a sharp increase in 137Cs activity concentrations in sediments corresponds the fallout from the April 1986 Chernobyl nuclear power plant accident. The activities of 137Cs in fresh subsamples were measured for 60 min using an EG&G Ortec ACETM-2K gamma spectrometer equipped with a four-inch NaI/TI detector at the Geological Survey of Finland.

For the chemical analysis of environmentally harmful substances (e.g. heavy metals) various methods were used (e.g. ICP-MS, ICP-OES, Leco (C, N, S)). Grain size distribution of the sediments was analysed using sieving and Sedigraph. In the laboratory, the samples were weighed for wet weight, freeze-dried, and weighed for dry weight. All samples were sieved <2 mm in order to remove objects larger than 2 mm (plant and animal remains, FeMn-concretions). The samples from different depths from all sampled cores were analysed for carbon and nitrogen using a Leco CHN-600 instrument. The samples were treated with a hydrofluoric acid–perchloric acid leach. Element concentrations were obtained from sample solutions using the inductively coupled plasma mass spectrometry (ICP-MS), or inductively coupled plasma optical emission spectroscopy (ICP-OES), depending on the element. Mercury was measured with an Hg-analyser through pyrolytic extraction (US EPA Method 7473). These laboratory procedures were performed by Eurofins Labtium Ltd. laboratory in Kuopio, Finland.

2.2.3. Geological interpretation

The data for geological maps usually originate from either manual interpretation or (semi-) automatic interpolation of acoustic-seismic data, including single-beam echo sounder, multibeam echo sounder (MBES), side-scan sonar (SSS), and seismic profiler data, as well as sediment-sample descriptions and analyses (e.g., Hughes Clarke et al. 1996, Coggan et al. 2007, van Lancker et al. 2013, Jakobsson et al. 2016, Kaskela et al. 2019). Here GTK's and SGU's geological maps were generated from sediment core analysis, acoustic-seismic profiles, and side scan sonar mosaics. A bathymetric model was also used in geological map construction.

The sediment echo sounder and seismic profiler records were processed and converted to a format that is suitable for the used interpretation system(s). Side-scan sonar records were converted to geo-referenced raster files, which were joined together in a mosaic representing the acoustic response of the seabed surface.

Acoustic-seismic profiles were interpreted using Meridata MDPS software. Acoustic-seismic profiles were interpreted based on the acoustic properties of the (sub-) surface material (e.g., porosity, bulk density). In the interpretation, boundaries between different geological units, which are presented in Table 1, were digitized. The following geological units (substrate classes) were interpreted from acoustic-seismic profiles in GTK's detail areas: bedrock, till/diamicton, sand and gravel, mixed sediment (glacioaquatic), glacial clay (rhythmites, varved silty/sandy clay), postglacial clay (sulphide bearing clay), gyttja clay, recent mud.

Table 1. Harmonisation/translation of GTK and SGU Geological classes into EMODnet Seabed substrates.

Geological class/ GTK	**GTK Comment for the pilot area**	**Geological class/ SGU**	**SGU Comment for the pilot area**	**EMODnet Substrate class (mod. Folk 5)**
Bedrock	Bedrock (and sedimentary bedrock) outcrop, boulders/stones/gravel	Bedrock	Outcrop of bedrock	Rock and boulders
Till	Complex bottom: Boulders, Gravel >2% and clay, mud, sand	Till	Unsorted material, in many places washed out to some degree leaving a coarse residual cover	Mixed sediments
Sand and gravel	Mainly glaciofluvial deposits (e.g. eskers). Often eroded.	Postglacial gravel	Probably washed out and redeposited coarse material	Coarse grained sediments
Secondary Sand	Sandy material eroded e.g. from eskers or tills and redeposited. Generally around islands and shoals	Postglacial fine sand	Usually redeposited and contains several other fractions from gravel to mud	Sand
		Postglacial sand	Redeposited material usually with no or very little of other fractions	
Glacioaq.mixed sediment	Mixture of sediments, gravel, sand, silt, clay	-	-	Mixed sediments
Glacial clay	Gravel, sand, clays and silts formed during deglaciation. Homogeneous and varved deposits of silt and clay.	Glacial Clay	Clay formed during the deglaciation, contains to some extent coarser material and when outcropping covered by a thin veneer of sand/gravel.	
-	-	Silt	Both primary and secondary material, usually contains other fractions as well, ranging in size from sand to mud	Mud to muddy sand
Ancylus clay	Clay and silt	Postglacial Clay	Soft clay usually contains gyttja and some silt. Indicates ongoing sedimentation.	
Litorina clay	Gyttja/mud, Clay, Silt			
Recent gyttja/Mod. mud	Gyttja/mud. Indicates ongoing sedimentation.			

The interpreted profiles were then converted into so-called substrate ribbons representing seafloor substrate type and exported into a mapping program (Esri ArcGIS software). The distribution of the seabed substrates was manually outlined from the substrate ribbons and sediment samples with the help of either side-scan sonar mosaics or multibeam backscatter mosaics together with high resolution water depth information (e.g. from the MBES).

As the geological map provides (sub)surface information usually for the upper 1 meter of the seabed, also seabed surface substrate maps were produced for the area. The seabed substrate maps were produced here by translating national seabed geological data into the EMODnet substrate classification scheme, the Folk sediment classification (Kaskela et al. 2019; Table 1). The Folk 5 classification includes rock & boulders, coarse sediment, mixed sediment, mud to muddy sand and sand. The seabed surface substrate data describes the uppermost part of the seabed, from the water-bottom interface to a vertical limit of +/- 30 cm, correlating with the approximate sample depth in the majority of cases (e.g., box corer and Van Veen grab sampler).

2.2.4. Spatial Models

In addition to the interpreted maps from both GTK and SGU, SGU also modelled high resolution surface substrate maps (% cover of grainsizes in 5 m resolution) for the Haparanda pilot area and also modelled the whole SEAmBOTH region (probability of substrate grainsizes and sedimentation rates) at 100 m resolution. The regional model was then further used as a predictor variable in the species and habitat models (Chapter 8).

2.2.4.1. Pilot area models

Substrate grainsize and biological percent cover data was modelled at 5 m resolution using SGU's sediment samples and camera observations from the Haparanda pilot area, together with depth and sonar mosaics from the acoustic survey.

Predictor variables were developed from 1 m resolution bathymetry and 1 m resolution sonar mosaic (a combination of backscatter from multibeam and sonar mosaic from the geoswath sonar), using both pixel-based metrics (ArcGIS) as well as object-based metrics (ENVI Fx module). The predictor variables were computed to 5-meter pixels using different summary statistics to retain as much information as possible from the 1 m resolution data. For the grainsize models, SGU also used data from two ongoing similar projects in the Baltic Sea (North Midsea Bank and Hoburgs Bank surveys), to further strengthen the models.

The machine learning algorithm was a generalized boosted model (GBM), using Boosted Regression Trees, and executed from the Caret package. The pilot area modeling followed at large the methods described in Kågesten et al 2019.

Once a first round of substrate modelling was completed (Haparanda pilot area), the models were evaluated. Based on expert interpretation of the models together with high resolution sonar data, a second training data set was produced by a " a copy and paste" action, where each site was duplicated and moved to a nearby location judged to be of same substrate compositions, but where sonar artefacts distorted the model results. Only data from independent sites were used for test/train partitions to evaluate model performance. The models were then rerun to produce an improved set of models. This final tweaking of model outputs is still ongoing at the time of writing this report, hence the results in the report are based on the first round of models. Only minor and cosmetic changes are expected for the final models once they are published, permission pending.

2.2.4.2. Regional models

A regional substrate model was produced by collecting substrate samples from SGU, SEAmBOTH biological surveys and EMODnet. In areas with missing substrate samples on the Finnish side, points were samples from polygons from GTK geology maps. Data was collated in six classes; soft (clay-silt), sand, coarse (gravel - pebbles and cobbles < 6 cm) and hard (hard clay and grain sizes > 6 cm). As there was not enough quality data to produce a model of percent cover on a regional scale, presence / absence records were used to create probability models, then used as proxies for cover. Absence records were created by assigning absence to classes not present at a location. The final outputs were normalized to represent % cover by dividing by the total sum of all models in each pixel.

Modelling was performed on a raster stack where bathymetry from EMODnet was used together with available depth data from SEAmBOTH and other available data over Swedish waters. From this data, different morphological metrics were produced, such as slope, topographical index and rugosity. Wave action and water movement was modelled out of both a simplified wave exposure (fetch and average winds), a depth-attenuated wave exposure based on this exposure model and bathymetry, as well as water movement (orbital velocity) on the seabed calculated with linear wave theory from average wave height and length, using data from the Copernicus data hub, combined with bottom currents from the same source. To improve the model of soft substrates, a model of sedimentation rates, based on cesium samples, was created from data by EMODnet, and added as a predictor in the substrate model.

Data and predictors were prepared using ArcGIS and the spatial modelling was performed with R. The machine learning algorithm was a generalized boosted model (GBM), using Boosted Regression Trees, and executed from the Caret package.

2.3. Results

According to the regional models, the SEAmBOTH area as a whole is dominated by sand to coarse sediments (58 %) followed by soft substrates (clay -silt, 33 %) and hard bottom (8 %). The geological maps from the pilot areas show that the seafloor consist mainly of gyttja clay (Litorina clay) (~38 %). Till and glacioaquatic mixed sediments cover ~33 % and ~13 % of the seafloor, respectively. Modern accumulation areas cover approximately 5% of the seafloor. Glacial clays cover ~3 %, sand and gravel cover ~1 %, and sand covers ~7 % of the seafloor. Bedrock outcrops exist very seldom in the area. However, the seabed substrate types are very unevenly distributed in different areas. In the area offshore Kemi, the seafloor consists mainly of till (~57 %). The gyttja clays and modern mud cover there ~17 % and ~15 % of the seafloor, respectively. In the open sea areas, gyttja clays are the most dominant substrates, covering ~60 %, or more, of the seafloor. Generally, hard substrates (bedrock, till and gravel) are seldom exposed at the seafloor in water depths deeper than 30 m in the pilot study areas. In greater water depths, seabed surface substrates are dominated by soft clay and mud.

Canyons or canyon-like seabed features are the most striking broad scale geomorphological features of the area. They are often tens of meters deep, hundreds of meters wide and kilometres up to tens of kilometres long depressions at the seabed. These canyons are probably ancient river channels, which formed when the water level was significantly lower than today (e.g. Nenonen, 1995). The riverbeds appear to be extensions of land-based riverbeds (at least partly) and were apparently formed before the last glaciation.

The fine scale geological/geomorphic features discovered in the SEAmBOTH area include erosional hard clay structures. In these features the clay is very compact, and it can create complex reef-like structures. These features are very similar to "clay labyrinth" feature found earlier in the Finnish coastal area by Metsähallitus (see also Kotilainen et al., 2017). In addition, several features related to sediment transport (e.g. ripples), have been observed in the area. All of these fine scale geomorphic features are relatively small and occur patchily, thus the general geological maps do not capture them.

The elevated concentrations of harmful substances, such as cadmium (Cd), lead (Pb), zinc (Zn) and mercury (Hg) are recorded in the seabed sediments in the SEAmBOTH area. The concentrations of heavy metals in surface sediments have generally declined over the last decades. However, in some areas, concentrations of Cd and Zn in the subsurface sediments are still relatively high. The subsurface Cd concentrations are harmful, according ERL standards, in all sediment cores from Kemi offshore area, and also in two sediment cores in Hailuoto Subway Canyon area. Also, the subsurface concentrations of Zn are above ERL heavy metal toxicity level in several sediment cores in Kemi offshore area, as well as in two sediment cores from Hailuoto Subway Canyon area.

2.3.1. Survey

In the Finnish side, altogether a total length of ~1500 km acoustic-seismic profiles were recorded in four study areas: Offshore Kemi, Hailuoto North, Hailuoto Subway Canyon and Ulkokrunni (Fig. 6), covering approximately 318 km2. Survey lines are situated approximately 100–200 meters from each other. In addition, 44 surface sediment cores were recovered from the seafloor. The surface sediment cores were used to provide information on the accumulation and distribution of harmful substances in the sediments.

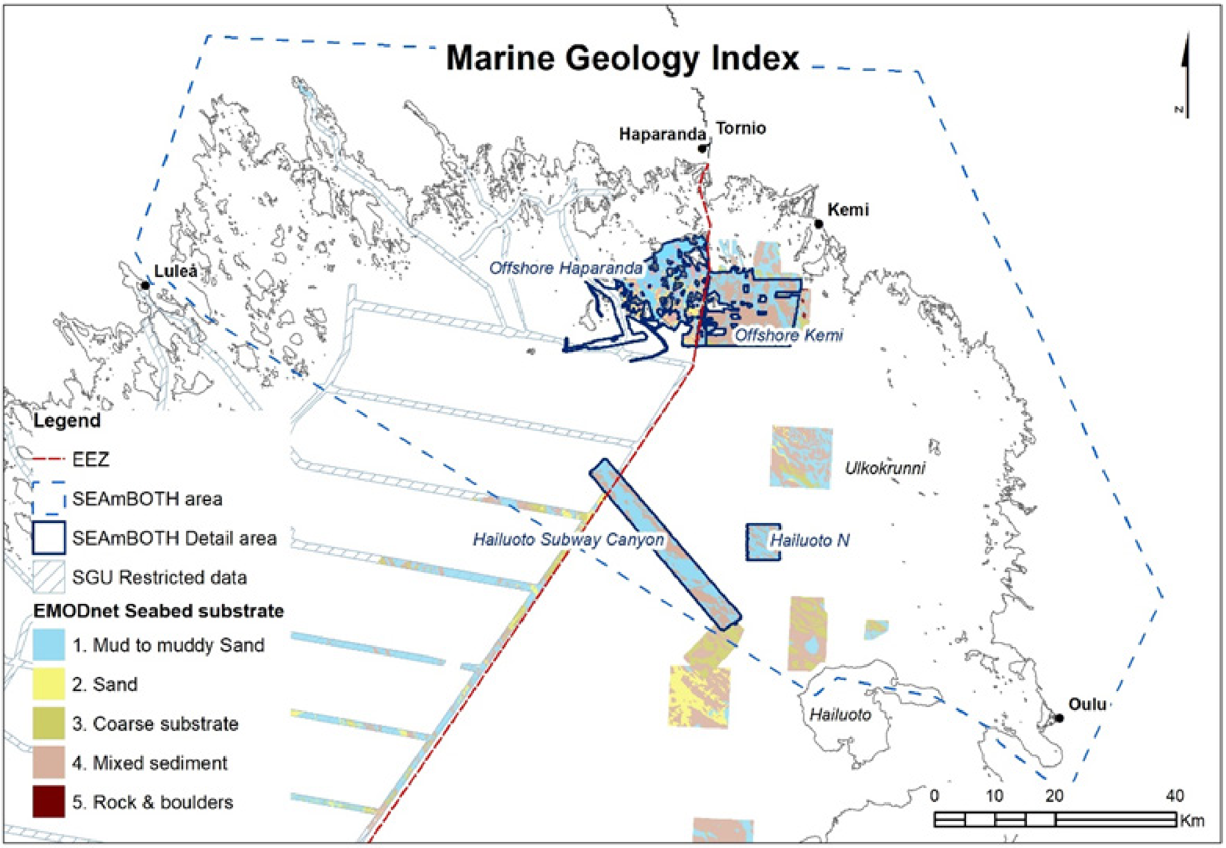

Figure 6. The main geological study areas in Sweden and Finland, in SEAmBOTH area in the Bothnian Bay. The seabed substrate data (a scale of 1:100 000) is shown with EMODnet Folk 5 classification. The map shows also existing "old" seabed substrate data from the area. Map by GTK & SGU.

In the Swedish side, SGU collected ca 200 seabed samples for ground truthing and run ~2800 km of survey lines with a combined length of 3400 km resulting in a nearly complete coverage of the detailed survey area of 193 km 2. The Haparanda pilot area had a maximum depth of 65 meter and was generally mapped to 3 meters depth (shallowest depth reading from the sonar was 0.7 m).

The Finnish and Swedish hydroacoustic survey data covered relatively large areas but overlapped only within a limited study area offshore Haparanda/Kemi. This overlapping 10 km2 study area is covered by a dense net of acoustic-seismic survey tracklines (Figs. 7–9).

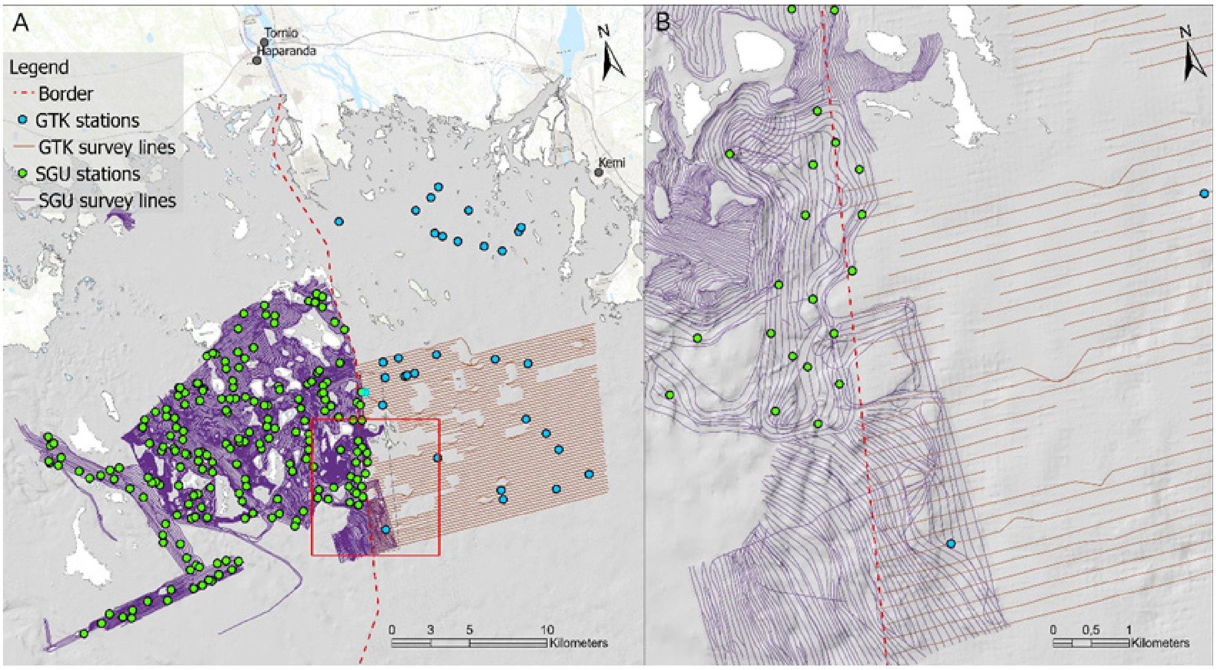

Figure 7. (A) Acoustic survey lines and stations for sediment samples and camera observations from the Haparanda and Kemi pilot areas. (B) closeup showing how density of survey lines varies between GTK and SGU and also by local geography (i.e. shallow waters and islands). Map by GTK & SGU.

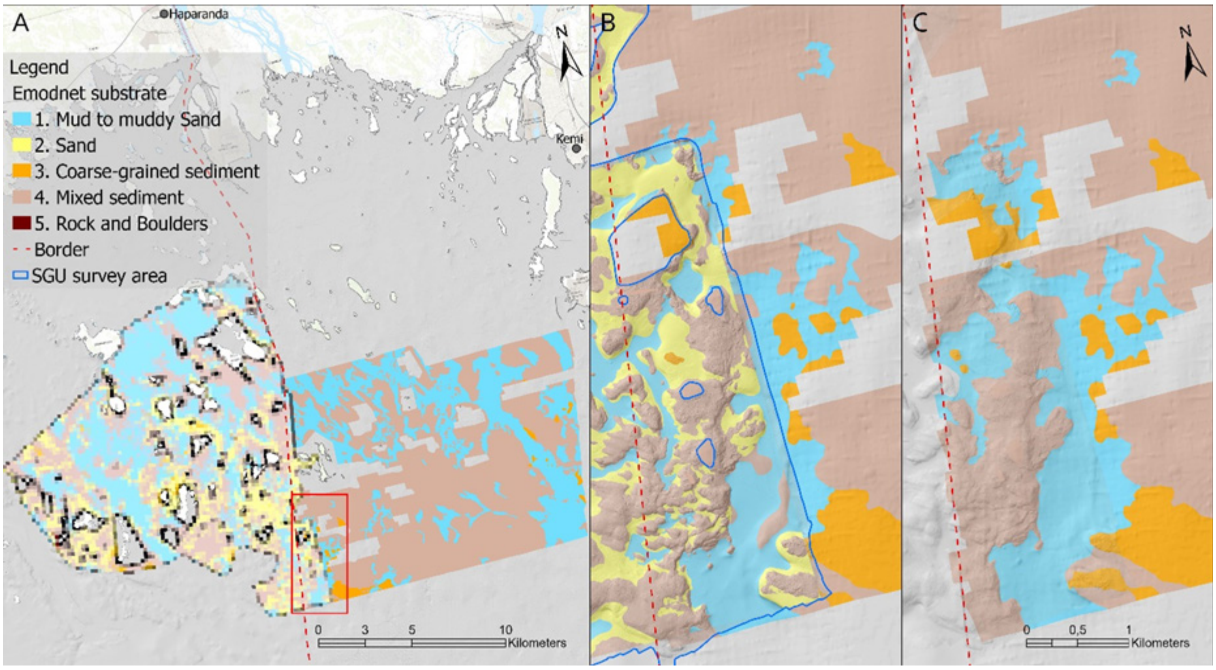

Figure 8. (A) Example of GTK and SGU's geological maps of Haparanda/Kemi offshore areas translated into seabed surface substrates using Folk and Ward classification (same as EMODnet). Maps are presented at a scale of 1: 100 000. SGU's map is displayed at very low resolution due to restrictions. (B) Overlapping border area showing SGU's map on top of GTK's map. (C) same as B, but only showing GTK's map. Map by GTK & SGU.

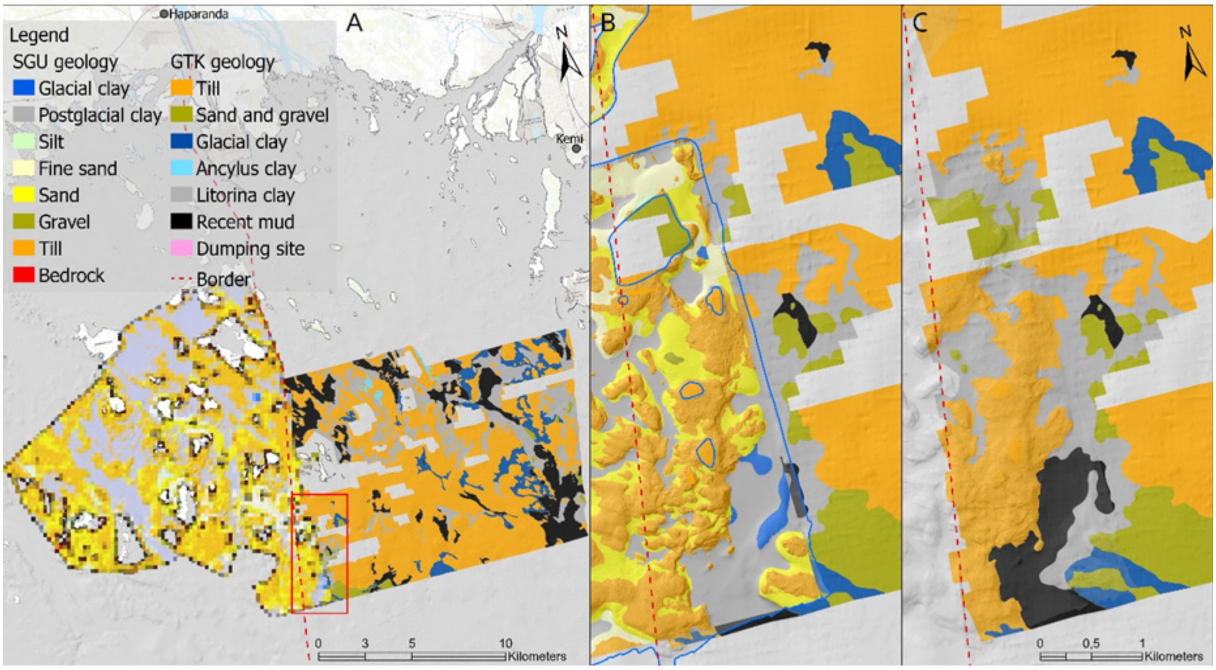

Figure 9. (A) Example of GTK and SGU's geology maps of Haparanda/Kemi offshore areas. Maps are presented at a scale of 1: 100 000. SGU's map is displayed at low resolution due to restrictions. (B) Overlapping border area showing SGU's geology map on top of GTK's geology map. (C) same as B, but only showing GTK's geology map. GTK's map (C) does not show the fine scale features (and seabed substrate polygons) at the same detailed level as SGU's map (B), due to limited number/scarcity of survey tracklines in this area (see Fig. 7). Map by GTK & SGU.

The detailed survey area in Sweden was interpreted as described in section 2.1.2.2. The primary stratigraphic sequence (going from deepest and upwards) is bedrock, till, glacial clay and postglacial clay. But as the till was reworked and washed out over time, finer sediments (sand, silt, and clay) were redeposited in less exposed areas and the coarser sediments (gravel, stones, and boulders) remained, forming a coarse residual layer on the till and in some places, where the till was completely washed out, directly on the bedrock. This process, which is ongoing and accentuated by the eustatic uplift, has resulted in a more complex composition of the upper part of the stratigraphic sequence. The sediments comprising the surface area are (in order of magnitude) till 43 %, postglacial clay 35 %, sand and fine sand 20 %, while all others are less than 1 %. Postglacial clay generally has a more general distribution and till a markedly patchier occurrence.

2.3.2. Maps and statistics

In the Finnish side, the local scale bathymetric (Fig. 12), geological (Fig. 9) and seabed substrate (Fig 10) maps have been produced from Offshore Kemi, Hailuoto North and Hailuoto Subway Canyon areas covering approximately 318 km2. These maps were produced at a scale of ~1: 20 000, but the maps are presented at a scale of 1:100 000 due to permission issues (The Finnish Defence Forces/The Defence Command; Permission decision AP10925, 4273/15.05.00/2018, 14th June 2019).

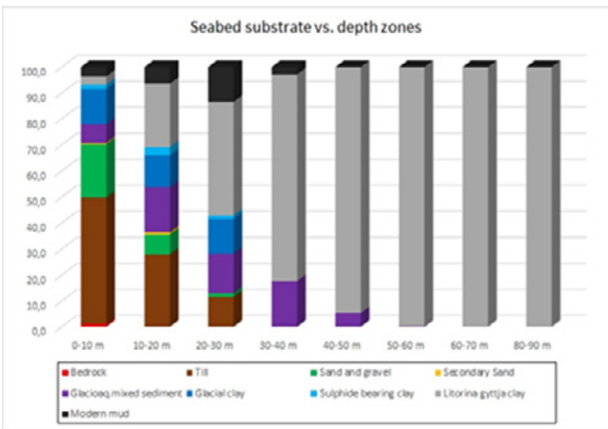

Figure 10. Occurrence (%) of various substrate types in different water depth zones, in the Finnish side of SEAmBOTH area, in the Bothnian Bay. Data include results from SEAmBOTH surveys and also the existing and available GTK's previous geological data.

Six main sedimentary units above the bedrock are distinguished from GTK's data; (1) till,(2) glacioaquatic mixed sediments, (3) glacial clays/varved clays, (4) sulphide bearing clays, (5) gyttja clays, and (6) topmost 'recent' organic bearing gyttja (mud). Till and its deposits can be found above the bedrock almost everywhere in the study area. Above till, glacioaquatic mixed sediments and glacial clays/varved clays (and silts) occur at several places. Above glacial clay, sulphide bearing clays occur in places and gyttja clays can be found often. In some sheltered basins, recently accumulated gyttja (mud) can be found in the uppermost part of the sediment column.

Spatial distribution of different substrate types on the seafloor (i.e. substrates that are exposed at the seabed), in the SEAmBOTH detail areas are shown in Fig 10 and Table 2. The seafloor of this area consists mainly of gyttja clay (Litorina clay) (~38 %). Till and glacioaquatic mixed sediments cover ~33 % and ~13 % of the seafloor, respectively. Modern accumulation areas cover approximately 5 % of the seafloor. Glacial clays cover ~3 %, sand and gravel cover ~1 %, and sand covers ~7 % of the seafloor. Bedrock outcrops exist very seldom in the area (less than 1 %).

Table 2. The areal coverage (km2, %) of different seabed substrate types in the area offshore Haparanda (SGU), the area offshore Kemi (GTK), Hailuoto North (GTK), Hailuoto Subway Canyon, and also in all SEAmBOTH detail pilot areas together (total). The geological classes (used in GTK and SGU) and EMODnet substrate classes are shown in the table.

		Area offshore Haparanda/SGU		Area offshore Kemi/GTK		Hailuoto N/GTK		Hailuoto Subway Canyon/GTK		SEAmBOTH Detail areas (total)		EMODnet Substrate class
Geological class/GTK	Geological class/SGU	Area (km2)	Area (%)	Area (km2)	Area (%)	Area (km2)	Area (%)	Area (km2)	Area (%)	Area (km2)	Area (%)	(mod. Folk 5)
Bedrock	Bedrock	0	0	0	0	0	0	0	0	0	0	Rock and boulders
Till	Till	63	43	90	57	0	0	0	0	153	33	Mixed sediments
Sand and gravel	Postglacial gravel	1	1	3	2	0	0	0	0	5	1	Coarse grained sediments
Secondary Sand	Postglacial fine sand	7	5	0	0	0	0	0	0	7	2	Sand
	Postglacial sand	22	15	0	0	0	0	0	0	22	5	
Glacioaq.mixed sediment		0	0	0	0	11	34	52	40	63	13	Mixed sediments
Glacial clay	Glacial Clay	0	0	11	7	0	0	0	0	12	3	
	Postglacial silt	2	1	0	0	0	0	0	0	2	0	Mud to muddy sand
Ancylus clay	Postglacial Clay	0	0	1	0	0	0	0	0	1	0	
Litorina clay	Postglacial Clay	51	35	27	17	21	66	78	60	178	38	
Recent gyttja/Mod. mud	Postglacial Clay	0	0	24	15	0	0	0	0	24	5	
	Total	147	100	157	100	32	100	130	100	466	100	Total

However, the seabed substrate types are very unevenly distributed in different areas (Fig 10, Table 2). In the area offshore off Kemi, the seafloor consists mainly of till (~57%). The gyttja clays and modern mud cover there ~17% and ~15% of the seafloor, respectively. Till (~43 %) and postglacial clays (~35 %) dominate also the area offshore Haparanda. In the open sea area, in Hailuoto Subway Canyon and in Hailuoto N, gyttja clays are the most dominant substrates, covering ~60% and ~66% of the seafloor, respectively. In both open sea areas, glacioaquatic mixed sediments are also common, covering ~40% and ~34% of the seafloor, respectively.

When looking at seabed substrate distribution in different water depth zones based on Finnish data (Fig. 10), it is visible that hard substrates (bedrock, till and gravel) are not exposed at the seafloor in water depths deeper than 30 m. In greater water depths, seabed surface substrates are dominated by clay and mud. The modern mud accumulation seems to occur in the water depths shallower than 40 meters. In the shallow water (0–10 m) areas, seabed substrates are dominated by the hard substrates, which cover ~70 % of the seafloor in this depth zone.

2.3.3. Recent sedimentation rates and harmful substances in the sediments

In order to study recent sedimentation rates as well as occurrence/concentrations of environmentally harmful substances in the sediments, a total of 44 sites were sampled in the SEAmBOTH area in the Bothnian Bay. The sampling locations, from water depths between 4–60 m, were selected carefully using acoustic-seismic profiles. Sediment cores were recovered from three different areas; from the vicinity of Kemijoki estuary, from Kemi offshore area, and from open sea area, Hailuoto Subway Canyon. Recent sedimentation rates, based on 137Cs activity concentrations, varied in these sediment cores between 2–3.9 mm/year in Kemijoki/Tornionjoki estuary, 2.4–6.9 mm/year in area offshore Kemi, and 2.6–8 mm/year in Hailuoto Subway Canyon.

Here we show the concentrations of cadmium (Cd), lead (Pb), zinc (Zn) and mercury (Hg) from selected sediment cores (Fig. 11). Cadmium concentrations show relatively similar trends in all sediment cores. Cd concentrations increase from the bottom towards the subsurface maxima, which occurs between 10–30 cm in cores depending on their sedimentation rates. Above the maximum values, concentrations decrease towards the surface (the present day) at every site, in all areas. The highest subsurface Cd concentrations, over 3 mg/kg, occur in the sediment cores from Kemi offshore area (Fig. 11E). Subsurface maximum Cd concentrations are above "effects range-low" (ERL) heavy metal toxicity level (1.2 mg/kg; Long et al. 1995) in all sediment cores from Kemi offshore area, and also in two sediment cores in Hailuoto Subway Canyon area (Fig. 11H).

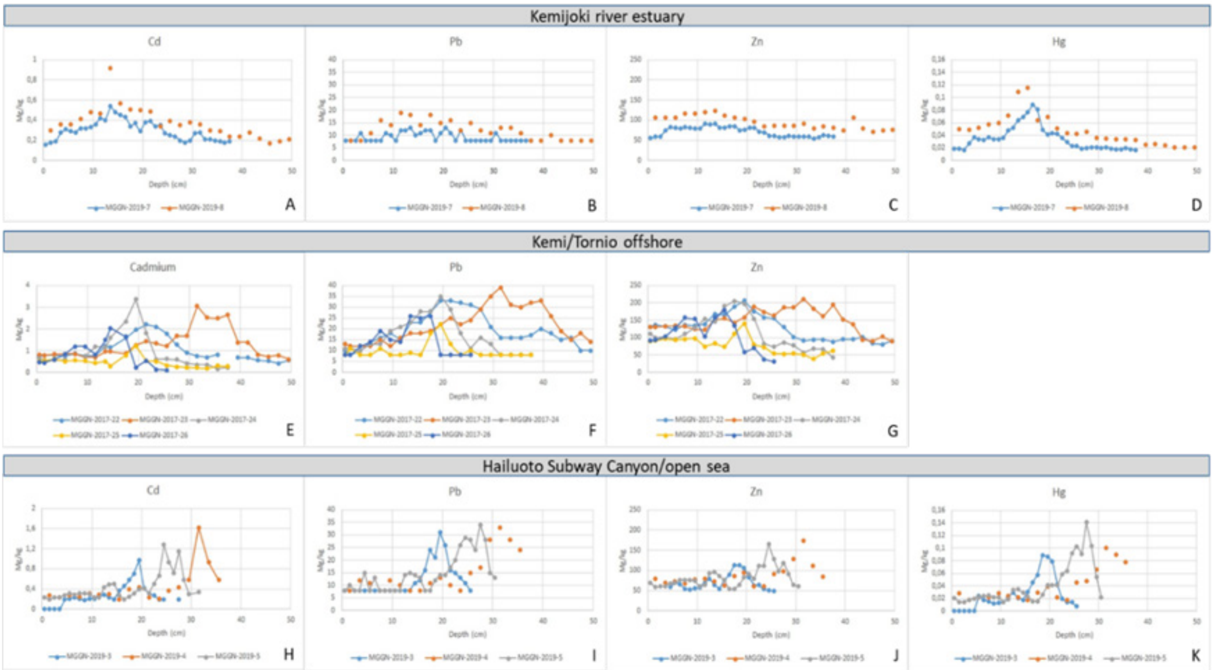

Figure 11. Cadmium (Cd), lead (Pb), zinc (Zn) and mercury (Hg) concentrations (mg/kg) in the sediment cores from the vicinity of Kemijoki/Tornionjoki river estuary (A, B, C, D), Kemi/Tornio offshore area (E, F, G. Note: mercury concentrations are not shown for this area), and Hailuoto Subway Canyon open sea area) (H, I, J, K).

The vertical distribution of lead indicates that in the vicinity of Kemijoki/Tornionjoki river estuary, in the lowermost sediment samples (deeper than 36 cm), the concentrations are below the detection limit (<10 mg/kg) (Fig. 11B). At these sites, Pb profiles show a slight increasing trend towards the subsurface maximum values (at ~14–11 cm) and decrease then towards the surface. Pb concentrations are relatively low in these river estuary sediments. In Kemi offshore area, the peak of Pb concentrations in sediment cores were achieved between 32 and 13 cm, and in Hailuoto Subway Canyon between 32 and 19 cm. Thereafter the concentrations decrease towards the surface. The highest Pb concentrations (39 mg/kg) occurred at the depth of 31–32 cm in the core MGGN-2017-23. The 137Cs activities (in the sediment cores) suggest that the highest concentrations of lead in these sediment cores are from the late 1960's and 1970's. A decreasing trend in lead concentrations towards the surface was visible at every site.

The vertical distribution of zinc (Fig. 11C, -G, and -J) is very similar to lead distributions. In the lowermost subsamples, Zn concentrations are usually less than 80 mg/kg. The Zn profiles at the sites close to Kemijoki/Tornionjoki river estuary show an increasing trend towards the subsurface maximum values (~14–11 cm). Above the maximum values, the concentrations decrease slightly towards the surface. In Kemi offshore area, the peak of Zn concentrations in sediment cores were achieved between 32 and 15 cm, and in Hailuoto Subway Canyon between 32 and 18 cm. Thereafter the concentrations decrease towards the surface. The highest Zn concentrations (>200 mg/kg) occurred subsurface in several cores in Kemi offshore area (Fig. 119G). These high Zn concentrations are above ERL heavy metal toxicity levels (150 mg/kg; Long et al., 1995). This level is exceeded also in two sediment cores from Hailuoto Subway Canyon area (Fig. 11J). The 137Cs activity concentrations in the sediment cores suggest that the highest concentrations of Zn are from the 1970's to the early 1980's.

In the lowermost subsamples, mercury concentrations are usually less than 0.03 mg/kg. The vertical distributions of Hg in the sediment cores, at sites close to Kemijoki/Tornionjoki river estuary, show an increasing upward trend, towards the subsurface maximum values (~17–15 cm). Since then, the concentrations decrease towards the sediment surface (Fig. 11D). In sediment cores from Hailuoto Subway Canyon, maximum Hg concentrations were achieved between 32 and 18 cm. Thereafter the concentrations decrease towards the sediment surface. Maximum mercury concentrations (0.141 mg/kg) occurred at the depth of 27–28 cm in the core MGGN-2019-5 (Fig. 11K). According to 137Cs activity concentrations in the sediment cores, the highest concentrations of mercury are from the early 1960's to1970's.

2.3.4. Seabed features

The average and maximum water depths of the whole SEAmBOTH area are 19 and 125 metres, respectively. In a broad scale the seabed is characterised by a relatively smooth, slightly tilted eastern side and a steeply sloped and broken western area. A similar difference can be observed in the landscapes of the Swedish and Finnish coasts. On its Finnish side, the seafloor of the Bothnian Bay slopes slightly to the west/south-west. The seafloor of the Bothnian Bay on its Swedish side is more fragmented. The deepest area is located in the south-western part of the study area.

The most striking broad scale morphological features are canyons or canyon-like seabed features (Figs. 1 and 12). They are often tens of meters deep, hundreds of meters wide and kilometres up to tens of kilometres long depressions at the seabed. In addition to valleys and canyon-like seabed features, also other broad scale geomorphic features like basins, plains and various elevations occur in the SEAmBOTH area (see also Kaskela et al., 2012). Both the ridges and canyons run mainly in a northwest to southeast direction. This northwest-southeast orientation has been emphasised by the direction of the largest fracture zones within the bedrock running parallel to the main flow direction of the continental ice sheet.

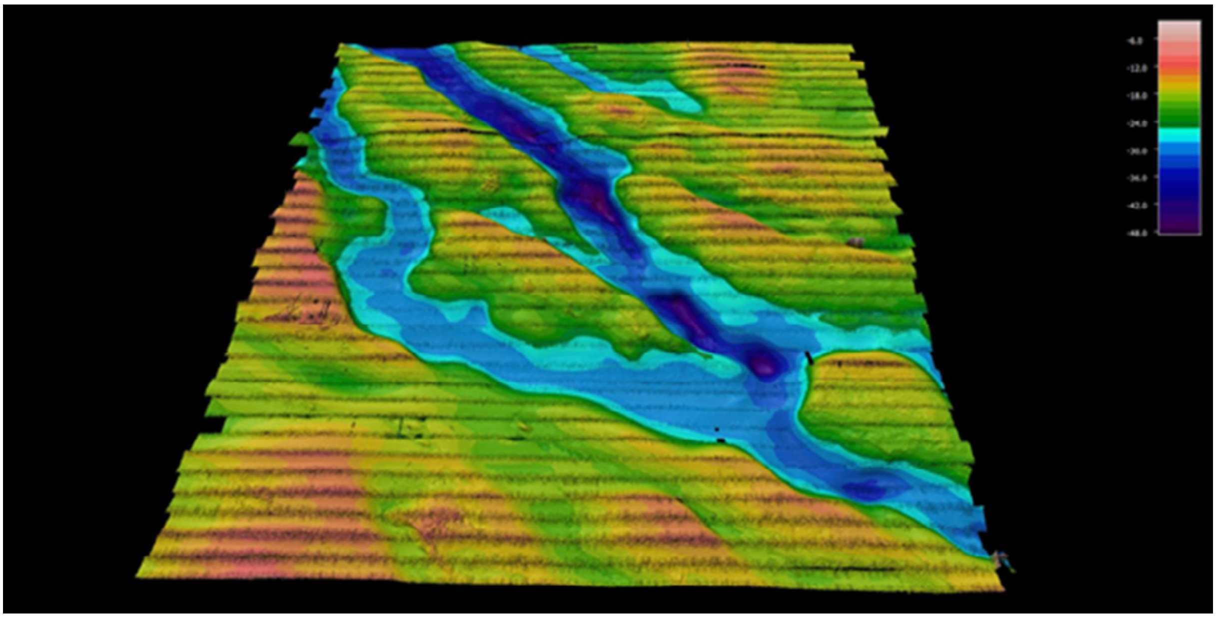

Figure 12. The multibeam echosounder image illustrates seafloor topography of the canyon in Hailuoto North detail SEAmBOTH area, the Bothnian Bay. Figure by GTK.

High resolution acoustics surveys (e.g. MBES, SSS) provided information on various fine scale geological/geomorphic features in the SEAmBOTH area. These surveys show in more detail how structurally complex large areas of the shallow seafloor are, and also the dynamic nature of the seabed with many areas showing signs (ripples) of sediment transport (Fig. 13). One feature which is likely under-represented in the interpreted maps is hard clay structures, which occur very patchily and are generally in the order of 10s of meters large, hence the general geological maps do not capture them. The clay is very compact (shaped by glacial processes) and can create complex reef like structures. Figure 13 shows example of different fine scale structures seen in the high resolution multibeam data.

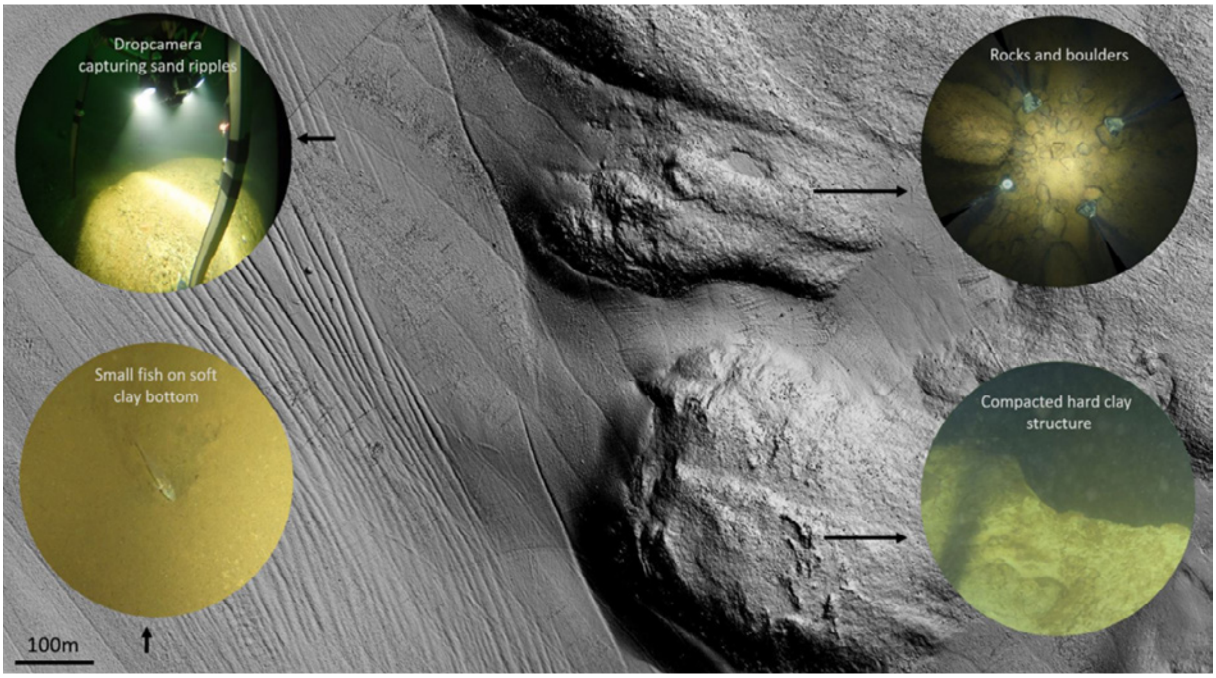

Figure 13. Multibeam hillshade (0.5 m resolution) with underwater photos from SGUs survey in the Haparanda pilot area. Though the main geological features are captured in the interpreted geological maps, many fine scale features such as sand ripples and small patches of hard clay structures are not. Figure by SGU.

2.3.5. Spatial models

Due to pending permission to show maps in full resolution, the results from the Haparanda pilot area and the whole SEAmBOTH area (affecting the Swedish side, the Finnish side of the model only uses open data), the modelled results are not shown in full resolution. However, examples without coordinates, as well as lower resolution maps and statistics, are shown in this section.

2.3.5.1 Pilot area models

The main focus in the pilot area was modelling surface substrates. However, since the drop-camera data used to train the models also includes biological data on sessile benthic organisms in the survey area, these were also included in the modelling efforts. The following eight substrate components have been modelled (each individual model in parenthesis): soft sediments (fine clay, silt), sand, coarse sediments (gravel, stones/pebbles) and hardbottom (large stones, boulders, large boulders, and hard clay). The following biological components have been modelled: colonized substrate, detritus, filamentous algae, Ephydatia fluviatilis (sponge), Cordylophora caspia (freshwater hydroid). At the time of writing the report, the final models are still in progress, hence the models may change slightly from what is displayed in the results here. Once SGU publishes these maps (permission pending) they will also include model accuracy in the metadata. Figure 14 shows an example how substrate and species models compare with the interpreted geological map. In general, similar patterns are seen in both substrate model and the thematic interpreted substrate map. However, the substrate models capture much variations within the thematic classes as well as soft transitions, indicating that even a very detailed thematic map (1:25000) is still a significant simplification of the true natural complexity of the seascape. In addition, the comparisons between the model outputs and the thematic map suggest that there are more sand – coarse sediments in the very top surface substrates than the thematic substrate map indicates. A possible explanation for this is that the “EMODnet substrate” map is a direct translation from the geological map which captures the main substrate in the top 1 m of the seafloor.

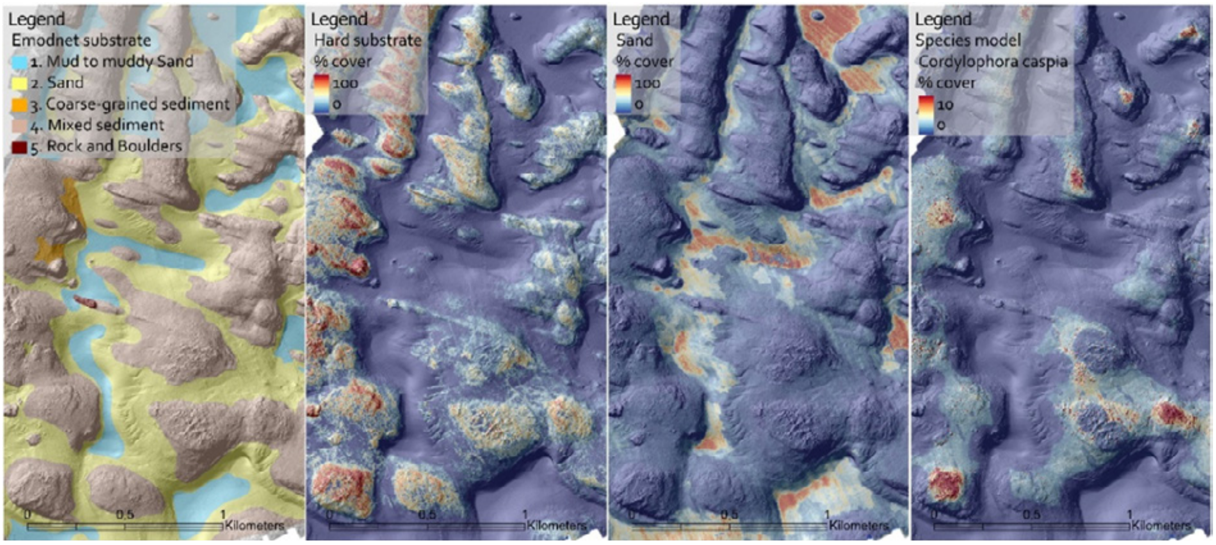

Figure 14. Comparison between interpreted geological map and examples of high-resolution model outputs. Notice how overall patterns are similar but that there is a lot of variation within each thematic interpreted geology class. (A) Interpreted geological map in Emodnet/Folk classes. (B) Hardbottom model 5 m resolution. (C) Sand model 5 m resolution. (D) Species model Cordylophora caspia (freshwater hydroid) 5 m resolution, including the substrate models as predictor variables to improve performance. Map by SGU.

2.3.5.2. Regional models

The substrate models for the whole SEAmBOTH area are shown in Figure 15. The accuracy of the models is currently only available for the presence/absence aspect of the models (Table 3). The accuracy for the adjusted models representing percent cover for each substrate component needs further studies and should be used with caution when used to represent absolute coverages rather than general spatial trends. Furthermore, Figure 16 shows the comparison between local and regional models and indicates that the regional models capture the general patterns of the distribution of sediments on the seafloor, but struggle to capture patchy distributions (such as smaller hardbottom features). It is likely that the quality and resolution of available environmental data (such as high resolution multibeam) at the regional scale is to blame, as well as the quality of the ground truthing data from a multitude of sources.

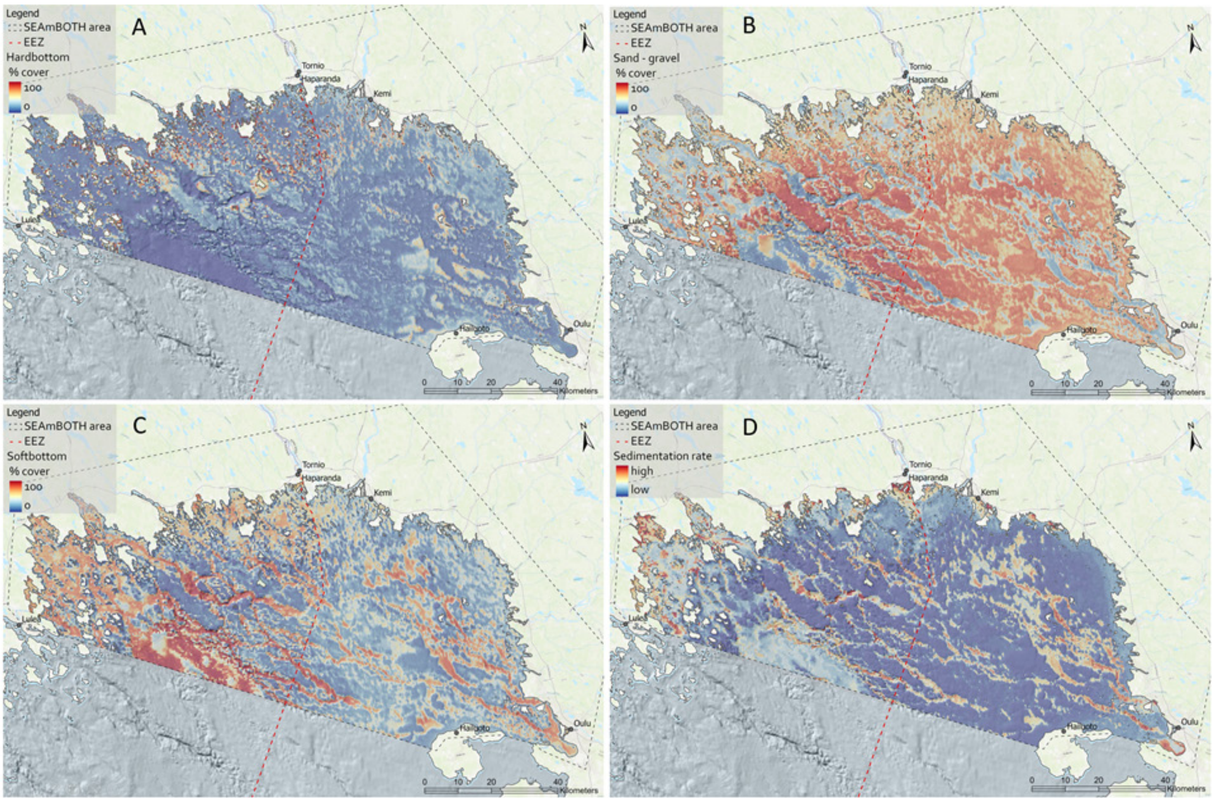

Figure 15. Model results from regional substrate model. (A) Hard substrate (> 6 cm grainsize). (B) combined results from sand and coarse models (gravel – cobbles < 6 cm). (C) soft substrate model (clay-silt). (D) sedimentation rates. Map by SGU.

