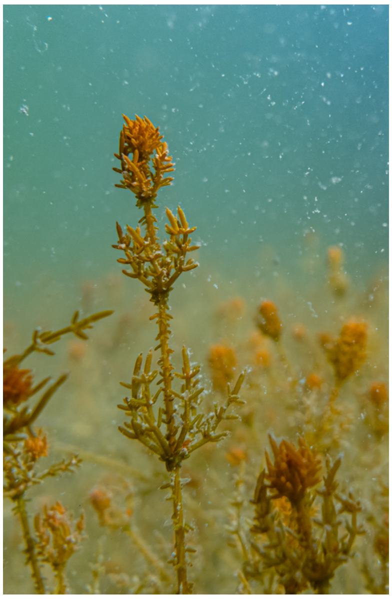
FORSKNINGSRAPPORTER
FRÅN
HUSÖ BIOLOGISKA STATION

No 169 (2024)



Karl Weckström, Henna Rinne, Maija Häggblom & Sonja Salovius-Laurén

Marine inventories to support ecosystem-based management and the expansion of the MPA network in the Åland Islands – Final report of the ÅlandSeaMap project (2019–2023)

(Marina inventeringar för att stöda ekosystembaserad förvaltning och utvecklandet av marina skyddsområdesnätverket på Åland – Slutrapport för ÅlandSeaMap projektet (2019–2023)

Åbo Akademi

I publikationsserien **Forskningsrapporter från Husö biologiska station** rapporteras forskning utförd i anknytning till Husö biologiska station. Serien utgör en fortsättning på serierna **Husö biologiska station Meddelanden** och **Forskningsrapporter till Ålands landskapsstyrelse**. Utgivare är Husö biologiska station, Åbo Akademi. Författarna svarar själva för innehållet. Förfrågningar angående serien riktas till stationen under adress: Bergövägen 713, AX-22220 Emkarby; telefon: 018-37310; e-post huso@abo.fi. (Även: Åbo Akademi, Miljö- och marinbiologi, Aurum, Henriksgatan 2, 20500 Åbo).

The series **Forskningsrapporter från Husö biologiska station** contains scientific results and processed data from research activities of Husö biological station, Biology, Åbo Akademi University. The authors have full responsibility for the contents of each issue. The series is a sequel to the publications **Husö biologiska station Meddelanden** and **Forskningsrapporter till Ålands landskapsstyrelse**. Inquiries should be addressed to Husö biological station, Åbo Akademi University. Address: Bergövägen 713, AX-22220 Emkarby, Finland; phone: +358-18-37310; e-mail: huso@abo.fi (Also Åbo Akademi University, Environmental and Marine biology, Aurum, Henriksgatan 2, FIN-20500 Åbo, Finland)

Redaktör/Editor: Tony Cederberg

ISBN 978-952-12-4375-2

ISSN 0787-5460

Forskningsrapporter från Husö biologiska station. No 169 (2024): 1-42. ISSN 0787-5460 ISBN 978-952-12-4375-2

Marine inventories to support ecosystem-based management and the expansion of the MPA network in the Åland Islands – Final report of the ÅlandSeaMap project (2019–2023)

(Marina inventeringar för att stöda ekosystembaserad förvaltning och utvecklandet av marina skyddsområdesnätverket på Åland – Slutrapport för ÅlandSeaMap projektet (2019–2023)

Karl Weckström[a], Henna Rinne[a], Maija Häggblom[b] & Sonja Salovius-Laurén[a]

Husö biologiska station, Åbo Akademi
22220 Emkarby, Åland, Finland

[a]Åbo Akademi University, [b]Government of Åland

Abstract

The Baltic Sea is increasingly exploited by society, which generally harms the underwater environment. Comprehensive and high-quality data on marine environments is essential to manage and maintain ecosystems and ecosystem services effectively. This information is obtained by mapping species and habitat distributions. The ÅlandSeaMap project systematically surveyed the coastal waters of the Åland Islands from 2019 to 2022.

With comprehensive and high-quality data collected before and during the project, it was possible to create species distribution models for species and species assemblages. Human impacts in the area were also identified and evaluated, with the available data being combined into one map layer. A site selection analysis with the Marxan planning tool was run using the collected spatial data. The most suitable areas for protection were identified in different scenarios, considering predetermined protection goals based on national and international assessments. Results were presented for and discussed with stakeholders at all stages of the site selection process.

The results of the ÅlandSeaMap project are the basis for the ongoing expansion of the marine protected area network in the Åland Islands. Some areas in Kökar and northern Brändö have already been selected and redeemed by the Government of Åland and will reach protection status in the near future. Further, results are actively used for supporting ecosystem-based management, e.g. for improving the monitoring program for macrophytes, for environmental permissions, and for impact assessments in the marine environment. The project was done in close cooperation between Åbo Akademi University and the Government of Åland.

Sammanfattning

Östersjön nyttjas allt mera av människan, vilket i regel påverkar undervattensmiljöerna negativt. För att kunna förvalta havsmiljöerna på bästa sätt och upprätthålla ekosystemtjänster är det nödvändigt att känna till hur havsmiljön ser ut och fungerar. Detta kan studeras genom att kartera undervattensmiljöer för att få information om utbredningen av arter och habitat. Inom ÅlandSeaMap projektet har de åländska kustvattnen systematiskt inventeras mellan 2019 och 2022.

Med ett omfattande informationsunderlag av hög kvalitet var det möjligt att framställa utbredningsmodeller för marina arter och habitat. Data över mänskliga aktiviteter i området identifierades, utvärderades och sammanställdes på kartor. På basis av insamlad information utfördes en skyddsområdesvalsanalys med planeringsverktyget Marxan. I analysen identifierades olika scenarier för områden som skulle vara lämpligast att skydda så att de förutbestämda skyddsmålsättningarna enligt internationella och nationella bedömningar uppfylldes. Resultat presenterades och diskuterades med intressenter under alla stadier av områdesvalsprocessen.

Resultaten av ÅlandSeaMap projektet utgör grunden för den pågående förbättringen av det marina skyddsområdesnätverket på Åland. Områden med höga naturvärden runt Kökar och norra Brändö har redan valts ut och inlösts av Ålands landskapsregering och kommer att nå skyddsstatus inom kort. Resultaten används också aktivt för att stöda övrig ekosystembaserad förvaltning t.ex. för att förbättra uppföljningsprogrammet för marina makrofyter samt för utlåtanden och konsekvensbedömningar. Projektet utfördes i nära samarbete mellan Åbo Akademi och Ålands landskapsregering.

Glossary

BLM: Boundary length modifier
BRT: Boosted regression trees
CBD: Convention on Biological Diversity
COP: Conference of the Parties
EN: Endangered (according to the Red List of Finnish Species)
GIS: Geographical information system
HELCOM: Helsinki Commission
MPA: Marine protected area
MSP: Maritime spatial planning
NT: Near threatened (according to the Red List of Finnish Species)
SCP: Systematic conservation planning
SPF: Species penalty factor (feature penalty factor)
SYKE: Suomen ympäristökeskus (Finnish Environment Institute)
Velmu: Vedenalaisen meriluonnon monimuotoisuuden inventointiohjema (Finnish inventory programme for underwater marine diversity)
VU: Vulnerable (according to the Red List of Finnish Species)
ÅAU: Åbo Akademi University
ÅLR: Ålands landskapsregering (Government of Åland)
ÅMHM: Ålands miljö- och hälsoskyddsmyndighet (The Åland Environmental and Health Protection Authority)
ÅSM: ÅlandSeaMap

Table of contents

1 Introduction 1

2 Material and methods 4

2.1 The study areas for underwater surveys 4

2.2 Methods for underwater biological surveys 5

2.2.2 Data collection 6

2.3 Environmental data and species distribution modelling 7

2.4 Identifying suitable areas for marine protection 9

2.4.1 The Marxan decision-support tool 9

2.4.2 Identifying biological and geological values – assigning protection goals 9

2.4.3 Identifying and ranking human pressures in the study area 10

2.4.4 The Marxan site selection analysis 13

2.5 Stakeholder involvement 14

3 Results 15

3.1 Underwater surveys 15

3.2 Species distribution models 19

3.3 Site selection analysis 21

3.4 The representation of conservation features 23

3.5 Establishment of new MPAs 24

3.6 Stakeholder involvement, feedback, scientific output, and general outreach 26

4 Discussion 29

4.1 Project results in marine management of the Åland Islands 29

4.2 Stakeholder involvement and raising awareness 31

4.3 Evaluation of the methods 32

4.3.1 Underwater surveys 32

4.3.2 Site selection analysis 32

4.4 Future challenges 33

5 Conclusions 34

6 Acknowledgements 34

7 References 35

Appendices

1 Introduction

Terrestrial and marine nature is continuously becoming more fragmented and impacted by human activities and exploitation (EUROPEAN COMMISSION 2020, CBD/COP/DEC15/4, MAXWELL et al. 2020). A global loss of biodiversity is taking place through the multiple pressures society exerts on ecosystems, also in the marine environment. Biodiversity loss impairs the ocean's capacity to provide food, maintain water quality, and recover from perturbations (WORM et al. 2006). To enable the sustainable use of the sea areas, science-based and informed management decisions are essential (LONG et al. 2015). Ecosystem-based management is a process that integrates biological, social, and economic factors into a comprehensive strategy aimed at protecting and enhancing sustainable practices, diversity, and productivity of natural resources (LONG et al. 2015). Ecosystem-based management requires general information on existing nature values (habitats and species), e.g., how they are spatially distributed and interact. This kind of knowledge is also essential for planning protected area networks. According to international agreements on biodiversity, 30% of land and water areas should be protected, of which 10% should be under strict protection (CBD/COP/DEC15/4, EUROPEAN COMMISSION 2020). The 30% protected area coverage goal established by international agreements requires ecological representativeness. This means that species and ecoregions should be represented in the protected areas (CBD/COP/DEC15/4, MAXWELL et al. 2020). According to Aichi Target 11 (UNEP/CBD/COP/10/27), at least 10% of coastal and marine areas should have been protected by 2020. However, this target was far from being fulfilled in the Åland Islands when the project started in 2019.

The Åland Islands’ coastal waters are a geographically and biologically diverse region of the Finnish archipelago, and the northern parts represent some of the most pristine areas of the Baltic Sea (BONSDORFF et al. 1991). The mosaic-like character of the Åland Islands’ archipelago includes multiple different types of marine habitats. The sandy shores in the west, the geo-morphologically peculiar Lumparn Bay, the rocky northern shores and underwater reefs, as well as the esker islands in the southeast, have been identified as nature areas of particular interest (RINNE et al. 2019, LAPPALAINEN et al. 2020). Previous underwater surveys in the area have concentrated on mapping Natura 2000 habitats: reefs, sandbanks, and shallow bays. Also, long-term monitoring of marine macrophytes has been carried out in the area for about 20 years.

The unique environment, both on land and in the sea, is very important for safeguarding traditional knowledge, culture, economy, and livelihoods for people in the region. In general, the inhabitants of the Åland Islands are culturally close to and economically dependent on the sea. The nature of the Åland Islands is highly appreciated for recreation, and many visitors are attracted to the area. Maritime industries, e.g. fishing, leisure boating, shipping, and aquaculture are traditional uses of the sea in the area. Currently also wind energy production is expanding in the sea areas of the Åland Islands. Although important for local people, these different human activities cause many pressures to the marine environment, such as increased turbidity, nutrient enrichment, disturbance, and habitat destruction (EUROPEAN COMMISSION 2021, FOGELBERG 2021).

Of the Åland Islands' marine waters, approximately 3% are protected (5% of the coastal waters). The modest area coverage of the marine protected area (MPA) network is due to the lack of resources and knowledge on the distribution of marine nature values (habitats and key species) worth protecting. The Government of Åland (ÅLR) is committed to expanding the MPA network (GOVERNMENT OF ÅLAND 2022) according to international agreements and to developing and improving marine ecosystem-based management.

Historically, MPAs have been established on an *ad hoc* basis without extensive knowledge of the underwater environment (AGARDY et al. 2011, VIRTANEN et al. 2018). Traditionally, decisions have been influenced by factors of less ecological significance, including scenic beauty, recreational value, or charismatic animals, rather than by the multiple levels of biodiversity, ecosystem processes (functions and services), cost-effectiveness, threats, or ecological status. Areas protected without knowledge of the marine environment and existing nature values may create a false perception of achieved protection (AGARDY et al. 2011). Today, there are tools that allow for systematic conservation planning (SCP), where comprehensive data on different levels of biodiversity and nature values can be brought together with data on human activities. However, due to the complexity of bio- and geodiversity, SCP is often forced to work with proxies, such as sub-sets of species, species assemblages, or habitats (MARGULES & PRESSEY 2000). One major challenge of SCP is selecting adequate proxies for biodiversity, i.e., nature values that represent ecological processes that contribute to maintaining ecosystem function (MARGULES & PRESSEY 2000). Habitat-forming species work as effective proxies for biodiversity and uphold ecosystem functioning as they support extensive species assemblages. Within the Åland Islands, bladderwrack (*Fucus vesiculosus*), eelgrass (*Zostera marina*), and blue mussels (*Mytilus trossulus*) are habitat-forming species. On a habitat level, e.g. shallow bays with high macrophyte diversity are essential for the recruitment of many fish species and as feeding grounds for birds. Thus, protecting these habitats supports conserving the whole marine ecosystem.

The potential for successful protection depends on an area's sufficient size, connectivity, and the environmental status of adjacent systems (AGARDY et al. 2011). SCP aims to identify priority sites through a process that is efficient, repeatable, transparent, and considers the interests of all different user groups (ARDRON et al. 2010). SCP follows the primary principles of connectivity, adequacy, representation, and effectiveness (ARDRON et al. 2010) and nine additional concepts: comprehensiveness, representativeness, complementarity, threat, vulnerability, efficiency, irreplaceability, replacement cost, and flexibility (KUKKALA & MOILANEN 2013). SCP further emphasises stakeholder involvement to ensure the future efficiency of the established MPA by including local knowledge, transparency, and education. Stakeholder involvement in SCP is essential for a protected area's success and a balance between ecological conservation and socioeconomic needs should be met (BAN et al. 2009, DAY 2017).

In SCP, decision support software have become increasingly common (SCHWARTZ et al. 2018), and considering multiple species and habitats in MPA planning is required for developing coherent and functional conservation solutions (NICHOLSON & POSSINGHAM 2006, SARKAR et al. 2006). The benefits of decision support software are that they guide users through complex decision-making processes and provide an objective approach to proposals for protected areas. Decision support software enable the exploration of multiple good solutions over various scenarios, speeds up planning processes, and allows for the consideration of more comprehensive and uniform solutions. Multiple decision support tools are used worldwide to evaluate, and design protected area networks, e.g. Marxan (BALL & POSSINGHAM 2009), MarZones (WATTS et al. 2009), Zonation (MOILANEN et al. 2009), and prioritizr (HANSON et al. 2023). Marxan was selected for this project due to the transparency of the analysis and the approach the tool uses to build protected area networks, among others, setting percentual protection goals and exploring multiple scenarios.

The aims of the ÅlandSeaMap (ÅSM) project were to:

- Create a comprehensive knowledge base of the Åland Islands' underwater nature by collating existing data and making new inventories.
- Survey previously unmapped areas of the Åland Islands' coastal waters.
- Create spatial data and map products to support ecosystem-based management of the Åland Islands' sea area.
- Propose new areas for marine protection using the Marxan decision-support tool.
- Designate new MPAs.
- Increase the general public's awareness of the underwater nature values of the Åland Islands.

The ÅSM project was a cooperation between Åbo Akademi University (ÅAU) and the Government of Åland (ÅLR). Husö biological station, the field station of ÅAU in the Åland Islands, and ÅLR have collaborated on water-related research since 1961. ÅAUs experience in marine research and involvement in the national Velmu programme made the university a suitable lead partner for mapping marine areas around the Åland Islands and for providing data and expertise to support the expansion of the Åland Islands MPA network.

The environmental agency of ÅLR is a very small division of officials and project workers, and the division's resources for biological inventories and research are limited. The agency is responsible for environmental consciousness, environmental protection, biodiversity, minimising climate impact, waste treatment, a healthy human environment, animal health, animal welfare, food safety, and water conservation.

The following people participated in the project:

Åbo Akademi University: Sonja Salovius-Laurén (project lead), Henna Rinne (planning of biological inventories, GIS work, species distribution modelling, reporting), Karl Weckström (GIS work, head of biological surveys 2022, site selection analysis, reporting), Jean-François Blanc (doctoral researcher), Charlotta Björklund (head of biological surveys 2019, 2021), Linn Engström (biological surveys 2019, head of biological surveys 2020), Petra Arola (biological surveys 2019, 2022), Johan Malmberg (biological surveys 2020, 2021), Patrik Ståhl (biological surveys 2021, 2022), Floriaan Eveleens Maarse (biological surveys 2021).

Government of Åland: Maija Häggblom (project planning, data user), Susanne Vävare (data user), Ted Waleij-Slight (data user), Charlotta Björklund (data user).

Funding was received through the Baltic Sea Conservation Foundation and The European Maritime and Fisheries Fund. Further, the Government of Åland, Åbo Akademi University and Husö biological station, and the Åbo Akademi Endowment supported the project.

2 Material and methods

2.1 The study areas for underwater surveys

The Åland Islands are an autonomous region located in southwestern Finland. The sparsely inhabited, diverse, and mosaic-like archipelago consists of approximately 6 700 islands (1 527 km^2) and 7 600 km^2 of coastal sea area. Prior to the ÅSM project, approximately 3 400 km^2 of the coastal areas remained unmapped. The previous data on the underwater environment was mainly collected in an earlier mapping project (RINNE et al. 2019) but also in smaller-scale surveys, research projects and as a part of the macrophyte monitoring (SCHEININ & SÖDERSTRÖM 2005, PUNTILA 2007, SNICKARS 2008, KAUPPI 2011, HOLGERSSON 2013, KIVILUOTO 2013, SAARINEN 2015, ENGSTRÖM 2018, HUHTALA 2018, VALKONEN 2020).

The target areas for biological surveys were selected where no systematically collected data on the underwater marine environment existed or where previously collected data was scarce. The marine underwater surveys were conducted as three extensive mapping efforts. In 2019, surveys were conducted in the W-NW-N Åland Islands; in 2020, in the NE-E Åland Islands; and in 2021, in the SE-S Åland Islands (fig. 1). Additionally, in 2022, complementary surveys were made where additional information was still needed. The data collected in 2022 was also used to evaluate the species distribution models built based on earlier data.

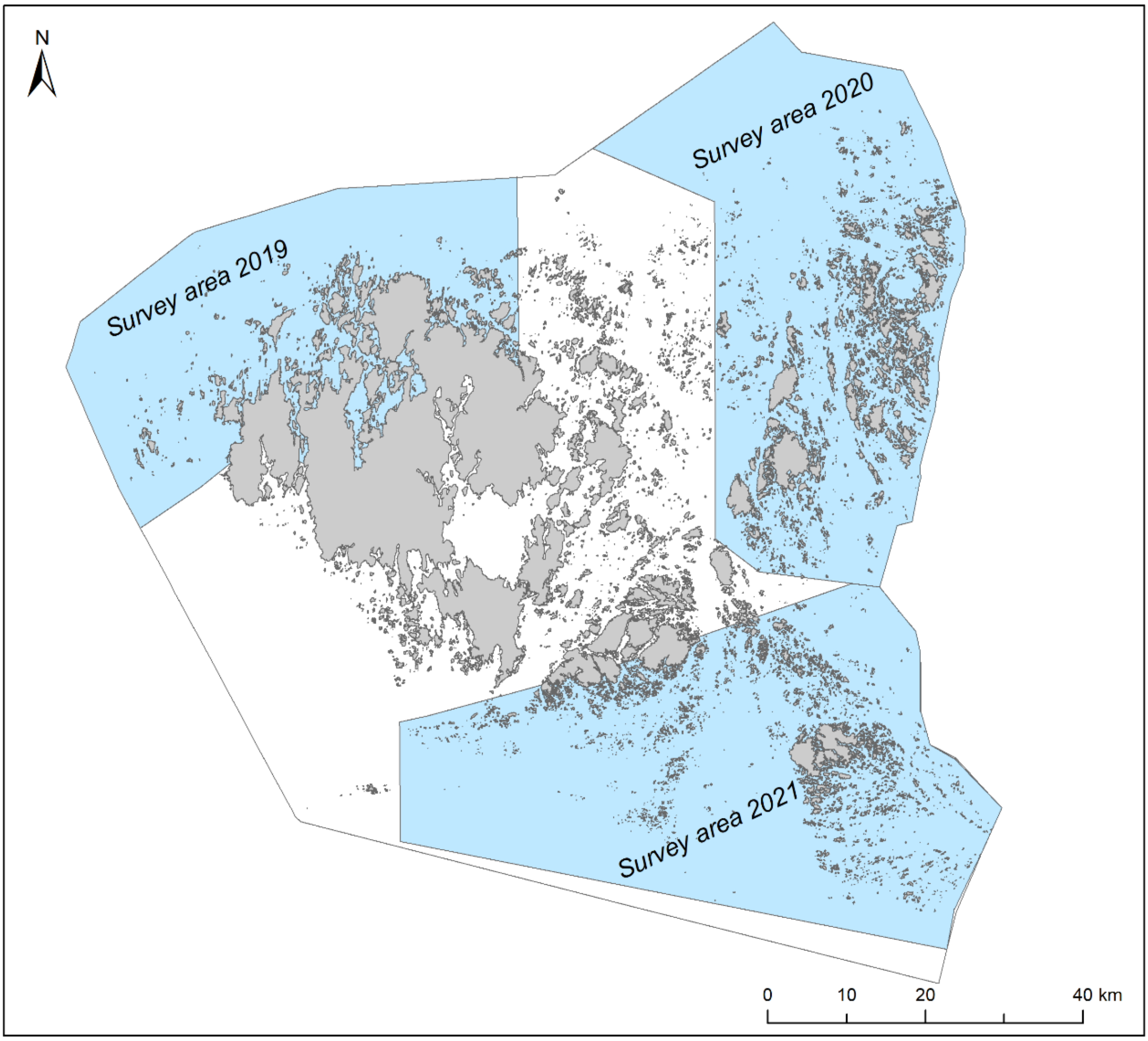


Figure 1. Map illustrating the survey areas for the large-scale mapping efforts (2019–2021).
Figur 1. Karta över de storskaliga karteringsinsatserna (2019–2021).

2.2 Methods for underwater biological surveys

The underwater biological surveys were conducted according to the guidelines used in the Finnish inventory programme for underwater marine diversity (Velmu) (METSÄHALLITUS 2022) so that collected data were comparable with the national Velmu data. The primary methods included drop-video filming and scuba diving transects. To a lesser extent, snorkelling and underwater and aerial drones were utilised.

The drop-video surveys were planned using a stratified random sampling design. The stratification consisted of five depth classes (0–5, 5–10, 10–15, 15–20, and 20–25 m) and three exposure classes (<10 000, 10 000–50 000, and >50 000; ISAEUS 2004). Additionally, half of the survey points were placed on reefs based on the model by KASKELA and RINNE (2018). A broad representation of environmental variability in data collection ensured the suitability of data for species distribution models. The scuba diving transects were also placed using a stratified random sampling design, but only exposure was used for stratification. Furthermore, transects were placed so that the whole inner-middle-outer archipelago gradient was represented. A more in-depth description of the mapping design can be found in RINNE et al. (2019).

In 2019, some survey points were manually placed around areas of special interest. These included areas with a high modelled probability of *Z. marina*, sheltered charophyte communities, red algal communities, and the outer reefs within Märket and Mörskärskallan Natura 2000 sites. In 2020, areas of special interest included the Åva Ring formation, the Ytterstberg Natura 2000 site, and areas west of Enklinge. In 2021, a special effort was made to survey reefs and lagoons within Velmu's Marine Nature 2020/2021 campaign (TAKOLANDER et al. 2023) to collect data for developing indicators of environmental status.

In 2022, areas of additional mapping interest were selected after receiving results from the site selection analysis. Areas with scarce survey points and low representation of dive transects were selected depending on their potential ecological value and feasibility of surveying efforts. Survey points (dive transects) were placed manually in the areas of interest. Aerial images, depth charts and species distribution models were used in the placement.

2.2.2 Data collection

Fieldwork was mainly conducted by a three-person team of two divers and an assistant. Drop-video filming was carried out by lowering a video camera close to the seafloor. An approximately one-minute-long recording of continuous footage of the habitat (covering 20 m^2 of seafloor on average) was filmed. The camera was connected by cable to an external screen for a live video feed on the surface. The boat was allowed to drift during the filming, with minor corrections when needed. The material was later analysed, and the substrate and species cover (%) recordings were made for the covered area. Scuba diving transects were placed perpendicular to the shore. The vegetation, substrate, and fauna along a 100 m transect were mapped by determining the coverage (%) in a 2 m^2 area (extending 1 m on both sides of the transect). A mapping square was surveyed every 10 m distance along the transect or every 1 m change in depth, determined by whichever criteria were filled first. The species-specific cover of macrophytes, macroalgae, sessile fauna, and substrate was recorded on a scale of 0–100%. The substrate recordings were based on the 17-level classification used in the Velmu program (bedrock, boulders > 300 cm, boulders 120–300 cm, boulders 60–120 cm, stones 10–60 cm, stones 6–10 cm, gravel, sand, silt, clay, mud, hard clay, concretions, sandstone, artificial substrates, peat, and tree trunks). The depth, amount of sedimentation, and epiphytic growth were also recorded for each study point.

Additionally, the lower depth limit of vegetation, the lower depth limits of twelve proposed indicator species (METSÄHALLITUS 2022), and the upper and lower depth limits of the *F. vesiculosus* belt (coverage ≥30%) were recorded if present. Also, the terrestrial habitat of the shore at diving sites was classified according to the Natura 2000 habitat type (COUNCIL OF THE EUROPEAN UNION 1992, Appendix I) and further by the LuTU (*Luontotyyppien uhanalaisuus*) habitat type (REINIKAINEN et al. 2018). Invasive terrestrial species on the shore were also recorded, if observed.

2.3 Environmental data and species distribution modelling

In species distribution modelling, comprehensive full-cover distribution maps are produced based on point observations of species (presence/absence) and environmental data. Species distribution models predict where a species or habitat has a high probability of occurring based on actual *in situ* mapping data and full cover environmental data, such as salinity, substrate, and depth.

In this project, species distribution models were built using the boosted regression trees (BRT) method (ELITH et al. 2008). Modelling was conducted using the *gbm* package (GREENWELL et al. 2022) in R (R CORE TEAM 2021). BRT utilises a combination of regression trees and boosting. Regression tree models relate a response to their predictors by repeating binary splits. Boosting is an adaptive method that combines multiple simple models to enhance predictive performance (ELITH et al. 2008). Data collected between 2002 and 2021 were included in the species distribution models. As the aim was to model representative occurrences of species, observations were filtered to include only observations of 10-30% minimum coverage as species presence (tab.1). The filtered observations were then transformed into a presence-absence data frame. In each model, the data were divided into a training dataset (80% of the total data) used to build the model and a test dataset (20%) used to test the model.

The models were evaluated using the ROC curve. The ROC curve is a probability function that plots out the true positive rate against the false positive rate, i.e. if a positive prediction made by the model was true or false when compared with the test data that was not included in the model. The AUC value represents the area under this curve, the closer to 1 the value is, the better the separability between true and false positives.

Table 1. The modelled conservation features (species and communities), number of considered observations, minimum coverage for a representative observation, and AUC (Area Under the ROC [Receiver Operating Characteristic] Curve) value. The AUC value indicates the predictive power of the produced model.

Tabell 1. De modellerade naturvärdena (arter och samhällen), antal beaktade observationer, minsta täckningsgraden för en representativ observation och AUC (arean under ROC kurvan). AUC värdet påvisar den producerade modellens prediktiva förmåga.

Conservation feature	Number of observations	Minimum coverage (%)	AUC
Fucus vesiculosus L.	488	30	0.95
Red algal communities	755	30	0.94
Perennial filamentous algae	144	10	0.86
Potamogeton sp. and *Stuckenia* sp.	1068	30	0.89
Ranunculus sp.	30	10	0.86
Zannichellia sp. and *Ruppia* sp.	311	10	0.92
Myriophyllum sp.	99	30	0.94
Ceratophyllum demersum L.	49	30	0.95
Exposed charophytes	316	10	0.93
Sheltered charophytes	749	10	0.97
Najas marina L.	485	10	0.97
Zostera marina L.	198	10	0.98
Annual filamentous algae	1043	30	0.99
Chorda filum (L.) Stackhouse and *Halosiphon tomentosum* (Lyngbye) Jaasund	621	10	0.91
Mytilus trossulus Gould	1165	30	0.92

Multiple abiotic environmental factors affect the distribution of macrophytes (RINNE et al. 2011). In-depth reviews of abiotic environmental variables that affect the occurrence of rocky shore macroalgae are found in RINNE et al. (2011) and for soft bottom macrophytes in HANSEN & SNICKARS (2014). The environmental variables used as predictors in the species distribution modelling were depth (Velmu 2019), exposure (modelled according to ISAEUS 2004), exposure of the sea floor (modelled according to BEKKBY et al. 2008), Secchi depth (LAPPALAINEN et al. 2019), phosphorus and nitrogen content (interpolated values based on 10-year average values from summertime measurements), the slope of the sea floor (values based on the depth model), and distance to sand (data from CORINE land cover: http://www.syke.fi/avointieto, distance calculated with the Cost Distance function in ArcGIS).

The modelled species distribution maps were an important input to the Marxan analysis, where they were considered as conservation features, i.e. important nature values that the MPA network aims to protect. In addition, other previously produced maps on species and habitat distribution were used in the analysis as conservation features (see full list in Appendix I).

2.4 Identifying suitable areas for marine protection

2.4.1 The Marxan decision-support tool

The site selection and decision-support tool Marxan (BALL & POSSINGHAM 2009) was used to identify the most suitable areas for nature protection. Marxan (marine spatially explicit annealing) is the most used software in marine conservation planning (WATTS et al. 2009, DELAVENNE et al. 2012). Marxan aims to answer a minimum set coverage problem, i.e. reach the set targets of a protected area network at the lowest cost. In conservation planning, targets are the minimum quantity or proportion of a nature value (e.g. a habitat or a species) in the planning area that should be included in the solution. For example, a target can be that 30% of each habitat is included within the MPA network.

The analysis relies on data on spatial distribution of important nature values and different pressures caused by humans. Marxan addresses the presented problem by applying a simulated annealing optimisation algorithm. The Marxan site selection analysis is run by dividing the planning area into smaller planning units and defining, for each planning unit, which nature values occur within it and to what extent (e.g. areal coverage). A cost for including a planning unit into an MPA is also defined. This cost is derived from a cost layer map that can be based on the area of planning units, the price to redeem an area, the monetary losses if an area is protected (e.g. potential losses if commercial fishing is restricted), or weighted values based on multiple factors. In this project, a weighted socio-economic cost layer was built based on human activities at sea. A protection goal, often % coverage, is defined for each nature value. Additionally, a species penalty factor (SPF) can be defined for each nature value for not reaching protection goals. This ensures that all targets are met. To adjust the size of uniform selected areas a boundary length modifier (BLM) can be applied. Using the BLM ensures that the MPA network that best reaches the set targets, does not consist of many very small and scattered areas. When Marxan is run, the site selection analysis randomly tests different solutions for the network layout and, through the simulated annealing algorithm, identifies the solution that fulfils the protection goals with the lowest cost (ARDRON et al. 2010, SERRA-SOGAS et al. 2020).

2.4.2 Identifying biological and geological values – assigning protection goals

In the Marxan analysis carried out in this project, 37 different nature values were included:

- Marine Natura 2000 habitats that occur in the area (7)
- HELCOM biotopes that are often defined by habitat-forming or most characteristic species (17)
- Rare and threatened species (9)
- Economically important species (4)

For a complete list and references, see Appendix I and ÅBO AKADEMI (2021).

The nature values included in the analysis are hereinafter referred to as *conservation features*. These conservation features are also summarised in tab. 5 together with the results on achieved protection levels. A minimum level of protection (% of geographical extent) was determined based on national and international agreements (e.g. HELCOM 2010) and through expert consultations (27 Finnish and six international Baltic Sea experts). The base protection level was set at 20%.

2.4.3 Identifying and ranking human pressures in the study area

In the Marxan site selection analysis, the selection of suitable areas for protection was guided away from areas with high levels of human pressure using two different methods. Some areas were completely excluded from the analysis due to a particular activity in the area, making it unsuitable for nature protection. These activities included fish farms, large-scale dredging sites and areas used for dumping dredged material, harbours, guest harbours, large fairways, and public beaches (tab. 2).

Table 2. Activities and facilities that make an area unsuitable for nature protection in the site selection analysis. The geographic extent of each human use is excluded from the site selection analysis, meaning that it cannot be selected as part of the proposed solution. The base for exclusion column uses pressures described in MSFD Annex III (EUROPEAN PARLIAMENT AND COUNCIL OF THE EUROPEAN UNION 2008) and in HELCOM (2016). Additional information is found in Appendix I.
Tabell 2. Aktiviteter och anläggningar som gör ett område olämpligt för naturskydd i områdesvalsanalysen. Den geografiska utsträckningen av varje enskild mänsklig aktivitet har uteslutits från områdesvalsanalysen, vilket innebär att den inte kan bli vald som en del av lösningsförslaget. Grund för uteslutning kolumnen använder miljöpåverkan beskrivna i ramdirektivet om en marin strategi (2008/56/EG: bilaga III) och i HELCOM (2016). Tilläggsinformation finns presenterad i bilaga I.

Activity	Description	Data source	Base for exclusion
Harbours	A 1 km buffer zone surrounds large harbours, and a 500 m buffer the ports for the archipelago ferries.	CORINE Land Cover 2018, ÅLR 2021	Change of seabed substrate and morphology, disturbance or damage to the seabed, changes in hydrological conditions, light pollution, noise, and input of microbial pathogens.
Fairways	Large fairways with buffer zones according to the depth of the fairway. A 1 km buffer surrounds fairways deeper than 7 m, and a 500 m buffer zone fairways 3-6.9 m deep. Shallower fairways are not excluded.	Finnish Transport Infrastructure Agency 2021	Disturbance or damage to the seabed, emissions, oil spills, polluting ship accidents, litter, sewage discharges, disturbance of species, input of microbial pathogens, input or spread of non-indigenous species, and noise.
Large-scale dredging and dumping of dredged material	Areas where dredging or dumping occurred after 2000. A 2 km buffer zone is applied.	Finnish Transport Infrastructure Agency 2021	Change of seabed substrate and morphology, disturbance or damage to the seabed, changes in hydrological conditions, impulsive noise, deposit of (possibly) contaminated dredged material, and input of organic material.

Table 2 (continued). Activities and facilities that make an area unsuitable for nature protection in the site selection analysis. The geographic extent of each human use is excluded from the site selection analysis, meaning that it cannot be selected as part of the proposed solution. The base for exclusion column uses pressures described in MSFD Annex III (EUROPEAN PARLIAMENT AND COUNCIL OF THE EUROPEAN UNION 2008) and in HELCOM (2016). Additional information is found in Appendix I.

Activity	Description	Data source	Base for exclusion
Fish farms	Point data on current fish farms. The farms' yearly phosphorous load determines the buffer zone size: < 1000 kg P → 1 km, 1000 - 2000 kg P → 2 km, > 2000 kg P → 3 km.	ÅLR 2021, ÅMHM 2021	Nutrient load, potential release of hazardous substances, increased traffic, and noise.
Guest harbours	Guest harbours with an added 500 m buffer zone.	Suomen vierassatamat Oy 2021	Change of seabed substrate and morphology, disturbance or damage to the seabed, changes in hydrological conditions, light pollution, noise, and input of microbial pathogens.
Public beaches	Public beaches with an added 250 m buffer zone.	ÅMHM 2021, https://www.aland.com/artikel/hitta-alla-badstrander-pa-Aland accessed 2021	Leisure boating, mechanical disturbance, and noise.

The other approach was including a spatial cost layer into the analysis. A spatial cost layer allows the inclusion of human-induced pressures, that may affect biodiversity, but do not need to be completely excluded from the analysis. In this analysis, the cost layer comprised of socioeconomic data that was cumulatively combined into a single comprehensive spatial layer (20*20 m cell size). Data included shipping intensity, underwater noise, potential areas for aquaculture and wind parks, urban areas, areas with intense human activity, submarine cables and pipes, the intensity of leisure boating, and privately owned coastal waters (see tab. 3 for more detailed information). The activities were assigned a weighted pressure value (0–1, where 1 presents high pressure) determined through expert meetings and a literature review. As the analysis steers the site selection away from the areas with a high "cost", the sites selected by the analysis have a higher degree of "naturalness", while still considering human interests. Areas with a high cost can be included in a solution produced by the analysis if the value of adding the conservation features in the area outweighs the cost.

Table 3. Activities, pressures and planned uses that reduce the suitability of a site as a marine protected area in the site selection analysis. The considered uses were assigned a weighted cost value to make the site selection analysis favour areas less impacted by human interests. The relevance column uses pressures described in MSFD Annex III (EUROPEAN PARLIAMENT AND COUNCIL OF THE EUROPEAN UNION 2008) and in HELCOM (2016). Additional information is found in Appendix I.

Tabell 2. Aktiviteter, mänsklig påverkan och planerade användningsområden som minskar lämpligheten av ett område för marint miljöskydd i områdesvalsanalysen. De beaktade aktiviteterna har tilldelats ett vägt kostnadsvärde som styr områdesvalsanalysen mot områden vilka är mindre påverkade av människans intressen. Relevans kolumnen använder trycken beskrivna i ramdirektivet om en marin strategi (2008/56/EG: Bilaga III) och i HELCOM (2016). Tilläggsinformation finns presenterad i bilaga I.

