Mapping of Natura 2000 Annex 1 Habitats in Sweden

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Introduction

General characteristics of the BALANCE pilot area 3

The Archipelago Sea is a shallow sea area with over 40 000 rocky islands and islets (larger than ½ ha), between the large Åland islands in the west and the Finnish mainland and the Hanko peninsula in the east. In the north lies the Bothnian Sea and in the south the Northern Baltic Sea Proper. The environment of the archipelago is the result of a continuous land uplift; small islets have been transformed into big islands and finally to parts of the growing mainland. The water depth, exposure of the shore, sea bottom type and many other environmental factors vary even within small areas. Together with the strongly meandering shoreline this results in an archipelago of extremely varied natural environments.

Even though the area is quite shallow (average depth about 23 m), the bottom topology is mostly steep and even in the inner parts of the archipelago there are deeps that reach over 90 meters. The deepest areas in the Archipelago Sea are over 100 meters deep and the highest islands are about 40 meters above the sea level. While most islands are rocky, some are of glacio-fluvial origin: eskers, clay deposits, potholes, end moraines and ice-marginal formations. Because of the deep channels between the islands, most of the water exchange between the Bothnian Sea and the Baltic Proper occurs through the Archipelago Sea. The main current in the Archipelago Sea runs from southeast to north, from the Gulf of Finland to the Bothnian Bay. The Archipelago Sea is essentially tide-less, but irregular water level fluctuations of up to 1 m occur due to winds and atmospheric pressure gradients. The shallowness and the rugged seafloor topography diminish water exchange between the archipelago and the open sea areas (Mälkki et al., 1979). Sea bottom oxygen deficiency is common in the areas of poor bottom water exchange (Virtasalo et al. 2005). The sedimentation pattern is very complicated due to the glacio-isostatic land uplift (Mäkinen & Saaranen 1998), resulting continuous change between the areas of accumulation, transportation and erosion. The seafloor is a patchy combination of various substrates like bedrock, moraine formations (till), gravel and sand, clays of different ages (hard and soft) as well as very soft mud (Häkkinen, 1990).

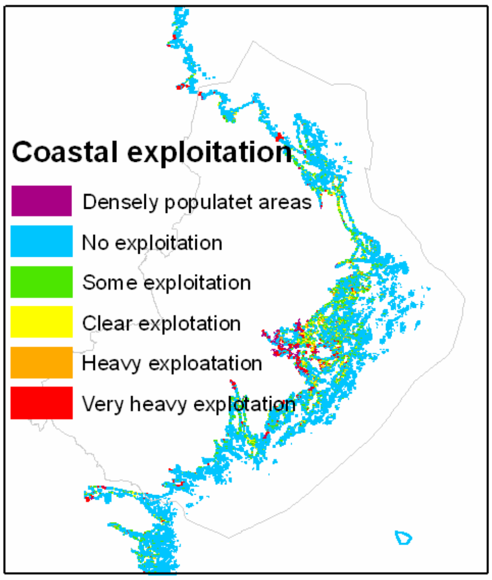
The area of the Arhipelago Sea can be divided into certain archipelago zones (*coastal zone*, *inner archipelago*, *outer archipelago* and *open sea zone*) based on the exposure, shore type and vegetation. The innermost *coastal zone* is comprised mostly of large islands covered by forests (coniferous to mixed forests with pine, fir, birch and alder) and sheltered, narrow water passages. Much of the shoreline is vegetated with reeds. In the *inner archipelago*, the proportion of water-covered area grows, but is still smaller than the proportion of land. Islands continue to have forest cover close to the shoreline and sheltered bays are lined by reeds.In the *outer archipelago*, there are fewer islands and they are smaller in size. Water areas are dominant and islands form small groups separated by open water. Small islands are without trees, even though there are still many larger forested islands. The shores are rocky and without vegetation. Further out, in the *open sea zone*, there are only small skerries and sand ridges without any trees.

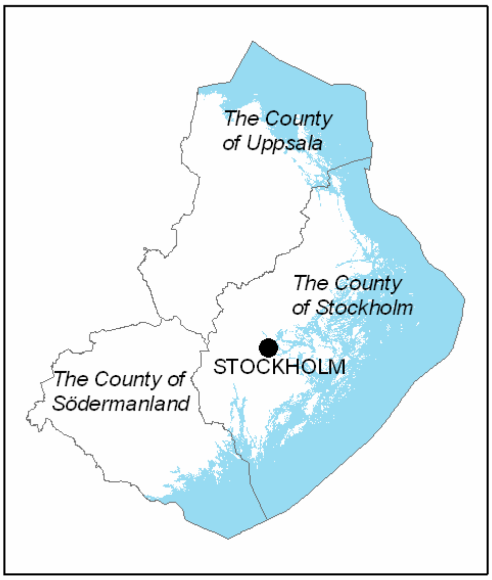
Changes in the ice conditions are depending on the archipelago zone rather than on the latitude. Ice covers the inner and middle parts of the Sea practically every winter from January to April. Only during colder winters the outer archipelago is covered by strong ice (late January - March). The average number of ice days in the outer regions is 20-60, in the inner archipelago 80-100 and in the coastal zone 100-120.

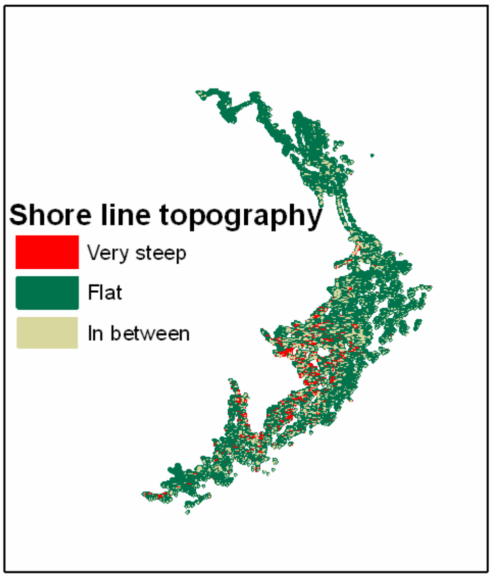
The archipelago area with tens of thousands of islands is topologically and geologically very heterogeneous, and the habitats are therefore usually small, with a very complex mix of soft and hard substrates. The vegetation of the steep rocky shores is zonal. A border of filamentous algae covers the first upper zone closest to the surface followed by *Fucus vesiculosus* –beds down to 4-6 meters. However, *F. vesiculosus* has disappeared from some areas due to eutrophication, and has been replaced by filamentous algae (e.g. *Cladophora glomerata*). Below this zone filamentous macroalgae, mainly *Furcellaria lumbricalis*, *Sphacelaria arctica* and *Phyllophora pseudoceranoides*, dominate down to 15-20 m. *Hildenbrandia rubra* and *Pseudolithoderma* can grow even below 20 meters. In areas of clear water, vascular plants (such as *Potamogeton perfoliatus* and *Zannichellia major*) are often encountered also below the *F. vesiculosus* –zone. Fields of *Zostera marina* can be found here and there in the sandy areas of the outer archipelago. The blue mussel *Mytilus edulis* covers vegetation free rocky bottoms. Typical fish species are the Baltic herring (*Clupea harengus*), pike *(Esox lucius*), whitefish (*Coregonidae*), perch (*Perca fluviatilis*) and flounder (*Platichthys flesus*). Endangered species found in the Archipelago Sea include White-tailed eagle (*Haliaeetus albicilla*), Caspian tern (*Sterna caspia*), Greater scaup (*Aythya marila*) and Ringed seal (*Phoca hispida*).

Background on the area/sites

The Swedish part of BALANCE pilot area 3 covers the vast archipelago area in the counties of Södermanland, Stockholm and Uppsala (figure 1). The archipelago area is about 300 km long and up to 100 km wide and covers 14 500 km^2 of sea. The Swedish archipelago is separated from the Åland archipelago by a narrow strait, about 10 km wide and 50 m deep at the shallowest part. North of the sill the water is mainly influenced by freshwater discharges from both the Bothnian Bay and Bothnian Sea, while south of the sill the water is more influenced by the conditions in the Baltic Sea Proper (figure 2).







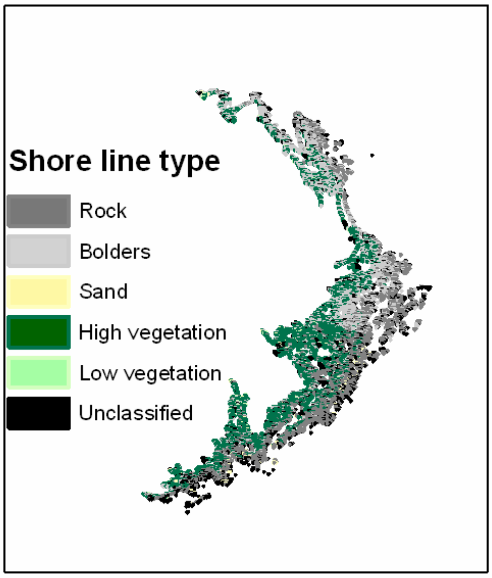


Figure 1. The city of Stockholm has a central role in the pressure from physical exploitation as being the most densely populated part in the study area. The exploitation along the coast is gradually decreasing in a circle from Stockholm. In the County of Stockholm 32% of the shore line is exploited. In the County of Uppland the exploitation it is somewhat higher (16% of the shore line) than in the county of Södermanland (10 % of the shore line). Outside densely populated areas the exploitation is dominated by summer cottages. They are strongly associated with the number of boats and local eutrophication. The outer archipelago has no or very little exploitation (Smedberg 2006).

The topography of the study area is steeper in the south and more flat in the north. The coastal zone and inner archipelago are dominated by moraine coasts and are forested. Tree cover declines towards the outer archipelago and the proportion of rocky and stony shores increases. The southern part has a larger proportion of rocky shores, while the exposed areas in the north have a higher proportion of stone and shingle shores. Sand is not common but more frequent in the southern part due to glaciofluvial deposits. Fine sediments are present in small sheltered areas along the coast and are more frequent in the coastal zone and the inner archipelago.

The land rise is 4-6 mm per year, and is continuously changing the landscape, turning shallow sheltered inlets into lakes, eventually cutting them off from the sea. The succession in these bays and inlets allows for highly dynamic and heterogeneous environments, resulting in high biodiversity. The northern part of the study area is topographically more flat and therefore more influenced by the land upheaval.

There are strong salinity gradients in the pilot area, both in a north-south direction as well as from the inner archipelago to the outer parts. The salinity in the outer archipelago varies from around 5 psu in the northern parts to around 7 in the south. In the innermost bays and fladas the salinity may get down to 3-4 psu or sometimes even further, depending on inflow of freshwater. Since many marine as well as freshwater organisms have their distribution limits at these salinities, this gradient, together with a similar gradient in wave exposure largely shapes the biota.

The maximum depth for vegetation differs depending on light attenuation, ranging from around 2 to 10 m, with the shallowest maximum depth in the inner parts. This is mainly influenced by nutrient runoff from land, which has a strong effect on the biota. This becomes increasingly evident in more densely populated parts of the archipelago, e.g. the Stockholm area.

Water temperature and ice cover also varies between the inner and outer parts of the archipelago. The inner parts warm up earlier than the seaward areas, and cool down earlier in the autumn. Since fish are very sensitive to temperature, the dynamics of temperature variations has a large influence on fish migrations within the area. Many coastal fish species use more shallow, sheltered and, thus warmer parts of the archipelago as nursery areas.

Table 1. Depth areas from Nautical charts in the Swedish part of pilot area 3 (Swedish Environmental protection Agency 2006).

Depth	**Area (km^2)**	**% of total area**
0-3 m	680	5%
3-20 m	2 480	17%
20-50 m	4 920	34%
> 50 m	4 690	32%
Restricted information of depth (6-200 m)	1 760	12%
Sum	**14 530**	**100%**

Table 2. Wave exposure in shallow areas in the Swedish part of pilot area 3. (Swedish Environmental protection Agency 2006).

Wave exposure	**Within depth 0-3 m (%)**	**Within depth 3-20 m (%)**
Ultra/extremely sheltered	23%	3%
Very sheltered	22%	13%
Sheltered	31%	28%
Moderately exposed	19%	20%
Exposed/very exposed	4%	32%

Table 3. Wave exposure along the shore line and the proportion of unexploited shores within each exposure class (the Swedish part of pilot area 3) (Smedberg 2006).