Overall, the models indicate that the most common substrate in the region's shallow and exposed sea area is sand and coarse substrates (58 %), followed by soft substrates (33 %) mainly found in the deeper areas and in the valleys and canyon-like seabed features (described in 2.3.4. seabed features). Hard bottom is of patchier occurrence (8 % of the area) and is mainly found in the shallower areas. However, a comparison with the much higher resolution models from the Haparanda pilot area (Fig. 13) suggest that hardbottom might be under-represented in the regional models, which use much coarser depth data, and lack any sonar mosaic data, which is important to identify smaller patches of seabed features.

Table 3. Table showing proportions of substrate in the whole SEAmBOTH area based on the regional model results. These numbers have not been fully calibrated to grainsize analysis (the reported accuracy is only explaining the model's ability to predict presence/absence) and should be used with caution.

Model	Model unit	Total area (km^2)	Mean cover	Accuracy (presence/absence)
Soft substrate	probability	2508	33 %	74.5 %
Sand – cobbles	probability	4415	58 %	72.5 % (sand), 68.1 % (coarse)
Hard substrate	probability	625	8 %	79.9 %

2.3.5.3 Spatial and thematic resolution

An important aspect of any map is what resolution they capture of the natural world, both spatially and thematically, and another aspect is accuracy. To provide a sense of what the modelled maps from the SEAmBOTH area show and what they do not, a visual comparison of the high resolution substrate model and the regional model is provided (Fig. 16), as well as an example of how spatial resolution distorts our knowledge about specific features (Fig. 17). In addition, figures 8 and 9 show the differences between two interpreted maps with different underlying survey effort, and figure 14 shows the differences between a high-resolution modelled map and an interpreted map. The results from these comparisons indicate that the regional model is able to predict general trends and distributions but fail to detect fine scale features, such as smaller patches of hardbottom. The regional models also have a lower thematic resolution than the pilot area model due to lower quality of the model training data (only absence presence training data while the pilot area model used lab verified percent coverages). The spatial and thematic resolution of the interpreted maps are clearly depending on survey effort (i.e. quality and density of acoustic data and samples/images).

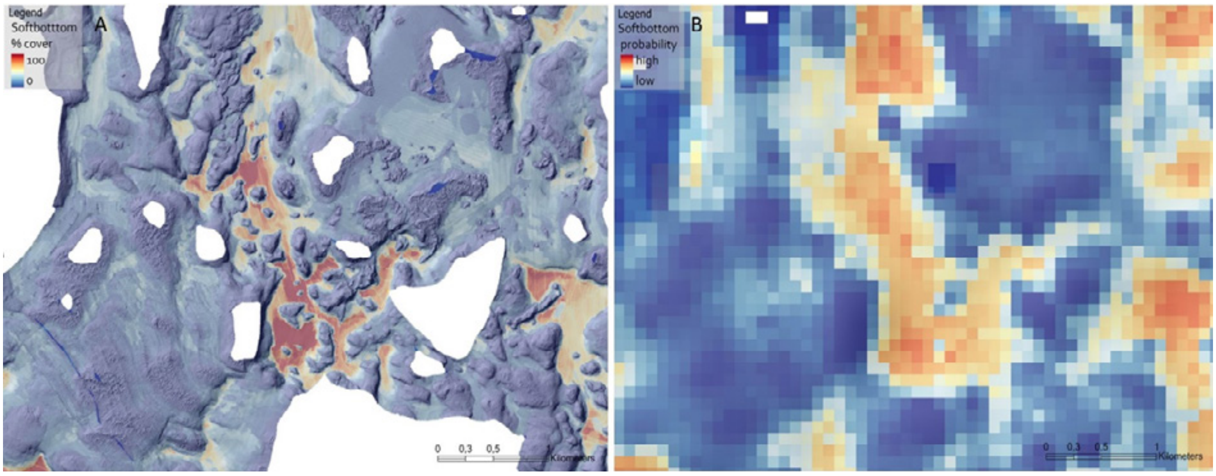

Figure 16. Comparisons between regional substrate model and the local substrate model from the Haparanda pilot area. Overall patterns are similar but much detail, such as smaller areas with hardbottom, is missing in the regional model. (A) Pilot area soft (clay-silt) substrate model. (B) regional soft (clay-silt) substrate model.

When comparing how model outputs for the pilot area model change with spatial resolution (Fig. 17) in a spatially complex area, one can see that the main features are visible up until 50 m resolution but are completely obscured at 250 m resolution. Many small-scale features, such as hard clay structures, are obscured already at 10 m resolution.

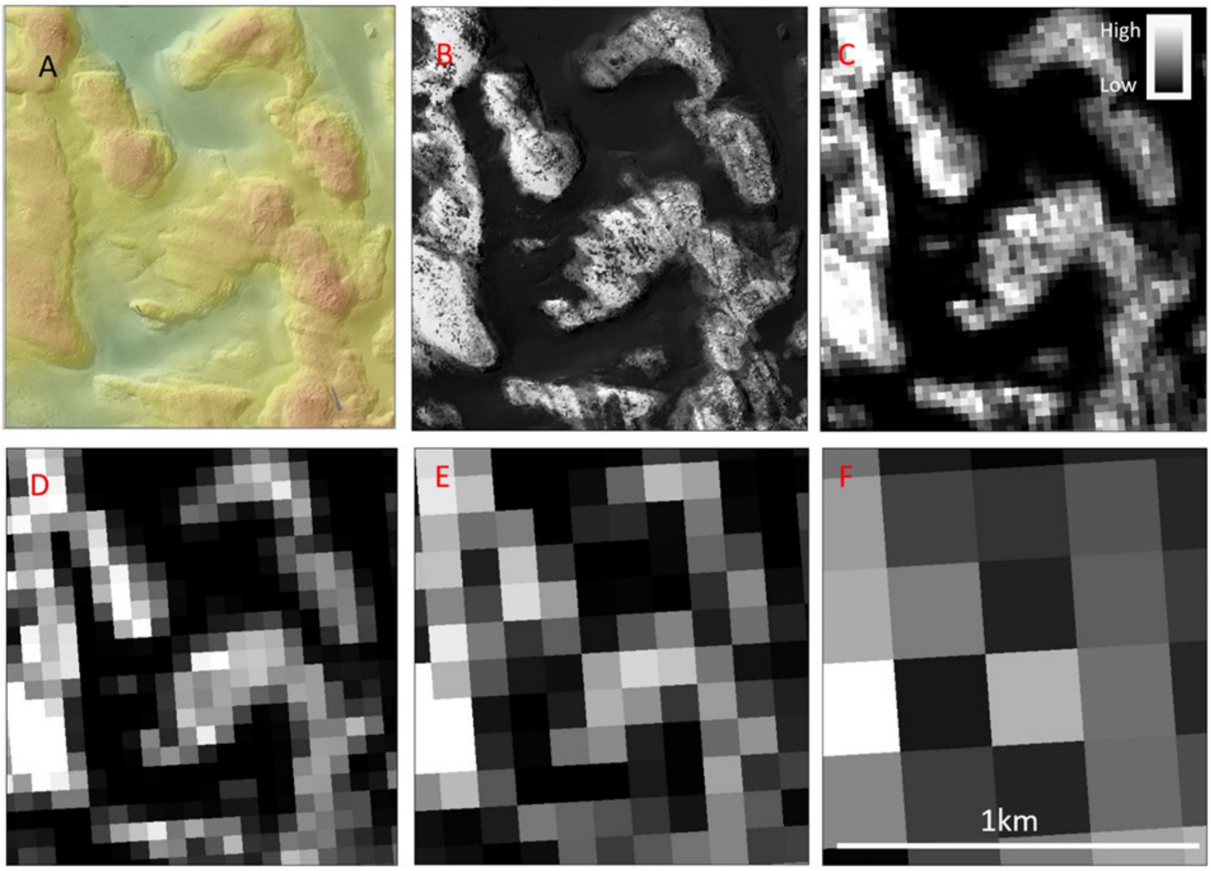

Figure 17. Examples of how different spatial resolutions capture features on the seafloor from Haparanda pilot area. (A) 1 m multibeam data. (B - F) hard substrate model at resolution 5 m (A), 20 m (B), 50 m (C), 100 m (E) and 250 m (F).

2.4. Discussion

Mapping the relatively shallow, complex seafloor in uncharted, weather exposed, and turbid waters in the northern Bothnian Bay provided a real challenge to both GTK and SGU. The initial plan for the project was to also include a Lidar survey to map the very shallow part of the area, which would have been very useful for both navigational and mapping reasons. Shallow water surveys require a greater number of survey line kilometres (from multibeam echosounder or side scan sonar) than deeper water surveys for full coverage seafloor mapping. At the same time, the information from the detail pilot area surveys has disclosed many seabed features not visible in existing or coarser data. In order to scale up this effort and provide high quality seabed information from similar kind of exposed, shallow and complex Archipelago Sea areas while keeping costs and time within reasonable limits, the survey technologies needs to be refined further. A promising piece of technology already on the market is small Automated Surface Vessels that can collect data independently (and running on efficient low energy electric power rather than large diesel engines) while they main survey vessel can act as a mothership and spend more time on sampling then survey. This way navigational hazards can also be mitigated in a safe way.

Even if the survey was challenging, especially in the shallow areas in the Haparanda archipelago, significant areas were mapped and the overlapping mapping effort at the Swedish/Finnish border provided useful insight in similarities and differences in the mapping methods and the effect of different survey effort per area mapped. With a denser net of survey track lines, more detailed information and higher seafloor coverage (full coverage seafloor mapping) can be achieved, but the areal coverage is then less (or the effort significantly higher!). The trade-off between resolution and coverage depends on the intended use, so no clear recommendations can be made for future projects – only that the effect of lower mapping density is clear and requires a conversation about intended use of the maps before the survey commences.

The conversation about survey effort also spills over to modelled maps. As shown in figures 15 and 16, it is now relatively easy to produce detailed and good-looking maps over large areas with existing data using spatial modelling techniques. However, once high-quality data becomes available, such as in the pilot areas, it is apparent that good underlying data quality is always important to capture the natural variability. With only low quality or low-resolution environmental variables (such as depth) available, the models fail to capture more complex areas well. This does not lessen the value of the regional models but only highlights that it is important that we understand what different models are good for (and what they fail to show) when putting the maps to work.

Another conversation to be had is the value of seafloor knowledge from deeper areas. When considering ecological values in this project, the focus has been on the shallower areas where most of the biological diversity is found. This is also shown in the SGU survey in the Haparanda pilot area where only a handful of sessile benthic species where identified below 5 meters. However, to fully understand the ecosystem from shallow to deeper waters, fish and infauna is also an important part of the ecosystem and here the deeper geological maps will likely play an important role. We hope that the maps produced in the SEAmBOTH project will lead to new uses of this kind of data in future studies.

Finally, a word on the legal obstacles to work with seabed data today. Military restrictions are a significant challenge to tackle, especially in these kind of collaborations between several countries. It was also the main reason why a Lidar survey was not carried out on the Swedish side, causing a major setback to the mapping of SEAmBOTH project area. Even if SGU applied for permission to share their data at the start of the project (now almost three years ago), the permission is still pending (a first application was denied, and the second application is still unresolved and complementary information was recently provided with examples from the final maps and models). The Finnish side has been more successful, and SGU also got permission to survey a small area in Finland along the border which was very useful to the project. A recommendation to future projects is to provide very detailed examples of how the products will look like, and to start the process early! Hopefully the SEAmBOTH data can serve as a good example and help future projects move along faster with permissions. The effect of different resolutions displayed in figure 17 is one way to provide information and apply for multiple resolutions.

3. Physical and chemical marine environment

3.1. Physical and chemical water quality in Northern Bothnian Bay

Abiotic features like oxygen concentration and water salinity have a fundamental effect on the distribution of species. Physical and chemical water quality of Northern Bothnian Bay was monitored during the SEAmBOTH project in summers 2017, 2018, and 2019. Apart from normal water quality analyses (for example salinity, turbidity, secchi depth, temperature, oxygen concentration, nutrients, total organic carbon TOC), also analyses needed for the development of remote sensing methods in the Bothnian Bay were added in monitoring. A total of 25 monitoring stations were included in the SEAmBOTH project.

The Northern Bothnian Bay is characterized by freshwater runoff from several large rivers causing very low salinity levels near river estuaries (< 0,1 PSU). Outside from river estuaries, salinity varies with depth and season. During winter, spring, and early summer, the lighter freshwater spreads out under ice or on the upper layer and deeper layers are more saline. Usually, salinity varies between 1–2 PSU in upper layers/shallow areas and between 2–3 PSU in deeper layers/areas.

Rivers are also a major source of humus, phosphorus, and nitrogen in northern Bothnian Bay. Average transparency is only about 1,5–2,0 meters near river estuaries but reaches over 3 meters in offshore stations. The humic content of water is quite high (average dissolved organic carbon content between 5,5–6,7 mg/l in different stations), but turbidity and number of suspended solids is low outside the river estuaries.

Total phosphorus and nitrogen concentrations are highest in river estuaries and in some sheltered bays/areas where waste waters from industry or from population centres are discharged. Otherwise, the nutrient levels are quite low, reflecting mainly oligotrophic conditions. Chlorophyll-a concentration, which indicates the amount of phytoplankton in water, is also highest near river estuaries and in some sheltered areas. Otherwise, the average concentration is between 3,0–4,5 µg/l in different stations reflecting slightly eutrophic conditions.

4. Remote sensing

The SEAmBOTH project used satellite observations (EO, Earth Observation) to detect spatial and temporal changes in the water quality in the area of the Bothnian Bay. The estimation of water quality using satellite observations is based on measurements of sun light reflected from the water. The instruments on satellites observe this light in various spectral channels (or bands), typically covering the optical and infrared wavelength regions. Mathematical models (algorithms) are then used to convert the signal into information about the water quality parameters. The most common parameters are:

- Concentration of Chlorophyll-a (Chl-a, a proxy for phytoplankton biomass)
- Turbidity (a measure of scattering in water, which is related to the concentration and type of particles suspended in water)
- Absorption by Coloured Dissolved Organic Matter (aCDOM, a measure of the amount of decomposed vegetation matter in water)
- Water transparency (a measure of the overall clarity of water)
- Surface temperature

The main advantages of using Earth Observation (EO) for aquatic monitoring are the superior spatial and temporal coverage of satellite instruments. A satellite image provides a continuous grid of measurements from a target area in cloud-free conditions. Therefore, the amount of observations is manifold in comparison to point-wise observations provided by station sampling and transects measured on-board ships. The Baltic Sea is observed every cloud-free day using instruments on two sentinel-3 (S3) satellites. Shallow areas where the bottom may be visible are rejected when water quality is estimated. Sentinel-2 (S2) satellites provide higher resolution instruments that are needed when investigating the inner parts of the coastal waters. S2 has less frequent overpasses than the S3 but still provides 2–3 observations per week.

The work presented here is based on collaboration between three partners. The Finnish Environment Institute (SYKE) was responsible mainly for the development and processing related to S2 data. Brockmann Geomatics Sweden AB (BG) concentrated on the utilization of S3 data. Stockholm University (SU) was responsible for providing in situ measurement protocols and performing measurements in the study area.

Having good quality in-situ data is extremely important. Without good reference data the development of EO methods cannot succeed. SU provided optical measurement protocols and data quality requirements at an early stage of the project, so that they could be used by various monitoring groups and subcontractors when doing optical measurements.

Water quality products processed from S2 and S3 satellite images were validated during the SEAmBOTH project. The Baltic Sea and especially the Bay of Bothnia are challenging areas for the utilization of EO for water quality estimation. In comparison to other sea areas in the world, water in this region often appears darker. This is due to the high light absorption by CDOM combined with relatively low particle concentration.

The SEAmBOTH validation efforts also provided insight on the performance of some of the publicly available algorithms in the project area. No fixed processing chains or "on-the-shelf" products for a generation of water quality products with the S3 data in the SEAmBOTH project area could be defined through the project. It is likely that the problems are mainly due incorrect atmospheric correction, which is the first step in the processing of satellite images.

Another part of the SEAmBOTH project work was to model the reflectance of the Bothnian Bay using a radiative transfer model Hydrolight (Sequoia, USA). This work utilized the Inherent Optical Properties (IOPs) measured during the SEAmBOTH project. The results showed that the reflections could be best predicted when using the IOPs measured in the Bothnian Bay compared to using more general IOPs from the Baltic Sea. More work needs to be done to refine the model, but this initial work shows very promising results. This information is required in order to develop a dedicated processor for the processing of ocean colour data over the Bothnian Bay, which is characterized by a very high humic absorption (brown/humic waters) combined with relatively low scatter from particles.

Besides the more practical bio-optical work in the SEAmBOTH project, it also included the provision of bio-optical measurements training and joint protocols to the monitoring groups. This type of training and data quality control should be continued in order to reduce the uncertainties in the evaluation of satellite data (see Bio-optical protocols in the Remote Sensing Report).

One of the objectives for developing EO methods for the Bothnian Bay was to provide input data for ecological modelling (Chapter 3.2 in the Remote Sensing Report). Single images often have clouds and do not cover the target area completely. It is therefore advantageous to use a longer time period to collect satellite data and compute average pixels values to be used as input data in the model. This also reduces the noise that can occur in the data. An example of such a temporal composite image is shown in figure 18. Those locations at which elevated values of turbidity are consistently found are visible as yellow and red areas. The areas with relatively high turbidity include e.g. river estuaries and areas where dredging is taking place, leading to a strong resuspension of sediments.

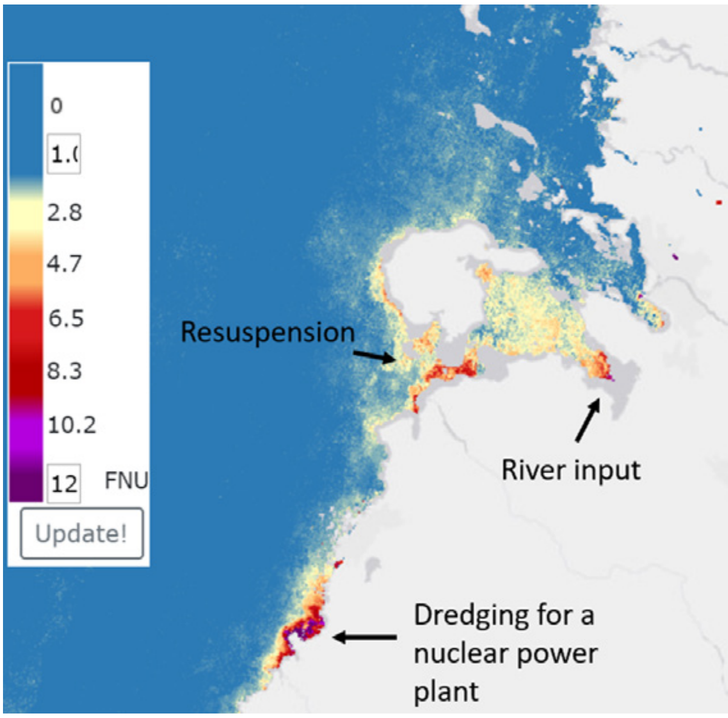

Figure 18. Turbidity composite of summer 2017 (1.7–7.9). Note the increased values of turbidity (measured in FNU) in river estuaries (indicating run-off from rivers) and dredging areas (indicating resuspended sediments). Map by SYKE.

SYKE publishes its EO products through the TARKKA service (www.syke.fi/tarkka/en). TARKKA is a website with remote sensing products showing satellite images; it includes true colour images, maps of water quality parameters, and time series plots allowing the users to conveniently browse different products, to zoom in and out, and to pan into an area of interest. The service also provides various GIS datasets, like shoreline, drainage basin division, and WFD (Water Framework Directive) water bodies to overlay them on top of the satellite data. The results show that water quality parameters such as turbidity and CDOM can be estimated well in the Bothnian Bay using S2 observations.

The algorithms tested here are continuously being updated. So, it will be valuable to repeat these analyses with additional data and new versions at a later stage. Usually, a number of 25–30 matchups between satellite and in-situ data are required, to derive the uncertainties statistically. Hopefully, this can be accomplished in a future joint project on the Bothnian Bay. The in-situ dataset collected during the SEAmBOTH project has been a valuable resource for the algorithm testing and development. It is important to keep the water quality sampling going at a consistently high level in the SEAmBOTH region. Hopefully this can be achieved during a future joint project in the Bothnian Bay.

The full report of the study, Remote sensing – Satellite based water quality assessment in the Gulf of Bothnia, can be found at https://seamboth.files.wordpress.com/2020/04/seamboth-remote-sensing-report.pdf

5. Biological inventories

5.1. Background

There are approximately 289 different macro species living in the Bothnian Bay, without including bird species (HELCOM 2012). While the number of macro-species in the northern Bothnian Bay is lower than in most other parts of the Baltic Sea, due to the brackish water and extreme variations in temperature and light conditions, more endemic species live in the northern Bothnian Bay than in any other parts of the Baltic Sea (CBD 2018). The low salinity (and instances of freshwater occurrence) in the northern Bothnian Bay makes it a suitable, albeit stressful, environment for marine and freshwater species (Snoeijs-Leijonmalm 2017). Of those 298 macro-species, there are 116 macrophyte species that have adapted to the environment of the northern Bothnian Bay (HELCOM 2012). During the SEAmBOTH project field work and literature review we found 159 species and 126 genera of Flora (10 species of Charophytes, 20 species of water mosses, 28 genera of Algae, and 114 species of vascular plants, see table 5 and Appendix 1, SEAmBOTH species list) in the SEAmBOTH area alone.

Some of these species are considered indigenous to the Baltic Sea, like Baltic water plantain Alisma wahlenbergii (Hyvärinen et al. 2019) (see info box). However, due to pressures such as climate change and human development around coastal and marine ecosystems, these indigenous species are under threat of extinction (HELCOM 2018b). The loss of these indigenous species and their habitats can have a negative effect on the ecosystems and on their services, on which humans rely (Millenium Ecosystem Assessment 2005).

Over the course of the SEAmBOTH project, updates were made to the Red List of Finnish Species and it was determined that every 9th species in Finland is threatened (Hyvärinen et al. 2019). Of the nine previous red list species found on the Finnish side of the Bothnian Bay, five species were downgraded to a lower threat status. Alisma wahlenbergii and Hippuris tetraphylla changed from endangered EN to vulnerable VU, while Macroplea pubipennis changed from vulnerable VU to near threatened NT. Positively, a water moss Fissidens fontanus has been downgraded from near threatened NT/RT to least concerned LC. All downgrades were decided based on the new information and data gathered since the last evaluation for red list species in 2010 (Hyvärinen et al. 2019). Notably, due to the species Hippuris lanceolate becoming more widely recognized, it has had its taxonomy updated and is now listed as near threatened NT.

Note: On 22nd April 2020 the Swedish Species Information Centre published an update of the Red list of species for 2020 (SLU Artdatabanken, 2020). Some species mentioned within this report might therefore have a changed threat status from previous status update from 2015.

ADDITIONAL INFORMATION - THREATENED SPECIES

The following four macrophyte species and one beetle species have adapted to, and are occurring in, the northern Bothnian Bay. All five species are categorized as threatened species according to the Helsinki Commission (HELCOM 2013b), the Finnish Ministry of the Environment (Hyvärinen et al. 2019) and the Swedish Species Information Centre (The Swedish Species Information Centre 2020).

Alisma wahlenbergii (Holmb.) (Habitats Directive Annex II & IV)

Suomi: Upossarpio	**Criteria: B1b(iii)c(iv)+2b(iii)c(iv)**	**(Finnish Red List Status: VU)**
Svenska: Småsvalting	**Criteria: B2ab(ii,iii,iv,v)**	**(Swedish Red List Status: VU)**

Alisma wahlenbergii (Fig. 19) is an endemic perennial aquatic plant that grows on soft bottoms comprised mostly of sand with some mud or silt mixed in (Viitasalo et al. 2017). A. wahlenbergii grows in shallow clear brackish waters around 0.05 to 0.45 m deep but can occur in depths of up to 1.5 m (HELCOM 2013b). The plant is often found on shallow mudflats. The plant lives almost exclusively underwater during its lifespan (Viitasalo et al. 2017). The base of A. wahlenbergii is rosette shaped with 5–20 emerging leaves. The leaves are 10 to 30 cm long, 1 to 3 mm wide, ribbon shaped, and have a dark green colour (Mossberg & Stenberg 2005). The flowers are arranged in panicles, where one stem supports multiple pedicels with a single flower or fruit. The flowers have a white colour, whereas the fruits are green. A. wahlenbergii usually blooms between July and August and produces seeds in August and September (HELCOM 2013b).

Alisma wahlenbergii benefits from open habitats due to its low competitiveness. Reeds can quickly take over a suitable habitat for A. wahlenbergii, especially in eutrophicated areas. Human activities such as dredging, and construction are also detrimental to A. wahlenbergii due to the increased water turbidity and pollution and loss of habitat (HELCOM 2013b).

Figure 19. Alisma wahlenbergii is a shallow water species with a few long leaves permanently submerged. Photo by Essi Keskinen, Metsähallitus.

Crassula aquatica (L.) (Habitats Directive Not Included)

Suomi: Paunikko	**Criteria: B2ab(ii,iii,iv,v)c(iii,iv)**	**(Finnish Red List Status: VU)**
Svenska: Fyrling	**Criteria: B2ab(ii,iii,iv,v)C(iv)**	**(Swedish Red List Status: NT)**

Crassula aquatica (Fig. 20) is an annual succulent plant that grows on sandy, silty, clay, or pebbly shores. It grows in slightly brackish or freshwater environments and is often found in muddy riverbanks. C. aquatica can occur under water down to a depth of 0.5 m, or on wet banks partially submerged or above water (HELCOM 2013b). C. aquatica can be up to 5 cm in height and grows mostly vertically with no branching in the stems. The leaves are located opposite of each other on the stem with non-altering intervals and are needle shaped with a length of 3 to 5 mm (Mossberg & Stenberg 2005). The leaves can appear reddish when not submerged in water (Viitasalo et al. 2017). The flowers are located in the petioles and appear white or reddish (Mossberg & Stenberg 2005). C. aquatica flowers between July and September.

Crassula aquatica usually occurs in clay and muddy lakes near or in the water. It can also appear on seaside beaches, river estuaries or meadows and mudflats with grazing as it benefits from an open habitat. It usually has a patchy distribution in a suitable habitat, the distribution can vary depending on the way the seeds were dispersed or stored in an area. Due to its low competitiveness with species that benefit from eutrophication, such as reeds, it can quickly be taken over when eutrophication occurs (HELCOM 2013b).

Figure 20. Crassula aquatica is a little vascular plant at the water's edge, sometimes on dry land and sometimes at very shallow water. Photo by Manuel Deinhardt, Metsähallitus.

Hippuris tetraphylla (L.) (Habitats Directive Annex II & IV)

Suomi: Nelilehtivesikuusi	**Criteria: A2ace+3ce**	**(Finnish Red List Status: VU)**
Svenska: Ishavshästsvans	**Criteria: B1ab(ii,iii,iv,v)+2ab(ii,iii,iv,v)**	**(Swedish Red List Status: CR)**

Hippuris tetraphylla (Fig. 21) is a perennial aquatic plant that grows in shallow slightly brackish waters on soft bottoms (HELCOM 2013b). Its length is usually between 15 and 40 cm. It occurs primarily in sheltered waters such as bays (Mossberg & Stenberg 2005), but it can also be found in shoreline meadows and mudflats. The stems of H. tetraphylla have a red colour, both above and below the water surface (Viitasalo et al. 2017). The leaves are arranged in whorls consisting of 4 to 6 leaves. The leaves are approximately 10 to 15 mm long and 3 to 5 mm wide, appear oval and are blunt. The flowers are located in the petioles and appear like red fruits resting on the leaves. H. tetraphylla flowers as early as June to August (Mossberg & Stenberg 2005).

The overgrowth of reeds on shoreline meadows poses a threat for Hippuris tetraphylla (Viitasalo et al. 2017). H. tetraphylla cannot compete with the increased growth rate of reeds in areas with high eutrophication. Furthermore, human activities in bays are decreasing the available habitats for populations of H. tetraphylla (HELCOM 2013b).

Figure 21. Hippuris tetraphylla has small purplish flowers at the petioles. Photo by Essi Keskinen, Metsähallitus.

Persicaria foliosa (H. Lindb.) (Habitat Directive Annex II & IV)

Suomi: Lietetatar	**Criteria: B2b(i,ii,iii,iv,v)c(iii,iv)**	**(Finnish Red List Status: EN)**
Svenska: Ävjepilört	**Criteria: B2ab(ii,iii,iv)**	**(Swedish Red List Status: NT)**

Persicaria foliosa (Fig. 22) is an annual plant that can grow in shallow slightly brackish or fresh water. P. foliosa prefers to settle in soft bottoms composed of sand or a mix of sand and silt, however, it can also be found near more rocky bottoms in the archipelago (HELCOM 2013b). It is a typical plant in river estuaries and mudflats. It can grow to be 40 cm long with the stem usually having a red / pink colour. The leaves are on alternating sides between internodes and can be up to 10 cm long and usually 3 to 5 mm wide. The leaves are almost flat being 0,2 to 0,8 mm thick. The flowers are located in the petioles and can have a green, red or pink colour. P. foliosa blooms between July and September (Mossberg & Stenberg 2005).

Persicaria foliosa is a very weak competitor. Habitats that experience processes which open up the area, such as grazing, ice-scouring, or water level fluctuations are beneficial for P. foliosa. P. foliosa is also sensitive to pollution and disturbance due to construction near its suitable habitats (HELCOM 2013b).

Figure 22. Persicaria foliosa has flat long leaves and can be found at river estuaries. Photo by Niina Kurikka, Metsähallitus.

Macroplea pubipennis (Reuter) (Habitat Directive Annex II & IV)
Suomi: Meriuposkuoriainen **Criteria: B2ab(iii,iv)** **(Finnish Red List Status: NT)**
Svenska: Stor natebock **(Swedish Red List Status: DD)**

Macroplea pubipennis (Fig. 23) is an aquatic beetle that spends its whole life cycle underwater (egg, larvae, pupa, adult). The female lays its eggs on the roots of aquatic plants in a jellylike pocket (Nilsson 1996), and larva and pupas are attached to the roots of aquatic plants (Bøving 1906, Nilsson 1996). In July-August they emerge to the open as adults. M. pubipennis can be found from sheltered shallow waters at a depth range of 25–50 cm with abundant vegetation. It feeds on submerged aquatic plants (Potamogeton, Stuckenia, Myriophyllum etc.) and it rarely ventures far from the reed edge. Adult beetles are usually seen crawling together on aquatic plants with the smaller male riding on the female's back (HELCOM 2013b).

M. pubipennis is straw-coloured and about 6–7 mm in length with long limbs and antennas (SYKE 2014). On its back it has stripes which consist of dots in a row. When determining different Macroplea species one needs to pay attention to small differences in e.g. the colouring of their back and the shape of their spikes at their bottom.

Macroplea pubipennis is threatened by dredging and construction on the shores. Also boat traffic, changes in the water quality, and eutrophication can decrease the number of suitable habitats. The destruction of habitats can isolate populations since M. pubipennis cannot easily cross obstacles, for example, fairways (HELCOM 2013b, Viitasalo et al. 2017).

Figure 23. A small beetle Macroplea pubipennis lives always under water. Photo by Länsstyrelsen Norrbotten.

5.2. Methods

At the beginning of the project, it was decided that the biological mapping would be done according to VELMU methods from the Finnish national underwater mapping program (VELMU, 2019). The reason for this is that VELMU inventory program has collected more than 100 000 data points using these methods (Fig. 24), which have been refined for over 10 years to best serve the data needs. In Sweden, only a national standardised method for macrophyte inventories by dive transects exists (HaV, 2016b). This method fitted well with the method described in VELMU and data collected by it could easily be used both for Swedish national purposes and SEAmBOTH project modelling. For collecting point data by snorkelling, wading or drop-video, no national standardised method is yet decided upon in Sweden. The VELMU methods were found to be suitable for use also on the Swedish side and were hence applied.

Figure 24. Biological sampling methods include drop-video, wading, snorkelling and diving. Photos by Metsähallitus.

Guidelines for mapping methods (i.e. underwater mapping), specifically for the northern Bothnian Bay, have been collected during the SEAmBOTH project (see Chapter 12.2). An example of this are the river estuaries in the northern Bothnian Bay (see Chapter 6.3). The river estuaries are huge and affect almost one third of the SEAmBOTH project area. Some of the basic biological VELMU methods have been better modified to fit both the estuaries with low water transparency and shallow, muddy bottoms, and to the extremely shallow large areas that can be found in the project area.

Drone photo mosaics (Fig. 25) could be a useful tool for mapping extremely shallow and large areas for vegetation, as well as some river estuaries, where moving with any other means is difficult because of shallow water and soft bottom. In the SEAmBOTH project drones were used to try mapping some shallow bays and taking beautiful aerial photos of flads and lagoons, shallow bays and river estuaries. In the future, drones could be used in a more systematic way for habitat and nature type inventories.

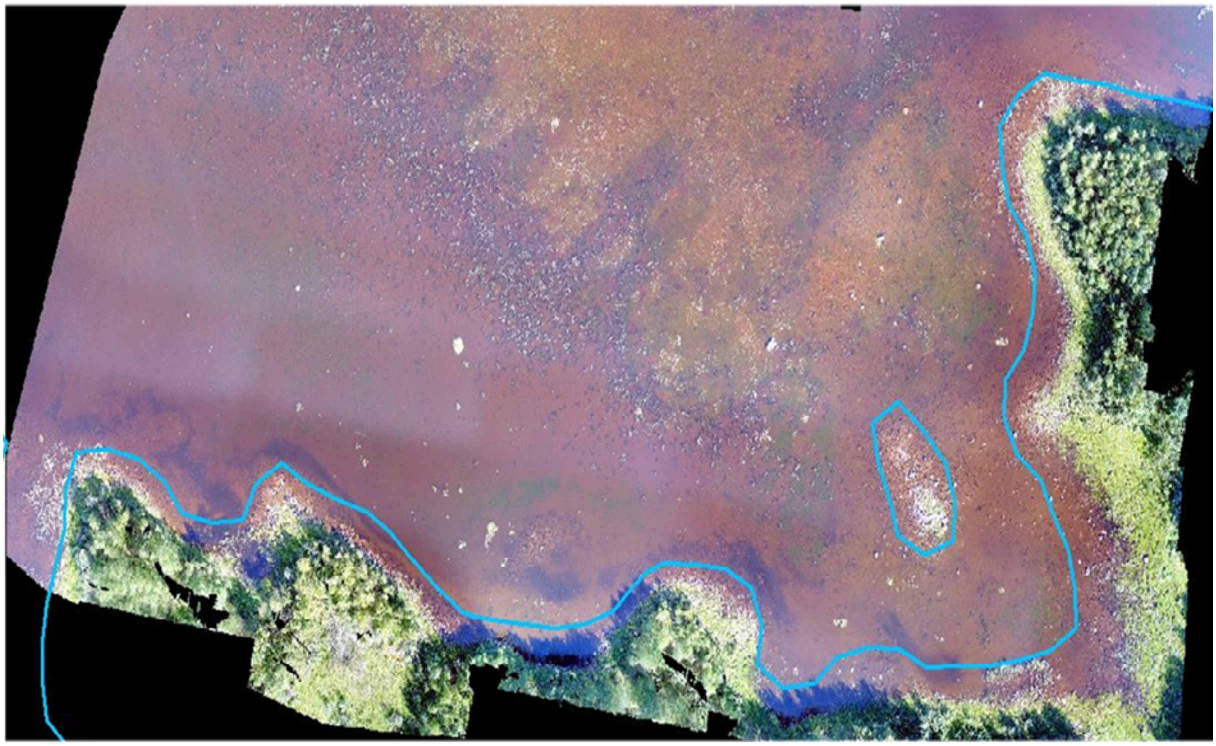

Figure 25. Drone orthomozaics could be used in very shallow water for analysing habitats. Blue line is the shoreline on map. Photo by Suvi Saarnio, Metsähallitus.

Field work was conducted during three field seasons (2017–2019) by Metsähallitus, Länsstyrelsen, and ELYs. Biological field data was gathered from all inventory teams at the end of the field seasons and collated by Metsähallitus. In order to be used as point data, the Swedish dive transect data were first transformed from one point per transect to one point per transect segment before sent off.

Samples of benthic macro fauna were collected and analysed from two different areas on the Swedish side, the Haparanda archipelago in 2018 and Rånefjärden in 2019. In Haparanda archipelago 25 samples were collected at depths of between 9,8 and 61 meters. In Rånefjärden 51 samples were collected at depths of between 3 and 25,3 meters. Sampling and analysis were done according to national Swedish standard for soft bottom macro fauna (Leonardsson, 2004; HaV, 2016a). For full details of the two studies, see reports in Appendix 9 (Bottenfaunaprovtagning i Haparanda skärgård 2018) and 10 (Undersökning av bottenfauna i Råneå skärgård, 2019).

The comparison of two benthic macro fauna sampling methods was conducted at Hailuoto island intensive station in June 2018. The benthic macro fauna sampling methods and classification indexes differ between Finland and Sweden in coastal areas. On the Finnish side, sampling has been done with Ekman sampler (pooled sample from 5 grabs), while on the Swedish side, van Veen sampler is used. In Finland, the Brackish water Benthic Index (BBI) is used in benthic macro fauna status assessment, whereas the Benthic Quality Index (BQI) is applied in Sweden (Leonardsson et al. 2009).

As van Veen sampling will be used in Finland outer coastal waters, we wanted to test if there are any differences between pooled Ekman sample and a van Veen sample. The sampled area is about the same with both methods. Parallel samples were taken 11.6.2018 on ten stations in outer coastal waters near Hailuoto island. The depths of the stations were between 21 and 25 meters. For further details in Appendix 11 (Pohjaeläimistön kahden näytteenottomenetelmän vertailu 2019).

5.3. Results (species occurrences and findings of threatened species)

A total of about 23 000 sampling points of macrophyte data were collected from the project area and used for production of maps (Table 4, Fig. 26).

Table 4: The amount of total biological sampling points done in the SEAmBOTH area during project field seasons (Diving/snorkelling, wading, or video) and in other projects.

	Finland			Sweden			
	other projects	in SEAmBOTH	Total	other projects	in SEAmBOTH	Total	Grand Total
Dive or snorkelling	1874	691	2565	1819	1463	3282	5847
Video	10460	1377	11837	659	713	1372	13209
Wading	1741	2856	4597		8	8	4605
Grand Total	**14075**	**4924**	**18999**	**2478**	**2184**	**4662**	**23661**

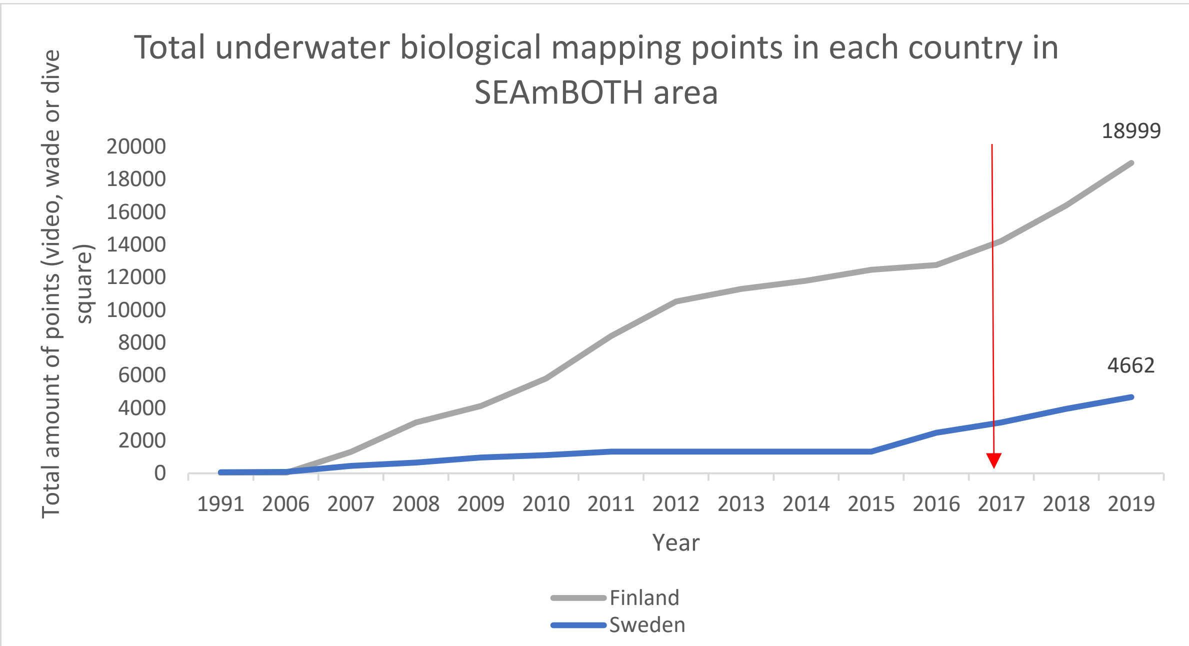

Figure 26. Cumulative accumulation of biological sampling points per year in Finland and Sweden. The red arrow is the start of SEAmBOTH project.

A total number of 150 and 159 macrophyte or other Flora species were recorded during the project in Sweden and Finland, respectively (Table 5), altogether 167 species. A majority of these were vascular plant species, from nine different genera. Ten species of charophytes were found and up to 20 water mosses (17 in Sweden), 23 in all.

Table 4: The amount of total biological sampling points done in the SEAmBOTH area during project field seasons (Diving/snorkelling, wading, or video) and in other projects.

	FIN	SWE	Total
Charophytes (species)	10	10	10
Water mosses (species)	20	17	23
Water mosses (genera)	12	9	14
Algae (species)	15	10	16
Algae (genera)	28	20	32
Vascular plants (species)	114	113	118
Vascular plants (genera)	76	74	76
Species	159	150	167
Genera	126	113	132

Complete reports from four macrophyte inventories including dive transects on the Swedish side during 2017, 2018 and 2019, are published at the website of Länsstyrelsen I Norrbottens län (Wallin, Qvarfordt & Borgiel, 2017, 2018a, 2018b, 2019).

Many hundreds of sightings of endangered species were found in both countries, with about half of the findings new (see info box for more information about some of the threatened species).

The results from the benthic macro fauna sampling within the Haparanda archipelago showed observation of 10 different species/genera with an average of 2, 83 species/genera per sample. The biological diversity may therefore be classified as relatively low. Monoporeia affinis, Marenzelleria spp. and Oligochaeta spp. were the most abundant species. The average abundance was 171 individuals/m2, but it varied highly between samples. No benthic macro fauna species found on the Swedish red list of threatened species were observed (ArtDatabanken, 2015). Presence of hydrogen sulphide in the substrate may indicate lack of oxygen on the substrate surface. No smell of hydrogen sulphide from the substrate was noted at any of the sampling stations, which indicates the bottoms at those stations were oxygenated. For further details see Appendix 9 (Bottenfaunaprovtagning i Haparanda skärgård 2018).

The results from the benthic macro fauna sampling in Rånefjärden showed observations of 16 different species/genera. The most common species/taxa were Monoporeia affinis, Oligochaeta sp. and Chironomidae sp. The influence of freshwater to the area was seen in a number of freshwater species being present in the samples. The diversity of species was slightly higher than what is common to find in deeper, more offshore sample stations, mainly due to the heterogenic character of the area and influence of freshwater. No species found on the Swedish red list of threatened species were observed (ArtDatabanken, 2015). The two species/genera, Marenzelleria sp. and Potamopyrgus antipodarum, classified as alien species within Sweden, were found at four stations. The substrate at the sampling stations varied between silt, clay, mud and gravel. Observations of ferromanganese concretions were made at 7 of the 51 stations. In Rånefjärden, the smell of hydrogen sulphide was noted at two stations of depth of 7,5 respectively 10,5 m. For further details see Appendix 10 (Undersökning av bottenfauna i Råneå skärgård, 2019).

The results from the benthic macro fauna sampling at Hailuoto intensive station showed observations of 10 different species/taxa. Alien species Marenzelleria sp. and oligochaete Potamothrix hammoniensis were found in every 20 sample, whereas Monoporeia affinis only in two samples. Oligochaetes Psammoryctides barbatus and Limnodrilus hoffmeisteri were observed on seven samples. Oligochaeta and Marenzelleria sp. made up 79–100 % of the benthic macro fauna community. Cyanophthalma obscura and chironomid Procladius sp. were common, but not abundant. Comparisons between the Ekman pooled sample and the van Veen sample at Hailuoto intensive station showed that benthic macro fauna abundance, richness, Shannon diversity, and BBI-index were larger in the Ekman sampling, most clearly in richness. Statistically, the difference was significant only in richness. The average richness was in Ekman samples 4.5 species/taxa and van Veen samples 3.4 species/taxa. The average abundance was 440 individuals/m2 in Ekman pooled sample and 375 individuals/m2 in van Veen sample. In general, there was a lot of variation between samples.

The most probable reason for the difference is that the pooled Ekman samples represent a larger area than one van Veen grab, although parallel samples were taken at the same place. The situation becomes more obvious, if the sediment quality varies or benthic macro fauna is patchily located. Species richness is one parameter of BBI-index, which may explain the lower BBI in van Veen samples. Benthic macro fauna status according to the BBI-index was moderate in both cases, although the difference inside moderate class was quite big. Using Swedish BQI-index Ekman samples represent good status and van Veen samples moderate status.

BBI is adapted to Baltic Sea conditions. It presumes that species diversity and the proportion of sensitive species declines in accordance with environmental stress. In the Bothnian Bay, benthic macro fauna community is naturally scarce, thus single species have bigger weight to classification result. Freshwater species, such as oligochaetes and chironomids, are a natural part of the benthic macro fauna in the Bothnian Bay, but in BBI they are regarded as tolerant species expressing environmental stress. In addition, sensitive species are sensitive to low salinity as well. For these reasons, benthic macro fauna expresses lower status compared to phytoplankton and physical-chemical variables in the Bothnian Bay.

To improve the understanding of setting threshold values for BBI, efforts to find old benthic macro fauna data expressing more pristine conditions were made. However, only littoral zoobenthos data from Krunnit Island was found. Originally, the intention was to test the new Swedish benthic macro fauna index pBQI on Finnish benthic macro fauna data, but as the new index is still under development such tests were not performed. It will need to be tested in a future co-operation. The need to develop benthic macro fauna classification in the Bothnian Bay still remains, but as sampling methods are now similar in Finland and Sweden, developments towards a common approach can be accomplished easier.

5.4. Discussion

Though the SEAmBOTH project area is shared between Finland and Sweden, there are unique differences between the species biodiversity in each country. For example, some species found in one country may be rare or absent in the other. By analysing SEAmBOTH project inventories 2017–2020, as well as previous research results, flora and fauna species presences were compiled (See Appendix 1) to compare species differences in Finland and Sweden. Interestingly, vascular plant species were quite similar between the two countries, with only a few species being found only in one country. Three species of vascular plants appear only on the Finnish side. Hippuris tetraphylla is found in large numbers in Krunnit archipelago but is only found in Sweden outside of the SEAmBOTH area. Stratiotes aloides has not been found in Sweden in the sea areas yet but is found all over Finland and in the SEAmBOTH area, while Hydrocharis morsus-ranae has not been found in the Swedish sea area. Only the invasive species, Elodea nuttalli, is commonly found in Sweden and close to the Finnish border of Tornio, but not yet in the Finnish Bothnian Bay.

Although vascular plants are similar between Finland and Sweden, algae and water mosses are a bit more varied (table 5). These differences in species presences could be attributed to differences in environmental factors between the two countries. Alternatively, or additionally, the differences could also be linked to differences in number of sampling points or sampling in different habitats, a lack of knowledge and insufficient data on the species as well as the inability to identify some organisms to species level. The more inventories there will be done on the Swedish side the more species of e.g. water mosses and algae will most likely show up there.

Benthic fauna, fish, and bird species were not the focus of this project, but some observations were included in the biological inventories as well as previous research findings are also presented (table 5).

2018 showed to be an important and productive year for SEAmBOTH with regards to species presence. Both Finland and Sweden reported new species for the first time during this field season. Macroplea pubipennis, an underwater beetle, is rare or non-existent in most countries, and has been observed in Finland, but SEAmBOTH has recorded the first findings of the beetle in Sweden. While the Charophyte Chara braunii is common in lush underwater meadows on the Swedish side, few observations of the species had been found in Finland and only three findings in the Finnish SEAmBOTH area previously. In the summer of 2018, a few individuals began showing up in the SEAmBOTH field surveys in Finland and the known number of Chara braunii sites in whole of Finland more than doubled.

Many water mosses (23 in total) have been found in the SEAmBOTH project area (See Appendix 1). Water mosses are mostly freshwater species which can tolerate some level of brackish water. The highest number of species are found in the river estuaries where the water is the least saline. The most widely distributed species are Fontinalis antipyretica, Fissidens fontanus and Oxyrrhyncium speciosum, which was recently identified as this species in Finland (it was previously thought to be Rhyncostegium riparioides and then Platyhypnidium riparioides) (pers. com. Huttunen 2018, pers. com. Ulvinen 2018). Field season 2019 proved to be very important in finding new species of water mosses in the Finnish side of the SEAmBOTH area - five previously unknown species were found, mostly in river estuaries and other fresh or near fresh water areas (Fontinalis dichelymoides, Bryum sp., Straminergon stramineum, Drepanocladus polygamous, Hygrohypnum ochraceum). An alien invasive fish species ringed goby Neogobius melanostomus, which has spread to the Baltic Sea from the Ponto-Caspian region, is spreading north fast. Its northernmost known individual was found in the Finnish SEAmBOTH area outside of Oulu in the summer of 2018. In Sweden, this species only exists further south.

Along with species presence data, Appendix 1 includes SEAmBOTH species Red List status in both Finland and Sweden.

During the 2019 field season, data was also collected for a thesis: "An overview of Finnish nature conservation management and occurrences of four threatened species in the northern Bothnian Bay" by Sjef Heijnen, Has University of applied sciences, Netherlands https://seamboth.files.wordpress.com/2020/03/sjef-heijnen-thesis-seamboth-internship-metsc3a4hallitus-definitive-version.pdf. The study provided information about differences in nature conservation management and analysis of threatened species occurrence in the Finnish SEAmBOTH project area. Information about differences in nature conservation management showed that strict habitat definitions occasionally limit the ability to protect areas in close vicinity to nature reserves, making it difficult to pre-emptively protect habitats which do not fit the habitat definition but can become a habitat befitting the strict habitat definition if certain measures would be executed. Analysis of threatened species occurrence during the timespan of the SEAmBOTH project in the northern Bothnian Bay in Finland showed, that the highest densities of threatened species occurrences were found inside nature reserves. The highest densities were observed in the Kemi river estuary, northside of Ulkokrunni and Kempeleenlahden ranta, where on average one threatened species occurred every 1 km2. However, for further conclusive results the sample size of threatened species occurrences needs to be higher. Therefore, this study can be used as an incentive to gather more data and perform more analysis about threatened species occurrence. It would be recommended to conduct a long-term study of monitoring occurrences of threatened species in a systemic order in an area inside a nature reserve and outside the nature reserve in close vicinity. Another possibility could be to examine threatened species occurrences before the implementation of the European wide nature reserve network, the Natura 2000 network, and compare it to new occurrences after the implementation of the Natura 2000 network. The final recommendation is to explore the idea of citizen science to gather more observations of threatened species in the northern Bothnian Bay.

6. Marine habitats and biotopes

6.1. Natura 2000

The northern Bothnian Bay hosts a rather different marine environment compared to the rest of the Baltic Sea. Low salinity, annual ice cover, shallow shores, and land uplift are some of the environmental conditions present in the area making its habitats and composition of species rather unique. Not only do the interpretations of Natura 2000 habitat definitions differ between Finland and Sweden, the habitats also have different characteristics in the north compared to the south of the Baltic Sea, where "templates" for habitat descriptions tend to be formed. This makes mapping and managing the Natura 2000 areas a challenge, but with cooperation within the bay, local knowledge may spread and support be given.

The activity 6.1 in the SEAmBOTH project was therefore dedicated for closer investigation of the Natura 2000 habitat interpretations of Sweden and Finland, with the purpose of making communication and management across the border more harmonised. A report from the workshop of the activity can be found in Appendix 3 with a full description and results. Below follows a short summary.

Natura 2000 is a network of protected areas across all the 28 EU countries. The network includes habitats with core functions, such as breeding sites for threatened species, and rare natural habitat types in the need of protection. The habitats are listed in the Habitats Directive (European Commission, 1992) where they are all listed, described, and defined. The EU has published an interpretation manual for how the different habitat types should be defined (European Commission, 2007). Yet countries apply different interpretations, usually as a mean to adapt the habitat types to their national environmental conditions. Sweden and Finland have a relatively similar natural environment and share the Baltic Sea between them. The countries have, however, interpreted the definitions of the Natura 2000 habitat types slightly differently. The interpretations from the Swedish national manual (Naturvårdsverket, 2011), the Finnish national manual (Airaksinen & Karttunen, 1999), and the Natura 2000 guide by SYKE and Metsähallitus (2019) were compiled, compared, and discussed during the workshop. A list of characteristic species suitable for describing the habitat types within the SEAmBOTH area was also compiled (see report in Appendix 3).