Activity	Cost	Description	Data source	Relevance
Shipping intensity	0–1	Raster layer presenting a standardised value for number of ships per year. Based on Baltic Sea AIS data.	HELCOM 2019	Disturbance or damage to the seabed, input of ambient underwater noise, air emission of hazardous substances and deposition to the sea, oil spills, polluting ship accidents, beach and other litter, emission of nutrients from land and shipping and deposition to the sea, sewage discharges, disturbance of species, input of microbial pathogens, and input or spread of non-indigenous species.
Underwater noise	0–0.88	Raster layer on Baltic Sea underwater noise	BIAS project data 2014	Disturbance to fish, birds, and marine mammals.
Potential areas for aquaculture	0.2	Areas (polygons) proposed for future aquaculture (algae and mussel farming) in the Åland Islands maritime spatial plan.	Havsplanen 2021	Disturbance to the seabed during construction, increased traffic, and noise.
Urban areas	0.8	Areas selected based on the CORINE Land Cover classification (raster data). The classes include continuous urban fabric, discontinuous urban fabric, industry or commercial units, road and rail networks and associated land, port areas, airports, mineral extraction sites, dump sites, and construction sites. Areas under 1 ha are not considered. A 500 m buffer zone was applied.	CORINE Land Cover 2018	Riverine inputs and direct discharges of hazardous substances from the coast, beach and other forms of litter, riverine inputs and direct discharges of nutrients from the coast, organic matter input, and microbial pathogens input.
Areas of intense use	0–1	Standardised value for the number of small jetties and small-scale dredgings per square kilometre. Raster created based on point data.	MH 2021	Disturbance, small-scale habitat loss, increased turbidity, and sedimentation.
Cables and pipelines	0.5	The extent of submarine cables and pipelines (line data), including a 100 m buffer zone.	Traficom 2021	Disturbance to the seabed and heat emission.
Potential areas for offshore wind industry	0.5	Areas (polygons) for possible offshore wind industry development in the Åland Islands maritime spatial plan.	Havsplanen 2021	Disturbance to seabed during construction, potential adverse effect on birds, and noise.

Table 3 (continued). Activities, pressures and planned uses that reduce the suitability of a site as a marine protected area in the site selection analysis. The considered uses were assigned a weighted cost value to make the site selection analysis favour areas less impacted by human interests. The relevance column uses pressures described in MSFD Annex III (EUROPEAN PARLIAMENT AND COUNCIL OF THE EUROPEAN UNION 2008) and in HELCOM (2016). Additional information is found in Appendix I.

Activity	Cost	Description	Data source	Relevance
The intensity of leisure boating	0–0.83	Model on the intensity of leisure boating created in the Sustainable Shipping and Environment of the Baltic Sea (SHEBA) project. The model considers fuel consumption, AIS data, visits to small harbours, and the depth of the area.	HELCOM project SHEBA 2018	Traffic, emissions, noise, erosion, and disturbance
Privately owned water	0.2	The ownership status of the coastal waters (polygon data).	Landskapets fastighetsverk 2022	

2.4.4 The Marxan site selection analysis

Before the analysis was run, three scenarios were devised:

A) A baseline scenario where human impact and interest were not considered. This scenario identified areas that meet the conservation targets set for the analysis (tab. 5) while minimizing the area selected. In other words, this scenario identified areas with high nature values, without considering human activities or the current MPA network. As neither current MPAs nor human activities are considered, the scenario is not a realistic basis for developing an existing MPA network, as was the aim in the Åland Islands. However, the result identifies ecologically important areas in the coastal waters of the Åland Islands, regardless of whether they are currently protected or not. In addition, this information is useful when potential areas for MPAs are compared or evaluated for protection and as a support for maritime spatial planning.

B) A scenario where areas most suitable for protection were identified, but considering the existing MPA network, that was embedded as part of the solution, as well as human impacts.

C) An identical to scenario B, but water ownership was also considered so that areas not owned by ÅLR were given higher cost (see tab. 3).

Pre-treatment of the spatial data was done in ArcMap (v. 10.5) using the ArcMarxan toolbox (v. 2.0.2, APROPOS INFORMATION SYSTEMS INC.) to create the input files for Marxan. All spatial data were converted to raster format with a resolution of 20*20 meters, except for point data, which were kept in shapefile format. The survey area (coastal waters of the Åland Islands) was divided into planning units (500*500 m squares), resulting in approximately 35 000 planning units. The shape and size of the planning units best suited for our study area were evaluated in a preliminary study (AROLA 2020), and the resulting number of planning units is within the recommended range for Marxan (ARDRON et al. 2008).

With all the files prepared, the initial runs of Marxan were performed. The parameters for Marxan were set to 100 runs, 10^7 iterations, BLM was set to zero, and SPF to one for the initial runs. The number of iterations was tested through the iteration calibration tool in the ArcMarxan toolbox. Following the initial runs, BLM was calibrated to achieve suitable clustering. For scenario A, BLM was set to 1 000, and for B, BLM was set to 0.002, and for C, BLM was set to 0.004. After that, SPF was increased until all 100 runs achieved the set protection goals. The penalty factor was set to ten for all scenarios.

The results of the site selection analysis for each scenario were visualised on two maps. Firstly, a selection frequency map represented how often a planning unit was selected as part of the solution in the 100 runs that all filled the conservation targets. Secondarily, a map depicting the solution was produced, i.e., areas selected as suitable for protection, with the lowest (i.e. best) score of the 100 runs.

The analysis calculates the achieved protection of a conservation feature in the scenarios as well as the spatial extent (% coverage) of conservation features present in the selected planning units. These results were also manually evaluated in ArcMap to ensure the reliability of the results.

2.5 Stakeholder involvement

According to the principles of SCP, stakeholder involvement is essential for a transparent planning process and the functionality of new MPAs (BAN et al. 2009). The project aimed to inform about the background and aims of the project, current mapping efforts, and results of the inventories, e.g. presentations of the distribution maps. Throughout the site selection process, stakeholders were encouraged to discuss and send feedback to the project. In the Åland Islands, the stakeholder involvement was not made through an official process. However, there were several ways to give feedback and influence the work at different stages, e.g. during presentations and discussions, via a questionnaire, and e-mail correspondence. Throughout the project, stakeholders and the public were informed through local and national news outlets and social media according to a carefully made communication plan.

3 Results

3.1 Underwater surveys

During the ÅSM project, 2 706 high-resolution data points on underwater nature values were obtained from 206 scuba-diving transects. Habitat-level data was acquired from 959 drop-video points. In addition, data from 10 684 survey points collected by Husö biological station around the Åland Islands were collated to form a common database (tab. 4, fig. 2). In 2022, 46 additional dives were conducted in areas selected as suitable for protection in the site selection analysis, but none or sparse *in situ* data points existed. This meant that we could further evaluate the accuracy of the distribution models used in the site selection analysis.

Table 4. The number of mapping transects and data points per method and year collected by Husö biological station (Åbo Akademi University) and the ÅlandSeaMap project in the Åland Islands. The number of new data points collected within ÅlandSeaMap in bold.

Tabell 3. Antalet karteringstransekter och datapunkter för de olika karteringsmetoderna per år insamlade av Husö biologiska station (Åbo Akademi) och ÅlandSeaMap projektet på Åland. Antalet nya karteringspunkter samlade inom ÅlandSeaMap i fetstil.

Year	Dive transects (data points)	Snorkelling transects (data points)	Drop-video points	Aquascope points	Total data points
2002		118 (1271)			1271
2003		154 (1577)			1577
2004	32 (261)	44 (451)			712
2005	7 (58)			160	218
2007	27 (217)				217
2008	39 (361)				361
2010	25 (267)				267
2011	28 (288)		489		777
2012	12 (172)				172
2013	27 (466)				466
2015	19 (285)	13 (36)	20		341
2017	75 (992)	1 (6)	425		1423
2018	53 (653)	49 (468)	548		1669
2019	**41 (455)**		**401**		**856**
	14 (157)		231		388
2020	**42 (533)**		**417**		**950**
2021	**33 (487)**	**45 (595)**	**139**		**1221**
2022	**45 (636)**	87 (825)	**2**		**638** 825

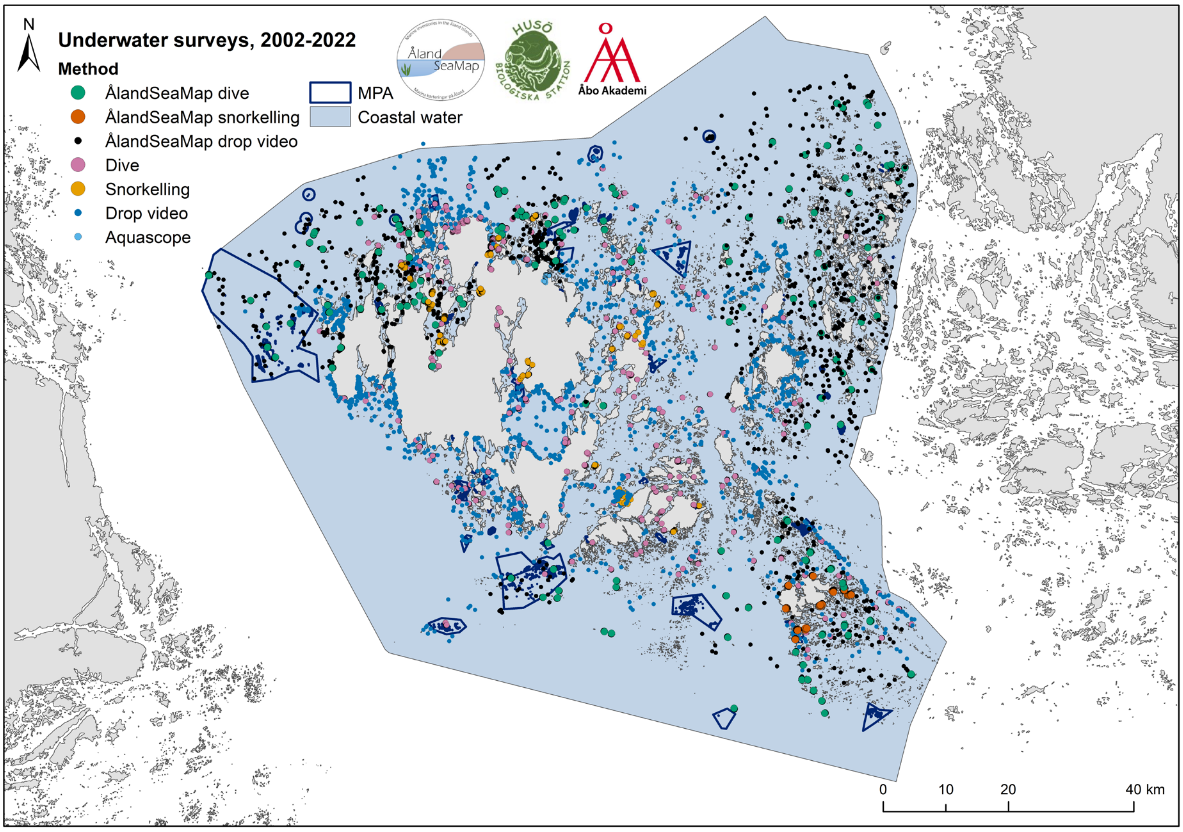


Figure 2. A Map illustrating data points surveyed in underwater inventories 2002–2022 in the Åland Islands. New points surveyed within ÅlandSeaMap are drawn in green (dive), dark orange (snorkelling) and black (drop-video).

Figur 2. En karta över de inom projektet undersökta och sammanställda data från undervattenskarteringar 2002–2022 på Åland. Nya punkter karterade inom ÅlandSeaMap är markerade i grön (dyk), mörkorange (snorkling) och svart (drop-video).

The marine environment of the Åland Islands hosts a number of valuable habitats and threatened or rare species. The exposed rocky shores of the northeast and southern outer archipelago host high red algal diversity and coverage (fig. 3b, fig. 6c). The coastal waters are rich in underwater reefs that support extensive blue mussel beds and algae communities (fig. 3b, fig. 6a). *Zostera marina* meadows (fig. 3c) are somewhat common on the sandy bottoms of the western Åland Islands, Lumparn Bay, and around the esker islands in the southeast (fig. 6d, see also RINNE et al. 2019). Both sheltered and exposed shallow bays occur frequently around the Åland Islands. Charophytes are common in many shallow bays and can grow in highly diverse meadows (fig. 3d). However, the effects of eutrophication are discernible around the Åland Islands. For example, the ecological status of macrophytes in parts of the eastern archipelago is lower than expected. Additionally, some bays are dominated by opportunistic fast-growing macrophytes, and anoxia caused by decomposing algal mats is not uncommon. Rare or threatened species surveyed during the project include the red algae *Rhodomela confervoides* (NT) and *Chara virgatum* (VU) (fig. 4), the stonewort *Chara horrida* (EN) (fig. 5), and the seagrass *Z. marina* (NT). Habitat-forming *F. vesiculosus* shows regional differences in occurrence in the Åland Islands and is most common on the northern shores (fig. 6b), where it can grow down to eight meters deep (see also RINNE & SALOVIUS-LAURÉN 2020). The esker islands of northeastern Kökar are unique and both geologically and biologically diverse (RINNE et al. 2019). The leaf beetle *Macroplea pubipennis* (NT) was also found in the Åland Islands during the ÅSM project.

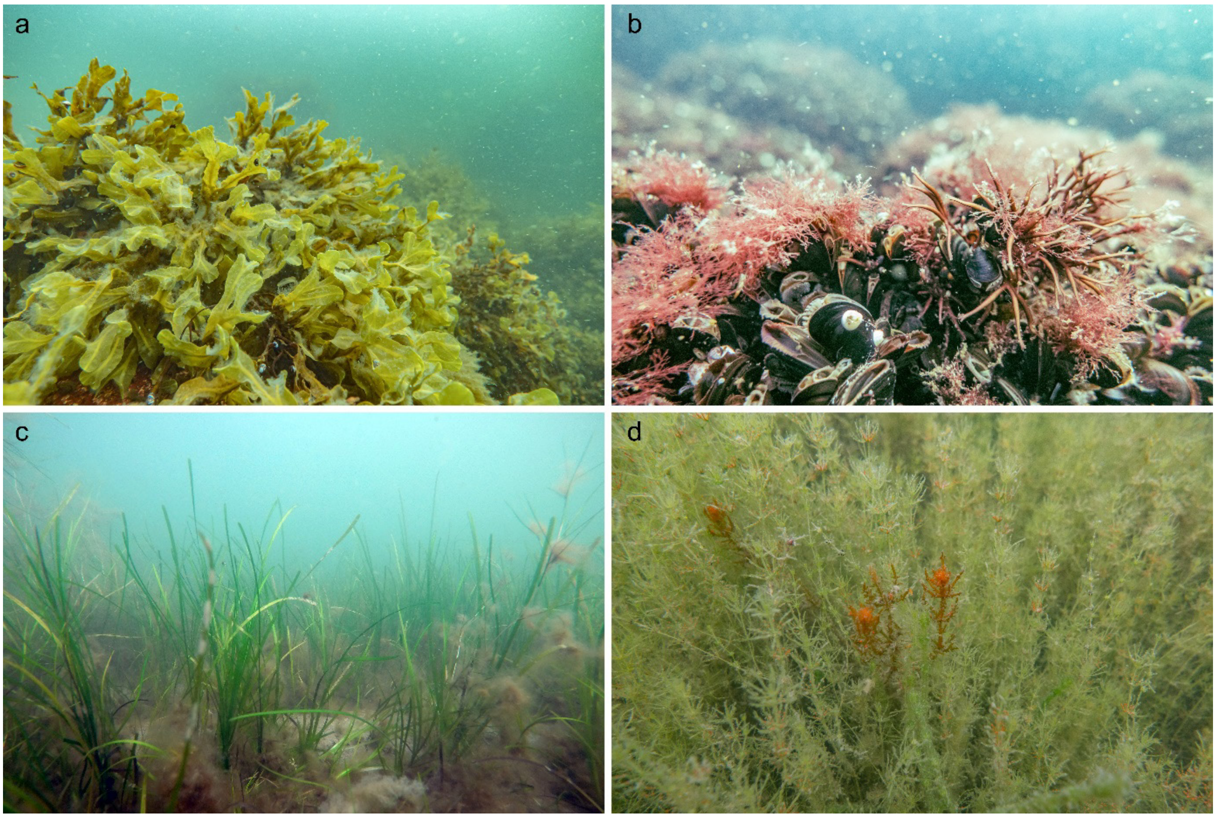


Figure 3. Four key habitats that occur in the Åland Islands' coastal waters: a) a *Fucus vesiculosus* belt in Geta; b) *Furcellaria lumbricalis* and *Ceramium tenuicorne* on a *Mytilus trossulus bed*; c) a *Zostera marina* meadow; and d) a charophyte meadow with *Chara aspera*, *Chara canescens*, and *Chara tomentosa* in a shallow sheltered bay in Finström. Pictures a–c by Petra Arola and d by Karl Weckström. Edits by Tony Cederberg.

Figur 3. Fyra nyckelhabitat som förekommer i de åländska kustvattnen: a) ett Fucus vesiculosus bälte i Geta, b) Furcellaria lumbricalis och Ceramium tenuicorne på en Mytilus trossulus bädd, c) en Zostera marina äng och d) en kransalgsäng med Chara aspera, Chara canescens och Chara tomentosa i en grund skyddad vik i Finström. Bilder a–c fotograferade av Petra Arola och d av Karl Weckström. Bilder editerade av Tony Cederberg.

Figure 4. Red hornweed, *Ceramium virgatum* from southern Föglö. Picture by Karl Weckström.

Figur 4. Grovsläke, Ceramium virgatum från södra Föglö. Bild tagen av Karl Weckström.

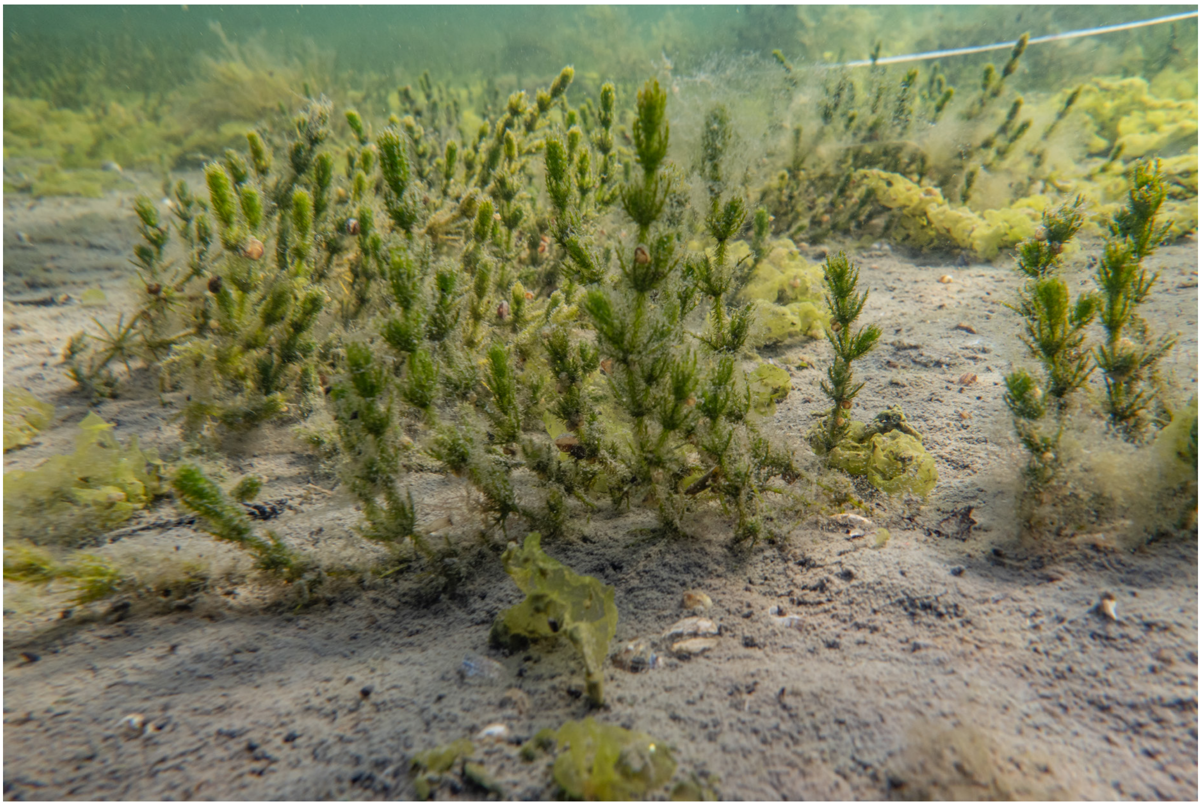


Figure 5. *Chara horrida* on Kökar. Picture by Floriaan Eveleens Maarse.

Figur 5. Raggsträfse, Chara horrida på Kökar. Bild tagen av Floriaan Eveleens Maarse.

All data from the field surveys were recorded in a database. This includes observations not directly used in the site selection analysis, such as the maximum depth distribution of selected species, the upper and lower depth limits of the *F. vesiculosus* belt, and invasive terrestrial species on the shore. This information is especially useful in future assessments as the upper and lower depth limits of macrophytes are shifting due to climate change and eutrophication through, e.g. reduced ice scouring and reduced light penetration (KAUTSKY et al. 1986, EVELEENS MAARSE et al. 2020). *Fucus vesiculosus* belts are of special interest as a key habitat (KAUTSKY et al. 1992), and their depth distribution has been reduced in the Baltic Sea (KAUTSKY et al. 1986). Thus, this data can provide a baseline for updating monitoring protocols and future Water Framework Directive and Habitats Directive reporting. Invasive terrestrial species, e.g. beach rose (*Rosa rugosa*), can outcompete native species on sandy beaches, a threatened habitat (HELCOM 2013b), and were noted as they are actively being removed to protect the environment. During our surveys, marine macroscopic litter was rare in the coastal waters, although it occurred to some extent on shores.

3.2 Species distribution models

In total, 15 distribution models (listed in tab. 4) were created; see Appendix I for all the produced distribution models visualised as maps. The models had high AUC (Area Under ROC [Receiver Operating Characteristic] Curve) values (0.86–0.99), which indicates high predictive performance (tab. 1). The models were published separately in a data catalogue, presented as distribution maps (for example see fig. 6, RINNE & SALOVIUS-LAURÉN 2021), and communicated to experts and stakeholders prior to the site selection analysis. This was done to get feedback on the produced species distribution maps and to ensure transparency.

The additional surveys conducted in 2022 filled in knowledge gaps and confirmed that the predictive models were reliable in the surveyed areas. Using the data collected in 2022 as a test data set and rerunning the species distribution models, we could evaluate the accuracy of the predictive models in areas where no or sparse survey points existed. The models for *F. vesiculosus* (AUC=0.76), Red algal communities (AUC=0.74), *M. trossulus* beds (AUC=0.86), annual filamentous algae (AUC=0.84), perennial filamentous algae (AUC=0.66), *Potamogeton* sp. and *Stuckenia* sp. communities (AUC=0.93), and *Zannichellia* sp. and *Ruppia* sp. communities (AUC=0.66) were evaluated. The results indicate that the produced models have high reliability. The weaker performance of the models for perennial filamentous algae and *Zannichellia* sp. and *Ruppia* sp. communities can be explained by the reduced accuracy of the depth model and the dynamicity of sandy bottoms in the outer archipelago. All the models depend on depth as a predictor, and as the accuracy of the depth layer is reduced towards the outer archipelago, so does the accuracy of the predictive model. However, the reduced accuracy can be compensated for when used together with species distribution models, aerial or satellite images, and local knowledge. Within the more intensively mapped areas, the predictive power of the models is high.

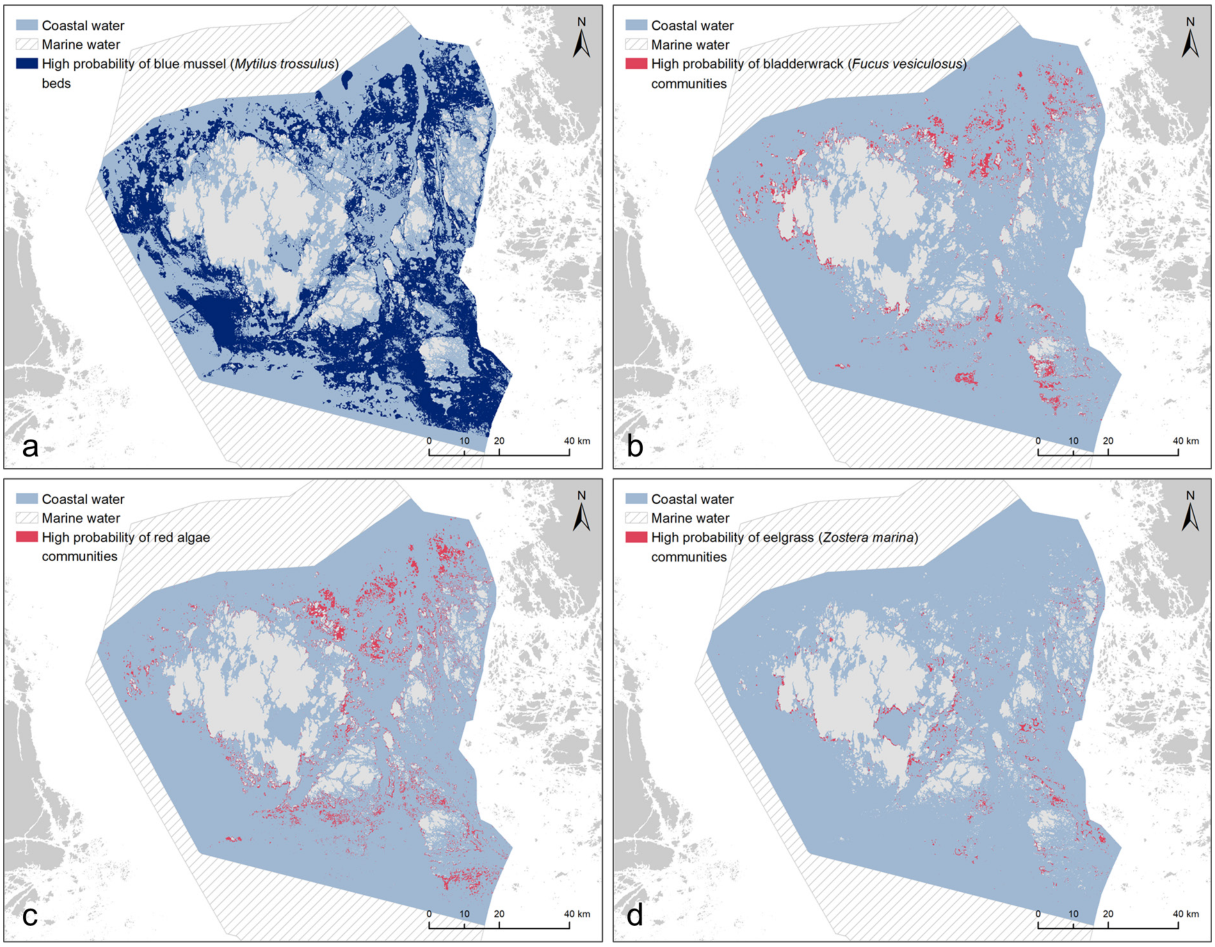


Figure 6. Species distribution models for: a) *Mytilus trossulus* beds; b) *Fucus vesiculosus* communities; c) red algal communities; and d) *Zostera marina* communities. The models show areas with a high probability for the occurrence of the species. All the produced maps can be found in Appendix **I**.

Figur 6. Artdistributionsmodeller för: a) Mytilus trossulus bäddar*, b) Fucus vesiculosus, c) rödalgssamhällen och d) Zostera marina. Modellerna synliggörs på kartor och visar områden med hög sannolikhet för förekomst av arterna. Alla de producerade kartorna finns i bilaga I.*

3.3 Site selection analysis

The site selection analysis produced 100 calibrated solutions for a potential MPA network that fulfil the protection goals set for the conservation features. The most important conservation areas were illustrated through a frequency map (defined by how often a planning unit was selected over these 100 runs). Of the 100 runs, the best scoring solution was also illustrated as a proposed MPA network (fig. 7–9). The results were published separately in a report (SALOVIUS-LAURÉN & WECKSTRÖM 2022) and communicated to experts and stakeholders.

In scenario A (fig. 7), planning units were selected solely based on the amount of conservation features present in a planning unit. In the scenario, only area was used as a cost to minimise the area covered by the MPA network. The optimal solution produced in scenario A, i.e. the best scoring run in Marxan, resulted in an MPA network covering 1 134 km^2, corresponding to 14.6% of the coastal waters.

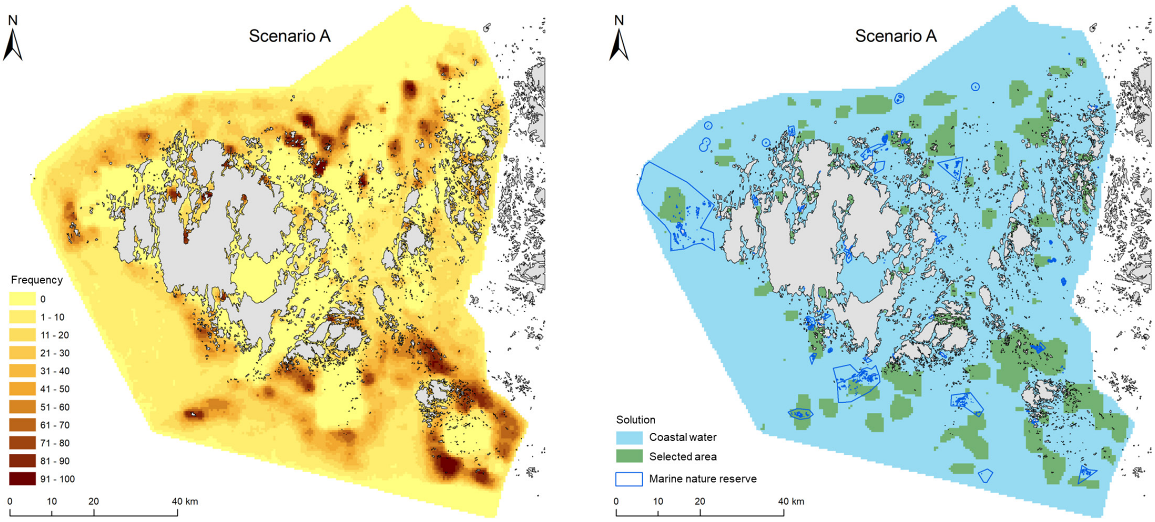


Figure 7. Results of scenario A (only conservation features and area are considered). The map on the left illustrates the frequency at which a planning unit was selected as part of a solution over 100 runs. The map on the right shows the proposed network that fulfils the set of protection goals with the lowest area (the best solution). Also, the current MPA network is shown on the map in blue.

Figur 7. Resultaten av scenario A (endast skyddsobjekt och areal är beaktade). Kartan till vänster illustrerar urvalsfrekvensen av en planeringsenhet under 100 körningar av områdesvalsanalysen. Kartan till höger illustrerar skyddsområdesnätverket som uppfyller de uppställda skyddsmålen till den lägsta arealen (den bästa lösningen). Befintliga skyddsområden markerade i blått på kartan.

Scenario B (fig. 8) identified areas with high conservation value when the current MPA network was included and automatically considered as a part of the solution. Human activities were also included, with some areas excluded (e.g. harbours, fish farms, and large fairways, see tab 2) and some areas included in the cost layer (e.g. leisure boating, urban areas, and noise, see tab 3). The optimal solution produced in scenario B, i.e. the best scoring run in Marxan, resulted in an MPA network covering 1 283 km^2 of sea area, corresponding to 16.5% of the coastal waters.

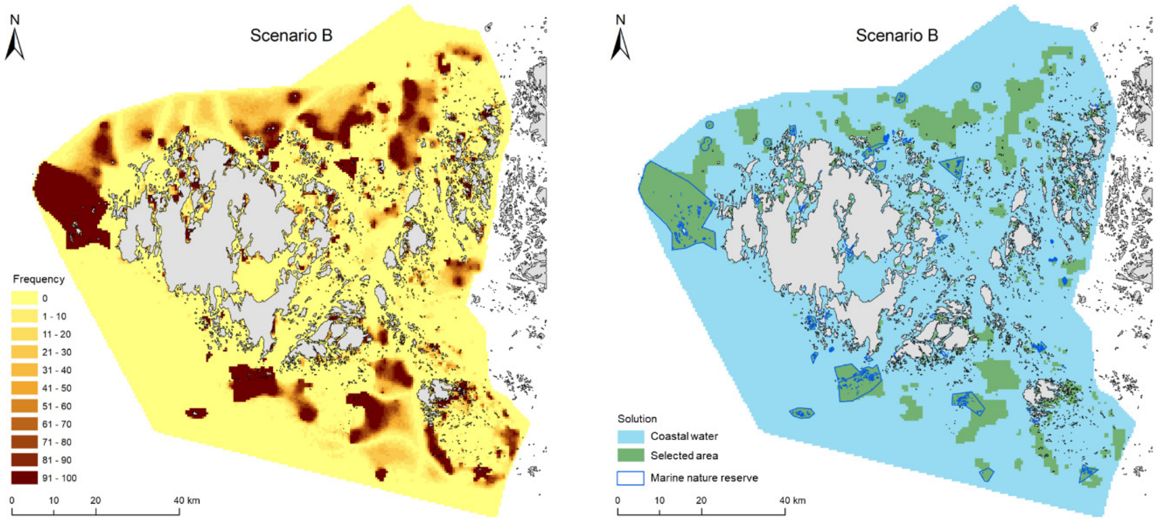


Figure 8. Results of scenario B (conservation features, existing MPAs and human activities are considered). The map on the left illustrates the frequency at which a planning unit was selected as part of a solution over 100 runs. The map on the right shows the proposed network that fulfils the set protection goals to the lowest cost and area in scenario B (the best solution). Also, the current MPA network is shown on the map in blue.

Figur 8. Resultaten av scenario B (skyddsobjekt, befintliga skyddsområden och mänskliga aktiviteter är beaktade). Kartan till vänster illustrerar urvalsfrekvensen av en planeringsenhet under 100 körningar av områdesvalsanalysen. Kartan till höger illustrerar skyddsområdesnätverket som uppfyller de uppställda skyddsmålen till den lägsta kostnaden och arealen i scenario B (den bästa lösningen). Befintliga skyddsområden markerade i blått på kartan.

Scenario C (fig. 9) was identical to scenario B, but the ownership of the water area was included by assigning privately owned water a cost. In practice, this meant that coastal water areas governed by ÅLR were prioritised over privately owned water as suitable for protection if conservation values were equal. The optimal solution produced in scenario C, i.e. the best scoring run in Marxan, resulted in an MPA network covering 1 303 km^2 of the sea area, corresponding to 16.7% of the coastal waters.

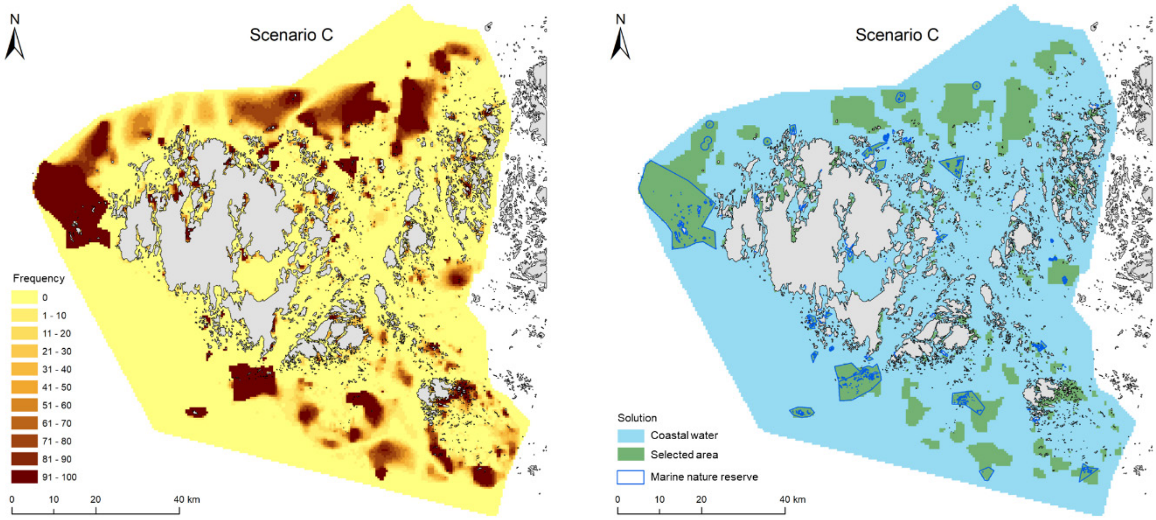


Figure 9. The results of scenario C (conservation features, MPAs, human activities, and ownership are considered). The map on the left illustrates the frequency at which a planning unit was selected as part of a solution over 100 runs. The map on the right shows the proposed network that fulfils the set protection goals to the lowest cost and area in scenario C (the best solution). Also, the current MPA network is shown on the map in blue.

Figur 9. Resultaten av scenario C (skyddsobjekt, befintliga skyddsområden, mänskliga aktiviteter och ägandeförhållanden beaktade). Kartan till vänster illustrerar urvalsfrekvensen av en planeringsenhet under 100 körningar av områdesvalsanalysen. Kartan till höger illustrerar skyddsområdesnätverket som uppfyller de uppställda skyddsmålen till den lägsta kostnaden och arealen i scenario C (den bästa lösningen). Befintliga skyddsområden markerade i blått på kartan.

3.4 The representation of conservation features

Representation, i.e. the percentage of each conservation feature that would be protected, was evaluated for the existing MPA network and for each Marxan scenario (A, B and C). The suggested additions to the current MPA network produced by the site selection analysis were calibrated so that all protection goals were met. Due to the spatial optimisation, protection can even exceed the set goals by selecting larger uniform areas and biologically diverse communities supporting multiple conservation features (tab. 5). This may especially affect the more common conservation features, such as *M. trossulus* and annual filamentous algae.

When the existing MPA network was evaluated, only two conservation features, i.e. important areas for grey seals and communities of annual filamentous algae, reached the protection goals. Many of the conservation features included in the analysis have no representation in the existing MPA network, including rare and threatened species, communities, and habitats (tab. 5).

Table 5. All the conservation features included in the Marxan site selection analysis, the protection goal (%) defined in the analysis, and their protection level (%) (modelled distribution or point observations) in the current (2021) MPA network and, respectively, the produced scenarios A, B, and C.

Tabell 5. Alla de naturvärden som beaktades i Marxan områdesvalsanalysen, skyddsmålet (%) som definierades i analysen, den procentuella andelen av ett naturvärdes modellerade distribution eller punktobservationer som representerades av det befintliga (2021) skyddsområdesnätverket respektive de framställda scenarierna A, B och C.

