BALANCE Interim Report No. 30

Mapping of Natura 2000 habitats in Baltic Sea Archipelago areas

Baltic Sea Region
INTERREG III B

BALANCE

<table>
<tr><td colspan="2">Title
Mapping of marine Natura 2000 habitats in GIS - a case study from the Stockholm archipelago and Archipelago Sea</td><td colspan="4">BALANCE Report No.
30</td></tr>
<tr><td colspan="2" rowspan="2">Authors
Sandra Wennberg, Anna-Leena Nöjd, Cecilia Lindblad</td><td colspan="4">Date
31 March 2008</td></tr>
<tr><td colspan="4">Approved by</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Revision</td><td>Description</td><td>By</td><td>Checked</td><td>Approved</td><td>Date</td></tr>
<tr><td colspan="2">Key words</td><td colspan="4">Classification
☒ Open
☐ Internal
☐ Proprietary</td></tr>
</table>

CONTENTS

0 PREFACE

This report presents the methodology applied for mapping marine Natura 2000 habitats present in the Swedish and Finnish archipelagos in the Baltic Sea. The report also summarises data requirements to perform the mapping (thematic and spatial resolution of the available GIS-data), wanted GIS-data to be able to improve the mapping and recommendations to managers how the results can be used.

The Swedish Environmental Protection Agency started to develop the GIS-mapping for some of the marine Natura 2000 habits in 2003 and has used the result on a national level. The work was undertaken because GIS-mapping has the potential to support the national reporting to EU regarding total coverage of the habitats including percentage with long term protection. The mapping presented in this report is a further development that can be used as input to an implementation of a trans-national and ecosystem-based approach to management and marine spatial planning, thus promoting a sustainable development within the Baltic Sea Region.

The methodology is based on the use of general maps and nautical charts and special effort has been put to achieve harmonized results cross national boarders to meet requirements for international reporting. The transnational cooperation gave insights in similarities and differences in available national GIS-data and the report presents different approaches to use available data but still come up with comparable results.

The methods, results and recommendations presented in this report represents independent international partnership, and do not represent any national or official viewpoint of the involved organisations. The work is part financed by the European development fund BSR INTERREG IIIB Neighbourhood Programme and partly by involved partners.

More information of the BALANCE project is available at www.balance-eu.org and of the BSR INTERREG IIIB Neighbourhood Programme at www.bsrinterreg.net.

Sandra Wennberg[a] *and Anna Nöjd*[b]

March 2008

Metria, Sweden[a] *and SYKE, Finland*[b]

1 INTRODUCTION

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 habitats (i.e. habitat types in danger of disappearance and whose natural range mainly falls within the territory of the European Union).

All countries within the community are obliged to report how much of each habitat there is in the country and how much of this that has a long term protection within Natura 2000 sites or other national protection areas. Each country also has to make sure that the protected sites do fulfil the goals of a network that will ensure maintenance of the habitats and their species. In order to do this some knowledge of the geographical distribution and area cover of the habitats are needed.

The avalable information from marine inventories do not meet the requirements of geographical knowledge today. Although having a high degree of detail at the local level the visited areas are few and scattered. Thererfor, methods that use all avaliable information and combinations of thees are needed to give an estimate of the total covarage of the habitats as well as to give managers overview and a basis for planning.

1.1 The study area – description

Pilot area 3 is situated between the Finnish mainland and the Hanko peninsula in the east over the Åland islands and the Stockholm archipelago to the Swedish mainland and the Counties of Stockholm, Södermanland and Uppland in the west. 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.

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 area is characterized by the more than XX 000 islets, small and larger islands. 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 Finnish and northern part of Swedish side the study area is topographically more flat and therefore more influenced by the land upheaval.