Conclusions from the workshop:

- Regarding the interpretations of habitat types, Finland has overall a broader, more vegetation based, perspective on definitions and delimitations than Sweden, which is seen to be more systematic and harmonized.
- Due to the land uplift and almost freshwater like conditions at sea, delimitating habitat types in the northern Bothnian Bay is complicated. Estuaries are one example where this is specifically apparent. There needs to be alternative definitions, as those that are applicable for the rest of the Baltic Sea may not work here.
- Mudflats and sandflats (1140- like habitat but without the tide) is a common habitat type within the northern Bothnian Bay. It is of the greatest need for it to be investigated and mapped on the Finnish side.
- Listing common characteristic species for the area was relatively easy, the habitat types are very similar across the border. Only a few exceptions existed where characteristic species had to be applied to only either Finland or Sweden.
- There's a profound common consensus on what the most threatened habitat types are and that estuaries, mudflats, lagoons, and large shallow bays should be focused upon in terms of modelling and mapping.

A small test was done to see if Natura 2000 habitats can be identified and drawn on map using VELMU-point inventory data and aerial images. VELMU-point data collected in 2018 and 2019 from two test areas (Jakopankki-island in Lapland and Kahvankari-island in Oulu region) was used in this purpose. Aerial photos were used as a base, and VELMU-point data was used to determine the vegetation, bottom substrate and habitats found in the inventoried areas. Finnish Natura areas, habitat codes, characteristics of inventoried areas, species found in the areas and seabed values were considered. This made it easier to define the borders for the habitat types and to digitize areas from the aerial view. Figure 27 shows an example of digitized habitats from the island of Kahvankari in front of Oulu. Colorful dots indicate collected data points in the area.

Figure 27. Kahvankari-island in front of Oulu. Habitats identified include sandbanks, reefs and lagoons. Map by Virpi Karén, ELY-centre of Northern Ostrobothnia.

In most cases, digitizing habitats using VELMU data and aerial imagery was simple. The aim of the work was to test if this point data-aerial photograph -method can give a good overview of the habitats, their locations and surface areas. The method was proven to work well. However, it was noticed that when the inventories were made by using straight lines to circular areas such as the coastal lagoon (1130), the data collected, such as depth, seabed quality, and species coverage, did not provide a detailed picture of the area and its features. Locating the points following the shape of the inventory area could give even better results with the same sampling effort. The quality of the inventory and the analysis of the inventory data would also be improved if comprehensive in-depth information was available from the regions already in the inventory planning.

Aerial images by NLS (National Land Survey of Finland) were precise enough for this work, but images taken with a drone might bring more detailed information from specific areas. Especially from small reefs and sandbanks far out at the sea, more detailed images than what NLS is providing might be needed for defining habitats, and in very shallow areas even vegetation can be identified from drone images in some cases, and this information is often valuable for drawing habitats on a map.

The digitized Natura 2000 habitats have been exported to the SAKTI-database (Finland) and the full report on "Defining Natura 2000 habitats using point data and aerial images" can be found from https://seamboth.files.wordpress.com/2020/04/defining-natura-2000-habitats-using-point-data-and-aerial-images-1.pdf

6.2. Mudflats

One Natura 2000 habitat that Sweden has, and Finland doesn't, is the tidal mudflats 1140. There is a prominent tide on the west coast of Sweden, while on the Finnish side the tide only varies by about 1 cm at the most. During the Natura 2000 habitat and nature value workshops (Chapter 6.1, Appendix 3) it was apparent that the extremely shallow muddy areas are very important habitats in the northern Bothnian Bay. The coasts are very shallow (especially on the Finnish side of the SEAmBOTH area), gently sloping, and the water level can change by up to 2–3 m in a matter of days due to the variation in air pressure and wind direction.

The large, shallow, muddy, and silty areas that are sometimes slightly under water, sometimes dry, are important feeding grounds for migrating birds and host a variety of endangered and directive species, mainly Hippuris tetraphylla, Alisma wahlenbergii and Crassula aquatica. Limosella aquatica is considered regionally threatened in Sweden and is also found in mudflats.

While it is clear, that the mudflats found in the SEAmBOTH area are not tidal mudflats according to Natura 2000 habitats directive, they are still important habitats in the northern Bothnian Bay. Since this habitat does not fall into the Natura 2000 habitats, it has been somewhat neglected in the nature conservation of the northern Bothnian Bay.

Since tidal mudflats 1140 Natura 2000 habitats were already defined in Sweden, we also wanted to define possible mudflat areas in the Finnish SEAmBOTH area. To start defining mudflats (Fig. 28) on the Finnish side, a depth model was first used to isolate shallow areas (< 0,5 m) close to the shore (100 m). This raster was then converted to a polygon and small areas of under 500 m2 were deleted. The mudflats polygons were checked with aerial images and the local knowledge of the Finnish side of the project area.

Figure 28. Digitized possible mudflats outside Ulkokrunni island in Finland. Map by Suvi Saarnio, Metsähallitus.

In the future, bottom substrate should be considered so that the rocky areas could be excluded from the model. At this point some of the known rocky areas were deleted but it was impossible to fix all the polygons with the time available. Many of the polygons were too small and did not include the whole possible mudflat area and some of these were also corrected (especially the Krunnit Nature Reserve and the Oulu area). The biggest problem, in addition to the missing bottom substrate information, is that the depth data is not accurate enough in the shallow parts. For example, the Kraaseli island in front of the city of Oulu has shallow water all around it, but in the model, it was not considered as a mudflat area due to incorrect depth model. Human pressures should also be taken into consideration, as many of the polygons were located inside harbours.

6.3. River estuary mapping

River estuaries are one of the most important habitats for birds, fish, underwater vascular plants, and Charales. Birds and fish use the river estuaries to feed and breed, with many fish also migrating through the area to breed in the rivers. During the mappings that were carried out in the SEAmBOTH-project between 2017–2019, it was discovered that river estuaries have a remarkable range of vascular plants with several endangered species populating these areas. The number of water moss species was also impressive as these species are mostly adapted to fresh water, but the river itself may be unsuitable because of too strong a current or soft bottom sediment. The more biological sampling that was done in the river estuaries, the more new water moss species were found to live in the Bothnian Bay.

There is a need to define the borders of river estuaries as legally binding protection measures are often tied to clearly defined parts of the environment. Based on EU directives, protective measures can only be placed on an area when they have been defined. However, drawing a border on river estuaries is very difficult in the brackish water environment, especially in the Bothnian Bay area, due to the extremely low salinity, which prevents us from using salinity as a straightforward indicator of the estuary turning into a sea. In the SEAmBOTH-project it was aimed to try and find suitable methods to define estuarine areas without relying only on the differences in salinity.

Pre-field methods consisted of modelling and analysing aerial images. The data collected in the field was from dive transects, underwater drop video sites, wading points, and salinity samples. After the fieldwork, collected biological samples were categorized into “river species” and “brackish water species” based on literature and expert analysis. All the inventory points were plotted on a map (Fig. 29).

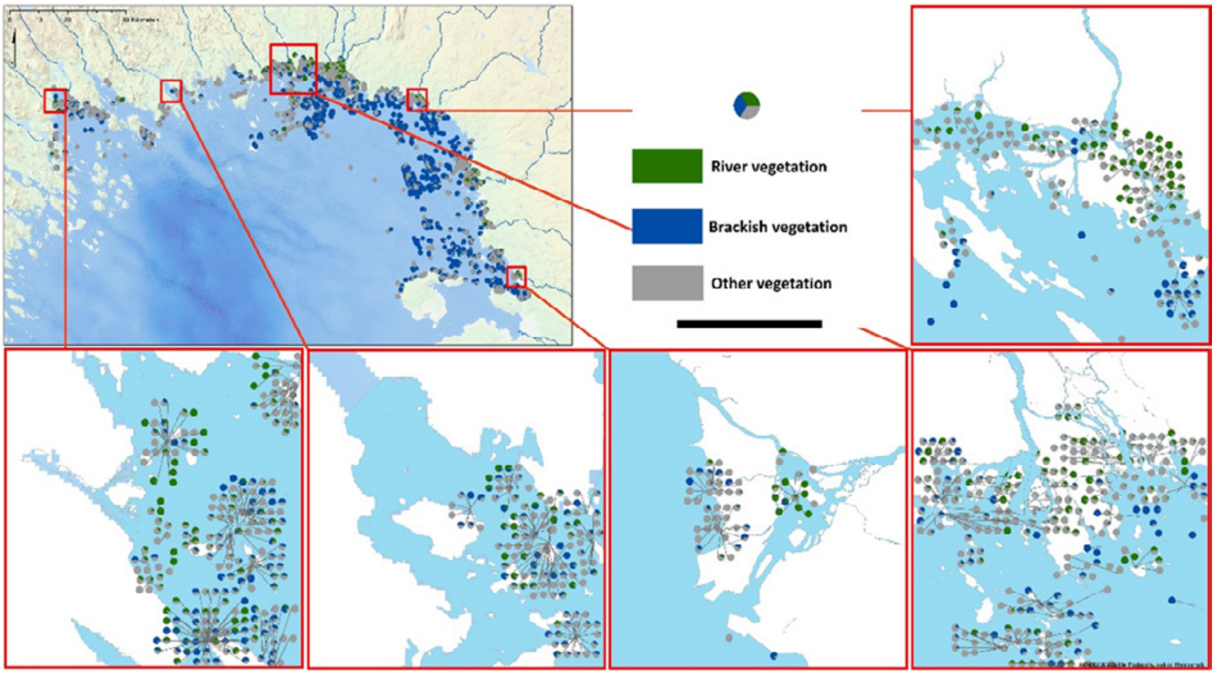

Figure 29. “River species” and “brackish water species” plotted on a map. Map by Jaakko Haapamäki, Metsähallitus.

The results of the species categorization were presented on a map to compare the results to a model based on physical factors and expert analysis. Our results from field work completed in 2017–2018 indicate that species categorization can be used for defining river estuaries. Figure 30 is showing the results from Kemijoki-river with data collected up to 2018. A numerous amount of points was done during 2019 in the SEAmBOTH-area, but unfortunately there was no time to process the latest data for the river estuary modelling. This work on defining river estuaries in the northern Bothnian Bay should continue in the future. A full report from the study can be found at https://seamboth.files.wordpress.com/2020/03/estuary-report-1.docx.

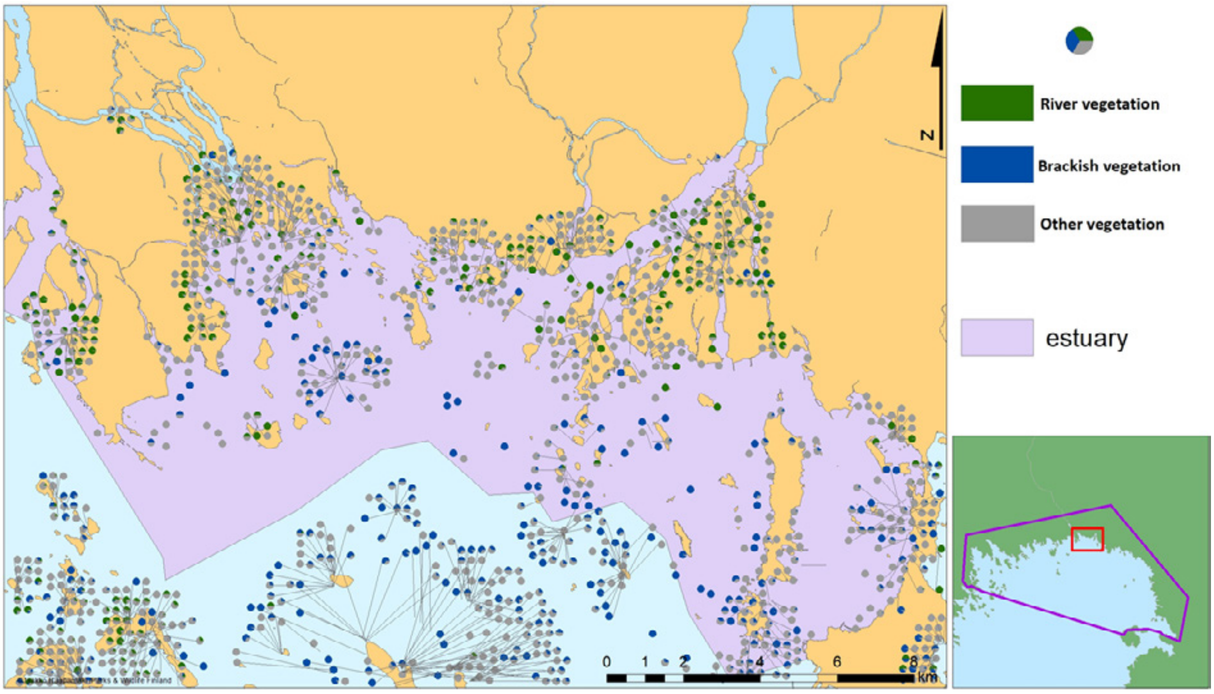

Figure 30. Example of river estuary mappings from Kemi-Tornio area until 2018. The light purple area is the Natura2000 habitat Estuary 1130 and the red line with dots marks the border of the river estuary when defining the river estuary habitat with vascular plants. Map by Jaakko Haapamäki, Metsähallitus.

6.4. HELCOM Underwater Biotopes (HUB)

Biotic and abiotic environments together form biotopes. Biotopes can be used to group similar areas in the environment to easily approachable categories. To be able to make comparisons between different regions and countries in the Baltic sea region, a common system is needed. The European Nature Information System (EUNIS) is a pan-European system with only a few classes in the Baltic sea scale. There was a need for more detailed classification, and this resulted in the HELCOM underwater biotope and Habitat Classification System (HUB). HUB is EUNIS compatible, even though in the HUB a biotope is defined as "the combination of a habitat and an associated community of species", this definition differs somewhat from the EUNIS one (HELCOM 2013a).

HUB is a hierarchical classification system with 6 levels and split rules leading from one level to the next i.e. if criterion Z is true, then biotope 1; if criterion Z is false, then biotope 2 (HELCOM 2013a, Fig. 31). HUB levels 1–3 describes habitats (the abiotic environment) and are split based on environmental parameters. Levels 4–6 describes the biotopes (abiotic and biotic environment) and are hence split based on biological features.

Figure 31. Levels of HELCOM HUB underwater biotope classification system (HELCOM 2013a).

The combined field inventory data in the SEAmBOTH area was classified into HUB biotopes to be presented in a spatial format (Fig. 32). Biotopes were examined by level 5 (characteristic community) indicated in the following chapters by a letter and level 6 (dominating taxa) indicated by a number.

Following biotopes were found in the project area:

- A1 Emergent vegetation - Phragmites australis
- A2 Emergent vegetation - Cyperaceae
- B1 Submerged rooted plants - Potamogeton perfoliatus and/or Stuckenia pectinata
- B2 Submerged rooted plants - Zannichellia spp. and/or Ruppia spp. (and/or Zostera noltii)
- B3 Submerged rooted plants - Myriophyllum spicatum and/or Myriophyllum sibiricum
- B4 Submerged rooted plants - Charales
- B6 Submerged rooted plants - Ranunculus spp.
- C5 Perennial algae - Filamentous algae
- D Aquatic moss
- G1 Hydrozoa
- J Epibenthic sponges
- L6 Unionidae
- P Infaunal insect larvae
- Q4 unattached ceratophyllum
- Q5 unattached aegragrophila linnaei
- R Soft crustose algae
- S1 Annual algae - Filamentous annual algae
- T: Sparse epibenthic communities
- U1: Meiofauna
- U2: Anaerobic organisms
- V: Mixed epibenthic macrocommunity

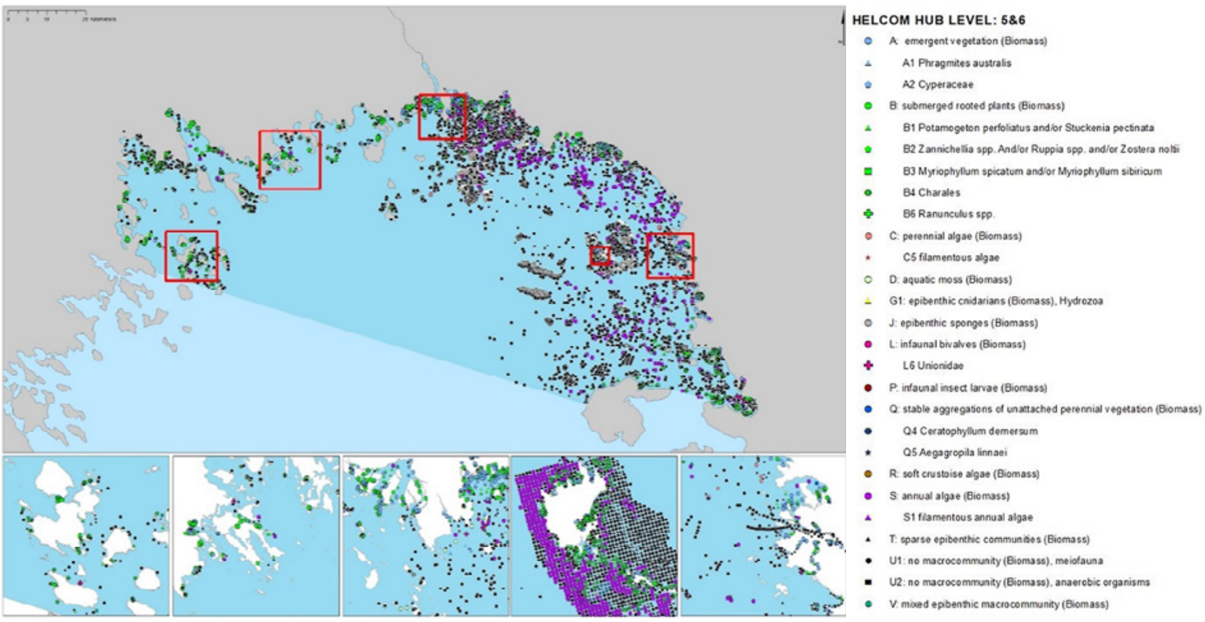

Figure 32. HUB visualization in the SEAmBOTH project area. Map by Jaakko Haapamäki, Metsähallitus.

Regarding the emergent vegetation and submerged rooted plants, all HUBs were present within the project area, except submerged rooted vegetation B5 Najas marina and B7 Zostera marina. The HUBs S3 Annual algae Vaucheria and B8 Eleocharis spp. did not show up as existing in the project area. Vaucheria and Eleocharis spp. Are, however, certainly present species within the area and the sampled data and/or HUB analysis must have simply failed to detect their presence as HUBs.

As the northern Bothnian Bay is highly influenced by the freshwater input from rivers, the flora of macrophyte species include several freshwater species often with high percentage of cover. For example, species of Sagittaria ssp., Sparganium ssp., Potamogeton gramineus, Callitriche ssp., Elodea ssp., Subularia aquatica, Nuphar lutea, and Nymphaea alba are commonly occurring in the marine environment in the SEAmBOTH project area. Where they grow, they are often a dominating taxon and are quite likely to perform a distinct biotope function, as required by the definition of a HUB (HELCOM, 2013a).

7. Human activities and pressures

Human activities can negatively impact the marine ecosystems, and cause significant changes in the marine environment, either in the form of disturbance, degradation, or destruction of habitats. In general, threats resulting from human activities can be categorized as those that can be manageable, e.g. fishing, and as those where management measures do not necessarily have an effect e.g. climate change.

7.1. Human activity data

In general, human activity data relies on national reporting systems. For the SEAmBOTH project, the human activities data was gathered from a wide variety of sources: orthophotos, HELCOM, Finnish Transport Infrastructure Agency, Swedish National Land Survey, Swedish Maritime Administration, Vahti (Compliense monitoring system), and from EMODnet Human activities.

There are many human activities that are affecting the marine areas of the Bothnian Bay, such as coastal construction, industry, marine traffic, and tourism. All have varying effects on the environment and cause different levels of pressure on marine nature. Eutrophication and climate change are both having a strong impact on the Bothnian Bay as well, but they are difficult to try to mitigate locally. In the SEAmBOTH project, the focus was given to more local pressures.

Mapping of human activities from orthophotos started in a small scale in Finland in the project SEAGIS 2.0. After it became clear that the data produced, especially on small scale dredging, was a vast improvement on existing information, the mapping was expanded to include all Finnish coastal areas and other human activities visible from orthophotos. To get a good dataset for the project the work was also done for the whole SEAmBOTH area (Figures 33 and 34).

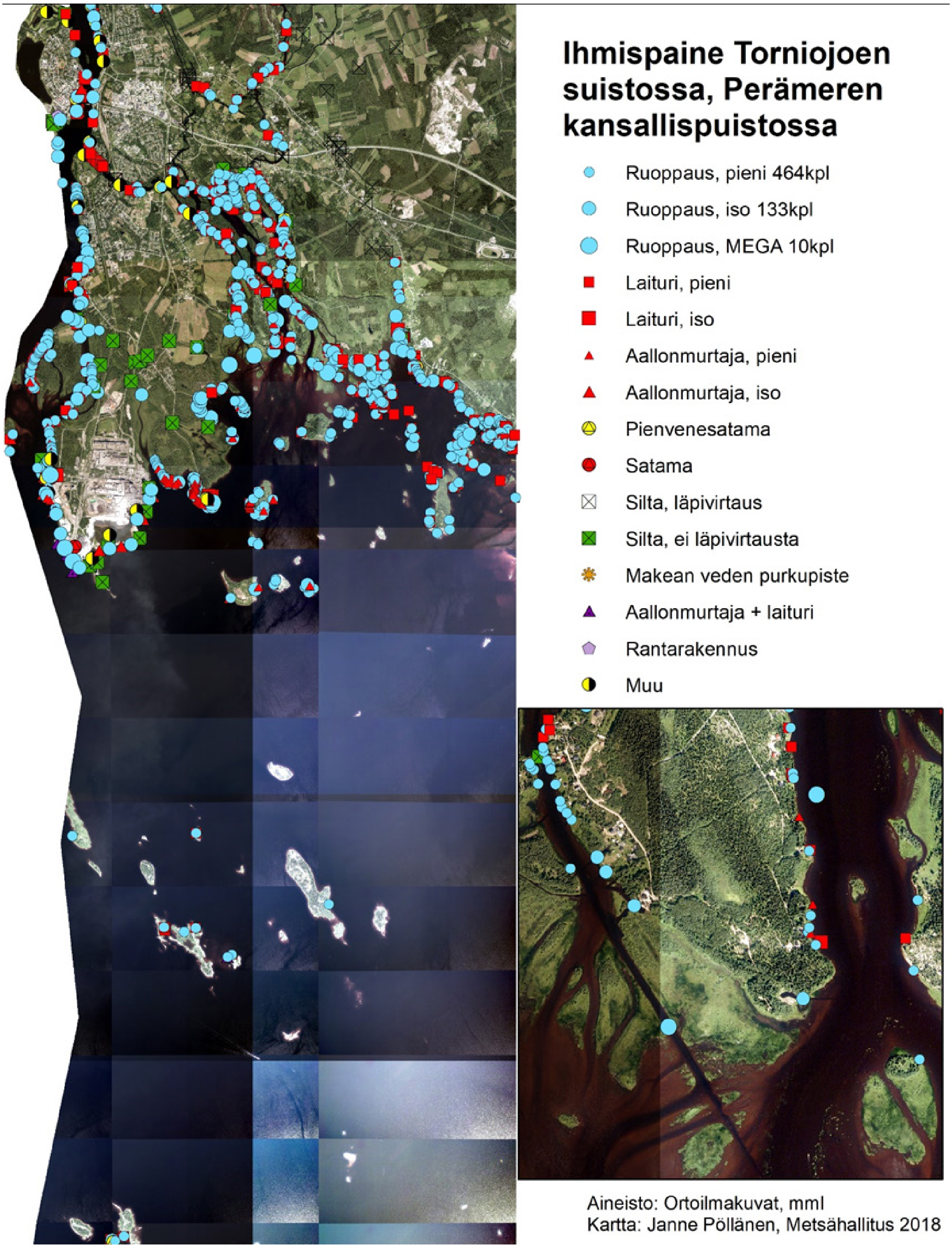

Figure 33. An example of using aerial images (south of Tornio) for mapping human pressures. Blue dots are different size dredgings and red squares are jetties, the rest are bridges, harbours, break waves, etc. Map by Janne Pöllänen, Metsähallitus.

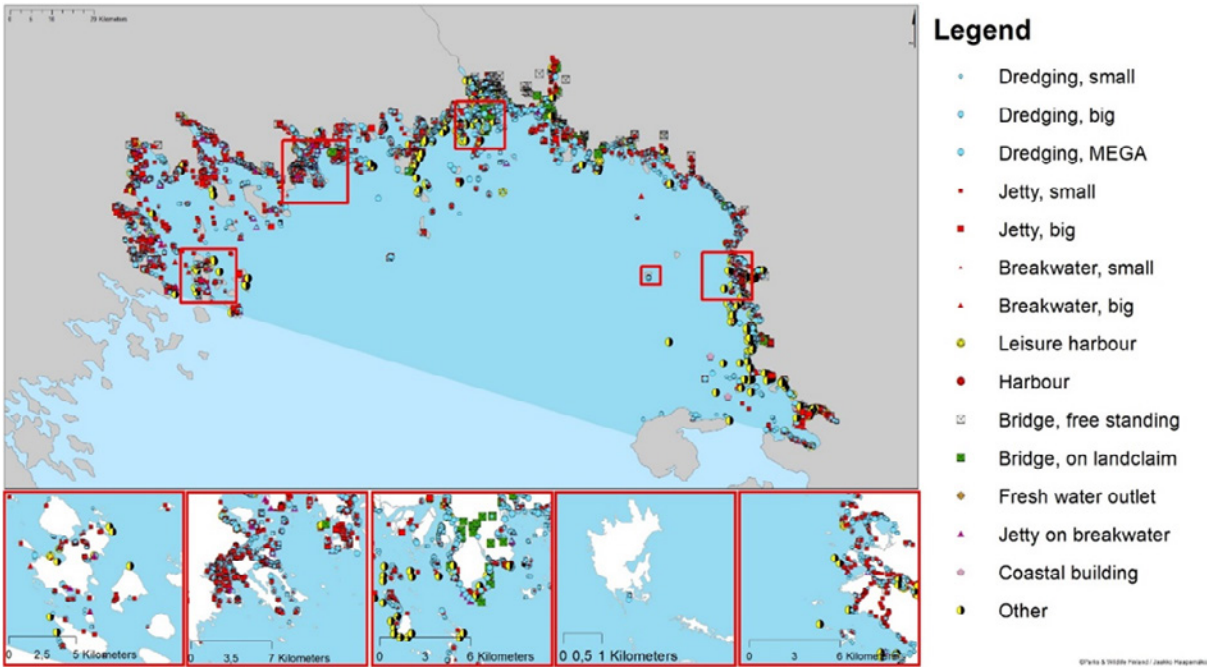

Figure 34. Human pressures interpreted from aerial images across the whole SEAmBOTH project area. Map by Jaakko Haapamäki, Metsähallitus.

7.2. Definition of pressures resulting from human activities

There exists little knowledge on how human activities degrade the marine ecosystems, as such data for the evaluation seldom exists (e.g. monitoring data before and after activity). Therefore, to have an estimation of how activities are affecting marine life in the SEAmBOTH area, an expert knowledge workshop was arranged, where project members defined which human activities have an impact on marine ecosystem, as well as the severity, disturbance, and extent of activities leading to pressures. Estimations were done in a MOSAIC-type of fashion (see Chapter 9.1.).

As a result, two severity classes were produced for each activity: physical loss (total destruction of the habitat) and disturbance (the effect of activity on site and surroundings). For instance, an area covered by a bridge, is a "lost habitat", whereas the disturbance resulting from a bridge, due to shading etc. can be only a few meters. In the workshop, each activity was assigned a "weight value", representing the estimated relative negative effect the pressure has on nature values. Physical loss weights were assigned based on how much loss the activity causes within each 20*20m raster cell (Table 6). For example, the spatial data for a bridge might cover the entire raster cell, but loss mostly only occurs under the pillars; the entire cell area is presumably not lost. Moreover, loss and disturbance extents were defined for each activity (Table 6). Though "loss" is here defined to be total destruction of a habitat where the activity occurs, the affected area had to be estimated for some of the loss spatial data that were in point or line format.

Table 6. Human activities leading to physical loss and disturbance of the seabed, as defined by experts in a MOSAIC-type workshop. The larger the (negative) number, the larger the impact is.

Human activity leading to pressure	Physical loss weights	Disturbance weights	Extents for loss	Extents for disturbance
Bridges	-10	-10	Cells intersecting feature	Cells intersecting feature
Coastal defence and flood protection	-40	-20	Cells intersecting feature	Cells intersecting feature
Deposition of dredged material	-25	-12	Cells intersecting feature. 500m buffer for points.	500m buffer
Dredging (capital and maintenance)	-30	-15	Cells intersecting feature. 10/25/50m buffer for points depending on size.	500m buffer
Finfish mariculture	-7	-11	150m buffer (consists of only point data)	1 000m buffer
Harbours	-35	-7	Cells intersecting feature	40m buffer
Jetties	-5	-5	Cells intersecting feature	60m buffer
Land claim (excluding harbours, oil terminals)	-40	-2	Cells intersecting feature	40m buffer
Marinas and leisure harbours	-15	-5	100m buffer (consists of only point data)	200m buffer
Recreational boating and sports	-3	-10	Cells intersecting feature	Cells intersecting feature
Shipping density	-10	-15	1*1km AIS density grid	1*1km AIS density grid
Wind farms (operational)	-30	-12	30m buffer (consists of only point data)	100m buffer
Anchorage	-10	-6	Cells intersecting feature	Cells intersecting feature
Fishing effort (all gear types)	0	-5	N/A	ICES c-square grid (0.05° × 0.05°)

7.3. Human pressure modelling

A total of 14 different human activities were included for developing human pressure layers (see Table 6). Resulting pressure layers were used as an input in the Zonation analysis but were also used independently to identify impacted degraded areas.

For each activity, two separate layers were created: one representing the extent of the physical loss and the other disturbance. Some pressures, for example wind farms, were determined to have a local presence/absence like effect; i.e. the effect occurs exactly where the activity occurs. Other pressures, like disturbance from dredging, were determined to have a more gradient like effect. The highest intensity is located where the activity occurs, but the activity also affects the surrounding area with intensity correlating with the distance to the activity. Some activities, like dredging (Fig. 35) and shipping, were rescaled according to depth as the effects are presumed to become less marked with depth.

The extent layers for loss and disturbance were multiplied with the corresponding weight value for the given activity (see Table 6).

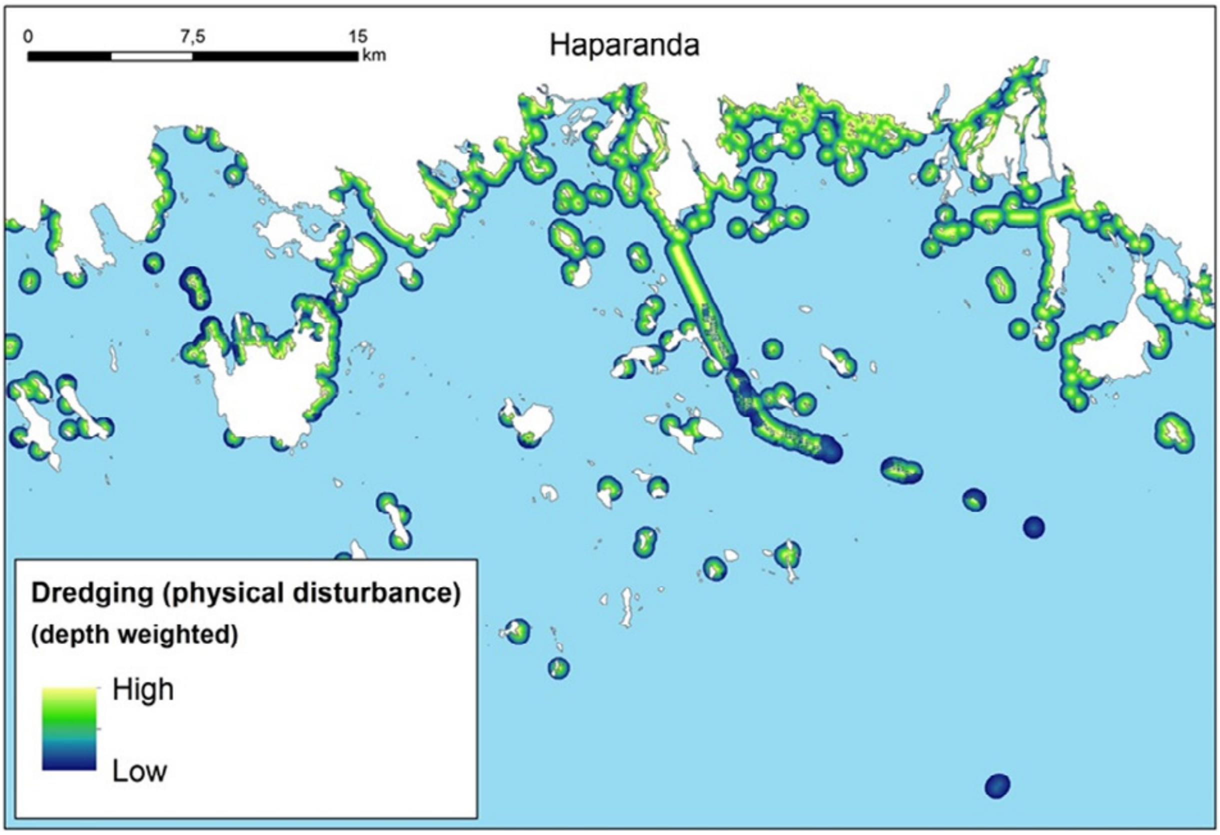

Figure 35. A raster map depicting the extent and intensity of physical disturbance caused by dredging. Depth was also taken into account as a mitigating factor. Map by Marco Nurmi, SYKE.

7.4. Results

Results show that a large part of the shoreline has been affected by human activity to at least some degree in the recent past (Fig. 34). A significant contributor to pressures near the coast is dredging (Fig. 35). Shipping effects a very large part of the SEAmBOTH area, though the effects are more diffuse than most activities and the activity is mostly relegated to deep areas. The analysis indicates that areas near Oulu, Kemi, Haparanda, and Karlsborg are most affected by human activities (Figures 36–38).

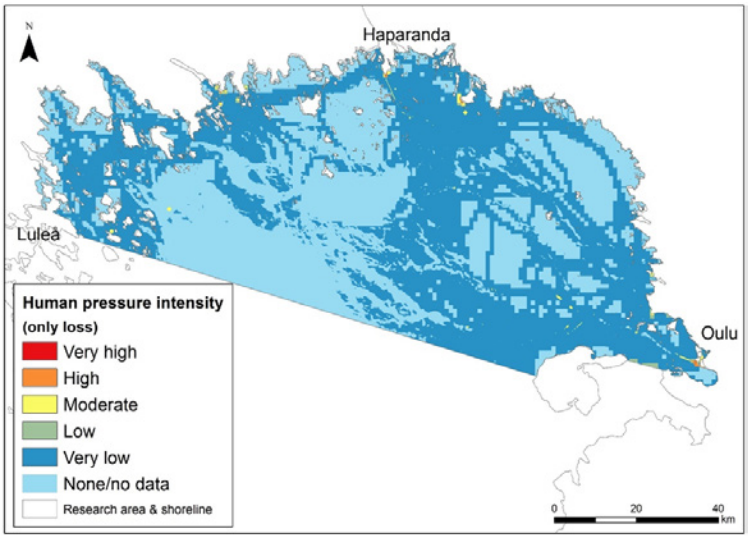

Figure 36. An aggregate of all weighted loss layers. Map by Marco Nurmi, SYKE.

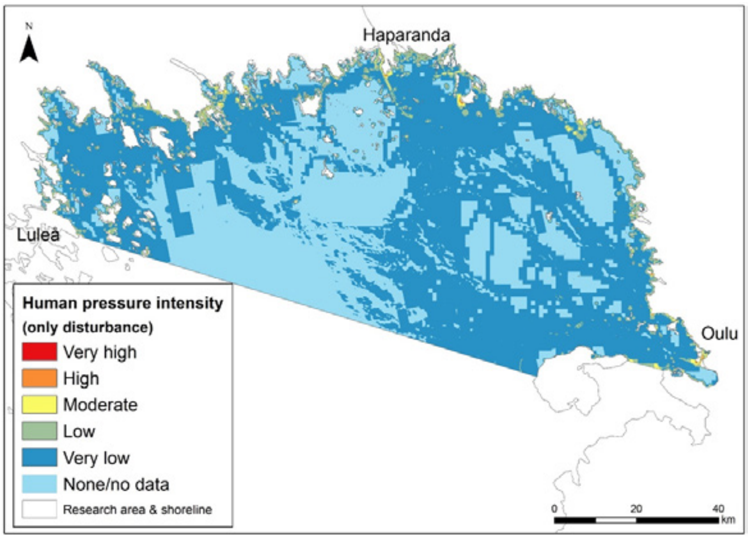

Figure 37. An aggregate of all weighted disturbance layers. Map by Marco Nurmi, SYKE.

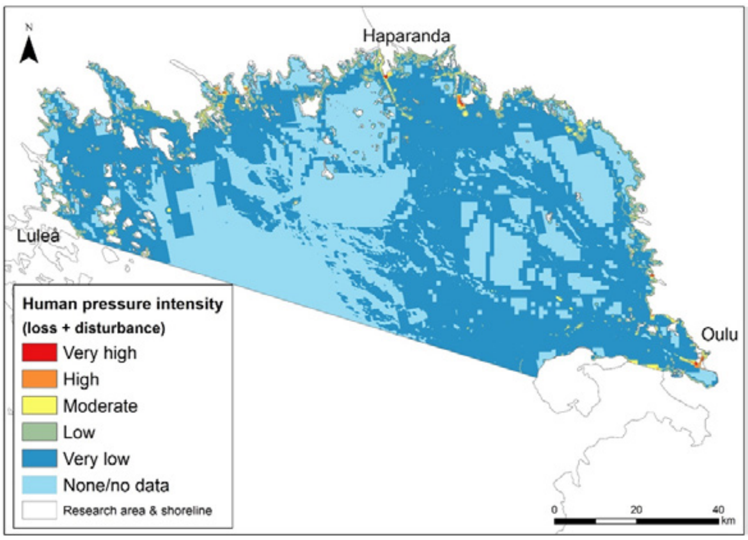

Figure 38. An aggregate of all weighted loss and disturbance layers. Map by Marco Nurmi, SYKE.

8. Ecological modelling

8.1. Species Distribution Models (SDMs)

Statistical modelling is a method where variables are used to explain the relationship of other variables. A key framework from ecological point of view is Species Distribution Modelling (SDM), where species observation data is combined statistically with the environmental information of where the species is living. Using that knowledge, likelihoods for the potential occurrence sites of species beyond the sites where inventories have already taken place, can be given. SDM is an umbrella term for various algorithms, which are usually correlative of nature, and can rely for instance traditional regression models or modern machine learning methods. In the SEAmBOTH project, Gradient Boosting Machine and relevant functions from Boosted Regression Trees (BRT) were utilized for modelling the potential distribution areas of several species (Friedman et al. 2000; Breiman 2017).

8.2. Collated data for SDM development

Data for SDMs relies on biological inventory data, where species are either observed as present/absent and, if present, usually the coverage of species is also recorded. In the SEAmBOTH area, around 23,000 sites with biological data had been visited and were used to build ecological models (Fig. 39). Species for which model development took place were based on the nature values-assessments (see Chapter 9.1).

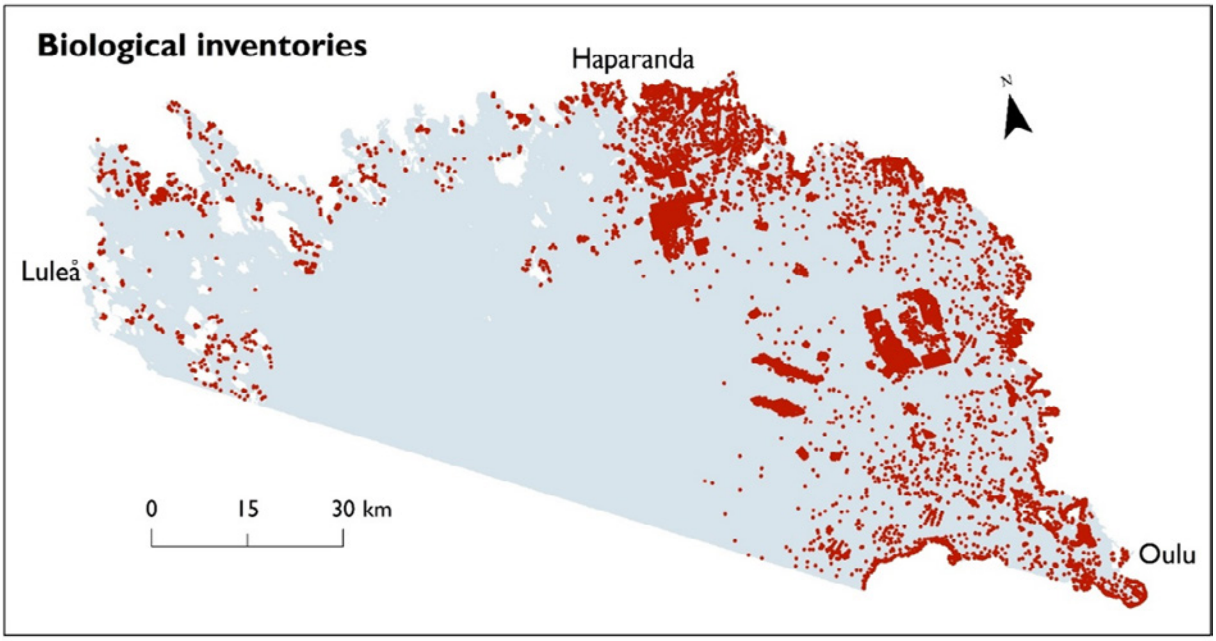

Figure 39. Biological inventories done in SEAmBOTH area represented as red points. Map by Elina Virtanen, SYKE.

As SDM also needs information about the environmental (habitat) preferences of species, in total 23 environmental layers were developed for the SEAmBOTH area and were based on geological, physical, and chemical parameters, either from the national monitoring sites or with the help of remote sensing (Chapters 2,3, and 4) (Table 7). For instance, seafloor fetch (Fig. 40) describes open areas of high exposure to wave action and shallow areas sites identified as shallow based on Sentinel-2 interpretations (Fig. 41).

Table 6. Human activities leading to physical loss and disturbance of the seabed, as defined by experts in a MOSAIC-type workshop. The larger the (negative) number, the larger the impact is.

Environmental predictor	**Description (and potential reference)**
Chlorophyll-a content (µg/l) (mean, max)	Content of chlorophyll-a in the water column, based on water monitoring samples
Depth (m)	Bathymetry model based on EMODnet bathymetry product and detailed national bathymetry
Nutrients (total nitrogen & phosphorous content) (mean, max)	Total nitrogen and phosphorous content in water column
Salinity (PSU)	Salinity content in the water column, based on water monitoring sites
Seafloor fetch (Index)	Descriptor of distance on seafloor to objects at the same depth zone, represents exposed/sheltered areas (Sahla, 2019)
Sediment types (%)	Hard, soft and coarse sediments (see section Geology).
Shallow areas (Index)	Shallow areas interpreted from Sentinel-2 images. A side product from turbidity estimations, before the removal of unreliable turbidity values
Substrate types (%)	Proportion of boulders, rocks, mud, sand and unstable substrates, modelled as probability to occur and as abundance using Random Forests based on biological inventories and observed substrate coverage (detailed methodology: Lappalainen *et al*. 2019)
Suface Wave Model (Index)	Wave exposure model (Isaeus 2004)
Turbidity (FNU)	Turbidity interpreted from Sentinel-2 images (see section on satellite interpretations)

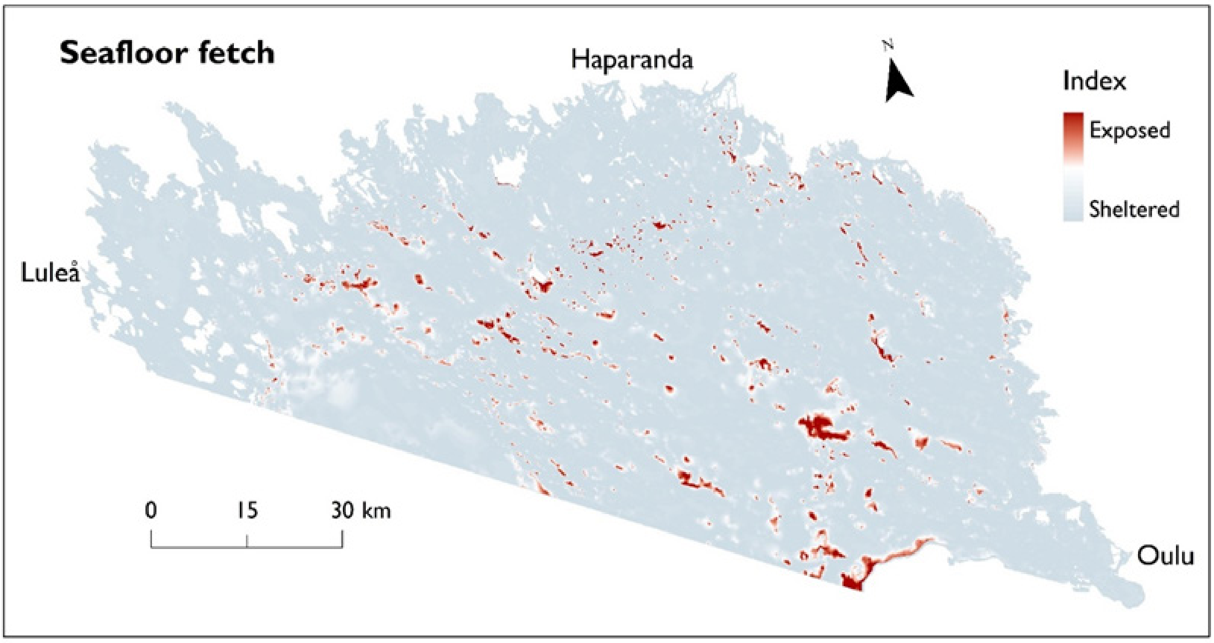

Figure 40. Seafloor fetch in the SEAmBOTH area. Red colour represents exposed areas and light blue sheltered ones. Map by Elina Virtanen, SYKE.

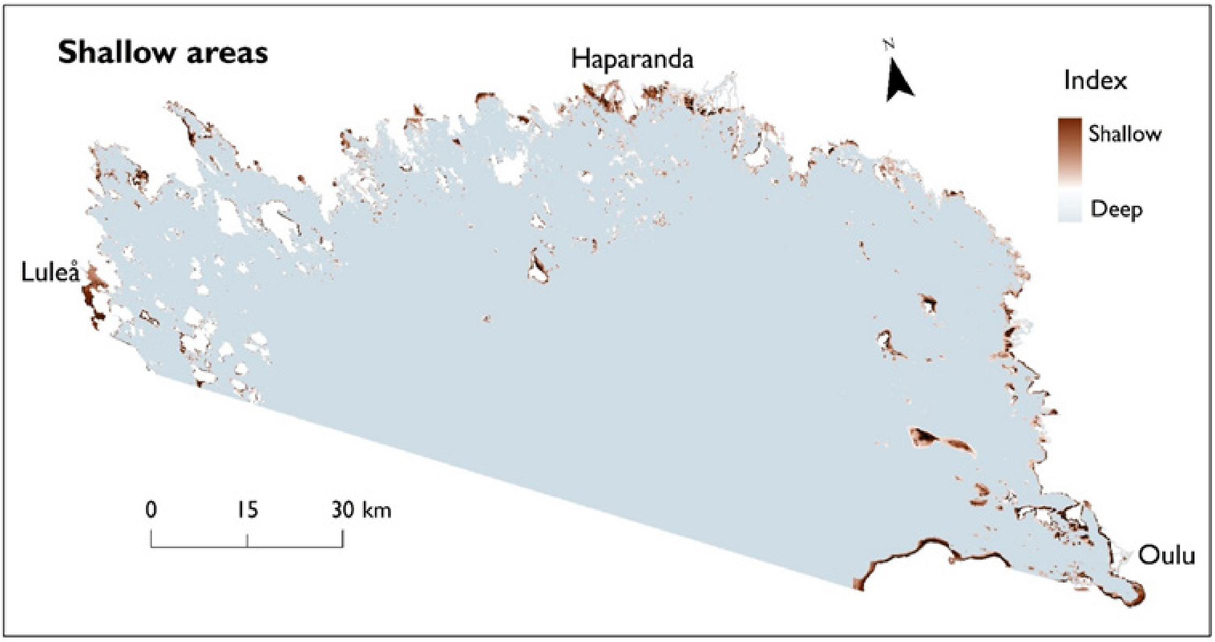

Figure 41. Shallow areas (brown colours) based on Sentinel-2 interpretations. Map by Elina Virtanen, SYKE.

8.3. Developed SDMs

Models were developed with GBM and relevant functions from BRT modelling methods. The selected approach develops several models and optimizes the prediction results based on various models (comparative to ensemble models). In general, model tuning parameters for all models were based on species prevalence, sample size, and optimizing the model performance with minimal prediction error. Only well performing models were selected for consecutive analyses. Performance evaluation relied on correlation between observed/predicted, deviance explained, and Area Under the Receiver Operating Characteristic curve (AUC) value, i.e. how well the model captures true and false positive and negatives (hit rate for predicting species presence/absence). AUC values above 0.9 indicate excellent, 0.7–0.9 good and below 0.7 poor predictions. Only well performing models were included in the nature value analyses (Chapter 9.2.).

Models were developed for six different ecosystem component groups (as defined in the nature value workshop, Chapter 9.1): Macrophyte meadows, Charales meadows, water mosses, Eleocharis acicularis & Subularia aquatica meadows, Dense reeds (> 25 % cover), and threatened species (Fig. 42 and 44).

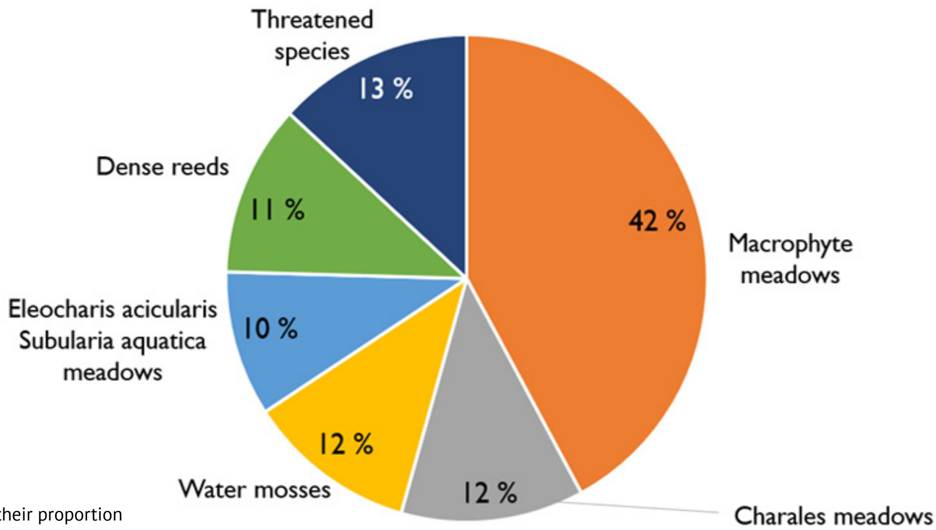

Figure 42. Developed SDMs as their proportion based on different ecosystem component groups.

Models performed well with mean correlation between observed and predicted 0.77, mean AUC values 0.98 and mean deviance explained 69 % (Fig. 43). In general, threatened species models were better, which is explained by the fact that their ecological niche is narrow, and easily captured in the SEAmBOTH area, compared to more general species, when distribution range continues outside SEAmBOTH area.