Wave exposure	**Shore line per wave exposure class (%)**	**Unexploited shore line within each wave exposure class (%)**
Ultra/extremely sheltered	35%	61%
Very sheltered	26%	65%
Sheltered	27%	86%
Moderately exposed	10%	96%
Exposed/very exposed	1%	98%
Sum	**100%**	**73%**

Background on relevant habitat mapping and modelling

The EU Habitat Directive is a Community legislative instrument in the field of nature conservation that establishes a common framework for the conservation of wild animal and plant species and natural habitats of Community importance. It provides for the creation of a network of special areas of conservation, called Natura 2000, to "maintain and restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest". Annex I lists today 218 European natural habitat types, including 71 priority (i.e. habitat types in danger of disappearance and whose natural range mainly falls within the territory of the European Union).

In the BALANCE pilot area 3 the following types of the EU Habitat Directive Annex 1 habitats can be found:
Type 1110 – Sublittoral sandbanks
Type 1130 - Estuaries
Type 1150 - Coastal lagoons
Type 1160 - Large shallow inlets and bays
Type 1170 - Reefs
Type 1610 - Baltic esker islands
Type 1620 - Boreal Baltic islets and small islands
Type 1650 - Boreal Baltic narrow inlets

The first attempt to map the spatial distribution of the EU Habitat Directive habitats in Sweden were done in 2003 (Axelsson 2003 and Cato et al 2003). The aim of the mapping effort at that point was to estimate the total distribution of the habitats per county and region, but not to define the exact boundary or location of each habitat. The later was expected to be done by each county administrative board. Although, the evaluation of the mapped habitats addressed how the analysis could be improved and what data that would require. The mapping efforts then changed to gather and analyse data describing physical factors in the marine environment. The purpose of this mapping was to compile datasets that covered the territorial waters, were comparable over regional boarders and could be used by the regional authorities to map the habitat distributions. In the report a first attempt to use the data to perform habitat modelling is presented. The project was reported in 2006 (Swedish Environmental Protection Agency 2006). Since 2003 several projects that focused on mapping of the shore line; coastal type (Philipsson & Lindell 2003 and Liljeberg & Wennberg 2006), Steepness of the shore line (Swedish Environmental Protection Agency 2006) and an indicator of physical exploitation of the coastline (Smedberg 2006).

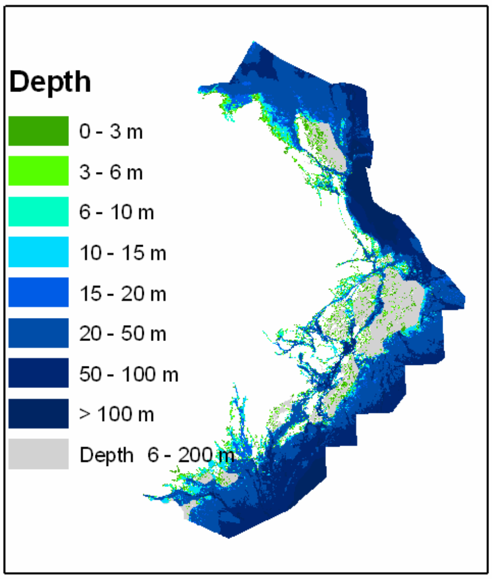
Aims
The aim of the current modelling exercise was to create maps on the spatial distribution of the EU Habitat Directive Annex 1 habitats that can be found in the BALANCE pilot area 3 that are comparable over the nation boarder between Sweden and Finland.

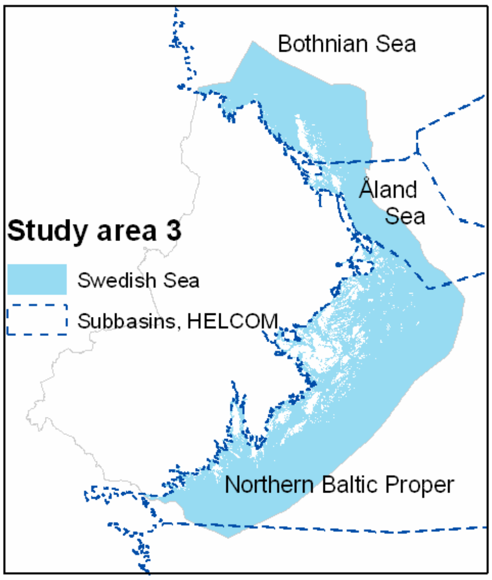
Material & Methods

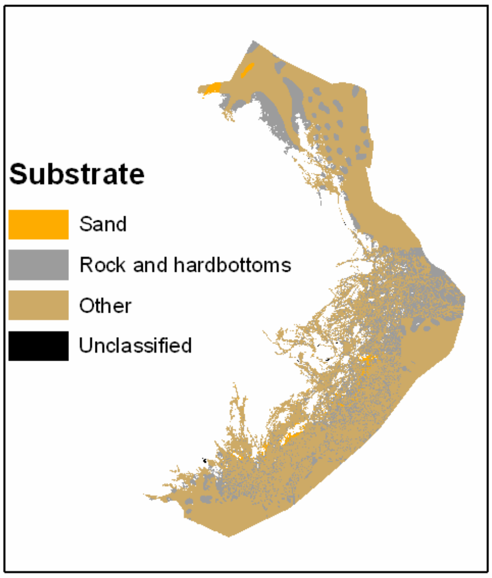
Variables/Predictors
In order to predict the EU Habitat Directive Annex 1 habitats the following layers were used:

- Land, lakes and sea (national geographic data, scale 1: 10 000 from two generations; up to 1996 and 1997-2006)
- Land, lakes and sea (national geographic data, scale 1: 50 000)
- Freshwater lakes and rivers (national geographic data, scale 1:250 000)
- Elevation curves (national geographic data, scale 1: 50 000)
- Depth curves and surfaces (nautical charts, scale 1: 50 000)
- Surfs and sub surface rocks (nautical charts, scale 1: 50 000)
- Terrain model based on the depth from nautical charts (TIN and 25 m raster)
- Wave exposure (Isæus 2004 and Swedish Environmental Protection Agency 2006)
- Bottom substrate (marine geological maps, scale 1: 50 000-1: 150 0000 (Cato et al, 2003))
- Soil type from geological maps (scale 1: 100 000)
- Forest cover (from the national product of the CORINE-project)
- Lagoons and estuaries (from the national product of the CORINE-project)
- Exploitation index along the coastline (Smedberg 2006)

The methods are based on tools in *ArcGIS* with the *Spatial analyst* extension and the model maker in *ERDAS Imagine*. The selection criteria for each habitat type are described below together with the definition of the habitats. The resulting layers are presence maps of the directive habitat in the BALANCE pilot area 3 (vector format).







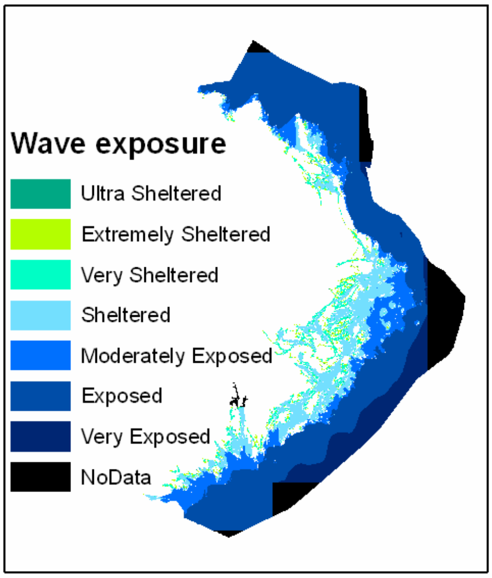


Figure 2. The Swedish part of pilot area 3 reaches over thre subbasins according to HELCOM and covers 14 500 km^2 of Sea.

The basic layers used to preform the GIS-analysis were national maps that separated land, lakes and sea (the base in all figures), depth from nautical charts, bottom substrate from marine geological maps and a classification of the wave exposure.

Depth data were raster layers based on the depth surfaces and a TIN that were rasterized resulution 25x 25 m). Quite large areas have no depth information (gray). In these areas the depth information is classified by the military defence.

The information from the marine geological map has different resolutions in the study area. The northern part only has very general interpolations of what substrates that occurs. The more detailed geological map of Stockholm that exists has been used to evaluate the results (not in figure).

The wave exposure is the general exposure on the coast (m^3/s) based on fetch and data from three vind stations (Isæus 2004). The continous raster has been classified to seven classes that correlate to the EUNIS classification and the presence of macrophytes (Swedish

Descriptions of Habitats

Type 1110 Sublittoral sandbanks

Sandbanks are elevated, elongated, rounded or irregular topographic features, permanently submerged and predominantly surrounded by deeper water. They consist mainly of sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present on a sandbank. Banks where sandy sediments occur in a layer over hard substrata are classed as sandbanks if the associated biota are dependent on the sand rather than on the underlying hard substrata. In the Swedish description a maximum depth is set to 30 meters.

Input data

- Bottom substrate information in vector format (Cato et al, 2003)

GIS selection criteria

Areas classified as sand and with a maximum depth of 30 meters.

Type 1130 Estuaries

Downstream part of a river valley, subject to the tide and extending from the limit of brackish waters. River estuaries are coastal inlets where, unlike 'large shallow bays' there is generally a substantial freshwater influence. The mixing of freshwater and sea water and the reduced current flows in the shelter of the estuary lead to deposition of fine sediments, often forming extensive intertidal sand and mud flats. Where the tidal currents are faster than flood tides, most sediment deposits to form a delta at the mouth of the estuary. Baltic river mouths, considered as an estuary subtype, have brackish water and no tide, with large wetland vegetation (helophytic) and luxurious aquatic vegetation in shallow water areas. The Swedish description of the habitat defines that mean sea level outlines the estuary towards land and the annual average stream flow into the estuary is > 2 m^3/s.

Input data

- Land/sea from maps (scale 1: 50 000)
- Lakes and rivers
- Depth
- Estuaries from the national product of the CORINE-project.
- Satellite images and aerial photos

GIS selection criteria

Sheltered areas with a freshwater influx from a river with a watershed > 1 km^2. A maximum depth of 3 meters at the point of the freshwater influx is allowed. The estuary is limited by the shoreline. Up stream the boundary will be set at the point of the river mouth. The outer boundary towards the sea is placed at the sill, if there is one. In cases where no sill is present (or unmapped), the outer boundary will be set at the 3 meter depth curve; however, the estuaries are not allowed to extend beyond "sheltering land".

GIS analysis

Sheltered areas with a freshwater influx (from a river with a watershed > 1 km^2) are a product of the analyses of 'lagoons' and 'large shallow bays and inlets'. These areas of potential estuaries are visually classified with reference data from satellite images, aerial photos and maps. Objects were deselected if they are artificial pools, if the river moth is located on an exposed coast or in waters deeper than 3 m. The remaining objects are manually outlined in GIS. The outline towards the river is at the point of the river mouth. The outline towards the open sea is either at a threshold or the 3 meter depth curve but not further out than were “sheltering land” ceases. Boundaries were drawn with special emphasis on placing the inner border up stream and the outer border towards the sea correctly. Between these two borders the polygon was drawn well up onto the surrounding land and the polygon was then cut against the shoreline. All estuaries from the Swedish CORINE-product are included.