Conservation feature	Protection goal (%)	Existing MPAs (2021)	Scenario A	Scenario B	Scenario C
Natura 2000 habitats (code)					
Sandbanks (1110)	20	0.0	50.2	20.2	20.2
Coastal lagoons (1150)	30	0.8	30.0	30.0	30.0
Large shallow inlets and bays (1160)	20	0.0	66.9	42.4	22.4
Reefs (1170)	20	6.6	20.0	20.0	22.1
Baltic esker islands (1610)	20	9.5	68.6	33.6	33.8
Boreal Baltic narrow inlets (1650)	20	0.0	20.7	20.0	20.1
Boreal Baltic islets and small islands (1620)	20	4.5	26.2	22.0	20.4
HELCOM habitats					
Fucus vesiculosus L.	30	6.3	30.0	30.4	30.0
Red algae communities	30	7.0	30.0	30.0	30.0
Perennial filamentous algae	20	9.5	20.0	27.9	26.6
Potamogeton and *Stuckenia* communities	20	0.5	21.0	20.2	20.0
Ranunculus communities	20	0.3	28.1	21.5	20.2
Zannichellia sp. and *Ruppia* sp.	20	0.8	20.0	20.0	20.0
Myriophyllum communities	10	1.0	24.3	25.8	27.1
Ceratophyllum communities	10	0.2	21.8	15.6	12.6
Exposed stonewort communities	20	0.8	24.6	24.3	26.0
Sheltered stonewort communities	20	1.4	24.4	23.7	25.4
Najas marina L.	20	1.6	24.8	24.8	20.1
Zostera marina L.	20	1.8	21.5	20.0	20.0
Annual filamentous algae	5	5.6	31.8	27.6	28.1
Chorda filum (L.) Stackhouse and *Halosiphon tomentosum* (Lyngbye) Jaasund	10	3.2	21.6	15.5	14.3
Vaucheria sp.	10	0.0	39.4	35.0	38.0
Mytilus trossulus Gould	10	7.3	18.6	21.9	20.6
Polyp communities	20	0.0	21.2	21.2	21.2
Threatened or rare species					
Chara connivens P. Salzman ex A. Braun	50	0.0	66.7	66.7	66.7
Chara horrida Wahlstedt	50	0.0	52.9	52.9	52.9
Ceramium virgatum Roth	50	0.0	52.6	52.6	57.9
Rhodomela confervoides (Hudson) Silva	30	14.0	34.9	48.8	37.2
Baltic flounder	20	8.5	27.5	20.0	20.0
IBA and FINIBA	30	11.5	30.0	30.6	30.0
Halichoerus grypus Fabricius	10	13.3	19.5	37.2	44.9
Pusa hispida botnica Gmelin	20	0.9	20.2	21.9	24.0
Sea spawning *Coregonus lavaretus* L.	30	0.0	30.0	30.2	30.3
Economically important species					
Perca fluviatilis L.	20	0.5	20.0	20.0	20.0
Zander lucioperca L.	20	0.3	20.2	20.4	20.8
Esox lucius L.	20	0.3	20.0	20.0	20.0
Baltic *Clupea harengus* L.	20	5.6	20.0	20.0	20.0

3.5 Establishment of new MPAs

Based on the site selection analysis, the most suitable areas for protection were identified and some new areas have already been redeemed by ÅLR to be included in the MPA network (fig. 10). These include Storklyndan naturreservat (795 ha, fig. 10a), Storskär – Kalhäran (2088 ha, fig. 10b left), Hemmingshärsfjärden (806 ha, fig. 10b right), and Stornäset naturreservat (270 ha, fig. 10c). However, progression towards comprehensive protection is still underway. All the areas have yet to reach full legal protected status. Efforts are ongoing both to expand the MPA network and to develop management plans. This process involves collaboration with local communities and stakeholders to ensure sustainable management and conservation of these vital ecosystems.

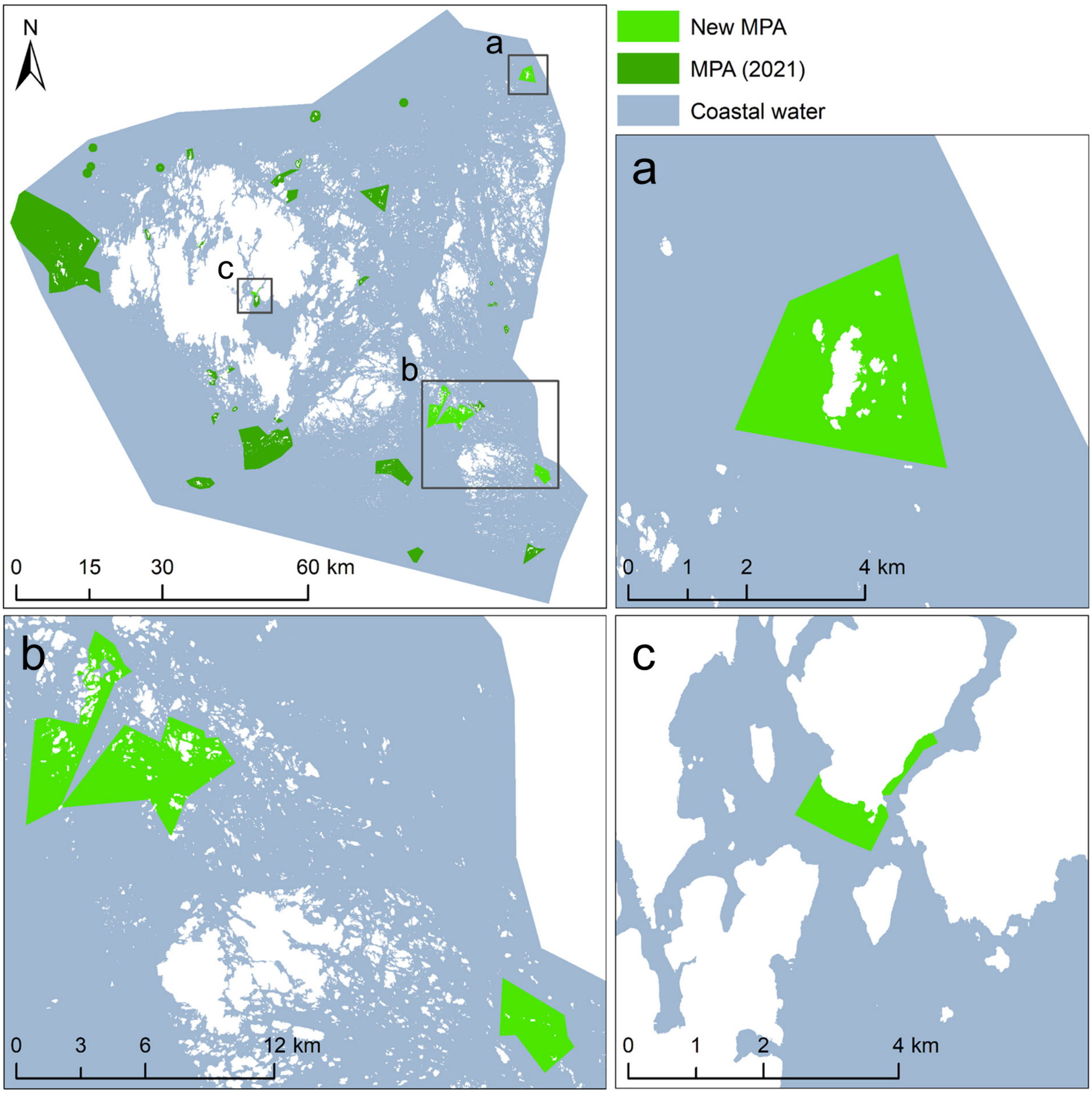


Figure 10. Map of the new protected areas (2021–2023) established during the ÅlandSeaMap project and the marine protected areas (MPAs) established before 2021. The polygons for new MPAs are indicative, and all areas have not reached full legal protected status yet.

Figur 10. Karta över nya skyddsområden (2021–2023) inrättande under ÅlandSeaMap projektet samt marina skyddsområden inrättade före 2021. Polygonerna för de nya skyddsområdena är approximativa och alla områden har inte ännu nått fullständigt juridiskt skyddsområdesstatus.

3.6 Stakeholder involvement, feedback, scientific output, and general outreach

Altogether, more than 1 000 people were directly reached by the project. During the project, 15 open presentations for the public and 18 presentations for experts in the field were held. These events included presenting the project, a specific part of the project, progress, and results. One open webinar was held for the public, where the background to the project, marine conservation planning, and the planned site selection analysis were presented. Prior to the public commenting of the proposed conservation features, maps of nature values and costs to be included in the site selection analysis were summarised, presented, and published in a data catalogue (RINNE & SALOVIUS-LAURÉN 2021). Additionally, a poll survey was conducted for the public as an alternative to written correspondence. During the project, newspapers were contacted four times (local and national). These and other direct press contacts resulted in 16 newspaper articles, four periodical articles, and seven reports by the Finnish Broadcasting Company (YLE). Members of the project were also interviewed by Ålands Radio & TV six times. Additionally, a documentary film on the key species *F. vesiculosus* was produced to raise awareness and promote a citizen science offshoot project. The material used for the site selection analysis and the analysis results were published on the project homepage, and the involvement of the public was encouraged throughout the project. Information about the project was shared through the project's social media accounts (Facebook, Instagram, and Twitter), and involvement opportunities were promoted.

The feedback from the public mainly addressed the data representing areas for fishing and hunting. According to stakeholders, the maps did not accurately represent the coastal water areas where fishing and hunting are exercised. Data that would better represent these areas were not readily nor publicly available. The stakeholders also questioned the reasons for including fishing and hunting as a pressure/cost in the analysis, as they were considered small-scale and rather to improve the marine environment (e.g. by indirectly reducing predation on fish stocks by seals and great cormorants, *Phalacrocorax carbo*) rather than causing pressures. After reviewing the feedback and available data, the areas for fishing (recreational, household, secondary source of livelihood, and commercial fishing) and hunting, including islands previously owned by the Swedish Crown (*holmar av krononatur*), were excluded as a cost from the analysis. This was done as most of the coastal waters of the Åland Islands are used for fishing, and a study area-wide uniform cost would be insignificant for the analysis. As a result of the feedback, also important spawning areas for sea-spawning white fish were included as a conservation feature. The Government of Åland Fisheries Bureau provided the spatial data.

Additional outreach was performed through an open webinar and presentations for stakeholders, the local environmental agency, and politicians (e.g. Kustvattendagarna, 2022). The project was also presented to experts in marine biology on multiple occasions, e.g. at the FINMARI (Finnish Marine Research Consortium) Researcher Day 2020, Oikos conference 2022, Velmu seminar on marine nature

2022, Velmu international conference 2023, the eMSP NRSB project's international workshop 2023, and the Baltic Sea Science Congress 2019 and 2023.

ÅSM has also produced offshoot projects in collaboration with ÅLR and the Velmu program. Studies on *F. vesiculosus*-associated invertebrate fauna were conducted to describe the small-scale temporal and spatial variation in the faunal communities, as well as effects of isolation. The results of these studies have further been presented to the working group on crustaceans for the Finnish Red List of species. In collaboration with the Velmu program, special attention was given to mapping reefs and shallow bays to develop indicators for water quality and environmental status. Together with ÅLR, the bay Slottsundet was mapped, and suggestions for new sites for monitoring macrophytes in the outer archipelago of the Åland Islands were proposed (FINNBÄCK 2021). Data collated and collected within ÅSM has also contributed to the identification of the ecologically significant underwater areas in Finland (LAPPALAINEN et al. 2020), to the development of the MPA network in Finland (KUUSELA et al. 2022), and to the HELCOM "State of the Baltic Sea" holistic assessment (HELCOM 2023).

The data collected within the project was used when updating species distribution maps in the book Havets skattkammare: en upptäcktsresa i Finlands marina undervattensnatur, 2021 (Swedish updated version of Meren aarteet: löytöretki Suomen vedenalaiseen meriluontoon, 2017). Due to the information collected within the ÅSM project, an additional chapter on the underwater nature of the Åland Islands was added to the book. The project has also been presented in magazines, e.g. Skärgård (2021) and Inblick (2023). The recently published new Velmu map service, providing information on the underwater nature in Finland, also contains ÅSM data. Therefore, species distribution maps now also cover the sea areas around the Åland Islands (https://velmu.syke.fi/). Within ÅSM, twelve peer-reviewed articles and five scientific reports have been published (tab. 6). Students have been involved in the project and the offshoot projects, which has resulted in seven M.Sc. theses.

Table 6. Scientific output (Peer-reviewed articles, Master's theses, reports, and book) related to the ÅSM project.
Tabell 6. Vetenskaplig output (peer reviewed artiklar, magistersavhandlingar, rapporter och en bok) anknutet till ÅSM projektet.

Scientific output

Peer reviewed articles (12)

RINNE, H., M. BOSTRÖM, C. BJÖRKLUND & M. SAHLA, 2020. Functionality of HELCOM HUB classification in describing variation in rocky shore communities of the northern Baltic Sea. Estuar. Coast. Shelf Sci. 249, 107044.

NYMAN, A., H. RINNE, S. SALOVIUS-LAURÉN & H. VALLIUS, 2020. The distribution and characterization of gas domes in Lumparn Bay, Åland Islands, northern Baltic Sea. J. Mar. Syst. 208, 103359.

EVELEENS MAARSE, F., S. SALOVIUS-LAURÉN & S. SNICKARS, 2020. Long-term changes in the phytobenthos of the southern Åland Islands, northern Baltic Sea. Nord. J. Bot. 36, 1–11.

RINNE, H. & S. SALOVIUS-LAURÉN, 2020. The status of brown macroalgae *Fucus* spp. and its relation to environmental variation in the Finnish marine area, northern Baltic Sea. AMBIO 49, 118–129.

EVELEENS MAARSE, F., S. SALOVIUS-LAURÉN & S. SNICKARS, 2021. Physical drivers of epi- and infauna communities related to dominating macrophytes in shallow bays in the Northern Baltic Sea. Estuar. Coast. Shelf Sci. 262, 1–12.

RINNE, H. & K. KOSTAMO, 2022. Distribution and species composition of red algal communities in the northern Baltic Sea. Estuar. Coast. Shelf Sci. 269, 107806.

GAGNON, K., H. HERLEVI, J. WIKSTRÖM, M.C. NORDSTRÖM, T. SALO, S. SALOVIUS-LAURÉN & H. RINNE, 2022. Distribution and ecology of the recently introduced tanaidacean crustacean *Sinelobus vanhaareni* Bamber, 2014 in the northern Baltic Sea. Aquat. Invasions 17, 57–71.

Table 6 (continued). Scientific output (Peer-reviewed articles, Master's theses, reports, and book) related to the ÅSM project.

SALO, T. & S. SALOVIUS-LAURÉN, 2022. Green algae as bioindicators for long-term nutrient pollution along a coastal eutrophication gradient. Ecol. Indic. 140, 109034.
RINNE, H., J.-F. BLANC, T. SALO, M.C. NORDSTRÖM, N. SALMELA & S. SALOVIUS-LAURÉN, 2022. Variation in Fucus vesiculosus associated fauna along a eutrophication gradient. Estuar. Coast. Shelf Sci. 275, 107976.
BLANC, J.-F., H. RINNE & S. SALOVIUS-LAURÉN, 2023. Relationship between *Fucus* coverage and algal diversity in the northern Baltic Sea. J. Sea Res. 191, 102312.
WECKSTRÖM, K. & S. SALOVIUS-LAURÉN, 2023. Diel activity patterns of rocky shore macroinvertebrates in the northern Baltic Sea. J. Sea Res. 193, 102376.
SALO, T., H. RINNE, E. RANCKEN, J.-F. BLANC, S. SALOVIUS-LAURÉN & M.C. NORDSTRÖM, 2023. Environment-and scale-dependent changes in the functioning of invertebrate communities associated with *Fucus vesiculosus*. Estuar. Coast. Shelf Sci. 108411.

Master´s theses (7)

AROLA, P., 2020. Ålands marina naturskyddsområden – planering och utveckling av skyddsområdesnätverket med hjälp av Marxan. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 51 pp.
WECKSTRÖM, K., 2020. Dygnsvariation i rörelsemönster hos marina evertebrater. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 52 pp.
SALMELA, N., 2021. Diversitet, abundans och variation i evertebratsamhällen i *Fucus*-bälten längs eutrofieringsgradienter. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 51 pp.
RANCKEN, E., 2022. Funktionell biodiversitet hos blåstångens evertebratsamhällen längs med en eutrofieringsgradient. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 32 pp.
NIEMINEN, A., 2022. Vem äter blåstång? – Medborgarforskning som en metod för att undersöka blåstångens evertebratsamhällen i Skärgårdshavet. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 33 pp.
EKLUND, W., 2023. Variation i blåstångens (*Fucus vesiculosus*) evertebratsamhällen längs en djupgradient. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 38 pp.
SNICKARS, V., 2023. Småskalig variation i evertebratsamhällen bland blåstången, *Fucus vesiculosus*, i Skärgårdshavet. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 46 pp.

Published reports (4)

LAPPALAINEN, J., L. KURVINEN & L. KUISMANEN (eds.), 2020. Suomen ekologisesti merkittävät vedenalaiset meriluontoalueet (EMMA) – Finlands ekologiskt betydelsefulla marina undervattensmiljöer (EMMA). Suomen ympäristökeskuksen raportteja: 8/2020, 294 pp.
ÅBO AKADEMI, 2021. Underlag för skyddsområdesvalsanalysen med MARXAN, Åland 2021 - Datakatalog med faktablad.
SALOVIUS-LAURÉN, S. & K. WECKSTRÖM, 2022. Ålands värdefulla undervattensmiljöer på kartan – diskussionsunderlag för skyddsområdesplanering.
VIRTANEN E., L. FORSBLOM, F. HAAVISTO, E. KESKINEN, S. KIVILUOTO, L. KUISMANEN, A. LAINE, S. SALOVIUS-LAUREN & M. VIITASALO. 2022: Itämeri. In: Kuusela, S., M. Annala, T. Kontula, N. Leikola, A.-M. Määttänen, R. Virkkala & E. Virtanen (eds.). Kohti kattavaa suojelualueverkostoa. Luonnon monimuotoisuuden turvaamisen painopisteet Suomessa. Suomen ympäristökeskus, Helsinki. Suomen ympäristökeskuksen raportteja 18/2022. pp. 35–77.

Unpublished reports (1)

TAKOLANDER, A. R. BOMAN, L. FORSBLOM, S. SALOVIUS-LAURÉN, S. KORPINEN, J. HOIKKALA, E. VIRTANEN & L. KURVINEN, 2023. VELMU Meriluonto 2021 – Indikaattorit. Internal Finnish Ministry of the Environment report. Unpublished. 39 pp.

Books (1)

VIITASALO, M., K. KOSTAMO, E.-L. HALLANARO, W. VILJANMAA, S. KIVILUOTO, S. SALOVIUS-LAURÉN, J. EKEBOM & P. BLANKETT (eds.), 2021. Havets Skattkammare: En Upptäcktsresa I Finlands Marina Undervattensnatur. Gaudeamus, Helsinki, 543 pp.

4 Discussion

The ÅlandSeaMap project produced a variety of products that enable improved ecosystem-based management of the sea areas around the Åland Islands:

- The data collected in the project via systematic mapping forms a solid database on species occurrences together with the existing data, which can be used in marine management contexts and research.
- Species distribution maps resulting from the species distribution modelling, as well as habitat maps, provide an essential component to ecosystem-based maritime spatial planning in the region.
- The different scenarios produced in the Marxan analysis are a practical tool that can be used in guiding the expansion the MPA network in the Åland Islands towards the international goals of 30% protection.

The following chapters discuss project results and evaluates their use in different management contexts in more detail.

4.1 Project results in marine management of the Åland Islands

The produced species distribution models and maps constitute an excellent base for the future planning of sea area use. They have already been used, e.g., for evaluating the effects of aquaculture development and for environmental impact assessments for the planned wind power industry. It is also pertinent that the species and habitat maps, as well as Marxan results, are considered when updating the maritime spatial plan for the Åland Islands in the near future. For example, the cost layer included in the site selection analysis describes the distribution and strength of human impacts on the marine environment and is thus a valuable input to maritime spatial planning.

The collected data, distribution maps, and the site selection analysis directly support the implementation of the Habitats Directive in the Åland Islands as the material facilitates future monitoring and reporting. They also serve as important background information for the development of monitoring and programs related to both the Marine Strategy Framework Directive and the Water Framework Directive. The project has also contributed to Baltic Sea-wide marine protection work through, e.g. HELCOM. Data was used and can also in the future be used in, e.g. status assessments and when evaluating the Baltic Sea MPA network as a whole. Additionally, the data collected in the project can be utilised in other regional assessments.

The results of the Marxan site selection analysis in the Åland Islands provided insight on the distribution of marine nature values and how to prioritise MPA designation. The importance of area-based protection is recognised in conservation science (e.g. GRORUD-COLVERT et al. 2021). However, area-based protection requires not only area, but also enforced restrictions, effective management (inside and outside the protected area), and monitoring to function, as well as globally encompassing efforts to reduce the adverse impacts on the environment by human activities (O'LEARY et al. 2016, MAXWELL et al. 2020, GRORUD-COLVERT et al. 2021). Recent studies have proposed that a minimum area protection of 30–40% of planning areas is required for adequate protection and ≥ 50% to reach most MPA targets (O'LEARY et al. 2016). In the ÅSM project, no areal percentage goal (e.g. 30% of coastal waters protected) was set for the Marxan analysis. Instead, we used the habitats and species in the study area as a starting point. The protection goals were set for individual nature values to ensure their representation in the results. With this, we aimed to produce a solid base for developing the MPA network of the Åland Islands and to identify a set of MPAs that would ensure the minimum level of protection for the important species and habitats. Therefore, the proposed MPA network has a comparatively low total area coverage (16,7%). This can be considered as a baseline and guidance for future protection work, but to achieve international conservation targets, the "30 by 30" commitment, even more protective measures need to be taken. However, the analysis also showed that by reserving approximately 16% (Scenario C) of the Åland Islands' coastal water for nature protection through a qualitative and systematic process, a mean protection level of nearly 30% could be achieved for the considered nature values.

In this site selection analysis, the base protection goal was set to 20%. Only very common and less sensitive nature values (e.g. annual filamentous algae) were assigned lower protection goals (< 20%) as they are less sensitive to anthropogenic pressures and frequently occur together with other species and within habitats included in the analysis. A 30% goal was set for some nature values, e.g. the relatively common but essential habitat-forming species *F. vesiculosus*. The rare and threatened species had higher protection goals; the protection goal for *C. horrida* (EN), *C. connivens* (rare and Finnish observations only from the Åland Islands), and *C. virgatum* (VU) was set to 50%. Further, the analysis also included rare and threatened species mapped within other projects: sea spawning whitefish, *Coregonus lavaretus* (VU); flounders, *Platichtys flesus* and *P. solemdali* (NT); and ringed seal, *Pusa hispida botnica* (NT). Although threatened and rare species had increased protection goals in the site selection analysis, special attention will be required to protect areas that are important for threatened species to ensure adequate protection.

MPAs need defined management plans that include monitoring schemes and restrictions with sound motivation. Without management, the benefits of an MPA cannot be achieved. Possible restrictions need to have positive effects on the nature values within the protected area or contribute to upholding the environmental status of the area. Management should also be adaptive to ensure compliance, stakeholder collaboration, and achieving the goals of the MPA (GRORUD-COLVERT et al. 2021). Frequent monitoring inside and outside a designated MPA is necessary to evaluate the performance of the in-place protection. In the Åland Islands, ÅLR is responsible for drawing up and updating the management plans.

A special challenge for marine conservation planning, both in the Åland Islands and the rest of Finland, is that most of the coastal sea areas are privately or jointly owned and not managed by governmental agencies. Therefore, new areas for protection often require redeeming or private protection on a voluntary basis. The Marxan analysis shows that many high biodiversity areas that should be included in an effective MPA network (e.g. many coastal bays) are privately owned waters. To protect the nature values of these areas, their importance on biodiversity should be promoted to local people and encourage them to take protective measures.

4.2 Stakeholder involvement and raising awareness

The ÅSM project proactively engaged stakeholders in the process before the analysis. Many people showed interest in the project and the site selection analysis throughout the process. Continuous and broad communication is essential for the success of conservation efforts. However, the success of stakeholder engagement is difficult to estimate. Stakeholder engagement was restricted to some extent due to the pandemic, as some events were organised online. As the site selection analysis was carried out within a project and was not an official government-led process, it was emphasised in all communication, presentations, and reports that the results produced are to support the designation of new MPAs rather than be a completed plan for new MPAs. Despite this, feedback often treated the results as a finalised plan rather than decision support for managers.

Underwater nature, in general, and maps presenting their distribution, are difficult for the public to appraise. Feedback from the public was primarily directed toward the spatial layers considering fish, birds, and seals, which are more familiar to them. However, all the distribution maps have been presented to Baltic Sea experts and were well-received. During the work on the first maritime spatial plan for the Åland Islands (Havsplanen 2021), a map-based survey on the public perception of the marine environment was conducted. The results highlighted the northeastern archipelago as especially important for nature and cultural values (data shared by ÅLR). After the results of the site selection analysis were published and presented, most feedback has been directed to ÅLR as the environmental bureau continues the efforts to expand the MPA network. The major criticism was directed towards the general concept of area-based conservation measures, i.e. MPAs. However, the science-based approach used received a positive response.

4.3 Evaluation of the methods

4.3.1 Underwater surveys

The methods used for underwater surveys were considered to provide accurate, yet comprehensive data. Observations from scuba diving transects gave high-resolution data on species and enabled sampling for accurate species identification. In contrast, the drop-video method efficiently collected information on underwater habitat types and, to a lesser extent, species. There are, however, restrictions to the methods. The morphology of some macrophytes can be highly variable and, in some cases, display high similarity to other macrophyte species. For example, the red algae *Ahnfeltia plicata*, which has previously been found in the Åland Islands, might still occur but was not found during our surveys possibly due to the similarity of its' free-living ecotype to *Furcellaria lumbricalis*. Similarly, the red algae *Phyllophora pseudoceranoides* and *Coccotylus truncatus* cannot be discerned from each other without genetic methods in the northern Baltic Sea. Some taxa need to be grouped when analysing drop-videos due to only having access to footage of a species' macroscopic characters for species identification. This concerns mainly filamentous algae (e.g. *Ectocarpus silicosus/Pylaiella littoralis*), *Potamogeton* sp. and *Stuckenia* sp., and *Zannichellia* sp. and *Ruppia* sp. Grouping of taxonomic groups decreases the valuable species-level information and causes problems, e.g. when calculating diversity indices. Genetic methods (e.g. metabarcoding and microsatellite genotyping) could alleviate these limitations as species identification is not dependent on morphology. The additional information provided by genetic methods could increase the knowledge of species distributions and provide information on the connectivity of populations, enhancing the effectiveness of MPA networks.

New methods were explored for underwater mapping by testing the use of aerial and underwater drones, along with side sonar technology. The goal was to develop new methods that could potentially speed up survey processes. However, these techniques require further evaluation and development to ensure their effectiveness and efficiency.

4.3.2 Site selection analysis

The Marxan tool enables a repeatable and transparent site selection analysis. However, it requires knowledge of geographic information systems (GIS), how to process spatial data, and the use and calibration of the tool itself. One restriction of Marxan is the calibration of the BLM. After the equation has been balanced, there is no correct amount of clustering, and the size of the selected areas is subjective. The result Marxan produces is a complete protected area network, i.e. the separate areas take into account each other and how much of conservation features are represented in the network as a whole. This means that when new MPAs are established that are not, due to different reasons, exactly aligned with the proposed network, the proposed network would need to be updated. However, the analysis can be updated to account for newly established MPAs, adjusted protection goals, or new data, as needed. The Marxan site selection analysis did not prioritise certain conservation features over others and rather aimed to fulfil all set protection goals. Conservation planning focusing on threatened and rare species may reduce the protection of overall biodiversity (VIRTANEN & MOILANEN 2023). The approach used in this project should reduce the risk of rare species driving the site selection and promote selecting areas that are suitable for multiple groups of species.

4.4 Future challenges

The focus of the ÅSM project was on the coastal waters of the Åland Islands. The mapped areas and the site selection analysis cover the relatively shallow coastal waters that host the most biodiversity and that are presently most exposed to human pressures. The offshore areas of the Åland Islands remain unmapped. These areas are likely to host important nature values. For example, there are known shallows (<10 m deep) in the southern Åland Islands offshore areas that are important feeding areas for marine birds. These areas will be mapped within the EU LIFE-IP Biodiversea (2022-2029) project. Surveying of deep mussel reefs and benthic fauna could also be considered in the future in the coastal waters, as the ÅSM project concentrated on mapping the photic, vegetated zone (<25 m areas).

Connectivity was not included in the site selection analysis, as there was not enough reliable data on current patterns of species dispersal and movement within the complex archipelago area. Further, the ecological implications of connectivity have only been assessed for a few species. However, there are studies from the Baltic Sea that have included the Åland Islands in their connectivity (JONSSON et al. 2020) and dispersal (ROTHÄUSLER et al. 2015) models. The areas identified as important for protection in the ÅSM site selection analysis have also been identified as important connectivity hot spots in these studies (ROTHÄUSLER et al. 2015, JONSSON et al. 2020). Additional high-resolution data on current species dispersal patterns would be needed to better assess the connectivity of populations and to apply it in the development of the Baltic Sea-wide MPA network.

Comprehensive and long-term projects create continuity in science, monitoring, education, and networking. This creates added value through offshoot projects, educating future experts, and developing a high-quality database on the environment. In this project, the close collaboration with local managers was of utmost importance and paved the way for comprehensive, high-quality, and useful end products. Comprehensive information on the general state of the sea is essential for targeting management efforts. Data collected within ÅSM for the Velmu Marine Nature 2020/2021 campaign have become a part of the national species distribution models produced by the Finnish Environment Institute (Syke) within the Velmu programme. New projects that will continue and build upon the ÅSM project have already started, e.g. LIFE-IP Biodiversea and the ÅAU Centre of Excellence (Centre for Sustainable Ocean Science). Within these projects, marine conservation and restoration are developed nationally, and challenges and solutions to marine wicked problems are explored through a transdisciplinary approach.

5 Conclusions

The results of the ÅSM project are a valuable asset to ecosystem-based management of the coastal areas of the Åland Islands and the underwater environment of the northern Baltic Sea. The mapping data and produced maps will act as permanent resources supporting the continuous development of the MPA network. The process should be dynamic, and the site selection analysis can be rerun when new information on the underwater environment is collected, and new conservation efforts are implemented.

We hope that the gathered information on the underwater environment and its nature values in the Åland Islands is continuously used. The results of the site selection analysis, together with the collated data, point observations from the field, and produced species distribution maps, can together or separately, support marine conservation, maritime and coastal spatial planning, restoration efforts, environmental permitting procedures, and ecosystem-based proactive management. The data will also provide a comprehensive baseline for detecting change in the environment over time.

6 Acknowledgements

We thank the external funders of the project, the Baltic Sea Conservation Foundation and The European Maritime and Fisheries Fund. Further, the project was supported by the Government of Åland, Åbo Akademi University, Husö biological station, and the Åbo Akademi Endowment. We have appreciated the close contact with the Baltic Sea Conservation Foundation throughout the project. We also want to thank all the staff at Husö biological station, especially Tony Cederberg, Martin Snickars, and Dennis Hellström. This project utilised research infrastructure as part of the FINMARI consortium (Finnish Marine Research Infrastructure network). We also want to acknowledge the collaboration with the coastguard during the trip to Märket and keeping track of our diving, and further Sjöräddningen, when all did not go as planned. All the friendly and curious people who have come into contact with the project and harbours that have welcomed us – you were greatly appreciated. Stakeholders and everyone who has provided feedback during the project have validated our work and are acknowledged for their help with planning the MPA network to protect our sea. We thank Roxana Preston for the language review and editing. Finally, a massive thank you to all the field workers who made this project possible.

7 References

AGARDY, T., G.N. DI SCIARA & P. CHRISTIE, 2011. Mind the gap: Addressing the shortcomings of marine protected areas through large scale marine spatial planning. Mar. Policy 35: 226–232. https://doi.org/10.1016/j.marpol.2010.10.006

AIRAKSINEN, O. & K. KARTTUNEN, 2001. Natura 2000-luontotyyppiopas. 2. korjattu painos. Ympäristöopas 46. Suomen ympäristökeskus. URI: http://hdl.handle.net/10138/41087

APROPOS INFORMATION SYSTEMS INC. ArcMarxan Toolbox, Version 2.0.2. Available at https://aproposinfosystems.com/

ARDRON, J.A., H.P. POSSINGHAM & C.J. KLEIN (eds.), 2010. Marxan Good Practices Handbook, Version 2. Pacific Marine Analysis and Research Association, Victoria, BC, Canada. 165 pp. Available at www.pacmara.org

AROLA, P., 2020. Ålands marina naturskyddsområden – planering och utveckling av skyddsområdesnätverket med hjälp av Marxan. M.Sc. thesis. Environmental and marine biology, Åbo Akademi University, 51 pp.

BALL, I.R., H.P. POSSINGHAM & M. WATTS, 2009. Marxan and relatives: software for spatial conservation prioritisation. In: MOILANEN, A., H.P. POSSINGHAM & K. WILSON (eds.). Spatial conservation prioritisation: Quantitative methods and computational tools, Oxford University Press, Oxford, pp. 185–195.

BAN, N.C., C.R. PICARD & A.C.J. VINCENT, 2009. Comparing and Integrating Community-Based and Science-Based Approaches to Prioritizing Marine Areas for Protection. Conserv. Biol. 23, 899–910. https://doi.org/10.1111/j.1523-1739.2009.01185.x

BEKKBY, T., P.E. ISACHSEN, M. ISÆUS & V. BAKKESTUEN, 2008. GIS Modeling of Wave Exposure at the Seabed: A Depth-attenuated Wave Exposure Model. Mar. Geod. 31: 117–127. https://doi.org/10.1080/01490410802053674

BONSDORFF, E., K. AARNIO & E. SANDBERG, 1991. Temporal and Spatial Variability of Zoobenthic Communities in Archipelago Waters of the Northern Baltic Sea-Consequences of Eutrophication? Int. Revue ges. Hydrobiol. 76(3), 433–449.

CBD/COP/DEC15/4, 2022. Kunming-Montreal Global Biodiversity Framework. URL: https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-14-en.pdf

COUNCIL OF THE EUROPEAN UNION, 1992. Council directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Protecting Europe's biodiversity (Natura 2000). OJEU 206, 7–50.

DAY, J.C., 2017. Effective Public Participation is Fundamental for Marine Conservation – Lessons from a Large-Scale MPA. Coast. Manage. 45: 470–486. https://doi.org/10.1080/08920753.2017.1373452

DELAVENNE, J., K. METCALFE, R.J. SMITH, S. VAZ, C.S. MARTIN, L. DUPUIS, F. COPPIN & A. CARPENTIER, 2011. Systematic conservation planning in the eastern English Channel: comparing the Marxan and Zonation decision-support tools. ICES J. Mar. Sci. 69(1), 75–83. https://doi.org/10.1093/icesjms/fsr180

ELITH, J., J.R. LEATHWICK & T. HASTIE, 2008. A working guide to boosted regression trees. J. Anim. Ecology 77: 802–813. https://doi.org/10.1111/j.1365-2656.2008.01390.x

ENGSTRÖM, L., 2018. Kartering och habitatklassificering av undervattensmiljön i Lumparn. Forskn. rapp. från Husö biol. stat. No 152, 41 pp.

EUROPEAN COMMISSION, 2020. EU Biodiversity Strategy for 2030 – Bringing nature back into our lives. COM(2020) 380 final. Brussels: Publications Office of the European Union.

EUROPEAN COMMISSION, 2021. Transforming the EU's Blue Economy for a Sustainable Future, COM(2021) 240 final. Brussels: European Commission, Directorate-General for Maritime Affairs and Fisheries.

EUROPEAN PARLIAMENT & COUNCIL OF THE EUROPEAN UNION, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). OJEU 164, 19–40.

EVELEENS MAARSE, F., S. SALOVIUS-LAURÉN & M. SNICKARS, 2020. Long-term changes in the phytobenthos of the southern Åland Islands, northern Baltic Sea. Nord. J. Bot. 38(10). https://doi.org/10.1111/njb.02751

FINNBÄCK, L., 2021. Förslag på nya övervakningspunkter av makrofyter i Ålands ytterskärgård baserat på karteringsdata. Forskn. rapp. från Husö biol. stat. No 161, 19 pp.

FOGELBERG, O., 2021. Miljörapport över havsplan för Åland. HAVSPLANERING 2021 - ÅLANDS LANDSKAPSREGERING, 22 pp. URL: https://www.regeringen.ax/sites/default/files/attachments/page/miljorapport-over-havsplan-for-aland.pdf

GREENWELL, B., B. BOEHMKE, J. CUNNINGHAM, 2022. gbm: Generalized Boosted Regression Models. R package version 2.1.8.1, https://CRAN.R-project.org/package=gbm

GRORUD-COLVERT, K., J. SULLIVAN-STACK, C. ROBERTS, V. CONSTANT, B. HORTA E COSTA, E.P. PIKE, N. KINGSTON, D. LAFFOLEY, E. SALA, J. CLAUDET, A.M. FRIEDLANDER, D.A. GILL, S.E. LESTER, J.C. DAY, E.J. GONÇALVES, G.N. AHMADIA, M. RAND, A. VILLAGOMEZ, N.C. BAN, G.G. GURNEY, A.K. SPALDING, N.J. BENNETT, J. BRIGGS, L.E. MORGAN, R. MOFFITT, M. DEGUIGNET, E.K. PIKITCH, E.S. DARLING, S. JESSEN, S.O. HAMEED, G. DI CARLO, P. GUIDETTI, J.M. HARRIS, J. TORRE, Z. KIZILKAYA, T. AGARDY, P. CURY, N.J. SHAH, K. SACK, L. CAO, M. FERNANDEZ & J. LUBCHENCO, 2021. The MPA Guide: A framework to achieve global goals for the ocean. Science 373, eabf0861. https://doi.org/10.1126/science.abf0861

HANSEN, J.P. & M. SNICKARS, 2014. Applying macrophyte community indicators to assess anthropogenic pressures on shallow soft bottoms. Hydrobiologia 738, 171–189. https://doi.org/10.1007/s10750-014-1928-z

HANSON, J.O., R. SCHUSTER, N. MORRELL, M. STRIMAS-MACKEY, B.P.M. EDWARDS, M.E. WATTS, P. ARCESE, J. BENNETT, H.P. POSSINGHAM, 2023. prioritizr: Systematic Conservation Prioritization in R. https://prioritizr.net, https://github.com/prioritizr/prioritizr

HELCOM, 2010. Towards an ecologically coherent network of well-managed Marine Protected Areas – Implementation report on the status and ecological coherence of the HELCOM BSPA network: Executive Summary. Balt. Sea Environ. Proc. No. 124A. 12 pp. URL: https://helcom.fi/wp-content/uploads/2019/08/BSEP124A.pdf

HELCOM, 2013a. HELCOM HUB – technical report on the HELCOM underwater biotope and habitat classification. Balt. Sea Environ. Proc. No. 139.

HELCOM, 2013b. Red List of Baltic Sea underwater biotopes, habitats and biotope complexes. Balt. Sea Environ. Proc. No. 138.

HELCOM, 2013c. HELCOM Red List of Baltic Sea species in danger of becoming extinct. Balt. Sea Environ. Proc. No. 140.