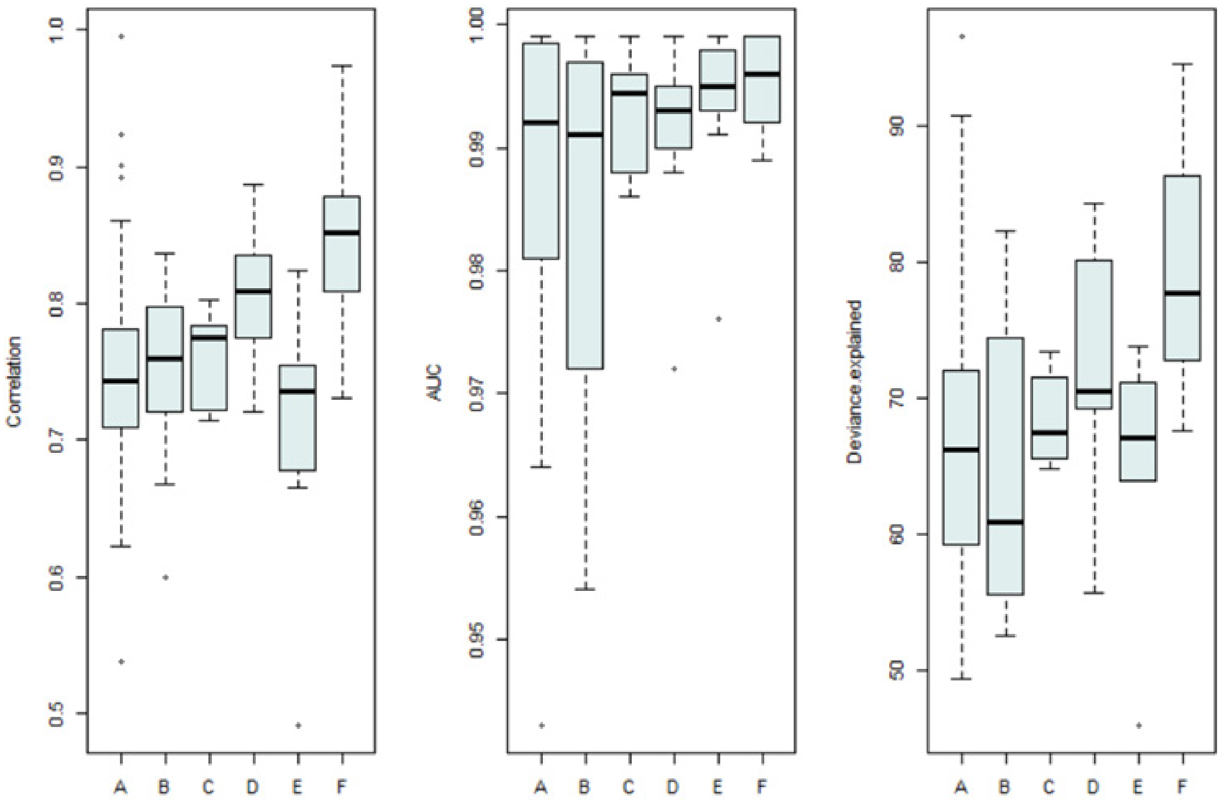

Figure 43. Developed SDMs and their correlation, AUC value and Deviance explained (%) according to different ecosystem component groups. A= Macrophyte meadows (>25 % cover), B= Charales meadows (>25 % cover), C=water mosses, D=Eleocharis acicularis & Subularia aquatica meadows (>25% cover), E= Dense reeds (> 25 % cover), and F=threatened species.

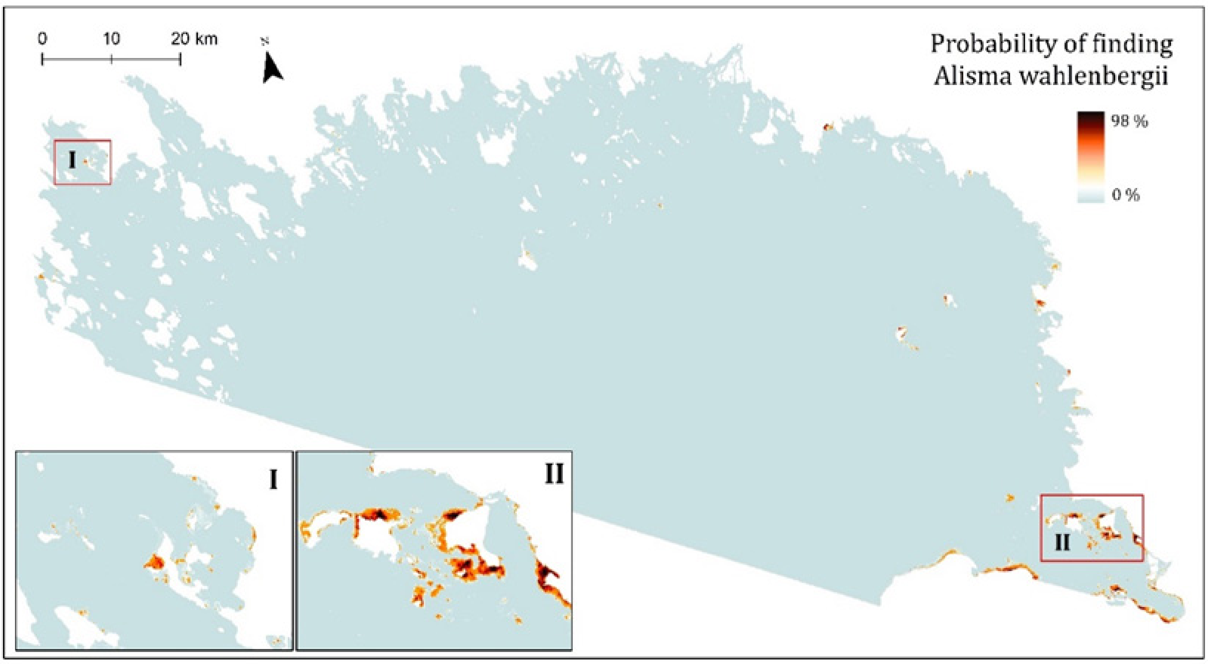

Figure 44. An example of a developed SDM, Alisma wahlenbergii in the SEAmBOTH area and zoomed-in examples. Map by Elina Virtanen, SYKE.

9. Nature values

For management purposes it is important to know which areas of nature to prioritize for conservation and where expansion of human activities is more suitable. Areas with higher nature values are targeted for conservation, but how do we know to apply a nature value and how do we compare different habitats and species? The question of nature valuation is a rather complex topic with no one single answer. On a global level the Convention on Biological Diversity appoint so called Ecologically and Biologically Significant Marine Areas (EBSA) throughout the world. Those are areas that fulfil a certain set of criteria in terms of e.g. uniqueness/rarity, special importance for life history stages of species, and importance for threatened, endangered, or declining species and/or habitats (CBD, 2020). In Finland a national project to identify ecologically significant marine underwater areas, so-called EMMAs (Ekologisesti merkittävät vedenalaiset meriluontoalueet) have found and described 87 marine areas along the coast of Finland (Lappalainen, Kurvinen & Kuismanen, 2020). The identification of the areas was based upon data from the VELMU project, analysed by the spatial prioritization tool Zonation (Virtanen et al. 2018) and reviewed by experts for final decision. The evaluation of the EMMA areas was based upon the same criteria used for the EBSA evaluation with slight modifications.

In Sweden there is a current ongoing work developing a national standardized framework for nature value assessment in the marine environment named Mosaic (Methods for spatial, adaptive, and integrative ecosystem-based assessment of conservation values) (Hogfors, Fyhr & Nyström Sandman, 2017). A draft of the Mosaic ecosystem component list for the Gulf of Bothnia has been made. There ecosystem components (species, habitats, or biotopes) have been identified and scored based upon the best available knowledge at the time. The geographical extent of this list covers the whole Bothnian Bay. In order to identify prioritized nature values within the SEAmBOTH project area, a more local approach needed to be taken. An agreement was made amongst the project participants to use the Mosaic framework as a template to evaluate nature values but adapt it to relevant ecosystem components from the project area and give scores from a local perspective of the northern Bothnian Bay. The identified nature values would then be taken and used within the Zonation analysis as weights, in order to produce a balanced ranking, i.e. nature values map in project activity 5.

9.1. Use of Mosaic framework to identify nature values

As part of activity 6.4 Harmonization of marine nature values, a workshop was arranged to identify and prioritize nature values by using Mosaic framework. Participants of the workshop included people with knowledge, experience, and/or other relations to working with nature values within the northern Bothnian Bay. The results from the workshop were later used within the Zonation analysis as assigned weights in order to produce maps of nature values in project activity 5. A report from the activity 6.4 can be found in Appendix 6 with a full description and results. Below follows a short summary.

In short, Mosaic consists of two parts (Hogfors Fyhr & Nyström Sandman, 2017). A basic nature value assessment in which the question of what ecosystem components are valued is answered. Secondly, there is an in-depth nature value assessment answering the question of where these ecosystem components are located spatially. The first part (1) is in turn divided into two parts; 1a. assesses the ecological and biological value and 1b. assesses the ecosystem services value. The workshop focused only on part 1a. "The assessment of the ecological and biological value (1a.)" is based upon four criteria. For each of the criteria the ecosystem component is given the score of 0, 1, 2, 4 or 10. The criteria are:

- **Life cycle importance**
  How important is the ecosystem component for a critical phase in life for one or several mobile/migratory species? The scoring of this criteria depends both on the importance for a critical life phase and the strength of the spatial correlation (i.e. to what extent the ecosystem component limits/restricts distribution and/or size of the population of the species).

- **Threat status**
  The threat status is based upon the classification of the ecosystem component within existing lists of threatened species/biotopes. The HELCOM red list was used for Baltic Sea biotopes, the Swedish red list from The Swedish Species Information Centre (2015), the international IUCN red list, and the Assessment of threatened habitat types in Finland (2008 and 2018) (Kontula & Raunio 2019).

- **Biodiversity contribution**
  To what extent does the ecosystem component contribute to biodiversity of species and populations?

- **Ecological function**
  Does the ecosystem component perform a function of importance from an ecologically holistic perspective? This is evaluated from three perspectives; importance of function, interchangeability, and occurrence.

Firstly, ecosystem components were identified and suggested by the participants. Secondly the list was reviewed and completed to ensure it properly reflected the marine environment of the northern Bothnian Bay. Finally, scores were given to the listed ecosystem components according to the Mosaic criteria. The results can be seen in Table 8. The top three highest scores (i.e. highest nature values) were appointed to estuaries, lagoons/shallow sheltered bays, and macrophyte meadows.

Table 8. Important ecosystem components in the northern Bothnian Bay were prioritized and scored according to the four criteria of Mosaic framework. The final score can be seen in column "Sum" in bold. "Additions" are ecosystem components added during the review after the workshop.

EC	1. Life cycle importance	2. Threat status	3. Biodiversity	4. Ecological function	Sum	Comments
Water mosses	>2 ?	2–4	4–(10)	10	**>18**	Lack of knowledge
Charales meadows	4	10	10	2	**20**	2. VU in Fin, NT in HELCOM
Coastal nursing ground for siika/sik/white fish	2	0	1	4 ?	**7**	Hard!
Dense reed (in water)	4	0	4	4	**12**	
Muddy/sandy beaches	10	2 ?	4	4	**20**	
Persicaria foliosa occurrence	>2 ?	10	1	1	**>14**	
Feeding ground for wading birds	10	4	2	4	**20**	
Estuaries	4	10	10	10	**28**	1.Migratory birds and fish. 2. EN in Finland, CR in HELCOM. 4. Sediment transportation, change of water, flooding control, interchangeability is low, limited numbers of them, many are regulated
Lagoons/shallow, sheltered bays	10	4 (10?)	10	4	**28**	1.Nursing area, all used by some species. 2. Fladas (VU) others are not threatened. 4. Feeding, shelter, low interchangeability, quite high occurrence
Submerged reefs	2 ?	2	2	4	**10**	1.We don't know, maybe fish/benthic animals hiding and feeding, nursing there. 2. Not on a threat list, but lack of knowledge in general. 3. Some biodiversity, relatively high in comparison to surrounding sea floor.
Seal resting areas	10	4	1	2	**17**	1.Critical for seals. 2. Ringed seal (NT). 4. Top predator, high interchangeability, quite high occurrence
White gammarus *(Monoporeia affinis)* occurrence	2	10	1	4	**9**	1.Can possibly limit one/several species. 2. Under investigation. Gammarus bottoms EN in Fin, NT in HELCOM 4. Important food source, important for decaying
Shallow areas with emergent vegetation	4	0	4	2	**10**	1.Insect, fish lay eggs there. 2. Difficult to classify. 4. Relatively interchangeable
Macroplea pubipennis occurrence	2 ?	10	1	1 ?	**13**	1.We don't know, might possibly limit species? 2. NT in Fin 4. Don't know enough about the specie
Macrophyte meadows	10	4	10	2–4	**>26**	1.Critical for small fish, migratory birds. 4. Filtering, nutrient
Spawning grounds for predatory fish	10	10	2	2(–4)	**24**	2.Coastal exploitation. 4. Feeding ground, predatory fish has a top-predator function
Alisma wahlenbergii occurrence	0	10	1	1	**12**	2. VU in Fin, VU in Swe
Eleocharis acicularis, *Subularia aquatica* meadows	?	4	4–10	4	**>18**	2. Outcompeted by reed, in Finland considered threatened (CR), LC in Swe. More of it in SEAmBOTH area than further south 4. Feeding ground, stabilising the soil.
Mixed bottom habitats	0	0	4	1	**5**	
Hippuris tetraphylla occurrence	0	10	1	1	**12**	2. VU in Fin. None existing in Swe
Gathering areas for water birds	10	2	4	4	**20**	1.High spatial correlation gives a score ten. 4. Seed dispersion, dig bottom, food for other birds, predatory birds, poop nutrients
Additions						
Sea ice cover	10	10	4	4	**28**	1.Very high important for e.g. ringed seal, very high spatial correlation 2. VU in Fin, VU in HELCOM 3. Contribute to a relatively high biodiversity. Ice scraping create conditions for seashore flora. 4.High importance of function, low interchangeability, occurrence today common, but in future drastically decreased → 4?
Chara braunii >5 ind/% cover	0	10	1	1	**12**	1.As far as we know? 2.VU in Swe and Fin
Limosella aquatica >5 ind/% cover	0	4	1	1	**6**	1.As far as we know? 2.NT in Swe, LC in Fin
Crassula aquatica >5 ind/% cover	0	10	1	1	**12**	1.As far as we know? 2. NT in Swe, VU in Fin

9.2. Zonation analyses and parameters

Zonation is a spatial prioritization tool, where different interests (e.g. ecology, costs) are balanced in a way so that loss of biodiversity is kept as low as possible. Input spatial data can be anything, covering, for instance, biodiversity, threats, and costs. Zonation synthetizes information in a way that most important areas, from an ecological point of view, can be identified. Zonation produces a hierarchical, iterative prioritization across the landscape based on the value of a site (cell), which depends on e.g. amount of data and weights given. Highest rank values receive cells that have high overall species richness, highly weighted species/ecosystems/habitats, and lowest sites which are degraded, pressurized and/or naturally low in species diversity. Zonation first removes the least valuable cells from the landscape, while at the same time minimizing the loss to biodiversity. Thus, areas not worth conserving are dropped out first and areas of high value to conservation are left until the end. As a result of Zonation analysis, users get a sequence of cell removal (priority values), species range size rarity, and performance curves summarizing the conservation coverage which would be achieved in any top priority fraction selected from the priority rank maps.

Zonation also requires information about how each feature is balanced across the prioritization. Assignment of weights can be equal in respect of each other, but usually a hierarchical way is adopted as was done also here. Assignment of weights closely followed the Mosaic nature value assessment and human pressure workshops, where experts assigned values to different ecosystem components and human activities leading to pressures. The values were converted to Zonation weights, in a way that balances weights across ecosystem and pressure components.

9.3. Nature values in the SEAmBOTH area

As a result, ecological models (Chapter 8), and human pressures (Chapter 7) were integrated with Zonation to cross-border nature value maps and are represented here with highest ranked value multiplied with weighted range size rarity value, emphasizing species richness and ecosystem function (Fig. 45). Highest nature value areas are river estuaries, shallow bays, and offshore islands with less human activities and, consequently, less pressures. As high as 96 % of the nature values are located in the 10 % of the geographical total SEAmBOTH area, which suggests that nature values are rather concentrated. Moreover, that 10 % holds also 57 % of the human pressures (Fig. 46). This implies that nature values are burdened by pressures resulting from various human activities, such as small-scale dredging and harbour activity.

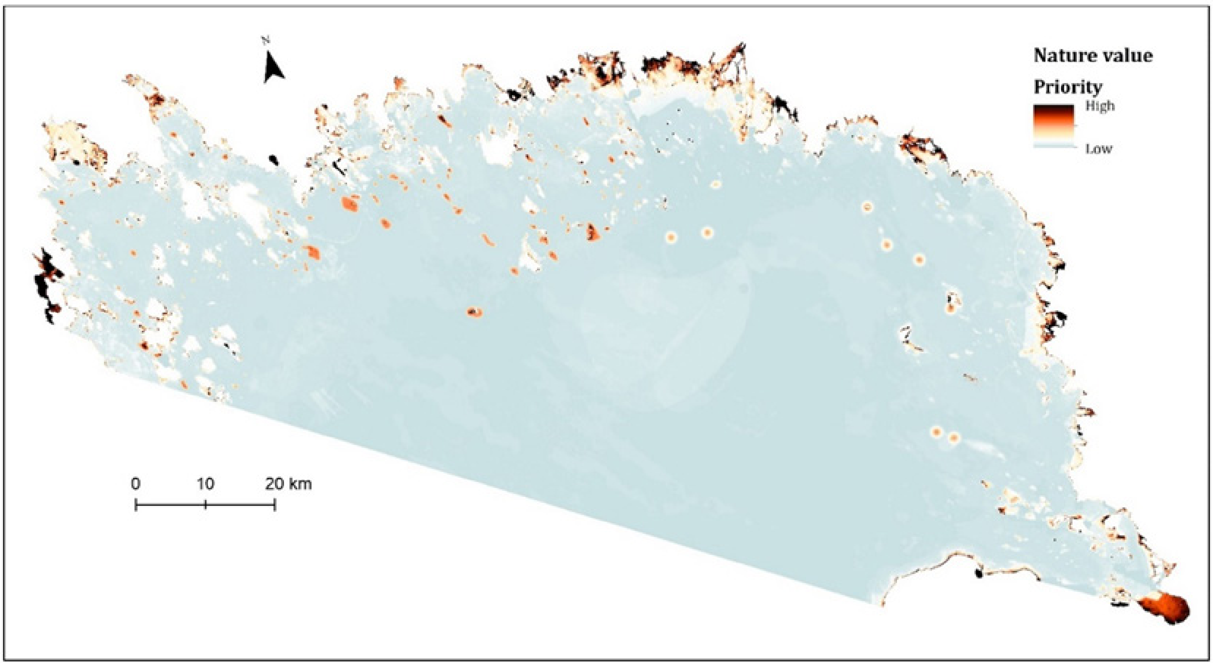

Figure 45. Nature values in the SEAmBOTH area according to spatial prioritization (Zonation) and expert judgement (Mosaic-framework). Map by Elina Virtanen, SYKE.

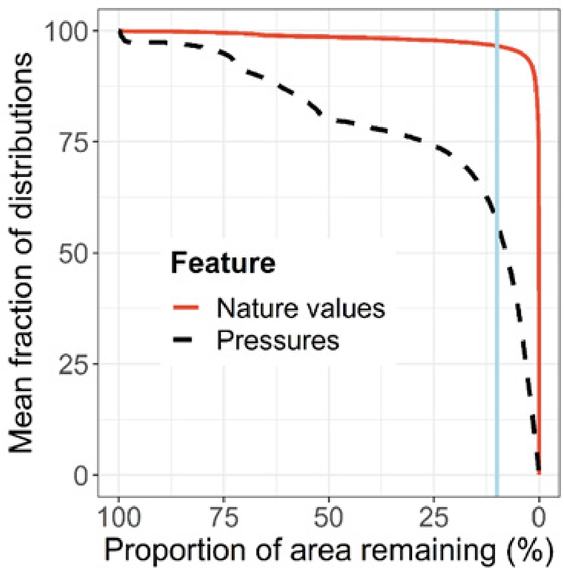

Figure 46. Performance curve of Zonation nature value prioritization. These curves (red=nature values, dashed black line=pressures) summarize the mean nature value cover achieved across different feature groups (section 9.1) from the top-priority areas of the SEAmBOTH priority rank map. Blue colour indicates the 10 % cover of area.

10. Users of marine maps and the marine management

The SEAmBOTH project has collected a substantial amount of new data and information and produced maps of the marine environment. To ensure that the information becomes available to users, communication with stakeholders has been vital. In addition, to strive for a sustainable Bothnian Bay, having available data and maps is not enough, there was also a need for management cooperation across the border. Two activities of the project were therefore focused on these matters; 7.1. Workshops with end-users (Appendix 7) and 6.3. Comparison and harmonisation of management and planning (Appendix 5). During these two activities, valuable feedback, insights, and knowledge were gained and contributed to the development of not only the end-products of the project, but also the project partners' understanding of the society surrounding the northern Bothnian Bay (and hopefully the participating stakeholders and marine managers and case officers as well).

10.1. Input from stakeholders

To produce and provide material and information that is relevant and accessible for stakeholders one must understand the users and their needs. The activity 7.1. Workshops with end-users was conducted with the purpose of collecting input from end-users of the SEAmBOTH products and stakeholders within the project area in order to better understand how to make the end-products more usable and accessible, as well as to highlight and raise discussion about the Bothnian Bay marine environment.

In the first phase of the activity, a stakeholder analysis was conducted. It was followed by workshops, meetings, and talks with people from various stakeholder groups in Finland and Sweden from the end of 2018 until the beginning of 2020. A report from the activity can be found in Appendix 7 with a full description of undertaken activities and the results. Below follows a short summary with some examples of given feedback.

Groups of stakeholders that participated in workshops and/or contributed with feedback to the project were:

- Officials within planning and environmental management
- Recreational users e.g. boaters, scuba divers, fisher men, summer cottage owners
- Commercial fishing
- Environmental and conservation NGOs
- Scientific community and universities
- School teachers and students
- Industry and companies, e.g. wind power, tourism, harbours, etc.

In Oulu, two workshops were organized with open invitations to stakeholders from all different groups. They took place during the spring and autumn in 2019 with around 30 participants each time. Focus of the first workshop was on attitude to, and issues concerning, the Bothnian Bay. The second workshop focused on maps and information about the area and user's feedback.

In Luleå, discussion meetings were held with environmental case officers during winter 2019. Feedback was also collected from visits and discussions with people e.g. high school teachers, dive club members, and national representatives within marine management during 2019. A workshop was held in February 2020 with various officials at the County Administrative Board to review drafts of marine maps produced within the project and collect feedback for the publication of them.

Regarding stakeholder's attitudes to the Bothnian Bay, as well issues and the future of the Bay (discussed during the first workshop in Oulu), participants mentioned the Bay as a source for wellbeing in a future "good situation" scenario. There they also saw positive human interaction with the Bothnian Bay e.g. fish populations in a good state, no endangered species or habitats, a functioning fishing culture, human activities on a sustainable level, increased number of leisure boating destinations, and up-to-date data available as a preferred future situation. Increasing emissions, continued building on shallow shores, no access to natioal parks, databases that are hard to use, and planning of the sea that does not work are examples of concerns raised for a future "bad situation" scenario of the bay. To secure the conditions in the Bothnian Bay and ensure all stakeholder's wellbeing, participants highlighted: the importance of good planning, involvement of stakeholders in open dialog meetings, research and correct information, control of the littering, minimizing environmental effects of new projects, and cooperation on national and international levels.

Regarding end-user needs and requests of maps/material, stakeholders from almost all groups overall expressed a need and wish for any information about the Bothnian Bay. The available information today is very sparse, and any maps or material will be beneficial. The need for having data and information open and accessible to users was also commonly mentioned. More knowledge about the species was a common wish and species guidebook was asked for by several stakeholders.

Some examples of feedback given about the marine maps and their publication:

- Must be possible to look at different layers of maps at the same time. Digital maps are a must. Openly available.
- Additional information to complement the maps about why certain plants, nature, etc. are important. Help reading and understanding the maps.
- Proper meta data which is easy to understand. Must explain how the map came together.
- For maps based upon models (e.g. potential species distributions), the map should include some indication of probability so the level of quality/reliability of the map can be seen.
- Maps showing nature values are useful, and especially if combined with human activities maps.
- The colouring schemes of the maps are important, some colours are very difficult to see.
- People need to be informed about the existence of marine data and maps, where to find and how to use them, otherwise they are of no use.

10.2. Marine management across the border

Over the course of two days, representatives of marine managers and case officers from around the northern Bothnian Bay from Sweden and Finland met for a workshop in Oulu as part of the project activity 6.3 Comparison and harmonisation of management and planning. The aim of the workshop was to gain a better understanding of each other across the state border and to learn from each other's practices in daily work, bringing together marine management from both sides of the northern Bothnian Bay. Both countries share the same sea with similar environmental conditions and human activities present. For conserving and protecting the environment, both have a set of legal tools, i.e. laws and regulations, to use in order to ensure this. As EU member states, both Finland and Sweden fall under the same EU directives regarding the marine environment. However, how Finland and Sweden have implemented the directives and which national laws differ, makes marine management different. In this workshop, discussions were focused on following issues of management within the marine environment: protected areas, species protection, and environmental permissions related to the marine environment. In addition, a shorter introduction was given to marine spatial planning in respective countries. A report from the activity can be found in Appendix 5 with a full description of the workshop and the results of the activity. Below follows a short summary.

To better understand the marine management in each other's country, a compilation and comparison of the organisations and its respective actors were made. Summarised in Tables 9 and 10.

Table 9. List of names, abbreviations and description of actors involved in marine management in respective country.

	Organisation name	Abbreviation	Description
Sweden	Swedish Agency for Marine and Water Management *Havs-och vattenmyndigheten*	SWAM *HaV*	Government agency overseeing marine and water related issues
	Environmental Protection Agency *Naturvårdsverket*	EPA *NV*	Government agency overseeing environmental issues
	County Administration Board *Länsstyrelsen*	CAB *Lst*	Government authority, one per region (21 regions) Implementation of government tasks. Link between government/national agencies and municipalities/the people Work in areas of environment, agriculture, community planning and housing, animal welfare, regional growth, cultural environment, integration, energy and climate etc.
	Municipalities *Kommuner*		290 within Sweden, 3 within SEAmBOTH project area
Finland	Ministry of the Environment		
	Regional councils	RC	Joint municipal authority, one per region (18 regions) Two main functions: regional development and regional land use planning
	Aluehallintovirasto Regionalförvaltningsverket	AVI	State regional administrative agencies (Government authority). Five of them within the country. Previously called *länsstyrelsen.*. Work in areas of *basic* public services, legal rights and permits, education and culture, occupational health and safety, environmental permits, rescue services and preparedness
	Centres for Economic Development, Transport and the Environment *NTM-centraler*	ELY centres	Responsible for regional implementation of and development tasks of the central government. 15 centres within Finland. Three main areas of responsibility: 1) Business and industry, 2) Transport and infrastructure 3) Environment and natural resources
	Finnish Environment Institute *Finlands miljöcentral*	SYKE	Multidisciplinary research and expert institute. Funded by government and external
	Metsähallitus *Forststyrelsen*	MH	State-owned enterprise responsible for the management of state-owned land and water. Includes both public services "National Parks Finland" (nature conservation and recreation), forestry (Metsätalous oy) and Property development
	Municipalities		311 within Finland, 7 within SEAmBOTH project area

Table 10. Summary of how the marine-related EU directives are implemented into national law in Finland versus Sweden and responsible organisations.

EU directives	**Habitats directive** Goal: to reach favourable conservation status of habitats and species		**Marine strategy framework directive** Goal: to reach good environmental status of marine waters		**Maritime spatial planning directive** Goal: to promote sustainable growth, development and use of marine areas		**Water framework directive** Goal: to reach good status of bodies of water (inland, river, surface and ground)	
	Finland	**Sweden**	**Finland**	**Sweden**	**Finland**	**Sweden**	**Finland**	**Sweden**
National law	Nature Conservation Act (areas implemented also by Water Act and other acts controlling land use)	Environmental Code, chp 7 & 8 Species Protection Decree (2007:845)	Act and Government decree on Water Resources Management (Act 1299/2004, decree 1040/2006) Government decree on Water management Regions (1303/2004)	Marine environment decree (2010:1341) Also in Environmental Code, e.g. chp 5, 7, 8, 11	Land Use and Building Act and decree	Marine spatial planning decree (2015:400) Also in Environmental Code, chp 4	Act and Government decree on Water Resources Management Government decree on Water management Regions (1303/2004) *Emissions:* Act on Marine Protection (1994/1415), beyond the EEZ-zone of Finland Act and decree on Environmental Protection (Act 527/2014) etc..	Decree of management of water environment (2004:660) Also in Environmental Code, chp 5
Responsible organisation	Ministry of the Environment SYKE, ELY-centres, Metsähallitus	Environmental Protection Agency SWAM advising for marine areas/species	Ministry of the Environment in co-operation with M. of agriculture and forestry and M. of traffic and communication	SWAM	Ministry of Environment Regional Councils, RC of Southwest Finland coordinating. Government signs the plan.	SWAM, the government sign the plans.	Ministry of Environment, Ministry of agriculture and forestry	SWAM (advisory and reporting to EU
Operational organisation	ELY centres, Metsähallitus	CAB, municipalities	ELY centres, Metsähallitus, SYKE	CAB Measures also by CAB and municipalities	Regional councils	SWAM, with advise from CAB	ELY Centres, Finnish Environmental Institute, Natural Resources instutute	Water agencies (five in Sweden) CAB, municipalities (undertake measures)

On top of EU directives, both countries implement nationally derived strategies. Sweden has, for example, the environmental quality objectives set to be achieved by 2020. Even though only one out of 16 goals seem to have be achieved, it has been useful in prioritizing of resources and has played its part in the establishing of marine protected areas. In Sweden, work is also guided by the Agenda 2030, which not only focuses on nature but to all parts of society, therein to sustainable use of natural resources. In Finland, several smaller strategies have been initiated, for instance, the biodiversity strategy, and focus has not thereby been on large pictures but on parts of nature.

Each issue of the workshop started with an introduction to the issues from each country. Then followed a discussion amongst the participants, focused on three central questions:

1. What are the main differences and similarities between the countries?
2. What basis/background information is used in decision-making?
3. What are you/your organization in further need of?

In the end of the workshop participants were asked to write down their wishes, questions they wanted to be answered, and/or resources they wished they had in a dream-scenario of a perfectly functioning marine management within the northern Bothnian Bay (Fig. 47).

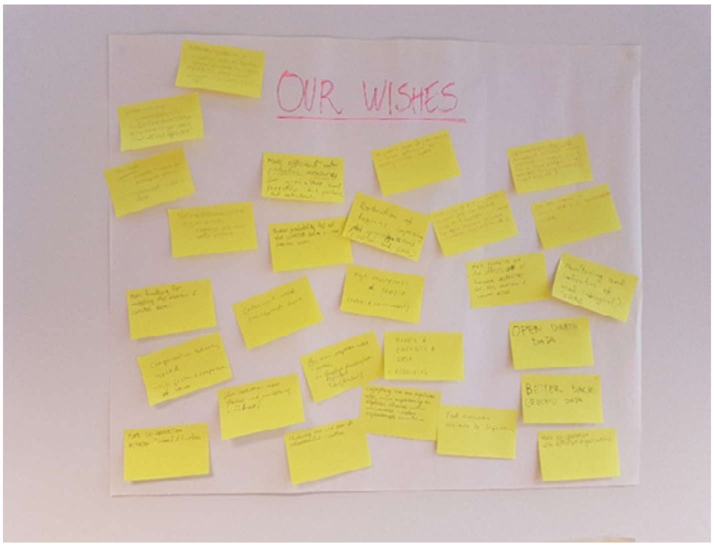

Figure 47. Wishes from marine managers of questions they wanted to be answered and/or resources they wished they had in a dream-scenario of a perfectly functioning marine management within the northern Bothnian Bay.

Conclusions from the workshop:

- The marine environment and the types of cases that are handled are very similar between the countries, a continued collaboration would be beneficial to learn more from each other in detail.
- Both countries struggle with the fact that many protected areas in the sea are not including actual marine values. Most areas were established long ago when data and information available on the marine environment were much scarcer than today. Similar types of protected areas are used for similar purposes in both countries. In Sweden, more decisions are made on a regional level in comparison to Finland where more are decided on a national level. Sweden is now working more actively to increase protected areas (by national legislation) than Finland.
- Information on protected species is scarce. Laws might not be functioning efficiently and cases including protected species may therefore be quite complex to handle.
- Knowledge and information on the effects on marine nature values from human activities are important for making well-grounded decisions for environmental permissions. This is currently lacking in both countries.

11. Outreach

Effective communication can play a vital role in efforts to gain support and understanding for the project and for the management and mapping of the seas. One of the project's main objectives was to facilitate open communication with the authorities and organizations involved in planning and management; as well as corporations and contractors, who could benefit from the project results, and nature conservation organizations. Additionally, the project strived to inform and educate members of the general public living in the project area, in order to spark interest about sea related issues and create a change in attitude towards protecting the Bothnian Bay. But in order to affect people's opinion about wanting to protect the sea, they need to understand what is in there and why it is so special. As underwater nature is not something that can be reached or seen by everyone, it is vital to "bring the nature to the people" and inform them about the special features about the Bothnian Bay.

Over the past three years, the project has been involved in various events and activities in order to share project related experiences and get the local communities involved (Table 11). Also, by means of different media channels e.g. press releases, news reports, radio, podcasts, and social media, SEAmBOTH has increased awareness among project stakeholders, organizations, general public, and management authorities on the topic of sustainable development, in the hope that proper conservation actions can take place in the Bothnian Bay.

Table 11. The number of media hits, events, congresses, workshops etc. where SEAmBOTH project group members and organizations have participated in the past three years, or been part of, and the number of participants who have attended the events.

	Number	Participants
National meetings and seminars	15	350
International seminars, meetings and congresses	8	500
Workshops	8	200
Events	15	45 000
Teaching (school, university, teachers)	21	1270
Radio appearances	8	
TV appearances	3	
Newspaper or magazine articles	13	
Internet articles, pages etc. other than social media	20	
Blog posts	157	
Other	2	

11.1. Scientific community

SEAmBOTH project members from different project organizations attended national and international scientific meetings, workshops, and seminars both to tell about the results and the work done in the SEAmBOTH project and to learn from other projects working with similar issues (Table 11). Some of the events participated were, for example, the 4th Colloquium of Finnish Geosciences in Turku, Finland and GEOHAB 2019 in St. Petersburg, Russia.

11.2. Public events

Project members have been extremely active in participating in events during the project. One proud accomplishment has been the activities at local schools and in the community. SEAmBOTH has done this by offering field excursions, presenting demonstrations to students and local residents, and giving talks on some of the daily tasks required for this project. Other times, members of the SEAmBOTH team hosted teacher workshops, visited schools, and presented talks about various subjects on the Bothnian Bay and the project. The SEAmBOTH project also created several teaching resources such as PowerPoint presentations, workbooks, and games that allow students to learn about the sea in a fun and engaging way. The project also produced teaching material of underwater species and nature types in Finnish, Swedish, and English for the SEAmBOTH area (accessible at https://seamboth.com/results/), as well as a photo bank for future use. Additionally, SEAmBOTH further contributed to public outreach by participating in events aimed at the general public, for example, Dive Perämeri, Toivon Agenda 2030, the Raahe Maritime Festival and Tornio harbour day (Table 10). Through these activities the hope is that the SEAmBOTH can promote the sustainability of the Bothnian Bay for future generations.

SEAmBOTH final seminar was held at the University of Oulu 20th of February 2020. The seminar was open to everyone and collected about 70 people in the lecture hall and more than 20 people online. The Geography Research Unit and the Biology Research Unit offered students credits for participating in person and citating a number of presentations.

The program consisted of both SEAmBOTH project members' presentations as well as invited guest speakers, who presented, for example, future climate change scenarios for the Baltic Sea, connectivity of the nature conservation areas in the Bothnian bay, history of marine research in the Bothnian Bay, notes from the end users of our project etc. The presentations can be viewed as recordings in the SEAmBOTH webpage under Final seminar https://seamboth.com/final-seminar/

11.3. Media

The media has been useful in spreading the SEAmBOTH message on the importance of sustainable management of the seas. Project members have been active in keeping the public informed about the project through different media outlets as well as on various social media platforms. To date, the project has been reported in 44 news reports, TV, radio broadcasts, podcasts, websites, newspapers, and magazine publications.

Additionally, the SEAmBOTH webpage (https://seamboth.com/) was created in January 2018 and has been updated regularly since then. The webpage contains information about the project in the form of news, reports, data, videos, blogs, and anything pertaining to the SEAmBOTH project. On the webpage (https://seamboth.com/results/) you can for example find and download the species guidebooks and watch the SEAmBOTH movie.

Social media has also played an integral part in reaching the public. Since the beginning of the project, all project members have posted SEAmBOTH related material to their own individual social media pages (Facebook, Twitter, Instagram) with #SEAmBOTH #Interreg #Interregnord. Field season videos can be viewed on YouTube and information is also shared on the Bothnian Bay National Park Facebook page (https://www.facebook.com/peramerenkansallispuisto/), which currently has 2,454 followers (26.4.2020) and Luontotyypit (https://www.facebook.com/SuomenLuontotyypit/), which has 3606 followers (27.4.2020) and which tells about the nature conservation work that Metsähallitus is doing.

11.4. Blogs

Blogs are currently one of the most popular methods in sharing knowledge and building awareness to the general public, and SEAmBOTH has put a lot of pride and effort into being active bloggers. Some project happenings can be found on various project partner organization blogs such as http://metsahallitusmerella.blogspot.com/; however the blog is not available in English. To make information about the project more readily available, the SEAmBOTH blog (https://seamboth.com/blogg/) was created to include informative and easily accessible project information. The blogs are used to showcase and promote the project, connect and interact with people, and expand knowledge about the Bothnian Bay.

Posts were added to the project blog approximately once per week. All partners have participated in writing the blogs. To date, 121 blog posts have been added in English to SEAmBOTH page and 39 blogposts to Metsähallitus merellä Finnish blog. The blog includes a diverse series of topics related to the project and the Bothnian Bay. Blog titles are based around ten main themes + Finnish blog (Table 12). Overall, the blog has been well received with a total of more than 20 000 (26.4.2020) total views and has been seen in approximately 90 different countries around the world. All the published blogs are compiled and published in a pdf format. They can be found and downloaded for easy reading from the project website, https://seamboth.com/results/.

Table 12. Project blog series topics with brief descriptions of their content.

Table 12. Project blog series topics with brief descriptions of their content.

Blog Themes	Description
'How We Do It'	Describes methods behind project procedures e.g. field inventory methods, data collation, mapping and modelling.
'People Behind the Scenes	Introduces members of the project from all project partners.
'Field Stories'	Details various experiences that occurred during field work.
'Special Places'	Describes more specifically about locations visited in the field that deserve attention.
'Special Species'	Describes more details about species occurring in the project area e.g. endangered, vulnerable, alien or otherwise interesting species.
'Unique Habitats'	Describes habitats in the project area of concern or other interest that need more focus.
'Reports & Highlighted Issues'	Discusses news and interesting subjects involving the SEAmBOTH project.
'Final results'	Describes results of the project
'Human pressures'	Blogs about human pressures
'Public Outreach'	Describes school events, public events and other events and teaching we have taken part as SEAmBOTH
'Metsähallitus merellä'	Metsähallitus blog in Finnish tells stories from the field and from the office, written by Metsähallitus marine biologists, field workers, volunteers, planners and nature surveyors, as well as interns

12. Guidelines and utilization of results

In this chapter you find collected information on where to find the data and maps that have been produced during this project. There are also gathered tips, recommendations, and guidelines regarding marine mapping and management across the Swedish-Finnish border that are based upon experiences and lessons learnt throughout the project.

12.1. Where to find maps and data

Remote sensing products, such as maps of turbidity, chlorophyll-a and sea surface temperatures, can be found at TARKKA map portal http://wwwi4.ymparisto.fi/i4/eng/tarkka/index.html?type=RGB&date=2020-03-26&datespan=1&name=DEFAULT&lang=en&zoom=5.31&lat=64.23000&lon=26.00000

In Sweden, marine data is reported to SMHI Svenskt havsarkiv (SHARK) (https://www.smhi.se/data/oceanografi/datavardskap-oceanografi-och-marinbiologi) the national database for marine physical, chemical and biological data. Reported data can be accessed and is free for use and download.

Observations of threatened species in Sweden are reported to the species database Artportalen, https://www.artportalen.se/.

Geographical data can be found at Länsstyrelsernas Geodatakatalog and downloaded for use within geospatial processing program, https://ext-geodatakatalog.lansstyrelsen.se/GeodataKatalogen/

Länskarta Norrbotten is the regional map portal for county Norrbotten with maps that can be viewed openly, directly online. https://ext-geoportal.lansstyrelsen.se/standard/?appid=24e3c74537b04bab85109e8973d86396

Finnish data can be found in the open webpage of the national VELMU programme https://paikkatieto.ymparisto.fi/velmu/

Finnish biological data can be found in the LajiGIS database for people working in the environmental management and related field, and in an open www.laji.fi portal for species.

SEAmBOTH ecological models and nature value maps can be found from the SYKE Research Data Service https://ckan.ymparisto.fi/dataset

Swedish geological maps with different themes can be generated and downloaded from SGUs web site through either Kartvisaren https://apps.sgu.se/kartvisare/kartvisare-maringeologi.html

Or Kartgenerator: http://apps.sgu.se/kartgenerator/maporder_sv.html

Please note that for the moment marine geological maps are not published due to security concerns. These issues are expected to be resolved shortly. Meanwhile, requests can be handled through SGUs information service: https://www.sgu.se/produkter/kundtjanst/

Most of the map layers that were produced in the SEAmBOTH project can be downloaded from the project's Results -page https://seamboth.com/results/ Please sea the page a few times since the maps are uploaded there as they are finished. The page will be maintained at least until June 1st 2021 but maybe not longer.

12.2. Material published on the SEAmBOTH website, www.seamboth.com

Species guidebooks:

Perämeren vesikasvio (in Finnish) https://seamboth.files.wordpress.com/2020/03/seamboth_a5_0220_saavutettava2131.pdf

Introduction to marine species of northern Bothnian Bay (in English) https://seamboth.files.wordpress.com/2020/03/seamboth-introduction-to-marine-species-of-the-northern-bothnian-bay.pdf

Marine species of the northern Bothnian Bay (in English) https://seamboth.files.wordpress.com/2020/03/seamboth-marine-species-of-the-northern-bothnian-bay.pdf

Blogs vol 1 https://seamboth.files.wordpress.com/2020/02/seamboth_blogs_blogit.pdf
Blogs vol 2 https://seamboth.files.wordpress.com/2020/05/seamboth_a4_web_blog2.pdf

Defining Natura 2000 habitats from point data and aerial images https://seamboth.files.wordpress.com/2020/04/defining-natura-2000-habitats-using-point-data-and-aerial-images-1.pdf

Estuary report https://seamboth.files.wordpress.com/2020/03/estuary-report-1.docx

Sjef Heijnen Thesis SEAmBOTH - Internship Metsähallitus https://seamboth.files.wordpress.com/2020/03/sjef-heijnen-thesis-seamboth-internship-metsc3a4hallitus-definitive-version.pdf

Remote sensing – Satellite based water quality assessment in the Gulf of Bothnia https://seamboth.files.wordpress.com/2020/04/seamboth-remote-sensing-report.pdf

12.3. Material published on other websites

Reports from macrophyte inventories in Haparanda, Kalix, Råneå and Luleå:

Marin vegetationsinventering i Norrbottens län – dykinventering 2017 https://www.lansstyrelsen.se/norrbotten/tjanster/publikationer/marin-vegetationsinventering-i-norrbottens-lan-2017---dykinventering.html

Marin vegetationsinventering i Haparanda skärgård 2018 https://www.lansstyrelsen.se/norrbotten/tjanster/publikationer/marin-vegetationsinventering-i-haparanda-skargard-2018.html

Marin vegetationsinventering i Råneå och Kalix 2018
https://www.lansstyrelsen.se/norrbotten/tjanster/publikationer/marin-vegetationsinventering-i-ranea-och-kalix-2018.html

Marin vegetationsinventering i Luleå och Kalix 2019
https://www.lansstyrelsen.se/norrbotten/tjanster/publikationer/marin-vegetationsinventering-i-lulea-och-kalix-2019.html

12.4. Guidelines for marine mapping and management

A full report from project activity 7.2. Guidelines can be found in Appendix 8.

Biological field surveys

Suitable methods for biological field sampling in the project area

- A survival suit or a dry suit is essential for doing shallow wading points in the northern Bothnian Bay because the shores are so gently sloping, and the shallow shoreline is so wide, that approaching by boat is often impossible, but boots are not enough.
- Wading with water binoculars is a good method for biological field sampling in the very shallow areas, for example, along shores and river estuaries, as long as the bottom substrate is not too soft and muddy. If bottom substrate makes wading unsuitable, then snorkelling is an option. Snorkelling is easiest applied when depth is about 0.6 – 1.0 m. A drop-video camera can be used when depth is more than one meter. With drop videos the species identification is more difficult, and it is usually only possible to get to genus level. A rake is preferably used in addition to the video camera to take a sample of macrophytes from the bottom and identify the exact species. Diving is the best method for collecting species coverage data of highest quality in areas deeper than one meter. The method is, however, time consuming, requires specialized equipment and skills and is the costliest of all methods.
- In the shallow areas of the Bothnian Bay, small inflatable boats and SUP boards are the best means of transport. A bigger boat can be used for longer distances and for moving the smaller vehicles and field staff from one place to another.
- When diving in the often-murky waters of the Bothnian Bay, a torch and a knife or a cutter are vitally important.
- Water moss species and algae species can usually not be identified underwater, samples are always needed to be taken for closer examination.
- Drone could be used for shallow water inventories in addition to field sampling, and especially for defining Natura 2000 habitats.
- Check the exact water level on your site at least once or twice per day from the closest water level station and adjust the measured depth - water level can change 2 – 3 m in just a few days in the northern Bothnian Bay! Adjust your measured depth according to the water level in the data protocol.

Drop-video analysis

- For analysis of drop-videos we have used the method described in the VELMU-manual (VELMU, 2019) and recommend it for use within the area. A continuous analysis of a 30 second video sequence provides a quick and reliable opportunity for identification of species and their percentage of coverage.
- Expected level of species identification from drop-video (note that this depends upon quality of video and environmental circumstances. With complementary samples taken by a rake, the level of identification increases substantially).
- Species level: Potamogeton perfoliatus, Stuckenia pectinata, Alisma wahlenbergii, Tolypella nidifica, Najas marina (southern Bothnian Bay outside SEAmBOTH area), Aegagrophila linnaei (ball shape), Lemna trisulca, Nuphar lutea, Nymphaea alba, Sagittaria sagittifolia x natans, Callitriche hermafroditica (when flowering), Hildenbrandia rubra, Ephydatia fluviatilis, Spongilla lacustris, Saduria entomon, Anodonta anatina, Pomatoschistus minutus (the only species within the genus in the area), Cordolyphora caspia (the only colony-forming polyp within the area), Zannichellia palustris (only Z. palustris can be found in the Bothnian Bay)
- Genus level: Potamogeton sp., Isoetes sp., Elatine sp., Callitriche sp., Ranunculus sp., Myriophyllum sp., Vaucheria sp., Sparganium sp., Fontinalis sp., Eleocharis sp
- Charales or Chara/Nitella.

- Detailed high-quality drop-camera imagery from deeper and exposed water was successfully implemented from SGUs SV Ocean surveyor using a rotating semiautomated camera system ~70 cm above the seafloor, also benefiting from high quality sonar data in site selection. However, speed of deployment can likely be improved in future surveys (for example by using an array of cameras eliminating moving parts) to provide more data/effort.

Identification of species

- Species guidebooks for specifically the northern Bothnian Bay has been developed during the project. They can be found and downloaded from the SEAmBOTH webpage https://seamboth.com/results/
    - Introduction to marine species of the northern Bothnian Bay – a shorter guide to give you an overview of the most common underwater species and families of plants you may find in the bay, their characteristics and common habitats.
    - Marine species of the northern Bothnian Bay – a comprehensive guide of almost all plant species found in the water of the bay and some of the most common and easily seen animals.
    - Perämeren vesikasvio – the Finnish language comprehensive guide to almost all aquatic flora that can be found in the northern Bothnian Bay
- Literature and other sources we have found helpful when identifying species from the Bothnian Bay:
    - Den nya Nordiska floran / Suuri Pohjolan kasvio, Mossberg, B. & Stenberg, L. 2003, Wahlström & Widstrand, Tangen.
    - Alger vid Sveriges östersjökust, Tolstoy, A. & Österlund, K. 2003, ArtDatabanken, SLU, Uppsala.
    - Blindow, I., Krause, W., Ljungstrand, E. & Koistinen, M. 2007. Bestämningsnyckel för kransalger i Sverige. [Key to the Swedish species of charophytes] – Svensk Bot. Tidskr. 101: 165–220. Uppsala. ISSN 0039-646X
    - Artfakta at ArtDatabanken, https://artfakta.se/artbestamning
    - Den virtuella floran, Naturhistoriska Riksmuseet http://linnaeus.nrm.se/flora/
    - Charophytes of the Baltic Sea, H. Schubert & I.Blindow, 2013.
    - Retkeilykasvio, L. Hämet-Ati et al. 1998, Luonnontieteellinen keskusmuseo.
    - Finnish Biodiversity Info Facility www.laji.fi

Depth and seabed data

Suitable methods for biological field sampling in the project area

- Data from aerial based survey (Lidar and to some degree also passive light sensors from aerial surveys and satellites)) would be very useful for avoiding navigational hazards and mapping the shallow water (~0–5 area), unfortunately this was not available in the SEAmBOTH project as initially planned. An alternative/complementary way to improve the shallow water mapping is to integrate automated surface vehicles (ASVs) in the acoustic surveys. There are already functional systems on the market, and there is promising research to develop fast hydrofoil-based systems that provide small but still stable survey platforms in some degree of wave exposure.
- A conversation to be had for similar future project is what survey effort and data quality the project strives for. It was apparent in this project that more effort per area results in much more details, however, it also restricts the total area of the survey. The examples provided in this report can hopefully serve as valuable input to strike the right balance for project needs.
- The use of Lidar for shallow water mapping may provide high resolution data of the seafloor in shallow areas. However, such data is usually surrounded with restrictions due to national security concerns. Lidar measurements are highly specialized and requires both advanced technique and knowledge. In order to do a mapping with Lidar today in Sweden, a suitable company needs to be contracted via competitive tendering. Due to information security aspects of such assignment, the Swedish law requires a certain administrative process to be followed. The experience from this project is that the administrative process requires substantial time and resources. A competitive tendering should be started years (two years at least) before the measurements are planned to be executed in field.
- Sharing depth data (or any other data about seafloor geography) between partners and with the public has been a challenge in this project. Though we started early with permissions, the result has been unsatisfactory and caused some major disturbances to the project. On the Finnish side it has been more successful than the Swedish side, and SGU even got permission to survey a small portion of the Finish waters. Our best advice for future projects is again to start early, but also to provide more specific examples of how exactly the final results will look like (which is a challenge before the project has been completed…). Hopefully the SEAmBOTH data once published, as well images from this report, can provide some of the needed examples and improve the dialog and understanding between the agencies responsible for permissions, and the applicants.

- According to the TERRITORIAL SURVEILLANCE ACT, the detailed bathymetry and seabed substrate data is subject to authorisation. The authorisation process for sharing and publication of bathymetry or seabed substrate data may take a long time. Thus permissions (for data sharing and publication) should be discussed with national defence forces and their representatives already in the early phase of the project.

Geological field surveys

Techniques/methods/equipment recommended for geological surveys in the project area

- SGU experienced unique challenges in the Haparanda pilot area included turbid and largely unchartered exposed but shallow waters, this led to quite time intensive survey operations. The main vessel SV Ocean Surveyor had difficulties navigating safely due to old charts, and the small launch Ugglan had difficulties operating in the exposed rough waters. In order to adapt to these conditions, the two vessels were working together to open safe passages for the large vessel where possible in order to survey new deeper areas and also to sample on areas already mapped by the small launch. One additional challenge included combining sonar data from multiple sensors, especially backscatter/sonar mosaic data from three different systems (this was solved quite well in post processing operations). For improvements, we believe this kind of survey can benefit greatly by having a Lidar and / or drone and maybe satellite survey done of all shallow water areas to optimize logistics and navigation safety. Also, using Automated Surface Vessels to assist in mapping the shallow waters is a promising technology to make better use of ship time and to decrease the carbon footprint of the survey operations.
- For geological seabed surveys, combined use of various acoustic-seismic investigation and sediment sampling methods are needed. Acoustic-seismic surveys should include both a sub bottom profiling (echo sounding) and seismic profiling. In addition, to provide full-coverage bathymetry and seabed topography, as well as imaging seabed surface features/structures, multibeam echo sounding and side scan sonar imaging are essential. Ground-truthing by sediment/seabed substrate sampling and using an underwater video camera are needed.
- Survey effort: It was apparent in the overlapping maps along the border area that higher resolution multibeam surveys done on the Swedish side allowed for more detailed interpreted maps than the wider swath lower resolution survey on the Finnish side. High resolution modelling was deemed to only be feasible on Swedish data (both due to sample number and data quality). However, high resolution survey cost more and take more ship time, especially in the shallow water depths. It will be important in future similar work to decide what map resolution (thematic and spatial) and quality is needed when deciding on the survey effort per area.
- Geological/seabed substrate classification schemes should include various substrate classes/geological units as the seabed of the study area is very heterogenous. Here we have used following classes: bedrock, till/diamicton, sand and gravel, mixed sediment (glacioaquatic), glacial clay (rhythmites, varved silty/sandy clay), postglacial clay (sulphide bearing clay), gyttja clay, and recent mud.
- The most striking broad scale geomorphological features of the area are canyons or canyon-like seabed features. These features are often tens of meters deep, hundreds of meters wide and kilometres up to tens of kilometres long depressions at the seabed. In addition to the main features mapped, the sonar data and a few sample locations indicates that small patchy hard clay structures are more common in these areas than the maps show. Sampling has to be done very carefully and based on high resolution sonar data to identify these features since they typically have small and patchy distribution.