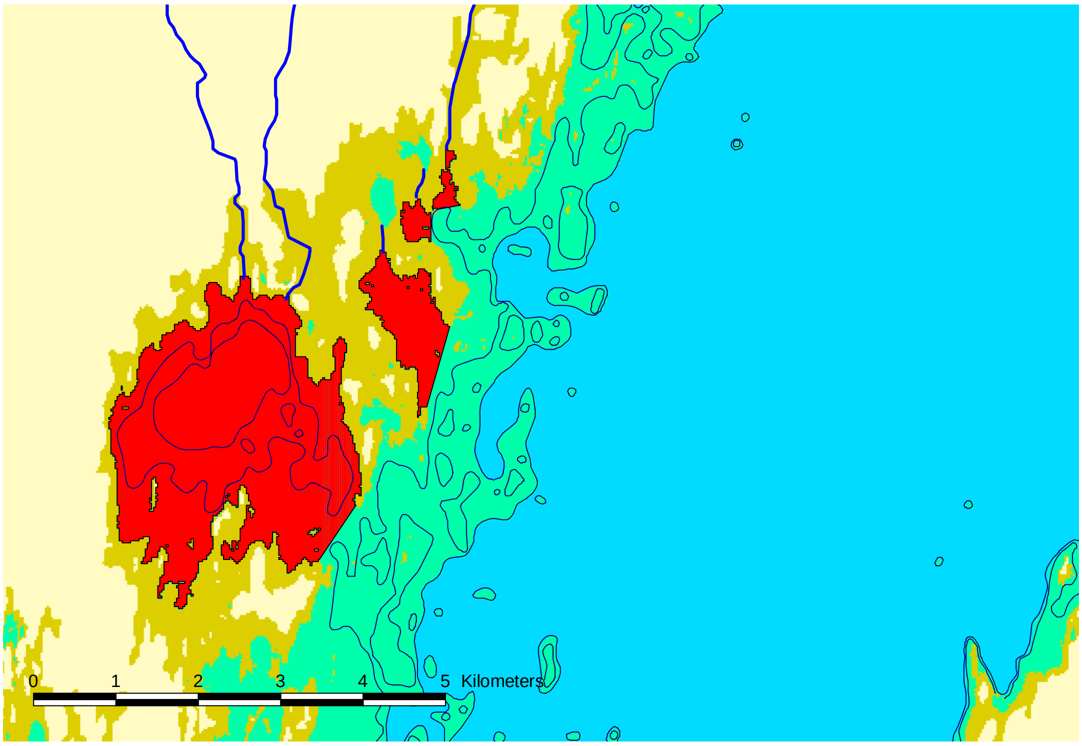


Figure 3. Three examples of how the outline of estuaries towards the sea was drawn. Estuaries in red, shallow water (0-6 m) in green, deeper water in blue, low land (0-5 m a.s.l.) in dark yellow and higher land in light yellow. The upper two estuaries are outlined at the 3 m depth curve, the estuary in the middle is outlined where “sheltering land” ceases and the lower estuary is outlined at a sill.

Type 1150 Coastal lagoons

Lagoons are expanses of shallow coastal salt water, of varying salinity and water volume, wholly or partially separated from the sea by sand banks or shingle, or, less frequently, by rocks. Salinity may vary from brackish water to hypersalinity depending on rainfall, evaporation, and through the addition of fresh sea water from storms, temporary flooding of the sea in winter or tidal change. Flads and gloes, considered a Baltic variety, are small, usually shallow, more or less delimited water bodies still connected to the sea or have been cut off from the sea very recently by land upheaval. Characterised by well-developed reedbeds and luxuriant submerged vegetation and having several morphological and botanical development stages in the process whereby sea becomes land. In the Swedish description Coastal lagoons are usually less than 4 meters depth and have limited water exchange with the sea. They do not have major freshwater influx from rivers or streams. They are usually smaller than 25 ha and are both smaller and more shallow than 1160. Rockpools are not lagoons.

Input data

- Land, lakes and sea
- Freshwater lakes and rivers
- Depth
- Elevation
- Lagoons from the national product of the CORINE-project
- Exploitation index of the coast line

GIS selection criteria

Gloes are lakes, wholly separated from the sea. They are less than 30 meters from the shoreline and located lower than 5 meter a.s.l.

Partially separated lagoons are inlets with a mouth towards the sea less than 30 meters wide. Maximum depth is 6 meters.

None of the lagoon-types have a freshwater influx (from a river with a watershed > 1 km^2), they are smaller than 30 hectares and they do not have physical exploitation along the shore line.

GIS analysis

Gloes: Lakes were selected from the older map (date from 1990-1996) maps. A buffered shoreline was produced by rasterizing the sea in 15 m pixels and expanding the surface one pixel up towards land. A selection was made from the lakes that intersect with the new shoreline, and that are located between the 5 meter elevation curve and 6 meter depth curve.

Partially separated lagoons: Land, sea and lakes were converted to raster with 15 m pixels. Land was expanded one pixel and the result was converted back to vector. Sea-areas that had become separated from the "larger" sea were identified, rasterised and expanded one pixel back to its original outline. Lagoons more shallow than 6 meter were selected.

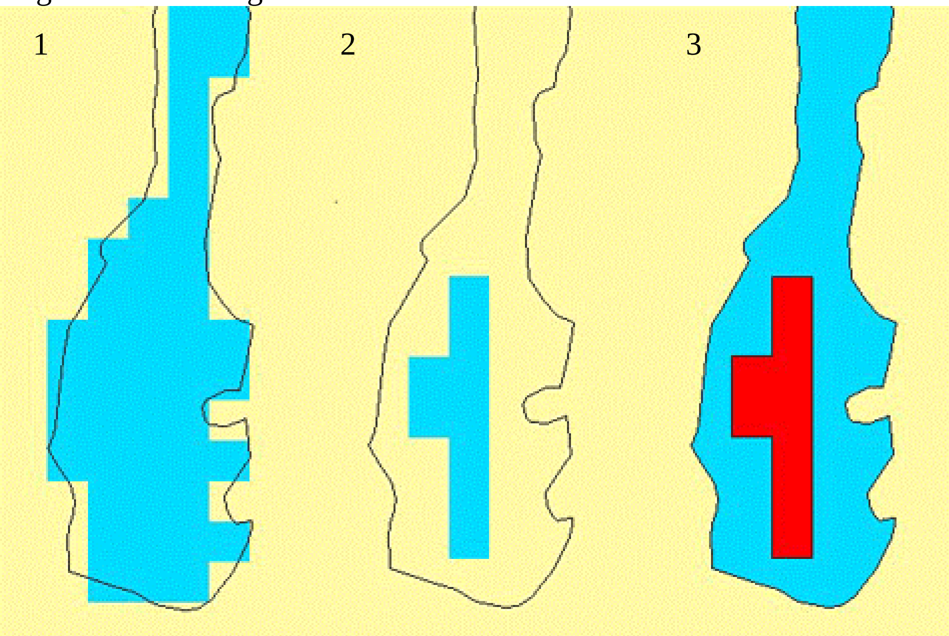


Figure 4. Lagoons partially separated from the sea were identified by a raster analysis. Land and sea were converted to a raster with 15 m pixel size (1), the land class (yellow) was expanded one pixel (2) and the remaining sea pixels converted to vector. Sea-objects that had become separated from the large sea were selected in the vector layer (3). These were converted back to raster and expanded one opixel back to their original size.

From the results two more selections were made; 1) the lagoons shall not intersect with a shoreline that is exploited and 2) they shall not be larger than 30 hectares. The operation is done on both the older and the newer maps (dates 1990-1996 and 2006). Lagoons that intersect the recent sea are saved as partially separated lagoons, those not intersecting with the recent sea are merged with the Gloes. All lagoons from GSD Marktäckedata (Swedish CORINE-product) were included.

Type 1160 Large shallow inlets and bays
Large indentations of the coast where, in contrast to estuaries, the influence of freshwater is generally limited. These shallow indentations are usually sheltered from wave action and contain a great diversity of sediments and substrates with a well developed zonation of bentic communities. These communities have generally a high biodiversity. The limit of shallow water are sometimes defined by the distribution of *Zosteretea* and *Potametea* associations. In the swdish description the limit of shallow water is defined by the depth distribution of vegetation and the habitat are usually larger than 25 ha.

Input data
- Land and sea from maps (scale 1: 50 000)
- Freshwater lakes and rivers
- Depth

GIS selection criteria
The area defined as large shallow inlets and bays has land within 1 km in 5 of 8 directions. They do not have a freshwater influx (from a river with a watershed > 1 km^2), and less than 20 % of their area are deeper than 15 meters. They are larger than 20 hectares.

GIS analysis
A raster with sea and land was created from maps (scale 1: 50 000). The sea pixels were analysed weather or not they are within 1 km to land in 5 of 8 directions (N, NE, E, SE, S, SW, W, NW). In this part of the analysis land areas smaller than 1 hectare were considered as sea as their sheltering effect were considered too small.

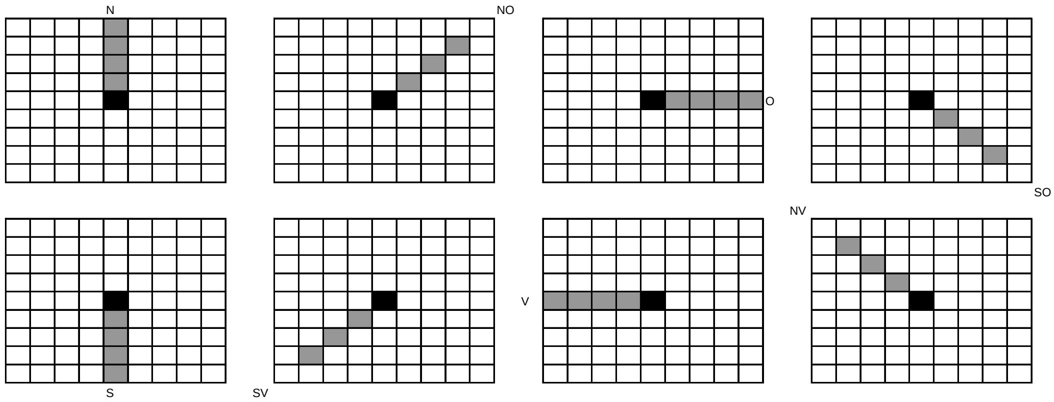


Figure 5. The figure shows a scetch of the the neighbourhood in the GIS-model that identifies sheltered sea. The neighbourhood (gray) around each pixel (black) is seasched eight times, once for each direction. The analysis returns the maximum value that equals 1 if land is within the neighbourhood and 0 otherwise to the centre pixle. The eigt results are then summarized. In the analysis the gray area is one pixel (25 m) wide and 1 km long.

The output raster only included sea areas that fulfilled the criterion. The result was vectorised and gaps within “potential bay areas” were included in the “bay”. Areas intersecting with rivers were deselected. The area of shallow (< 15 meter depth) and deep (> 15 meter depth) were calculated for each object. Finally areas intersecting with land, with less than 20 % of the area being deep waters (> 15 m) and a total area larger than 20 hectares were selected.

Type 1170 Reefs
Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions.
Clarifications:

- *“Hard compact substrata”* are: rocks (including soft rock, e.g. chalk), boulders and cobbles (generally >64 mm in diameter).
- *“Biogenic concretions”* are defined as: concretions, encrustations, corallogenic concretions and bivalve mussel beds originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species.
- *“Geogenic origin”* means: reefs formed by non biogenic substrata.
- *“Arise from the sea floor"* means: the reef is topographically distinct from the surrounding seafloor.
- *“Sublittoral and littoral zone”* means: the reefs may extend from the sublittoral uninterrupted into the intertidal (littoral) zone or may only occur in the sublittoral zone, including deep water areas such as the bathyal.

Where an uninterrupted zonation of sublittoral and littoral communities exists, the integrity of the ecological unit should be respected in the selection of sites. A variety of subtidal topographic features are included in this habitat complex such as: Hydrothermal vent habitats, sea mounts, vertical rock walls, horizontal ledges, overhangs, pinnacles, gullies, ridges, sloping or flat bed rock, broken rock and boulder and cobble fields. Additional description in Sweden: Mussel beds are included if the coverage of mussels are more than 5-10 %. The reef is delimited from the surrounding seafloor when soft bottoms cover more than 50 % or when the biogenic concretions cover less than 5- 10 %. Mean sea level outlines the reef towards land.

Input data

- Depth information in a 25 meter raster and point data of surfs and sub surface rocks from nautical charts
- Land and sea from map (scale 1: 10 000).
- Wave exposure

GIS selection criteria
Vertical extension of the reefs is from the surface down to a maximum depth of 10 meters. The reef should rise from the seafloor. Zonation of algae is most likely to be found in exposures from very sheltered to exposed (4 000-1 000 000 m^2/s). In the absence of geological data, rocks from nautical charts and areas with a depth of 0-6 meters intersecting with wave exposure class “sheltered” or higher (> 10 000 m^2/s) are considered indicative of rocky substrate. Areas containing or connecting to land in their horizontal boundaries are excluded.