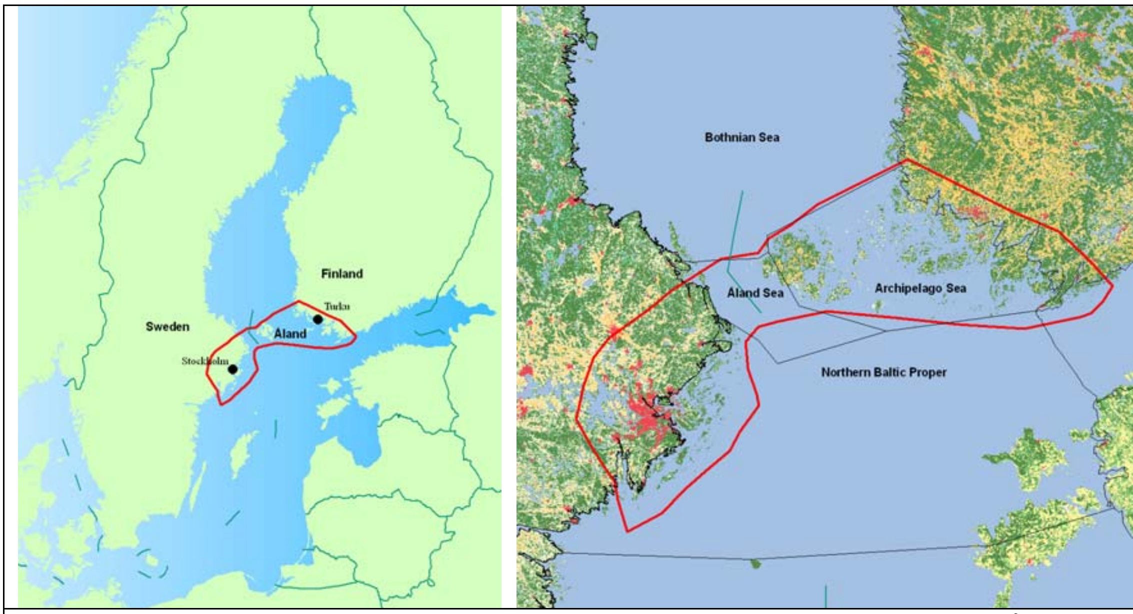

Fig. 1. *Pilot area 3 is situated between the archipelago areas in southern Finland over the Åland archipelago to the Stockholm archipelago. The salinity in the outer archipelago varies from around 5 psu in the northern parts to around 7 in the south (correlated with the basins). In the innermost bays and fladas the salinity may get down to 3-4 psu or sometimes even further. The major cities influence human impact on the environment.*

Despite the abundance of islands, the sea is dominated by deeper (> 20 m) waters, and the maximum depth over 400 m (Landsortsdjupet). The sea floor within the upper 50 m of the Baltic is very varied, ranging from bare rock to soft, highly organic sediments. Below this depth muddy bottoms predominate.

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. Sand is not common but more frequent in the southern part of the Swedish part due to glacio-fluvial 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 innermost coastal zone is comprised mostly of large islands and sheltered, narrow water passages. Much of the shoreline is vegetated with reeds. In the inner archipelago, 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 forming small groups separated by open water. Further out, in the open sea zone, there are only small skerries.

Ice covers the inner and middle parts of the archipelago 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 area is essentially tide-less, but irregular water level fluctuations of up to 1 m occur due to winds and atmospheric pressure gradients. Sea bottom oxygen deficiency is common in the areas of poor bottom water exchange (Virtasalo et al. 2005).

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 sandy areas. The blue mussel *Mytilus edulis* covers vegetation free rocky bottoms. 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 and Åbo area.

1.2 Marine Natura 2000 habitats in the study area

In the BALANCE pilot area 3 eight types of the EU Habitat Directive Annex I marine habitats can be found (including those coastal habitat types, which include the subtidal part). The coastal habitats that, in the Baltic, occur primarily above the waterline, such as sandy beaches, stony banks and vegetated cliffs were excluded from this study.

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.

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 form a delta at the mouth of the estuary. Estuaries of the Baltic Sea, with brackish water and no tidal action, are regarded as a separate subtype from the estuaries on the Atlantic coast. Estuaries often have large wetland vegetation (helophytic) and luxurious aquatic vegetation in shallow water areas. Estuaries are defined in the Finnish Natura Handbook (Airaksinen & Karttunen, 1998) as "inlets where the impact of fresh water is considerable". 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.

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.

On the Finnish coast, lagoons include flads, gloes and, more rarely, lagoon-like enclosed bays. Flads and gloes are small, shallow and clearly distinct basins, which are characterized by a highly developed reed zone and lush submerged vegetation. Flads are small enclosed bays with narrow openings to the sea that are often becoming blocked by a growing sill. Flads are usually very shallow, mainly less than 5m deep. Gloes are lakes formed by flads that have recently lost contact with the sea, but still have an intermittent saline water inflow during high water events. As a guideline, a glo develops into a lake, when it loses its intermittent connection with the sea. This happens when land uplift raises the lake above the maximum high water level, which on the Finnish coast South of the Quark, is approximately 1.4 meters above sea level. In the more general 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.