Geological field surveys

- Data tables should be collated by the people in charge of the data to avoid mistakes.
- Harmonization of data between countries is a priority. Fortunately, national monitoring data collection criteria are same between Finland/Sweden.
- Most important would be that data scientists share their information of how they are doing things, to increase cooperation
- Metadata format should be harmonized between countries

Modelling

- Most important and relevant predictors in the SEAmBOTH project area are gradients that describe freshwater-salinity continuum, bathymetry, substrates and turbidity. Most importantly, due to the extremely shallow nature of the project area, the exact shoreline information creates challenges for building ecological models, as the shoreline may shift kilometres in “low tide”. Thus, for the future, good idea would be to produce some sort of minimum/maximum shoreline, where from recent history, using for instance water level information, EO and land uplift data, reference shoreline (mean), and its maximum deviation from that reference, would be produced. This would ease the modelling part, where “exposure above sea level” would bring valuable information for modelling distributions of species tolerant for this shift, and on the other hand, modelling distributions of species which are rather sensitive to concurrent "exposure to above sea level".

- Suitable resolution depends on the purpose. Best way of doing ecological models is to model the phenomena at the scale where phenomena occurs, for instance, if species are living in a certain shoreline, fine-scale models (resolution of meters) would come into question. However, this is not usually possible due to the resolution deficiencies of predictor data and computational restrictions. If models are produced at a fine resolution, it´s always easier to upscale the resolution (aggregate) than downscale, as the true phenomena may not be captured during the downscaling (this of course does not apply in all situations, say for instance in downscaling salinity from 1 nmi to 1 km).
- Comparisons of different results depending on resolution of bathymetry and substrate e.g. pilot areas vs project area models.
- Nature value analyses depend on the input data, i.e. ecological models. Accuracy of the ecological models instead depends on the accuracy of predictors, adequacy of species samples in relation to its environmental tolerances, and of the geographical area in question. Modelling becomes challenging, if the environmental gradient is under-sampled in the area where models are developed. If ecological data is not present, also expert opinion can be used, for instance in the form of participatory mapping.
- Environmental variables (salinity, turbidity, phosphorus, nitrogen etc.) should be gathered in a series with fixed sampling sites to get a long-time average for modelling, in most of the cases, but then again there are situations where actually the extremes determine species distributions. For instance, concurrent hypoxic events, even for short periods, may deteriorate ecological communities, but this is not usually seen in the long time averages. Same applies to other environmental variables as well.
- If accurate bathymetry data is not available for modelling purposes, most important is to get the trend right. Meaning, declining by distance from the shoreline, or sandy beach. That is to say, digital elevations models are easily available, using their information close to the shore the bathymetry trend can be corrected, and sandy beach usually also continues as underwater parts of sandy shore below the water, which is important information for some species preferring sandy substrates.
- For substrate modelling over larger areas, which in turn are used in the biological modes, it is necessary to also include any data collected during biological surveys. However, the geological data from these surveys vary in quality and limit the usefulness of the substrate models. It is important to keep standardising and improving geological data also from the biological surveys. Additional samples and grainsize analysis together with drop-camera surveys is one way to ensure higher quality data.

Satellite remote sensing

- Protocols for sampling and measurement methods for chlorophyll-a, colored dissolved organic matter (CDOM), turbidity, suspended particulate matter (SPM) and Secchi depth have been developed. By using the latest protocols, we can ensure a high quality and comparable in situ measurements from all over the bay.
- Water quality parameters such as turbidity and CDOM can be estimated well in the Bothnian Bay using Sentinel-2 observations. The water quality estimates provided by high resolution instruments are especially valuable in coastal regions, whereas moderate resolution instruments can cover open sea areas with more frequent coverage.
- With Sentinel-3 OLCI data, examples of Chl-a time series with good correspondence with station sampling were shown at many of the investigated stations. However, the best performing Chl-a algorithm (MPH) was not developed for areas with low Chl-a concentration and extreme aCDOM (brown/humic) waters and over stations with this combination of water type the performance was not convincing. Dedicated development of an algorithm to estimate Chl-a in high aCDOM waters is a task for future research and development projects.
- The SEAmBOTH validation efforts provided insights on the performance of some publicly available algorithms in Gulf of Bothnia waters. As one example, the Neural Net algorithm (C2RCC) that also is available and downloadable as a standard Sentinel-3 product from EUMETSAT, was tested with unsatisfactory results for e.g. chlorophyll a. Promising results could be identified for some stations, but the same algorithm did not perform well everywhere. Hence, no fixed processing chains, or "on-the-shelf" product, for generation of water quality products with Sentinel-3 data in the Gulf of Bothnia could be defined through this study.
- Development of water quality algorithms over dark water types requires long time series before a sufficient level of confidence in the results can be reached. We recommend that water quality sampling is kept at high level in this region, and that the sampling follows the optical protocols utilized here. In addition to determining the in-situ concentrations of Chl-a, CDOM and turbidity, it is also important to collect more data on the inherent optical properties. Getting improved information about the water depth in coastal areas is also important.

Marine management

- Sharing knowledge and experiences is very important, we can learn a lot form each other. The marine environment and human activities surrounding the habitats are very similar. Further cooperation recommended for example regarding management plans and permissions within Natura 2000 areas.
- The presence of land uplift together with highly varying water levels in the northern Bothnian Bay calls for a more flexible approach to defining borders of habitats.
- Mudflats and sandflats that are sometimes covered by water and sometimes above are today an unrecognized habitat in Finland. In Sweden they are defined as the Natura 2000 habitat 1140. Not recognizing them mean they face a risk of being overlooked in conservation and for protection measures.
- Several the Natura 2000 areas in the SEAmBOTH project area are today not suitable in terms of extension to protect what is intended. Those would need a revision of borders in the future.
- Information and understanding of more offshore areas (shallow – deep areas) are still limited. This is also partly due to the fact that the full importance to fish, birds and mammals, or even benthic fauna, were not included in the mapping of valuable and sensitive areas in the SEAmBOTH project.
- It should be noted that in this report the nature values that we discuss and talk about are limited to the definitions we have set (shallow water, biodiversity, and flora/fauna, rather than fish/infauna/productivity etc). If we would have had a better and more detailed knowledge of the functions of the offshore environments (and more resources), our maps might have looked quite different.
- For future revision of the HUB classification system, we suggest considering including a number of biotopes of species commonly occurring in the marine habitat of Bothnian Bay but that today are not identified as HUBs. Those are mainly biotopes with species of a freshwater origin.
- Managers and decision-makers have a great need for data and information on the marine environment of the area (basic background data such as depth and substrate, distribution of species and endangered species, appointed valuable habitats, to name a few). Such information needs to be easily available and understood. Preferably gathered to one or a few sources at the most.

Suggestions from users to make maps available and easy to use

- Maps should be easy to find on digital, online map portals. Collecting information in a national database/map portal is preferred. For users around the Bothnian Bay it is also beneficial to be able to access and use maps across the border.
- Additional information to complement the maps about why certain plants, nature etc are important. To help the user understand the maps. Pictures to illustrate what the maps show, may also help the user.
- Proper meta data which is easy to understand. Must explain how the map came together.
- For maps based upon models (e.g. potential species distributions), the map should include some indication of probability so the level of quality/reliability of the map can be seen.
- The colouring scheme of the maps is important, some colours are very difficult to see. For example, blue and green may appear as the same colour.
- Most important of all, people need to be informed about the existence of marine data and maps, where to find and how to use them, otherwise they are of no use.

13. Data gaps and future needs

Where do we have the most severe lack of knowledge and data?

Biological field surveys

Finnish side, most severe lack of knowledge:

- Differentiating between some reefs and sandbanks which appear on top of each other in substrate models.
- Directed search of Macroplea pubipennis north of Oulu.
- How do different human pressures' effect on underwater nature?

Finnish side, lesser lack of knowledge:

- Directed search for Crassula aquatica along the coast.
- Search for Chara baltica, whose identification in the Finnish side is not sure.

Swedish side, most severe lack of knowledge:

- Need of more macrophyte inventories. The coast is far from fully covered but has now got some inventories as a good start. The middle and outer archipelago has very limited inventories. Both shallow areas, close to the islands, as well as deeper areas, are in need of inventories.
- Glo lakes. There are many along mainland as well as on islands and hardly any inventories of them at all.
- Reefs and sandbanks. To differentiate them for mapping purposes. To increase knowledge of plants and animals living on/around them. Probably many more water mosses and algae species than what we have found up until today.
- Directed search for Hippuris tetraphylla along the coast.
- Directed search for Alisma wahlenbergii. Today, there are two main areas where they are known to exist but there is potential for more areas.
- Directed search for Macroplea pubipennis to better understand its distribution along the whole of the Bothnian Bay coast.

Geological field surveys

Many areas still lack high resolution depth and seafloor substrate data. Some data can potentially be found and further improved upon at the Hydrographic Administrations of each respective country, but many areas have very poor and old data. For example, the few areas in the shallow offshore areas that was surveyed, showed a complex seafloor topography with many interesting features that we still know little about, partly due to the challenging navigational hazards in the region, which made survey work dangerous and slow. Like in many other places, the notorious "white ribbon" (the area between what can easily be surveyed from the air to the deep waters which are efficient to survey from a ship) has poor data in most of the Bothnian Bay region. To improve the geological and biological maps we need to be able to collect high resolution data in a cost-efficient way in these areas.

High resolution modelling of substrates and other seabed features will be an important part of future work but is dependent on high quality data. To further improve the usefulness of these kind of models, geological data from both shallow and deep field work (whether it is mainly done for biological or geological reasons) needs to be improved, and shallow water remote sensing needs to be combined with deeper acoustic surveys to further improve seamless maps in the Bothnian Bay region (and include the areas south of the SEAmBOTH study area). This would enable better and more representative maps of abiotic habitats and Natura 2000 areas alike.

What are our most important areas/issues for research/work in the future?

River estuaries are very interesting and important habitats. We have started the mappings in 2017 in Finland but there are still plenty of areas to map and even more on the Swedish side. In addition to vegetation mappings, salinity samples could be taken regularly in different areas and from different depths. Maybe the most interesting future research with river estuaries would be to choose one river estuary and follow it, and map it, very closely. For example, Tornio river estuary (from both Finnish and Swedish side) with daily salinity samples and more detailed mapping of the vegetation, both in shallow and deep areas. Fish and birds are prevalent and important to the estuaries and could therefore also be studied and added to the developing knowledge about the function of estuaries.

The effect of fluctuating water levels (mainly due to strong winds) would be an interesting thing to research in the Bothnian Bay and how it affects the species in the area. For example, in 2019 a lot of Charales species were burnt by the sun due to the water level being low for a long period. Also, a lot of other vascular plants were affected by the dryness. How do the coverage and distribution of macrophyte species change with fluctuating water levels?

How are underwater areas and their connected flora and fauna affected by human activities? It would help us to better assess zone of loss and disturbance for different activities. It is important to understand such effects in order to ensure the right measures are taken when it comes to planning and decision-making of human activities at the sea.

To improve the use of remote sensing within the northern Bothnian Bay, water quality sampling needs to be kept at high level in the region, and it is important that the sampling follows the optical protocols developed within the project. In addition to determining the in-situ concentrations of Chl-a, CDOM and turbidity it is also important to collect more data on the inherent optical properties. Getting improved information about the water depth in coastal areas is also important. Dedicated development of an algorithm to estimate Chl-a in high aCDOM waters is a task for future research and development projects.

Submarine canyons are key areas for understanding the transfer of detrital sediments (including e.g. harmful substances) from the coastal areas to the deep basins. The seabed/sediment dynamics and related biological and physicochemical processes should be studied in these key areas.

In the current project, most ecosystem values were found in the very shallow areas. This is due to the high biodiversity on these areas but also due to how we have defined nature values. If a complete food web approach would be implemented, also the values of the deeper seabed habitats to fish and other animals could be better understood and managed, and ultimately put the seabed maps to even more work. The connection between substrate and seabed features with infauna and fish is one area that can be improved.

Survey technologies needs to be more efficient to be able to cover larger areas with high quality data. It will enable managers to have a more complete view of important features and ecosystem functions when they consider trade-offs and priorities in a sustainable blue economy. A promising way is to combine remote sensing data from the air (Lidar, aerial surveys and satellites) and ship-based surveys which are completed by above, on and below water drones. Drones are run on efficient electric battery powered engines and could significantly help reduce the carbon footprint of seabed surveys, as well as improving cost to data quality ratios. More research and implementation are needed.

In the future, possibilities of EO to be integrated with ecological modelling, should be thoroughly investigated. Satellite-derived bathymetry, turbidity, and temperature are just few of the examples, which would improve the accuracy of species distribution models. Thus, to continue the refinement of ecological models with satellite-derived environmental products, and with detailed substrate models, should be a priority.

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Appendix

1. SEAmBOTH species list

VASCULAR PLANTS

Species	FIN	IUCN	SWE	IUCN		Species	FIN	IUCN	SWE	IUCN		Species	FIN	IUCN	SWE	IUCN
Agrostis sp.	X		x			*Glaux maritima*	X	LC	x	LC		*Potamogeton natans*	X	LC	X	LC
Agrostis stolonifera	X	LC	X	LC		*Hieracium sp.*	X		x			*Potamogeton obstusifolia*	X	LC	X	LC
Alisma plantago-aquatica	X	LC	X	LC		*Hippuris tetraphylla*	X	VU		CR		*Potamogeton perfoliatus*	X	LC	X	LC
Alisma wahlenbergii	X	VU	X	VU		*Hippuris vulgaris*	X	LC	X	LC		*Potamogeton praelongus*	X	LC	X	LC
Alnus incana	X	LC	x	LC		*Hippuris x-lanceolata*	X	NT	x	LC		*Potamogeton pusillus*	X	LC	X	LC
Angelica archangelica ssp. litoralis	X	LC	x	LC		*Honkenya pebloides*	X	LC	x	LC		*Potentilla sp.*	X		x	
Argentina anserina	X	LC	x	LC		*Hydrocharis morsus-ranae*	X	LC		LC		*Potentilla palustris*	X	LC	x	LC
Bidens sp.	X		x			*Iris pseudoacorus*	X	LC	x	LC		*Primula nutans*	X	EN	x	LC
Butomus umbellatus	X	LC	X	LC		*Isoëtes sp.*	X		X			*Ranunculus sp.*	X		X	
Calamagrostis sp.	X		x			*Isoetes echinospora*	X	LC	X	LC		*Ranunculus confervoides*	X	LC	X	LC
Calla palustris	X	LC	X	LC		*Isoetes lacustris*	X	LC	X	LC		*Ranunculus peltatus spp. peltatus*	X	LC	X	LC
Callitriche sp.	X		X			*Juncus sp.*	X		x			*Ranunculus peltatus ssp. baudotii*	X	LC	x	LC
Callitriche cophocarpa	X	LC	x	LC		*Juncus gerardii*	X	LC	x	LC		*Ranunculus reptans*	X	LC	X	LC
Callitriche hamulata	x	LC	X	LC		*Lathyrus palustris*	X	LC	x	LC		*Rumex sp.*	X		X	
Callitriche hermaphroditica	X	LC	X	LC		*Lemna minor*	X	LC	x	LC		*Rumex aquaticus*	X	LC	x	LC
Callitriche palustris	X	LC	X	LC		*Lemna trisulca*	X	LC	X	LC		*Sagittaria sp.*	X		X	
Caltha palustris	X	LC	x	LC		*Leymus arenarius*	X	LC	x	LC		*Sagittaria natans*	X	LC	x	LC
Carex sp.	X	LC	X			*Limosella aquatica*	X	LC	X	NT		*Sagittaria sagittifolia*	X	LC	x	NT
Carex acuta	X	LC	x	LC		*Lysimachia thyrsiflora*	X	LC	X	LC		*Sagittaria sagittifolia x natans*	X		X	NE
Carex aquatilis	X	LC	x	LC		*Lythrum salicaria*	X	LC	X	LC		*Salix sp.*	X		x	
Carex cespitosa	X	LC	x	LC		*Menyanthes trifoliata*	X	LC	X	LC		*Salix phylicifolia*	X	LC	x	LC
Carex diandra	X	LC	x	LC		*Myosotis sp.*	X		x			*Schoenoplectus sp.*	X		X	
Carex halophila		LC	x	LC		*Myrica gale*	X	LC	x	LC		*Schoenoplectus lacustris*	X	LC	x	LC
Carex nigra	X	LC	x	LC		*Myriophyllum sp.*	X		X			*Schoenoplectus tabernaemontani*	X	LC	X	LC
Carex paleacea	X	NT	x	NT		*Myriophyllum sp./Ceratophyllum sp.*	X		X			*Sparganium sp*	X		X	
Carex rostrata	X	LC	x	LC		*Myriophyllum alterniflorum*	X	LC	X	LC		*Sparganium angustifolium*		LC	x	LC
Carex vesicaria	X	LC	x	LC		*Myriophyllum sibiricum*	X	LC	X	LC		*Sparganium emersum*	X	LC	x	LC
Ceratophyllum demersum	X	LC	X	LC		*Myriophyllum spicatum*	X	LC	x	LC		*Sparganium gramineum*	X	LC	X	LC
Chamerion angustifolium	X	LC	x	LC		*Myriophyllum verticillatum*	X	LC	X	LC		*Sparganium erectum*	X	NT		LC
Cicuta virosa	X	LC	X	LC		*Nuphar lutea*	X	LC	X	LC		*Sparganium natans*		LC	x	LC
Crassula aquatica	X	VU	X	NT		*Nymphaea candida*	X	LC	x	LC		*Spergularia salina*	X	LC	x	LC
Deschampsia bottnica	X	LC	x	LC		*Nymphaeaceae*	X		X			*Stellaria sp.*	X		x	
Elatine sp.	X		X			*Nymphea alba*	X	LC	X	LC		*Stratiotes aloides*	X	LC		LC
Elatine hydropiper	X	LC	X	LC		*Ophioglossum vulgatum*	X	LC	x	LC		*Stuckenia filiformis*	X	LC	X	LC
Elatine orthosperma	X	LC	X	VU		*Parnassia palustris*	X	LC	x	LC		*Stuckenia filiformis x pectinata*	X		X	NE
Elatine triandra	X	LC	x	LC		*Pedicularis sp.*	X		x			*Stuckenia pectinata*	X	LC	X	LC
Eleocharis sp.	X		X			*Pedicularis palustris*	X	LC	x	LC		*Stuckenia vaginata*	X	LC	X	NT
Eleocharis acicularis	X	LC	X	LC		*Persicaria foliosa*	X	EN	x	NT		*Subularia aquatica*	X	LC	X	LC
Eleocharis mamillata	X	LC	x	LC		*Persicaria hydropiper*	X	LC		LC		*Triglochin maritima*	X	LC	x	LC
Eleocharis palustris	X	LC	X	LC		*Peucedanum palustre*	X	LC	x	LC		*Triglochin palustris*	X	LC	x	LC
Eleocharis palustris subsp. palustris var. lindbergii	X	NE	x	NA		*Phalaroides arundinacea*	X	LC	x	LC		*Typha latifolia*	X	LC	x	LC
Eleocharis parvula	X	LC	(x)	LC		*Phragmites australis*	X		X	LC		*Utricularia sp.*	X		X	
Eleocharis uniglumis	X	LC	x	LC		*Poa sp.*	X		x			*Utricularia australis*	X	LC	(x)	LC
Elodea canadensis	X	NA	X	NA		*Poaceae spp.*	X		X			*Utricularia intermedia*	X	LC	x	LC
Elodea nuttallii			X	NA		*Potamogeton sp.*	X		X			*Utricularia minor*	X	LC	x	LC
Epilobium sp.	X		x			*Potamogeton alpinus*	X	LC	X	LC		*Utricularia vulgaris*	X	LC	X	LC
Equisetum sp.	X		X			*Potamogeton berchtoldii*	X	LC	X	LC		*Valeriana sp.*	X		x	
Equisetum fluviatile	X	LC	X	LC		*Potamogeton compressus*	X	LC	X	VU		*Vicia cracca*	X	LC	x	LC
Filipendula ulmaria	X	LC	x	LC		*Potamogeton friesii*	X	NT	X	NT		*Viola sp.*	X		x	
Galium sp.	X		x			*Potamogeton gramineus*	X	LC	X	LC		*Zannichellia palustris*	X	LC	X	LC
Galium palustre	X	LC	x	LC		*Potamogeton gramineus x perfoliatus*	X		X	NE		*Zannichellia palustris var. repens*	X		X	LC
Galium uliginosum	X	LC	x	LC												

ALGAE (Chlorophyta))				
Species	FIN	IUCN	SWE	IUCN
Acrosiphonia arcta	X	LC		LC
Aegagrophila linnaei	X	LC	X	LC
Bulbochaete sp	x			
Chaetophora lobata / Chaetophora incrassata	X	DD	x	NE
Cladophora sp.	X		X	
Cladophora fracta	X	LC	X	LC
Cladophora glomerata	X	LC	X	LC
Drapernaldia sp	x			
Mougeotia sp.	X		X	
Rhizoclonium sp.	X			
Spirogyra	X		X	
Ulothrix sp.	X		X	
Ulothrix zonata	X	LC	X	LC
Ulva sp.	X		X	
Zygnema sp.	X			

ALGAE (Rhodophyta)				
Species	FIN	IUCN	SWE	IUCN
Audouinella sp.	X			
Bangia atropurpurea	X	NE		NE
Batrachospermum sp.	X		X	
Torularia atra / Batrachospermum atrum	X	NT	x	LC
Batrachospermum gelatinosum	x	LC	x	LC
Ceramium tenuicorne	X	LC	X	LC
Hildenbrandia sp.	X		X	
Hildenbrandia rubra	X	LC	X	LC
Polysiphonia fucoides		LC	X	LC

ALGAE (Phaeophyta)				
Species	FIN	IUCN	SWE	IUCN
Battersia arctica / Sphacelaria arctica	x	LC		LC
Ectocarpus siliculosus	X	LC		LC
Heribaudiella fluviatilis			x	LC
Pylaiella littoralis	X	LC		LC
Pseudolithoderma sp.			X	
Sphacelaria sp.	X		X	

Other Algae & Bacteria				
Species	FIN	IUCN	SWE	IUCN
Beggiatoa sp.			X	
Vaucheria sp.	X		X	
Rivularia sp.	X		X	
Spirulina sp.	X		X	
Nostoc sp.	x		x	
Nostoc pruniforme	x			LC

WATER MOSSES				
Species	FIN	IUCN	SWE	IUCN
Bryophyta sp.	X		X	
Bryum sp.	x		x	
Calliergon cordifolium	X	LC	x	LC
Calliergon megalophyllum	X	LC	X	LC
Drepanocladus sp.	X		X	
Drepanocladus aduncus	X	LC	X	LC
Drepanocladus polygamus	x	LC	x	LC
Drepanocladus sordidius	x	LC	X	LC
Fissidens sp.	X		x	
Fissidens adianthoides	X	LC		LC
Fissidens fontanus	X	LC	X	LC
Fissidens osmundoides	X	LC	x	LC
Fissidens pusillus	X	LC		LC
Fontinalis sp.	X		X	
Fontinalis antipyretica	X	LC	X	LC
Fontinalis dalecarlica	X	LC	X	LC
Fontinalis dichelymoides	x	NT		DD
Fontinalis hypnoides	X	LC		LC
Hygrohypnum luridium	X	LC		LC
Hygrohypnum ochraceum	x	LC		LC
Leptodyctium riparium	X	LC		LC
Marchanthiophyta sp.	X		x	
Oxyrrhynchium speciosum	X	LC	X	NT
Oxyrrhynchium hians			x	LC
Sarmentypnum exannulatum			X	LC
Sarmentypnum trichophyllum (Warnstorfia trichophylla)	X	LC	X	LC
Scapania undulata			x	LC
Straminergon stramineum	x	LC		LC
Timmia austriaca	x	LC		LC

CHAROPHYTES				
Species	FIN	IUCN	SWE	IUCN
Chara sp.	X		X	
Chara/Nitella	X		X	
Chara aspera	X	LC	X	LC
Chara aspera var. subinermis	X		X	
Chara baltica	x	LC	X	LC
Chara braunii	X	VU	X	VU
Chara globularis	X	LC	X	LC
Chara virgata	X	LC	X	LC
Nitella sp.	X		X	
Nitella flexilis	X	LC	X	LC
Nitella flexilis vel opaca	X		X	
Nitella opaca	X	LC	X	LC
Nitella walhbergiana	X	LC	X	LC
Tolypella nidifica	X	LC	X	LC

Chironomidae		
Species	FIN	SWE
Ablabesmyia		x
Ablabesmyia monilis	x	
Ablabesmyia phatta	x	
Ceratopogonidae	x	x
Chaetocladius		x
Chironomidae	x	x
Chironomus plumosus	x	x
Chironomus semireductus	x	
Cladopelma		x
Cladopelma viridulum	x	
Cladotanytarsus	x	x
Cryptochironomus	x	x
Dicrotendipes	x	x
Harnischia	x	x
Harnischia curtilamellata	x	
Microtendipes	x	
Microtendipes chloris	x	
Microtendipes pedellus	x	x
Monodiamesa	x	x
Monodiamesa bathyphila	x	
Orthocladiinae	x	x
Orthocladius		x
Pagastiella	x	x
Pagastiella orophila	x	x
Paralauterborniella	x	x
Paralauterborniella nigrohalteralis	x	x
Paratanytarsus	x	x
Pentaneurini		x
Polypedilum		x
Polypedilum nubeculosum	x	
Polupedilum pullum	x	
Potthastia		x
Potthastia longimanus	x	
Procladius	x	x
Protanypus		x
Psectrocladius	x	x
Psectrocladius limbatallus	x	
Psectrocladius sordidellus	x	
Pseudochironomus	x	x
Pseudochironomus prasinatus	x	x
Stempellina	x	x
Stempellina almi	x	
Stempellina edwardsi	x	
Stempellina subglabripennis	x	
Stictochironomus	x	x
Stictochironomus sticticus	x	
Tanypodinae	x	x
Tanytarsus		x
Tanytarsus lugens	x	
Zalutschia		x

ANIMALS		
Species	**FIN**	**SWE**
Acari		x
Agraylea		x
Anadonta	x	
Anadonta anatina	x	x
Ancylus fluviatilis	x	
Arcteonais lomondi		x
Arctopelopia	x	
Asellus aquaticus	x	x
Athripsodes	x	x
Athripsodes juv.	x	
Athripsodes cinereus	x	x
Aulodrilus	x	
Aulodrilus pluriseta	x	x
Baetis rhodani	x	
Bathyomphalus contortus		x
Bithynia	x	
Bithynia tentaculata	x	x
Bivalvia	x	x
Caenidae	x	
Caenis sp.	x	
Caenis horaria	x	x
Caenis lactea	x	
Candona	x	
Ceraclea juv.	x	
Ceraclea annulicornis	x	
Chaoboridae	x	
Chaoboridae flavicans	x	
Cladocera	x	
Copepoda	x	x
Cordylophora caspia	x	x
Corophium volutator		x
Cristatella mucedo		x
Cryptotendipes	x	
Culicidae	x	
Cyanophthalma obscura	x	x
Demicryptochironomus	x	
Demicryptochironomus vulneratus	x	
Diptera		x
Dytiscidae	x	x
Elmidae	x	
Empididae		x
Enchytraeidae	x	
Ephemera		x
Ephemera vulgata	x	x
Ephemeroptera		x
Ephydatia sp.	x	
Ephydatia fluviatilis	x	x
Erpobdella octoculata		x
Fredericella sultana		x
Gammarus sp.	x	x
Gammarus duebeni	x	
Gammarus oceanicus	x	
Gammarus salinus	x	
Gammarus tigrinus	x	
Gammarus zaddachi	x	
Glossiphonia	x	
Glossiphonia complanata	x	x
Gyraulus	x	
Gyraulus acronicus		x
Gyraulus albus	x	x
Gyraulus crista		x
Halacarina	x	
Halicryptus spinulosus	x	
Haliplidae	x	x
Haliplus	x	
Helobdella stagnalis	x	x
Heptagenia sulphurea		x
Hydra sp.	x	x
Hydrachnidae		x
Hydracarina	x	
Hydrobiidae	x	x
Hydroptila sp.	x	
Idotea sp.		x
Jaera albifrons	x	
Limecola balthica		x
Limnephilus		x
Limnius	x	
Limnodrilus	x	x
Limnodrilus hoffmeisteri	x	x
Limnodrilus udekemianus		x
Lymnaea stagnalis	x	x
Lymnaea peregra	x	x
Lymnea sp.		x
Lymnaeidae	x	
Macoma baltica	x	

ANIMALS		
Species	**FIN**	**SWE**
Macoma baltica	x	x
Marcopelopia	x	
Macroplea appendiculata		x
Macroplea mutica		x
Macroplea pubipennis	x	x
Marenzelleria	x	x
Marenzelleria neglecta		x
Marenzelleria viridis		x
Mermithidae	x	
Mesostoma	x	
Micronecta	x	
Monoporeia sp.		x
Monoporeia affinis	x	x
Mysidae	x	x
Mysis relicta	x	x
Mystacides	x	
Myxas glutinosa	x	
Naididae	x	
Nanocladius balticus	x	
Nematoda		x
Neureclipsis bimaculata		x
Noteridae	x	
Oecetis ochracea	x	x
Oecetis lacustris	x	
Oecetis testacea	x	
Oligochaeta	x	x
Ostracoda		x
Oulimnius	x	
Oulimnius tuberculatus	x	
Pallaseopsis quadrispinosa	x	x
Paludicella articulata		x
Parakiefferiealla smolandica	x	
Paranais litoralis	x	
Physa fontinalis	x	x
Piona	x	
Piscicola geometra	x	x
Pisidium	x	x
Pisidium amnicum	x	
Pisidium henslowanum	x	
Pisidium casertanum	x	
Pisidium subtruncatum	x	
Pisidium juv.	x	
Pisidium / Sphaerium	x	x
Planariidae	x	
Planariidae torva	x	
Planorbidae	x	
Planorbarius corneus		x
Polycentropus flavomaculatus	x	
Polychaeta		x
Polyps	x	x
Potamopyrgus antipodarum	x	x
Potamopyrgus jenkinsi		x
Potamothrix	x	
Potamothrix hammoniensis	x	x
Prostigmata		x
Prostoma	x	x
Prostoma graecense		x
Psammoryctides	x	
Psammoryctides barbatus	x	
Radix	x	
Radix balthica/labiata	x	
Saduria entomon	x	x
Slavina appendiculata	x	
Sphaeriidae	x	x
Sphaerium		x
Spirosperma ferox	x	x
Spongilla lacustris	x	x
Stylaria	x	
Stylaria lacustris	x	
Stylodrilus	x	
Tabanidae	x	
Tanytarsini	x	
Theodoxus fluviatilis	x	x
Thienemannimyia	x	
Trichoptera	x	x
Tubifex tubifex	x	x
Tubificidae		x
Turbellaria		x
Valvata	x	x
Valvata macrostoma	x	x
Valvata piscinalis	x	x
Valvata sibirica		x

Zooplankton	
Species	**SWE**
Acantholeberis curvirostris	x
Acartia	x
Acartia bifilosa	x
Asplanchna	x
Bivalvia	x
Bosmina coregoni	x
Bosmina coregoni maritima	x
Bosmina longirostris	x
Brachionus	x
Cercopagis	x
Ceriodaphnia	x
Chydoridae	x
Collotheca	x
Copepoda	x
Cyclopoida	x
Cyclops	x
Daphnia	x
Daphnia cristata	x
Daphnia cristata cristata	x
Daphnia cucullata	x
Daphnia cucullata cucullata	x
Diaphanosoma	x
Diaptomus	x
Eurytemora	x
Evadne nordmanni	x
Filinia	x

Zooplankton	
Species	**SWE**
Harpacticoida *Acantholeberis curvirostris*	x
Hydrachnidiae	x
Ilyocryptus	x
Kellicottia	x
Kellicottia bostoniensis	x
Kellicottia longispina	x
Keratella cochlearis	x
Keratella cochlearis cochlearis	x
Keratella eichwaldi	x
Keratella quadrata	x
Keratella quadrata quadrata	x
Leptodora kindti	x
Limnocalanus macrurus	x
Mesocyclops leuckarti	x
Notholca	x
Ostracoda	x
Podon polyphemoides	x
Ploesoma	x
Podonidae	x
Podon polyphemoides	x
Polyarthra	x
Polyphemus pediculus	x
Spionidae	x
Synchaeta	x
Synchaeta baltica	x
Thermocyclops oithonoides	x
Tintinnopsis lobiancoi	x
Trichocerca	x

2. SEAmBOTH metadata

Dataset	Data type / resolution	Temporal aspect	Variables	Method	Comments	Data by
Field inventory data (wide)	point	1991-2019	Species data as coverage percentages, substrate, depth and other variables from field inventories	Combined in excel, processed in R for long/wide conversions		MH/JH
Field inventory data (long)	point	1991-2019	Species data as coverage percentages, substrate, depth and other variables from field inventories	Combined in excel, processed in R for long/wide conversions		MH/JH
HELCOM HUB classification	point	1991-2019	HUB classes, depth	Field inventory data classified with HUB formulas	More info on HUB: matti.sahla@metsa.fi	MH/JH
Ortophoto mappings	point	2010-	Human activities visible from aerial images	Done by hand from aerial images	more info on methodology: matti.sahla@metsa.fi	MH
Nature values?	raster	2019	Nature value raster		Elina	SYKE
Athropogenic pressure layer?	raster	2010-	Combined human pressures		Marco	SYKE

Variable	Method	Method additional info	Temporal aspect	Done by	Data source (FI)	Data source (SE)	Updated (FI)	Updated (SE)	Combined filename	Comments
Wave attenuated exposure at the seabed	Model	Bekkby et al. 2008	-	SYKE						
Surface exposure	GIS	Fetch calculation (Isaeus et al.)	-	SYKE						
Slope	GIS	ArcGis: Slope	-	SYKE						
Terrain ruggedness	GIS	BTM plug-in Arcgis	-	SYKE						
Secchi	EO	Optical models	2010-2015	SYKE/TK						
Euphotic depth	EO	Optical models	2010-2015	SYKE/TK						
Optical depth	EO	Optical models	2010-2015	SYKE/TK						
Turbidity	EO	Optical models	2010-2015	SYKE/TK						
Effect of rivers (multiplied by run-off)		ArcGis; Cost Allocation	2010-2015	SYKE/TK						
Chlorophyll-a	EO	Optical models		SYKE/TK						
Stony substrates	Interpretation/ Model		2010-2015	GTK/SGU						
Sandy substrates	Interpretation/ Model		2010-2015	GTK/SGU						
Rocky substrates	Interpretation/ Model		2010-2015	GTK/SGU						
Depth	Interpretation/ Model	ArcGis: TIN	2010-2015	GTK/SGU						
Hard/soft substrates	Interpretation/ Model	R: GLM?	-	GTK/SGU						
Seafloor fetch	fetch calculation		-	MH						More information: matti.sahla@metsa.fi
Distance/density to/of sandy beach (proxy for sandy sea substrate)	GIS	ArcGis; Euclidean distace	-	MH						
Chlorophyll-a	GIS	ArcGis; Spline with Barriers	2010-2015	MH	Hertta database	Vattendragsregistret				Variables combined from national datasets, Swedish data combined regionally to account for dispersation. More info: jaakko.haapamaki@metsa.fi
Total nitrogen	GIS	ArcGis; Spline with Barriers	2010-2015	MH	Hertta database	Vattendragsregistret				Variables combined from national datasets, Swedish data combined regionally to account for dispersation. More info: jaakko.haapamaki@metsa.fi
Total phosphorus	GIS	ArcGis; Spline with Barriers	2010-2015	MH	Hertta database	Vattendragsregistret				Variables combined from national datasets, Swedish data combined regionally to account for dispersation. More info: jaakko.haapamaki@metsa.fi
Oxygen concentration	GIS	ArcGis; Spline with Barriers	2010-2015	MH	Hertta database	Vattendragsregistret				Variables combined from national datasets, Swedish data combined regionally to account for dispersation. More info: jaakko.haapamaki@metsa.fi
Seabed bottom salinity	GIS	ArcGis; Spline with Barriers	2010-2015	MH	Hertta database	Vattendragsregistret				Variables combined from national datasets, Swedish data combined regionally to account for dispersation. More info: jaakko.haapamaki@metsa.fi
Surface salinity (mean, min)	GIS	ArcGis; Spline with Barriers	2010-2015	MH	Hertta database	Vattendragsregistret				Bottom salinity not possible because of bad data. Variables combined from national datasets, Swedish data combined regionally to account for dispersation. More info: jaakko.haapamaki@metsa.fi
Land claim	GIS			MH	Vesistötyö Vesty	Ortophotos (National land survey)	4.6.2018	2017	landclaim.shp	Swedish embankment data without free standing bridges + 1 spot in Finland
Coastal defence and flood protection	GIS			MH	Vesistötyö Vesty / Liikennevirasto		4.6.2018 / LIVI still missing			Finnish data is mostly from riverbanks outside 1 km buffer. No data from Sweden. Rest from ortophotos
Marinas and leisure harbours	GIS			MH	Manual ortophoto checking?	Ortophotos (National land survey)		2015	Marinas	From ortophoto mapping
Harbours	GIS			MH	Helcom	Helcom			Harbour_polygons_FI_SE	
Coastal exploitation	GIS	Buildings and roads with different buffers from shoreline		MH	MML/liikennevirasto	Swedish land survey maps + Swedish transport agency road database	1.6.2019	2013	C_expl_100m_FISE/C_expl_300m_FISE	
Dredging	GIS			MH	Vesistötyö Vesty / Liikennevirasto	Ortophotos (National land survey)	4.6.2018 / LIVI 6.8.2018	2013	Dredging_all_HELCOM_NT	Combination of HELCOM and ALL national data
Coastal dredging (small-scale dredging)	GIS			MH	Ortophotos	Ortophotos (National land survey)	1.6.2018	1.6.2018	Coastal dredging	Only from ortophoto mapping
Deposit of dredged material	GIS			MH	Vesistötyö Vesty / Liikennevirasto		4.6.2018 / LIVI 6.8.2018		deposits_merge	Helcom +national
Wind turbines (offshore)	GIS			MH	HELCOM?				Wind_turbines	
Finfish mariculture	GIS			MH	Vahti, geo-liittymä		6.6.2018		finfish_mariculture_clip	
Boating lanes / fairways	GIS			MH	Liikennevirasto	Ortophotos (National land survey)		2009 (lines)	shiplanes_merge	Converted Finnish data to polygons before merging
Jetties	GIS			MH	Liikennevirasto				Jetties_FISE_merge	Finnish data mostly larger piers, but used anyway because it's the only line data available.
Causeway	GIS			MH	Vesistötyö Vesty		4.6.2018		causeway	ortophotodata
Recreational boating	GIS			MH	Liikennevirasto	Sea charts/Swedish maritime administration		2016		Marinas and fairways combined
Agricultural areas	GIS			MH	CLC (tai Mavi Peltolohkorekisteri)	Swedish Board of Agriculture		2017	agriculture_merge	
Coastal industry	GIS			MH	Vahti?	Land survey maps/Lantmäteriet		2017	industry	
Cables	GIS			MH	Liikennevirasto	Sea Charts		2010	Cables_all	Merged national db and HELCOM
Waste water treatment discharge site (industry, municipal and other)	GIS			MH	Vahti, geo-liittymä		6.6.2018		waterborne_discharge	
Pipelines	GIS			MH	HELCOM? onko tarkempaa?	Swedish transport administration + ortofoton		2018	pipelines	only waterpipes from Finland, nothing from Sweden
Bridges	GIS			MH	Liikennevirasto (as points) or digiroad intersect water				Bridges	Used HELCOM
Coastal energy production	GIS			MH	Vahti, geo-liittymä	Registers and maps (Lantmäteriet, gröna kartan)	6.6.2018		powerplants	Found fossil fuel energy from HELCOM. Good enough?

Habitat	Filename	Method	Done by	Data source (FI)	Data source (SE)	Updated (FI)	Updated (SE)	Combined filename
Large shallow bays 1160	1160_Shallowbay	Arcmap/merge	MH/JH	MH	Lst	2019	2019	1160_Shallowbay
Coastal lagoons 1150	1150_Lagoon	Arcmap/merge	MH/JH	MH		2019	2019	1150_Lagoon
Small isles and islets 1620	1620_Islets	Arcmap/merge	MH/JH	MH		2019	2019	1620_Islets
Estuaries 1130	1130_Estuaries	Arcmap/merge	MH/JH	MH		2019	2019	1130_Estuaries
Mudflats 1140		Arcmap/merge	MH/JH	MH		2020	2019	

3. Activity 6.1 Harmonisation of Natura 2000 habitat interpretations

1. Introduction

The northern Bothnian Bay hosts a rather different marine environment compared to the rest of the Baltic Sea. Low salinity, annual ice cover, shallow shores, and land uplift are some of the environmental conditions present in the area making its habitats and composition of species rather unique. Not only do the interpretations of Natura 2000 habitat definitions differ between Finland and Sweden, the habitats also have different characteristic in the north compared to the south of the Baltic Sea, where "templates" for habitat descriptions tend to be formed. This makes mapping and managing the Natura 2000 areas a challenge, but with cooperation within the bay local knowledge may spread and support given.

The activity 6.1 in the SEAmBOTH project was therefore dedicated to closer investigate the Natura 2000 habitat interpretations of Sweden and Finland, with the purpose of making communication and management across the border more harmonised.

Below follows a description of the workshop conducted as part of the activity and the results of it.

2. Background

Natura 2000 is network of protected areas across all the 28 EU countries. The network includes habitats with core functions, such as breeding sites for threatened species and rare natural habitat types in the need of protection. The habitats are listed in the Habitats Directive (Council of European Union, 1992) where they are all listed, described, and defined. The EU has published an interpretation manual for how the different habitat types should be defined (European Commission, 2007). Yet countries apply different interpretations, usually as a mean to adapt the habitat types to national environmental conditions. Sweden and Finland have a relatively similar natural environment and share the Baltic Sea between them. The countries have however interpreted the definitions of the Natura 2000 habitat types slightly differently. In table 1 the interpretations from the Swedish national manual (Naturvårdsverket, 2011), the Finnish national manual (Airaksinen & Karttunen, 1999), and the Natura 2000 guide by Metsähallitus and SYKE (2019) have been compiled and compared.

Table 1. The table show a summary of description and delimitations of habitat types in comparison between the two countries. Apparent differences are highlighted in yellow.

		SWEDEN	FINLAND
1110 Sandbanks	**General description**	Permanently covered by water	Permanently covered by water
		Mainly sand but also gravel, rocks may occur	Mainly sand but also gravel, rocks may occur
		Free from vegetation or covered by seagrass and/or macroalgae	Free from vegetation or covered by Zostereteum marinae-/Cynodoceion nodosae - vegetation
	Delimitation	Usually shallow, max depth 30 m	Shallower than 20 m, but ecological entity should be considered, and can thus be even deeper than 20 m.
1130 Estuaries	**General description**	Freshwater effect	Freshwater effect
		Increased sedimentation creates sand/mud banks	Increased sedimentation creates sand/mud banks
		A delta landscape may occur	A delta landscape may occur
		Biotope complex	Biotope complex
		Rich and diverse flora	Rich and diverse flora
	Delimitation	As far out as freshwater effect is noticeable	As far out as freshwater effect is noticeable on the ecosystem
		Depth of max 6 m or where protective land ends	-
		Should have a yearly average flow freshwater > 2m3/s	-
1140 Mudflats	**General description**	Shallow soft, sandy and clay bottoms	Not recognised to exist in Finland
		Often no macrovegetation, but with large amounts of cyanobacteria and diatoms	
		Important habitat for wading birds	
	Delimitation	Lowest low water	
1150 Lagoons	**General description**	Completely or partially separated shallow bays	Completely or partially separated shallow bays
		Separated from the sea by threshold, dense vegetation or similar structure reducing water exchange	Separated from sea by sand banks or gravel-rock beds, sometimes cliffs
		Vegetation absent or abundant	Vegetation absent or abundant
	Delimitation	Depth < 4 m	Shallow
		Size < 25 ha	Small
1160 Large shallow inlets and bays	**General description**	Limited inflow of freshwater	Limited inflow of freshwater
		Sheltered	Sheltered
		Variation in bottom substrates	Variation in bottom substrates.
		Diversity of fauna and flora species	Diversity of fauna and flora species
		Shallow water defined by distribution of Zostera-or Potametea associations	Shallow water defined by distribution of Zostera-or Potametea associations
	Delimitation	Usually larger than 25 ha	Usually larger than 100 ha, max depth 6 m.
1170 Reefs	**General description**	Biogenic and/or geologic formations of hard substrate	Sublittoral and at low water exposed cliffs and sublittoral encrusted formations of organic origin
		Topographic differentiated from the sea floor by rising up from the bottom	Elevations rising from the sea bottom
		In sublittoral and littoral zone	Areas in littoral zone also included when vegetation/fauna extends continuously up to there
		Zonation benthic organisms, vegetation	Zonation benthic organisms, vegetation
		Mussel beds included if coverage > 10%	*(Reefs of organic origin are not commonly recognised)*
	Delimitation	More than 50% soft bottom and/or biogenic formations have less than 10% coverage	-

The Swedish Species Information Centre, responsible for reporting of the Natura 2000 habitats in Sweden, have been updating the interpretations of the marine habitat types. In 2017 a draft of their new suggestions was published (Artdatabanken, 2017), which by the end of 2019 was still waiting to be decided upon and taken into force. The draft was used during the workshop and its suggestions to changes were discussed. Some of the major suggestions for change were the following:

- Sandbanks 1110 – Remove the requirement of topographic formations "arising from the seafloor".
- Estuaries 1130 – Substitute the delimitation "where protective land disappear" and "at 6 m depth" with where freshwater effect is no longer detective and/or where the accumulation of sediment stops.
- Reefs 1170 - Remove the requirement of topographic formations "arising from the seafloor".

As part of the SeaGIS 2.0 project extensive work have been conducted on mapping and modelling some of the marine habitat types present within the Quark area. In March 2017 a workshop was arranged with project participants where outcomes of the habitat type mapping activities were discussed (SeaGIS 2.0, 2017). Some of the issues discussed there were, for example, the difficulties with mapping e.g. bays (1160) and lagoons (1150) along a coastline under constant land uplift, which requires more frequent updates of the maps, which is a relatively long administrative process. Questions regarding the habitat type reefs (1170) that were brought up were, for example, whether 15 m big boulders should be classified as reefs, and if "naked reefs" (i.e. reefs without vegetation and epifauna) should have the same protection status as reefs with rich vegetation and epifauna. These questions were brought into the SEAmBOTH workshop and discussed from a northern Bothnian Bay perspective.

In addition to the description and delimitation of the habitat types, the EU interpretation manual also list characteristic species for each of them. The EU-level descriptions of the habitat types and characteristic species is relatively broad. The national interpretations have in turn been made more focused towards the national environment. However, the characteristic species for a habitat type which may exist within the whole of the Baltic Sea, may not be as accurate for all areas of the sea. As the northern Bothnian Bay is quite different from the rest of the Baltic Sea with its freshwater conditions, for example, using the national interpretations for habitats types often comes with difficulties. Sometimes the characteristic species listed for a habitat type don't even exist in the Bothnian Bay.
To be able to make maps of the Natura 2000 habitats across the northern Bothnian Bay the project needed a common interpretation, or mutual understanding, of them. A workshop was therefore organized with the aim of answering following questions:

1. How to define marine habitat types within the SEAmBOTH area?
2. What characteristic species are suitable to use to describe the habitat types within the SEAmBOTH area?
3. Which are the most threatened habitat types?
4. Which habitat types to prioritise for modelling and mapping?

3. Method

On the 13th and 14th of November 2018 a workshop was held with project member participants and staff from the County Administrative Board of Norrbotten (CAB), Lapland and northern Ostrobothnia ELY-centres, and Metsähallitus. A total of seven participants were present, including the workshop leader.

Day one was dedicated to question 1 and day two to question 2, 3, and 4 (see stated questions above). It was decided to focus on only the true marine habitat types, i.e. 1110, 1130, 1140, 1150, 1160 and 1170. Narrow inlets and bays (1650) are also a marine habitat but as none exist in the project area, they were excluded.

On day one all the habitat types were discussed, their interpretations compared and examples from either side of the bay shown. In the end, a mutual definition for each of the habitat types were agreed upon. During the second day potential characteristic species were discussed amongst the participants and a final draft of a list agreed upon.

5. Results

Below follow the results of the workshop, both with summaries of the discussions as well as the final outcomes.

Question 1. How to define marine habitat types within the SEAmBOTH area?

Table 2. Comments made during the workshop to the interpretation of the habitat type definitions.

Habitat type code	Habitat name	Comments
1110	Sandbanks	-In general interpretation and in-reality mapping are similar btw countries -difficult to model. May be mistaken with reefs. Need in field verification -Fin sometimes include above surface sandbanks, = 1140 in Swe. With 1140 available, no need for Fin to do so.
1130	Estuaries	-With new Swe definition very similar btw countries. -Important to have whole estuary area protected, not small patches as today. Doesn't fulfil the purpose. -delimitation towards land differ: Fin: where mineral soil start/where there is water influence/where terrestrial nature type start e.g. 91D0 May overlap with these as well. Swe: at mean water level. -delimitation upstream and downstream differs: Fin: upstream where the marine (saltwater) influence ends. Swe: at river mouth boundary
1140	Mudflats and sandflats	Today not recognised as a Natura 2000 habitat existing in Finland due to definition of "tidal" mudflats. The type of habitat is however relatively common and characterizing for the shallow shores of northern Bothnian Bay.
1150	Coastal lagoons	Definition and use fairly similar. Delimitation towards land: Fin: where mineral soil starts or where terrestrial type overlap. In Swe mean water level. Finland take the whole area affected by the glo/flada into account, up to highest high water one could say. That is preferred in SEAmBOTH area as water levels are constantly changing and surrounding reeds e.g. may otherwise by not included even though they may constitute important function for the habitat.
1160	Large shallow inlets and bays	Swe includes sea areas between e.g. inland/mainland-island ("sund"). In Fin they only exist in the south. Fin guidelines says they should be wider than long (to differentiate from 1650). Not used in reality, too artificial delimitation. Delimitation towards land as in 1150 and 1130. Max depth should only be used as guidelines. These are ordinary bays, more open and exposed than lagoons but still more sheltered than the straight coastline.
1170	Reefs	Fin don't include biogenic, e.g. mussel bed reefs (not an issue for us as there are no mussel beds in northern Bothnian Bay). Swe drafted new interpretation, which removes the prerequisite of "arising from sea floor". "Naked" reefs should be included. Serves as function home for e.g. water mosses, polyp organisms. If they don't count, then no reefs in northern Bothnian Bay. Big boulders ok to include too, as long as the function is there. Slopes too. Difficult to get accurate maps from modelling. Delimitation towards sea floor in Swe is when more than 50% turns into soft bottom. In Fin there is some difficulties to define the boundaries of the formation when the grain size varies from blocks to till. => borderline to the sandbanks? Not a big problem in practise, sandbanks and reefs can occur together.
1620	Boreal baltic islets and small islands	Not discussed. Terrestrial focused nature types
1630	Boreal Baltic coastal meadows	Not discussed. Terrestrial focused nature types
1640	Boreal baltic sandy beaches with perennial vegetation	Not discussed. Terrestrial focused nature types

General comments about the habitat types:

Estuaries

In Finland estuaries have been digitized by factors of bottom contour, salinity, direct of freshwater outflow and expert opinion. Gave a realistic expansion. Would suit ok with the estuary area mapped according to the new Swedish draft of definition of 1130.

In the Tornio-Kemi area the Natura 2000 protected areas are also small and fragmented, like on the Swedish side, and do not cover the whole estuary. A Natura 2000 area including the whole estuary ecosystem would need to be set up in order to protect it.

Reef and sandbanks

Modelling and reports have been made in Finland. Very difficult to get them accurate, need verification in field. When modelled, sometimes data from bottom substrate one-meter down is used. Become misleading as it is the top layer of the bottom that decides what organism may be living there.

Complications due to the land uplift

Due to substantial land uplift and variable water levels the shoreline changes rapidly. Draw and modify the maps and nature types constantly. Impractical. A need for more allowing nature type definitions and/or more complex nature types (including land and sea areas). For example, on the shores there should be a complex type "marine land uplift/ primary succession area" which without strict borderline can change into terrestrial land uplift area. These could be divided into subtypes as now defined habitats.

Table 3. The table show suggestions for interpretation of each of the habitat type, from a northern Bothnian Bay perspective.

Habitat type code	Name	Suggestion for interpretation
1110	Sandbanks	According to current Finnish/Swedish draft Set delimitation to always below surface and use 1140 for those areas included that are above surface sometimes.
1130	Estuaries	According to current Finnish/new Swedish draft. Delimitation towards land and upstream differs btw countries, pros and cons with both. Every estuary is different, need to be looked upon on each individual case.
1140	Mudflats and sandflats	According to Swedish definition.
1150	Coastal lagoons	According to current Finnish and Swedish draft. Delimitation towards land differs btw countries, pros and cons with both. Possible to include "transition zone" in Swe, as used with estuaries?
1160	Large shallow inlets and bays	Skip the wider -than -long rule. "Sund" are included if they have the same function as shallow, sheltered bays. Delimitation regarding depth and size only as guidelines. Adjusted according to local conditions. The function of bay is most important.
1170	Reefs	According to current Finnish/Swedish draft Include "naked" reefs, big boulders and slopes. As long as function is there.

Question 2. What characteristic species are suitable to use to describe the habitat types within the SEAmBOTH area?