GIS analysis

Surfs were added to the depth raster with a depth value of 0 meters. A terrain model separating peaks, flat areas and depression is made from the depth data by calculating a mean for a circle with 300 meter radius (Focal Statistics) and then subtract the result from the actual depth. The result of the calculation is divided into three classes, depressions, flat areas and peaks. The value delimiting peaks is set to -1. Areas deeper than 10 meters are excluded.
Potential hard bottoms was selected from two inputs. First depth areas between 0 and 6 meters that intersect with exposure class "sheltered" or higher was selected. Second, surfs and sub surface rocks were converted to raster (25 m resolution) and a buffer of 150 m around these were made by the using "Neighborhood Statistic" sum for a circle with a 150 radius. Values larger than 1 in the result together with the shallow areas in exposed positions are regarded as potential hard bottom.
The layer of potential reefs was created by selecting peak areas overlapping with potential hard bottom areas. Objects intersecting land are excluded (saved as a separate layer, if criteria will change) and areas mapped as sandbanks are removed. Reefs intersecting with the layer of "Islets and small islands" are removed from the reef-result and included in the "Islet" result. Finally only reefs within in exposures from very sheltered to exposed (4 000-1 000 000 m^2/s) are saved.

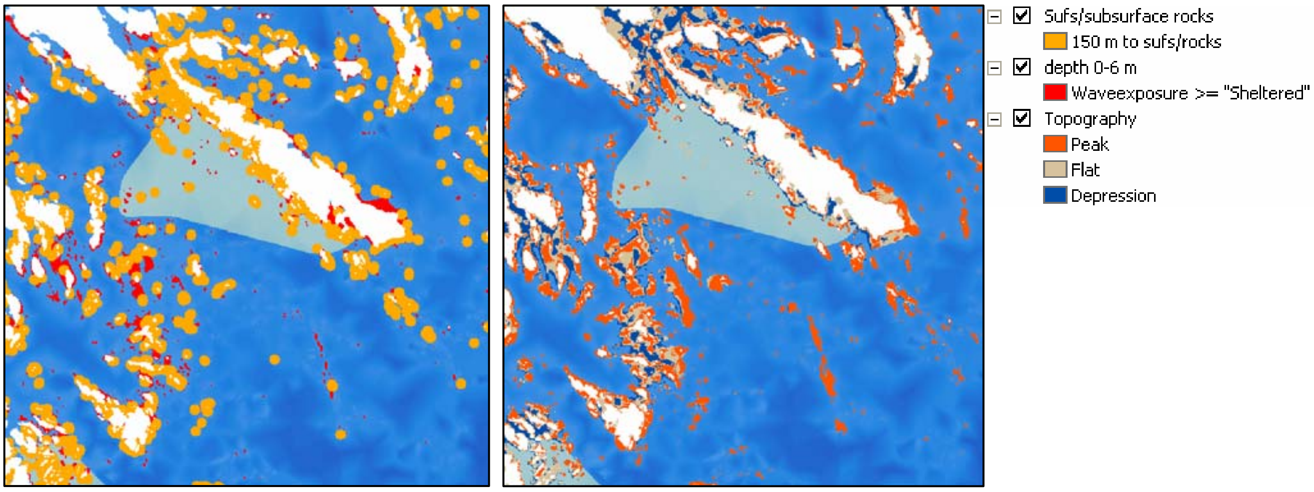


Figure 6. To the left; the selection of potential hardbottom are a combination of shallow exposed areas (red) and the neighbourhood of 150 m around surfs and subsurface rocks in nautical charts (orange). To the right; peaks (red) were selected within the depth 0-10 m. Peaks that are potential hard bottom constitute the reefs.

Type 1610 Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation

Glaciofluvial islands consisting mainly of relatively well sorted sand, gravel or less commonly of till. May also have scattered stones and boulders. The vegetation of esker islands is influenced by the brackish water environment and often by the ongoing land upheaval which causes a succession of different vegetation types. Several rare vegetation types (heaths, sands and gravel shores) and threatened species occur. Additional description in Sweden: The marine environment in connection to the islands is included in the habitat. Sublittoral sandbanks (1110) or reefs (1170) in connection with the esker islands are included in the esker islands habitat (1610).

Input data

- Land, lakes and sea (scale 1: 10 000)
- Depth
- Soil type

GIS selection criteria
Islands with glaciofluvial material. Surrounding water areas in a 200 meter buffer zone is included, down to a maximum depth of 6 meters.

GIS analysis
Islands intersecting with glaciofluvial material are selected. A buffer of 200 meter around the island is created and clipped with the depth area 0-6 meter. Finally land areas (that are not esker islands) are removed from the buffer zone.

Type 1620 Boreal Baltic islets and small islands
Groups of skerries, islets or single small islands, mainly in the outer archipelago or offshore areas. Composed of Precambrian, metamorphic bedrock, till or sediment. The vegetation of boreal Baltic islets and small islands is influenced by the brackish water environment, the ongoing land upheaval (in areas with intense land upheaval) and the climatic conditions. The vegetation types are influenced wind, dry weather, salt and many hours of sunlight. Land-upheaval causes a succession of different vegetation types. Bare bedrock is common. A lot of small islands have no trees. The vegetation is usually very sparse and consists often of mosaic-like pioneer vegetation communities. On some islands the species diversity is increased by nitrogenous excrement from birds. Many of the plants are xenophytic and lichens are common. Temporary or permanent rockpools are common and these are inhabited by a variety of aquatic plant and animal species. Boreal Baltic islets and small islands are important nesting sites for birds and resting sites for seals. The surrounding sublittoral vegetation is also included in the type 1620.

Input data

- Land, lakes and sea from maps (Due to 1997 and after, scale 1: 10 000)
- Depth
- Wave exposure
- Landcover from the Swedish CORINE-project

GIS selection criteria
The islands shall not have any forest. They should intersect with wave exposure class “sheltered” or higher (> 10 000 m^2/ s). Surrounding water within a 200 meter buffer zone is included, down to a maximum depth of 6 meters. Reefs in contact with the habitat are included.

GIS analysis
Islands with no forest cover are selected. A majority filter operation is executed on the classified wave exposure data in order to exclude single pixels. Islands intersecting with exposure class “sheltered” or higher are then selected. This selection forms the “land part” of the habitat.
Buffer zones of 200 meters are created around the selected islands. Areas with depth exceeding 6 meters are excluded from the buffered zones. Also, unselected islands and land are cut out of the buffered areas. Reefs in contact with the buffer zone are included in the habitat. Together with the land part these water areas constitute 1620.

Results

Habitat layers and maps
The maps of Natura 2000 habitats according to EU Habitat directive is one GIS-layer per habitat in UTM34N for study area 3. All maps cover the study area 3 in both Swedish waters and Finnish waters. The following GIS-layers are produced:

- 1110 Sublittoral sandbanks
- 1130 Estuaries
- 1150 Coastal lagoons (partially separated from the sea)
- 1150 Gloes (coastal lagoons wholly separated from the sea)
- 1160 Large shallow inlets and bays
- 1170 Reefs (rocky substrates)
- 1610 Baltic esker islands
- 1620 Boreal Baltic islets and small islands

Type 1650 Boreal Baltic narrow inlets is not mapped due to lack of data (identification of a threshold towards the sea) to separate them from Coastal lagoons and Large shallow inlets and bays.

Validation
The validation of the directive habitats was not performed due to the lack of the real field data on habitats.

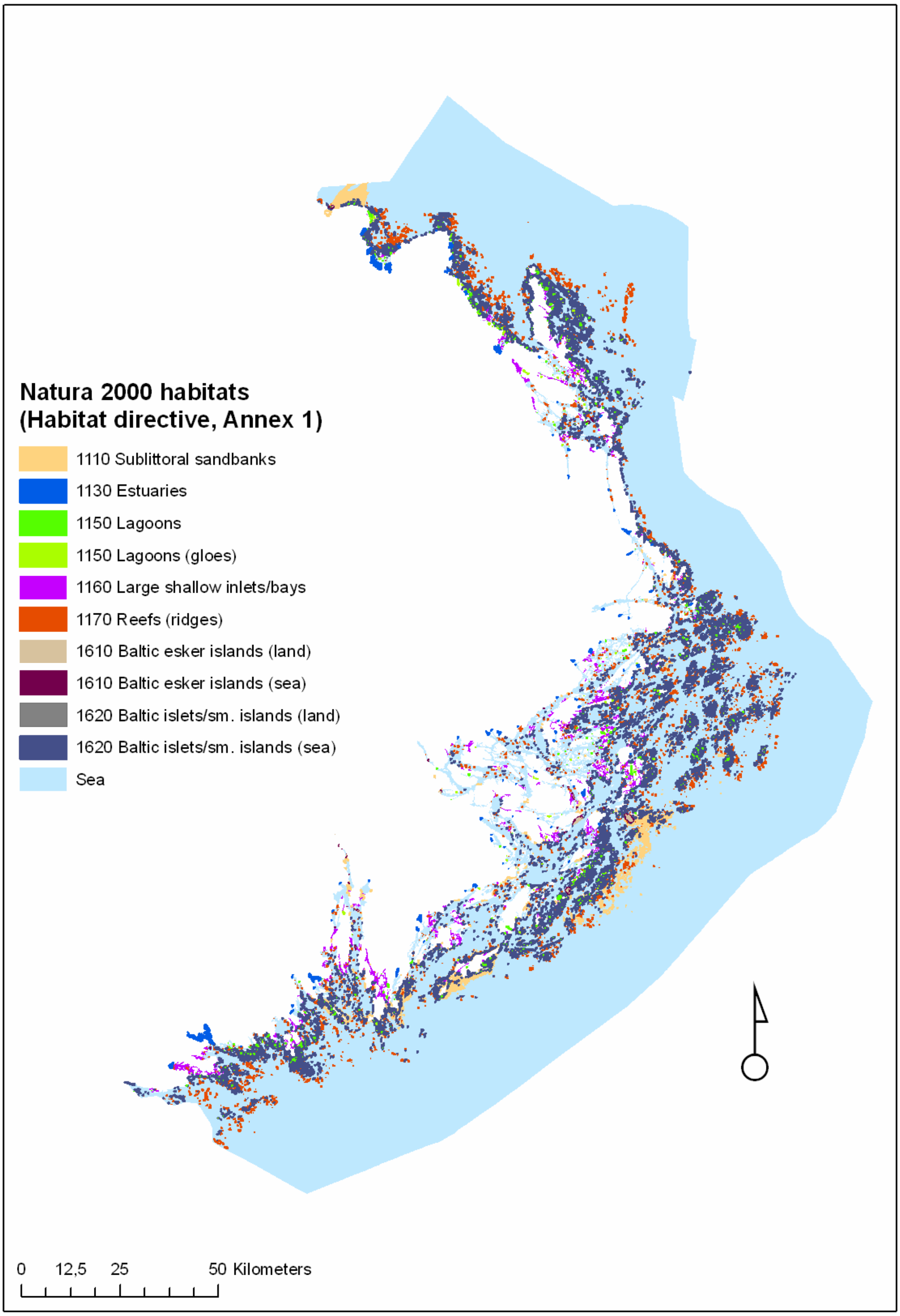


Figure 6. The distribution of Natura 2000 habitats according to the habitat directive Annex 1(the Swedish part of Pilot area 3).