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 is sometimes defined by the distribution of Zosteretea and Potametea associations. In the Swedish description the limit of shallow water is defined by the depth distribution of vegetation and the habitat are usually larger than 25 ha. The Finnish Natura habitat guidelines define large shallow bays as larger than 100 ha, wider than long, shallow (usually a maximum depth of 6m) bays with a soft bottom. Submerged vegetation is often present. A large shallow bay can have a freshwater input, but this must not affect the habitats characteristics.

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.

There are no biogenic reefs in the pilot area. However, rocky shores and underwater rocks (subtidal rocky bottom) with a zonation of communities are included in this habitat and are common in the outer archipelago. Bladder wrack is the largest species of algae of the hard bottom sublittoral in the Baltic Sea. It always grows submerged, from a depth of 0,5 meters down to 5-6 meters, depending on the water clarity. Dense and healthy bladder wrack zones are an important part of the primary production in the shallow sublittoral zone and they are essential for the animal communities living among them. The sublittoral community supported by bladder wrack is one of the most diverse in the Baltic Sea. In the south-western archipelagos of Finland a red algal zone grows below the bladder wrack zone extending down to 5-10 meters.

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. The Swedish description also includes the marine environment in connection to the islands in the habitat and defines that Sublittoral sandbanks (1110) or reefs (1170) in connection with the esker islands are included in the esker islands habitat (1610).

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 rock pools 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.

Type 1650 Boreal Baltic narrow inlets: Long and narrow bays in the Boreal Baltic sea area, which are partly separated from the open sea by a submerged sill. The inlets consist usually of soft mud. The salinity varies depending on the freshwater contribution or the salinity value of the Baltic Sea. The low tidal range and low salinity of the Baltic Sea creates an ecology that is different of that on the North Atlantic coast. The Swedish description defines that the bay is usually deeper than 4 meters, the length is at least 2 times longer than the width and the annual average stream flow into the estuary is less than 2 m^3/s. The Finnish Natura habitats guidelines also stipulate that the bay must be several kilometres long and are usually rather shallow with the depth of 10 meters on the average. There is a salinity gradient, and brooks and small rivers may run into the bay, but these must not exert a noticeable freshwater influence on the habitat. The habitat is fairly rare in Finland. Large reed stands are considered characteristic for the inner part of the bay.

1.3 Aims and objectives of the report

The aim of the modelling exercise was to create maps of the spatial distribution of the EU Habitat Directive Annex I habitats: 1) 1110 Sublittoral sandbanks, 2) 1130 Estuaries, 3) 1150 Coastal lagoons, 4) 1160 Large shallow inlets and bays, 5) 1170 Reefs, 6) 1610 Baltic esker islands and 7) 1620 Boreal Baltic islets and small islands. No attempt was made to model type 1650 Boreal Baltic, as they are distinguished by a sill at the mouth, which is not identifiable from the coarse depth models available. The maps should be comparable over the nation border between Sweden and Finland.

2 BACKGROUND DATASETS

The GIS-data used are general maps and nautical charts. Data sources are shown in table 1. From these an additional seven datasets were derived (table 2). The analyses are based on combinations of those and the data used for each habitat differ. The few data available used for validation and evaluation are described in chapter 2.3.

2.1 Existing datasets

Table 1: Data sources

Coutry Ref. no.	Dataset	Spatial scale / cell size	Source	Data owner
[F1]	Shoreline with land, sea, lakes and rivers	1:20,000	Basic map	NLS
[S1]	Shoreline with land and water	1:10,000	GSD-property map	SLS
[S2]	Shoreline, land, water and elevation curves	1:50,000	GSD-topogephic map	SLS
[S3]	Lakes and rivers with waterflow	1:150,000	GSD-general map	SLS
[F2]	River flow	N/A	Flow monitoring database	YH
[F3]	DEM	Scale?/25m	Elevation curves and shoreline in topographic map	NLS
[F4]	Exposed bedrock	1:5,000 – 1:10,000/25m	2001 topographic database	NLS
[F5]	Land use	1:100,000/25m	CORINE Land Cover 2000	YH
[S4]	Land use	1:50,000/25m	GSD-Land and Vegetation Cover (National CORINE)	SEPA
[S5]	Depth surfaces and sufs	1:50,000	Nautical chart	SMA
[F6],[S5]	Depth points, submerged and surface rocks	1:50,000	Nautical chart	FMA/SMA
[F6]	Depth isolines	1:50,000	Nautical charts	FMA
[F7],[S6]	Bottom substrate	1:100,000/100m (F) 1:100,000-500,000(S)	Cato et al. (2003) (S)	GTK/SGU
[F8],[S7]	Soil type on islands and main-	1:1,000,000/200m(F) 1:100,000 (S)	Soil map	GTK/SGU
[F9],[S8]	Wave exposure	25 m	Isaeus 2004	YH/SEPA
[F10]	Secchi depth	N/A	National water quality database	YH
[S9]	Coastal exploitation	1:10,000/25 m	Smedberg 2006	SEPA