HELCOM, 2016. Matrix between human activities and pressures. Available at https://helcom.fi/action-areas/maritime-spatial-planning/human-activities-and-pressures/

HELCOM, 2023. State of the Baltic Sea. Third HELCOM holistic assessment 2016-2021. Balt. Sea Environ. Proc. No. 194. URL: https://helcom.fi/post_type_publ/holas3_sobs

HOLGERSSON, E., 2013. Kartering av makrofyter, framtagandet av en klassificeringsmetod för att kunna beräkna ekologisk status för Ålands skärgård och skapandet av miljöövervakningsprogram. Forskn. rapp. från Husö biol. stat. No 134, pp. 48.

HUHTALA, H-P., 2018. Bedömning av mänsklig påverkan i och i närheten av, samt klassificering och utvärdering av grunda havsvikars undervattensväxtlighet på Åland. Forskn. rapp. från Husö biol. stat. No 151, pp. 30.

HYVÄRINEN, E., A. JUSLÉN, E. KEMPPAINEN, A. UDDSTRÖM & U.-M. LIUKKO (eds.), 2019. The 2019 Red List of Finnish Species. Ympäristöministeriö & Suomen ympäristökeskus, Helsinki, 704 pp.

ISAEUS, M., 2004. Factors structuring *Fucus* communities at open and complex coastlines in the Baltic Sea. Doctoral thesis, comprehensive summary. Stockholm University, Stockholm, 40 pp.

JONSSON, P. R., P.O. MOKSNES, H. CORELL, E. BONSDORFF & M. NILSSON JACOBI, 2020. Ecological coherence of Marine Protected Areas: New tools applied to the Baltic Sea network. Aquat. Conserv.: Mar. Freshw. Ecosyst. 30(4), 743–760. https://doi.org/10.1002/aqc.3286

KALLASVUO, M., J. VANHATALO & L. VENERANTA, 2016. Modelling the spatial distribution of larval fish abundance provides essential information for management. Can. J. Fish. Aquat. Sci. 74(5), 636–649. https://doi.org/10.1139/cjfas-2016-0008

KASKELA, A. & H. RINNE, 2018. Vedenalaisten Natura-luontotyyppien mallinnus Suomen merialueella. Geologian tutkimuskeskus, Tutkimustyöraportti 6/2018, 36 pp. URN: http://urn.fi/URN:NBN:fi-fe2020100883047

KAUPPI, L., 2011. Kartering av undervattenvegetation i kustområden i NV och SÖ Åland. Forskn. rapp. från Husö biol. stat. No 130, pp. 58.

KAUTSKY, N., H. KAUTSKY, U. KAUTSKY & M. WAERN, 1986. Decreased depth penetration of *Fucus vesiculosus* (L.) since the 1940's indicates eutrophication of the Baltic Sea. Mar. Ecol. Prog. Ser. 28(1–2), 1–8.

KAUTSKY, H., L. KAUTSKY, N. KAUTSKY, U. KAUTSKY & C. LINDBLAD, 1992. Studies on the Fucus vesiculosus community in the Baltic Sea. Acta Phytogeogr. Suec. 78, 33–48.

KIVILUOTO, S., 2013. Kartering och klassificering av undervattensmiljöer samt tillämpning av informationen på den regionala planeringen. NANNUT-projektet på Åland 2010-2012. Forskn. rapp. från Husö biol. stat. No 135, 44 pp.

KOSTAMO, K., H. ARPONEN, P. ELORANTA, S. KIVILUOTO, M. KOISTINEN & E. LESKINEN, 2019. Algae. In: The 2019 Red List of Finnish Species. Ympäristöministeriö & Suomen ympäristökeskus, Helsinki, pp. 149–156. URI: http://hdl.handle.net/10138/299501

KOTILAINEN, A., S. KIVILUOTO, L. KURVINEN, M. SAHLA, E. EHRNSTEN, A. LAINE, H. LAX, T. KONTULA, P. BLANKETT, J. EKEBOM, H. HÄLLFORS, V. KARVINEN, H. KUOSA, R. LAAKSONEN, M. LAPPALAINEN, S. LEHTINEN, M. LEHTINIEMI, J. LEINIKKI, E. LESKINEN, A. RIIHIMÄKI, A. RUUSKANEN & P. VAHTERI, 2018. Itämeri. In: Kontula, T., A. Schulman & A. Raunio (Eds.), 2018. Suomen luontotyyppien uhanalaisuus, osa 2. Luontotyyppien kuvaukset. Suomen ympäristökeskus ja Ympäristöministeriö, Helsinki. Suomen Ympäristö 5/2018. URI: http://hdl.handle.net/10138/37932

KUKKALA, A.S. & A. MOILANEN, 2013. Core concepts of spatial prioritisation in systematic conservation planning. Biol. Rev. 88, 443–464.

LAPPALAINEN, J., L. KURVINEN & L. KUISMANEN (eds.), 2020. Suomen ekologisesti merkittävät vedenalaiset meriluontoalueet (EMMA) – Finlands ekologiskt betydelsefulla marina undervattensmiljöer (EMMA). Suomen ympäristökeskuksen raportteja: 8/2020, pp. 294. URI: http://hdl.handle.net/10138/312221

LAPPALAINEN, J., E.A. VIRTANEN, K. KALLIO, S. JUNTTILA & M. VIITASALO, 2019. Substrate limitation of a habitat-forming genus *Fucus* under different water clarity scenarios in the northern Baltic Sea. Estuar. Coast. Shelf Sci. 218, 31–38. https://doi.org/10.1016/j.ecss.2018.11.010

LEHIKOINEN, A., A. JUKARAINEN, M. MIKKOLA-ROOS, A. BELOW, T. LEHTINIEMI, J. PESSA, A. RAJASÄRKKÄ, J. RINTALA, P. RUSANEN, P. SIRKIÄ, J. TIAINEN & J. VALKAMA, 2019. Birds. In: Hyvärinen, E., A. Juslén, E. Kemppainen, A. Uddström & U-M. Liukko (eds.), 2019. The 2019 Red List of Finnish Species. Ympäristöministeriö & Suomen ympäristökeskus. Helsinki, pp. 560–570. URI: http://hdl.handle.net/10138/299501

LIUKKO, U-M., H. HENTTONEN, K. KAUHALA, I. KOJOLA, E-M. KYHERÖINEN & J. PITKÄNEN, 2019. Mammals. In: Hyvärinen, E., A. Juslén, E. Kemppainen, A. Uddström & U-M. Liukko (eds.), 2019. The 2019 Red List of Finnish Species. Ympäristöministeriö & Suomen ympäristökeskus. Helsinki, pp. 571–576. URI: http://hdl.handle.net/10138/299501

LONG, R.D., A. CHARLES, R.L. STEPHENSON, 2015. Long, R. D., Charles, A., & Stephenson, R. L. (2015). Key principles of marine ecosystem-based management. Mar. Policy 57, 53–60. https://doi.org/10.1016/j.marpol.2015.01.013

MARGULES, C. R., & R.L. PRESSEY, 2000. Systematic conservation planning. Nature 405(6783), 243–253. DOI10.1038/35012251

METSÄHALLITUS, 2022. VELMU - Metodbeskrivning för kartering av bottenbiotoper 2022. Available at https://www.ymparisto.fi/fi/luonto-vesistot-ja-meri/luonnon-monimuotoisuus/suojelu-ja-tutkimusohjelmat/velmu-ohjelma

MOILANEN, A., A.M. FRANCO, R.I. EARLY, R. FOX, B. WINTLE & C.D. THOMAS, 2005. Prioritizing multiple-use landscapes for conservation: methods for large multi-species planning problems. Proc. Royal Soc. B, 272(1575), 1885–1891. https://doi.org/10.1098/rspb.2005.3164

NICHOLSON, E. & H.P. POSSINGHAM, 2006. Objectives for Multiple-Species Conservation Planning. Conserv. Biol. 20, 871–881. https://doi.org/10.1111/j.1523-1739.2006.00369.x

PUNTILA, R., 2007. Basinventering av potentiellt viktiga Chara-vikar på norra Åland. Forskn. rapp. från Husö biol. stat. No 119, pp. 68.

R CORE TEAM, 2023. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

REINIKAINEN, M., T. RYTTÄRI, T. KANERVA, H. KEKÄLÄINEN, K. KOSKELA, P. KUNTTU, M. MUSSAARI, M. von NUMERS, L. RINKINEVA-KANTOLA, M. SIEVÄNEN & K. SYRJÄNEN, 2018. Suomen luontotyyppien uhanalaisuus 2018. Luontotyyppien punainen kirja. Osa 2: Luontotyyppien kuvaukset. In Kontula, T., & A. Raunio (eds.), Suomen luontotyyppien uhanalaisuus 2018. Suomen ympäristö. http://julkaisut.valtioneuvosto.fi/handle/10024/161234

RINNE, H. & S. SALOVIUS-LAURÉN, 2020. The status of brown macroalgae *Fucus* spp. and its relation to environmental variation in the Finnish marine area, northern Baltic Sea. AMBIO 49, 118–129.

RINNE, H. & S. SALOVIUS-LAURÉN, 2021. Underlag för skyddsområdesvalsanalysen med MARXAN, Åland 2021: Datakatalog med faktablad. 70 pp. URN: https://urn.fi/URN:NBN:fi-fe202403059894

RINNE, H., S. SALOVIUS-LAURÉN & J. MATTILA, 2011. The occurrence and depth penetration of macroalgae along environmental gradients in the northern Baltic Sea. Estuar. Coast. Shelf Sci. 94, 182–191. https://doi.org/10.1016/j.ecss.2011.06.010

RINNE, H., C. BJÖRKLUND, J. HÄMÄLÄINEN, M. HÄGGBLOM & S. SALOVIUS-LAURÉN, 2019. Mapping Marine Natura 2000 habitats in Åland Final report. Forskn. rapp. från Husö biol. stat. No 153, pp. 36.

ROTHÄUSLER, E., H. CORELL & V. JORMALAINEN, 2015. Abundance and dispersal trajectories of floating *Fucus vesiculosus* in the Northern Baltic Sea. Limnol. Oceanogr. 60, 2173–2184. https://doi.org/10.1002/lno.10195

SAARINEN, A., 2015. Beräkning av ekologisk status för Ålands ytvattenförekomster utgående från kartering av makrofyter: ett förslag till övervakningsprogram och harmonisering av metoder mellan Åland och Finland. Forskn. rapp. från Husö biol. stat. No 141, pp. 52.

SALOVIUS-LAURÉN, S. & K. WECKSTRÖM, 2022. Ålands värdefulla undervattensmiljöer på kartan – diskussionsunderlag för skyddsområdesplanering. URL: https://www.regeringen.ax/sites/default/files/attachments/page/marxan_analysens_resultat_2022.pdf

SARKAR, S., R.L. PRESSEY, D.P. FAITH, C.R. MARGULES, T. FULLER, D.M. STOMS, A. MOFFETT, K.A. WILSON, K.J. WILLIAMS, P.H. WILLIAMS & S. ANDELMAN. Biodiversity conservation planning tools: present status and challenges for the future. Annu. Rev. Environ. Resour., 31, 123–159. https://doi.org/10.1146/annurev.energy.31.042606.085844

SCHWARTZ, M.W., C.N. COOK, R.L. PRESSEY, A.S. PULLIN, M.C. RUNGE, N. SALAFSKY, W.J. SUTHERLAND & M.A. WILLIAMSON, 2018. Decision Support Frameworks and Tools for Conservation. Conserv. Lett. 11, e12385. https://doi.org/10.1111/conl.12385

SCHEININ, M., & S. SÖDERSTRÖM, 2005. Kartering av vattenlevande makrofyter längs två inner-ytterskärgårdsgradienter på nordvästra och sydöstra Åland. Forskn. rapp. från Husö biol. stat. No 112, pp. 69.

SERRA-SOGAS, N., A. KOCKEL, E.T. GAME, H. GRANTHAM, H.P. POSSINGHAM & J. McGOVAN, 2020. Marxan User Manual: For Marxan version 2.43 and above. The Nature Conservancy (TNC), Arlington, Virginia, United States and Pacific Marine Analysis and Research Association (PacMARA), Victoria, British Columbia, Canada. 133 pp. URL: https://marxansolutions.org/wp-content/uploads/2021/02/Marxan-User-Manual_2021.pdf

SNICKARS, M., 2008. Coastal lagoons: assemblage patterns and habitat use of fish in vegetated nursery habitats. Doctoral thesis, comprehensive summary. Husö Biological Station & Environmental and Marine Biology, Åbo Akademi University, Åbo, 38 pp.

TAKOLANDER, A. R. BOMAN, L. FORSBLOM, S. SALOVIUS-LAURÉN, S. KORPINEN, J. HOIKKALA, E. VIRTANEN & L. KURVINEN, 2023. VELMU Meriluonto 2021 – Indikaattorit. Internal Finnish Ministry of the Environment report. Unpublished. 39 pp.

UNEP/CBD/COP/10/27, 2011. Report of the tenth meeting of the conference of the parties to the convention on biological diversity. URL: https://www.cbd.int/doc/meetings/cop/cop-10/official/cop-10-27-en.pdf

URHO, L., M.-L. KOLJONEN, A. SAURA, A. SAVIKKO, L. VENERANTA & A. JANATUINEN, 2019. Fish. In: Hyvärinen, E., A. Juslén, E. Kemppainen, A. Uddström & U.-M. Liukko (eds.). The 2019 Red List of Finnish Species. Ympäristöministeriö & Suomen ympäristökeskus, Helsinki, pp. 549–555. URI: http://hdl.handle.net/10138/299501

VALKONEN, L., 2020. Kartering och habitatsklassificering av undervattensmiljön i Geta. Forskn. rapp. från Husö biol. stat. No 155, 38 pp.

VIRTANEN, E.A., A. MOILANEN, 2023. High focus on threatened species and habitats may undermine biodiversity conservation: Evidence from the northern Baltic Sea. Divers. Distrib. 29(8), 979–985. https://doi.org/10.1111/ddi.13710

VIRTANEN, E.A., M. VIITASALO, J. LAPPALAINEN & A. MOILANEN, 2018. Evaluation, Gap Analysis, and Potential Expansion of the Finnish Marine Protected Area Network. Front. Mar. Sci. 5, 402. https://doi.org/10.3389/fmars.2018.00402.

VIRTANEN E., L. FORSBLOM, F. HAAVISTO, E. KESKINEN, S. KIVILUOTO, L. KUISMANEN, A. LAINE, S. SALOVIUS-LAUREN & M. VIITASALO. 2022: Itämeri. In: Kuusela, S., M. Annala, T. Kontula, N. Leikola, A.-M. Määttänen, R. Virkkala & E. Virtanen (eds.). Kohti kattavaa suojelualueverkostoa. Luonnon monimuotoisuuden turvaamisen painopisteet Suomessa. Suomen ympäristökeskus, Helsinki. Suomen ympäristökeskuksen raportteja 18/2022. pp. 35–77.

WATTS, M.E., I.R. BALL, R.S. STEWART, C.J. KLEIN, K. WILSON, C. STEINBACK, R. LOURIVAL, L. KIRCHER & H.P. POSSINGHAM, 2009. Marxan with Zones: Software for optimal conservation based land-and sea-use zoning. Environ. Model. Softw. 24(12), 1513–1521. doi:10.1016/j.envsoft.2009.06.005

WORM, B., E.B. BARBIER, N. BEAUMONT, J.E. DUFFY, C. FOLKE, B.S. HALPERN, J.B.C. JACKSON, H.K. LOTZE, F. MICHELI, S.R. PALUMBI, E. SALA, K.A. SELKOE, J.J. STACHOWICZ & R. WATSON, 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314(5800), 787–790. DOI: 10.1126/science.1132294

Appendices

Appendix I: data catalogue

Sandbanks (1110 Natura habitat)

Protection goal: 20%.

Justification for protection goal: Habitat directive habitat, classified as “vulnerable”. Sandbanks occur sparingly in the Åland Islands.

Data source: Geological Survey of Finland.

Description: Data based on echo soundings in 2017 carried out by the Geological Survey of Finland and underwater inventories conducted by Åbo Akademi University from 2018. The mapped sandbanks are located within the ridge area northeast of the island of Kökar. In most areas, geological surveys have not been carried out, so sandbanks may be found elsewhere.

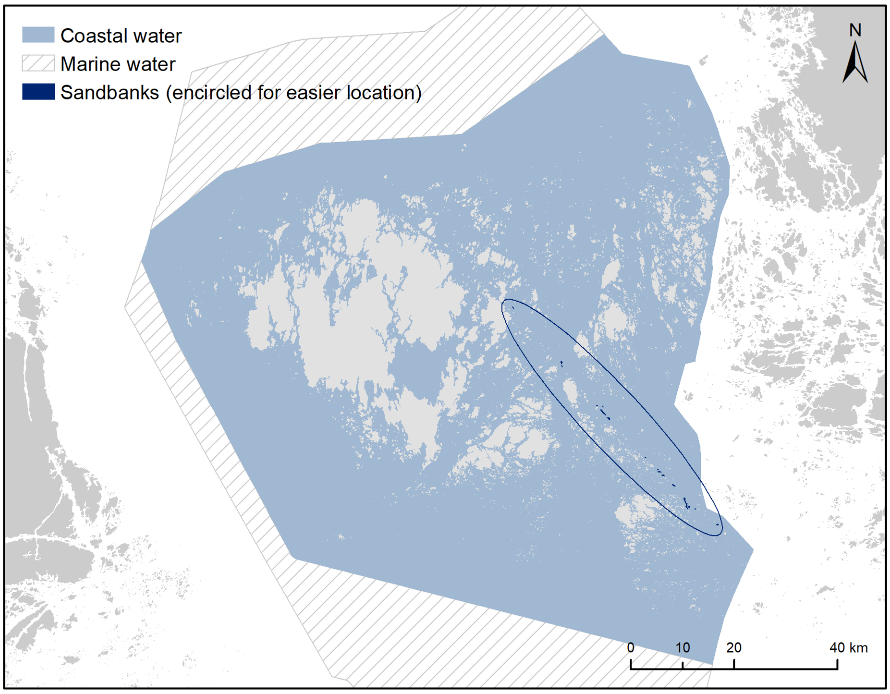
Data format and resolution: Polygon.

Data collection (time period/method): 2017, multibeam and side scan sonar.

Data quality: Information is reliable in the surveyed areas.

Data owner: Geological Survey of Finland.

Additional information: Survey report: RINNE et al. (2019): Mapping marine Natura 2000 habitats in Åland. Final report. Reports from Husö Biological Station No 153 (https://www.doria.fi/handle/10024/168137). A description of the different habitats can be found in AIRAKSINEN & KARTTUNEN (2001): Natura 2000 luontotyyppiopas. Suomen ympäristökeskus, Ympäristöopas 46 (https://helda.helsinki.fi/handle/10138/41087).



Coastal lagoons (1150 Natura habitat)

Protection goal: 30%.

Justification for protection goal: Special habitat according to the habitat directive (more than 20% protection should be achieved), classified as “endangered”, but is quite common around the Åland Islands. Important spawning grounds for fish.

Data source: Metsähallitus, the 2019 progress report of the implementation of the Habitats Directive.

Description: GIS-based model used in reporting for the habitat directive 2019. Lagoons that overlap with large shallow inlets and bays (1160) and boreal Baltic narrow inlets (1650) have been removed. Marsund in Eckerö was included in the model but has been removed (not a lagoon.)

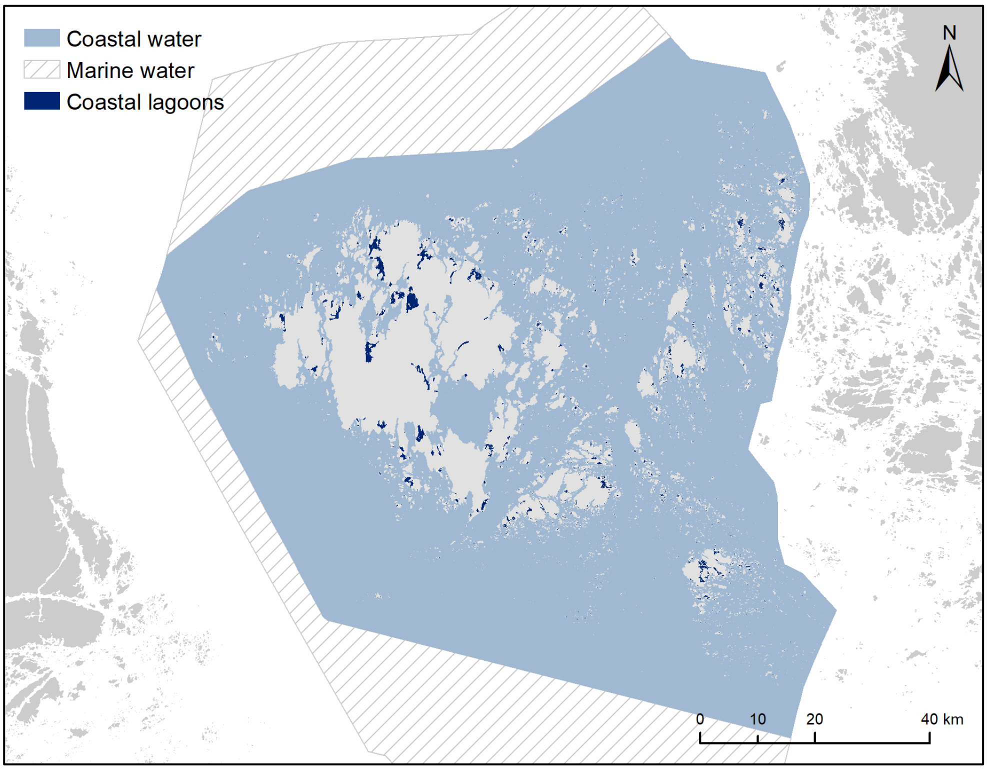
Data format and resolution: Polygon.

Data collection (time period/method): 2019 model, which uses, e.g. shoreline shape to identify lagoons.

Data quality: Model based on lagoon shape. Vegetation has not been surveyed in all lagoons.

Data owner: Metsähallitus.

Additional information: A description of the different habitats can be found in AIRAKSINEN & KARTTUNEN (2001): Natura 2000 luontotyyppiopas. Suomen ympäristökeskus, Ympäristöopas 46 (https://helda.helsinki.fi/handle/10138/41087).



Large shallow inlets and bays (1160 Natura habitat)

Protection goal: 20%.

Justification for protection goal: Habitat directive habitat, classified as “vulnerable”. Important spawning grounds for fish.

Data source: The Government of Åland, the 2019 progress report of the implementation of the Habitats Directive.

Description: One (1) bay in the Åland Islands (in Kumlinge) is reported in the Habitat directive report 2019. Potential large shallow inlets and bays (10, data from KIVILUOTO 2011) are included in the Lagoon habitat type. It is difficult to distinguish between the two habitats.

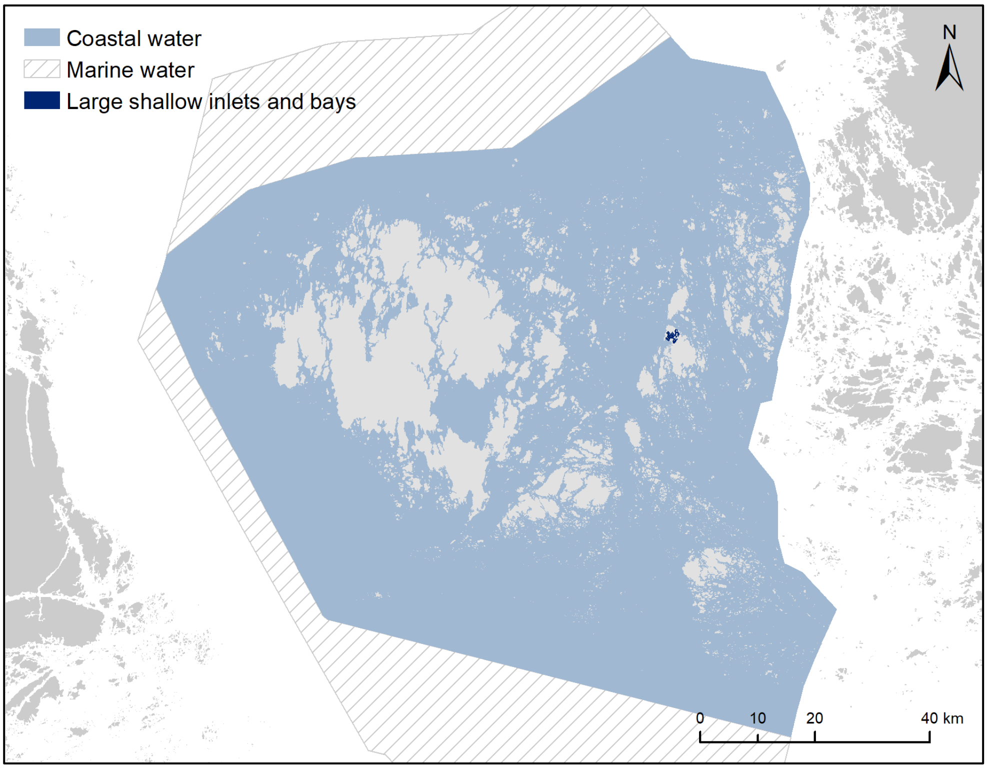
Data format and resolution: Polygon.

Data collection (time period/method): Mapping 2009–2011 (KIVILUOTO 2011, the Government of Åland).

Data quality: Primarily based on geomorphology (shape). Vegetation has not been systematically mapped.

Data owner: The Government of Åland.

Additional information: A description of the different habitats can be found in AIRAKSINEN & KARTTUNEN (2001): Natura 2000 luontotyyppiopas. Suomen ympäristökeskus, Ympäristöopas 46 (https://helda.helsinki.fi/handle/10138/41087).



Reefs (1170 Natura habitat)

Protection goal: 20%.

Justification for protection goal: Habitat directive habitat, classified as “vulnerable”. Common around the Åland Islands, important hotspots for biodiversity (algal communities, blue mussel reefs).

Data source: Geological Survey of Finland and Åbo Akademi University.

Description: Data is based on a model made in collaboration between Geological Survey of Finland and Åbo Akademi University in 2018. Used in connection to habitat directive's reporting in 2019 (minimum distribution is used here).

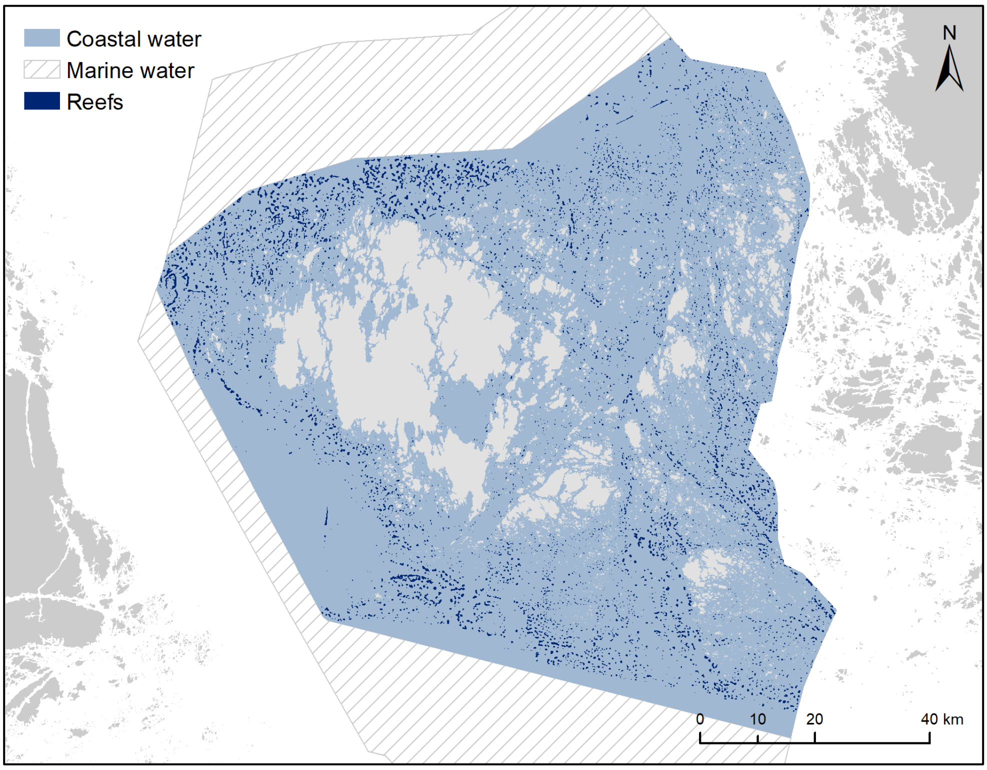
Data format and resolution: Polygon.

Data collection (time period/method): 2018, model based on depth and geomorphology.

Data quality: The model is affected by the quality of the depth model, which varies in different locations.

Data owner: Geological Survey of Finland and Åbo Akademi University.

Additional information: Report: KASKELA & RINNE (2018): Vedenlaisten Natura-luontotyyppien mallinnus Suomen merialueella. Geologian tutkimuskeskus 6/2018. A description of the different habitats can be found in AIRAKSINEN & KARTTUNEN (2001): Natura 2000 luontotyyppiopas. Suomen ympäristökeskus, Ympäristöopas 46 (https://helda.helsinki.fi/handle/10138/41087).



Underwater parts of esker islands (1610 Natura habitat)

Protection goal: 20%.

Justification for protection goal: Habitat directive habitat, classified as "near threatened".

Data source: Geological Survey of Finland.

Description: Data based on echo sounding performed by Geological Survey of Finland in 2017 as well as underwater inventories conducted by Åbo Akademi University in 2018.

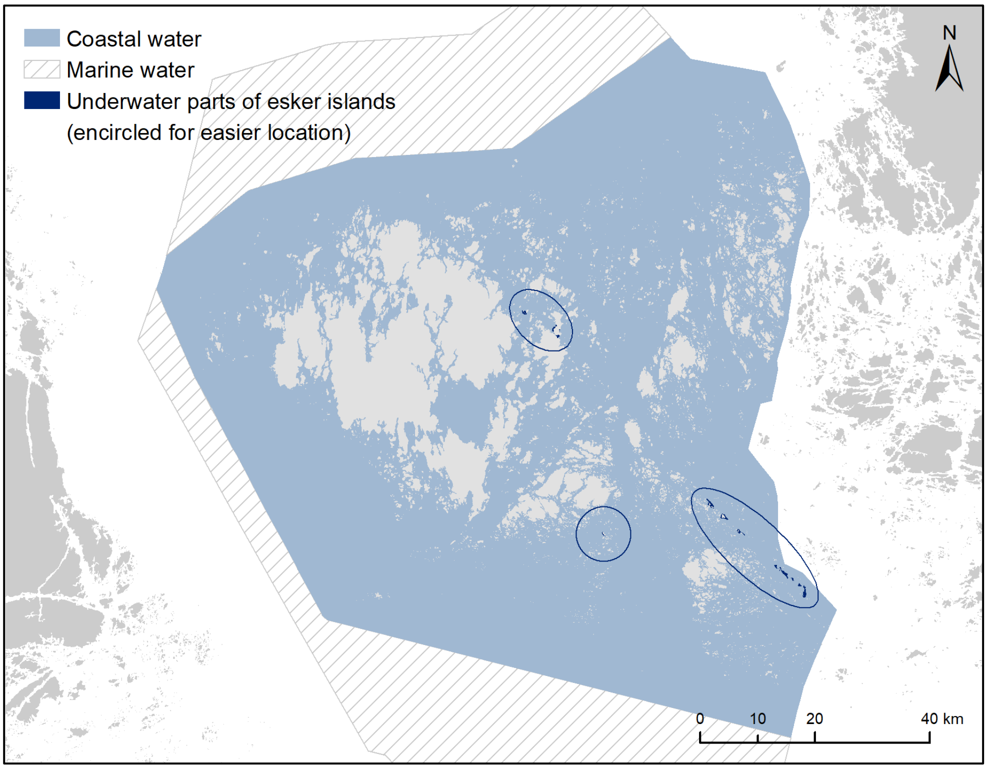
Data format and resolution: Polygon.

Data collection (time period/method): 2017–2018, multibeam, side scan sonar, and diving.

Data quality: Information is reliable in the surveyed areas.

Data owner: Geological Survey of Finland.

Additional information: Mapping report: RINNE et al. (2019): Mapping marine Natura 2000 habitat in Åland – Final report. Rapp. från Husö Biol. stat. No 153 (https://www.doria.fi/handle/10024/168137). A description of the different habitats can be found in AIRAKSINEN & KARTTUNEN (2001): Natura 2000 luontotyyppiopas. Suomen ympäristökeskus, Ympäristöopas 46 (https://helda.helsinki.fi/handle/10138/41087).



Boreal Baltic narrow inlets (1650 Natura habitat)

Protection goal: 20%.

Justification for protection goal: Habitat directive habitat, classified as “vulnerable”. Important spawning grounds for fish.

Data source: The Government of Åland, Habitats Directive report 2019.

Description: Narrow inlets (9) as reported in the 2019 progress report of the implementation of the Habitats Directive.

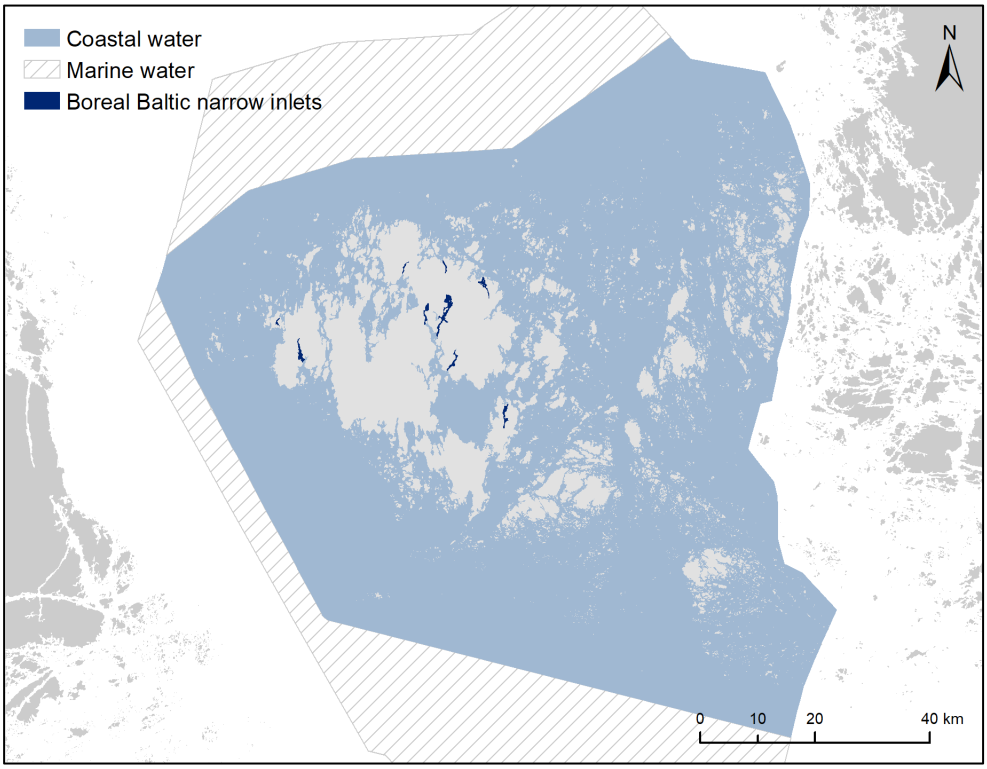
Data format and resolution: Polygon.

Data collection (time period/method): Mapping 2009–2011 (KIVILUOTO 2011, the Government of Åland).

Data quality: Mostly based on geomorphology (shape). Vegetation has not been systematically surveyed in all inlets.

Data owner: The Government of Åland.

Additional information: A description of the different habitats can be found in AIRAKSINEN & KARTTUNEN (2001): Natura 2000 luontotyyppiopas. Suomen ympäristökeskus, Ympäristöopas 46 (https://helda.helsinki.fi/handle/10138/41087).



Underwater parts of Boreal Baltic islets and small islands (1620 Natura habitat)

Protection goal: 20%.

Justification for protection goal: Habitats Directive habitat, classified as “near threatened”. Important hotspots for biodiversity (algal communities, blue mussel reefs).

Data source: Metsähallitus.

Description: The data is based on a model made in connection to the 2019 progress report on the implementation of the Habitats Directive. The model includes underwater parts of small islands (< 4 ha) where < 10% is covered in trees and which are located in the middle and outer archipelago. Islands in the inner archipelago are not included in boreal Baltic islets and small islands. The underwater parts have been defined as a 100 m buffer around the islands.

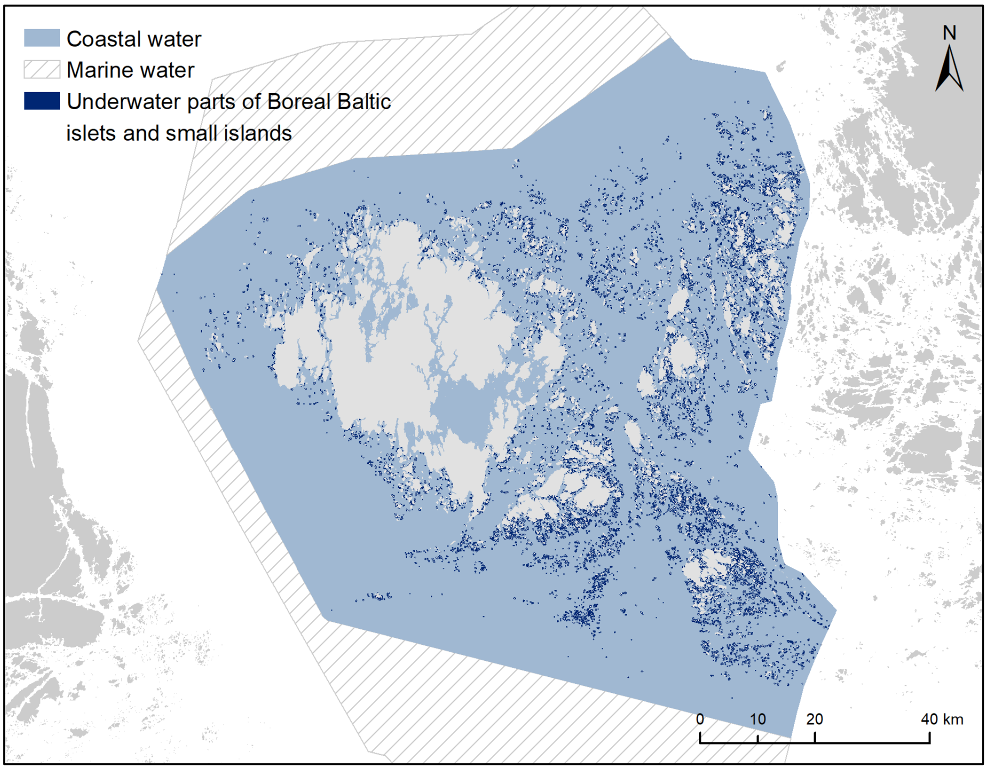
Data format and resolution: Polygon.