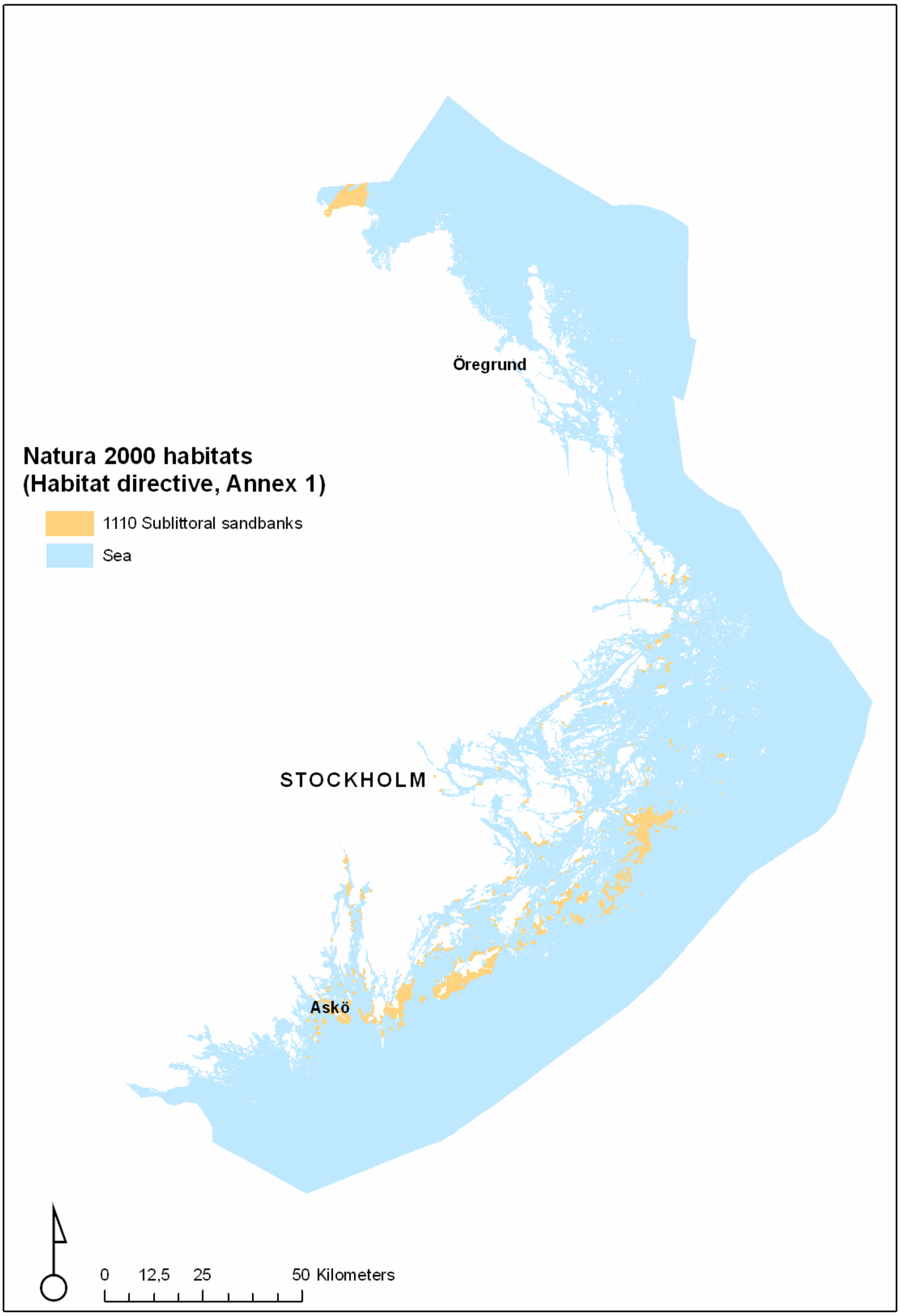


Figure 7. Map of type 1110 Sublittoral sandbanks.

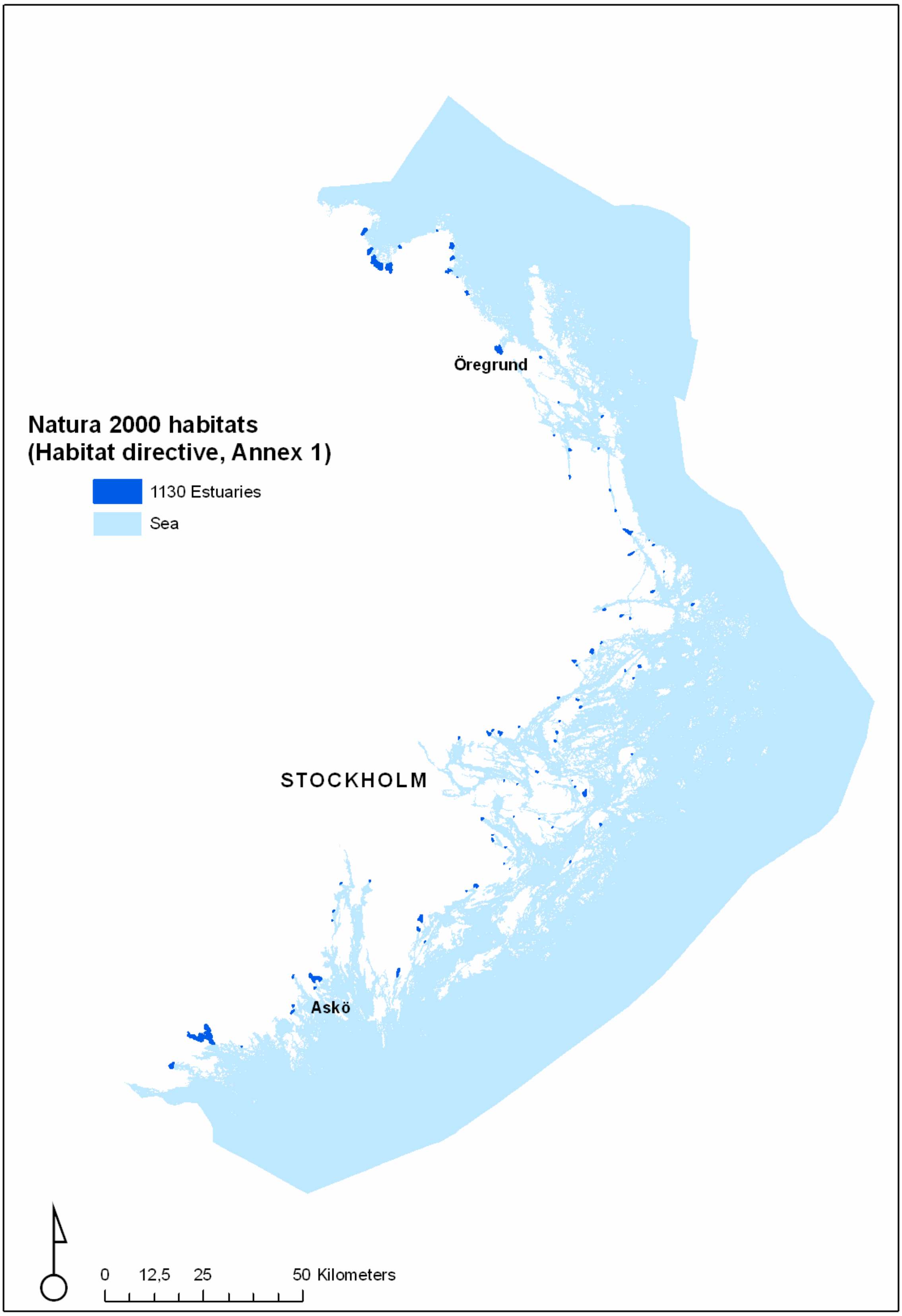


Figure 8. Map of type 1130 Estuary.

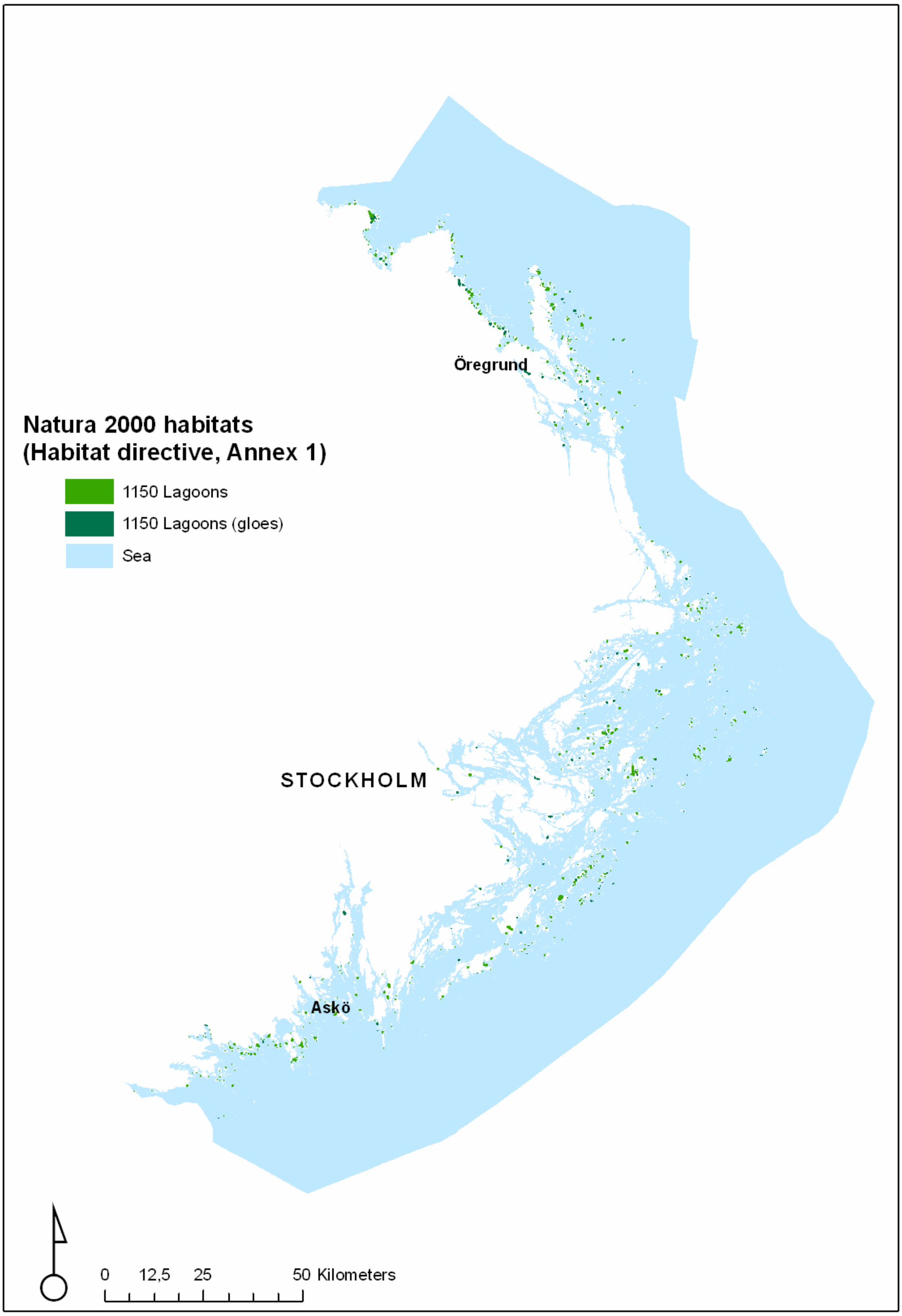


Figure 9. Map of type 1150 Coastal lagoons.