[S9]	Satellite data	25m	Landsat/Image2000	SEPA
[S10]	Arerial photo	1m	GSD-ortophoto	SLS
[S11]	Depth model	TIN	Nautical charts/SMA	SMHI

NLS/SLS = The Finnish/Swedish National Land Survey; FMA/SMA = The Finnish/Swedish Maritime Administration; GTK/SGU = Geological Survey of Finland/Sweden; YH = Finnish Environmental Administration, SEPA = The Swedish Environmental Protection Agency, SMHI=The Swedish Hydrological and Meteorological Institute

2.2 Modelled datasets

Table 2: Derived datasets

Country Ref. no.	Dataset	Spatial scale / cell size	Source, used information
[F11],[S11]	Depth model	25m	[F6],[S5] Depth as points and isolines, shoreline, elevation isolines
[F12],[S12]	Land and sea rasters	50, 15, 10m (F) 25, 15 m (S)	[F1],[S1],[S2] Vector shoreline
[F13]	Esker islands, polygon	1:20,000	Digitised from National esker survey (Kontturi & Lyytikäinen, 1987)
[F14]	Percentage of land in a 5 km neighbourhood	50m	[F12] 50m land and sea raster
[F15]	Archipelago zones	50m	[F14]
[F16],[S13]	Benthic terrain model	25m	Depth models
[F10]	Photic depth model	50m	Linear model of the value in [F14] and average July secchi depth.

The depth model in Finland was created using the Topo to raster function in ArcGIS using isolines and depth figures from nautical charts as input. The Swedish depth model was also crated based on isolines and depth figures from nautical charts although created by rasterizing an existing TIN.

The model of Photic depth was created on the Finnish part of the pilot area. To predict secchi depth a simple linear regression model was used based on the value in each cell of the percentage of land dataset [F14]. Secchi depth was found to have a negative correlation with the percentage of land in a five kilometre radius neighbourhood (figure 2). Photic depth was estimated at twice the secchi depth.

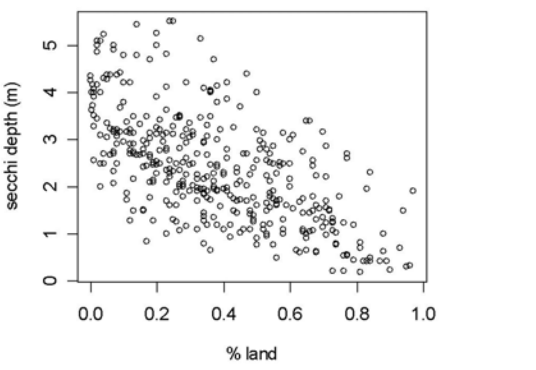

Fig. 2. *Secchi depth against the percentage of land within a five kilometer radius..*

Benthic terrain models were created using different methods in each country although both terrain models distinguish depressions, elevations and flat areas in the bathymetric data. Finland used the Benthic Terrain Modeller, an ArcGIS extension available from the NOAA website (http://www.csc.noaa.gov/products/btm/). The broad scale Bathymetric Position Index (BPI) tool was used to detect broad scale terrain variation appropriate for locating habitat features such as reefs. The BPI is created using an annulus shaped neighbourhood with a calculation comparing a cells depth value to that of surrounding cells to measure if it is on average higher or lower than its neighbours. Sweden used the tool Focal Statistics to calculate a mean depth for a circular neighbourhood and then subtracted the result from the actual depth. In both countries the 25m raster depth model and a radius of 300m for the neighbourhood was used.