Data collection (time period/method): 2019, GIS analyses and interpretation of aerial photographs.

Data quality: For the islands, good. The size of the underwater parts varies in nature; here, they are always the same, i.e. a 100 m buffer.

Data owner: Metsähallitus.

Additional information: A description of the different habitats can be found in AIRAKSINEN & KARTTUNEN (2001): Natura 2000 luontotyyppiopas. Suomen ympäristökeskus, Ympäristöopas 46 (https://helda.helsinki.fi/handle/10138/41087).



Bladderwrack communities (*Fucus vesiculosus*)

Protection goal: 30%.

Justification for protection goal: Classified as "endangered" (KOTILAINEN et al. 2018) but is quite common around the Åland Islands.

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: The model describes areas where there is a high probability that there are representative bladderwrack communities (bladderwrack cover ≥30%). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of the bladderwrack were water depth and exposure of the seabed.

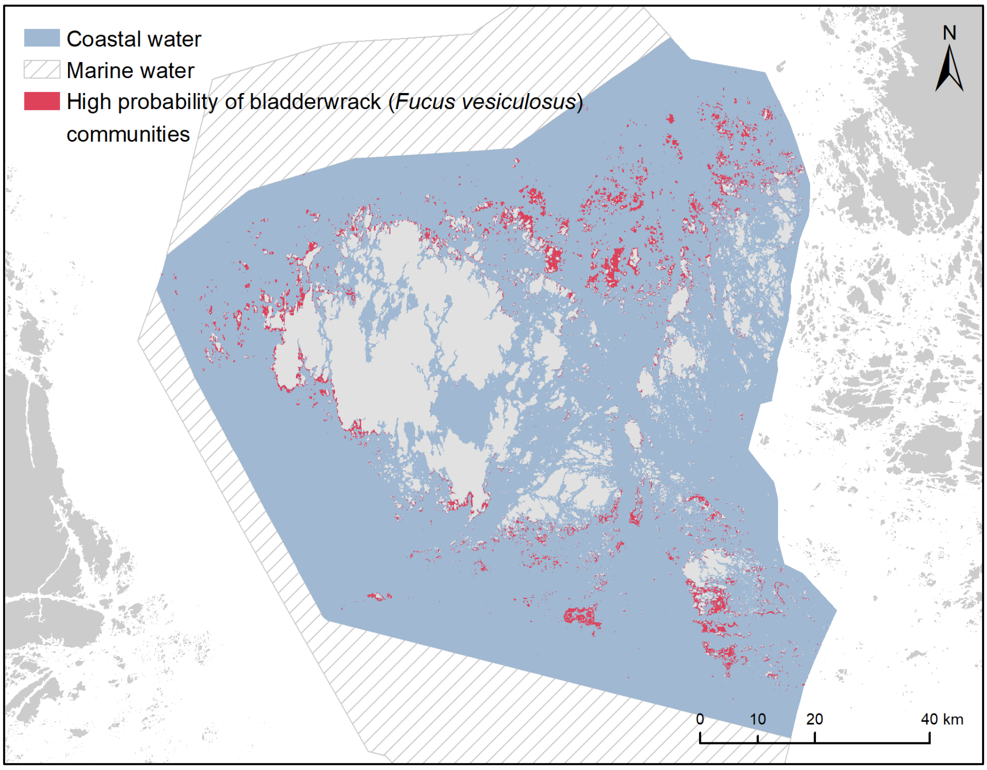
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through scuba diving, snorkelling, aquascope and drop-video filming during 2005–2021.

Data quality: 488 observations of bladderwrack (≥30% coverage) are included in the model, and when the model was evaluated, its reliability was high (AUC=0.95).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Red algae communities

Protection goal: 30%.

Justification for Protection goal: Classified as "endangered" (KOTILAINEN et al. 2018), in general, red algae are more common around Åland than in other marine areas in Finland.

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: The red algae communities include all species of red algae, as well as *Hildenbrandia rubra* (crustose red algae on hard surfaces). The model describes areas where there is a high probability that there are representative red algae communities (red algae cover ≥30%). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of the red algae were the slope of the seabed, water depth and exposure of the seabed.

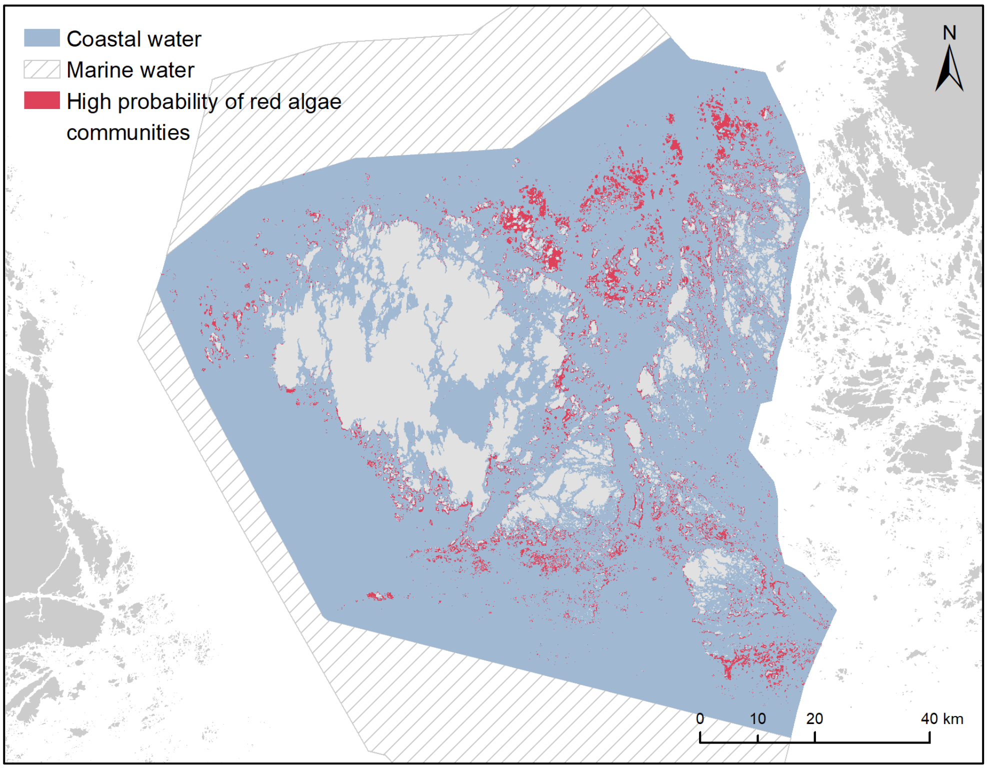
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through scuba diving, snorkelling, aquascope and drop-video filming during 2005–2021.

Data quality: 755 observations of red algae communities (≥30% coverage) are included in the model, and when the model was evaluated, its reliability was high (AUC=0.94).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Communities of perennial filamentous algae

Protection goal: 20%.

Justification for protection goal: Classified as "least concern" (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Perennial filamentous algae, including the species *Cladophora rupestris, Battersia arctica, Vertebrata fucoides* and *Rhodomela* confervoides. The model describes areas where representative communities with perennial filamentous algae are likely to occur (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of the perennial filamentous algae were salinity, exposure and the slope of the seabed.

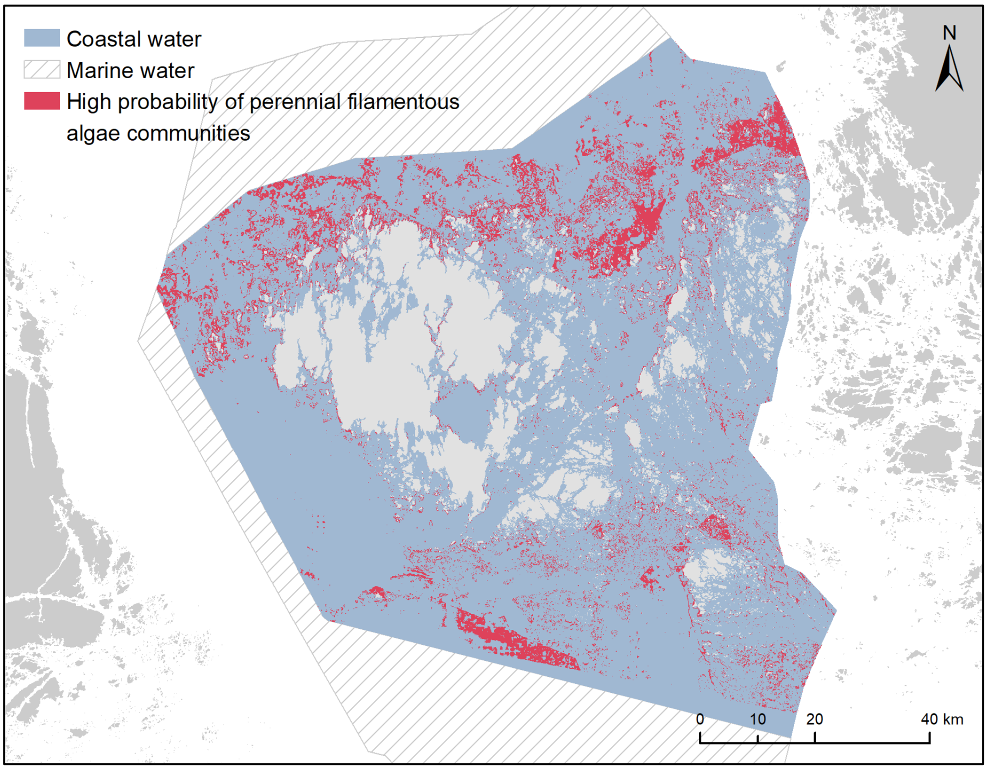
Data format and resolution: Raster, 20 x 20 m

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: 144 observations of perennial filamentous algae (≥30% coverage) are included in the model, and when the model was evaluated, its reliability was relatively high (AUC=0.86).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Pondweed communities (*Potamogeton* sp. and *Stuckenia* sp.)

Protection goal: 20%.

Justification for protection goal: Classified as “least concern” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Pondweed communities include common species like perfoliate pondweed (*Potamogeton perfoliatus*) and sago pondweed (*Stuckenia pectinata*), but also rarer species of pondweed. The model describes areas where representative pondweed communities are likely to occur (≥30% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of pondweed communities were water depth and exposure.

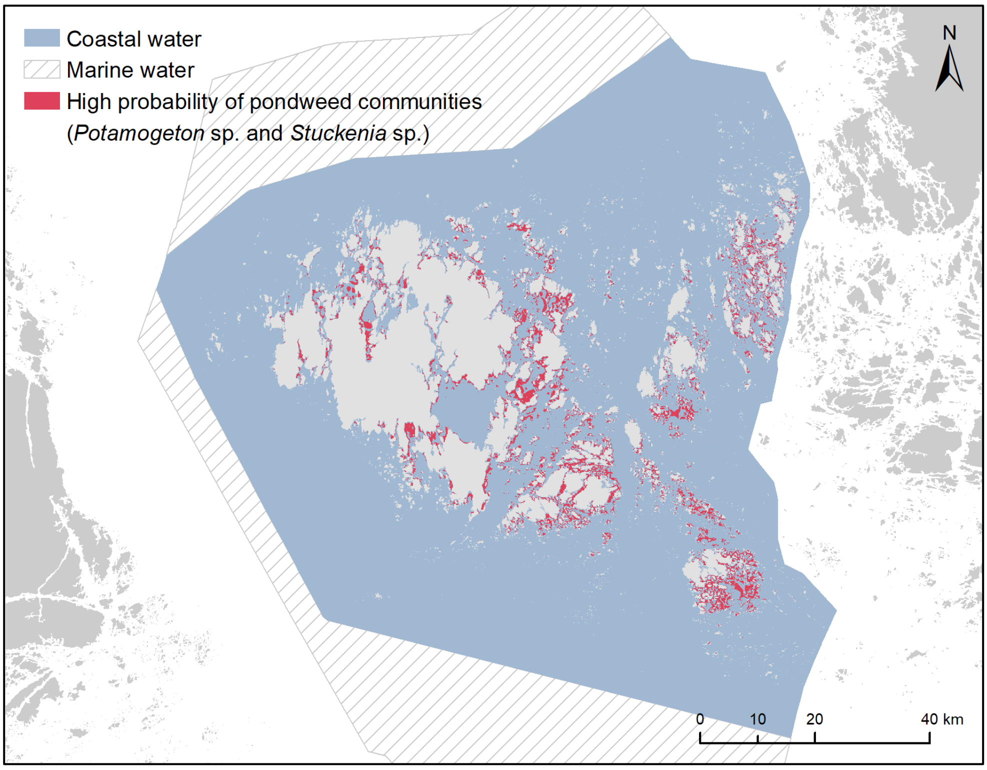
Data format and resolution: Raster, 20 x 20 m

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: 1068 observations of pondweed communities (≥30% coverage) were included in the model, and when the model was evaluated, its reliability was relatively high (AUC=0.89).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Communities of water crowfoots (*Ranunculus* sp.)

Protection goal: 20%.

Justification for protection goal: Classified as “near threatened” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Communities of water crowfoot include species like *Ranunculus peltatus subsp. baudotii* and *Ranunculus circinatus.* The model describes areas where representative pondweed communities are likely to occur (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of water crowfoot communities were water depth and water turbidity (Secchi depth).

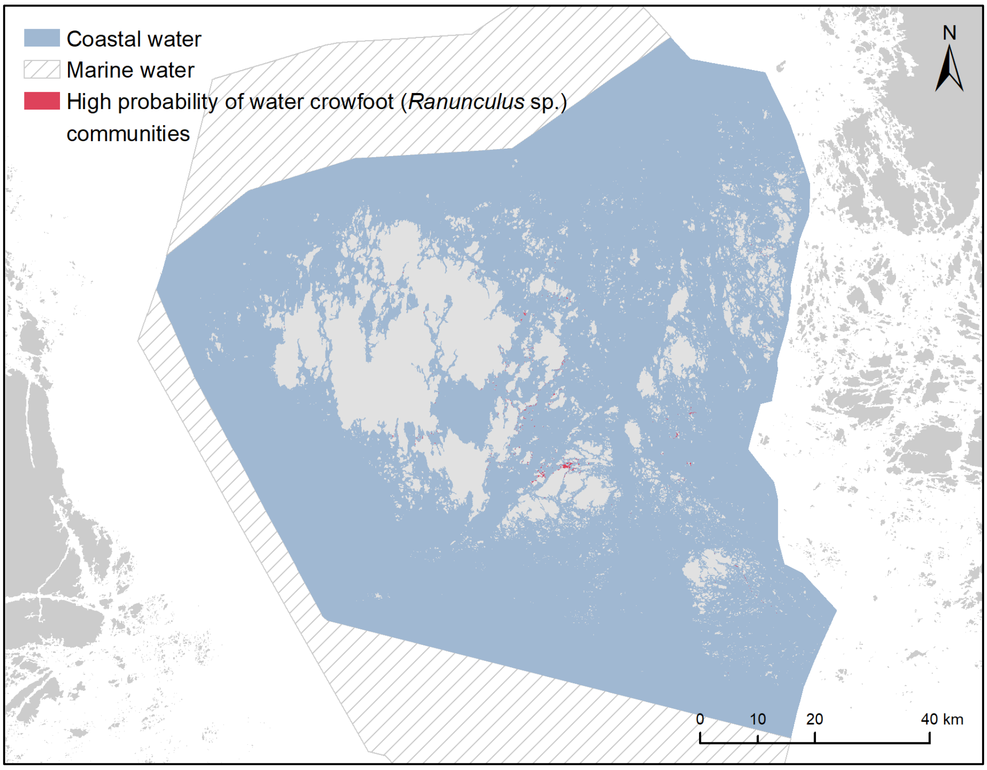
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: Only 30 observations of communities of water crowfoot (≥10% coverage) were included in the model, and when the model was evaluated, its reliability was relatively high (AUC=0.86).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Communities of horned pondweed (*Zannichellia* sp.) and widgeonweeds (*Ruppia* sp.)

Protection goal: 20%.

Justification for protection goal: Classified as ”near threatened” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Communities of horned pondweed and widgeonweeds includes, e.g. the species *Ruppia maritima* and *Zannichellia palustris*. The model describes areas where there is a high probability of representative horned pondweed and widgeonweeds communities (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of the horned pondweed and widgeonweeds communities were water turbidity (Secchi depth) and salinity.

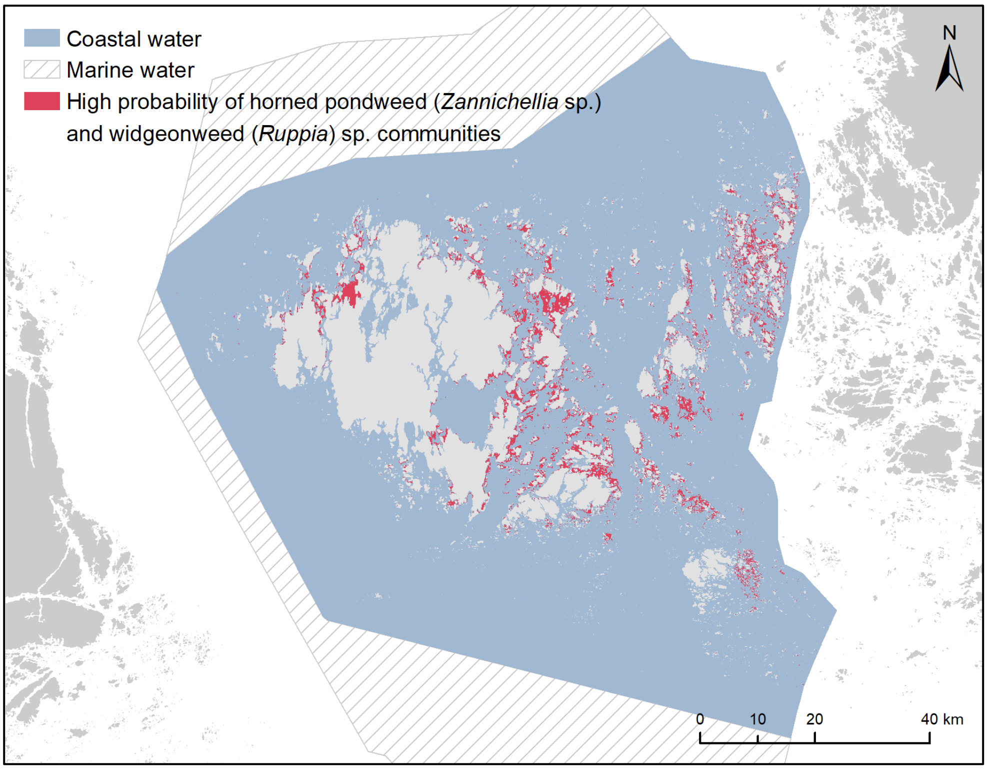
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: 311 observations of communities of horned pondweed and widgeonweeds (≥10% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.92).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Communities of watermilfoils (*Myriophyllum* sp.)

Protection goal: 10%.

Justification for protection goal: Classified as ”least concern” (KOTILAINEN et al. 2018). Generally benefits from eutrophication.

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: The model describes areas where there is a high probability of representative water-milfoil communities (≥30% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of water-milfoil communities were water turbidity (Secchi depth) and exposure.

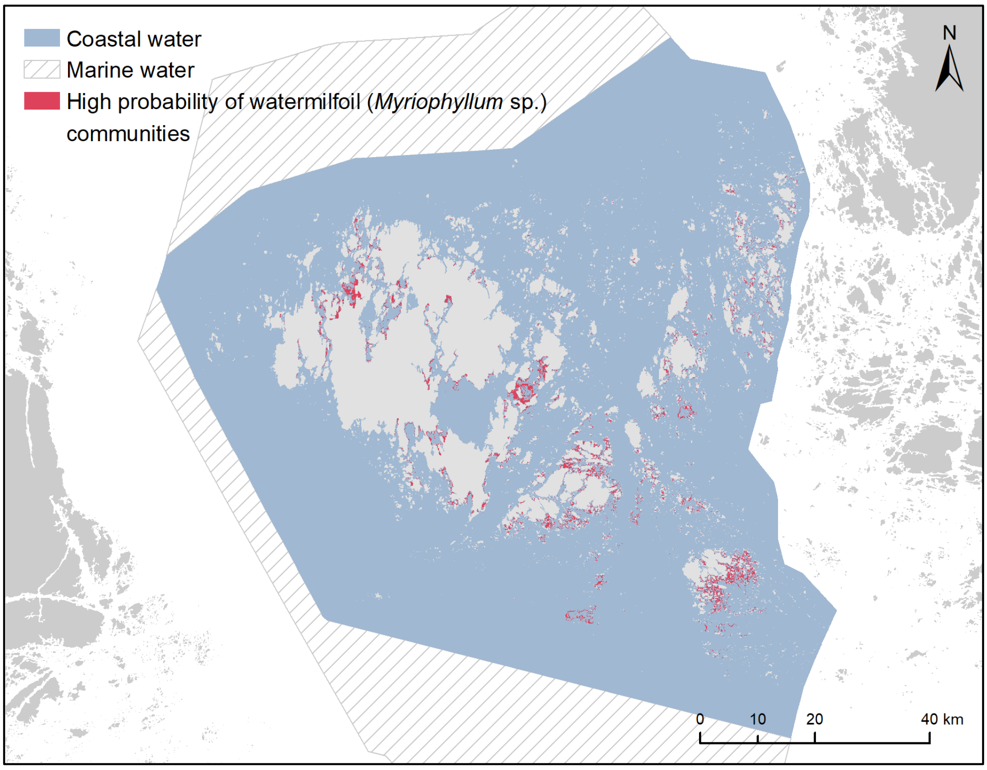
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: 99 observations of watermilfoil (≥30% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.94).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Hornwort communities (*Ceratophyllum demersum*)

Protection goal: 10%.

Justification for protection goal: Classified as "least concern" (KOTILAINEN et al. 2018). Generally benefits from eutrophication.

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: The model describes areas where there is a high probability of representative hornwort communities (≥30% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that affected the distribution of water-milfoil communities were water turbidity (Secchi depth) and exposure.

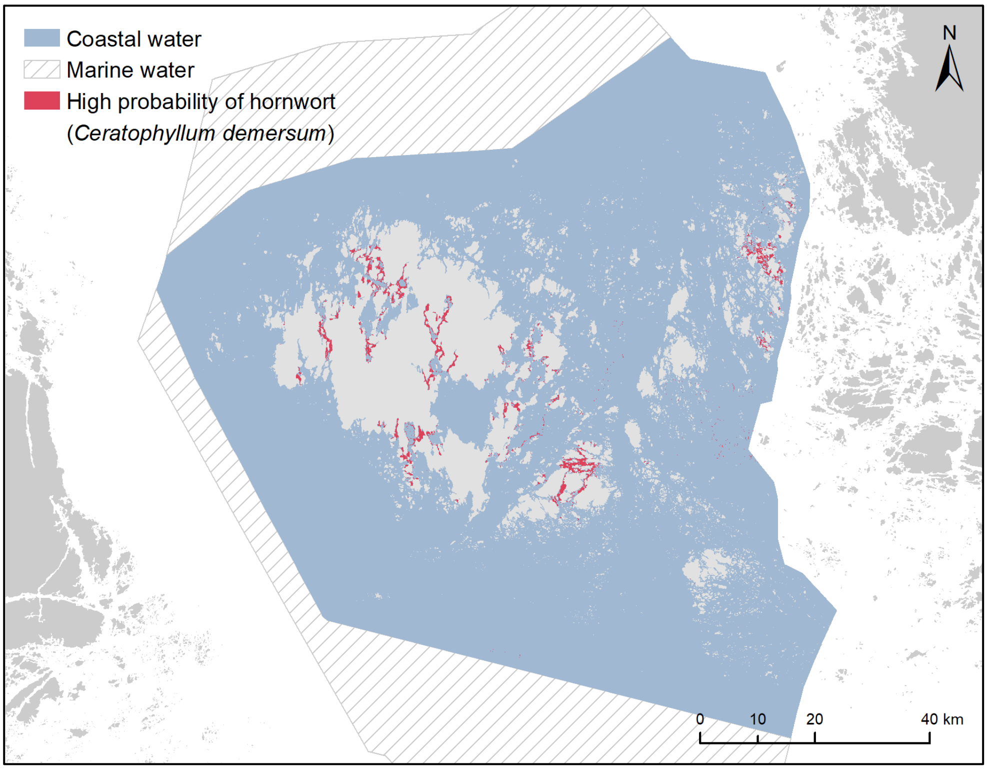
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: 49 observations of hornwort communities (≥30% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.95).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Exposed charophyte communities (*Chara aspera*)

Protection goal: 20%.

Justification for protection goal: Classified as ”near threatened” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Exposed charophyte communities consists of rough stonewort *Chara aspera* that grows on sandy bottoms. The model describes areas where there is a high probability of representative charophyte communities (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that influenced the distribution of rough stonewort were water depth and distance to sand.

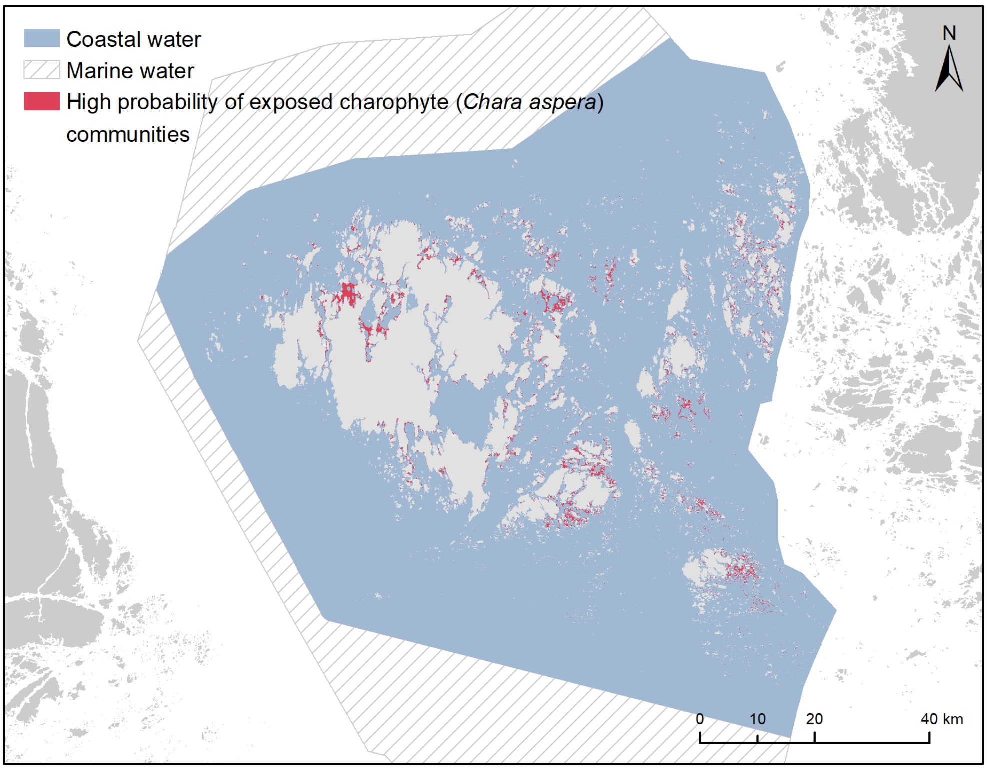
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: 316 observations of rough stonewort (≥10% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.93).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Sheltered charophyte communities (*Chara* sp.)

Protection goal: 20%.

Justification for protection goal: Classified as ”near threatened” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Sheltered charophyte communities include species like *Chara tomentosa* and *Chara baltica* but excludes *Chara aspera* that is more common on exposed sandy bottoms. The model describes areas where there is a high probability of representative charophyte communities (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that influenced the distribution of sheltered charophyte communities were exposure and salinity.

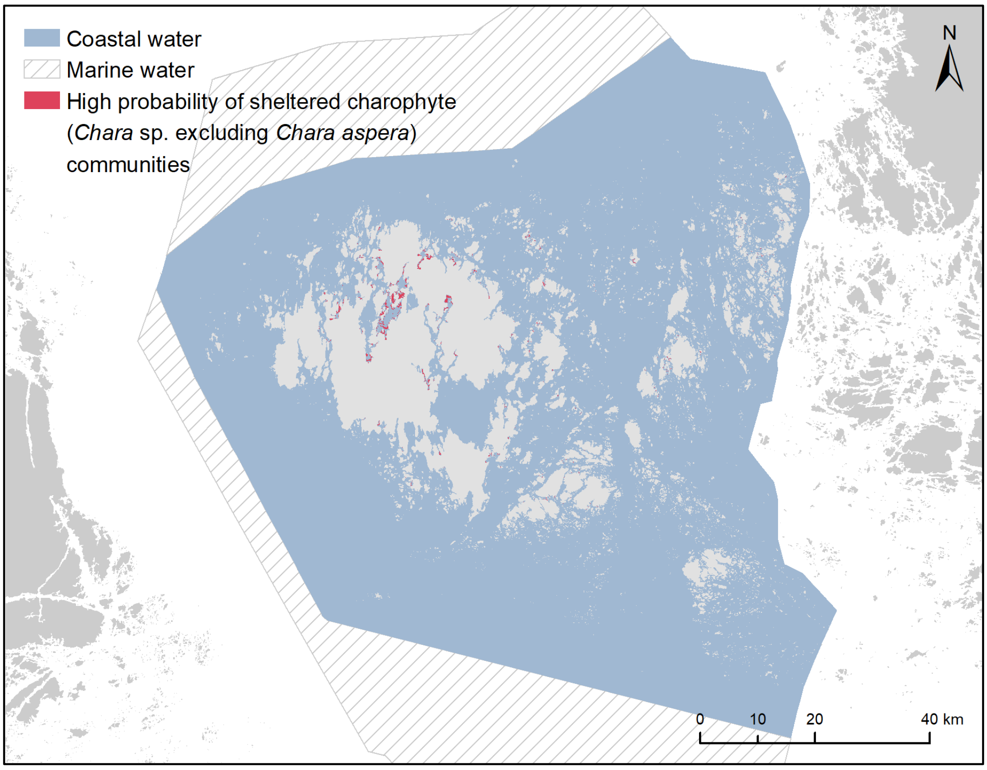
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: 749 observations of charophytes (≥10% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.97).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Spiny naiad communities (*Najas marina*)

Protection goal: 20%.

Justification for protection goal: Classified as “near threatened” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Communities of naiads only include spiny naiad (*Najas marina*). The model describes areas where there is a high probability of representative naiad communities (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that influenced the distribution of the spiny naiad were exposure and distance to sandy bottoms.

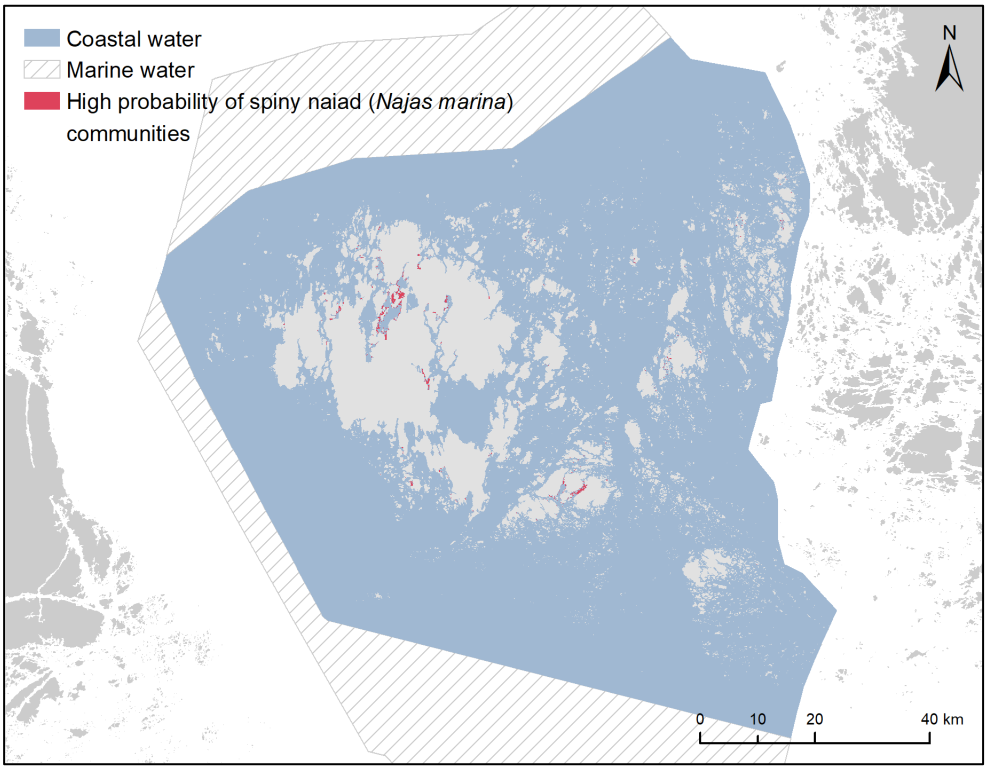
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: 485 observations of spiny naiad (≥10% coverage) were included in the model, and when the model was evaluated, its reliability was good (AUC=0.97).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Eelgrass communities (*Zostera marina*)

Protection goal: 20%.

Justification for Protection goal: Classified as ”vulnerable” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: The model describes areas where there is a high probability of representative eelgrass communities (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that influenced the distribution of eelgrass were distance to sand and water depth.

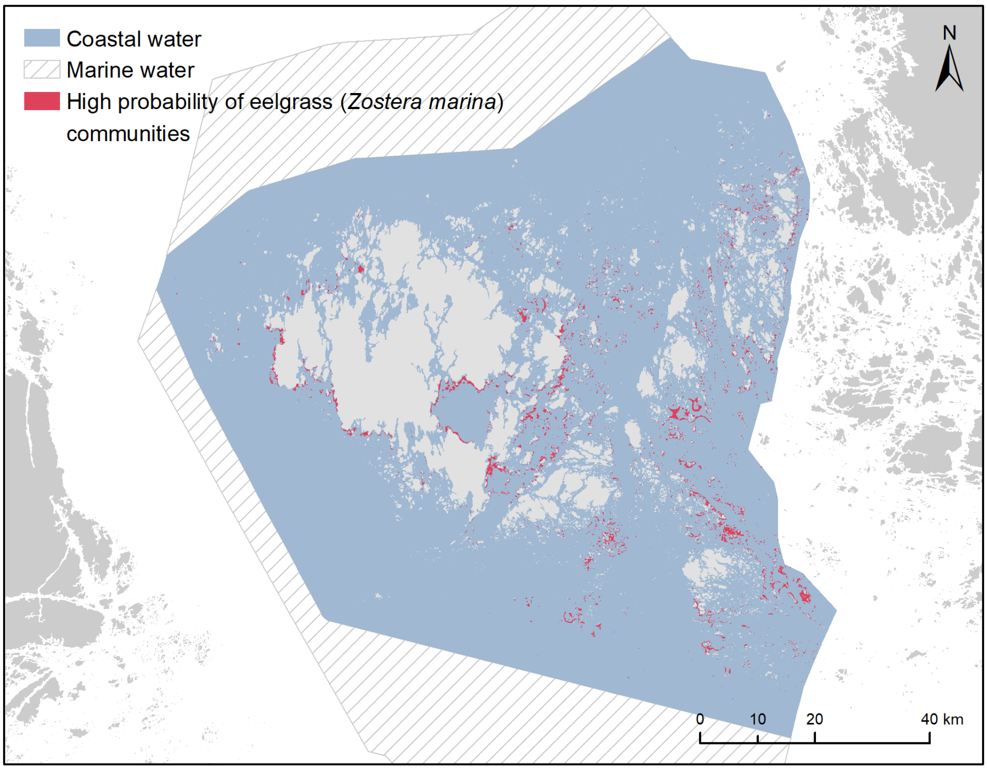
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: 198 observations of eelgrass (≥10% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.98).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Annual filamentous algae

Protection goal: 5%.

Justification for protection goal: Classified as "least concern" (KOTILAINEN et al. 2018). Annual filamentous algae generally benefit from eutrophication and are abundant around Åland (low need for protection).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description of data: Communities with annual filamentous algae include species like *Cladophora glomerata* and *Pylaiella littoralis*. The model describes areas where there is a high probability of representative annual filamentous algae communities (≥30% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that influenced the distribution of annual filamentous algae were depth and exposure on the seafloor.

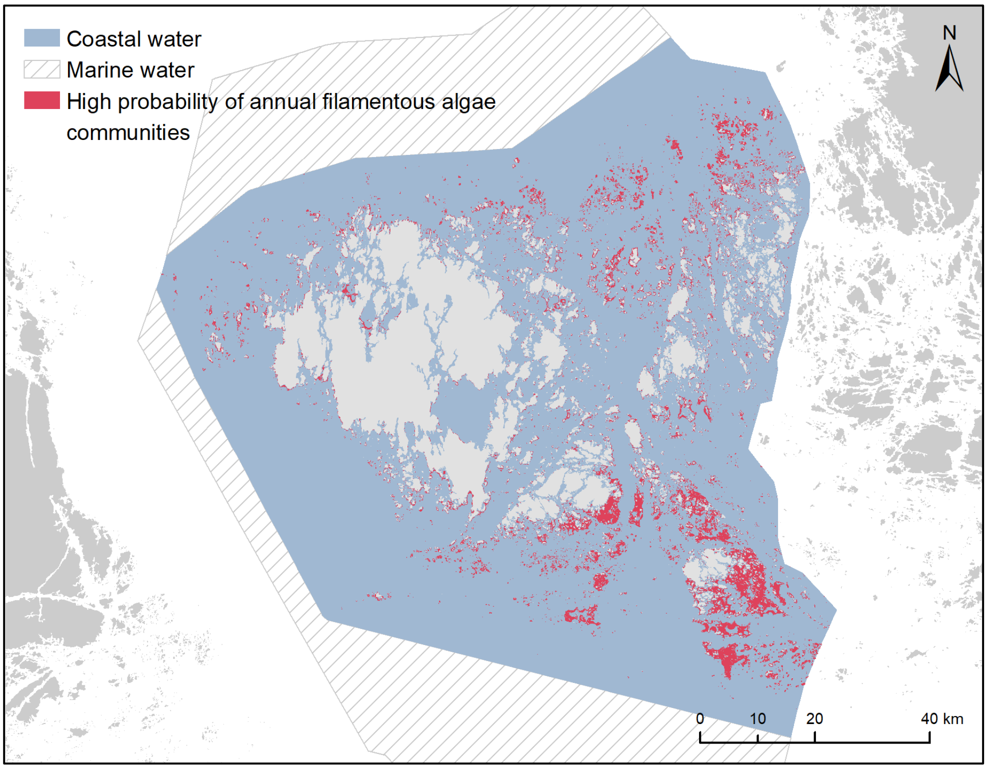
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: 1043 observations of communities with annual algae (≥30% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.99).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Chorda filum and *Halosiphon tomentosum*

Protection goal: 10%.