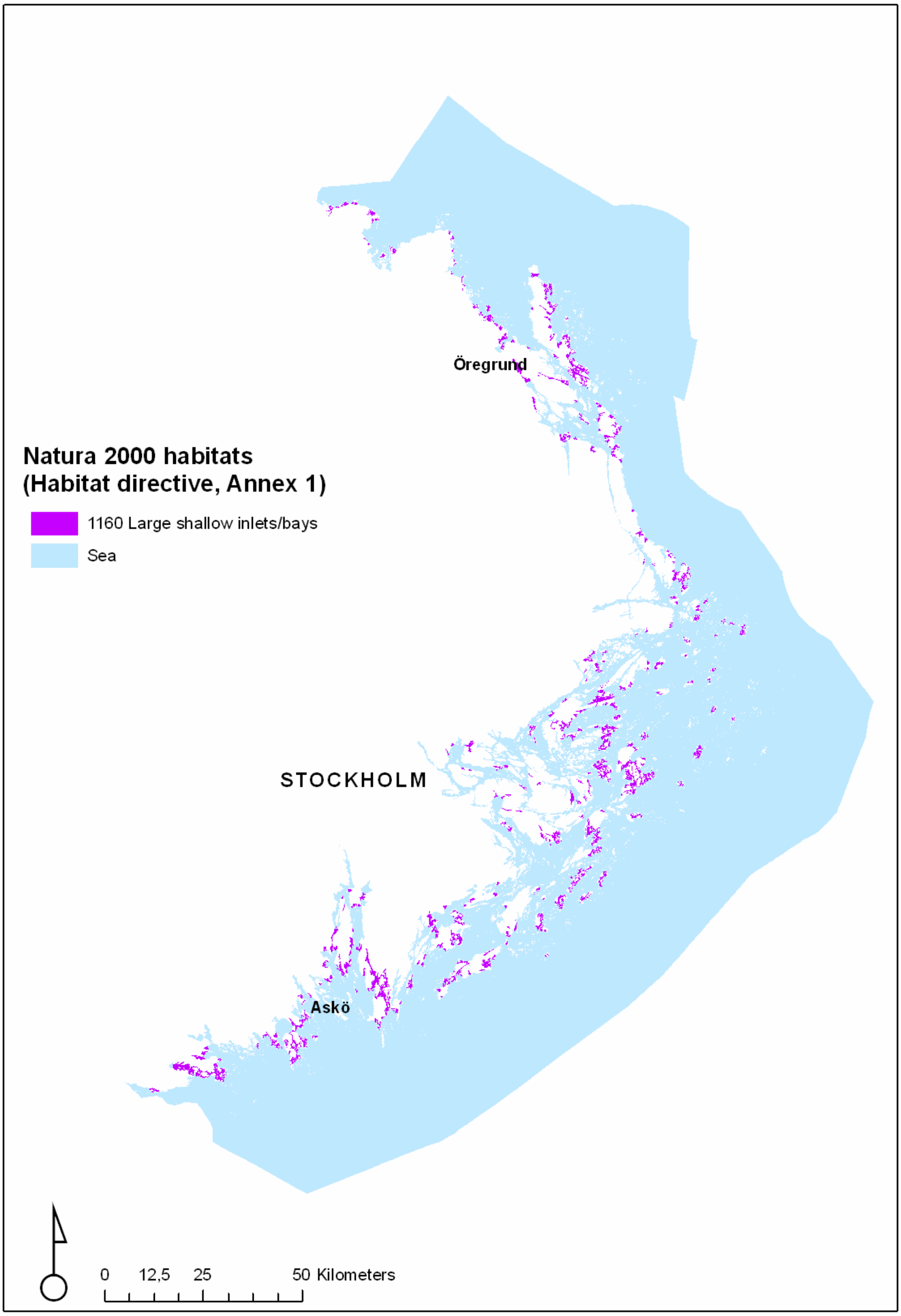


Figure 10. Map of type 1160 Large shallow inlets and bays.

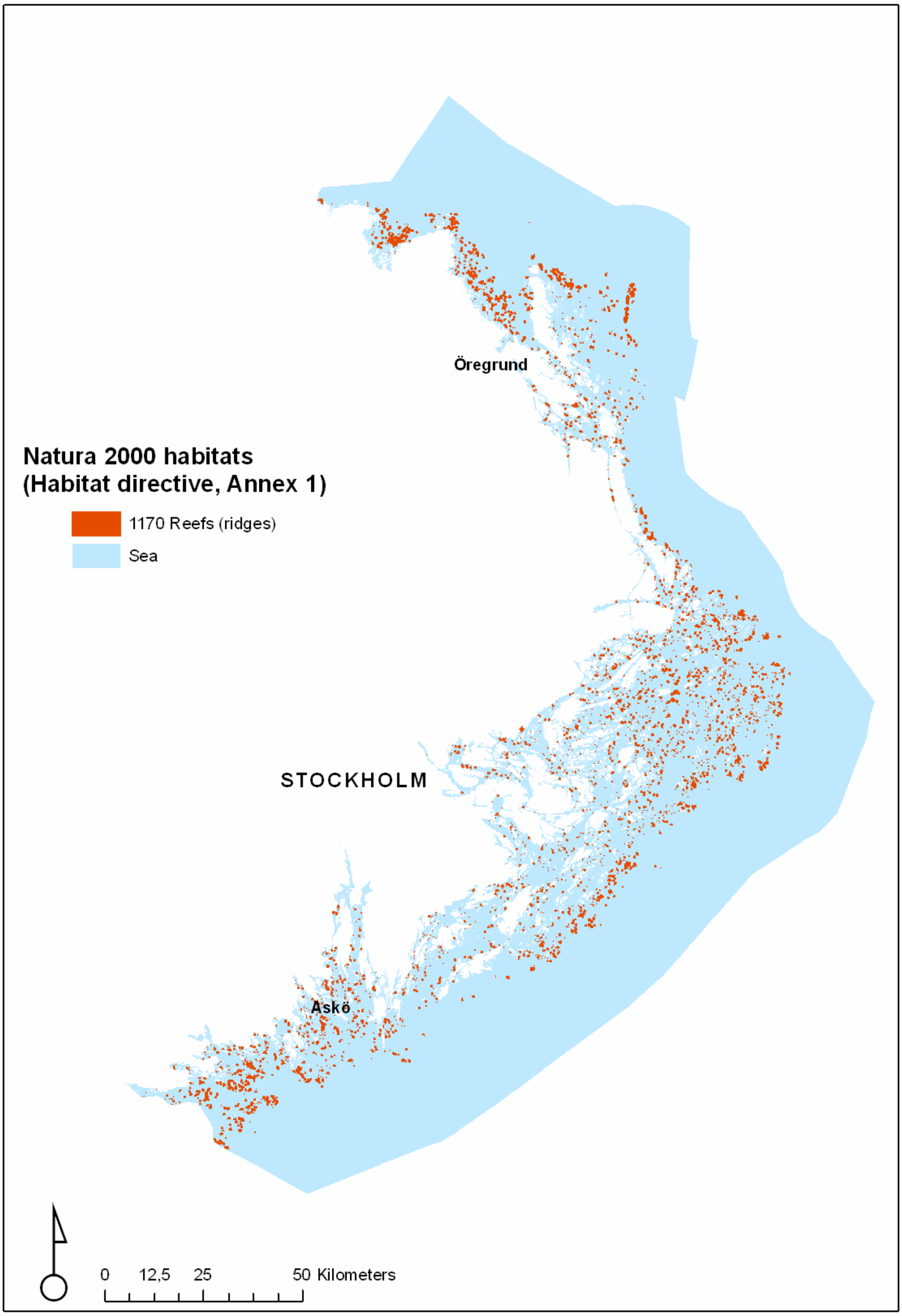


Figure 11. Map of type 1170 Reefs.

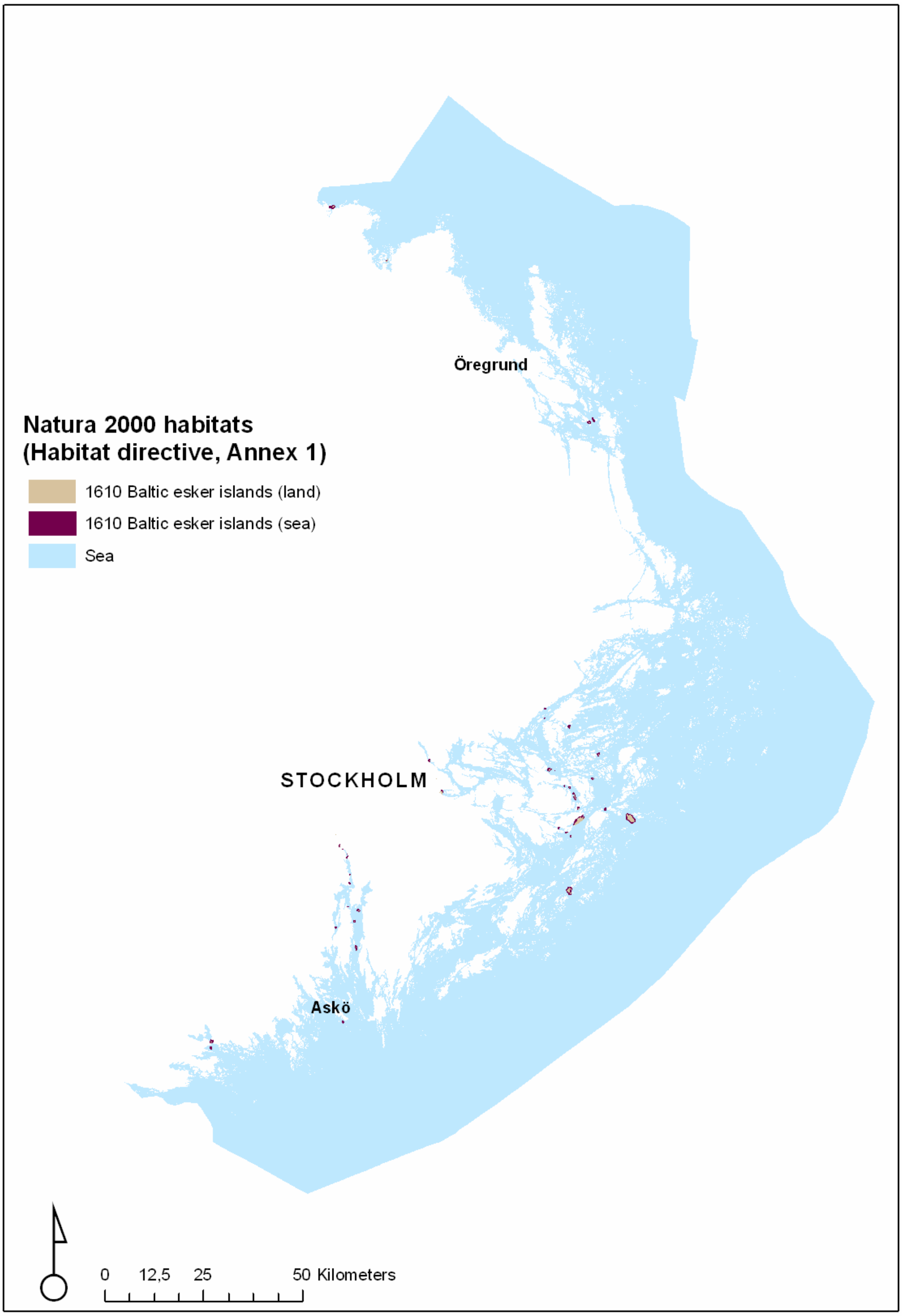


Figure 12. Map of type 1610 Baltic esker islands.

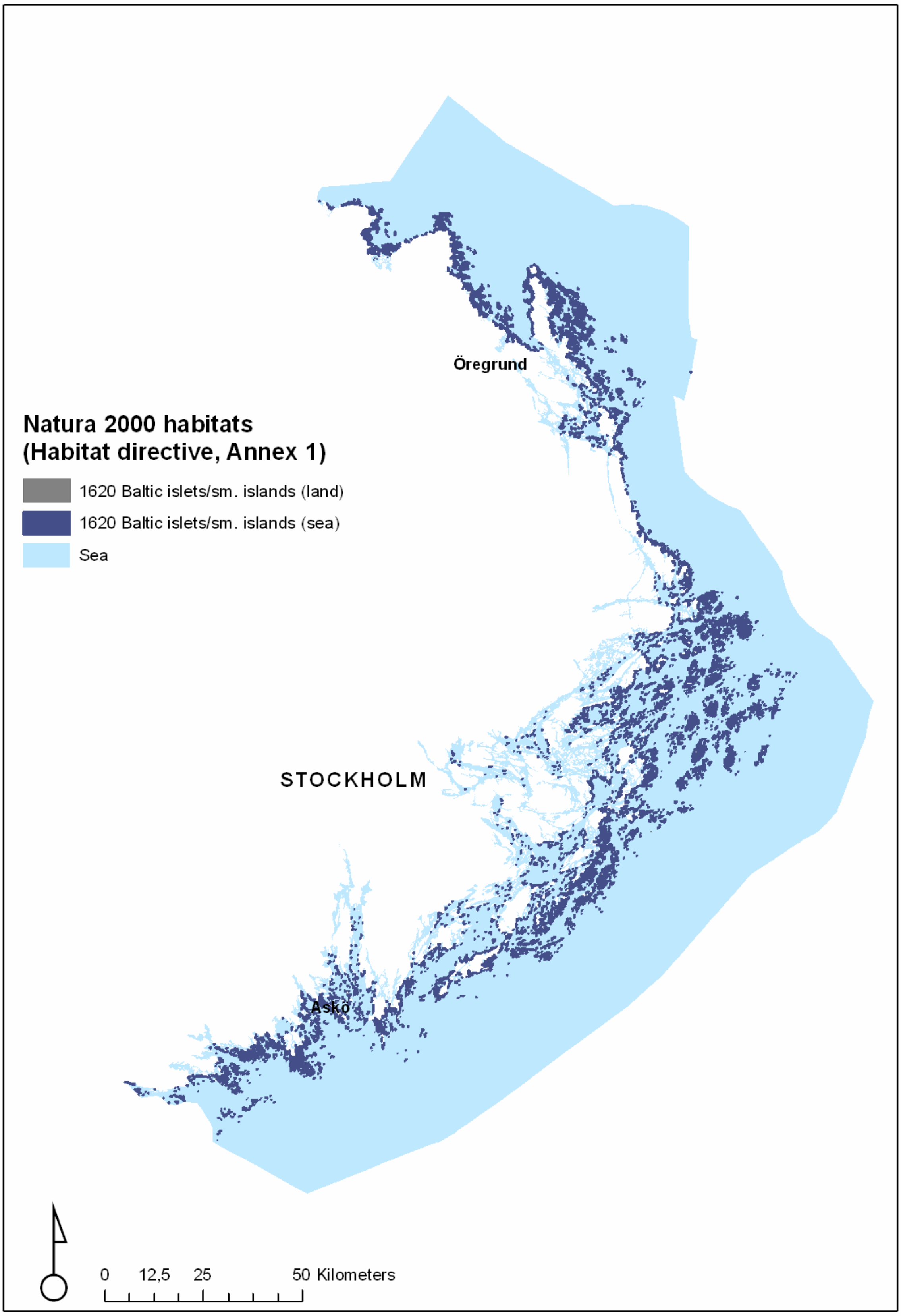


Figure 13. Map of type 1620 Boreal Baltic islets and small islands.