Table 4. List of locally adapted characteristic species for the northern Bothnian Bay, for each of the habitat types.

Habitat type code	Name	Characteristic species
1110	Sandbanks	Chara aspera Potamogeton filiformis Potamogeton perfoliatus
1130	Estuaries	(Phragmites) Schoenoplectus sp. Nymphae alba/Nuphar lutea Sparganium sp. Nitella wahlenbergiana Spongilla lacustris Alisma plantago-aquatica (fin) Persicaria foliosa
1140	Mudflats and sandflats	Limosella aquatica Crassula aquatica (Subularia aquatica) Alisma.wahlenbergii Hippuris tetraphylla (Fin)
1150	Coastal lagoons	Phragmites sp. Lemna trisulca Ranunculus confervoides Subularia aquatica Chara.braunii (swe) Myriophyllum sp. Potamogeton friesii Elodea sp. (Isoetes)
1160	Large shallow inlets and bays	Myriophyllum sp. Subularia aquatica Stuckenia.pectinata Potamogeton.friesii Elodea sp. (Isoetes) Vaucheria sp. Phragmites sp.
1170	Reefs	Water mosses (e.g. Fontinalis sp, Oxyrynchium spciosum, Fissidens sp, Hygrohypnum luridium) Filamentous algae Cladophora fracta Cladophora glomerata Aegagrophila linnaei Ephydatia fluviatilis Cordylophora caspia

Question 3. Which are the most threatened habitat types?

Summary of comments from the discussion.

Estuaries (1130)

- Often coastal exploitation in/around them. In Finland the rivers of Kiiminki, Simo and Tornio run free. Also smaller ones, Kuivajoki and Olhavanjoki are free, In Sweden Kalix and Råneå rivers are free from hydropower. Olhavanjoki has been severely dredged in 1970's, which has changed also the delta area.
- In Tornionjoki, Kemijoki and Oulujoki only small parts of the estuaries are protected. In Simojoki estuary only some islands are protected but not the water. Even the upper river itself is included in N2000. In Kiiminkijoki and Iijoki the whole estuaries are included in the Natura 2000 network. The whole river of Kiiminkijoki is also in N2000, not only the esturary. The rivers of Tornio and Kalix are included in the Natura 2000 but only small to none part of their estuaries are protected. The estuary of the Råneå river is within Natura 2000 protected area.

Shallow bays (1160)

- Under pressure from coastal exploitation. More so than lagoons as boat traffic and piers, harbours/marinas, and dredging tend to be more prevalent here than in lagoons, which usually are more inaccessible by boat from the start.

Lagoons (1150)

- In Finland, many are already protected. As Natura 2000 and through the Water Act which protects lagoons in "natural state" that are smaller than 10 ha.
- In Sweden, mostly lagoons within Natura 2000 areas in outer archipelagic islands are protected. Coastal mainland lagoons have little protection.

Reefs
- Are not seen as urgently threatened as maybe reefs in the southern Baltic are. Reefs here don't host the same biodiversity as southern reefs do and hence they don't have the same" hotspot" function. Commercial bottom trawling is also a limited activity within this area.

Run-off from land

- (leading to e.g. eutrophication and browning effect of the water)
- More common creating dykes in forest land in Finland than in Sweden. About 50-75% of the mires have been drained in North Ostrobothnia. The problem with acidic phosphate soils is present within the northern Bothnian Bay.
- Compared with the scores that was given to habitat types and other ecosystem components within the workshop of nature values, we found that these two rankings were very similar.

The highest rated ecosystem components (score > 20) were:
Estuaries 1130
Lagoons/shallow sheltered bays 1150, 1160
Macrophyte meadows
Charales meadows
Muddy/sandy beaches 1140
Spawning grounds for predatory fish
Feeding grounds for wading birds
-> Pretty much the same as we just classified as the most threatened habitats!

Question 4. Which habitat types to prioritise for modelling and mapping?

-> Focus on mapping coastal areas (i.e. estuaries, lagoons, shallow bays, mudflats). They are the habitat types with highest nature values (for example high species biodiversity, IUCN-listed species, habitats directive listed species, threatened habitats) and are currently believed to be under greatest pressure.
-> Are there mudflats (similar habitat to 1140 but without the tide present) on the Finnish side? A common and valuable habitat in the Bothnian Bay but is today unrecognised as a Natura 2000 habitat type in Finland.

6. Conclusions

In regard to the interpretations of habitat types, Finland has overall a broader, more vegetation-based perspective on definitions and delimitations than Sweden, which is seen to be more systematic and harmonized.

Due to the land uplift and almost freshwater like conditions at sea, delimitating habitat types in the northern Bothnian Bay is complicated. There needs to be alternative definitions, as those that are applicable for the rest of the Baltic Sea may not work here.

Mudflats and sandflats (1140 like habitat but without the tide) is a common habitat type within the northern Bothnian Bay. It is of greatest need for it to be investigated and mapped on the Finnish side.

Listing common characteristic species for the area was relatively easy, the habitat types are very similar across the border. Only a few exceptions existed where characteristic species had to be applied to either only Finland or Sweden. There's a profound common consensus on what the most threatened habitat types are, and that estuaries, mudflats, lagoons, and large shallow bays should be focused upon in terms of modelling and mapping.

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4. Activity 6.2 Overview of HUB classification within the northern Bothnian Bay

1. Introduction

In order to be able to identify, examine, follow-up, and manage the marine environment from local to international levels, there is a need to be able to classify the nature into units. On an international level the EU have defined a number of habitats that are important for animals and plants and thus in need of protection. They are so called habitat types, listed in the EU Habitats Directive (Council of the European Union, 1992) and included in the European wide Natura 2000 network of protected areas. The habitats are abiotic units, such as lagoons (habitat type code 1150) or large shallow inlets and bays (habitat type code 1160).

On a regional Baltic Sea level, HELCOM has produced a classification scheme, called the HELCOM Underwater Biotope and Habitat Classification System (HUB), based on existing inventories. Even though the environment of the Baltic Sea is consistent, different national mapping methods and definitions of the biotopes of the sea have made previous comparison of results between countries nearly impossible. The European Nature Information System (EUNIS) is a pan-European system with only a few classes in the Baltic sea scale. There was a need for more detailed classification, and this resulted in the HELCOM underwater biotope and Habitat Classification System (HUB). HUB is EUNIS compatible, even though in the HUB a biotope is defined as "the combination of a habitat and an associated community of species" this definition differs somewhat from the EUNIS one. The HUB classification system creates a common definition and understanding of the nature and allows for management and researchers to compare and follow-up distribution and status of underwater nature in the Baltic Sea on a regional level (HELCOM, 2013). In other words, the marine environment of the northern Bothnian Bay may be classified according to both habitat types as well as HUB biotopes.

The SEAmBOTH project will produce maps (activity 5) of occurring habitat types, HUBs, and valuable nature areas (activity 6.4) within the project area. However, the HUB classification system was developed based upon existing data and expertise during a time when data from the northern Bothnian Bay was relatively limited and sparse. During the SEAmBOTH project a substantial amount of new data from the area has become available. The purpose of this activity was therefore to go over occurring HUBs, compare, with present data, the compatibility of the system to the local environment of the northern Bothnian Bay, and make suggestions for adjustments.

2. HUBs in the northern Bothnian Bay

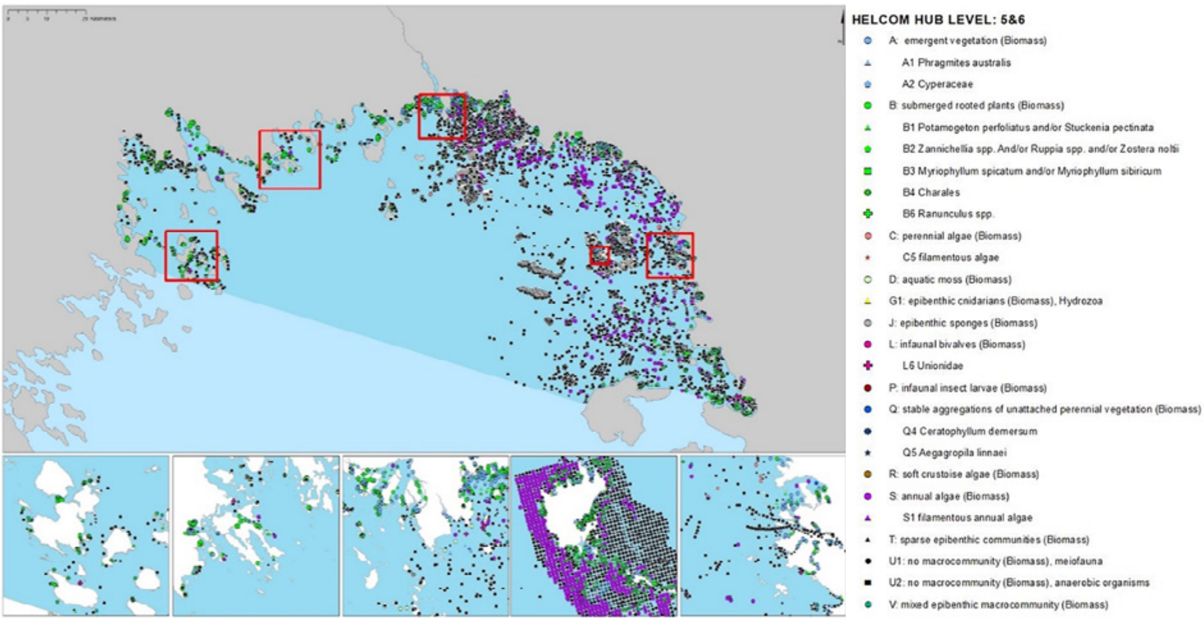
HUB is a hierarchical classification system with 6 levels, and split rules leading from one level to the next i.e. if criterion Z is true, then biotope 1; if criterion Z is false, then biotope 2 (HELCOM 2013a). HUB level 1-3 describes habitats (the abiotic environment) and are split based on environmental parameters, while level 4-6 describes the biotopes (abiotic and biotic environment) and are hence split based on biological features.

Picture 1. Levels of HELCOM HUB underwater biotope classification system (HELCOM 2013).

The combined field inventory data in the SEAmBOTH area was classified into HUB biotopes to be presented in a spatial format (activity 5). Biotopes were examined by level 5 (characteristic community) indicated by a letter and level 6 (dominating taxa) indicated by a number.

Following biotopes were found in the project area:

- A1 Emergent vegetation - Phragmites australis
- A2 Emergent vegetation - Cyperaceae
- B1 Submerged rooted plants - Potamogeton perfoliatus and/or Stuckenia pectinata
- B2 Submerged rooted plants - Zannichellia spp. and/or Ruppia spp. (and/or Zostera noltii)
- B3 Submerged rooted plants - Myriophyllum spicatum and/or Myriophyllum sibiricum
- B4 Submerged rooted plants - Charales
- B6 Submerged rooted plants - Ranunculus spp.
- C5 Perennial algae - Filamentous algae
- D Aquatic moss
- G1 Hydrozoa
- J Epibenthic sponges
- L6 Unionidae
- P Infaunal insect larvae
- Q4 unattached ceratophyllum
- Q5 unattached aegragrophila linnaei
- R Soft crustose algae
- S1 Annual algae - Filamentous annual algae
- T: Sparse epibenthic communities
- U1: Meiofauna
- U2: Anaerobic organisms
- V: Mixed epibenthic macrocommunity



Picture 2: HUB visualization in SEAmBOTH project area.

Regarding the emergent vegetation and submerged rooted plants, all HUBs were present within the project area except submerged rooted vegetation B5 Najas marina and B7 Zostera marina. The HUBs S3 Annual algae Vaucheria and B8 Eleocharis spp. did not show up as existing in the project area. Vaucheria and Eleocharis spp. are however certainly present species within the area and the sampled data and/or HUB analysis must have failed to detect their presence as HUB.

As the northern Bothnian Bay is highly influenced by the freshwater input from rivers, the flora of macrophyte species include several freshwater species, often with high percentage of cover. For example, species of Sagittaria sp., Sparganium sp., Potamogeton gramineus, Callitriche sp., Elodea sp., Subularia aquatica, Nuphar lutea, and Nymphaea alba are commonly occurring in the marine environment. Where they grow, they are often a dominating taxon and are quite likely to perform a distinct biotope function, as required by the definition of a HUB (Helcom, 2013).

3. References

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5. Comparison and harmonisation of management and planning, activity 6.3 of Interreg Nord SEAmBOTH project 2019-10-15 – 2019-10-16

Participants: Tupuna Kovanen (ELY), Linnea Bergdahl (CAB), Malin Kronholm-Bergkvist (CAB), Stina Johansson (CAB), Essi Keskinen (MH), Suvi Saarnio (MH), Jaakko Haapamäki (MH), Jaana Rintala (ELY), Tuomas Kallio (Council of Oulu Region), Mirja Heikkinen (ELY), Petra Pohjola (CAB), Maarit Vainio (ELY), Sjef Heijnen (MH and thesis cooperation)

Over the course of two days, representatives of marine managers and case officers from around the northern Bothnian Bay in Sweden and Finland met for a workshop in Oulu. The aim of the workshop was to gain a better understanding of each other across the state border and to learn from each other's practices in daily work, bringing together marine management from both sides of the northern Bothnian Bay. We share the same sea, with similar environmental conditions and human activities present. For conserving and protecting the environment we have a set of legal tools, i.e. laws and regulations, to use in order to ensure this. As EU member states, both Finland and Sweden fall under the same EU directives regarding the marine environment. However, how we have implemented the directives and which national laws we have differ, which in turn make our marine management different. In this workshop we focused discussions on following issues of management within the marine environment:
Protected areas
Species protection
Environmental permissions related to the marine environment
(and a shorter introduction to marine spatial planning in respective country)

Compilation and comparison of organisation regarding marine management

To better understand the marine management in each other's country we made a compilation and comparison of the organisations and its respective actors. Summarised in table 1 and 2.

Table 1. List of names, abbreviations and description of actors involved in marine management in respective country.

	Organisation name	Abbreviation	Description
Sweden	Swedish Agency for Marine and Water Management *Havs-och vattenmyndigheten*	SWAM *HaV*	Government agency overseeing marine and water related issues
	Environmental Protection Agency *Naturvårdsverket*	EPA *NV*	Government agency overseeing environmental issues
	County Administration Board *Länsstyrelsen*	CAB *Lst*	Government authority, one per region (21 regions) Implementation of government tasks. Link between government/national agencies and municipalities/the people Work in areas of environment, agriculture, community planning and housing, animal welfare, regional growth, cultural environment, integration, energy and climate etc.
	Municipalities *Kommuner*		290 within Sweden, 3 within SEAmBOTH project area
Finland	Ministry of the Environment		
	Regional councils	RC	Joint municipal authority, one per region (18 regions) Two main functions: regional development and regional land use planning
	Aluehallintovirasto Regionalförvaltningsverket	AVI	State regional administrative agencies (Government authority). Five of them within the country. Previously called *länsstyrelsen.* . Work in areas of basic public services, legal rights and permits, education and culture, occupational health and safety, environmental permits, rescue services and preparedness
	Centres for Economic Development, Transport and the Environment *NTM-centraler*	ELY centres	Responsible for regional implementation of and development tasks of the central government. 15 centres within Finland. Three main areas of responsibility: 1) Business and industry, 2) Transport and infrastructure 3) Environment and natural resources
	Finnish Environment Institute *Finlands miljöcentral*	SYKE	Multidisciplinary research and expert institute. Funded by government and external
	Metsähallitus *Forststyrelsen*	MH	State-owned enterprise responsible for the management of state-owned land and water. Includes both public services "National Parks Finland" (nature conservation and recreation), forestry (Metsätalous oy) and Property development
	Municipalities		311 within Finland, 7 within SEAmBOTH project area

Table 2. Summary of how the marine-related EU directives are implemented into national law in Finland versus Sweden and responsible organisations.

EU directives	Habitats directive Goal: to reach favourable conservation status of habitats and species		Marine strategy framework directive Goal: to reach good environmental status of marine waters		Maritime spatial planning directive Goal: to promote sustainable growth, development and use of marine areas		Water framework directive Goal: to reach good status of bodies of water (inland, river, surface and ground)	
	Finland	**Sweden**	**Finland**	**Sweden**	**Finland**	**Sweden**	**Finland**	**Sweden**
National law	Nature Conservation Act (areas implemented also by Water Act and other acts controlling land use)	Environmental Code, chp 7 & 8 Species Protection Decree (2007:845)	Act and Government decree on Water Resources Management (Act 1299/2004, decree 1040/2006) Government decree on Water management Regions (1303/2004)	Marine environment decree (2010:1341) Also in Environmental Code, e.g. chp 5, 7, 8, 11	Land Use and Building Act and decree	Marine spatial planning decree (2015:400) Also in Environmental Code, chp 4	Act and Government decree on Water Resources Management Government decree on Water management Regions (1303/2004) *Emissions:* Act on Marine Protection (1994/1415), beyond the EEZ-zone of Finland Act and decree on Environmental Protection (Act 527/2014) etc..	Decree of management of water environment (2004:660) Also in Environmental Code, chp 5
Responsible organisation	Ministry of the Environment SYKE, ELY-centres, Metsähallitus	Environmental Protection Agency SWAM advising for marine areas/species	Ministry of the Environment in co-operation with M. of agriculture and forestry and M. of traffic and communication	SWAM	Ministry of Environment Regional Councils, RC of Southwest Finland coordinating. Government signs the plan.	SWAM, the government sign the plans.	MInistry of Environment, Ministry of agriculture and forestry	SWAM (advisory and reporting to EU
Operational organisation	ELY centres, Metsähallitus	CAB, municipalities	ELY centres, Metsähallitus, SYKE	CAB Measures also by CAB and municipalities	Regional councils	SWAM, with advise from CAB	ELY Centres, Finnish Environmental Institute, Natural Resources instutute	Water agencies (five in Sweden) CAB, municipalities (undertake measures)

On top of EU directives, both countries implement nationally derived strategies. Sweden have for example the environmental quality objectives, set to be achieved by 2020. Even though only one out of 16 goals seem to be achieved it has been useful in prioritizing of resources and has played its part in the establishing of marine protected areas. In Swedish work is also guided by the Agenda 2030, which not only focus on nature but on all parts of society, therein sustainable use of natural resources. In Finland several smaller strategies have been initiated, for instance the biodiversity strategy, and focus has not thereby been on large pictures but on parts of nature.

Differences and similarities in the implementation of strategies and directives

There are some organizational differences. In Sweden usually a government agency is responsible and the CABs in turn do the operational work on a regional level. In Finland the organization is somehow more complex with more organisations involved. Environmental permits are for example handled by different organizations, small permits in municipalities and larger ones in 5 regional state administrative agencies. ELY supervise these in the cases where they include water and environmental issues. Municipalities give smaller permits that they supervise themselves (as in Sweden). In Sweden permits are written in growing order by municipalities / CAB / courts / Miljöprövningsdelegationen (appointed by CAB).

What comes to nature conservation and protection, responsible organization is ELY. MH is however giving permits to operate on state owned protected land. Permits are supervised by both ELY and MH for their own permits. In Sweden all such permits are handled by the CAB. There are cases when permit from both authorities is needed; for example picking up samples of protected species in national park. Comment from a finnish representative: "it is sometimes messy, but it still works".

In Finland organizations are split up based upon operational and administrative focus, like ELYs and MH who both work in the field of Nature Conservation. There was guessed to be no other reasons to this than historical. Sometimes this can cause difficulties.

Marine spatial planning

Tuomas Kallio (Regional Council) introduced the process of marine spatial planning and what is done so far in Finland. In Finland, 8 coastal regions are in charge of 3 spatial plans (two or more councils for each). These marine plans are made separately for 1) the Gulf of Finland, 2) northern Bothnian Sea, Quark and Bothnian Bay, and 3) the Archipelago sea and southern Bothnian Sea. There are two main goals for the marine spatial planning: blue growth and a good status of marine waters. The planning has made past baseline reviewing and discussing future scenarios and is now in the visions stage. This is the actual planning stage of the project.

In Finland marine spatial planning is split in two levels of strategic plans: the MSP plan and the regional spatial plan. The latter concerns in principle territorial sea area, where MSP covers also EEZ-area. The MSP plan is national and not legally binding, the regional spatial planning is more detailed and has some legal effects on territorial waters. Planning is also done on a municipal local scale as land use plans. There are no planned revisions for the MSP. As for the regional spatial plans, focus has been on certain themes at the time of reviewing and the last review took 8 years.

When looking at the map over the proposed MSP in Finland, a lot of similarities can be found with the Swedish proposed plan. The biggest difference is that Finland also looks at coastal waters, which is not the case in Sweden. There are a lot of conflicting interests in the sea nearest to the coast, so MSP work has been harder in Finland than in Sweden. Still large scale planning is very important specifically near the coast. To make the work possible, the shore is not covered in very much detail, for instance fishing and aquaculture are not considered.

The planning of wind energy areas is difficult and important in north. In the Gulf of Finland wind energy is not considered because of defense reasons. Planning of aquaculture is difficult, and not yet any solutions have been found. With marine nature values: there are existing MPA-networks, but how do we include hotspot-areas that have arisen from inventories? All in all marine spatial planning is at a good start, since there are a lot of up to date location analyses, including VELMU and analyses of offshore wind power and aquaculture.

Note: Since the meeting, MSP-planning has proceeded in Finland and is now in sketch phase; public hearing will be organized in May-June 2020 and the final three plans should be ready to be accepted in Regional Council in December 2020. The main theme is that plans are creating possibilities ("multi-use", blue growth) and looking at the future, in an ecologically sustainable way.

Cooperation with Sweden?

- There has been a couple of meetings with SWAM, and several cooperation projects have been happening across the Balitc Sea, eg. Baltic Scope.

Why does not Sweden also make plans for the coastal waters?

- Municipalities have the right to on their own plan the coastal area, therefore the Swedish MSP start outside of the coastal area. It is a very strongly independent system. In Finland there is a similar situation but regional plans are made and then also the MSP. In Finland the land use and bulding act says that the regional plans are legally guiding more detailed (municipal) plans, the MSP is a strategic plan, not binding, but a tool for more detailed planning.

Linnea Bergdahl introduced the process of MSP in Sweden. SWAM is responsible for the marine spatial planning in Sweden. CABs around the country are involved as commenting and e.g. providing data. In Sweden MSP is also split in three plans: 1) Gulf of Bothnia, 2) Skagerrak and Kattegat and 3) The Baltic Sea.

The planning started in 2016, the last proposal was made in spring 2019, this winter the final proposal will be submitted to the government. The MSP will be revised when needed or every 8th year.

At the moment it is stated that the MSP in Sweden is intended as guidance and will not be legally binding. There have been some concerns with how much it will actually influence decision making.

The plans have been made with the help of an environmental impact assessment (also used in Finland) and a sustainability assessment.

When looking at the MSP map it is clear that there are fewer activities than in the Finnish plan. It does not cover the archipelago area. In the Bothnian Bay Marakallen (a Natura 2000 protected area) is the only area designated primarily for nature conservation. The plan looks a bit different from the Finnish plan as both primary and secondary use considered for each area where there are overlapping interests. There is a huge area intended for defense usage and no wind power is planned in the Bothnian Bay. However, a sand extraction area is appointed in the Bothnian Bay (1 of 5 appointed sand extraction areas in Sweden). No such interest is appointed for the Finnish side.

Climate change is considered in the plan, so that the northernmost part of the Bothnian Bay is appointed as a climate refuge area, especially for ringed seals. Lack of marine data in the offshore areas has been significant during the planning process and hence planning has been a bit difficult on the Swedish side.

Protected areas

Sweden

The different protected areas in Sweden, listed according to the level of protection:

National parks are established by environmental protection agencies and are chosen on a national basis. These national parks are chosen to represent typical Swedish nature, to protect it but also to promote it, as recreational areas.

Nature reserves are established by the regional CAB (or sometimes municipalities) and are chosen on a regional basis. They are foremost chosen to protect nature values but also for recreational purposes, these purposes vary from reserve to reserve. All nature reserves have a decision and management plan.

Natura 2000-areas are suggested by CABs but decided upon by the government. New Natura 2000 -areas are seldom established and most of them were decided on in 2005. Revision is needed for the marine areas since marine values are now much better known than back in 2005.

Biotope protection areas are smaller protected areas mostly used in forests and there appointed by Skogsstyrelsen. They can also be decided by CAB or municipalities in marine environments. One potential future use for this protection class is for protecting lagoons, but with the presence of land uplift this might not be ultimate.

All these protection classes can be overlapping. Most common protected areas are nature reserves, and these overlap often with Natura 2000. In Norrbotten there is only one purely marine nature reserve.

Marine nature areas with no legal protection are Helcom **MPA's** (here Haparanda), **EBSAs** (ecologically and biologically significant areas, northern Bothnian Bay) and Unesco **World Heritage Sites** (Höga kusten/ Kvarken).

All protected areas are established, supervised and cared for in different units within CAB. The choosing of marine protected areas are encouraged by the action and strategy plan and commented upon by SWAM.

Table 3. Summary of protection of nature areas within Sweden

	Laws and regulations	Reasons for establishing protected area	Managing, operational organisation	Responsible agency
National parks	7 kap. 2§ miljöbalken (Environmental Code)	Preserve pristine nature and our common natural and cultural heritage. But also make parks inviting for tourism and outdoor activities. Sweden's six major habitat types: • Mountains • Lakes and watercourses • Coast and sea • Broad-leaved deciduous forest • Wetland • Coniferous forest	Swedish Environmental Protection Agency	Swedish Environmental Protection Agency
Nature reserves	7 kap. 4-6§ miljöbalken (Environmental Code)	• Preserve biodiversity • Conserve and preserve valuable, natural environments • Meet the needs for outdoor recreation areas • Protect, restore or recreate valuable, natural environments • Protect, restore or recreate the natural habitats for valuable, endangered species	County administrative board, Municipalities	Swedish Environmental Protection Agency and SWAM (Marine reserves)
Natura 2000	7 kap. 28§ miljöbalken (Environmental Code)	Natura 2000 network • Special Protection Areas (SPA) • Site of Community Importance (SCI) 89 habitats (60+ Norrbotten, 8 marine) 166 species (100+ Norrbotten, 5 marine)	County administrative board	Swedish Environmental Protection Agency
Biotope protection areas	7 kap. 11§ miljöbalken (Environmental Code)	Smaller areas of land and water that provide habitats for endangered animal and plant species. Two types of biotope protections: • General biotope protection (decided by the Governmnet). • Biotope protection on a case-to-case basis.	County administrative board, Municipalities, The Swedish Forest Agency	Swedish Environmental Protection Agency, Swedish Forest Agency

A large part of the establishing of protected areas is the negotiation with landowners. Mostly land is bought but conservation agreements are also possible. In Sweden appointed third-party are used in the negotiation with landowners. An economical compensation (marketvalue + 20%) is given for lost areas, the environmental protection agency distributes money for compensations. If a landowner does not want to sell, negotiations take a long time. Not uncommon that it takes 20 years. CAB has the right to make a decision even against the landowners will, but they can then file a complaint and the process can stretch out. The process is easier on state owned land. The environmental protection agency distributes money for the establishing of new protected areas according to year and budget. The budget has been quite large for the last 5 years.

Water is mostly not entirely privately owned, more commonly by municipalities or shared by several owners. Marine waters are often less infected areas for negotiation than land.

Threat towards the nature values, especially forests, is the main factor for the order in which areas are protected. The threats are not as imminent in marine areas so that prioritization in the protection of marine areas is not as needed.

Finland

There are a lot of similarities with nature protection in Sweden. All protection areas are established under the nature conservation act and decree. The different protected areas in Finland:

National parks are established on state land and Metsähallitus is responsible for these protection areas. As in Sweden these parks are used extensively for recreation.

Strict nature reserves are also established and managed by Metsähallitus. Strict nature reserves are more strictly protected than last and sometimes they are off limits for the public.

Other nature reserves, also managed by Metsähallitus, that are established on areas recognized in nature protection programmes. These reserves are protecting mostly habitat types and are smaller.

-> These above are always established by act (parliament) or decree (government, small areas < 100 ha Ministry of Environment). . On EEZ-area protection area can be established by government decree. **Privately owned protected areas**, established and managed by ELY (partly managed by MH)

Natura 2000 network, established by government and managed by MH and ELY depending on if it is on private or state land, overlapping in some cases. The Natura 2000 -areas are most privately owned by the coast, sometimes there are both in same area. There is only one strictly marine Natura-area (Merikalla) and this is based on geological not biological values. There are also some terrestrial Natura 2000-areas that include some marine habitats.

Landscape protection areas, mostly cultural or esthetic protection grounds. These also exist in Sweden and represent an old type of protection.

Habitat protection (smaller scale areas) is in Finland divided in three acts; nature conservation, forest and water acts: **Protected habitats (Nature conservation Act)**, smaller and limited protection areas eg. seashore meadows, sandy shores and dunes, established and managed by ELY. Only protected if ELY has identified these areas and given a decision.

Habitats important for strictly protected species, also small areas, established and managed by ELY, only two existing right now.
Forestry act: **protected forest habitats**, small valuable habitats which are protected directly by act. In Sweden maybe comparable to nyckelbiotoper?
Water act: **protected aquatic habitats**, small bodies of water of max 10ha, eg flads and gloes (larger water bodies e.g. those classified as Natura 2000 habitat lagoons are protected under that). These are directly protected by the act if they are in a natural state. ELY supervises these and permits are given by Regionförvaltningsverket/Aluehallintovirasto. No similar protection exists in Sweden, as only large natural areas are considered as protectable in Sweden at the moment.

Helcom MPA's. There are 5 in Northern Bothnian Bay and they just exist. All of them are also Natura 2000 -areas and protected that way. Some reports are sent and there is no special effect.
EBSA's. The same EBSA for the Northers Bothnian Bay is shared with Sweden.
Unescos World Heritage Site. The same site for Höga kusten / Kvarken is shared with Sweden.
"Emma-areas" are on their way to be chosen, which are like EBSA -areas but on a national level. Note: Emma-areas have now been published in March 2020.

Nature protection areas in Finland are established through national conservation programs. These programs are habitatwise, eg one for forests and one at another time for marches. They are led by ELY until private owned land is bought, then moved to Metsähallitus that does inventories and continues the work with establishing the nature reserve. This is sometimes a long process. To prevent for the nature values to not be lost, these areas are managed as conservation areas even before the decision has been made. The protection is not as strict though during the process as it would be in the final reserve.

Land compensations are similar in Finland as in Sweden, consisting of the market value + extra (in this is given Finland by lower tax). No consultants are used in Finland for negotiations with landowners. Also in Finland ELY has the right to buy the land against the land owners will. Privately owned protected areas can however not be managed against owners will. Sometimes there are many owners in one protected area and then a mutual permission is difficult to get. Resources for nature conservation vary from year to year, and these resources have mostly gone to Natura 2000 -areas. A 10-year Metso-named forest protection program is ongoing, and resources are growing due to increasingly positive view to nature conservation in politics. Conservation workers have been under-resourced for many years.

Zonation analysis was done to recognize the marine areas most worthy of protection. The results of the project showed that 2/3 of the valuable marine nature values are outside of the nature protection areas in Finland. Some extensions have been done to existing protected areas in the south, but revisions are complicated to do so work is slow. Now we have the knowledge of underwater nature values and lots of potential areas to choose but it's difficult to do as marine protection is not prioritized. In Sweden the problems are almost opposite; there is a pressure to start marine protected areas but very little information to base it upon.

Discussion

In Sweden large untouched areas should be protected, but what is large? In Finland an area does not need to be large to be routinely protected.

In Finland the situation for marine area protection is highly improved from say 10 years ago. Before VELMU (nation-wide marine inventory project which has been running since 2004) there were only scattered or old data, no time for inventories and before there was no manuals or tested methods. No inventory data are required for making protected areas in Finland so marine protection was nonexistent or only guessing. There are yet not a lot of new established protected areas based on VELMU data, but some extensions have been made in the south. Nowadays we have better inventories made in Finland. There is available GIS -data and time is planned for new inventories. Zonation analysis has helped in inventory planning. Many coastal areas are still lacking in information, especially as most of the information is video based and more specific information is needed from e.g. snorkeling or dive inventories. Metsähallitus can only make inventories in already protected areas, that's why projects like SEAmBOTH are important to investigate also areas outside of those protected.

Finland needs more detailed data. Most data are from drop video and old. Also needs analysis to indicate gaps.

In Sweden there is no national level data. There is only regionally based data and, in some areas, this is very scattered. Most inventories that have been made are focused on potentially protected areas, but we need information from everywhere, especially for use in environmental permits. In Sweden inventories can be demanded e.g. during permission processes, in the form of bottom samples. Also, if there are hints of special nature values existing, like Alisma wahlenbergii, inventories can be demanded. Most of the time though no information or hints are available.

In Sweden fish recruitment areas are known but information is not easily accessible. There is only general information, no specific.

For environmental permits GIS data is invaluable, and general information is of almost no use, often there is only 8 weeks' time to make a decision.

Sweden needs national level data to find valuable areas.

Both countries need information about effects of human activities. Guidelines for e.g. how does dredging influence underwater nature?
We need information about the state of protected areas, monitoring is lacking. Especially with ongoing activities where we don't know what the status has been or could be. Finland is writing a monitoring plan for marine areas, but they have no indicator species to use in the north. Maybe bottom fauna? Species composition? Macrophyte index?

In Sweden a hydromorphological pressures comparison along the coastline from 1960 until today is to be published as GIS-data. Helpful for example status assessments.

What basis/background information is used in decision-making?

- Finland: Threatened species data, VELMU data (for new areas)for Natura 2000 scattered point data and aerial footage, for new establishment of areas we can now make specific inventories.
- Sweden: For already established Natura 2000 areas barely any marine data was available, mainly only based upon aerial footage. For new areas we can use SEAmBOTH data and make specific inventories.
- Neither country have any specific regulations/guidelines to how much and/or what type of background data should be used for establishment of protected areas.

What are the main differences and similarities?

- In Finland conservation areas are established by ELY if land is private, by parliament, government or MInistry of Environment if land is state owned. ELY is also involved in MH cases when decrees or acts are being written. Municipalities normally don't establish conservation areas in Finland; but can designate protection areas in land use plans. In Sweden conservation areas are established mostly by CAB, EPA in the case of national parks, and sometimes municipalities and then it often is areas protected for recreational purposes.

- In Finland management of conservation areas is done by ELY if land if privately owned, by MH if state owned. (Although MH should manage also privately owned lands this is not a common procedure)Ministry of environment is not involved. In Sweden the conservation areas are managed by CAB or municipalities.

What are you/your organization in further need of?

- Sweden: Data collected, in a coherent way all around the country, to make comparison and analysis possible.
- Finland: More data on a detailed level for specific areas.
- Both: Monitoring programs to be able to make status updates on protected areas, with indicator species, biodiversity index or something that is usable for the northern Bothnian Bay area and comparable.

Protected species

Finland

Species protection is divided into the nature conservation act and the hunting act.

The hunting act divides species in game species and non-protected species (e.g. rats some birds and other "harmful" species). This division (concerning birds) is against EU-regulations but still lives on. However, there is regulation in hunting Act and Decree by which the protection of birds is in practice executed. In permit cases where hunting act species are involved, permits are handled by the Finnish wildlife agency/Suomen riistakeskus/Viltcentralen, CITES species permits are handled by SYKE. The ministry of agriculture and forestry is responsible for species protection under the hunting act.

The nature conservation act lists nationally protected species. Some of these species are directly protected by Act (birds and mammals) others protected by government decree (insects and plants). All the species listed in habitat's directive annex II and IV are (outcluding game species) are protected. Some inconsistency is present in species protection, for instance ravens are protected south of the reindeer area but not in it. Permits concerning protected species are made by ELY, in the case of birds it's specifically ELY of Southwest of Finland. The ministry of environment is responsible for species protection under the nature conservation act.

Fish protection: there is a list of (non-commercial) fish species in nature conservation act to which there is possible to apply regulations of natura conservation act (i.e protect species). This has never been applied in practice. Otherwise fishing is regulated by fishing act and decree.

In some cases, species may be classified as specially protected species, e.g. Alisma wahlenbergii, Persicaria foliosa and Hippuris tetraphylla. With these species also their surrounding habitat can be protected, when ELY has defined these distribution areas. Otherwise protection concerns harming species individuals; though lately the interpretation has been that also the destruction of habitat of protected species leading to disappearing of the species individuals is denied (i.e dredging where there grows Alisma wahlenbergii). However, this is not clearly stated in the Act.

Sweden

The bird's directive and habitats directive are incorporated into the species protection decree (20017:845) in Sweden. The decree specify which species are protected by law (on the EU habitats directive list plus those protected on a national level). All wild bird and mammal species are protected. All birds and mammals go under the hunting act. Exemptions can here be given for hunting. Fish, molluscs and crustaceans are regulated under the fishing act and decree.

Sweden also have animal and plant protection areas. Within those protection is often limited in in time and space, e.g. for bird nesting areas during breeding season when access then may be restricted/prohibited for humans.

All orchids, reptiles, amphibians and bird species are protected. There are differences in how species are protected, for instance species can be protected from physical harm and in other cases even disturbance of their habitat.

CAB handles species protection cases.

Discussion

CAB handles species protection permits, but not often such cases arise. In the marine environment in our area we have one plant listed on the EU habitats directive list: Alisma wahlenbergii. There have yet not been any permit cases in the Swedish Bothnian Bay involving marine plant species, as we are aware of.

In Sweden there are no good databases and probably a lot of species are probably overlooked in many cases. Artportalen (online database and map service of species within Sweden, https://www.artportalen.se/) is used by case officers to find observations of species that might be occurring at locations of e.g. planned building sites. This portal is however not "complete", especially so for marine species, where registered observations are very scarce or non-existing.

In Finland there have been a few cases per year where marine species (Alisma wahlenbergii) and the shoreline-based Persicaria foliosa have been involved. Mostly these have included dredging, but there have also been some larger cases like in building the road/bridge to the island of Hailuoto or harbour areas.

Both ELY in Finland and CAB in Sweden can demand inventories in handling permits for large projects, especially if there is some suspicion there are protected species present in the area. There are no limitations for what can be demanded. In Finland there is good data of Alisma wahlenbergii, HIppuris tetraphylla and Persicaria foliosa so there is no problem there, but for other species, for instance Macroplea pubipennis, information is sparse. In Sweden all data is sparse. In Finland species protection has not historically been taken so seriously in court decisions, but the feeling is that there has been a change in attitudes in recent years and species protection is today taken seriously in court processes.

Ecological compensation demands are discussed in both Sweden and Finland. In Sweden law states that compensations should be demanded when applicable, but compensation demands have not been much used. There have been some cases in mining industries and in the south even in marine environments then regarding the eelgrass Zostera marina. There is a case in Luleå where the charophyte Chara braunii was relocated as its habitat was being made into a road/embankment. Chara braunii is however not under the species protection decree, "only" red listed as vulnerable. Compensation has not been used in Finland, but some terms can be set in permits. The problem is, there is not a lot of knowledge about how some negative effect can be compensated, for instance in the case of Alisma wahlenbergii? Perhaps pay for protected areas, for instance land upheaval areas that can be a potential Alisma-sites in the future? When building roads protected species can be moved, but what use is it to move a species away from its optimal habitat to a new habitat that it has not naturally spread to, hence is not optimal for?

In both Sweden and Finland some species are protected with their surrounding habitat. But in Sweden protection is defined differently for each species and much more detailed than in Finland. In Finland all plants are protected in the same way, all animals the same way… The paragraphs are old and unrevised, after entering EU some things were added but nothing was rewritten.

Conclusion: a lot needs to be done. In Sweden information on protected species and their occurrences is spare and must increase. In Finland acts and decrees don't protect all species properly, only habitats directives count. In some instance it might be so that destruction of a plant's habitat is allowed but picking the plant is strictly regulated, since there is a derogation in nature conservation act for nationally protected species that the protection does not concern forestry, agriculture or building.

Which marine species are concerned/worked with?

- In Finland A. wahlenbergii, Hippuris tetraphylla, Persicaria foliosa and even Macroplea pubipennis occur sometimes in species protection cases. In Sweden we are not aware of any such case involving marine protected species.

What basis/background information is used in decision-making?

- Inventory data, observations of species. Sometimes (most often) very scarce. If there is data/information that indicate a protected species could be present within a location it is possible to demand further inventories. If no such indications exist it is difficult demanding further inventories. The larger (in terms of resources in budget) a development project is the more inventories can be demanded.

What are you/your organization in further need of?

- Better, more data on occurences of protected species, especially in Sweden where it is very scarce for marine species.
- In Finland, a wish for a revision of existing species protection paragraphs (Revision of Nature Conservation act has now been initiated).

Environmental permissions related to the marine environment

Sweden

CAB handles permits, writes bans und supervises illegal activities, regarding species, conservation areas and all bodies of water.

All work regarding the environment is regulated through the Swedish environmental code (Miljöbalken). The objective to the code is to promote a sustainable environment. The general rules are: when doing an activity everyone is responsible to limit the effects to the environment – if there is a risk to spoil the environment you must take "reasonable" precautions.

The environmental court grants big permits with CAB involved by commenting. Smaller permits are handled directly by CAB, e.g. dredging of waterways where the affected area smaller 500m2. Most of the permits involve dredging. Dredging is getting harder to limit and more permits are wanted.

Bans have been made on basis of the code statement that gains in projects have to be larger than the costs (negative environmental consequences). This statement has been removed so this formulation cannot be used to issue bans anymore. Bans can be made based on a poor choice in location, since you must choose the location with the least impact on human health and environment (SEAmBOTH marine maps with locations of nature values might be very useful for guiding decisions). If a project is planned in an area that has not yet been exploited, permits can be banned based on that it is a large unspoiled area, the area is important in order to protect specific natural aspects or species (SEAmBOTH maps of e.g. potential distribution of species might be very useful for guiding decisions), or it is culturally important and should be left untouched. No activity is allowed that might endanger the quality standards or ecological status of the water. In a lot of these cases general information about the underwater nature values is dearly needed. Unfortunately cumulative effects of small projects cannot be taken into account in permits and only big unspoiled areas are taken into account, not small ones.

Supervision is mostly based on private complaints. There is no time to do research internally to get a bigger picture. The complaint is moved to the police if a law is broken. In most cases we only have the possibility to see what has been done and not how it looked before. To try the case further in court, because animal or plant life has been harmed, we need proof from before the act was done. This is rarely possible, because we have so little spatial information about underwater nature (SEAmBOTH maps and inventory data might help!)

Finland

The environmental code in Finland has the same elements as in Sweden but in Finland these elements are more separated, in Sweden more combined.

Regional state administrative agencies (AVI) decides on permits concerning the environmental protection act and water act. ELY supervises acts and permits given by AVI. There have been resources to supervise some smaller permits but not everything and not whole acts. Sometimes complaints have been made by public to ELY because of inaction when destructive projects have been permitted.

Water act permits are needed if a project results in change in water state or the natural environment in water. Permits are needed for dredging if the dredged volume rises over 500m3. ELY must be notified always when dredging is done, although dredging volume stays under 500m3. Notifications are all looked at and sometimes this dredging may affect protected areas or species and then ELY can interfere. ELY can in these cases give guidance, demand to apply a permit or in most severe cases set a ban. in other cases (like valuable habitats, rare non-protected species etc) compliance is voluntary. When building in marine coastal areas, sometimes both environmental and water act permits are needed. Environmental protection permits are always needed in some cases e.g. in industrial projects and fish farming.

“Small” ditching and small dredging does not need permits, and this includes practically all ditching. The environmental problems are huge, especially in mires that are not protected but also the problem is seen in the sea. Public pressure is however arising, and the tide might be changing. Otherwise the same problems exist in Finland as in Sweden, with having to prove diminishing of nature values to be able to take complaints into court.
In Finland, certain small habitat types have a higher protection status, like coastal lagoons, but even these are not protected from the nutrient and solid matter loads.

Shoreline protection

Sweden

In Sweden, according to the environmental code, you must assure public access and maintain good living conditions for animals and plants along the shoreline, 100-300m from the shoreline in both directions. This protection does not include small waterways.
It is an old legislation, but a lot has been added through time, e.g. exemptions within LIS-areas (development sites along shores in rural areas where the shoreline protection law is exempted. Appointed by the municipality) . Shore protection is often not applied in cities.
Exemptions in shore areas are granted by municipalities (responsible and can discard protection) and those exemptions are overseen by CAB. If the area of concern is in a conservation area, e.g. nature reserve, CAB handles the process.

Exemptions can be given but only if access and nature values are not affected, or if the shoreline already is in use. It costs to get an exemption so sometimes people just ignore to apply for shore protection exemption and just build.

There are challenges in maintaining these unaffected shorelines. There is an overall lack of knowledge of how living conditions for plants and animals along the shore might be affected and by which type of activities. How can you be sure there is no effect on nature? Maybe one exemption is ok along a stretch of shoreline, but when several pile up next to each other, when have you reach a “tipping point”? The cumulative effect is difficult to handle. There is also a lack of supervision, nobody is checking if e.g. logging is done in the shoreline or the protected shoreline is made into a lawn. There is no easy accessible information on locations where previous exemptions have been given.

Finland

In Finland there are no real shore protection measures like in Sweden. Municipalities give permits to build on shores according to the land use and building act. Free access, the landscape and nature values should be taken into consideration in building along the shoreline but there are no absolute rules and in practice the shore line is free game, as long as ”a sufficient amount of unbuilt and unbroken shore-area remains in land use plans”. ELY used to supervise and guide municipalities, but not that much anymore. In the case of planning of large projects comments can be made.

In Finland there is a good register information in GIS about buildings and dredging along the shore (including those that have been made legally).

What are you/your organization in further need of?

- Information on marine environment also outside of protected areas (most data is now available from within protected areas).
- Guidelines for effects of human activities on the marine environment e.g. effect of sedimentation/increased turbidity originating from dredging.
- General, overview inventories are very important to get a hint of where to direct further investigations.
- Information on effects of land use (ditching etc) in catchment areas.
- GIS-data is very helpful and important.

Our wishes

Questions we want to be answered and/or resources we wished we had in a dream-scenario of a perfectly functioning marine management within the northern Bothnian Bay

- More co-operation between Finland and Sweden
- Information on what has protection value in the water
- Discussion with Finland on how to motivate ban on dredging
- Compensation hierarchy applied. Full (plus extra) compensation of losses
- More funding for mapping of the marine and coastal areas
- Catchment area considered more
- HOW to protect species and habitats in water, e.g. suitable prevention measures, or when a total ban?
- Laws which can limit, or require, adaptations of measures concerning water activities in already exploited areas.
- Money + experts + data -> resources
- High awareness of people of the nature and environment
- Better availability for all the collected data on the marine areas
- National database (gis-data) of given permits, dredgings and other water projects
- More efficient water protection measures for agriculture and forestry. And guidelines and instructions
- GIS-data e.g. of potential habitats for endangered species, "key-biotopes" in marine areas
- Overall picture of hydromorphological impact (GIS-data). Where do we have larger areas which are not exploited?
- Research/guidelines for impacts on natural habitats/species caused by dredging (turbidity), piers/ladders (changes in currents, shading etc)
- Restoration of lagoons, improving spawning areas (coastal and rivers)
- All possible data (GIS) accessible in the same database as easily visible layers
- Streamlining EIA across Finland and also across Finland and Sweden (on same topics, e.g. off-shore wind farms, fish factories etc)
- More involvement of citizens, reporting species and raising awareness of species
- More research about the effects of different human pressures to nature (e.g. how do small dredging effect, how does turbidity effect fish etc
- Stricter stance to lousy EIA:s and environmental crimes
- Monitoring and indicators of good (ecological) status
- More research on the effects of human activities for the marine and coastal areas
- Open depth data
- Better background data
- Real ecosystem approach to legislation
- More co-operation with different organisations

Conclusions

- Our marine environment and the type of cases we handle are very similar, a continued collaboration would be beneficial to learn more from each other in detail.
- Both countries struggle with the fact that many protected areas in the sea are not including actual marine values. Most areas were established long ago when data and information available on the marine environment were much less than today. Similar types of protected areas are used for similar purposes in the countries. In Sweden more decisions are made on a regional level in comparison to Finland where more is made from a national level. Sweden is now working more actively to increase protected areas (by national legislation) than Finland.
- Information on protected species is scarce, laws might not be practically functioning efficiently and cases including protected species may therefore be quite complex to handle.
- Knowledge and information on the effects on marine nature values from human activities is important to make well-grounded decisions for environmental permissions. Now this is lacking in both countries.

6. Activity 6.4 Harmonisation of marine nature values

1. Introduction

The description of activity 6.4 in the project application stated following:

On the Swedish side, there is an ongoing work to produces a framework for nature value assessment. This includes the assessment of lists of so-called ecosystem components (species, habitats, etc), which are defined and valued according to defined criteria. These lists will be compared and harmonized with similar work made in Finland in order to come up with regionally balanced and reviewed lists. The defined ecosystem component and their values will subsequently be used as a base for the production of habitat and nature value maps (activity 5).

Below follows a description of how the activity was undertaken and its results. The results are to be used primarily for the production of maps of nature values in project activity 5.

2. Background

For management purposes we need to know what pieces of nature to prioritise for conservation and where expansion of human activities is more suitable. Areas with higher nature values are targeted for conservation, but how do we know to apply a nature value and how do we compare different habitats and species? The question of nature valuation is a rather complex topic with no one single answer. On a global level, the Convention on Biological Diversity appoint so called Ecologically and Biologically Significant Marine Areas (EBSA) throughout the world. Those are areas that fulfil a certain set of criteria in terms of e.g. uniqueness/rarity, special importance for life history stages of species, and importance for threatened, endangered or declining species and/or habitats (Convention on Biological Diversity [CBD], 2020). In Finland a national project to identify ecologically significant marine underwater areas, so-called EMMAs, have found and described 87 marine areas along the coast of Finland (Lappalainen, Kurvinen & Kuismanen, 2020). The identification of the areas was based upon data from the VELMU project, analyzed by the spatial prioritization tool Zonation (Moilainen et al., 2014) and reviewed by experts for final decision. The evaluation of the EMMA areas was based upon the same criteria used for the EBSA evaluation.

In Sweden there is a current ongoing work developing a national, standardised framework for nature value assessment in the marine environment, named Mosaic (Methods for spatial, adaptive, and integrative ecosystem-based assessment of conservation values) (Hogfors, Fyhr & Nyström Sandman, 2017). A draft of the Mosaic ecosystem component list for the Gulf of Bothnia has been made. There ecosystem components (species, habitats, or biotopes) have been identified and scored based upon the best available knowledge at the time. The geographical extent of this list is over the whole Bothnian Bay. In order to identify prioritised nature values within the SEAmBOTH project area a more local approach needed to be taken. An agreement was made amongst the project participants to use the Mosaic framework as a template to evaluate nature values but adapt it to relevant ecosystem components from the project area and give scores from a local perspective of the northern Bothnian Bay. The identified nature values would then be taken and used within the Zonation analysis in order to produce maps of nature values in project activity 5.

In short, Mosaic consists of two parts. A basic nature value assessment in which the question of what ecosystem components are valued is answered. Secondly an in-depth nature value assessment answering the question of where these ecosystem components are located spatially. The first part (1) is in turn divided into two parts; 1.a. assesses the ecological and biological value and 1.b. assesses the ecosystem services value. For this activity we focused only on part 1.a.

The assessment of the ecological and biological value (1.a.) is based upon four criteria. For each of the criteria the ecosystem component is given the score of 0, 1, 2, 4 or 10. The criteria are:

1. Life cycle importance

How important is the ecosystem component for a critical phase in life for one, or several, mobile/migratory species? The scoring of this criteria depends both on the importance for a critical life phase and the strength of the spatial correlation (i.e. to what extent the ecosystem component limits/restricts distribution and/or size of the population of the species).

Table 1. Scoring definitions for the life cycle importance criteria. The table has been translated into English and adapted from: Mosaic – ramverk för naturvärdesbedömning i marin miljö by Hedvig Hogfors, Frida Fyhr and Antonia Nyström Sandman at AquaBiota Water Research, 2017.

<table>
<tr><th colspan="5">Part 1 – assessment per sea area
Part 1a – ecological/biological value and indirect ecosystem services
Life cycle importance</th></tr>
<tr><th>Score</th><th></th><th>Importance for critical life cycle phase</th><th>Spatial correlation between ecosystem component and the critical life cycle phases the EC is important for</th><th>Total assessment</th></tr>
<tr><td>10</td><td></td><td>The ecosystem component (EC) constitutes – or has a very high importance for – a critical life cycle phase of mobile species. The EC may restrict the extent of one or several species.</td><td>Very high spatial correlation</td><td>The EC may restrict one or several species and is – or has a very high spatial correlation with – a critical life cycle phase of mobile species.</td></tr>
<tr><td rowspan="2">4</td><td>Alt. 1</td><td>The EC has a high importance for a critical life phase of mobile species. The EC can most likely limit one or several species</td><td>Relatively high spatial correlation</td><td>The EC can most likely limit one or several species and has a relatively high spatial correlation with a critical phase of mobile species</td></tr>
<tr><td>Alt. 2</td><td>The EC constitutes of – or has a relatively high importance for – a critical phase of mobile species. The EC can possibly limit one or several species</td><td>Very high spatial correlation</td><td>The EC can possibly limit one or several species and is – or has a very high spatial correlation with – a critical phase of mobile species</td></tr>
<tr><td>2</td><td>Alt. 1</td><td>The EC has a relatively high importance for a critical phase of mobile species. The EC can possibly limit one or several species</td><td>Relatively high spatial correlation</td><td>The EC can possibly limit one or several species and has a relatively high spatial correlation with a critical phase of mobile species</td></tr>
<tr><td>~~1~~</td><td></td><td colspan="3">1 point may not be given for this criterion</td></tr>
<tr><td>0</td><td></td><td colspan="3">The EC does not constitute – or has not been proven to have any or only a negligible importance for- a critical phase of mobile species alt. has none or only low spatial correlation with a critical phase of mobile species</td></tr>
</table>

2. Threat status

The threat status is based upon the classification of the ecosystem component within existing lists of threatened species/biotopes. We used the HELCOM red list for Baltic Sea biotopes, the Swedish red list from The Swedish Species Information Centre, 2015, the international IUCN red list and the Assessment of threatened habitat types in Finland (2008 and 2018).