Justification for protection goal: Classified as ”least concern” (KOTILAINEN et al. 2018).

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Communities of *Chorda* and *Halosiphon* includes the species dead man's rope (*Chorda filum*) and furry rope weed (*Halosiphon tomentosa*). The model describes areas where there is a high probability of representative communities of *Chorda* and *Halosiphon* (≥10% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that influenced the distribution of *Chorda* and *Halosiphon* communities were depth and salinity.

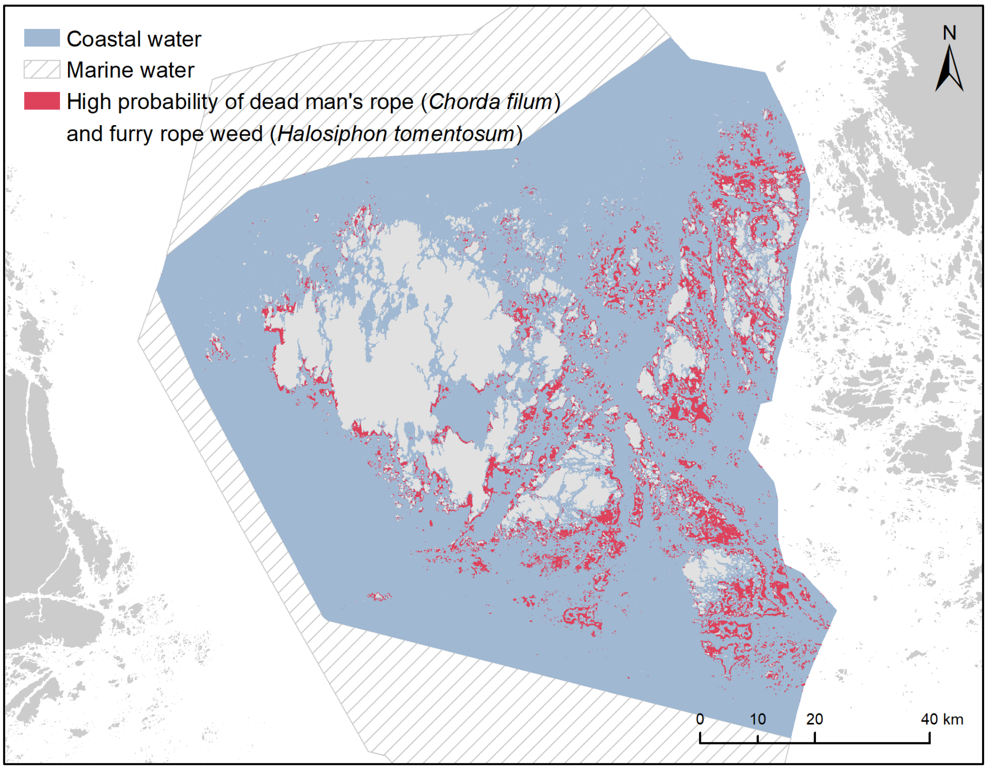
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: 621 observations of *Chorda* and *Halosiphon* communities (≥10% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC=0.91).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Communities of water felt (*Vaucheria* sp.)

Protection goal: 10%.

Justification for protection goal: Classified as ”least concern” (KOTILAINEN et al. 2018).

Data source: Point data from underwater surveys in the Åland Islands by Åbo Akademi University.

Description: Communities of water felt include the genus *Vaucheria.* Observations are unevenly distributed (possibly several different species of water felt) and the distribution model did not turn out to be reliable. Therefore, point data is used for *Vaucheria* occurrence (≥10% coverage).

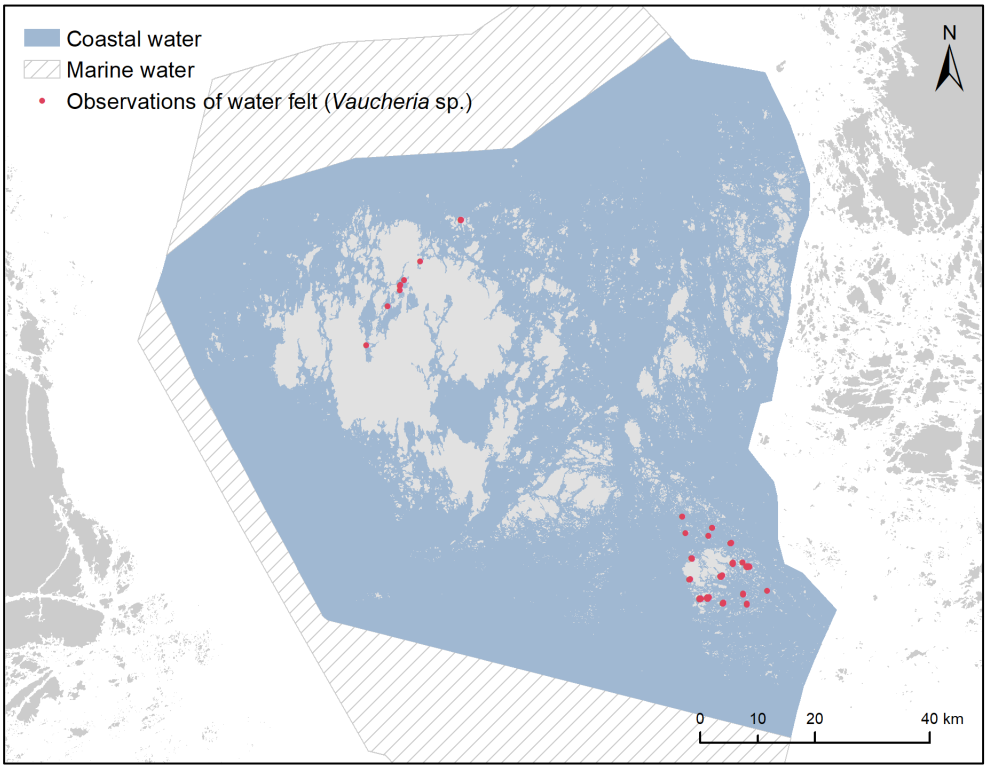
Data format and resolution: Point data.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2002–2021.

Data quality: Good for the observations, but water felt may occur outside the mapping points.

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Blue mussel communities (*Mytilus trossulus*)

Protection goal: 10%.

Justification for protection goal: Classified as ”least concern” (KOTILAINEN et al. 2018), common around the Åland Islands.

Data source: Distribution model based on data from marine underwater surveys in the Åland Islands by Åbo Akademi University.

Description: The model describes areas where there is a high probability of representative blue mussel communities (≥30% coverage). The Boosted Regression Trees (BRT) method was used for modelling and the most important environmental variables that influenced the distribution of blue mussels were depth and exposure.

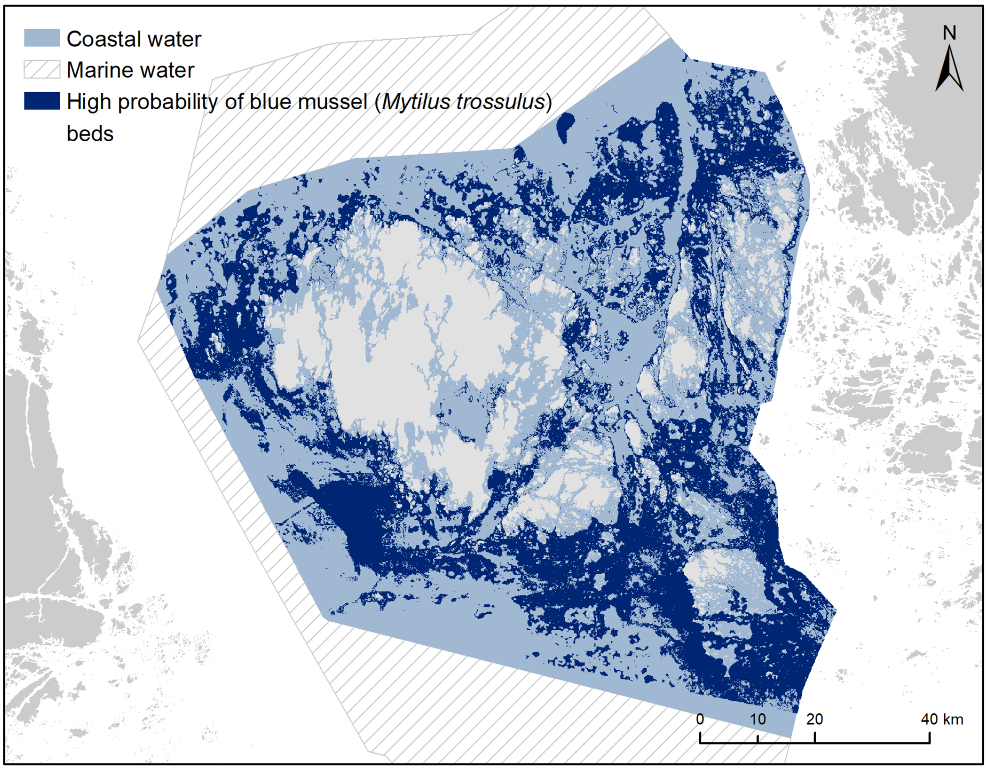
Data format and resolution: Raster, 20 x 20 m.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: 1165 observations of blue mussel communities (≥30% coverage) were included in the model, and when the model was evaluated, its reliability was high (AUC 0.92).

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Hydroid (*Hydrozoa*) communities

Protection goal: 20%.

Justification for protection goal: Classified as “data deficient”, i.e. the threat status of the habitat is unknown (KOTILAINEN et al. 2018).

Data source: Point data from marine surveys in the Åland Islands by Åbo Akademi University.

Description: Points where the coverage of polyps is ≥10%. The distribution models were not reliable because data on the bottom substrate is partly missing.

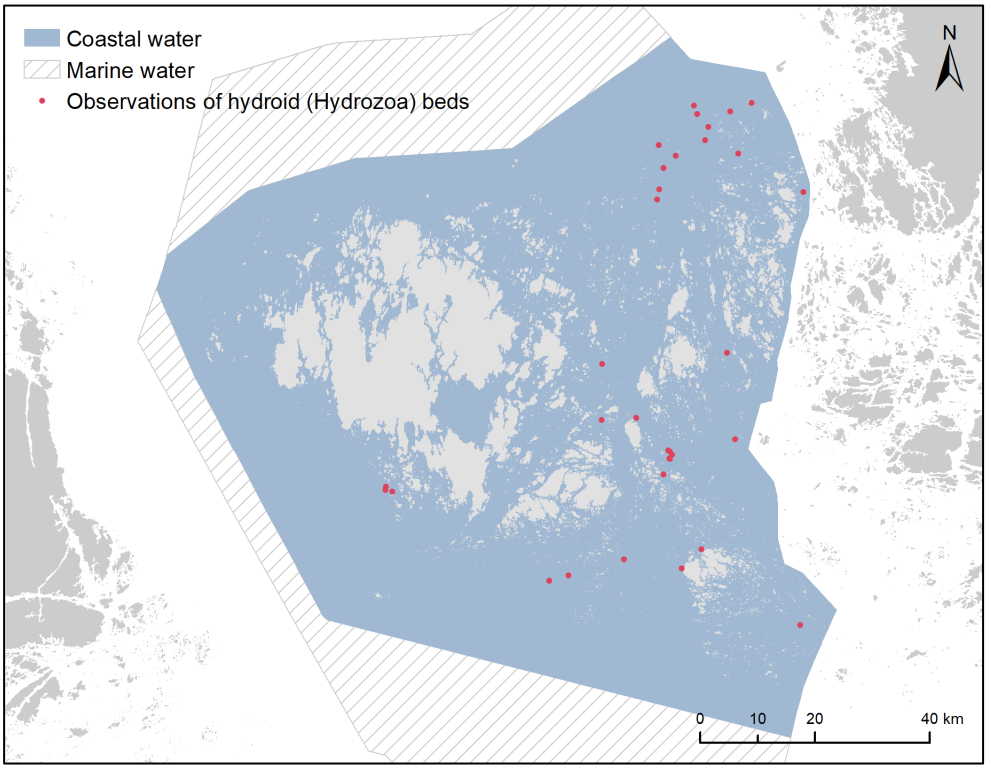
Data format and resolution: Point data.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: The point data is reliable. Only 33 observations of polyp bottoms with ≥10% coverage.

Data owner: Åbo Akademi University.

Additional information: Finnish Red List for habitats, the Baltic Sea (KOTILAINEN et al. 2018: https://julkaisut.valtioneuvosto.fi/handle/10024/161233).



Occurrences of convergent stonewort (*Chara connivens*)

Protection goal: 50%.

Justification for protection goal: The species is rare in the Åland Islands and occurs in Finland only in the Åland Islands.

Data source: Marine surveys in the Åland Islands by Åbo Akademi University.

Description: Data includes macrophyte mapping done by Husö Biological Station, Åbo Akademi University, since 2005.

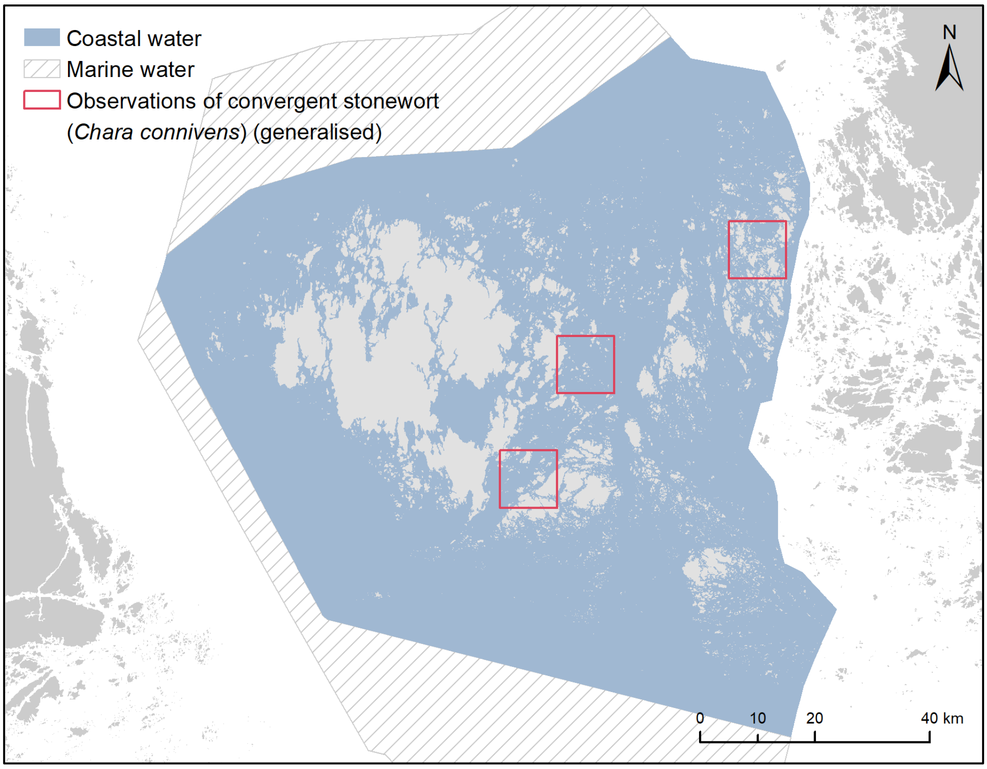
Data format and resolution: Point data. On the map, the observations have been drawn in 10 km x 10 km squares so that the exact locations cannot be estimated.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: Good, but the mapping is not comprehensive, i.e. the species may also be found elsewhere. Non-fertile individuals require DNA sampling for species identification.

Data owner: Åbo Akademi University and the Government of Åland.

Additional information: Reports from Husö Biological Station (https://www.doria.fi/handle/10024/167036).



Occurrences of *Chara horrida*

Protection goal: 50%.

Justification for protection goal: The species is rare and is classified as critically endangered in Finland (KOSTAMO et al. 2019).

Data source: Marine surveys in the Åland Islands by Åbo Akademi University.

Description: Data includes macrophyte mapping done by Husö Biological Station, Åbo Akademi University, since 2005.

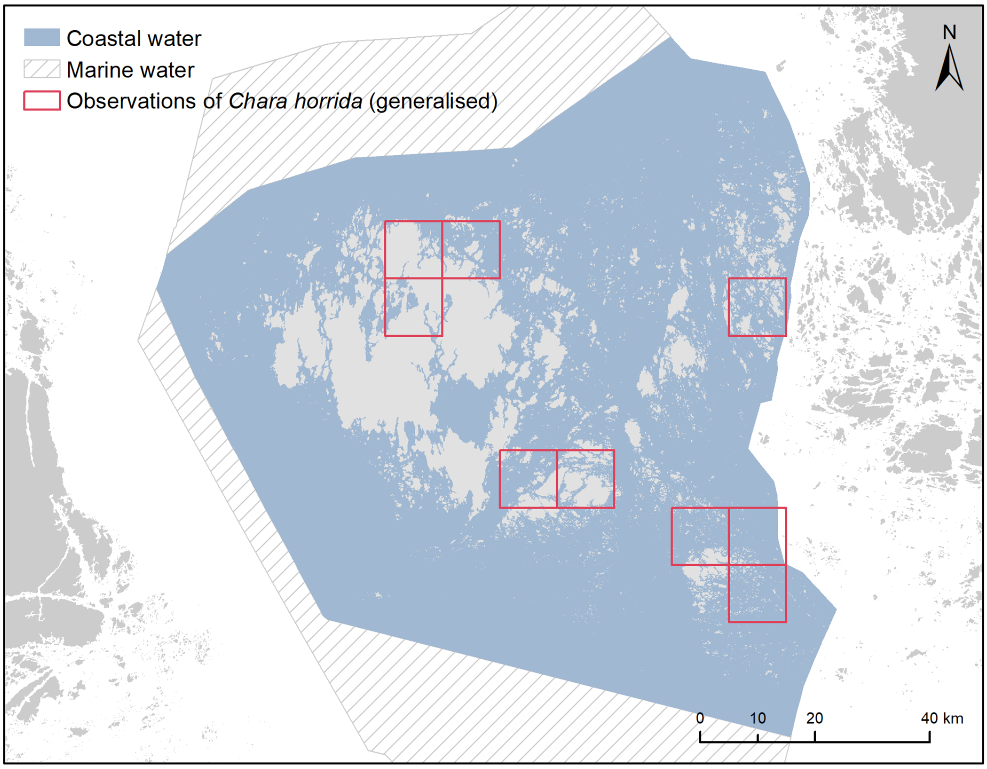
Data format and resolution: Point data. On the map, the observations have been drawn in 10 km x 10 km squares so that the exact locations cannot be estimated.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2021.

Data quality: Good, but the mapping is not comprehensive, i.e., the species may also be found elsewhere.

Data owner: Åbo Akademi University and the Government Of Åland.

Additional information: Reports from Husö Biological Station (https://www.doria.fi/handle/10024/167036). The Finnish Red List of species (2019, https://www.ymparisto.fi/punainenlista): algae (KOSTAMO et al. 2019).



Occurrences of red hornweed (*Ceramium virgatum*)

Protection goal: 50%.

Justification for protection goal: The species is rare. It is classified as “vulnerable” in Finland (KOSTAMO et al. 2019).

Data source: Marine surveys in the Åland Islands by Åbo Akademi University.

Description: Data includes macrophyte mapping done by Husö Biological Station, Åbo Akademi University, since 2005.

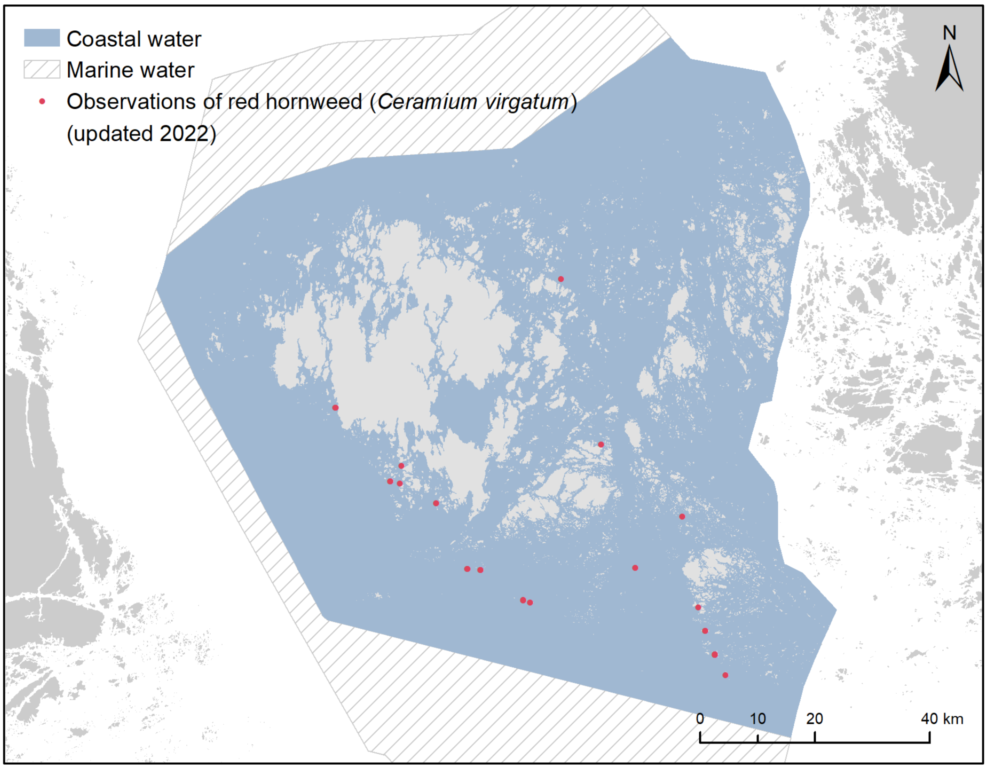
Data format and resolution: Point data.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope and drop-video filming during 2005–2022.

Data quality: Good, but the mapping is not comprehensive, i.e., the species may also be found elsewhere.

Data owner: Åbo Akademi University and the Government of Åland.

Additional information: Reports from Husö Biological Station (https://www.doria.fi/handle/10024/167036). The Finnish Red List of species (2019, https://www.ymparisto.fi/punainenlista): algae (KOSTAMO et al. 2019).



Occurrences of straggly bush weed (*Rhodomela confervoides*)

Protection goal: 30%.

Justification for protection goal: The species is relatively rare, occurs in the exposed outer archipelago. It is classified as “near threatened” in Finland (KOSTAMO et al. 2019).

Data source: Marine surveys in the Åland Islands by Åbo Akademi University.

Description: Data includes macrophyte mapping done by Husö Biological Station, Åbo Akademi University, since 2005.

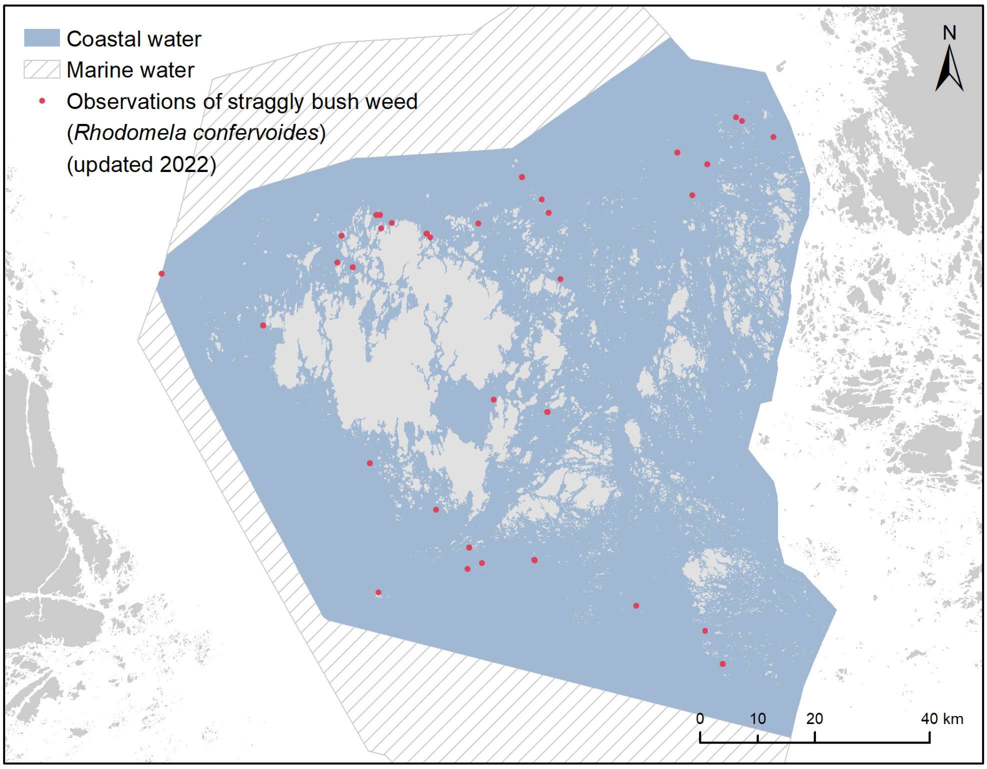
Data format and resolution: Point data.

Data collection (time period/method): Data was collected through diving, snorkelling, aquascope, and drop-video filming during 2005–2022.

Data quality: Good, but the mapping is not comprehensive, i.e., the species may also be found elsewhere.

Data owner: Åbo Akademi University and the Government of Åland.

Additional information: Reports from Husö Biological Station (https://www.doria.fi/handle/10024/167036). The Finnish Red List of species (2019, https://www.ymparisto.fi/punainenlista): algae (KOSTAMO et al. 2019).



Important areas for the Baltic flounder

Protection goal: 20%.

Justification for Protection goal: Classified as “near threatened” (URHO et al. 2019).

Data source: HELCOM, PanBalticScope project.

Description: Model showing areas that are potential spawning grounds for Baltic flounder.

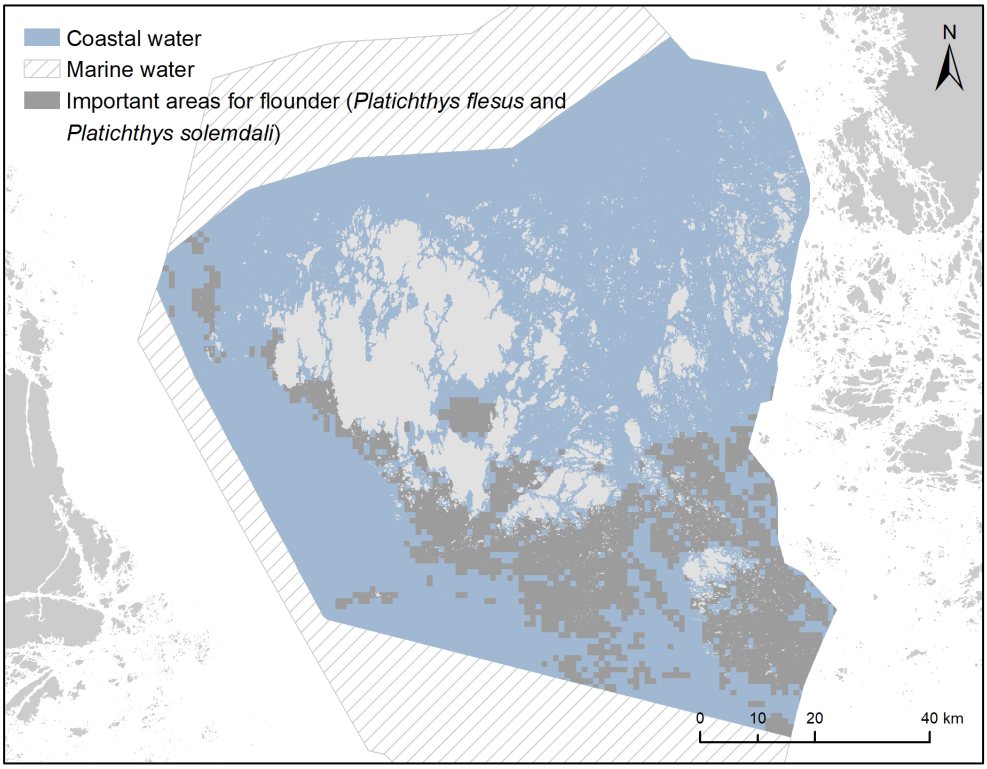
Data format and resolution: Raster, 1 km x 1 km.

Data collection (time period/method): The model has been produced within the PanBalticScope project 2018–2019.

Data quality: The model covers the entire Baltic Sea and is primarily based on salinity and water depth. Relatively rough model.

Data owner: HELCOM and PanBalticScope.

Additional information: Metadata and model description can be found at: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/707b057a-353c-4818-91ee-c73dd0e3aa4c . Finnish Red List of species (2019, https://www.ymparisto.fi/punainenlista): fish (URHO et al. 2019).



Important areas for sea-spawning white fish (*Coregonus lavaretus*)

Protection goal: 30%.

Justification for protection goal: Economically important species. Classified as "vulnerable" (URHO et al. 2019).

Data source: The Government of Åland Fisheries Agency.

Description: The map depicts important spawning areas (spawning and nursery grounds) for sea-spawning whitefish and has been produced within the project: *Fiske och fiskeriförvaltning i Ålands skärgård* (NEUMAN 2007). Data was collected through a survey study. A 500 m buffer zone has been added around the areas.

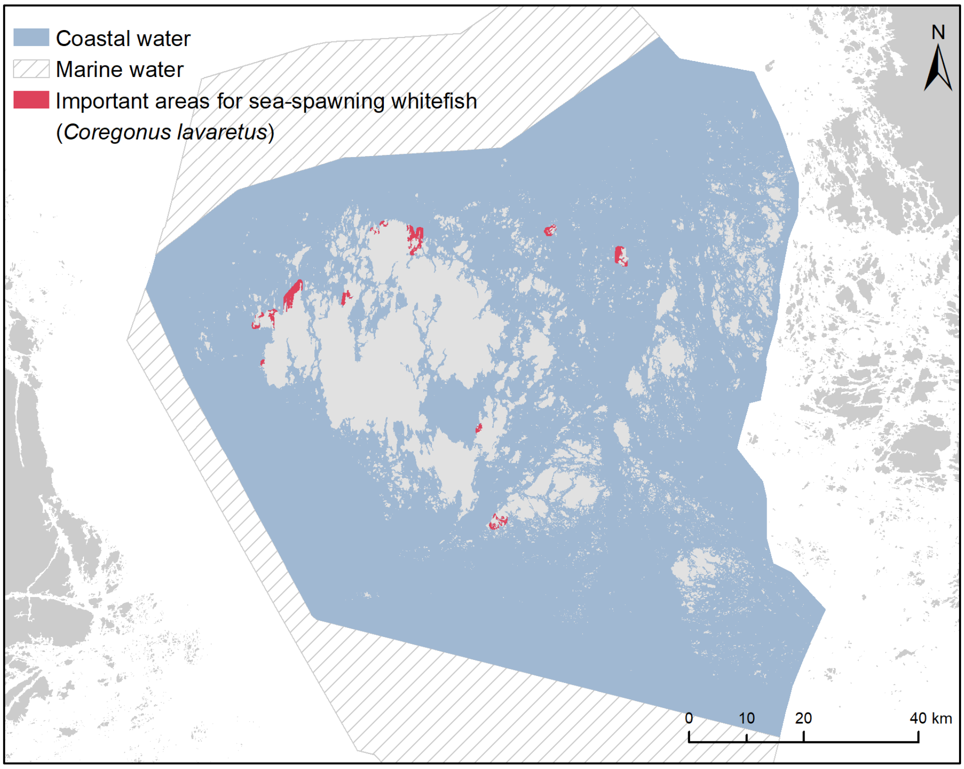
Data format and resolution: Polygon.

Data collection (time period/method): Data collected for a report series 2001–2006. Data collated and final polygons drawn 2007.

Data quality: Polygons based on survey responses. Data in use by the Fisheries Agency and is considered reliable.

Data owner: The Government of Åland.

Additional information:



Important bird areas

Protection goal: 30%.

Justification for protection goal: Birds Directive. Many seabirds are red listed (HELCOM 2013c, LEHIKOINEN et al. 2019).

Data source: Birdlife Finland and Birdlife International.

Description: The data includes both nationally important bird areas (FINIBA) and internationally important areas (IBA). These overlap to a large extent.

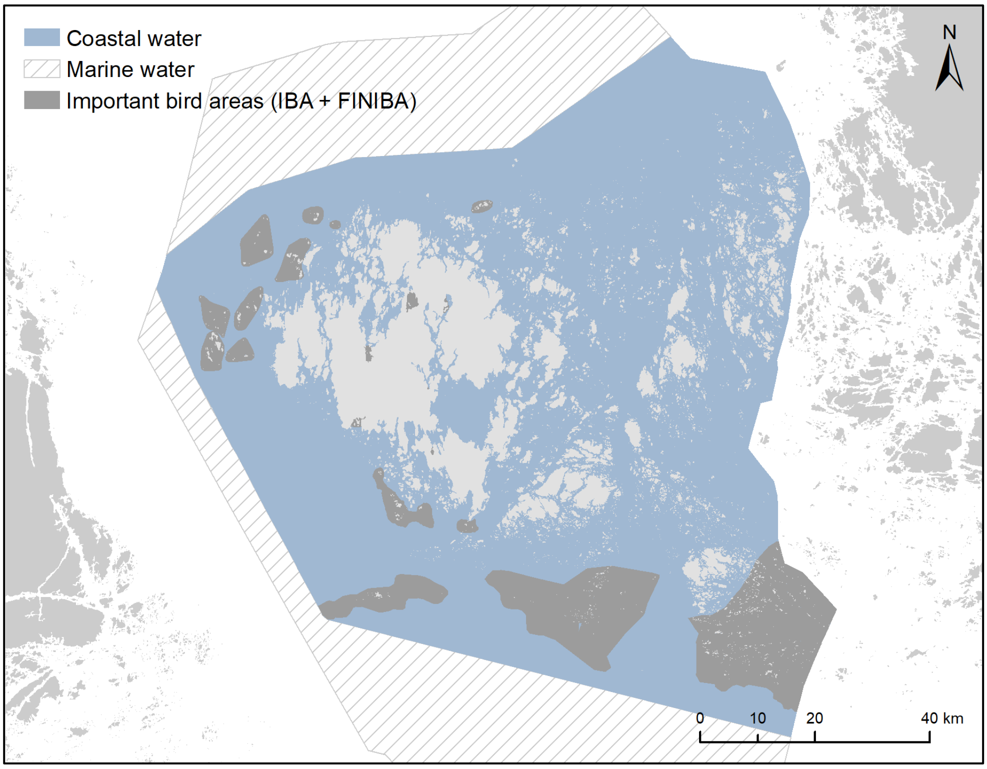
Data format and resolution: Polygon.

Data collection (time period/method): important bird areas in Finland (FINIBA) was defined in the early 2000s. New marine IBA areas were defined in 2016.

Data quality: Original polygons from Birdlife.

Data owner: Birdlife.

Additional information: HELCOM Red List of Baltic Sea species in danger of becoming extinct (2013, https://helcom.fi/wp-content/uploads/2019/08/BSEP140.pdf). Finnish Red List of species (2019, https://www.ymparisto.fi/punainenlista): birds (LEHIKOINEN et al. 2019).



Important areas for the grey seal (*Halichoerus grypus*)

Protection goal: 10%.

Justification for protection goal: The grey seal is listed in Annex II of the Habitats Directive. The grey seal is classified as “least concern” (HELCOM 2013c).

Data source: Natural Resources Institute Finland.

Description: The polygons are based on point data (http://riistahavainnot.fi/hylkeet/tiheys). The polygons cover areas with several skerries where grey seals breed.

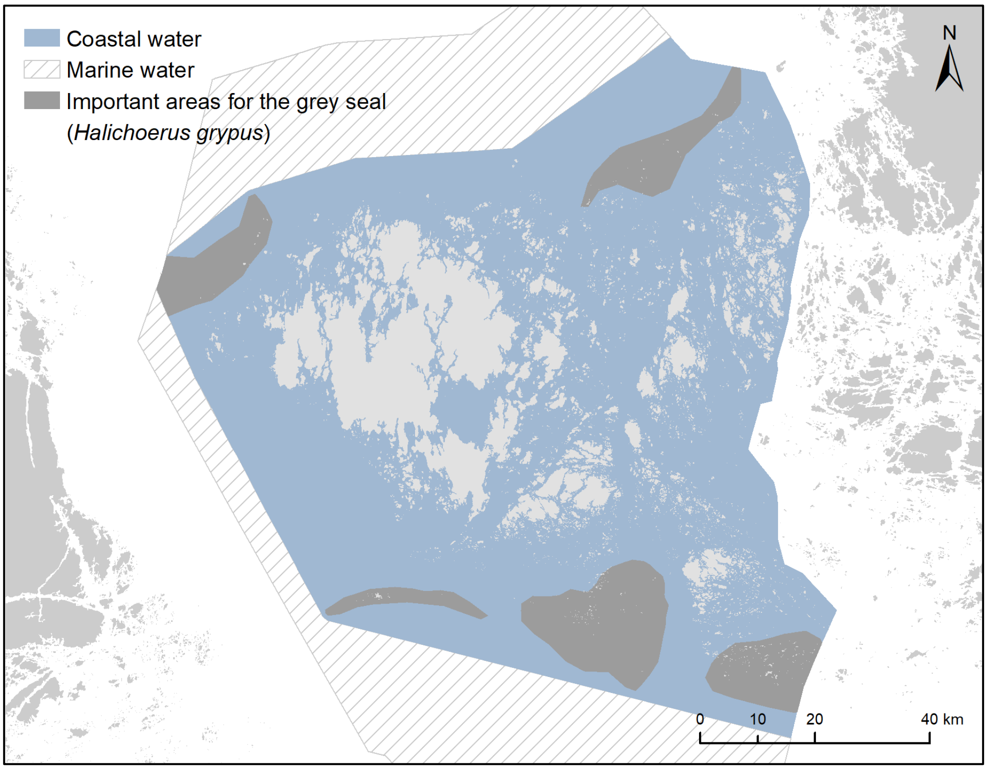
Data format and resolution: Polygon.

Data collection (time period/method): 2017, aerial inventories during the spring.

Data quality: Point data based on direct observations; polygons drawn around the points.