Discussion (with evaluation)

Quality and quantity of data – usefulness for habitat mapping/modelling
In general the modelled layers satisfy the needs of the large scale valuation of the coastal sea. Due to the poor quality of sediment data and depth the results are not valid for small-scale assessment of coastal sea.

Usefulness of used models and other methods
The methods are direct and very useful for this type of habitat modelling. However, the results are very sensitive to the quality of existing data. In order to obtain the high-quality small-scale habitat maps a small-scale map of the sediment characteristics and depth is needed (e.g. multi beam surveys). Besides sediment information these surveys have a potential to identify the key macrophyte groups. The knowledge on the biota may lead more accurate distinction of sediment characteristics (as different macrophyte species indicate different bottom types) and allow identifying habitats at higher details. Each habitat layer is discussed below.

Validation
Type 1110 Sublittoral sandbanks
The scale for the available data differs a lot. For most of the areas only large scale information is available showing only the dominating substrate. This kind of data may be used for statistical purposes over regions but is not suited for analyses of a specific spot.

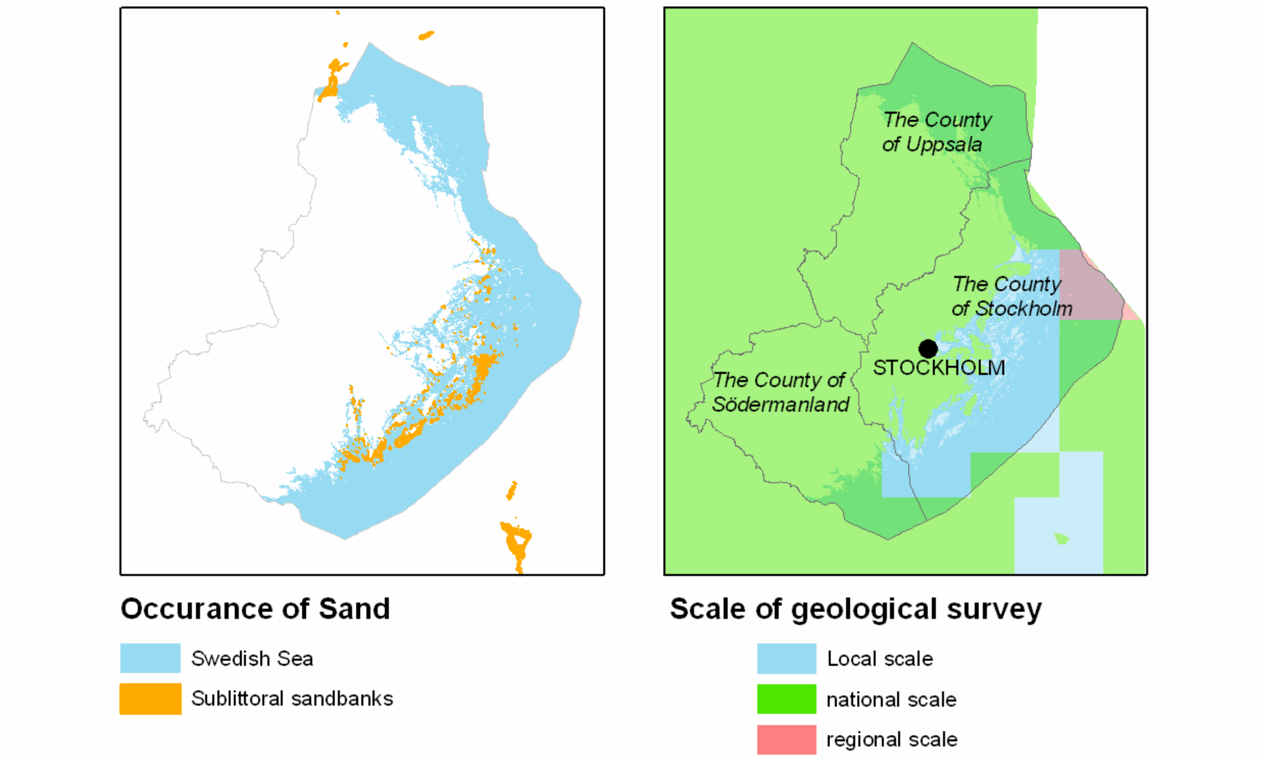


Figure 14. Occurrence of sublittoral sandbanks on the Swedish side of pilot area 3. The knowledge of where sandbanks occur is correlated to the scale of the geological survey.

The bottom substrate information generated by geological surveys has the sole purpose of showing geological information. This means that it shows the dominating substrate approximately 50 cm below the top layer that constitutes the substrate for plants and benthic animals. However, on bottoms with intense wave exposure and swift currents the actual substrate will coincide with the geological information, whereas on accumulation areas the actual substrate will differ from the classification in the geological map. Ground-truthing data would be required to assess the ability of this method to identify actual sandbanks and to compare the merit of including or excluding depth data in the analysis of potential sandbanks.

Type 1130 Estuaries
The criterion specifying the boundaries may need some revision. Boundaries are set somewhat arbitrary regarding the actual water mixing. Also, definitions of other coastal habitat types and their boundaries needs to be looked at, in order to ensure a more accurate estimation of the area covered by the habitat type 'estuaries'.

In general there seems to be an over estimation of the size of the area and the main reason is problem to determine where water mixing ceases. Freshwater inflow may be relatively too small to justify the extent of the estuary, or the outer boundary may be set to far out, compared to where the influence of freshwater ceases.

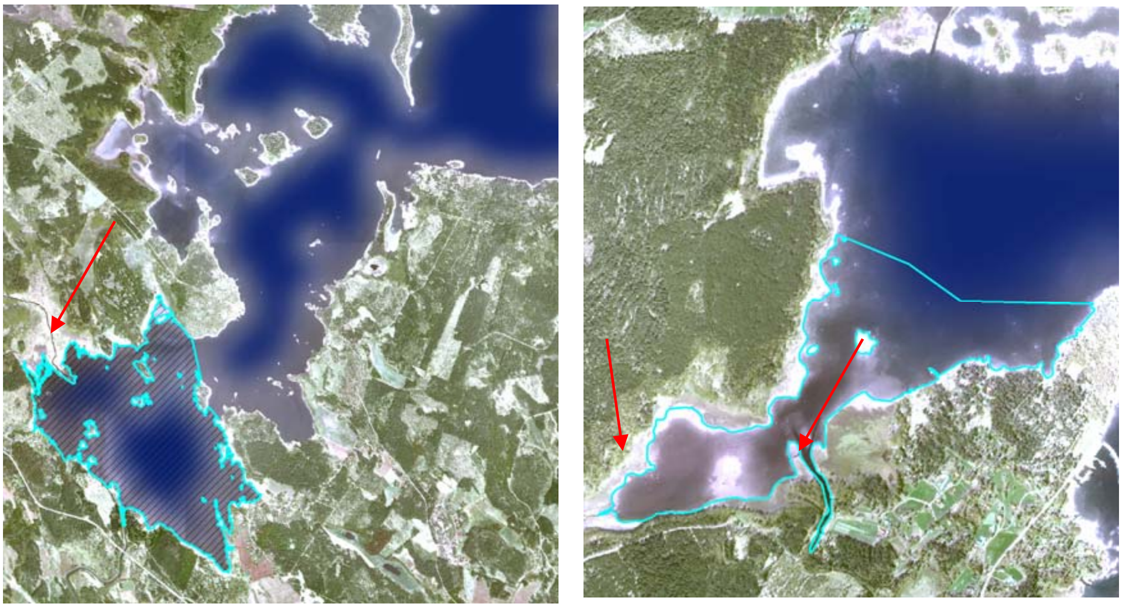


Figure 15. Two estuaries in the County of Uppland. The estuary boundary towards the sea is drawn in line with the 6 m depth curve. This seems to lead to an overestimation rather than an underestimation of the area, especially in the shallow archipelago of Uppland. Towards the land the estuary is drawn at mean sea level (according to maps), in many cases this leads to that the reed belts is not included in the area (arrow). An estuary can have more than one river mouths.

Type 1150 Coastal Lagoons
The results are shallow, sheltered water bodies that are wholly (gloes) or partially separated from the sea. The result in the gloe-file may include lakes that are not a part of the succession stages in the process of where sea becomes land (at least not in recent time). The results from the partially separated lagoon-analysis are missing lagoons smaller than 30 X 30 meters or areas more narrow than 30 meter. The analysis may also miss and outline objects too small that are outlined by submerged thresholds towards the sea as depth information at an adequate scale are missing.

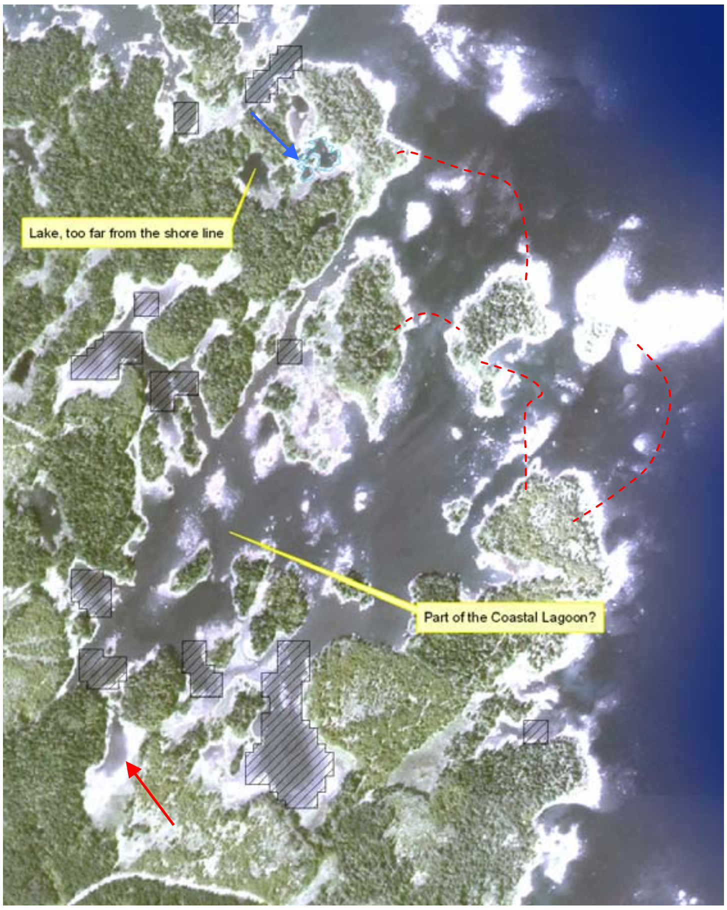


Figure 16. Coastal lagoons in the county of Uppland; partially separated from the sea (hatched areas) and gloes (blue outline and arrow). The analysis of gloes identifies lakes (according to maps) that are within 15 meter to the shore line. It may miss object in the flat topography of Uppland. The analysis of partially separated lagoons identifies shallow areas that have an opening towards the sea more narrow than 30 meters (may have several openings). The results probably underestimate the area of lagoons although identifies important locations. The analysis miss areas more narrow than 30 meters (red arrow). In the definition of lagoons a threshold towards the sea can outline the habitat. In lack of adequate depth data these areas can not be analysed. In the figure, a larger area of the shallow bay should most probably be included as several thresholds are present (red lines).