Table 2. Scoring definitions for the criteria threat status. The table has been translated into English and adapted from: Mosaic – ramverk för naturvärdesbedömning i marin miljö by Hedvig Hogfors, Frida Fyhr and Antonia Nyström Sandman at AquaBiota Water Research, 2017.

Part 1 – assessment per sea area Part 1a – ecological/biological value and indirect ecosystem services Threat status				
Score	**Swedish/HELCOM/IUCN red list**	**OSPAR red list**	**Other assessments**	**Total assessment**
10	Endangered (EN), critically endangered (CR), vulnerable (VU)	Threatened or decreasing	Threatened or decreasing	The highest score given
4	Near threatened (NT)	-	Near threatened or similar	The highest score given
2	Have before been classified as threatened or decreasing alt. is under investigation			
1	*1 point may not be given for this criterion*			
0	Not classified as threatened or decreasing			

Comments

If the ecosystem component is defined as having a high life cycle importance for one or several species (e.g. if the EC is a spawning ground or a nesting area), it may be relevant to assess the threat status of the specie the EC is important for. The spatial correlation between them must be high though and the EC must be a potential limiting factor for the specie.

Example: If we suppose the EC "spawning grounds for cod" would be a limiting factor for cod, assessment of the threat status of cod could add scores to the EC. If we instead assess the EC "nursing grounds for cod" and suppose that is not limiting for cod, the correlation between them is not that strong. Assessment of the threat status of cod could therefore not be used in the assessment of "nursing grounds for cod".

3. Biodiversity contribution

To what extent does the ecosystem component contribute to biodiversity of species and populations?

Table 3. Scoring definitions for criteria biodiversity. The table has been translated into English and adapted from: Mosaic – ramverk för naturvärdesbedömning i marin miljö by Hedvig Hogfors, Frida Fyhr and Antonia Nyström Sandman at AquaBiota Water Research, 2017.

Part 1 – assessment per sea area Part 1a – ecological/biological value and indirect ecosystem services Biodiversity	
Score	
10	EC contribute to a high biodiversity, relatively within the assessed sea area
4	EC contribute to a relatively high biodiversity, relatively within the assessed sea area
2	EC contribute to some biodiversity, relatively within the assessed sea area
1	EC does not contribute significantly to biodiversity, relatively within the assessed sea area, and does not form habitats.
0	Invasive alien species which constitute a threat towards biodiversity

4. Ecological function

Does the ecosystem component perform a function of importance, from an ecologically holistic perspective? This is evaluated from three perspectives; importance of function, interchangeability, and occurrence.

Table 4. Scoring definitions for the criteria ecological function. The table has been translated into English and adapted from: Mosaic – ramverk för naturvärdesbedömning i marin miljö by Hedvig Hogfors, Frida Fyhr and Antonia Nyström Sandman at AquaBiota Water Research, 2017.

<table>
<tr><th colspan="5">Part 1 – assessment per sea area
Part 1a – ecological/biological value and indirect ecosystem services
Ecological function</th></tr>
<tr><th colspan="2">Score</th><th>Importance of function</th><th>Interchangeability/resilience</th><th>Occurrence (potential and real) and total assessment</th></tr>
<tr><td colspan="2">10</td><td>Very high</td><td>Low</td><td>EC performs an important function (in addition to previous criteria) and is or has a great potential to be out of very high importance from an ecological holistic perspective.</td></tr>
<tr><td rowspan="2">4</td><td>Alt 1</td><td>High</td><td>Relatively low</td><td>EC performs an important function (in addition to previous criteria) and is or has a great potential to be out of high importance from an ecological holistic perspective. Relatively few other species may replace it.</td></tr>
<tr><td>Alt 2</td><td>Very high</td><td>Relatively low</td><td>EC performs an important function (in addition to previous criteria) and is or has a great potential to be out of very high importance from an ecological holistic perspective. Relatively few species may replace it, but it’s quite common so each single occurrence of the EC may be lowered in value.</td></tr>
<tr><td rowspan="2">2</td><td>Alt 1</td><td>Some</td><td>Relatively interchangeable</td><td>EC performs an important function (in addition to previous criteria) which has some importance from an ecological holistic perspective.</td></tr>
<tr><td>Alt 2</td><td>High</td><td>Relatively interchangeable</td><td>EC performs an important function (in addition to previous criteria) which is of high importance from an ecological holistic perspective. It is common so each single occurrence of the EC may be lowered in value.</td></tr>
<tr><td colspan="2">1</td><td>Low</td><td>Interchangeable</td><td>EC has (in addition to previous criteria) a low importance from an ecological holistic perspective.</td></tr>
<tr><td colspan="2">0</td><td>Harmful impact</td><td>Compete with native species</td><td>Invasive alien species threatening the ecological functions or outcompete other species.</td></tr>
<tr><td colspan="5">Comment
If EC is defined as having a life cycle importance for one or several species (e.g. if EC is a spawning ground or nesting area) it may be relevant to assess the importance of function and interchangeability for the species the EC is important for rather than the EC itself. It must though be a strong connection between the occurrence of the EC and the occurrence of the species. In other words, the EC should be a possible limiting factor to the species.
Example: If we suppose that EC” spawning ground for cod” could be limiting for the population of cod, the assessment of cod’s importance of function and interchangeability may also be what adds the score to EC “spawning ground for cod”. If we instead assess the EC “nursing grounds for cod” and suppose it’s not a limiting factor for cod, the connection between them is not as strong. Therefore, the EC “nursing ground for cod” can’t be directly substituted by assessment of cod’s importance of function and interchangeability. The scoring should be decreased or not given at all.</td></tr>
</table>

3. Methods

A workshop was arranged to, by expert opinion, identify and prioritise nature values. Participants of the workshop included people with knowledge, experience, and/or other relations to working with nature values within the northern Bothnian Bay. In this case the participants were project members and staff from the County Administrative Board of Norrbotten (CAB), Lapland and North Ostrabothnia ELY-centres, and Metsähallitus. A total of seven participants were present, including the workshop leader.

To familiarise ourselves with the framework and the scoring we did a first try scoring our own choice of random ecosystem component. During a follow-up discussion afterwards, we discussed questions and agreed on how to do the scoring.

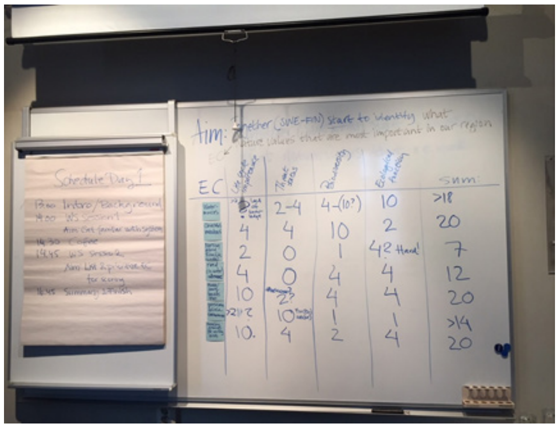

Figure 1. First try using the scores for a choice of ecosystem components.

Next everyone got to list ecosystem components that they themselves believed were important within the SEAmBOTH project area. All the suggested ecosystem components were displayed on the whiteboard in the room followed by an open discussion on whether the list was complete, or if we had some ecosystem components we would like to add.

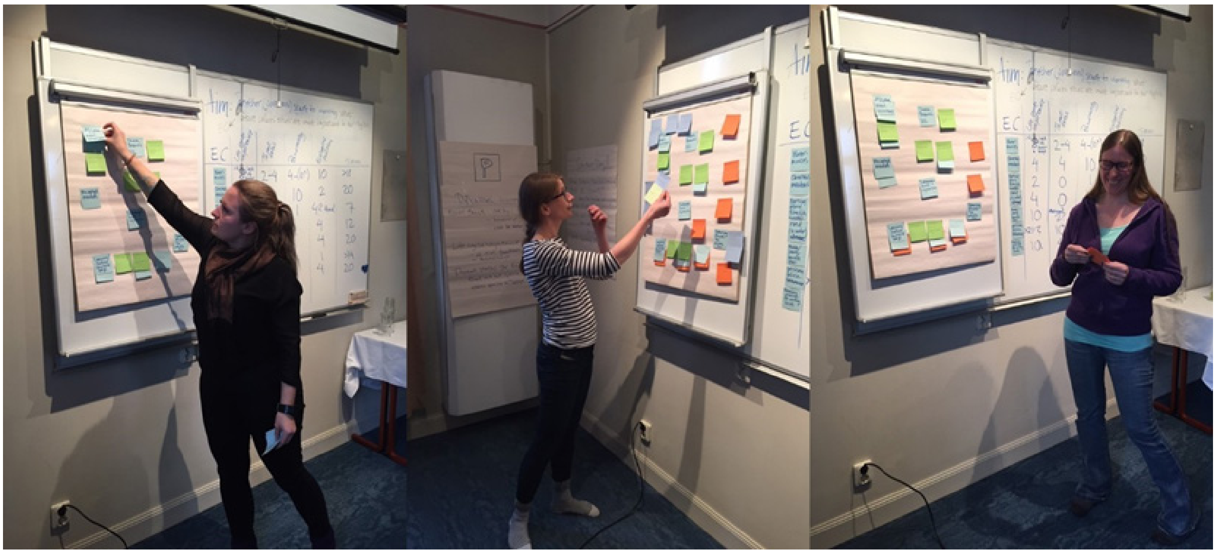

Figure 2. Suvi, Linnea and Essi suggesting important ecosystem components.

When we were satisfied with the list, we got six coloured dots to attach to the ecosystem components we believed needed to be prioritized.

Figure 3. Suggested ecosystem components (to the left) and prioritized (to the right).

After identification and prioritization of important ecosystem components, according to our experience and belief, it was time to test the Mosaic framework and see what the scoring would give as result. We worked through all the ecosystem components on our list and discussed and agreed on the scoring of them.

Figure 4. Linnea and Suvi discussing and agreeing on scores.

4. Results

The workshop ended with a result presented in figure 5 (the analog version) and table 6 (digitalised version).

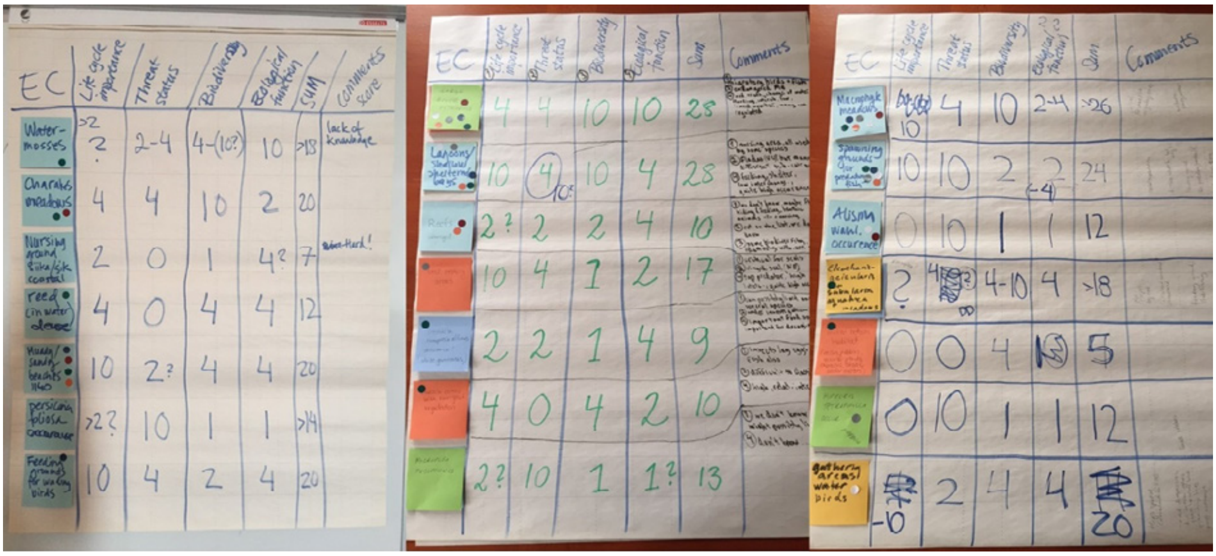

Figure 5. The first scored lists of important ecosystem components in the SEAmBOTH project region, i.e. the northern Bothnian Bay.

Table 5. Important ecosystem components in the northern Bothnian Bay, prioritized and scored according to the Mosaic framework. *Number of "dots" each ecosystem component received during the prioritization. The higher number of "dots" the more prioritized the ecosystem component is.

EC	Prioritisation*	1. Life cycle importance	2. Threat status	3. Biodiversity	4. Ecological function	Sum	Comments
Water mosses	1	>2 ?	2-4	4 – (10)	10	>18	Lack of knowledge
Charales meadows	2	4	10	10	2	20	2. VU in Fin, NT in Helcom
Coastal nursing ground for siika/sik	0	2	0	1	4 ?	7	Hard!
Dense reed (in water)	1	4	0	4	4	12	
Muddy/sandy beaches	4	10	2 ?	4	4	20	
Persicaria foliosa occurrence	0	>2 ?	10	1	1	>14	
Feeding ground for wading birds	1	10	4	2	4	20	
Estuaries	6	4	10	10	10	28	1.Migratory birds and fish. 2. EN in Finland, CR in Helcom. 4. Sediment transportation, change of water, flooding control, interchangeability is low, limited numbers of them, many are regulated
Lagoons/shallow, sheltered bays	5	10	4 (10?)	10	4	28	1.Nursing area, all used by some species. 2. Fladas (VU) others are not threatened. 4. Feeding, shelter, low interchangeability, quite high occurrence
Submerged reefs	2	2 ?	2	2	4	10	1.We don't know, maybe fish/benthic animals hiding and feeding, nursing there. 2. Not on a threat list, but lack of knowledge in general. 3. Some biodiversity, relatively high in comparison to surrounding sea floor.
Seal resting areas	1	10	4	1	2	17	1.Critical for seals. 2. Ringed seal (NT). 4. Top predator, high interchangeability, quite high occurrence
White gammarus *(Monoporeia affinis)* occurrence	1	2	10	1	4	9	1.Can possibly limit one/several species. 2. Under investigation. Gammarus bottoms EN in Fin, NT in Helcom 4. Important food source, important for decaying
Shallow areas with emergent vegetation	1	4	0	4	2	10	1.Insect, fish lay eggs there. 2. Difficult to classify. 4. Relatively interchangeable
Macroplea pubipennis occurrence	0	2 ?	10	1	1 ?	13	1.We don't know, might possibly limit species? 2. NT in Fin 4. Don't know enough about the specie
Macrophyte meadows	6	10	4	10	2-4	>26	1.Critical for small fish, migratory birds. 4. Filtering, nutrient
Spawning grounds for predatory fish	5	10	10	2	2 (-4)	24	2.Coastal exploitation. 4. Feeding ground, predatory fish has a top-predator function
Alisma wahlenbergii occurrence	2	0	10	1	1	12	2. VU in Fin, VU in Swe
Eleocharis acicularis, *Subularia aquatica* meadows	1	?	4	4-10	4	>18	2. Outcompeted by reed, in Finland considered threatened (CR), LC in Swe. More of it in SEAmBOTH area than further south 4. Feeding ground, stabilising the soil.
Mixed bottom habitats	1	0	0	4	1	5	
Hippuris tetraphylla occurrence	1	0	10	1	1	12	2. VU in Fin. None existing in Swe
Gathering areas for water birds	1	10	2	4	4	20	1.High spatial correlation gives a score ten. 4. Seed dispersion, dig bottom, food for other birds, predatory birds, poop nutrients
Additions							
Sea ice cover		10	10	4	4	28	1.Very high important for e.g. ringed seal, very high spatial correlation 2. VU in Fin, VU in Helcom 3. Contribute to a relatively high biodiversity. Ice scraping create conditions for seashore flora. 4.High importance of function, low interchangeability, occurrence today common, but in future drastically decreased → 4?
Chara braunii >5 ind/% cover		0	10	1	1	12	1.As far as we know? 2.VU in Swe and Fin
Limosella aquatica >5 ind/% cover		0	4	1	1	6	1.As far as we know? 2.NT in Swe, LC in Fin
Crassula aquatica >5 ind/% cover		0	10	1	1	12	1.As far as we know? 2. NT in Swe, VU in Fin

The results in table 5 show that the ecosystem components we prioritised highest were in general also those that received the highest scores according to the criteria in the Mosaic framework.

In comparison to the suggested ecosystem components and their scores in the Mosaic draft, our list (table 6) is relatively similar. This is mainly due to the local perspective that we used in evaluating the ecosystem components. For example, some species received lower score by us in threat status as they are more common here in the northern Bothnian Bay than on average in the Gulf of Bothnia.

Suggested ecosystem components (nature values) for modelling and to include in maps

The ecosystem components from table 5 are rearranged in table 6 in order of highest to lowest score with list of species to be included for each ecosystem component. This is to make it possible to identify and define them for the modelling and mapping process and find the relevant data.

Table 6. Suggested ecosystem components (nature values) for modelling and to include in maps

EC	Score	Adjusted name/definition	Species to be included
Estuaries	28	Estuaries 1130	
Lagoons/shallow, sheltered bays	28	Lagoons 1150 and large shallow inlets and bays 1160	
Macrophyte meadows	>26	Submerged tall vascular plant meadows, (>10cm) >25% cover	Elodea sp. Elodea canadensis Elodea nuttallii Callitriche sp. Callitriche hermaphroditica Callitriche palustris Callitriche hamulata Ranunculus confervoides Ranunculus sp. Thinleaf Potamogeton/Stuckenia spp. Broadleaf Potamogeton/Stuckenia spp. Potamogeton friesii Potamogeton compressus Potamogeton obtusifolius Potamogeton gramineus Potamogeton praelongus Potamogeton pusillus Potamogeton berchtoldii Potamogeton perfoliatus Stuckenia pectinata Stuckenia vaginata Stuckenia filiformis Potamogeton natans Myriophyllum sp. Myriophyllum alterniflorum Myriophyllum sibiricum Ceratophyllum demersum Utricularia sp. Utricularia vulgaris Alisma plantago-aquatica Alisma wahlenbergii Zannichellia palustris Potamogeton perfoliatus x gramineus Zannichellia palustris var. repens Sagittaria sp. Sparganium sp. Sparganium gramineum Nuphar lutea Nymphaea alba Ranunculus peltatus ssp. Peltatus Persicaria foliosa Tall vegetation
Spawning grounds for predatory fish	24	Spawning grounds for predatory fish	Perch Pike Thymallus thymallus
Feeding ground for wading birds	20	Feeding ground for wading birds	
Muddy/sandy beaches	20	Mudflats	
Charales meadows	20	Charales meadows >25% cover	Characeae Chara sp. Chara aspera Chara aspera f. subinermis Chara globularis Chara virgata Chara braunii Nitella flexilis/opaca Nitella opaca Nitella flexilis Nitella wahlbergiana Tolypella nidifica

EC	Score	Adjusted name/definition	Species to be included
Estuaries	28	Estuaries 1130	Tolypella nidifica
Gathering areas for water birds	20	Gathering areas for water birds	
Water mosses	>18	Water mosses meadows >10% cover	Water mosses Fontinalis antipyretica Fontinalis dalecarlica Fontinalis hypnoides Sarmentypnum exannulatum Oxyrrhynchium speciosum Drepanocladus sordidus Drepanocladus aduncus Fissidens fontanus F. adianthoides F. osmundoides Hygrohypnum luridum,
Eleocharis acicularis, *Subularia aquatica* meadows	>18	Submerged short vascular plant meadows (<10cm), >25% cover	Isoëtes sp. Subularia aquatica Limosella aquatica Elatine sp. Elatine orthosperma Elatine hydropiper Elocharis acicularis Lemna trisulca Crassula aquatica Ranunculus reptans Rosette plant Short vegetation
Seal resting areas	17	Seal resting areas (grey and ringed seal)	
Persicaria foliosa occurrence	*>14*	*Persicaria foliosa occurrence*	
Macroplea pubipennis occurrence	*13*	*Macroplea pubipennis* occurrence	
Dense reed (in water)	12	Emergent vegetation, >25% cover	Including: Schoenoplectus sp. Phragmites australis Equisetum sp. Equisetum fluviatile Agrostis stolonifera Typha latifolia Alisma plantago-aquatica Carex sp. Hippuris vulgaris Lysimachia thyrsiflora
Alisma wahlenbergii occurrence	12	*Alisma wahlenbergii occurrence and number of individuals*	
Hippuris tetraphylla occurrence	12	*Hippuris tetraphylla occurrence and number of individuals*	
Submerged reefs	10	Reefs 1170	
Shallow areas with vegetation?	10	Delete, included in	
White gammarus *(Monoporeia affinis)* occurrence	9	Deep soft bottoms with high abundance (>100 ind/m2?) of fauna	
Coastal nursing ground for siika/sik	7	Coastal nursing ground for siika/sik	
Additions			
Sea ice cover	28		
Chara braunii occurrence and number of individuals	12		
Limosella aquatica occurrence and number of individuals	6		
Crassula aquatica occurrence and number of individuals	12		

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7. Activity 7.1 Workshops with end-users report

1. Introduction

The activity was conducted with the purpose of collecting input from end-users of the SEAmBOTH products and stakeholders within the project area in order to better understand how to make the end-products usable and accessible, as well as highlight and raise discussions about the Bothnian Bay marine environment. In the first phase of the activity a stakeholder analysis was conducted. It was followed by workshops, meetings, and talks with people from various stakeholder groups in Finland and Sweden from the end of 2018 until the beginning of 2020.

In this report the workshops are described and replies, comments, and feedback from stakeholders collected.

2. Stakeholder analysis

A stakeholder analysis was conducted. Input for the analysis was gathered by participants during the project group meetings in Haparanda on 2018-04-25 and 2018-11-14. A total of 25 categories of stakeholders were identified. They were in turn classified into four groups, depending upon their level of assumed interest in the project and need for use of project results. The four groups were exemplified as follow:

Group 1: Professional planning and decision-making users;
Group 2: Recreational users (e.g. boaters, divers, general public, recreational fishing, NGO, environmental groups)
Group 3: School education users
Group 4: Other stakeholders with lower levels of interest and/or indirect relation to the project and its end-products.

It was decided that representative stakeholders within group 1, 2, and 3 would be contacted for a dialogue and feedback on end-products. Group 4 would be not be actively contacted but may receive information directly or indirectly when end-products are published at the end of the project.

3. Feedback from representatives of environmental case officers at County Administrative Board of Norrbotten

What maps do you have a need of?

- Maps that show the nature values are most useful. HUB (Helcom Underwater Biotope) maps, for example, need to be followed by explanation if they are to be useful. Vegetation maps don’t tell us what is important, you then need to know all the species to be able to use them.
- Maps of potential distribution of threatened/red list species are good to have. Maps of threatened HUBs can also be good (much better than just the HUBs).
- Natura 2000 habitat maps not used so much. Only within already protected areas as that’s where we have the cases. (Comment: may be because habitat maps have been so inaccurate, not used to concern about them?)
- Turbidity, wave exposure, substrate, and depth may be useful. Increases general knowledge
- Maps of human activities and impact are not so needed as cases often are very local and then a look at ortho images can easily detect. But, may be good to assess cumulative impact. Haven’t done that as much as should – maybe possible with these SEAmBOTH maps?!
- Want a guidebook on underwater species (vegetation mainly) in the Bothnian Bay! It should especially say what function the species might have.

How should the maps be outlined and packaged to be user-friendly?

- Complete, easy-to-understand metadata is important
- Some explanations as to what the maps show, why, and/or a link to where to find further information
- Good to have maps grouped together so all of them can be downloaded in one go – no risk of forgetting one then
- Very important maps are available to public. It is the actors/consultants whom need to provide the background material for cases.

4. Feedback from representatives of the Swedish Agency for Marine and Water Management

- Important collected data is made available in national databases.
- Maps of bathymetry are most important (and substrate)

5. Feedback from science high school teachers

- Suitable locations where we can bring students for field trips to study the marine life by water binoculars?
- What species can we expect to find? A guide to commonly occurring species would be good
- Maps where eutrophication is visible. Also, other water quality parameters on maps may be interesting to have
- Are there topics that students can make a small research project of their own about?
- If raw data is available, we can use it for practicing statistics etc. and make own studies of it
- Illustration of potential future effects of climate change in the Bothnian Bay would be interesting to see

6. Feedback from local dive club members and representatives of an environmental interest group

- Want a species guidebook for the local area. To learn to identify species while diving and be able to report them to online species portals (e.g. Artportalen in Sweden)
- Any information about the marine environment is interesting, we know so little!

7. Summary and feedback from Bothnian Bay Workshop 11.4.2019, Oulu

Organizer of the workshop: Metsähallitus, SEAmBOTH-project
Location: Oulu, 45special restaurant
Participants: 29
Timetable of the workshop:
12:00 Welcome and short introductions.
12:20 Introduction of SEAmBOTH-project.
13:20 Instruction of tasks in workshop and dividing groups.
13:30 Workshop part 1.
14:20 Coffee break.
15:00 Sea area planning.
15:30 Workshop part 2 instructions and dividing groups.
15:35 Workshop part 2.
16:30 Presenting results from workshops.
16:50 Summary, end words.

Shortly about working in the workshop

- In the first part of the workshop, work took place in stakeholder groups (recreational, fishing, industry & companies, planning & officials, conservation & research). Participants were divided based on their background/organization and so on. In the first part the condition and the use of the Bothnia Bay was discussed, based on the theme of the groups. In the end, groups decided the most important subjects/biggest problems/greatest challenges in the Bothnia Bay.
- In the second part, groups from the first part were dissembled and re-divided to new groups. The new groups had mixed participants from every stakeholder group. In the second part discussion was about the use of the Bothnian Bay and the issues discussed in the first part were put in order by significance and written down.

Workshops part 1: How the situation in Bothnian Bay should evolve? (Short summary from all groups)

- Predictions & studies in common use, public communication.
- More communication between organizations/corporations
- More discussion between different councils
- Municipalities should be more involved
- Development of fish steps and so on
- Development of grazing methods to protect the nesting of shorebirds
- Improvements on conservation of waters
- Founding of a community of natural parks
- Activating tourist agents
- Visibility to Bothnia Bay
- Increasing the usage of maps by "ordinary people"
- Taking better account on cooperative actions of different projects
- Sufficient reporting and high quality, specify by others than the project coordinator
- Improving the quality of river region's runoff
- Improving Metsähallitus' cold opinion on developing Röytä-island in Ii
- Taking city on board on developing the marines

Workshop part 1: The future of the Bothnian Bay – Good situation (Short summary)

- Attitude
  - Bothnia Bay is the source of the wellbeing for all, "living room"
  - Cooperation between different organizations
  - Recycle, control/monitoring
- More relevant data
- More resources
- More cooperation between experts
- No endangered species or habitats
- Good state of fish populations
- Conservation of underwater nature, not just islets
  - Big enough areas
- Up-to-date information about the Bothnia Bay constantly available
- Tourist agents know how to use the area in diverse ways
- Islands managed, open, no ticks
- Maintaining fishing culture!
- Different data sets comparable
- Up-to-date data
- Secure funding
- Human activity on sustainable level
- Taking into account the ecological impact and prevent the deterioration before it's happening
- Increasing the number of leisure boating destinations
- Connecting the island on the area with boat traffic
- Improving the condition of water systems
- Boat traffic ecological

Workshop part 1: The future of the Bothnian Bay – Bad situation (Short summary)

- Problems with plastic
  - Mostly caused by fishing
- Mining is affecting negatively
- Planning of sea areas doesn't have any effect
- NO communication between countries
- " Big hopes – no results"
- " No one is interested", no funding, no experts
- Terrace road to Hailuoto happens
- Emissions grow (fish farming, nutrient load)
- Shallow shores, which are important to the nature, will be built on
- Bothnia Bay will become polluted
- No access to natural parks
- False interpretation of data
- Divided data/database, hard to use
- Diversity shrinks, fauna and flora become simpler
- Environment becomes "worn out", which makes it less appealing to spend time in and harder to care about
- Eutrophication will continue

Workshop part 2: Discussion about the use of the Bothnian Bay (Short summary)

1. Do you think that every stakeholders' opinions have been taken into account equally in Bothnia Bay? What problems or challenges are there?

   - Hailuoto terrace road -project hasn't taken account on the voice of the nature, only traffic is accounted for. Also, sailors have problems with bridge openings (bridges have gotten shallower)
   - Problems with harbour of Röytä
   - Less money to leisure improvements
   - Conservation vs. utilizing
   - Part of tourism, and its consideration
   - Ordinary boat less people

2. What compromises about the use of Bothnia Bay could be done between the stakeholders?

   - Many different stakeholders can work in the same area – for example wind power, fish farming, tourism
   - There is need for compromises between forest owners and conservation (eutrophication)
   - Seal and cormorant compensations for fishers
   - Seal population management
   - Placement of buildings outside of the valuable areas (for example wind power)
   - Increasing local knowledge
   - Good planning (on advance)
   - No usage on the most vulnerable habitats, utilization of less sensitive areas
   - If nature's condition is deteriorated somewhere, it must be improved elsewhere

3. How to secure the conditions in Bothnia Bay?

   - Making everyone involved and trying to get everyone's voices heard
   - Supervision. Reducing emissions of plants. Minimizing the environmental effects of new projects. Managing the environmental load. Good legal control.
   - Research. Correct information (fishers, boat users). Making the research results public.
   - Adding awareness, publicity, attitudes
   - Controlling the littering!
   - Securing the funding. For example, environmental information, monitoring sea condition, and so on
   - Taking into account the condition of environment in financial use. Not deteriorating the conditions of nature.
   - Securing living conditions of fishes (breeding grounds)
   - Cooperation, national and international

4. How can we secure every stakeholders wellbeing in Bothnia Bay?

- Every stakeholder should participate on the same conversation, open dialog
- "Big maps" = all information is in one page
- No independent projects here and there, but more shared planning layers
- Cooperation: all groups with interests involved
- Different areas to different usage local/regional level, based on research (conservation, fishing, industry)
- Different stakeholders have different needs. Interaction – in same table! Conversation based on real information and research results. Researchers out!
- Different stakeholder groups heard equally
- Create open and conversational atmosphere

5. Other ideas that came up?

- More boating destinations to Bothnia Bay
- More workshops and conversation opportunities to projects
- Significance of voluntary work for example in restoring spawning areas
- Open access information is important!

Workshop part 2: Most important issues/biggest problems in Bothnia Bay

- Condition of the nature cannot get worse (mentioned in papers of two different groups)
- Condition of the sea
- Adding conservation of underwater nature (mentioned in four papers)
- Load to the environment
- Scattered loading
- Loading from the land
- Eutrophication (mentioned in three papers)
- Public communication
- Cooperation between nature parks + municipalities, countries and so on
- Securing the funding of monitoring the nature's conditions (mentioned in two papers)
- Climate change

8. Summary and feedback from Bothnian Bay Workshop 17.10.2019, Oulu

Workshop was organized in Kokardi-club and there were 30 participants. Workshop started with introducing SEAmBOTH-project (Essi Keskinen, Metsähallitus). Then Elina Virtanen from SYKE (Finnish Environment Institute) told via Skype about Zonation on Bothnia Bay. Then we watched a presentation from Juho Lappalainen (SYKE) about EMMA-work on the Bothnia Bay and after that Joonas Hoikkala (Metsähallitus) introduced us to different sea conservation areas. After this Jaakko Haapamäki (Metsähallitus) presented preliminary end products of SEAmBOTH-project. Then there was slightly different part with action painting workshop. In this part we painted together three Bothnia Bay -art works. In the last part on the workshop we examined the end products of SEAmBOTH-project and discussed how we could still improve the products and what other actions are still needed.

Most important notes from the discussion in the last part of the workshop

- Related to the end products:
  - o How to use the product is depended on the purpose, and the scale of the map. For example, human pressure map is usable in the large scale but in some cases would be good if it is possible to explore smaller areas in more details -> we will definitely need a digital version which can be used to zoom in on smaller targets.
    - Professional use vs. citizen use
    - Precise, smaller areas on the map on one time, interest of locals (for example own cottage beach)
  - o Different kind of needs -> we need different layers
    - Possibility to see what the layers hold (in easy way)
  - o Take into account the bigger public: Why do we need information on under water nature? What kind of nature is valuable? Why plants are important? -> We could offer information on these in leaflet/pdf/website/video (+lots of pictures). And specially in the front page of the map portal!!
  - o Proper definitions/keys, unambiguous/one explanation (easy to understand for public)
  - o Meta information, when is the mapping done/information gathered?
  - o Nature value map is interesting and useful to everyone, especially after when the data from Sweden is also usable
  - o “Discussion maps” with themes for specific groups, where you can see their impact, for example
  - o Updating the maps, for example new pressures (small dredgings)
    - Monitoring, updating new information
  - o We got rid of a seam between Finland and Sweden, but now we have a seam between projects
  - o 3D-modelling, where you can dive yourself
  - o Mandatory to get the data available on digital form and open access. Also, some ready maps available.
  - o All data in one place on border line, where you can examine them on top of each other
  - o Publicity and marketing are important. Important data needs to be in the knowledge of people and in use: we need to prepare for this when finishing data and after it! OBS. many haven’t even heard about VELMU-map service

Technical things:

- o Better view for deltas
  - Coloring of maps. For example, green and blue looks the same in pictures
- o Human pressure map could be simpler and easier to read if there were fewer classes
- o Hub-classes: How to separate them? How much is the biomass (size of the ball? Indication of biomass should be clearer)?
- o River effect: simpler data with combinations (remove water moss data)
- o There should be place names and area markings! For example, cities

Maps/data about following things:

- o Humus and other features of water (nutrients) water quality (visibility, human impacts, toxics)
- o Data of planktons
- o Salt
- o Diversity + coverage
- o Bottom invertebrates
- o Depth map 3 m and/or 6 m depth graphs
- o Human pressures should be on a map with nature values -> where are the conflict areas?
- o More general maps, for example nature types

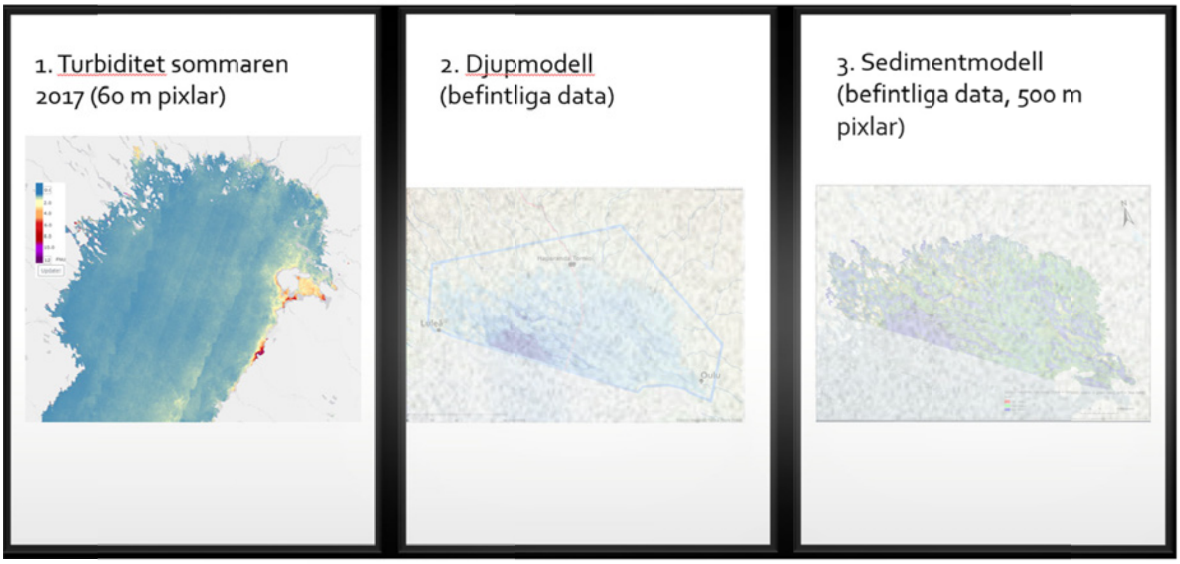
Other ideas and comments:

- o We should pay more attention on the global change and possible changes on our areas (note from organizers: climate change has not been studied on this project, but the effect on the underwater nature is now being explored by ECOnnect-project: http://www.metsa.fi/econnect)
- o We need pictures from Bothnia Bay, maybe on a map or some kind of picture bank. Would be important in evolving tourism. An idea: a webcam on some nice island. “Information boards” about underwater nature, placed in sea environment.
- o Games (Survivals on Bothnian Bay, Escape room in Bothnian Bay)

9. Summary and feedback from workshop on drafts of maps 2020-02-11, Luleå

During workshop with employees at the County Administrative Board of Norrbotten with work related to the Bothnian Bay.

Nine maps were introduced and handed out the participants. The maps were examples of types of maps that may be produced by the project.



Map 1 comments

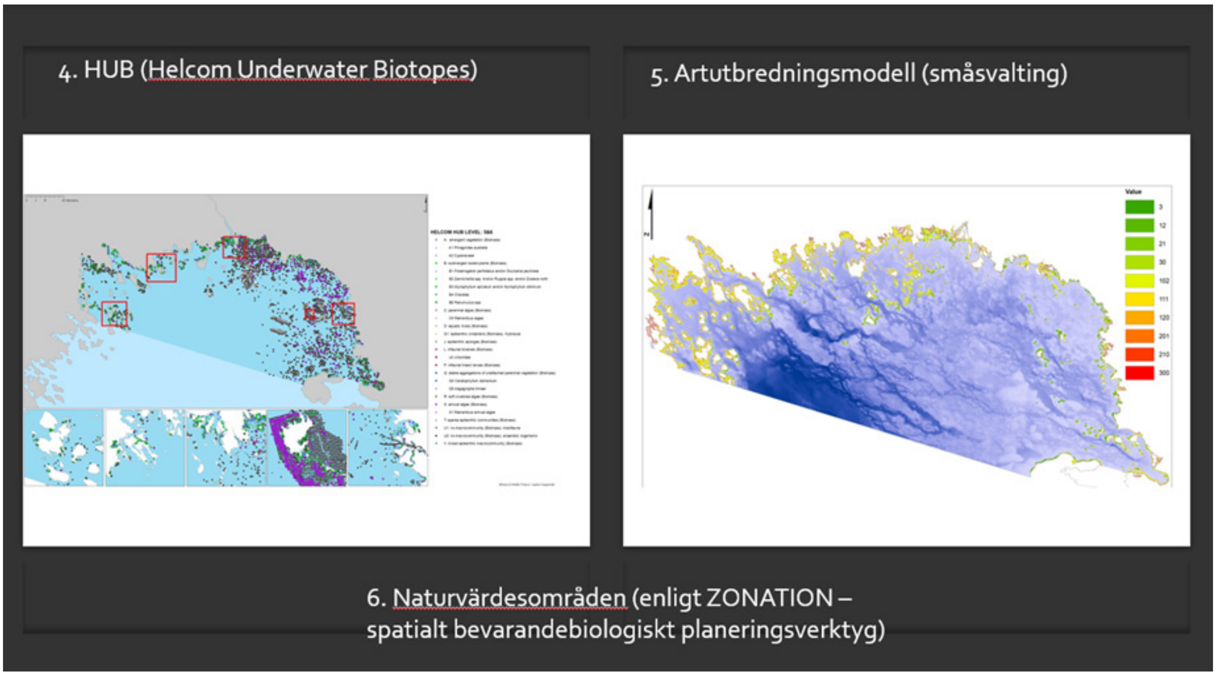
- Interesting in a time series. Can we get that?
- Turbidity used for status classification within the water framework directive. Very useful, especially to follow over time.

Map 2 comments

- Good depth maps are important for e.g. analyzing and assessing green infrastructure.
- Valuable when planning and executing field work/sampling.

Map 3 comments

- Sediment type map would be good to have together with map 3.
- Map 1-3 may not be needed to be published externally. Not so much use for general people.



Map 4 comments

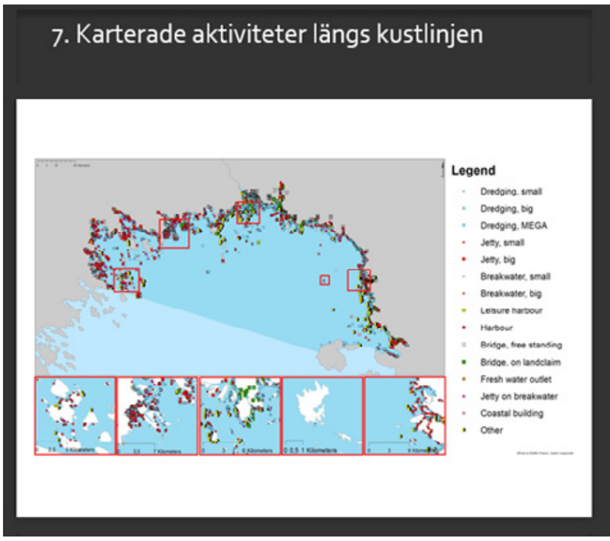
- Not used by us today but is a good way of illustrating this kind of data.

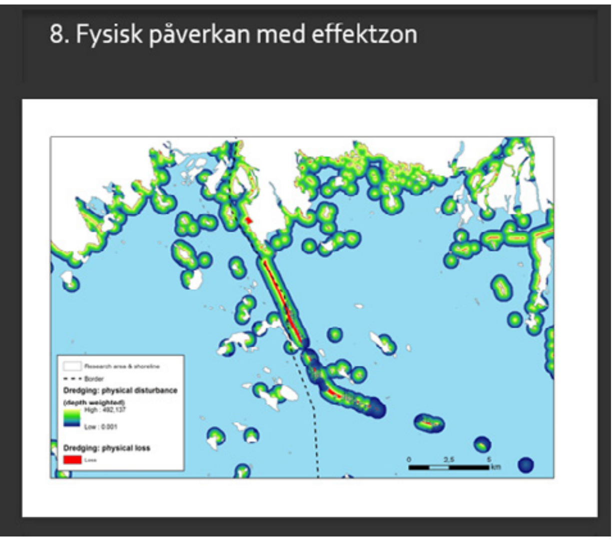
Map 5 comments

- Add indication of probability to the map so level of quality/reliability can be seen.
- Very useful to know where to direct inventories to. And as basis for decisions and nature protection measures.

Map 6 comments

- What is it based upon? How has it come together? Need some kind of explanation.
- Interesting and useful.





Map 7 comments

- Useful within water framework directive work. For status classification and suggestion of measures.
- Informative map. Is it possible to state what the type of e.g. jetties are (what is SMALL and BIG?)? State in metadata time of mapping. Would be very good to have follow-up of this regularly to see changes over time. May be interesting for people also externally.

Map 8 comments

- On its own it may lead to increased exploitation as it looks like everything is already exploited. Which opens for further exploitation. Is best used if combined with map 6 of nature values. Then you can see human activities in relation to valuable nature areas and where to direct or stop new activities.
- Good to use to find unexploited areas which overlap with habitats for certain species.

In general, for all maps:

- Good to have the probability stated at the modelled maps, to have some kind of measurement of the reliability of the map. Also, the governing factors included in the model, which ones of them were most important.
- Think about colours of the maps when publishing them. Some combinations are more difficult for people with colour blindness.
- All maps can be published internally. For external use, not so sure if any of them at all is relevant?

8. Activity 7.2 Guidelines report

Biological field inventory methods

Suitable methods for biological field sampling in the project area

- A survival suit or a dry suit is essential for doing shallow wading points in the northern Bothnian Bay because the shores are so gently sloping and the shallow shoreline is wide, that approaching by boat is often impossible, but boots are not enough.
- Wading with water binoculars is a good method for biological field sampling in the very shallow areas, for example along shores and river estuaries, as long as the bottom substrate is not too soft and muddy. If bottom substrate makes wading unsuitable then snorkeling is tan option. Snorkeling is easiest applied when depth is about 0,6-1,0 m. A dropvideo camera can be used when depth is more than one meter. With drop videos the species identification is more difficult, and it is usually only possible to get to genus level. A rake is preferably used in addition to the video camera to take a sample of plants from the bottom and identify exact species. Diving is the best method for collecting species coverage data of highest quality in areas deeper than one meter. The method is however time consuming, requires specialized equipment and skills and hence is the costliest of all methods.
- In the shallow areas of the Bothnian Bay small inflatable boats and SUP boards are the best means of transport. A bigger boat can be used for longer distances and for moving the smaller vehicles and field staff from one place to another.
- When diving in the often-murky waters of the Bothnian Bay a torch and a knife or a cutter are vitally important.
- Water moss species and algae species can usually not be identified underwater, samples are always needed to be taken for closer examination.
- Drone could be used for shallow water inventories in addition to field sampling, and especially for defining Natura 2000 habitats.
- Check the exact water level on your site at least once or twice per day from the closest water level station and adjust the measured depth - water level can change 2-3 m in just a few days in the northern Bothnian Bay. Adjust your measured depth according to the water level in the data protocol.

Dropvideo analysis

- For analysis of dropvideos we have used the method described in the VELMU-manual and recommend it for use within the area. A continuous analysis of a 30 second video sequence provide a quick and the most reliable opportunity for identification of species and their percentage of coverage.
- Expected level of species identification from dropvideo (note that this depends upon quality of video and environmental circumstances. With complementary samples taken by a rake the level of identification increases substantially).
  - Species level: Potamogeton perfoliatus, Stuckenia pectinata, Alisma wahlenbergii, Tolypella nidifica, Najas marina (southern Bothnian Bay), Aegagrophila linnaei (ball shape), Lemna trisulca, Nuphar lutea, Nymphaea alba, Sagittaria sagittifolia x natans, Callitriche hermafroditica (when flowering), Hildenbrandia rubra, Ephydatia fluviatilis, Spongilla lacustris, Saduria entomon, Anodonta anatina, Pomatoschistus minutus (the only species within the genus in the area), Cordolyphora caspia (the only colony-forming polyp within the area), Zannichellia palustris (only Z. palustris can be found in the Bothnian Bay)
  - Genus level: Potamogeton sp., Isoetes sp., Elatine sp., Callitriche sp., Ranunculus sp., Myriophyllum sp., Vaucheria sp., Sparganium sp., Fontinalis sp., Eleocharis sp
  - Charales or Chara/Nitella.

Identification of species

- Species guidebooks for specifically the northern Bothnian Bay has been developed during the project. They can be found and downloaded from the SEAmBOTH webpage https://seamboth.com/results/
  - o Introduction to marine species of the northern Bothnian Bay – a shorter guide to give you an overview of the most common underwater species and families of plants you may find in the bay, their characteristics and common habitats.
  - o Marine species of the northern Bothnian Bay – a comprehensive guide of almost all plant species found in the water of the bay, and some of the most common and easily seen animals.
  - o Perämeren vesikasvio – the Finnish language comprehensive guide to almost all aquatic flora that can be found in the northern Bothnian Bay

- Literature and other sources we have found helpful when identifying species from the Bothnian Bay:
  - Den nya Nordiska floran / Suuri Pohjolan kasvio, Mossberg, B. & Stenberg, L. 2003, Wahlström & Widstrand, Tangen.
  - Alger vid Sveriges östersjökust, Tolstoy, A. & Österlund, K. 2003, ArtDatabanken, SLU, Uppsala.
  - Blindow, I., Krause, W., Ljungstrand, E. & Koistinen, M. 2007. Bestämningsnyckel för kransalger i Sverige. [Key to the Swedish species of charophytes] – Svensk Bot. Tidskr. 101: 165-220. Uppsala. ISSN 0039-646X
  - Artfakta at ArtDatabanken, https://artfakta.se/artbestamning
  - Den virtuella floran, Naturhistoriska Riksmuseet http://linnaeus.nrm.se/flora/
  - Charophytes of the Baltic Sea, H. Schubert & I.Blindow, 2013.
  - Retkeilykasvio, L. Hämet-Ati et al. 1998, Luonnontieteellinen keskusmuseo.
  - Finnish Biodiversity Info Facility www.laji.fi

Depth data

- Data from aerial based survey (Lidar and to some degree also passive light sensors from aerial surveys and satellites)) would be very useful for avoiding navigational hazards and mapping the shallow water (~ 0-5 area), unfortunately this was not available in the SEAmBOTH project as initially planned. An alternative/complementary way to improve the shallow water mapping is to integrate automated surface vehicles (ASVs) in the acoustic surveys. There are already functional systems on the market, and there is promising research to develop fast hydrofoil-based systems that provide small but still stable survey platforms in some degree of wave exposure.
- A conversation to be had for similar future project is what survey effort and data quality the project strives for. It was apparent in this project that more effort per area results in much more details, however, it also restricts the total area of the survey. The examples provided in this report can hopefully serve as valuable input to strike the right balance for project needs.
- The use of Lidar for shallow water mapping may provide high resolution data of the seafloor in shallow areas. However, such data is usually surrounded with restrictions due to national security concerns. Lidar measurements are highly specialized and requires both advanced technique and knowledge. In order to do a mapping with Lidar today in Sweden, a suitable company needs to be contracted via competitive tendering. Due to information security aspects of such assignment, the Swedish law requires a certain administrative process to be followed. The experience from this project is that the administrative process requires substantial time and resources. A competitive tendering should be started years (two years at least) before the measurements are planned to be executed in field.
- Sharing depth data (or any other data about seafloor geography) between partners and with the public has been a challenge in this project. Though we started early with permissions, the result has been unsatisfactory and caused some major disturbances to the project. On the Finnish side it has been more successful than the Swedish side, and SGU even got permission to survey a small portion of the Finish waters. Our best advice for future projects is again to start early, but also to provide more specific examples of how exactly the final results will look like (which is a challenge before the project has been completed…). Hopefully the SEAmBOTH data once published, as well images from this report, can provide some of the needed examples and improve the dialog and understanding between the agencies responsible for permissions, and the applicants.
- According to the TERRITORIAL SURVEILLANCE ACT, the detailed bathymetry and seabed substrate data is subject to authorisation. The authorisation process for sharing and publication of bathymetry or seabed substrate data may take a long time. Thus permissions (for data sharing and publication) should be discussed with national defence forces and their representatives already in the early phase of the project.

Geological field surveys

Techniques/methods/equipment recommended for geological surveys in the project area

- SGU experienced unique challenges in the Haparanda pilot area included turbid and largely unchartered exposed but shallow waters, this led to quite time intensive survey operations. The main vessel SV Ocean Surveyor had difficulties navigating safely due to old charts, and the small launch Ugglan had difficulties operating in the exposed rough waters. In order to adapt to these conditions, the two vessels were working together to open safe passages for the large vessel where possible in order to survey new deeper areas and also to sample on areas already mapped by the small launch. One additional challenge included combining sonar data from multiple sensors, especially backscatter/sonar mosaic data from three different systems (this was solved quite well in post processing operations). For improvements, we believe this kind of survey can benefit greatly by having a Lidar and / or drone and maybe satellite survey done of all shallow water areas to optimize logistics and navigation safety. Also, using Automated Surface Vessels to assist in mapping the shallow waters is a promising technology to make better use of ship time and to decrease the carbon footprint of the survey operations.
- For geological seabed surveys, combined use of various acoustic-seismic investigation and sediment sampling methods are needed. Acoustic-seismic surveys should include both a sub bottom profiling (echo sounding) and seismic profiling. In addition, to provide full-coverage bathymetry and seabed topography, as well as imaging seabed surface features/structures, multibeam echo sounding and side scan sonar imaging are essential. Ground-truthing by sediment/seabed substrate sampling and using an underwater video camera are needed.
- Survey effort: It was apparent in the overlapping maps along the border area that higher resolution multibeam surveys done on the Swedish side allowed for more detailed interpreted maps than the wider swath lower resolution survey on the Finnish side. High resolution modelling was deemed to only be feasible on Swedish data (both due to sample number and data quality). However, high resolution survey cost more and take more ship time, especially in the shallow water depths. It will be important in future similar work to decide what map resolution (thematic and spatial) and quality is needed when deciding on the survey effort per area.
- Geological/seabed substrate classification schemes should include various substrate classes/geological units as the seabed of the study area is very heterogenous. Here we have used following classes: bedrock, till/diamicton, sand and gravel, mixed sediment (glacioaquatic), glacial clay (rhythmites, varved silty/sandy clay), postglacial clay (sulphide bearing clay), gyttja clay, and recent mud.
- The most striking broad scale geomorphological features of the area are canyons or canyon-like seabed features. These features are often tens of meters deep, hundreds of meters wide and kilometres up to tens of kilometres long depressions at the seabed. In addition to the main features mapped, the sonar data and a few sample locations indicates that small patchy hard clay structures are more common in these areas than the maps show. Sampling has to be done very carefully and based on high resolution sonar data to identify these features since they typically have small and patchy distribution.