Data owner: Natural Resources Institute Finland, Metsähallitus, and WWF Finland. Polygons drawn by Åbo Akademi University.

Additional information:



Important areas for the ringed seal (*Pusa hispida botnica*)

Protection goal: 20%.

Justification for protection goal: The ringed seal is listed in Annex II of the Habitats Directive. It is classified as "near threatened" in Finland (LIUKKO et al. 2019).

Data source: WWF Finland and Natural Resources Institute Finland.

Description: Areas are drawn by Åbo Akademi University and are based on the map in the report by HALKKA & TOLVANEN 2017: The Baltic Ringed Seal. An Arctic Seal in European Waters.

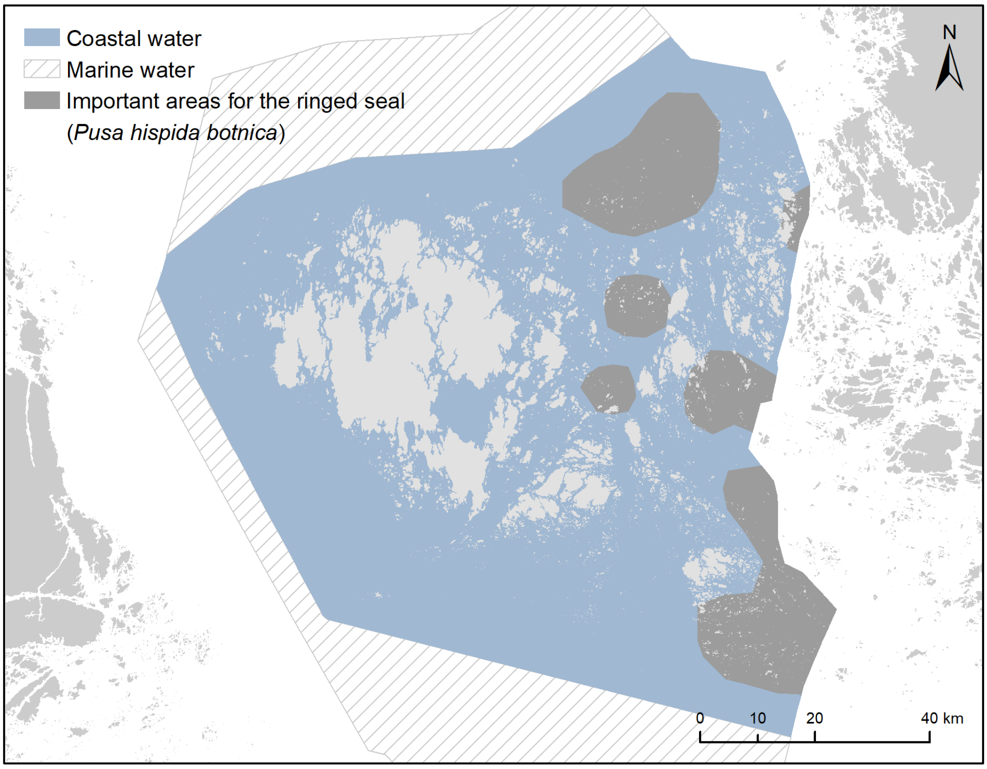
Data format and resolution: Polygon.

Data collection (time period/method): Aerial inventories 2005, 2010, 2011, and 2013.

Data quality: The original map is based on direct observations and buffer zones around the observations (see the report for details).

Data owner: Natural Resources Institute Finland, Metsähallitus, and WWF Finland. Polygons drawn by Åbo Akademi University.

Additional information: Report by HALKKA & TOLVANEN (2017), available at: https://wwf.fi/app/uploads/2/r/u/z4bm4bbejniod2hde4g2kce/wwf_norppa_2017_web_korj_d.pdf .



Important areas for perch (*Perca fluviatilis*)

Protection goal: 20%.

Justification for protection goal: Economically important species. Classified as "least concern".

Data source: Natural Resources Institute Finland.

Description: The model shows favourable or very favourable spawning grounds for the perch and was made by Natural Resources Institute Finland. The data has been supplemented with point data on important spawning grounds for pike and perch (the Government of Åland inventories 2018). A 500 m buffer zone has been added around the points rated highly (≥ 10 points) to get a more realistic (larger) spawning area. The point data overlaps a lot with the model.

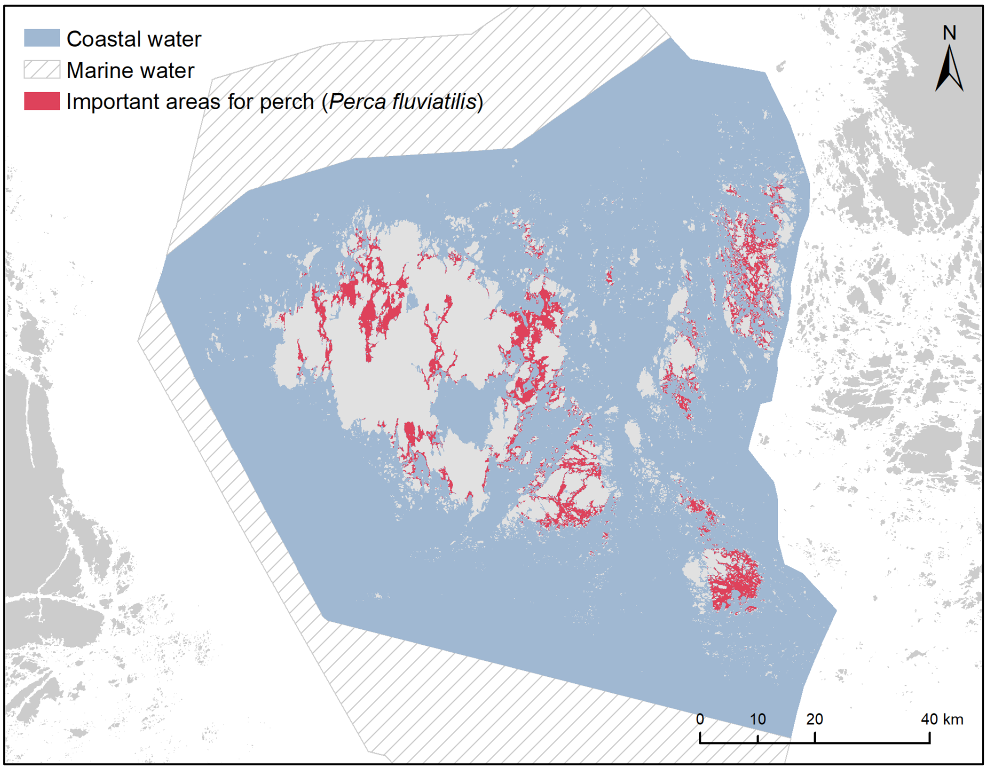
Data format and resolution: Raster (GeoTIFF).

Data collection (time period/method): Data collected in 2007–2014. The model was produced in 2015 (see reference below). Supplementary data collected in 2018, partly based on survey responses.

Data quality: Model.

Data owner: Natural Resources Institute Finland and the Government of Åland (for point data).

Additional information: KALLASVUO, M., J. VANHATALO & L. VENERANTA, 2016. Modelling the spatial distribution of larval fish abundance provides essential information for management. Can. J. Fish. Aquat. Sci. 74(5), 636–649. https://doi.org/10.1139/cjfas-2016-0008



Important areas for pikeperch (*Sander lucioperca*)

Protection goal: 20%.

Justification for protection goal: Economically important species. Classified as "least concern".

Data source: Natural Resources Institute Finland.

Description: The model shows favourable or very favourable spawning areas for pikeperch.

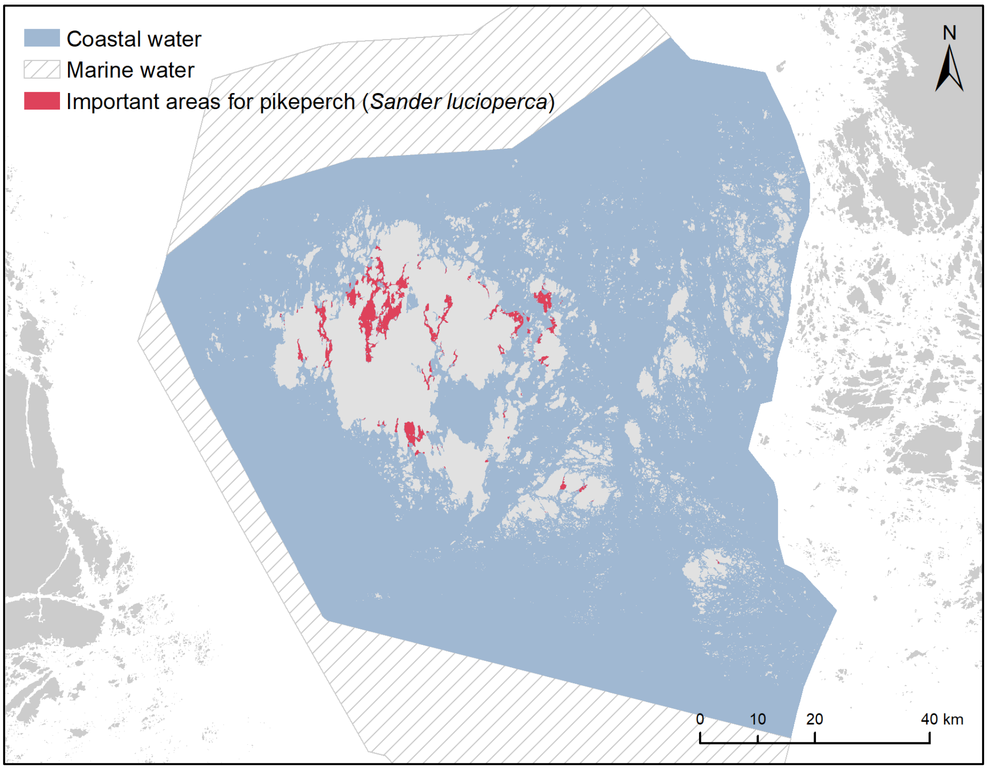
Data format and resolution: Raster (GeoTIFF), 50 m x 50 m.

Data collection (time period/method): Data collected in 2007–2014. Model produced in 2015 (see reference below).

Data quality: Model.

Data owner: Natural Resources Institute Finland.

Additional information: KALLASVUO, M., J. VANHATALO & L. VENERANTA, 2016. Modelling the spatial distribution of larval fish abundance provides essential information for management. Can. J. Fish. Aquat. Sci. 74(5), 636–649. https://doi.org/10.1139/cjfas-2016-0008



Important areas for pike (*Esox lucius*)

Protection goal: 20%.

Justification for protection goal: Economically important species. Classified as “least concern”.

Data source: The Government of Åland (the Fisheries Agency) and the Swedish University of Agricultural Sciences.

Description: Model showing areas that are very favourable for pike reproduction and pike fry (young-of-the-year). The model was produced within the BALANCE-project (2005–2007). Data was supplemented with point data on important spawning grounds for pike and perch (2018 inventories). A 500 m buffer zone has been added around the points rated highly (≥ 10 points) to include a more realistic (larger) spawning area. The point data overlaps a lot with the model.

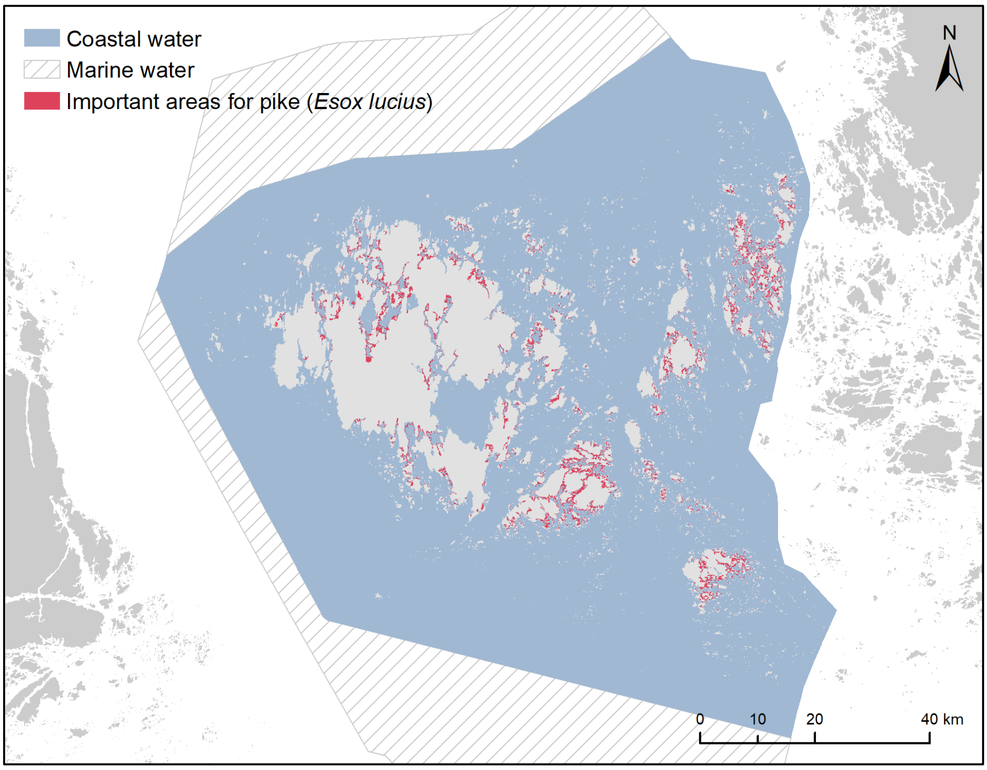
Data format and resolution: Polygon.

Data collection (time period/method): Model produced in 2005–2007. Supplementary data collected in 2018, partially based on survey responses.

Data quality: Model and point data.

Data owner: The Government of Åland and the Swedish University of Agricultural Sciences.

Additional information:



Important areas for Baltic herring (*Clupea harengus*)

Protection goal: 20%.

Justification for Protection goal: Economically important species. Classified as “least concern”.

Data source: Natural Resources Institute Finland.

Description: Model that describes very favourable spawning areas for Baltic herring. The northeastern and southeastern parts are missing from the model due to limitations in environmental parameters (exposure model) used as background for the model.

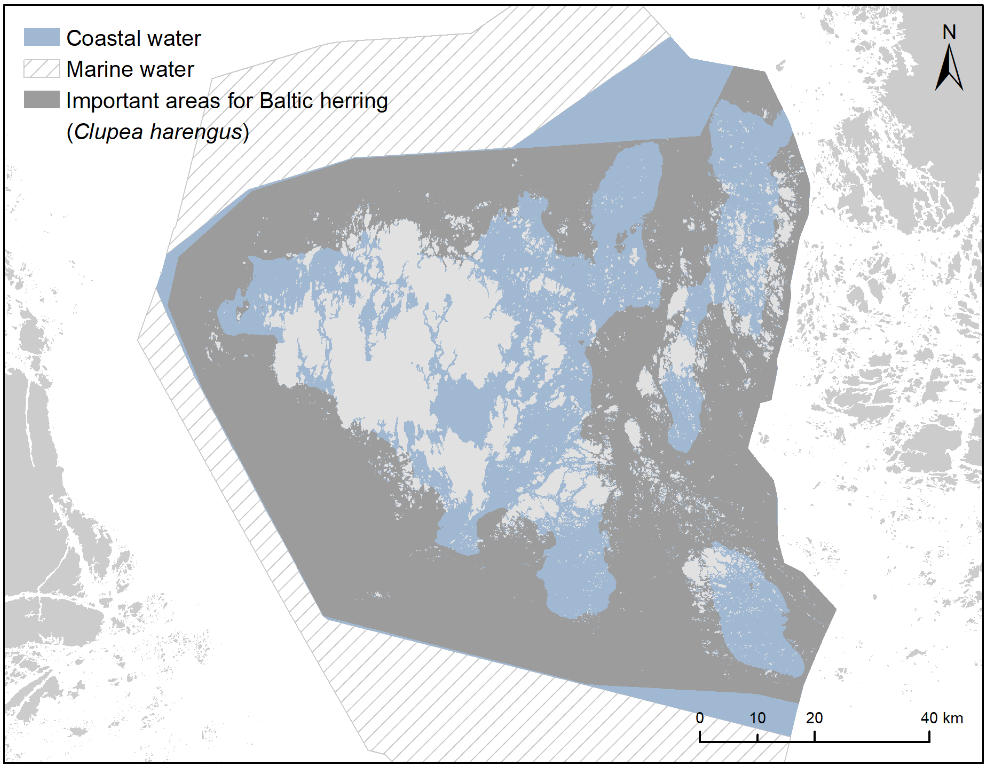
Data format and resolution: Raster (GeoTIFF).

Data collection (time period/method): Data collected in 2007–2014. Model produced in 2015 (see reference below).

Data quality: Model.

Data owner: Natural Resources Institute Finland.

Additional information: KALLASVUO, M., J. VANHATALO & L. VENERANTA, 2016. Modelling the spatial distribution of larval fish abundance provides essential information for management. Can. J. Fish. Aquat. Sci. 74(5), 636**–**649. https://doi.org/10.1139/cjfas-2016-0008



Harbours

Environmental effects: Traffic (disturbance), pollution, noise, and erosion.

Buffer size: 1 km for large harbours (Mariehamn, Långnäs, and Eckerö), 500 m for the archipelago traffic's smaller harbours (see tourism and recreation for guest harbours).

Treatment in Marxan analysis: Locked out → the areas will not be included in scenarios for the protected area network.

Data source: Corine Land Cover (CLC) 2018 for large harbours and the Government of Åland for the archipelago traffic's harbours.

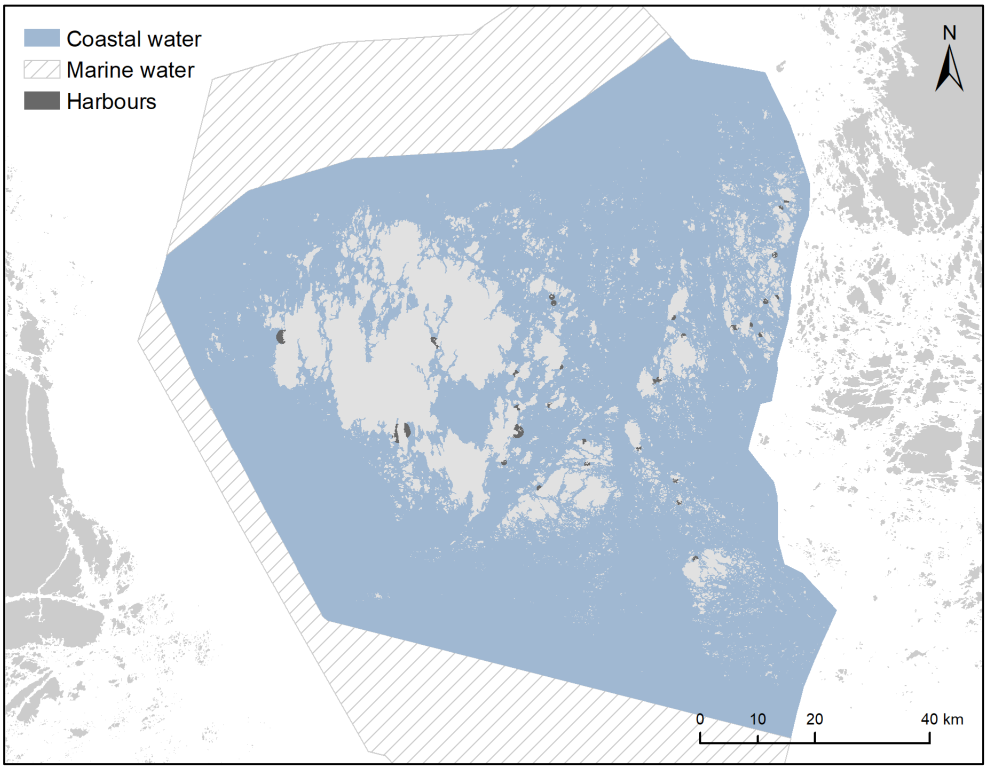
Description: Fairway (lines) with buffer zones.

Data format and resolution: CLC: 20 x 20 m raster data, harbours for archipelago traffic: point data.

Data collection (time period/method): CLC: 2018, the Government of Åland data 2021.

Data quality: Good.

Data owner: Finnish Environment Institute (CLC data) and the Government of Åland.



Fairways

Environmental effects: Traffic (disturbance), pollution, noise, and erosion

Buffer size: Varies with the size of the fairway: depth >7 m → 1 km, depth 3-6.9 m → 500 m, depth < 3 m, fairways are not considered.

Treatment in Marxan analysis: Locked out → the areas will not be included in scenarios for the protected area network.

Data source: Finnish Transport and Communications Agency.

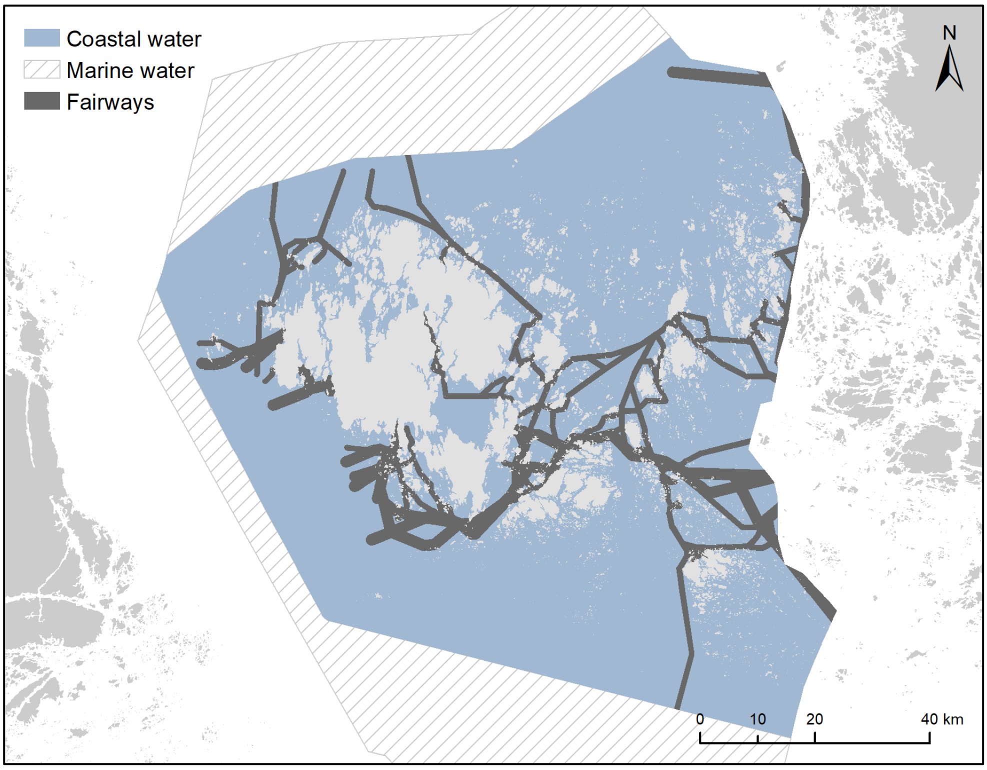
Description: Fairway (lines) with buffer zones.

Data format and resolution: Polygon (lines with buffer).

Data collection (time period/method): Data downloaded from the Finnish Transport and Communications Agency's service 2021.

Data quality: Good.

Data owner: Finnish Transport and Communications Agency.



Intensity of ship traffic

Environmental effects: Traffic (disturbance), pollution, noise, and erosion

Buffer size:

Treatment in Marxan analysis: Part of cost layer → areas with a lot of ship traffic are less likely to be proposed as part of the protected area network.

Data source: HELCOM.

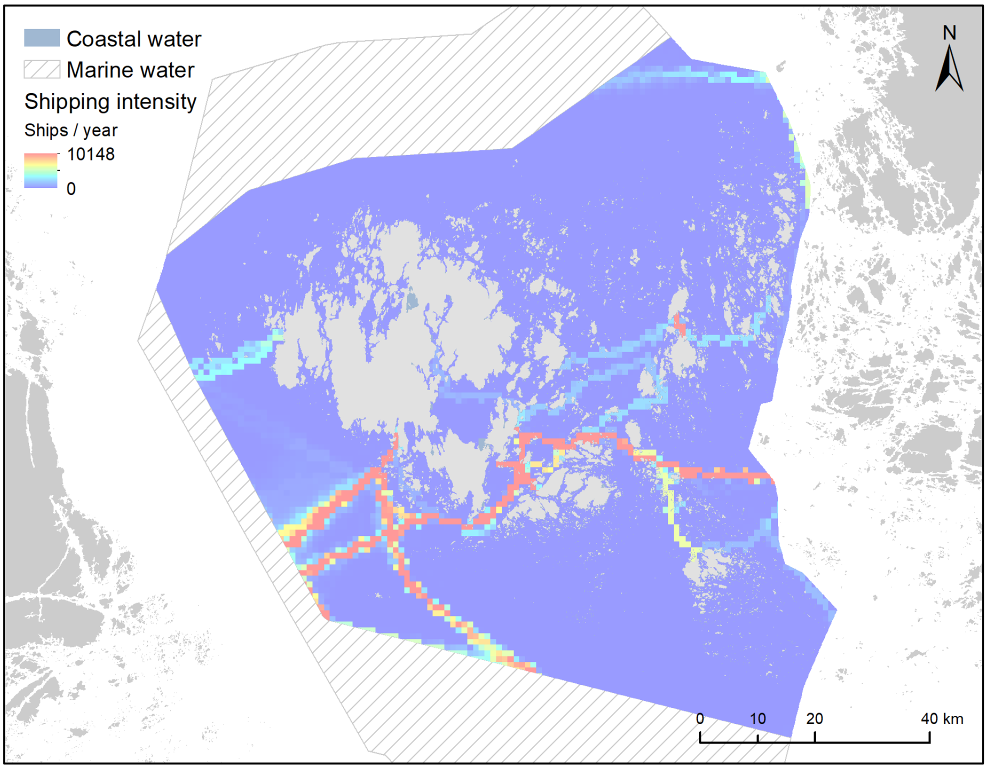
Description: The intensity of the traffic complements the information that only describes the existence of shipping lanes, especially in open sea areas where shipping lanes do not exist. Based on AIS data (Automatic Identification System) which shows how many ships passed through a 1 km x 1 km square in 2019. Intensity varies between 0 and 1.

Data format and resolution: Raster 1 km x 1 km.

Data collection (time period/method): 2019 (latest existing data from HELCOM).

Data quality: Good but rough resolution (1 km x 1 km pixel size).

Data owner: HELCOM.



Large scale dredging and dumping of dredged materials

Environmental effects: Habitat loss, large mechanical disturbance, heavy sedimentation, reduced water quality (potential release of heavy metals and other toxins from the sediment), and increased turbidity.

Buffer size: 2 km.

Treatment in Marxan analysis: Locked out → the areas will not be included in scenarios for the protected area network.

Data source: Finnish Transport and Communications Agency.

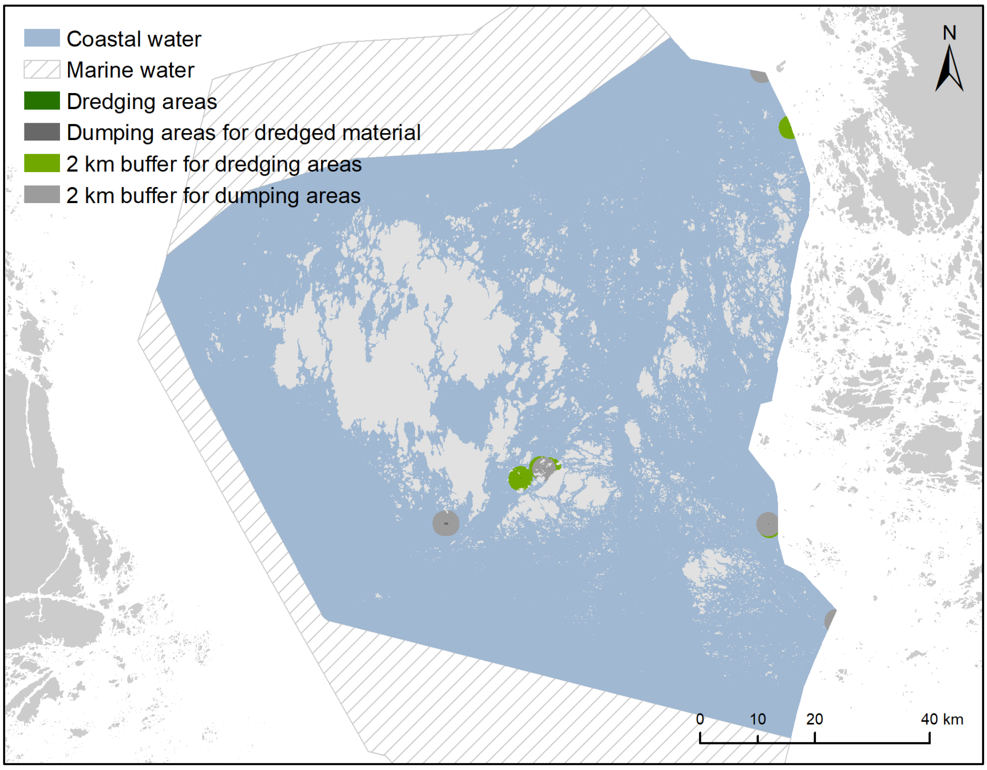
Description: Dredging and dumping done in the 2000s (2000 →).

Data format and resolution: polygon with 2 km buffer.

Data collection (time period/method): Data downloaded from the Finnish Transport and Communications Agency's service 2021.

Data quality: Only data available from the Finnish Transport and Communications Agency's service.

Data owner: Finnish Transport and Communications Agency.



Underwater noise

Environmental effects: Disturbance at least to fish, birds, and marine mammals.

Buffer size:

Treatment in Marxan analysis: Part of the cost layer → areas with a lot of underwater noise are less likely to be proposed as part of the protected area network.

Data source: HELCOM, BIAS project.

Description: Data represents continuous underwater noise, modelled to 0.5 km x 0.5 km raster. Data shows areas where sound pressure of third-octave bands exceeds 125 Hz at least 5% of the time. The intensity varies from 0 (92 dB re 1μPa) to 1 (127 dB re 1μPa), in the Åland Islands only up to 0.88. Data has been produced within the BIAS project (2014) for the entire Baltic Sea.

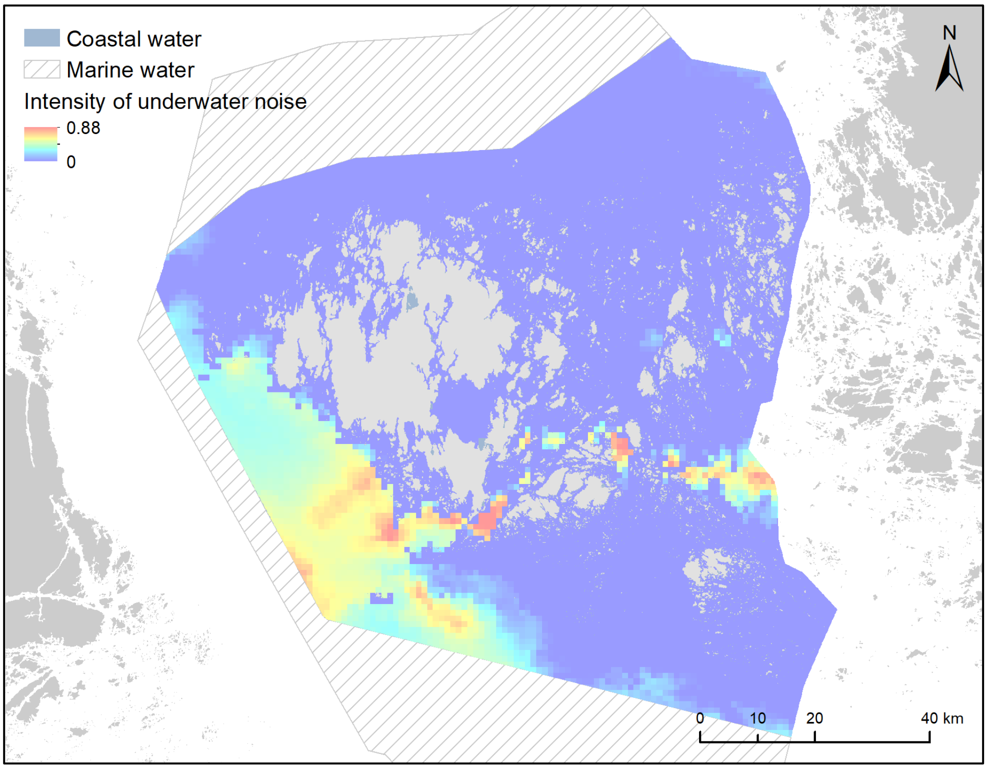
Data format and resolution: Raster 0.5 km x 0.5 km.

Data collection (time period/method): Modelling done 2014.

Data quality: The model covers the entire Baltic Sea with rough resolution. The model does not cover all archipelago areas.

Data owner: HELCOM, BIAS project.

Other: These results have been extracted with help of the BIAS soundscape planning tool, which was prepared within the EU LIFE project Baltic Sea Information on the Acoustic Soundscape (BIAS LIFE11 ENV/SE 841). More information available at: www.bias-project.eu .



Aquaculture, existing units

Environmental effects: Point loading of nutrients, residue of detergents and toxic paint, increased traffic, and noise.

Buffer size: Buffer sizes around aquaculture (fish farms) is determined by the phosphorous load/year (2020, see data description).

Treatment in Marxan analysis: Locked out → the areas will not be included in scenarios for the protected area network.

Data source: The Government of Åland: locations and the Åland Environmental and Health Protection Authority: nutrient load conditions.

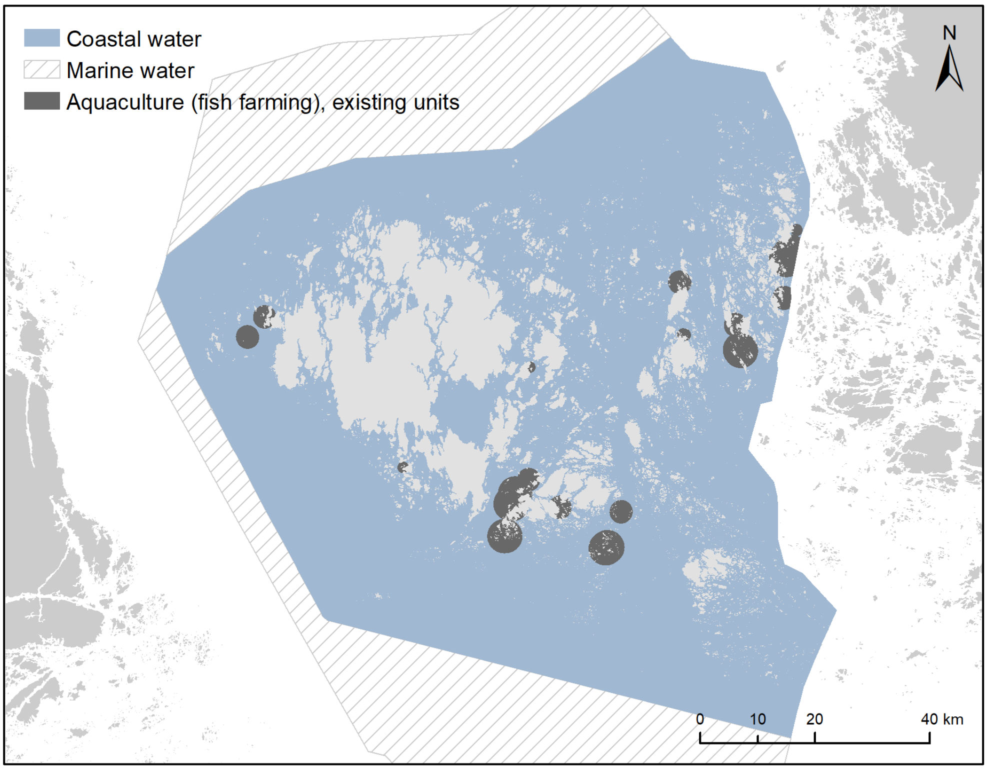
Description: Point data over existing fish farms. A buffer zone has been added around the locations to present the affected areas. Load size < 1000 kg P → 1 km buffer, load size 1000-2000 kg P → 2 km buffer, load size >2000 kg P → 3 km buffer. Rearing/breeding bags have not been noted.

Data format and resolution: Polygon (point data with buffer).

Data collection (time period/method): 2020.

Data quality: Good for the locations. The use of simple buffer zones is not optimal for representing the spread of emissions because currents and wind plays a large role.

Data owner: The Government of Åland and the Åland Environmental and Health Protection Authority.



Planned areas for aquaculture

Environmental effects: Disturbances during the building phase, increased traffic, and noise.

Treatment in Marxan analysis: Part of the cost layer → areas planned for aquaculture have reduced chances of being proposed as part of the protected are network.

Buffer size:

Data source: The Government of Åland, maritime spatial plan of Åland (Havsplanen) 2021.

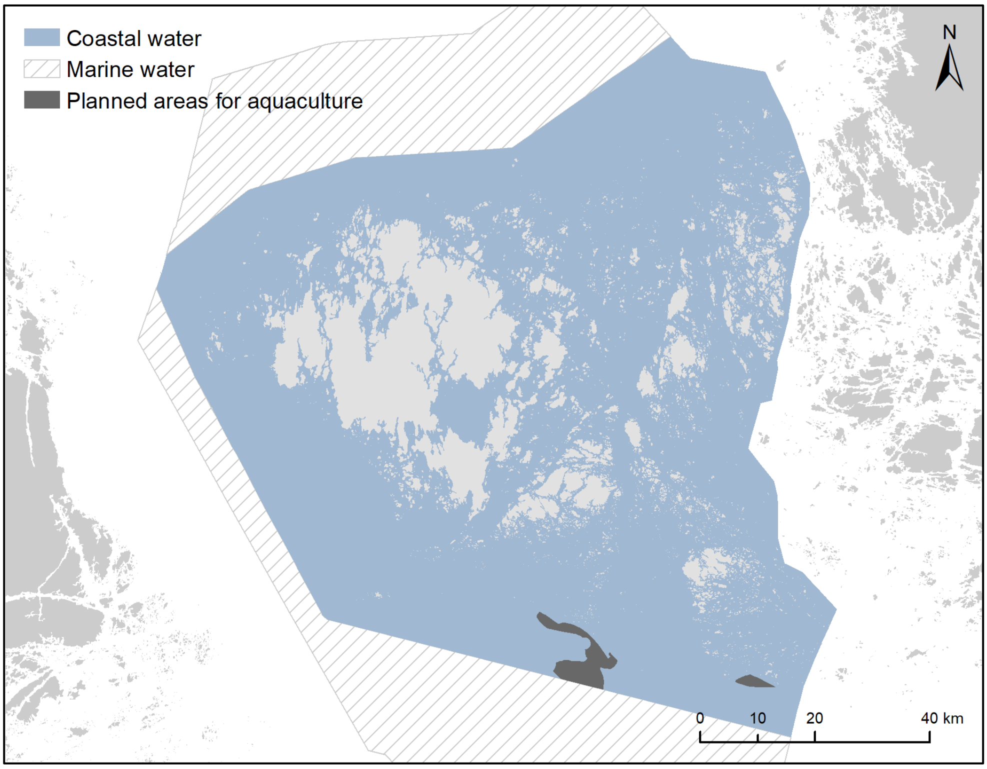
Description: Areas marked for potential use in aquaculture in Havsplanen (adopted 2021). The areas are marked based on the results from an EU-financed project whose objective was to identify solutions to grow algae in the Baltic Sea in a sustainable way (EU project GRASS).