Figure 17. A mapped "large shallow inlets and bays" at the same location as shown in figure 13. The analysis of lagoons and bays overlap to some extent. In this case the whole area is probably a Coastal lagoon, in others the areas are more probably Large shallow inlets and bays. As real field data on habitats are missing these overlaps have not been handled in the analysis. The results from both analysis shows shallow areas with a potential of high conservation value. .

False lagoons can be crated by the analysis in the outer archipelagos where islets and small islands are close enough together to form a “pool” (figure 15). These sites are, however, potential lagoons in the future with continuing land uplift. Previous evaluation showed that the major problem with the analysis was that artificial pools (harbours, piers) was included in the results, this problem should be eliminated as the exploitation index is used to find unexploited areas.

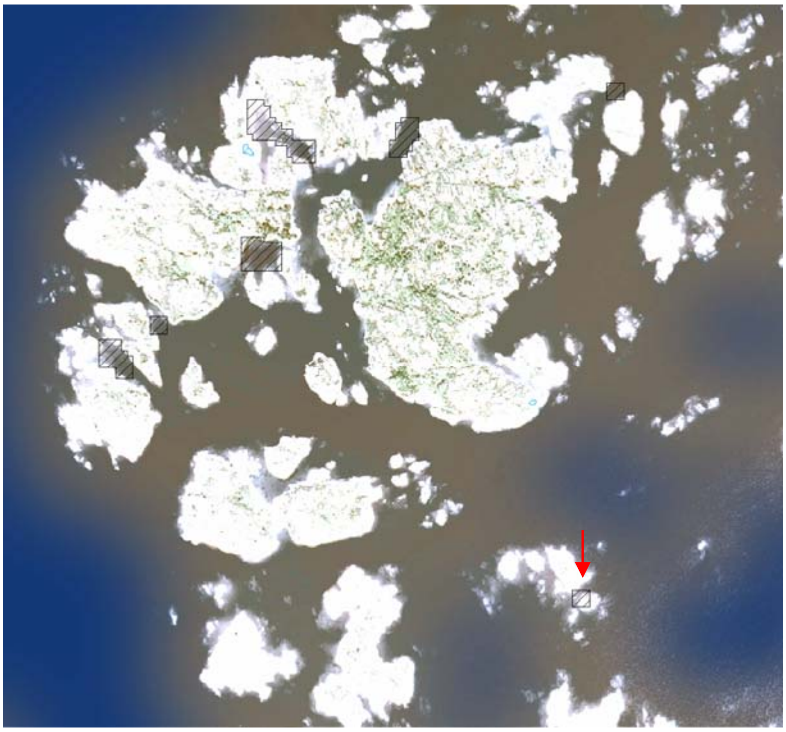


Figure 18. Costal lagoons (hatched areas) in the outer archipelago of Stockholm. False lagoons can be created in the analysis when small skerries are close to each other, forming a pool.

Type 1160 Large shallow inlets and bays

The results are shallow, sheltered water bodies; the outline is somewhat artificial and may appear strange. No information weather the object does have high biodiversity or a well developed zonation exists. In opposite of the lagoon analysis these areas are larger and objects are not excluded from the results if the shore line is exploited.

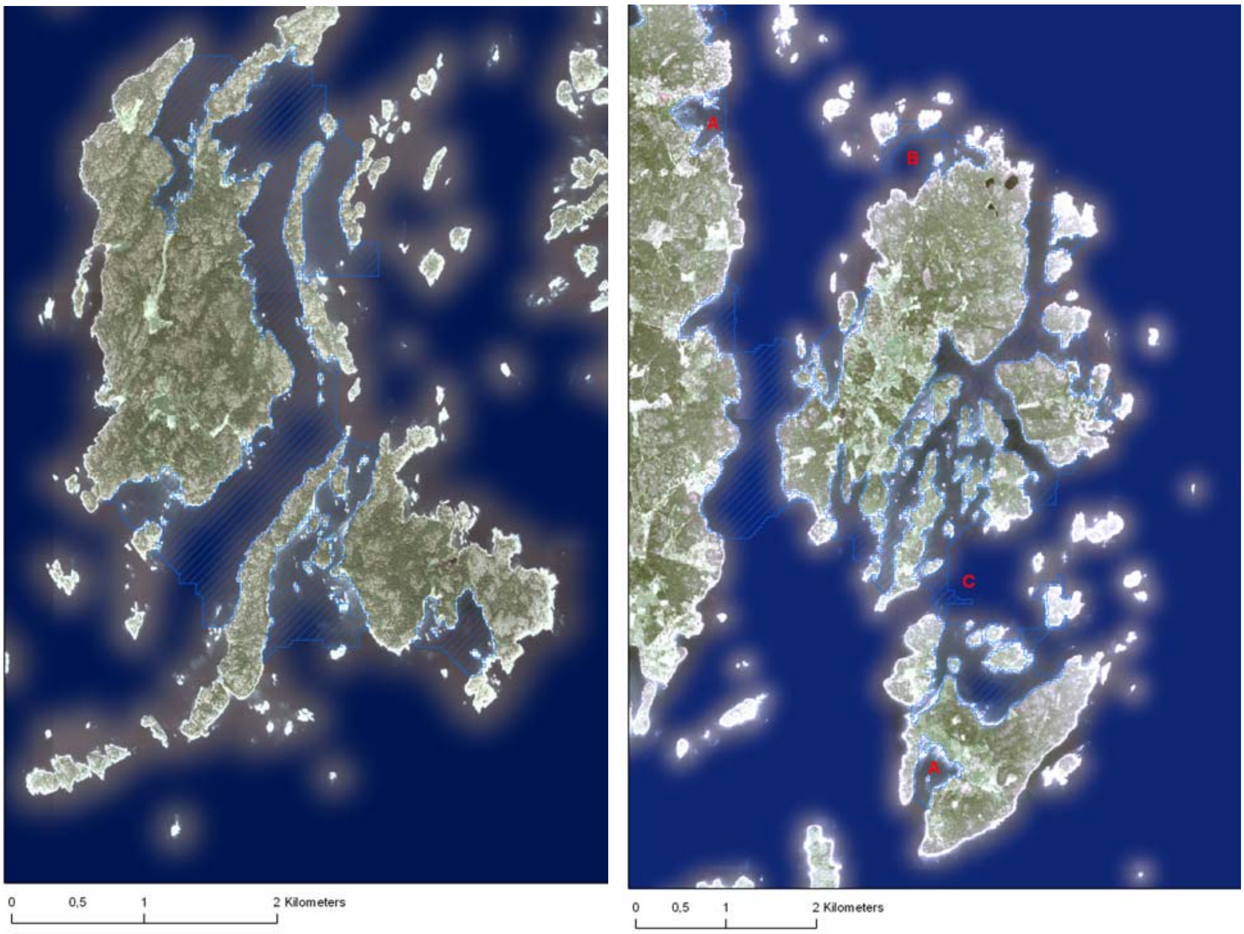


Figure 19. Mapped “large shallow inlets and bays” (hatched areas) in the County of Stockholm. The outline is usually good (se left figure and A in right figure), although the analysis is based on each pixels proximity to land in a raster. This can lead to that only areas closest to land are included (B) or outcrops of the bay into open sea (C).

Type 1170 Reefs

The method used is focused on reefs of geogenic origin, since there are no biogenic reefs of any relevance in pilot area 3. The method is a feasible process based on available input data. The accuracy of the selection process would improve with better depth data. Lacking and incomplete depth information in many areas is due to insufficient surveys and military restrictions. This mainly effect the creation of the terrain model, however, areas with depths of 6 meters and upwards are relatively well charted, as is the occurrence of surfs and sub surface rocks, even in the insufficiently surveyed areas. With better depth data in deeper areas , more deep reffs could be found, with the available data a maximum depth of 10 m were allowed.

The availability of geological data would also make the selection of reefs easier, by pointing out the rocky outcrops the reefs are made of. The geological data alone will, however, not be enough, because on what is marked as bedrock in the geological map, there may be a layer of sediment several tens of centimetres thick. Consequently, the detailed depth information giving a more accurate idea of bottom topography is essential, and information on wave action and currents can point out where the rock is likely to be bare. The extent of the selected areas may differ some, depending on how certain selection criteria is set. The radius of the circle for the “Focal Statistics” operation, when selecting peak areas, is one such criterion. Another is where to set the limit between the classifications between what is to be regarded as a peak and what is to be regarded as flat.

A comparison of the mapped reefs to the EUNIS-classification in the County of Stockholm (Mattisson 2005) gives that 81 % of the objects mapped as reefs are hardbottom substrates according to the detailed geological information. The area cover of the EUNIS-classes within the mapped reefs shows that besides hardbottoms, about 15 % of the area is glacial clays and 4 % is mixed bottoms.

Type 1610 Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation

The results have major uncertainties, and better geological information is needed to perform GIS-analysis. Although, mapping by interpretation of aerial photos may be a better approach. Only islands with glaciofluvial material are selected, although eskers forming a tongue of land could be included in the habitat, having the same type of environment. The map of soil types do not cover the whole area, its main extent is the county of Stockholm and Södermanland (se local surveys in figure 11) and is very limited in the county of Uppsala. Lacking data of macrophyte vegetation, surrounding sublittoral vegetation is included by allowing a buffer zone down to a depth of 6 meters. The presence of glaciofluvial material in the bufferzon is not included in the analysis as this data was considered too uncertain.

Figure 20 The only reported Esker island within a Natura 2000 site in the pilot area is “Billudden” (red arrow). It’s an esker forming a tongue of land and therefore not in the resulting layer of esker islands. Outside the Natura 2000 site, part of the same esker is an island and becomes mapped as an esker island (blue outline).

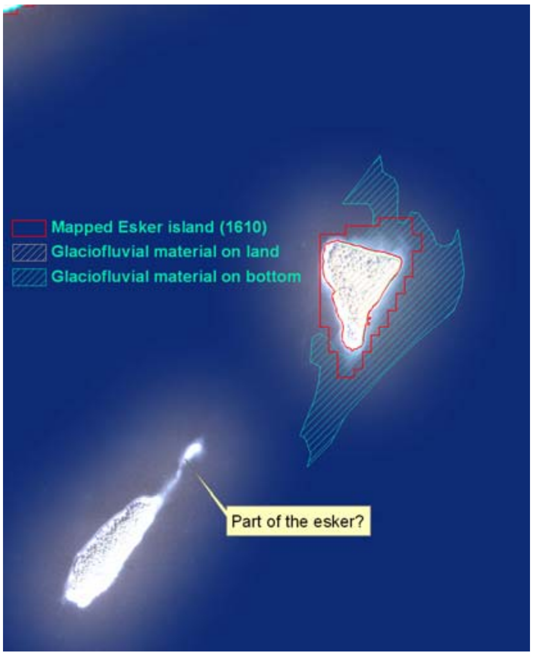


Figure 21. An Esker island in the County of Stockholm according to the GIS-analysis. The analysis probably misses esker islands.

Type 1620 Boreal Baltic islets and small islands
The analysis selects islands in exposed location with little or no trees. Esker islands are excluded from the results. The selected islands are well correlated to the description of the habitat, the uncertainty lies within the outlining of the surrounding marine environment. Lacking data of macrophyte vegetation, surrounding sublittoral vegetation is included by allowing a buffer zone down to a depth of 6 meters. In some areas this will be an overestimation in others an underestimation of the sublittoral vegetation cover around the islands.

Perspectives

Recommendations for best practised and guidelines for future work

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