Data collation

- Data tables should be collated by the people in charge of the data to avoid mistakes.
- Harmonization of data between countries is a priority. Fortunately, national monitoring data collection criteria are same between Finland/Sweden.
- Most important would be that data scientists share their information of how they are doing things, to increase the cooperation
- Metadata format should be harmonized between countries

Modelling

- Most important and relevant predictors in the SEAmBOTH project area are gradients that describe freshwater-salinity continuum, bathymetry, substrates and turbidity. Most importantly, due to the extremely shallow nature of the project area, the exact shoreline information creates challenges for building ecological models, as the shoreline may shift kilometres in “low tide”. Thus, for the future, good idea would be to produce some sort of minimum/maximum shoreline, where from recent history, using for instance water level information, EO and land uplift data, reference shoreline (mean), and its maximum deviation from that reference, would be produced. This would ease the modelling part, where “exposure above sea level” would bring valuable information for modelling distributions of species tolerant for this shift, and on the other hand, modelling distributions of species which are rather sensitive to concurrent “exposure to above sea level”.

- Suitable resolution depends on the purpose. Best way of doing ecological models, is to model the phenomena at the scale where phenomena occurs, for instance, if species are living in a certain shoreline, fine-scale models (resolution of meters) would come into question. However, this is not usually possible due to the resolution deficiencies of predictor data and computational restrictions. If models are produced at a fine resolution, it´s always easier to upscale the resolution (aggregate) than downscale, as the true phenomena may not be captured during the downscaling (this of course does not apply in all situations, say for instance in downscaling salinity from 1 nmi to 1 km)
- Comparisons of different results depending on resolution of bathymetry and substrate e.g. pilot areas vs project area models
- Nature value analyses depend on the input data, i.e. ecological models. Accuracy of the ecological models instead depends on the accuracy of predictors, adequacy of species samples in relation to its environmental tolerances, and of the geographical area in question. Modelling becomes challenging, if the environmental gradient is under-sampled in the area where models are developed. If ecological data is not present, also expert opinion can be used, for instance in the form of participatory mapping
- Environmental variables (salinity, turbidity, phosphorus, nitrogen etc.) should be gathered in a series with fixed sampling sites to get a long-time average for modelling, in most of the cases, but then again there are situations where actually the extremes determine species distributions. For instance, concurrent hypoxic events, even for short periods may deteriorate ecological communities, but this is not usually seen in the long time averages. Same applies to other environmental variables as well.
- If accurate bathymetry data is not available for modelling purposes, most important is to get the trend right. Meaning, declining by distance from the shoreline, or sandy beach. That is to say, digital elevations models are easily available, using their information close to the shore the bathymetry trend can be corrected, and sandy beach usually also continues as underwater parts of sandy shore below the water, which is important information for some species preferring sandy substrates.

Satellite remote sensing

- Protocols for sampling and measurement methods for chlorophyll-a, colored dissolved organic matter (CDOM), turbidity, suspended particulate matter (SPM) and Secchi depth have been developed. By using the latest protocols we can ensure a high quality and comparable in situ measurements from all over the bay.
- Water quality parameters such as turbidity and CDOM can be estimated well in the Bothnian Bay using Sentinel-2 observations. The water quality estimates provided by high resolution instruments are especially valuable in coastal regions, whereas moderate resolution instruments can cover open sea areas with more frequent coverage.
- With Sentinel-3 OLCI data, examples of Chl-a time series with good correspondence with station sampling were shown at many of the investigated stations. However, the best performing Chl-a algorithm (MPH) was not developed for areas with low Chl-a concentration and extreme aCDOM (brown/humic) waters and over stations with this combination of water type the performance was not convincing. Dedicated development of an algorithm to estimate Chl-a in high aCDOM waters is a task for future research and development projects.
- The SEAmBOTH validation efforts provided insights on the performance of some publicly available algorithms in Gulf of Bothnia waters. As one example, the Neural Net algorithm (C2RCC) that also is available and downloadable as a standard Sentinel-3 product from EUMETSAT, was tested with unsatisfactory results for e.g. chlorophyll a. Promising results could be identified for some stations, but the same algorithm did not perform well everywhere. Hence, no fixed processing chains, or "on-the-shelf" product, for generation of water quality products with Sentinel-3 data in the Gulf of Bothnia could be defined through this study.
- Development of water quality algorithms over dark water types requires long time series before a sufficient level of confidence in the results can be reached. We recommend that water quality sampling is kept at high level in this region, and that the sampling follows the optical protocols utilized here. In addition to determining the in-situ concentrations of Chl-a, CDOM and turbidity, it is also important to collect more data on the inherent optical properties. Getting improved information about the water depth in coastal areas is also important.

Marine management

- Sharing knowledge and experiences is very important, we can learn a lot form each other. The marine environment and human activities surrounding the habitats are very similar. Further cooperation recommended for example regarding management plans and permissions within Natura 2000 areas.
- The presence of land uplift together with highly varying water levels in the northern Bothnian Bay calls for a more flexible approach to defining borders of habitats.
- Mudflats and sandflats that are sometimes covered by water and sometimes above are today an unrecognized habitat in Finland. In Sweden they are defined as the Natura 2000 habitat 1140. Not recognizing them mean they face a risk of being overlooked in conservation and for protection measures.

- Several the Natura 2000 areas in the SEAmBOTH project area are today not suitable in terms of extension to protect what is intended. Those would need a revision of borders in the future.
- For future revision of the HUB classification system, we suggest considering including a number of biotopes of species commonly occurring in the marine habitat of Bothnian Bay but that today are not identified as HUBs. Those are mainly biotopes with species of a freshwater origin.
- Managers and decision-makers have a great need for data and information on the marine environment of the area (basic background data such as depth and substrate, distribution of species and endangered species, appointed valuable habitats to name a few). Such information needs to be easily available and understood. Preferably gathered to one or a few sources at the most.

Suggestions from users to make maps available and easy to use

- Maps should be easy to find on digital, online map portals. Collecting information in a national database/map portal is preferred. For users around the Bothnian Bay it is also beneficial to be able to access and use maps across the border.
- Additional information to complement the maps about why certain plants, nature etc are important. To help the user understanding the maps. Pictures to illustrate what the maps show may also help the user.
- Proper meta data which is easy to understand. Must explain how the map came together.
- For maps based upon models (e.g. potential species distributions), the map should include some indication of probability so the level of quality/reliability of the map can be seen.
- The colouring scheme of the maps are important, some colours are very difficult to see. For example, blue and green may appear as the same colour.
- Most important of all, people need to be informed about the existence of marine data and maps, where to find and how to use them, otherwise they are of no use.

Where do we have the most severe lack of knowledge and data?

Biological field surveys

Finnish side, most severe lack of knowledge:

- Differentiating between some reefs and sandbanks which appear on top of each other in substrate models
- Directed search of Macroplea pubipennis north of Oulu
- How do different human pressures affect underwater nature?

Finnish side, lesser lack of knowledge:

- Directed search for Crassula aquatica along the coast
- Search for Chara baltica, whose identification in the Finnish side is not sure

Swedish side, most severe lack of knowledge:

- Need of more macrophyte inventories. The coast is far from fully covered but has now got some inventories as a good start. The middle and outer archipelago has a very limited of inventories. Both shallow areas, close to the islands, as well as deeper areas are in need of inventories.
- Glo lakes. There are many along mainland as well as on islands and hardly any inventories of them at all.
- Reefs and sandbanks. To differentiate them for mapping purposes. To increase knowledge of plants and animals living on/around them. Probably many more water mosses and algae species than what we have found up until today.
- Directed search for Hippuris tetraphylla along the coast.
- Directed search for Alisma wahlenbergii. Today, there are two main areas where they are known to exist but there is potential for more areas.
- Directed search for Macroplea pubipennis to better understand its distribution along the whole of the Bothnian Bay coast.

Geological field surveys

Many areas still lack high resolution depth and seafloor substrate data. Some data can potentially be found and further improved upon at the Hydrographic Administrations of each respective country, but many areas have very poor and old data. For example, the few areas in the shallow offshore areas that was surveyed, showed a complex seafloor topography with many interesting features that we still know little about, partly due to the challenging navigational hazards in the region, which made survey work dangerous and slow. Like in many other places, the notorious “white ribbon” (the area between what can easily be surveyed from the air to the deep waters which are efficient to survey from a ship) has poor data in most of the Bothnian Bay region. To improve the geological and biological maps we need to be able to collect high resolution data in a cost-efficient way in these areas.

High resolution modelling of substrates and other seabed features will be an important part of future work but is dependent on high quality data. To further improve the usefulness of these kind of models, geological data from both shallow and deep field work (whether it is mainly done for biological or geological reasons) needs to be improved, and shallow water remote sensing needs to be combined with deeper acoustic surveys to further improve seamless maps in the Bothnian Bay region (and include the areas south of the SEAmBOTH study area). This would enable better and more representative maps of abiotic habitats and Natura 2000 areas alike.

What are our most important areas/issues for research/work in the future?

- River estuaries are very interesting and super important. We have started the mappings in 2017 but there are still plenty of areas to map in Finnish side and even more on the Swedish side. In addition to vegetation mappings salinity samples could be taken regularly in different areas and from different depths. Maybe the most interesting future research with river estuaries would be to choose one river estuary and follow & map it very closely. For example, Tornio river estuary (from both Finnish & Swedish side) with daily salinity samples and more detailed mapping of vegetation both in shallow & deep areas. Fish & birds could also be studied.
- The effect of fluctuating water levels (mainly due to strong winds) would be an interesting thing to research in the Bothnian Bay. How it affects the species in the area, for example in 2019 a lot of Charales species were burnt by sun with the water level being low for a long period. Also, a lot of other vascular plants were affected by the dryness.
- How are underwater areas and their connected flora and fauna affected by human activities? It would help us to better assess zone of loss and disturbance for different activities. It is important to understand such effects in order to ensure the right measures are taken when it comes to planning and decision-making of human activities by the sea.
- To improve the use of remote sensing within the northern Bothnian Bay, water quality sampling needs to be kept at high level in the region, and that the sampling follows the optical protocols developed within the project. In addition to determining the in-situ concentrations of Chl-a, CDOM and turbidity, it is also important to collect more data on the inherent optical properties. Getting improved information about the water depth in coastal areas is also important. Dedicated development of an algorithm to estimate Chl-a in high aCDOM waters is a task for future research and development projects.
- Submarine canyons are key areas for understanding the transfer of detrital sediments (including e.g. harmful substances) from the coastal areas to the deep basins. The seabed/sediment dynamics and related biological and physicochemical processes should be studied in these key areas.
- In the current project, most ecosystem values were found in the very shallow areas. This is due to the high biodiversity on these areas but also due to how we have defined nature values. If a complete food web approach would be implemented, also the values of the deeper seabed habitats to fish and other animals could be better understood and managed, and ultimately put the seabed maps to even more work. The connection between substrate and seabed features with infauna and fish is one area that can be improved.
- Survey technologies needs to be more efficient to be able to cover larger areas with high quality data. It will enable managers to have a more complete view of important features and ecosystem functions when they consider trade-offs and priorities in a sustainable blue economy. A promising way is to combine remote sensing data from the air (Lidar, aerial surveys and satellites) and ship-based surveys which are completed by above, on and below water drones. Drones are run on efficient electric battery powered engines and could significantly help reduce the carbon footprint of seabed surveys, as well as improving cost to data quality ratios. More research and implementation are needed.
- In the future, possibilities of EO to be integrated with ecological modelling, should be thoroughly investigated. Satellite-derived bathymetry, turbidity, and temperature are just few examples, which would improve the accuracy of species distribution models. Thus to continue the refinement of ecological models with satellite-derived environmental products, and with detailed substrate models, should be a priority.

9. Bottenfaunaprovtagning i Haparanda skärgård 2018

Benthic survey in Haparanda archipelago 2018
Erik Karlsson, Kasparas Bublys

Bottenfaunaprovtagning i Haparanda skärgård 2018
Benthic survey in Haparanda archipelago 2018
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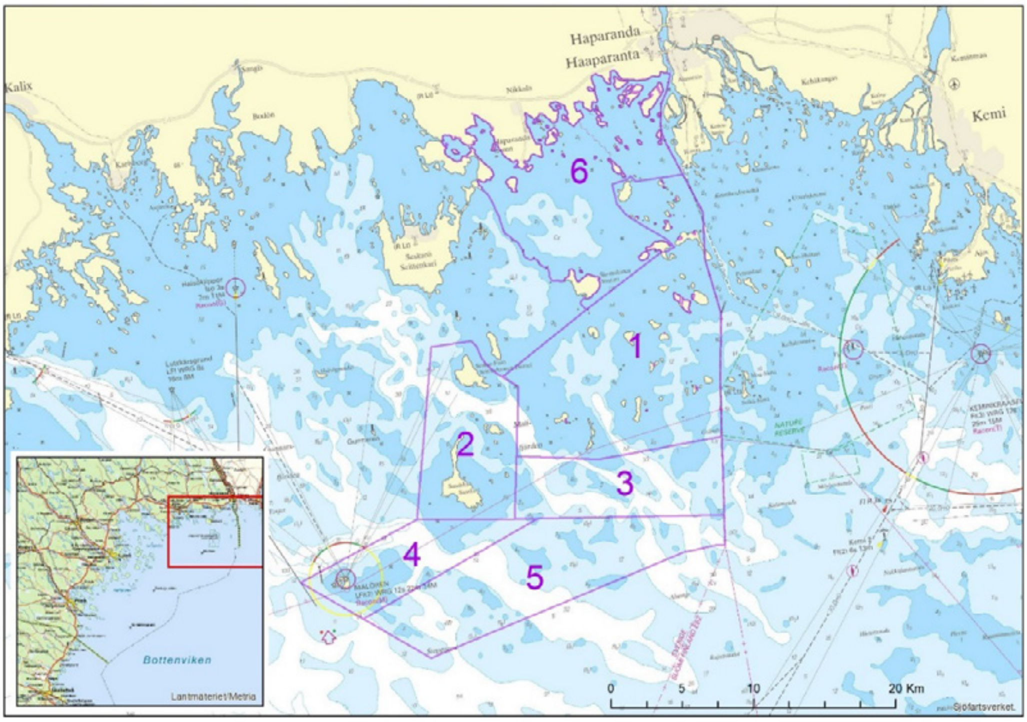
Bibliografisk referens: Karlsson, E., Bublys, K. (2019). Bottenfaunaprovtagning i Haparanda skärgård 2018. Öregrund: Sveriges lantbruksuniversitet.
Nyckelord: Bottenfauna, Haparanda skärgård

Bakgrund

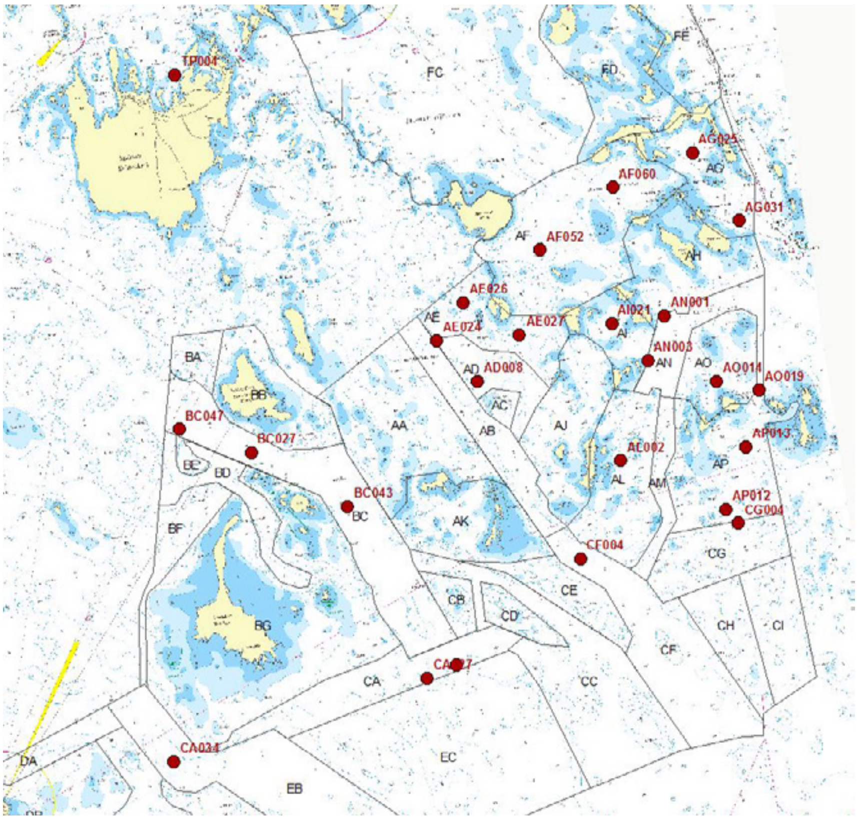
Inom Interreg projektet SEAmBOTH karterade Sveriges Geologiska undersökningar (SGU) havsbotten i Haparanda skärgård under sommaren 2018 (se figur 1 för undersökningsområde). Under denna kartering togs även bottenhugg med Van Veen-provtagare för att samla in information om vilka djur som lever i bottnarna i olika delar av området. Bottenhuggen genomfördes med samma metod som används inom den nationella miljöövervakningen av mjuka bottnar för att säkerställa att insamling, artbestämning, konservering etc. blev jämförbar.



Figur 1. Undersökningsområde för SGU med prioritering av olika delområden.

Metodik

Provtagning skedde ombord undersökningsfartyget Ocean Surveyor i samband med SGUs kartering av Haparanda skärgård 2018. I enlighet med nationell metodbeskrivning (Leonardsson 2004) togs ett bottenhugg med Van Veen-provtagare (huggyta: 0,1002 m2) på totalt 25 olika punkter, varav en låg utanför undersökningsområdet (se figur 2). Provpunkter placerades slumpmässigt ut för att täcka in området representativt med avseende på djup, struktur och lutning av botten. Punkternas djup varierade från 9,8 m ner till 61,0 m. Prover sållades med hjälp av en maskstorlek på 1 mm varefter djur och kvarvarande materialkonserverades i 95% etanol. På laboratorium sorterades fauna ut och artbestämdes till lägsta möjliga taxonomiska nivå med hjälp av Stereolupp. Varje art/taxa räknades och sedan vägdes arter/taxa (våtvikt i milligram) enskilt för varje prov. Prover konserverades åter i 95% etanol efter avslutad analys och arkiverades. Data rapporterades in för lagring till Svenskt HavsARKiv (SHARK). Vid analys hämtades tidigare data från SHARK som referens. Då inga bottenhugg hade tagits i området de senaste 10 åren användes samtliga bottenhugg tagna i Bottenviken mellan 2010 och 2019 på djup från 9,0 m till 65,0 m som referensdata.



Figur 2. Undersökningsområde med utmärkta provtagningspunkter för bottenfauna.

Resultat och diskussion

Totalt påträffades 10 olika arter/taxa på 23 provtagningspunkter inom undersökningsområdet. I genomsnitt påträffades 2,83 arter/taxa per prov. På två av de punkter som undersöktes observerades ingen bottenfauna, varav den punkt belägen utanför undersökningsområdet var en av dessa. Den biologiska mångfalden kan därför bedömas som relativt låg.

De dominerande arterna i undersökningsområdet, sett till abundans, var vitmärla (Monoporeia affinis), nordamerikansk havsborstmask (Marenzelleria spp.) samt fåborstmask (Oligochaeta spp.) (se tabell 1). Vitmärla är ett kräftdjur som spenderar större delen av sin tid nedgrävd i leriga bottnar och livnär sig på organiskt material, detritus, som faller ner till havsbotten. Vitmärlans bestånd är känsligt för föroreningar och syrebrist och används därför som biologisk indikatorart för Östersjön. Nordamerikansk havsborstmask är ett samlingsnamn på tre stycken invasiva arter (Marenzelleria viridis, Marenzelleria neglecta samt Marenzelleria arctia) som introducerades till Östersjön på 1990-talet, antagligen genom ballastvatten från fartyg. De lever normalt nergrävd i leriga sediment på relativt djupa bottnar och livnär sig, precis som vitmärlan, på detritus. Fåborstmask lever i mjuka sediment och livnär sig på detritus som intas tillsammans med sediment. Fåborstmask är, till skillnad från vitmärla, erkänt tålig för syrebrist och föroreningar.

Samtliga arter som observerades är allmänt förekommande i nordliga östersjön och ingen av de observerade arterna/taxa återfinns på Artdatabankens rödlista (ArtDatabanken 2015).

Tabell 1. Genomsnittlig abundans (antal per m2), biomassa (mg per m2) samt frekvens av förekomst i prov för samtliga arter/taxa som observerats.

Art	Abundans	Biomassa	Frekvens
Monoporeia affinis	88,2	227,74	0,76
Oligochaeta spp.	53,5	107,70	0,68
Marenzelleria spp.	17,2	205,43	0,52
Pisidium spp.	5,6	30,34	0,16
Chironomidae spp.	2,8	4,67	0,20
Saduria entomon	2,4	804,47	0,20
Praunus flexuosus	0,8	22,87	0,08
Gyraulus crista	0,4	0,40	0,04
Pallaseopsis quadrispinosa	0,4	1,28	0,04

Abundansen av bottenfauna varierade kraftigt mellan prov med en genomsnittlig abundans av 171 individer/m2. Abundansen av bottenfauna får anses vara relativt låg men i linje med vad som har observerats i referensdata från Bottenviken och inom ramen av det förväntade. I jämförelse mot referensdata var abundansen av fjärdermygglarv, Chironomidae spp., låg i undersökningsområdet. Detta förklaras med att provtagning inom miljöövervakning normalt sett sker i maj-juni månad medan föreliggande undersökning utfördes i mitten av september, då mängden fjädermygglarver bör ha minskat kraftigt av naturliga skäl. I undersökningsområdet observerades ett enstaka exemplar av Ribbskivsnäcka, Gyraulus crista, som inte hade observerats i referensdata. Undersökningsområdet ligger dock inom artens utbredningsområde.

Gyttjelera var det klart vanligaste substratet då 17 utav de 25 proven bestod av det. Detta återspeglas även i de arter/taxa som fanns i proverna då vitmärla, nordamerikansk havsborstmask och fåborstmask alla är arter som trivs väl i och karaktäriserar denna typ av substrat. Då övriga substrat endast återfanns i enstaka prov blir jämförelse mellan substrat omöjlig. Förekomst av svavelväte indikerar att syrebrist kan förekomma i sedimentytan. Det förekom ingen lukt av svavelväte på någon station inom undersökningsområdet och därför kan samtliga bottnar som undersöktes bedömas vara syresatta.

Yttemperatur och bottentemperatur varierade båda avsevärt men någon effekt på abundans och biomassa av bottenfauna kunde inte urskiljas. Någon signifikant effekt från djup på abundans av bottenfauna kunde heller inte konstateras medan det fanns en positiv korrelation mellan ökat djup och högre biomassa av bottenfauna. Den ökade biomassan är dock kraftigt kopplad till enstaka stora individer av Skorv, Saduria entomon, som återfanns på de två djupaste stationerna.

Sammantaget innefattar undersökningsområdet ett lågt antal arter/taxa med låga individtätheter av bottenfauna. Artsammansättningen karaktäriseras av arter som är kopplade till leriga sediment med detritus som huvudsaklig föda.

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10. Undersökning av bottenfauna i Råneåfjärden

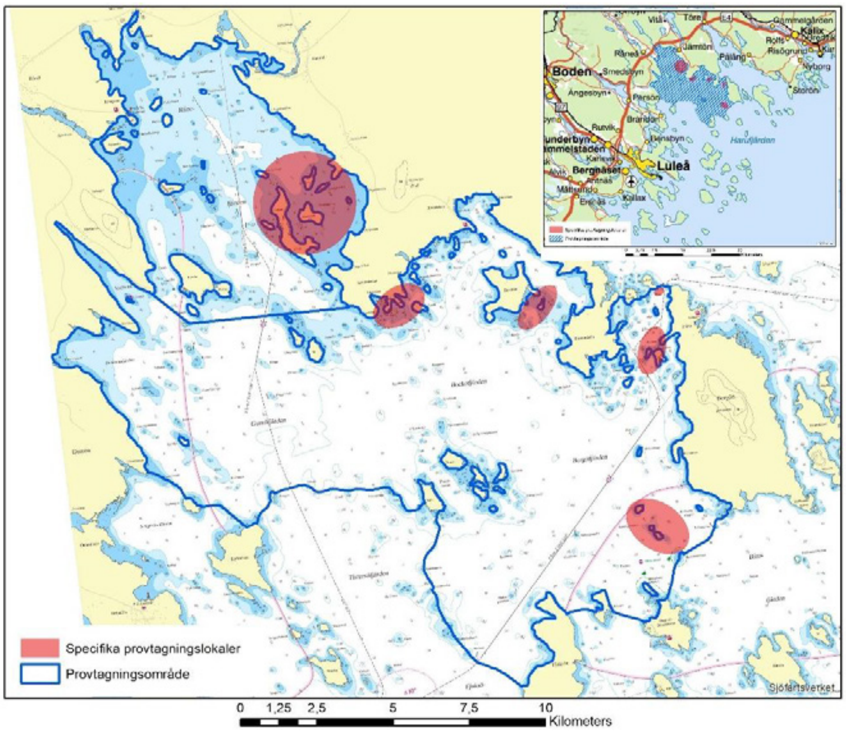
På uppdrag av Länsstyrelsen i Norrbottens län

1. Inledning

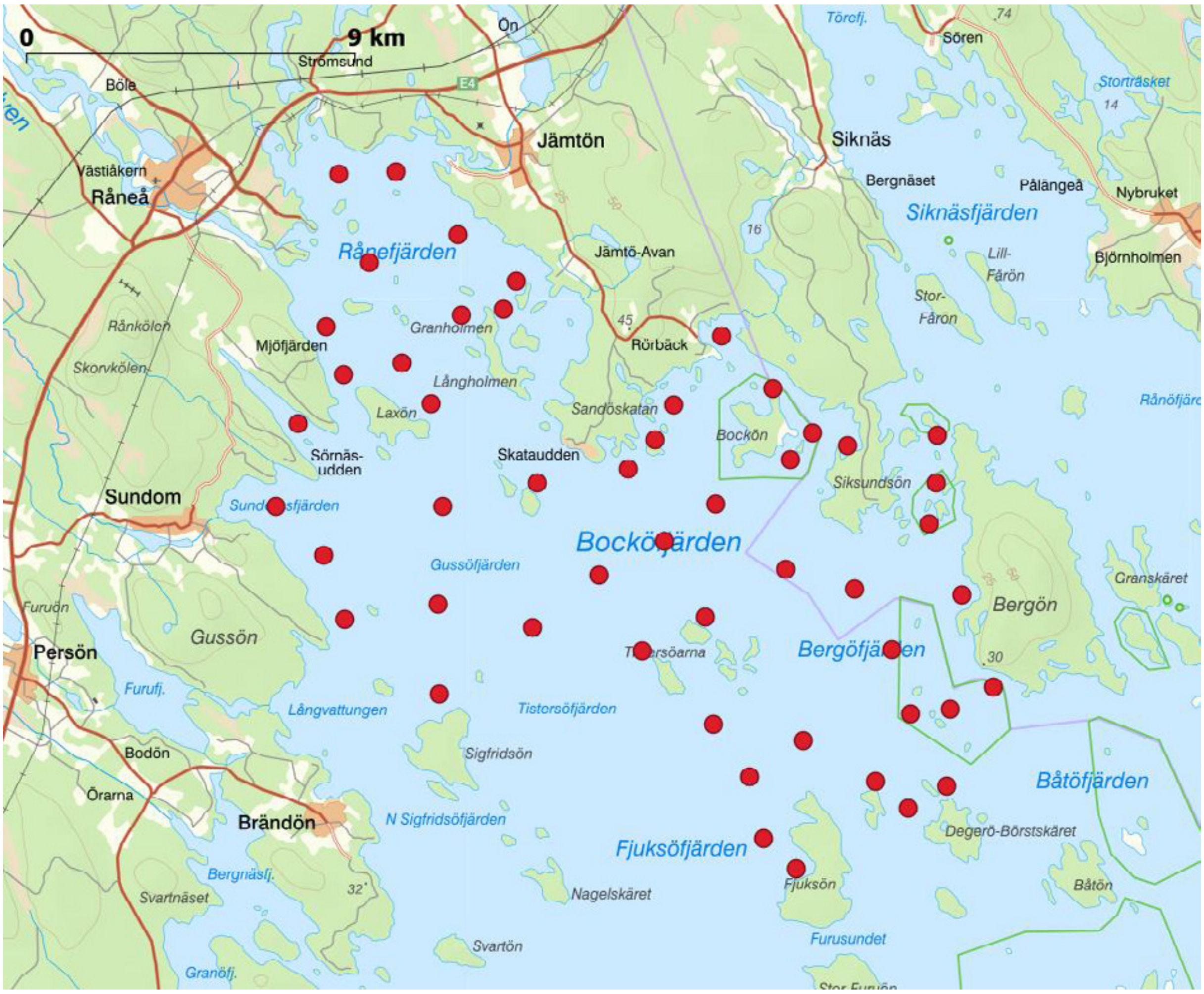
Pelagia Nature & Environment AB har på uppdrag av Länsstyrelsen i Norrbotten utfört provtagning samt analys av bottenfaunaprover från 51 lokaler i Råneåfjärden. Provtagning utfördes den 18:e och 19:e juni 2019.

2. Genomförande

Provtagning av bottenfauna utfördes av Arvid Ros och Viktor Gydemo den 18:e och 19:e juni med hjälp av så kallad Van Veen-huggare, som sänktes ner med hjälp av kran från arbetsbåt (SS-EN ISO 16665:2013). Sållning av proverna, genom 1 mm såll, genomfördes på båt. Urplockning av bottenfaunaproverna utfördes av Louise Franzén och analys utfördes av Rickard Degerman, båda vid Pelagia Nature & Environment AB. Figur 1 visar provtaget område samt specifika provtagningslokaler (rödmarkerade) i vilka minst en lokal vardera förlagts. Fördelningen av samtliga bottenfaunastationer återges i Figur 2. Pelagia Nature & Environment AB är ett av SWEDAC ackrediterat organ för provtagning, urplockning, analys och indexberäkning av bottenfaunaprover (ackrediteringsnummer 1846).
I bedömningsgrunderna för biologiska kvalitetsfaktorer i kustvatten och vatten i övergångszon (Havs- och vattenmyndighetens författningssamling 2013) fastställs att mjukbottenfauna i kustvatten och i dess övergångszoner skall klassificeras utifrån BQImindex (Benthic Quality Index). BQIm-index är baserat på de tre parametrarna artsammansättning, antal arter och antal individer.



Figur 1. Röda fält motsvarar de specifika provtagningslokalerna medan blå polygon visar på provtagningsområdets utbredning.



Figur 2. Bottenfaunastationernas lägen i Råneåfjärden.

3. Resultat och diskussion

Resultaten från bottenfaunaanalyserna har matats in i SMHI:s mall för zoobenthos, samt biläggs denna rapport till Länsstyrelsen i form av Excelfiler. Data som lagts i den aktuella mallen innefattar förutom information utifrån bottenfaunaanalyserna även information om positioner, väderförhållanden och sedimentförhållanden. Protokoll som inkluderar bland annat salinitetsdata levereras som en separat Excelfil till Länsstyrelsen. De arter och släkten som frekvent noterades i de undersökta områdena var framför allt Monoporeia affinis, Chironomidae sp. och Oligochaeta sp.

Att delproverna skiljer sig åt vid de olika lokalerna är förväntat och bedöms vara resultat av naturlig variation.

Förekomst av vitmärla (Monoporeia affinis) visar på goda förhållanden vid de undersökta lokalerna. Vid klassificering av bottenfauna enligt gällande bedömningsgrunder är förekomst av vitmärla en av de faktorer som resulterar i förhöjd ekologisk status. Variationen är dock väldigt stor vilket leder till att bedömningen av status inte går att säkerställa. Utöver detta påträffades de invasiva arterna Marenzelleria sp. och Potamopyrgus antipodarum vid fyra stationer.

4. Sammanfattning

Diversiteten vad gäller bottenfauna är i regel tämligen låg i hela Bottniska viken. Detta bekräftas till stor del i denna undersökning, även om diversiteten på grund av områdenas karaktär ibland var något högre än vad som vanligen noteras i standardmässigt utförda bottenhugg. Vidare noterades också en viss inblandning av sötvattensarter, vilket inte är ovanligt i strandnära grunda områden, speciellt om tillrinnande sötvatten finns nära. De arter och släkten som frekvent noterades i de undersökta områdena var framför allt Monoporeia affinis, Chironomidae sp. och Oligochaeta sp.

5. Referenser

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11. Pohjaeläimistön kahden näytteenottomenetelmän vertailu Perämerellä

Johdanto

Pohjois-Pohjanmaan elinkeino-, liikenne- ja ympäristökeskus (ELY-keskus) on tilannut Suomen ympäristökeskukselta (SYKE) selvityksen eri näytteenottomenetelmien vaikutuksista pohjaeläintuloksiin ja vesienhoitosuunnitelman mukaisiin luokittelutuloksiin Perämerellä. Pohjaeläinnäytteitä on otettu kahdella näytteenottomenetelmällä, van Veen-noutimella (1 nosto) ja Ekman-noutimella (5 noston kokoomanäyte), kymmeneltä havaintopaikalta Hailuodon edustalta, Oulun ulkomerialueelta (havaintopaikat Hailuoto_OUVY-10_1 – Hailuoto_OUVY-10_10). Kaikki näytteet otettiin 11.6.2018 Eurofins Environment Testing Finland Oy toimesta. Näytteet on poiminut ja määrittänyt Probenthos Oy ja tulokset on tallennettu Hertta-tietojärjestelmän POHJE-tietokantaan.

Työn tavoite on selvittää eroavatko samalla havaintopaikalla kahdella näytteenottomenetelmällä saadut tulokset toisistaan. Vertailussa käytetään seuraavia parametreja: pohjaeläinten lajirunsaus, yksilötiheys, Shannon-diversiteetti ja BBI indeksi. Samalla verrataan myös eroavatko vesienhoitosuunnitelman mukaiset pohjaeläinluokittelutulokset vesimuodostumatasolla.

Menetelmät

Aineisto haettiin POHJE-tietokannasta valmiiksi neliömetrikohtaisina arvoina (liite 1). Havaintopaikkojen syvyys vaihteli 21-25 m välillä ja kaikki havaintopaikat sijaitsevat samassa vesimuodostumassa 4_Pu_040 Hailuoto-Kuivaniemi. BBI laskentoja varten yhdistettiin harvasukasmadot Psammoryctides barbatus, Limnodrilus hoffmeisteri ja Potamothrix hammoniensis yhdeksi Oligochaeta-ryhmäksi. Procladius sp. siirrettiin ylemmälle taksonomiselle tasolle Chironomidae. Tämän jälkeen BBI laskettiin R-ohjelmalla Perus et al. 2007 mukaan. Tulosten vertailussa käytetään lajirunsaus ja Shannon-diversiteetti sekä määritettyjen taksonien perusteella laskettuna, että BBI laskentoja varten tehtyjen ryhmittelyiden jälkeen. Shannon-diversiteetti laskettiin binääristä logaritmifunktiota käyttäen (log2(x)), koska tämä versio Shannon-diversiteetti-indeksistä käytetään BBI-laskennassa. Näytteenottomenetelmien vertailu suoritettiin parametreille kahden riippuvan otoksen t-testillä. Testi vertaa eroavatko havaintopaikkakohtaiset arvot keskimäärin toisistaan.

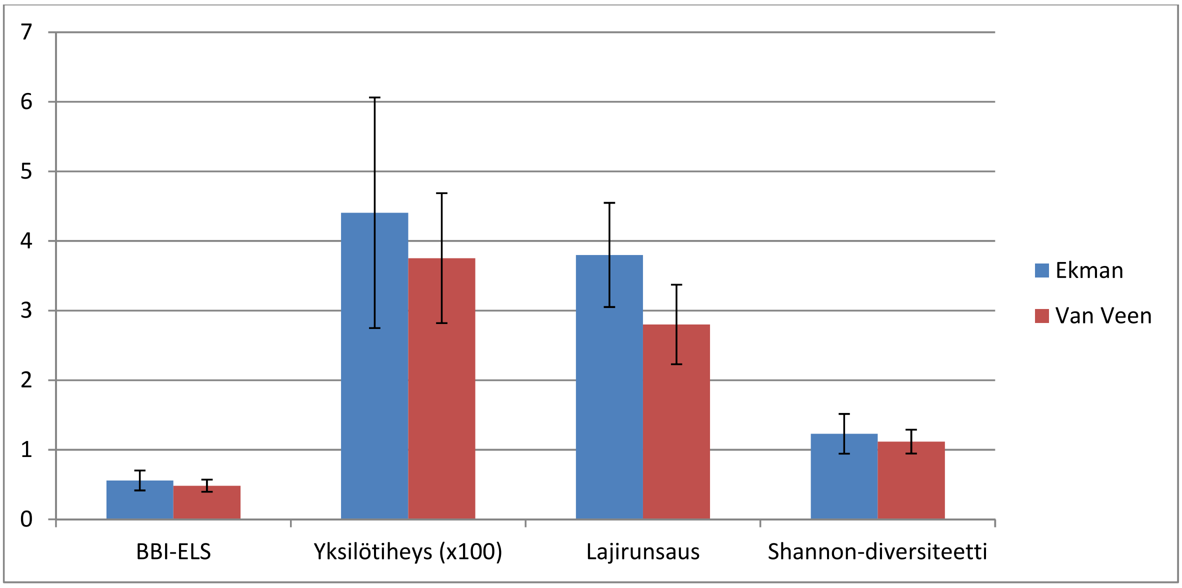
Vesimuodostuman luokittelutulos laskettiin myös R-ohjelmalla ensin muuttamalla BBI arvot BBI-ELS arvoiksi (Vuori et al. 2009) jonka jälkeen suoritettiin uudelleenotanta bootstrap-menetelmällä (Leonardsson et al. 2009). Uudelleenotanta suoritettiin 9999 kerta ja joka kerran jälkeen tallennettiin keskiarvo BBI-ELS:stä. Luokitteluarvoksi muodostuu uudelleenotannan keskiarvojen 20 prosenttipiste.

Vertailun vuoksi laskettiin näytteille myös ruotsalaisten luokittelussa käyttämä BQI indeksi (Leonardsson et al. 2009) ja sen luokitteluarvot.

Tulokset

Kaikilla havaintoasemilla harvasukasmadot (Oligochaeta) sekä monisukasmato Marenzelleria sp. dominoivat pohjaeläinyhteisöä (79-100 % yksilöistä). Muita yleisiä, mutta harvalukuisempia lajeja olivat viherlimamato Cyanophthalma obscura ja surviaissääski Procladius sp. Yhteensä havaittiin kymmenen lajia. Saman havaintoaseman pohjaeläintulokset vaihtelivat näytteenottomenetelmästä riippuen (Taulukko 1 ja 2) ja Ekman-kokoomanäytteiden keskiarvot olivat korkeampia kuin van Veen-näytteiden keskiarvot jokaisessa tutkitussa parametrissa (Kuvaaja 1). Selkein ero oli lajirunsaudessa, jossa keskimääräinen ero oli tilastollisesti merkittävä (Taulukko 3). Muissa tutkituissa parametreissa keskimääräinen ero ei ollut merkittävä.

Vesienhoitosuunnitelman mukaiset BBI luokittelutulokset olivat Ekman-kokoomanäytteet käyttäen 0,52 ja van Veen-näytteitä käyttäen 0,46 (Taulukko 4). Molemmat tulokset sijoittuvat ”Tyydyttävä” luokkaan, jonka alaraja on 0,37 ja yläraja 0,55 Perämeren ulkomerialueen yli 10 m syville pohjille (Vuori et al. 2009). BQI indeksin luokitteluarvot olivat Ekman-kokoomanäytteille 1,54 ja van Veen-näytteille 1,45 (Taulukko 4). Ruotsalaisten määrittämä Hyvä/Tyydyttävä luokkaraja on 1,5 Perämeren ulkosaaristoalueelle (Naturvårdsverket 2008).



Kuvaaja 1. Tutkittujen parametrien keskiarvot ± keskihajonta eri näytteenottomenetelmillä.
Kuvaaja 1. Tutkittujen parametrien keskiarvot ± keskihajonta eri näytteenottomenetelmillä. Yksilötiheyden keskiarvo ja keskihajonta on jaettu sadalla, jotta kaikki parametrit mahtuvat samaan kuvaajaan.

Taulukko 1. Eri näytteenottomenetelmillä otettujen näytteiden BBI-ELS arvot, yksilötiheys, lajirunsaus ja Shannon-diversiteetti. Lajirunsaus ja Shannon-diversiteetti laskettu BBI ryhmittelyn jälkeen.
Shannon-diversiteetti. Lajirunsaus ja Shannon-diversiteetti laskettu BBI ryhmittelyn jälkeen.

	BBI-ELS		Yksilötiheys		Lajirunsaus		Shannon-diversiteetti	
Havaintopaikka	Ekman	van Veen	Ekman	van Veen	Ekman	van Veen	Ekman	van Veen
Hailuoto_OUVY-10_1	0.352	0.294	486.5	449.1	4	2	0.76	0.80
Hailuoto_OUVY-10_2	0.537	0.392	477.5	379.2	3	2	1.26	0.98
Hailuoto_OUVY-10_3	0.551	0.512	441.4	499.0	5	4	1.17	1.15
Hailuoto_OUVY-10_4	0.789	0.572	216.2	299.4	4	3	1.68	1.32
Hailuoto_OUVY-10_5	0.303	0.557	738.7	548.9	3	3	0.73	1.27
Hailuoto_OUVY-10_6	0.715	0.390	360.4	369.3	5	2	1.50	1.00
Hailuoto_OUVY-10_7	0.556	0.574	333.3	259.5	3	3	1.29	1.31
Hailuoto_OUVY-10_8	0.581	0.506	270.3	339.3	3	3	1.23	0.92
Hailuoto_OUVY-10_9	0.678	0.572	360.4	219.6	4	3	1.48	1.32
Hailuoto_OUVY-10_10	0.518	0.462	720.7	389.2	4	3	1.19	1.10

Taulukko 2. Eri näytteenottomenetelmillä otettujen näytteiden lajirunsaus ja Shannon-diversiteetti. Arvot laskettu käyttäen taksonien määritystasoa.
laskettu käyttäen taksonien määritystasoa.

	Lajirunsaus		Shannon-diversiteetti	
Havaintopaikka	Ekman	van Veen	Ekman	van Veen
Hailuoto_OUVY-10_1	6	4	1.83	1.66
Hailuoto_OUVY-10_2	4	2	1.37	0.98
Hailuoto_OUVY-10_3	7	6	1.73	1.66
Hailuoto_OUVY-10_4	4	3	1.68	1.32
Hailuoto_OUVY-10_5	5	5	1.20	1.69
Hailuoto_OUVY-10_6	5	2	1.50	1.00
Hailuoto_OUVY-10_7	3	3	1.29	1.31
Hailuoto_OUVY-10_8	3	3	1.23	0.92
Hailuoto_OUVY-10_9	4	3	1.48	1.32
Hailuoto_OUVY-10_10	4	3	1.19	1.10

Taulukko 3. Kahden riippuvan otoksen t-testin tulokset. Parametreissa jossa p-arvot ovat pienempiä kuin 0,05 katsotaan eron näytteenottomenetelmien välillä olevan tilastollisesti merkittävä.

0,05 katsotaan eron näytteenottomenetelmien välillä olevan tilastollisesti merkittävä.

Parametri	p-arvo
BBI-ELS	0.154
Yksilötiheys	0.150
Lajirunsaus	0.008
Shannon-diversiteetti	0.254
Lajirunsaus (määritystaso)	0.007
Shannon-diversiteetti (määritystaso)	0.116

Taulukko 4. Vertailu näytteenottomenetelmien vesimuodostumakohtaisessa luokitteluarvossa ja Hyvä/Tyydyttävä luokkien raja-arvo (H/T raja).

Hyvä/Tyydyttävä luokkien raja-arvo (H/T raja).

	Ekman	van Veen	H/T raja
BBI luokitteluarvo	0.520	0.459	0.55
BQI luokitteluarvo	1.54	1.45	1.5

Tulosten tarkastelu

Ekman-noutimella otetut kokoomanäytteiden keskiarvot olivat korkeampia kuin van Veen-näytteiden keskiarvot sekä lajirunsaudessa, yksilötiheydessä, Shannon-diversiteetissa että BBI-ELS arvoissa. Myös BBI luokitteluarvo oli korkeampi Ekman-kokoomanäytteiden perusteella. Tilastollisesti kuitenkin vain lajirunsaudessa ero oli merkittävä.

Näytteiden pinta-alat eroavat hieman (Ekman-kokoomanäyte: 1110 cm2, van Veen näyte: 1002 cm2), mikä voi vaikuttaa lajirunsauden eroon. Muissa parametreissa näytteiden pinta-ala ei vaikuta, koska yksilötiheyden ovat laskettu neliömetrikohtaisesti. Ero pinta-aloissa on kuitenkin niin pieni, että jopa eri valmistajan noutimissa voi olla isompi vaihtelu. Todennäköisempi tekijä mikä voi vaikuttaa korkeampaan lajirunsauteen Ekman-kokoomanäytteissä on se, että vaikka näytteet otetaan samalta paikalta, viisi Ekman nostoa tulevat isommalta alueelta kuin mistä yksi van Veen nosto. Varsinkin jos pohjanlaatu on hajanainen tai pohjaeläimet esiintyvät laikuttaisesti, tällä voi olla vaikutusta. Lajirunsaus käytetään myös yhtenä parametrina BBI indeksissä, mikä osaltaan voi selittää alhaisemmat BBI-ELS arvot van Veen-näytteissä. Koska luokitteluarvo määritellään varovaisuusperiaatetta noudattaen, van Veen näytteiden perusteella laskettu BBI luokitteluarvo on alhaisempi kuin Ekman-kokoomanäytteiden perusteella, vaikka tilastollista eroa ei havaittu BBI-ELS arvoissa. Vaikka tilaluokka oli molemmilla näytteenottomenetelmillä sama, ero luokitteluarvossa on suhteellisen iso ”Tyydyttävä” luokan sisällä, mitä tarkoittaa, että mitä lähemmäs luokkarajaa luokitteluarvo on, sen isompi riski on että näytteenottomenetelmä voi vaikuttaa luokittelutulokseen. Jos esimerkiksi luokittelutulosta lasketaan ruotsalaisten käyttämää BQI indeksiä (Leonardsson et al. 2009) ja sen luokkarajojen mukaisesti päädytään eri tilaluokkiin. Ekman kokoomanäytteille BQI:n luokitteluarvo olisi 1,54 ja van Veen näytteille 1,45 (ruotsalaisten määrittämä Hyvä/Tyydyttävä luokkaraja on 1,5 Perämeren ulkomerialueelle (Naturvårdsverket 2008)).

BBI:n perusperiaate on, että hyväkuntoiset pohjaeläinyhteisöt ovat monimuotoisia ja herkät lajit dominoivat, kun taas heikossa tilassa olevat yhteisöt ovat köyhempiä ja toleranteilla lajeilla edustettuja (Rosenberg et al. 2004, Perus et al. 2007). Perämerellä, missä pohjaeläinyhteisö on luontaisesti vähälajinen, yksittäiset lajit saavat isoimman merkityksen luokittelutuloksessa. Täällä myös makean veden lajisto (esim. Oligochaeta ja Chironomidae), jota BBI:n herkkyysluokituksessa on arvioitu sietäviksi, on luontainen osa pohjaeläinyhteisöä. Tämä aiheuttaa tulkintavaikeuksia BBI tuloksissa, koska herkäksi arvioitu lajisto on myös herkkä matalalle suolaisuudelle. BBI:n onkin osoittautunut antavan heikompaa tilaluokkaan viittaavia tuloksia kuin muut rannikon luokitteluparametrit. Meneillään olevalla kolmannella vesienhoidon luokittelukierroksella fysikaalis-kemialliset olosuhteet ja kasviplankton ovat laskennallisesti luokiteltu hyvään tilaluokkaan, kun taas pohjaeläinten laskennallinen tilaluokka on välttävä.

Pohjaeläinluokittelua on tarve kehittää Perämerellä, jossa lajirunsaudet ja yksilötiheydet ovat matalat. Yksi vaihtoehto olisi tarkentaa lajimäärityksiä harvasukasmadoille (Oligochaeta) ja surviaissääskentoukille (Chironomidae). Tässä tarkastelussa määritystaso ei kuitenkaan vaikuttanut luokitustulokseen ja muissa vastaavissa vertailuissa on ainoastaan havaittu pieniä eroja tuloksissa (Blomqvist & Leonardsson 2016), joten tarkemmasta lajimäärityksestä ei välttämättä ole apua.

Muita ehdotuksia luokittelun kehittämiseksi olisi määrittää luokkarajat eri tavalla kuin nykyään. Nykymenetelmällä luokkarajojen määrittely perustuu oletukseen, että vertailuaineisto kattaisi koko häirintägradientin tasaisesti, jolloin paras 10 % prosenttia tuloksista on käytetty referenssitason määrittämiseksi. Tämä menetelmä ei kuitenkaan huomioi ihmispaineita suoraan, joten häirintägradienttia ei välttämättä kateta tasaisesti. Tilannetta voisi parantaa huomioimalla ihmispaineita paremmin luokkarajojen määrityksessä. Yksi ehdotus olisi kerätä vertailuaineistoa alueilta joilla ei esiinny merkittävää ihmispainetta ja tilastollisesti määrittää miten iso vaihtelu pohjaeläinyhteisöissä ja BBI tuloksissa on näillä alueilla. Hyvä-tilaluokka voisi sitten määrittää sen mukaan, että se huomioi tämän luonnollisen vaihtelun. Samaa periaatetta hyödyntäen olisi kokeilemisen arvoista testata miten pBQI (Blomqvist & Leonardsson 2016) laskentatapa soveltuisi Perämerelle. pBQI perustuu vertailuaineistoon häiriintymättömiltä alueilta ja vertaa tilastollisin menetelmin miten paljon seurantapaikkojen pohjaeläinyhteisö poikkeaa vertailualueen pohjaeläinyhteisöstä.

Tämän tarkastelun tuloksena voidaan todeta, että näytteenottomenetelmien välillä on pieniä eroja, mutta vesienhoitosuunnitelman mukaiseen luokitteluun erot eivät vaikuttaneet tämän aineiston perusteella. Tulokset kuitenkin viittaavat siihen, että alhaiset lajirunsaudet ja tiheydet sekä laikuttainen esiintyminen Perämeren pohjaeläinyhteisössä vaikuttavat lajirunsauteen niin että useammalla nostolla saadaan enemmän lajeja, vaikka näytteenotettu pinta-ala on suurin piirtein sama. Tämä tarkoittaa, että siirryttäessä van Veen näytteenottoon pohjaeläinseurannassa lajimäärä ja monimuotoisuusindeksi ja siten myös BBI indeksin arvo todennäköisesti laskee, mitä on syytä huomioida pohjaeläinluokittelun kehityksessä ja luokkarajojen asettamisessa.

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Liite 1. Selvityksen perustana käytetty pohjaeläinaineisto (lajikohtaiset yksilötiheydet neliömetri-kohtaisesti) Hailuoto_OUVY-10_1 – Hailuoto_OUVY-10_10 havaintopaikoilta. Kaikki näytteet ovat otettu 11.6.2018 ja seulottu 0,5 mm seulalla.

Paikan nimi	Näytteenotin	*Cyanophthalma obscura*	*Marenzelleria spp.*	*Psammoryctides barbatus*	*Limnodrilus hoffmeisteri*	*Potamothrix hammoniensis*	*Pisidium sp.*	*Saduria entomon*	*Monoporeia affinis*	*Procladius sp.*	Ceratopogonidae
Hailuoto_OUVY-10_1	Ekman		54.1	153.2	27.0	234.2			9.0	9.0	
Hailuoto_OUVY-10_2	Ekman		234.2		9.0	207.2				27.0	
Hailuoto_OUVY-10_3	Ekman	9.0	99.1	45.0	9.0	261.3		9.0		9.0	
Hailuoto_OUVY-10_4	Ekman	36.0	81.1			90.1				9.0	
Hailuoto_OUVY-10_5	Ekman		99.1	18.0	45.0	558.6				18.0	
Hailuoto_OUVY-10_6	Ekman	18.0	135.1			189.2				9.0	9.0
Hailuoto_OUVY-10_7	Ekman	27.0	117.1			189.2					
Hailuoto_OUVY-10_8	Ekman	18.0	162.2			90.1					
Hailuoto_OUVY-10_9	Ekman	45.0	99.1			207.2				9.0	
Hailuoto_OUVY-10_10	Ekman	18.0	162.2			504.5				36.0	
Hailuoto_OUVY-10_1	Van Veen		109.8	29.9	69.9	239.5					
Hailuoto_OUVY-10_2	Van Veen		219.6			159.7					
Hailuoto_OUVY-10_3	Van Veen		119.8	29.9	20.0	299.4			10.0	20.0	
Hailuoto_OUVY-10_4	Van Veen	29.9	99.8			169.7					
Hailuoto_OUVY-10_5	Van Veen		309.4	39.9	20.0	139.7				39.9	
Hailuoto_OUVY-10_6	Van Veen		199.6			169.7					
Hailuoto_OUVY-10_7	Van Veen	20.0	109.8			129.7					
Hailuoto_OUVY-10_8	Van Veen		259.5			69.9	10.0				
Hailuoto_OUVY-10_9	Van Veen	20.0	79.8			119.8					
Hailuoto_OUVY-10_10	Van Veen		139.7			239.5				10.0	