Data format and resolution: Polygon.

Data collection (time period/method): 2021.

Data quality: Relatively poor. Identification of suitable areas for algae aquaculture has been done at the Baltic Sea scale based on environmental variables. The identified areas in the Åland Islands are relatively open sea areas and therefore perhaps not the most suitable.

Data owner: The Government of Åland.



Areas for commercial fishing

Environmental effects: Mortality of fish, disturbance, increased traffic, and emissions.

Buffer size:

Treatment in Marxan analysis: Part of the cost layer → areas for commercial fishing have reduced chances of being proposed as part of the protected are network.

Data source: The Government of Åland.

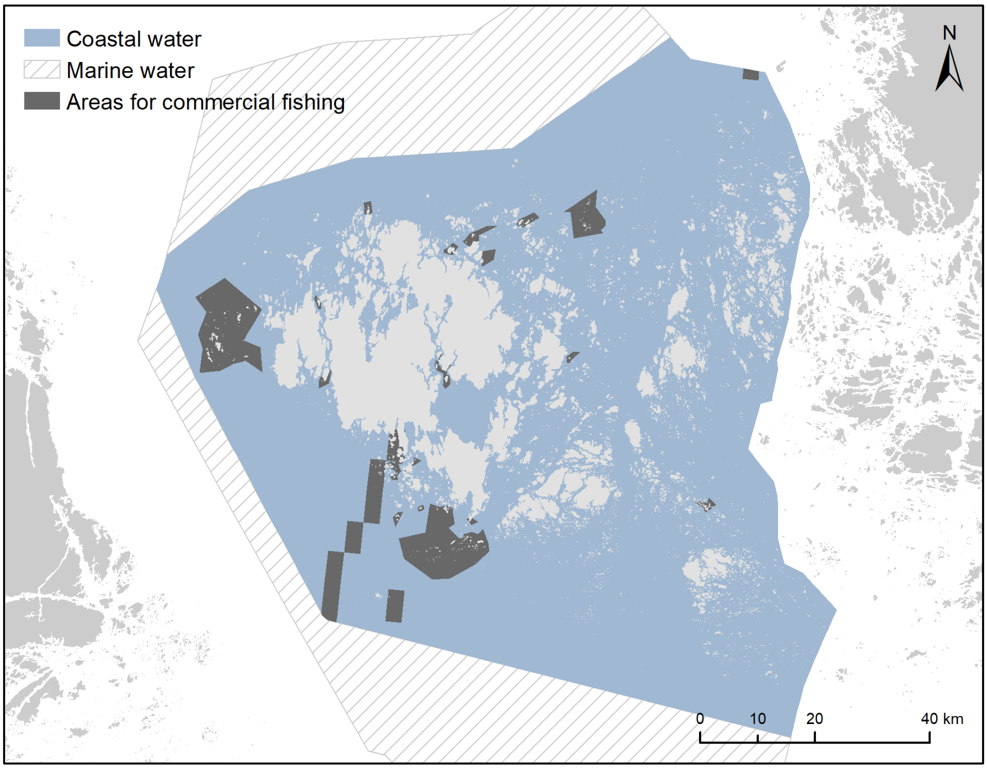
Description: Water areas managed by the Government of Åland where registered fishermen can apply for a permit for professional fishing (managed by the Government of Åland real estate agency). The data has been supplemented with HELCOM's data on fishing pressure (2009-2013). Areas with a fishing pressure of >250 h / year (any year between 2009 and 2013) have been included.

Data format and resolution: Polygon.

Data collection (time period/method):

Data quality: Good for the Government of Åland data, HELCOMs data is rough.

Data owner: The Government of Åland and HELCOM.



Marine areas close to urban zones

Environmental effects: Emissions/pollution, traffic, noise, and littering.

Buffer size: 500 m from the shoreline.

Treatment in Marxan analysis: Part of the cost layer → areas with a lot of activity have reduced chances of being proposed as part of the protected are network.

Data source: Corine Land Cover (CLC) 2018.

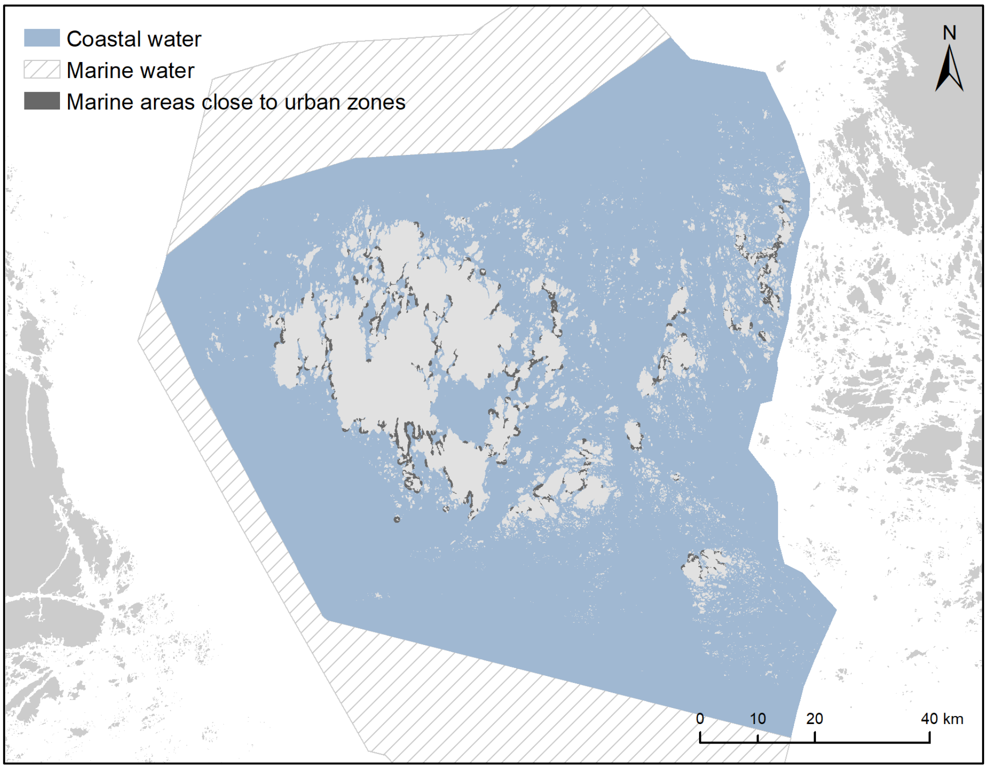
Description: Urban areas have been selected from Corine Land Cover and include the following classifications: dense urban structure, sparse urban structure, industry, service units, road network, port areas, airports, mineral extraction sites, landfills, construction sites. Areas < 1 ha have been deleted. A 500 m buffer has been added around coastal urban areas.

Data format and resolution: Raster 20 m x 20 m (converted till polygon due to technical reasons).

Data collection (time period/method): CLC 2018.

Data quality: Good, based on satellite images.

Data owner: Finnish Environment Institute, open data.



Areas of high activity: density of small-scale dredging and jetties

Environmental effects: Disturbances from different activities: boats, fishing, other recreation. Small-scale dredging results in habitat loss and increased turbidity/sedimentation.

Buffer size:

Treatment in Marxan analysis: Part of the cost layer → areas with a lot of activity have reduced chances of being proposed as part of the protected are network.

Data source: Point data, Metsähallitus (based on interpretations of aerial photography), analysis performed by Åbo Akademi University.

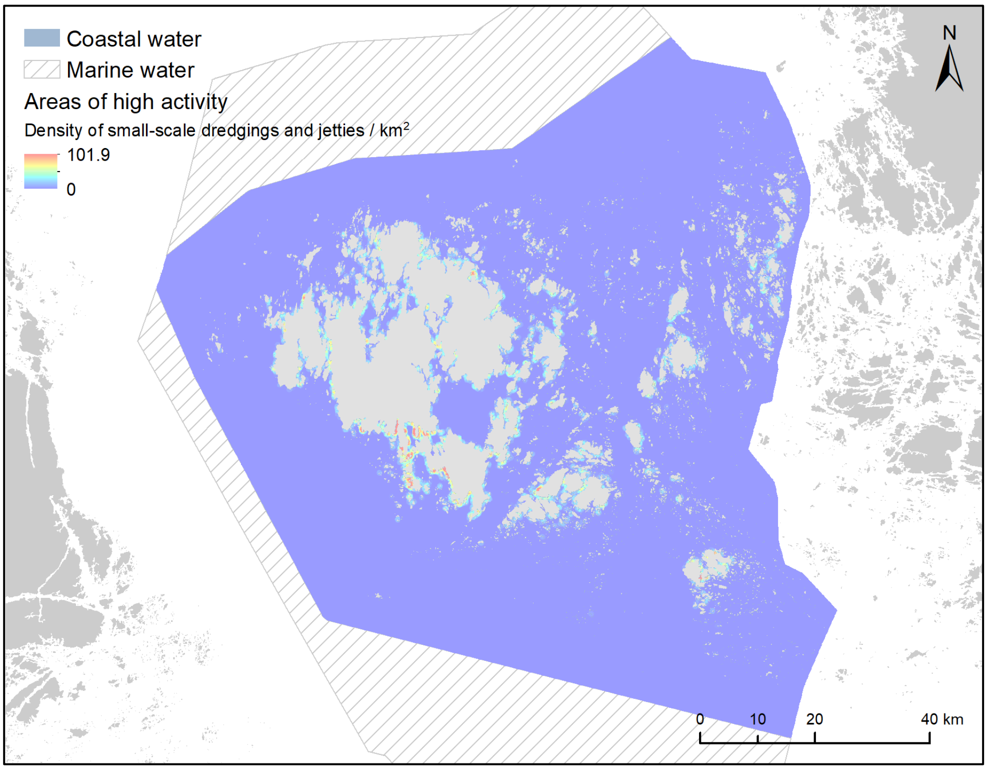
Description: Data describes areas where the density of small-scale dredging and jetties is high (a lot of human activity). Occurrences of jetties and dredged areas was chosen from Metsähallitus' point data (based on interpretations of aerial photography), and the density of these per km^2 was calculated by using a circle with a 500 m radius (point density).

Data format and resolution: Point data that was changed to a raster during the density analysis.

Data collection (time period/method): Interpretation of the aerial photographs was done during 2019–2021, density analysis during 2021.

Data quality: Good for original data, based on aerial photographs.

Data owner: Metsähallitus (original point data).



Cables and pipelines

Environmental effects: Disturbances, especially during maintenance.

Buffer size: 100 m.

Treatment in Marxan analysis: Part of the cost layer → areas with cables and pipes have reduced chances of being proposed as part of the protected are network.

Data source: Finnish Transportation and Communications Agency.

Description: Underwater cables and pipes with a 100 m buffer zone.

Data format and resolution: Polygon.

Data collection (time period/method): 2021.

Data quality: Good.

Data owner: Finnish Transportation and Communications Agency.

Data available upon request from the Finnish Transportation and Communications Agency.

Planned areas for offshore wind farms

Environmental effects: Disturbances on the seabed during the construction phase, effects on bird fauna and effects from different types of noise.

Treatment in Marxan analysis: Part of the cost layer → planned areas for offshore wind power have reduced chances of being proposed as part of the protected are network.

Buffer size:

Data source: The Government of Åland.

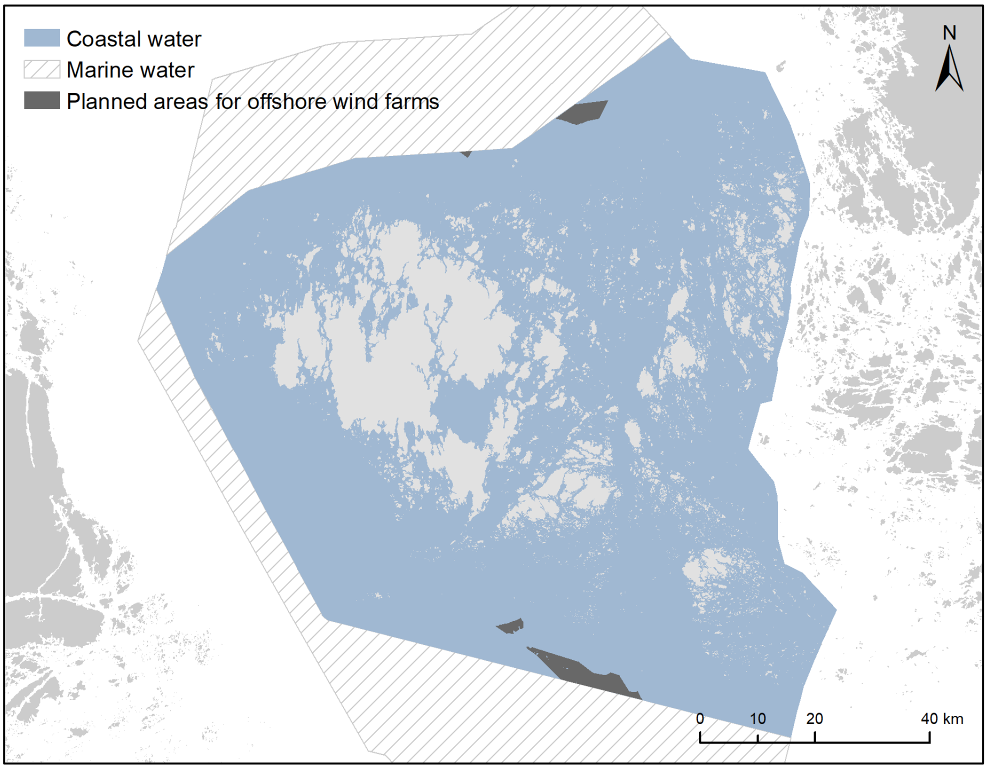
Description: Areas marked for potential expansion of offshore wind farming in Havsplanen (adopted 2021), and which have currently been assessed to be suitable for offshore wind power. The intended wind power areas are mainly located outside coastal waters.

Data format and resolution: Polygon.

Data collection (time period/method): 2021.

Data quality: Good.

Data owner: The Government of Åland.



Intensity of small boat traffic

Environmental effects: Traffic, emissions, noise, erosion, and mechanical disturbances.

Buffer size:

Treatment in Marxan analysis: Part of the cost layer → areas with intense small boat traffic have reduced chances of being proposed as part of the protected are network.

Data source: HELCOM.

Description: The model describes fuel consumption for small boats. It was created within the SHEBA project (Sustainable shipping and environment of the Baltic Sea). It is based on the presence of guest ports and marinas, as well as AIS data and fuel sales statistics. The model also takes into account the sea depth (greater effects in shallow areas). Index values vary between 0 and 1 (in the Baltic Sea, in the Åland Islands only up to 0.83).

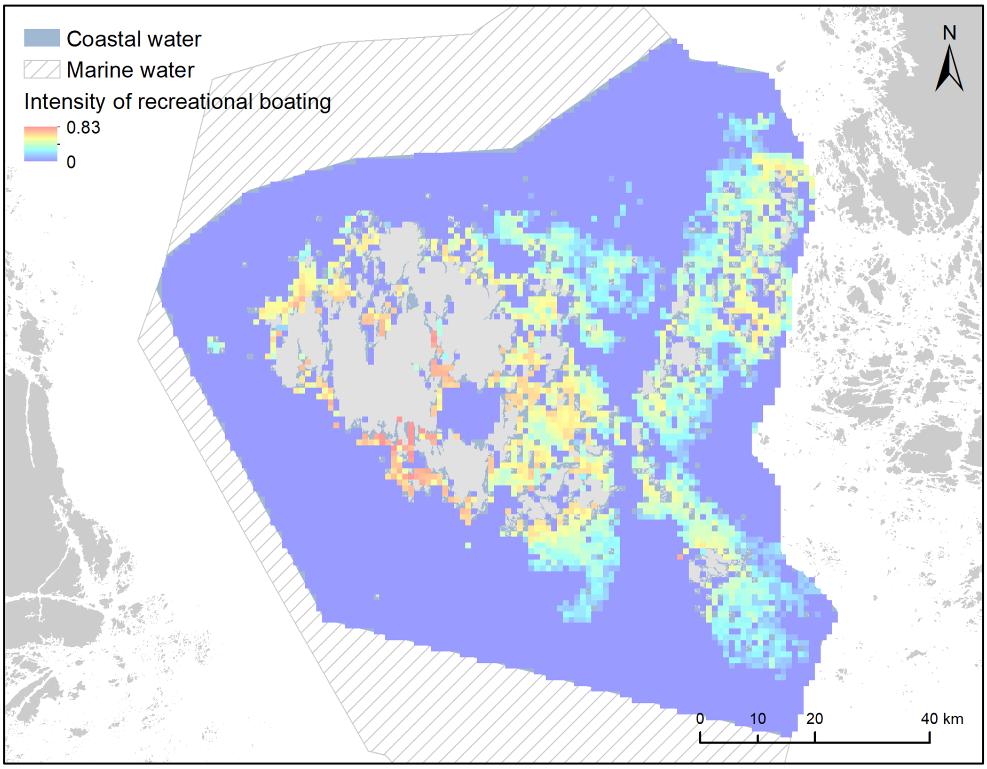
Data format and resolution: Raster (1 km x 1 km).

Data collection (time period/method): Model was updated 2018.

Data quality: Relatively poor due to rough resolution. Results in that the model excludes many inner bay and areas close to the coast.

Data owner: HELCOM, SHEBA project.

Other: Additional information available at: https://www.sheba-project.eu/ and original data available at: https://maps.helcom.fi/website/mapservice/ .



Guest harbours

Environmental effects: Traffic, erosion, sewage, and noise.

Buffer size: 500 m.

Data source: www.vierassatamat.fi

Treatment in Marxan analysis: Locked out → the areas will not be included in scenarios for the protected area network.

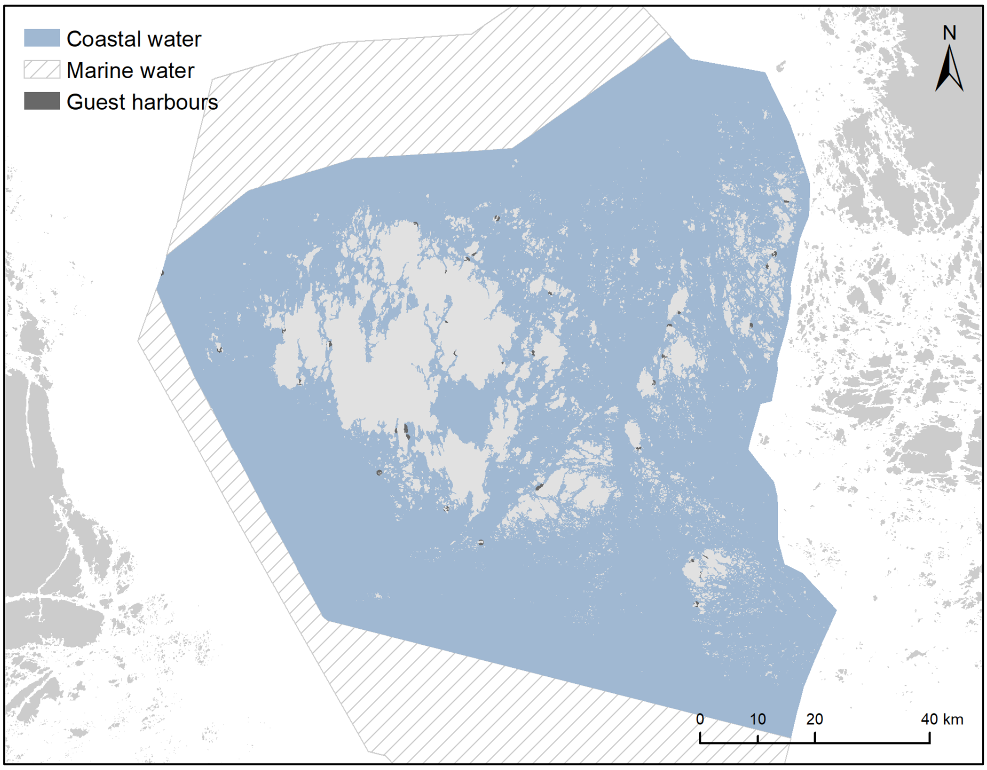
Description: Location for all public guest ports. A 500 m buffer has been added around the guest ports to include the areas affected by the ports.

Data format and resolution: Point data.

Data collection (time period/method): 2021.

Data quality: Good.

Data owner: Suomen vierassatamat Oy.



Public beaches

Environmental effects: Small boat traffic, mechanical disturbances, and noise.

Buffer size: 250 m.

Treatment in Marxan analysis: Locked out → the areas will not be included in scenarios for the protected area network.

Data source: The Åland Environmental and Health Protection Authority and the website https://www.aland.com/artikel/hitta-alla-badstrander-pa-aland .

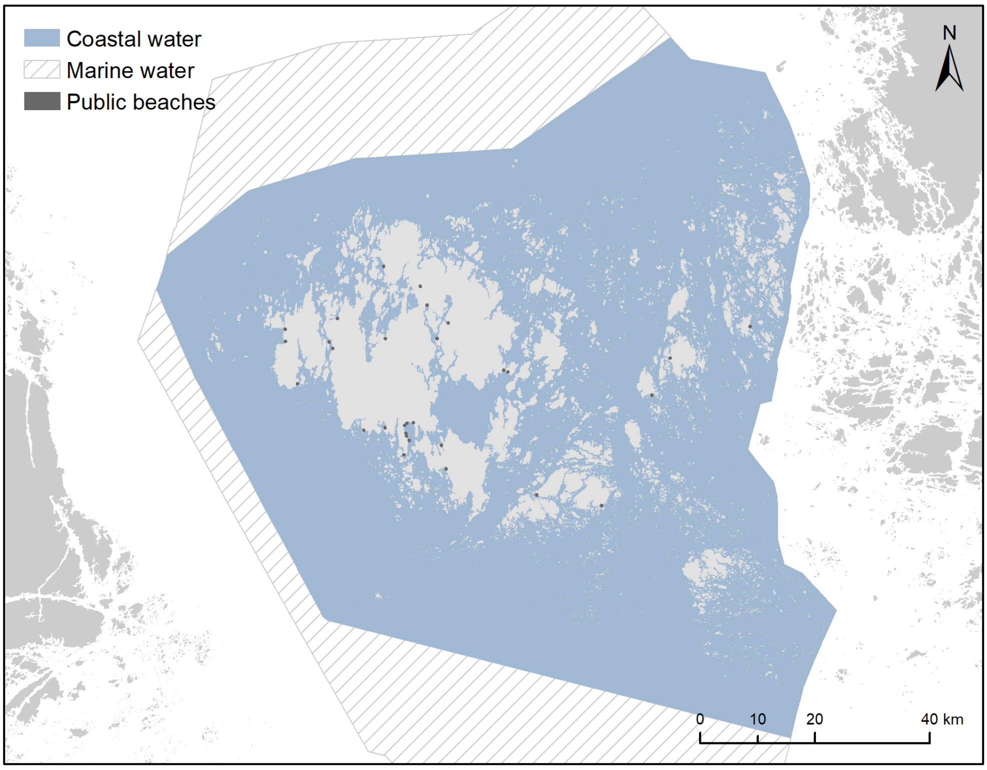
Description: Locations for beaches, large and small public beaches are included. Buffer zone was set as 250 m to cover areas likely to be affected by the public beaches.

Data format and resolution: Polygon (point data with buffer).

Data collection (time period/method): 2021.

Data quality: Good, but some beaches may be missing.

Data owner: The Åland Environmental and Health Protection Authority (larger beaches)



Areas for hunting and fishing

Environmental effects: Disturbances and mortality for seabirds and fish, and increased traffic.

Buffer size:

Treatment in Marxan analysis: Part of the cost layer → areas for hunting and fishing have reduced chances of being proposed as part of the protected are network.

Data source: The Government of Åland.

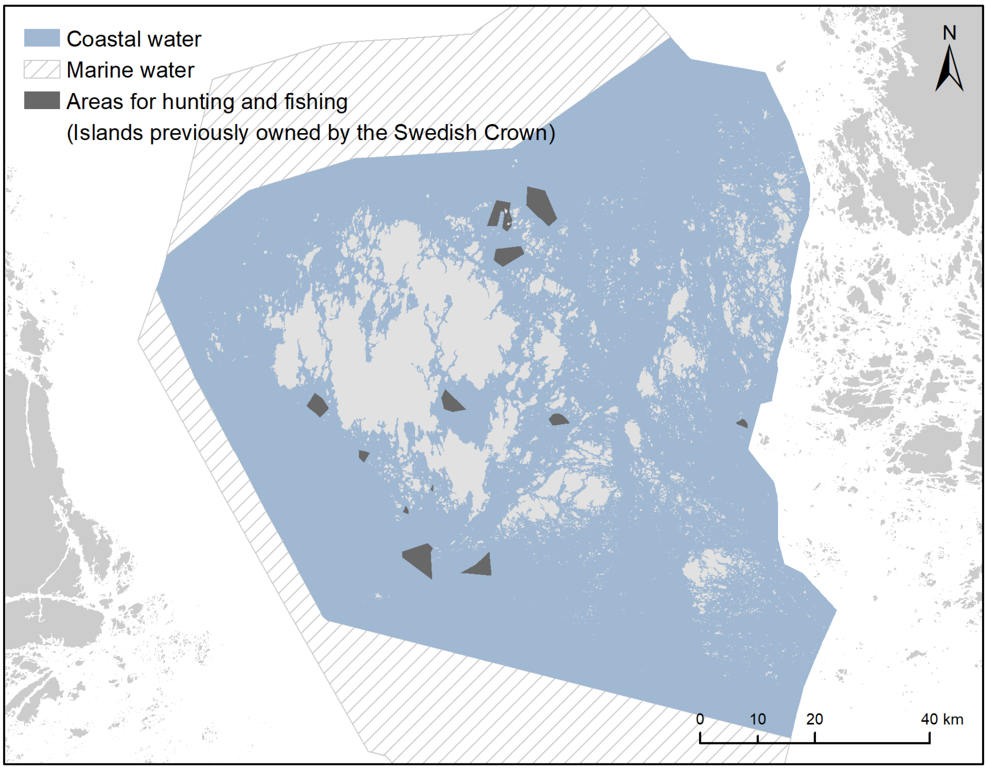
Description: Areas that used to belong to the crown (*holmar av kronoriatur*) where hunting and fishing can still be practiced by the public. In western Sundskären in Lemland and Harun others in Brändö only hunting is allowed.

Data format and resolution: Polygon.

Data collection (time period/method):

Data quality: Good.

Data owner: The Government of Åland.



Marine protected areas

Motivation: The goal with the analysis is to get concrete proposals for new protected areas. As the existing protected areas are "locked in" in the analysis, the potential new areas build on the existing protected area network. If only important areas of high ecological value are to be identified (alternative starting point for selecting new protected areas), it is not necessary to include the existing marine nature protected areas.

Data source: The Government of Åland.

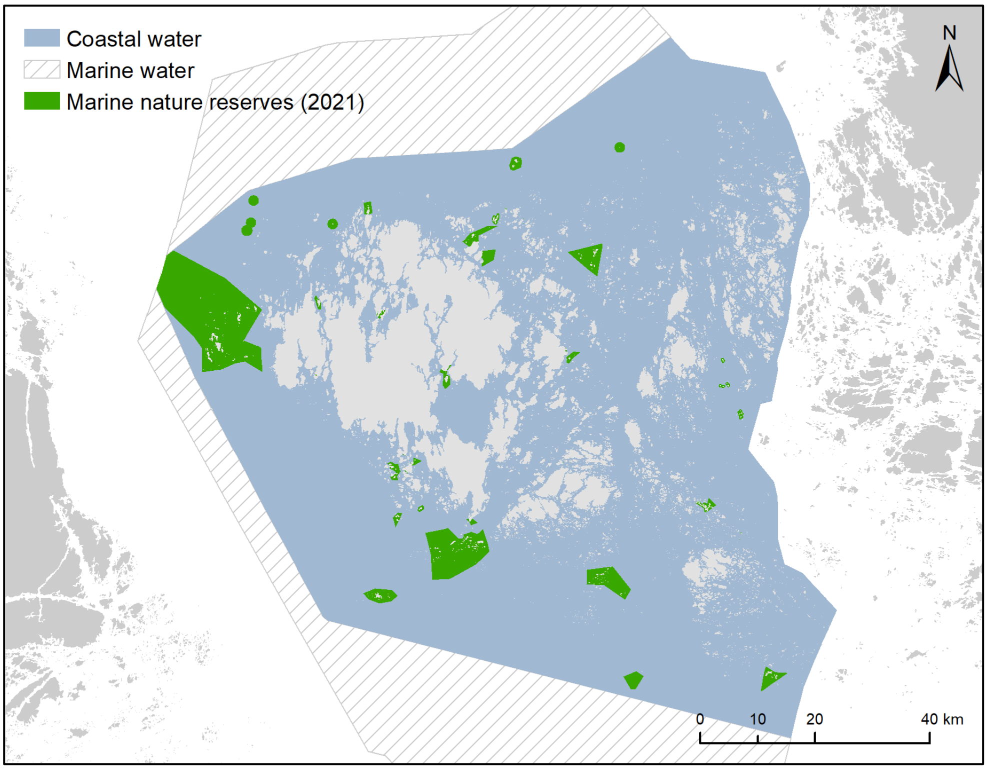
Description: Data includes marine protected areas, both Natura 2000 area and nature reserves (*naturreservat*).

Data format and resolution: Polygon.

Data collection (time period/method): 2021.

Data quality: Good.

Data owner: The Government of Åland.



Marine areas managed by the Government of Åland

Motivation: By including areas that are managed by the Government of Åland, potentially new protected areas are more easily found within the Governments area than within privately owned waters. Areas of high ecological value will continue to be identified within private areas as well, but the probability that they will be proposed as part of the protected area network is lower.

Data source: The Government of Åland.

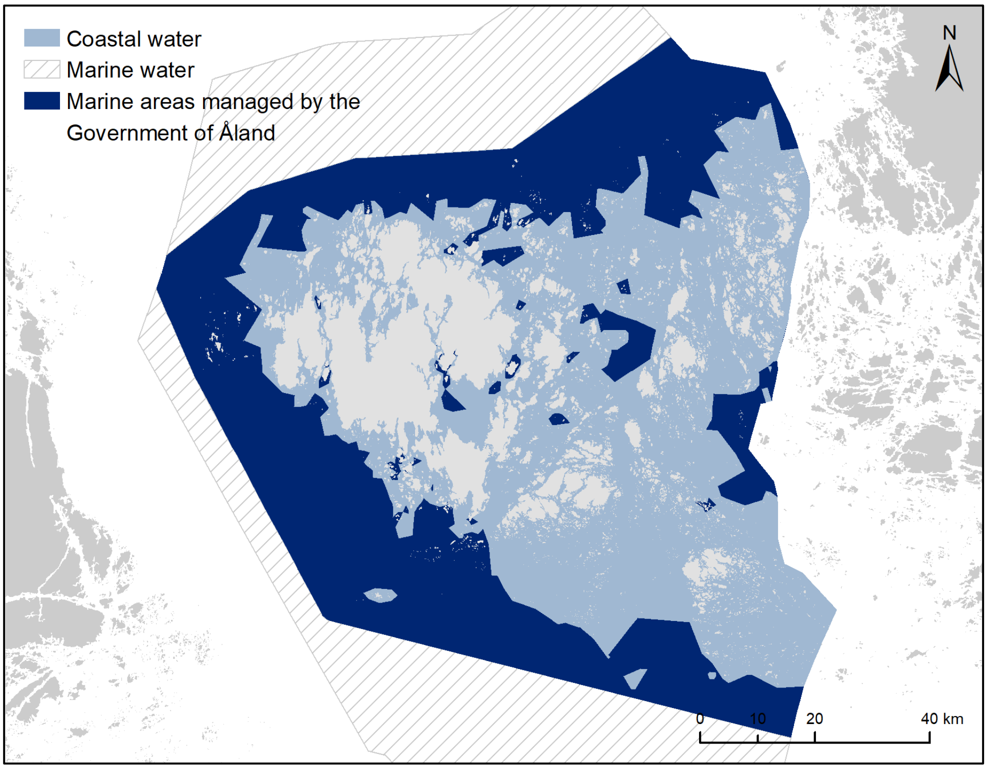
Description: Areas managed by the Government of Åland. Includes both properties (waters owned by the Government) and publicly owned waters.

Data format and resolution: Polygon.

Data collection (time period/method): 2021.

Data quality: Good.

Data owner: The Government of Åland.



De senaste Forskningsrapporterna från Husö biologiska station:

No 148 2017, HUHTALA, H-P. Grundkartering och bedömning av vattentäktspotential i fem åländska sjöar. (*Survey and assessment of water extraction potential of five lakes in the Åland Islands).*
No 149 2018, RAMSTEDT, R. Bedömning av faktorer som påverkar abborrens (*Perca fluviatilis*) tillväxt och födoval I Marsund/Bovik och Kumlinge I Ålands skärgård. (*An assessment of factors* affecting the growth *and diet of Eurasian perch (Perca fluviatilis) in Marsund/Bovik and Kumlinge in the archipelago of the Åland islands).*
No 150 2018, BLOMQVIST, S. & F. GRIPENBERG. Vandringsleder för fisk på Åland *(Fish migratory paths in the Åland Islands).*
No 151 2018, HUHTALA, H-P. Bedömning av mänsklig påverkan i och i närheten av, samt klassificering och utvärdering av grunda havsvikars undervattensväxtlighet på Åland. (*Estimation of anthropogenic impact within and near shallow coastal bays and classification and evaluation of their underwater vegetation in the Åland Islands).*
No 152 2018, Engström, L. Kartering och habitatklassificering av undervattensmiljön i Lumparn. *(Mapping and habitat classification of the underwater environment in Lumparn).*
No 153 2019, RINNE, H., BJÖRKLUND, C., HÄMÄLÄINEN, J., HÄGGBLOM, M. & S. SALOVIUS-LAURÉN. Mapping Marine Natura 2000 habitats in Åland – Final report. *(Kartering av marina Natura 2000 habitat på Åland – Slutrapport).*
No 154 2020, BLOMQVIST, S. En översiktlig inventering av fyra potentiella lekvikar i Ålands skärgård. *(An overview of four potential spawning areas in the archipelago of the Åland islands).*
No 155 2020, VALKONEN, L. Kartering och habitatklassificering av undervattensmiljön i Geta. *(Mapping and habitat classification of the underwater environment in Geta).*
No 156 2020, STÅHL, P. Grundkartering och bedömning av vattentäktspotential i fem åländska sjöar. *(Survey and assessment of water extraction potential of five lakes in the Åland Islands).*
No 157 2021, FINNBÄCK, L. Kartering av fisksamhällen och förekomst av plattfiskar och näbbgädda (*Belone belone*) på exponerade stränder på Åland. *(Mapping of fish communities and the occurrence of flatfish and garpike (Belone belone) on exposed beaches in the Åland Islands)*
No 158 2021, WECKSTRÖM, K. & J. WIKSTRÖM. Djuputbredning av makrofyter på mjukbottnar i en skärgårdsgradient. *(The depth distribution of macrophytes on soft bottoms in an archipelago gradient)*
No 159 2021, WIKSTRÖM, J. & K. WECKSTRÖM. Inverkan av vägbankar på vattenmiljön med fokus på hydrografi, bottenfauna och makrofyter – uppföljande studier. *(The effects of road embankments on the water environment, with focus on hydrography, zoobenthos and macrophytes – a follow up study).*
No 160 2021, JAKAUS, V. Påverkan av mindre muddringar på förekomsten och sammansättningen av fiskyngel. *(The impact of small-scale dredging on the abundance and diversity of juvenile fish).*
No 161 2021, FINNBÄCK, L. Förslag på nya övervakningspunkter av makrofyter i Ålands ytterskärgård baserat på karteringsdata. *(Suggestions for new sites for monitoring macrophytes in the outer archipelago of Åland Islands based on mapping data).*
No 162 2022, RANCKEN, E. Småskaliga muddringars effekter på förekomsten och sammansättningen av vattenvegetationen. (*The effect of small-scale dredging on the presence and composition of macrophytes).*
No 163 2022, PYKÄRI, J. Bottenfaunan i Ålands skärgård 2022. (*The benthic fauna of the Åland archipelago 2022)*
No 164 2022, ÖSTERLUND, J. Uppföljningsstudie av gösens (Sander lucioperca (L.)) och de allmänna fiskbeståndens förekomst i Ålands inre skärgård. (*Follow up study on the occurrence of pikeperch (Sander lucioperca (L.)) and the common fish stocks in the inner archipelago of Åland).*
No 165 2023, IKONEN, A. Vattenvegetationen i grunda havsvikar, ett återbesök till havsvikar karterade 2002. (*The water vegetation in shallow bays, a revisit to shallow bays mapped in 2002).*
No 166 2023, LILJEDAHL, A. Kartering av undervattensvegetationen i Fladan och Estviken, Åland *(Mapping of the underwater vegetation in Fladan and Estviken, Åland)*
No 167 2024, IKONEN, A. Vegetationskartering av Mönsfladan och Onsviken - ett återbesök. *(Vegetation mapping of Mönsfladan and Onsviken - a revisit)*
No 168 2024, PETTERSEN, S. Förändringar i fisksamhället längs en skärgårdsgradient på NV Åland - en uppföljningsstudie. *(Changes in the structure of the fish communities along an Archipelago gradient in the NW Åland - a follow-up study)*
No 169 2024, WECKSTRÖM, K., RINNE, H., HÄGGBLOM, M. & S. SALOVIUS-LAURÉN. Marine inventories to support ecosystem-based management and the expansion of the MPA network in the Åland Islands – Final report of the ÅlandSeaMap project (2019–2023) (*Marina inventeringar för att stöda ekosystembaserad förvaltning och utvecklandet av marina skyddsområdesnätverket på Åland – Slutrapport för ÅlandSeaMap projektet (2019–2023)*

ISBN 978-952-12-4375-2

ISSN 2954-1468

2024