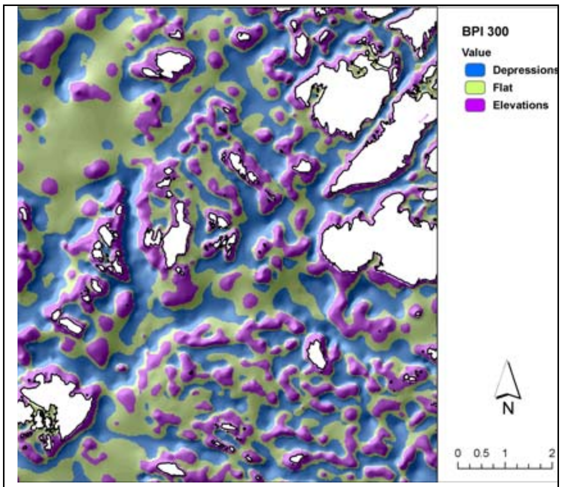

Fig. 3. *Benthic terrain model draped over a hill-shaded depth model*

2.3 Data for validation

2.3.1 Sweden

For evaluation of the results three layers with some habitat information were used:

- Inventory of shallow areas of high nature value in the archipelago of Svealand (The County Administrative board of Stockholm 2003)
- Mapped Marine Habitats with help from existing information and the European Nature Information System, EUNIS (Mattisson 2005)
- Inventory of shallow bays with a threshold towards the sea (The County Administrative board of Stockholm 1991)

The maped marine habitats according to EUNIS (Mattisson 2005) covers most of the Stockholm County and have both more detailed information of bottom substrate and depth than the data used in the models. The map is used to evaluate the results from the analysis of reefs.

The inventory of shallow areas with high nature value describes 176 locations spread over all counties in the pilot area (The County Administrative board of Stockholm 2003). 110 of these locations are field surveyed and are used for validating the shallow habitats of Large shallow inlets and bays, Lagoons and as Estuaries. 66 of the locations are river mouths with known high value for fish upstream the river and therefore a high probability to have high nature values in the marine environment. The selection of locations were based on previous inventories or local knowledge and is therefore not a total map of all shallow areas of high nature value but rather a sample of the former. The locations are defined as points in a GIS-layer with information of nature value (graded 1-5), value for fish (graded 1-5) and the degree of human impact on the locations (graded

1-5). The locations are also classified into succession stages connected to the continuous land-lift (preface to flada, flada, gloflada and glo). The majority of locations are sheltered bays or lagoons with soft bottoms. The purpose of inventory of shallow bays with a threshold towards the sea was water chemistry and physics. The GIS-layer points out 88 bays, the inventory is from 1991 and no other information from the inventory than the presence of these objects was used.

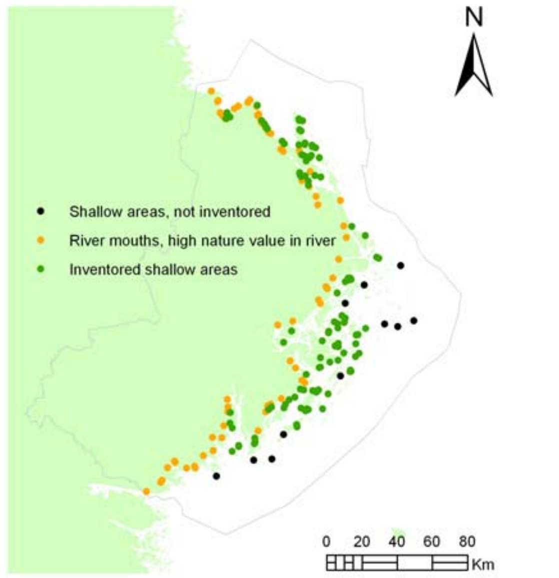

Fig. 4a. *The inventory of shallow areas with high nature value (the County administrative board of Stockholm 2003).*

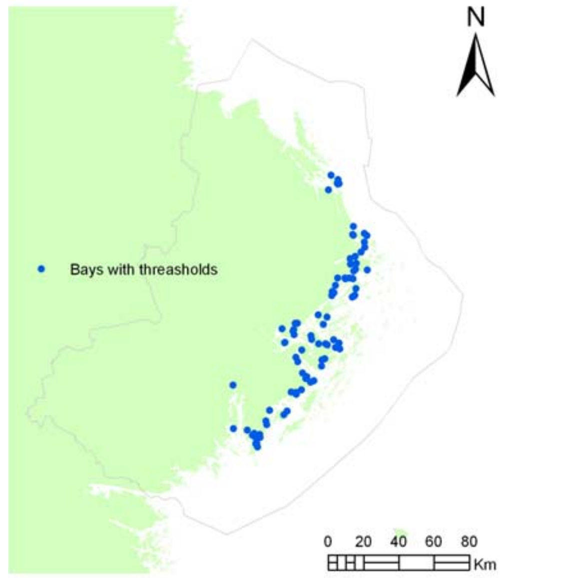

Fig. 4b. *Inventory of bays with a submerged sill towards the open sea (the County administrative board of Stockholm 1991).*

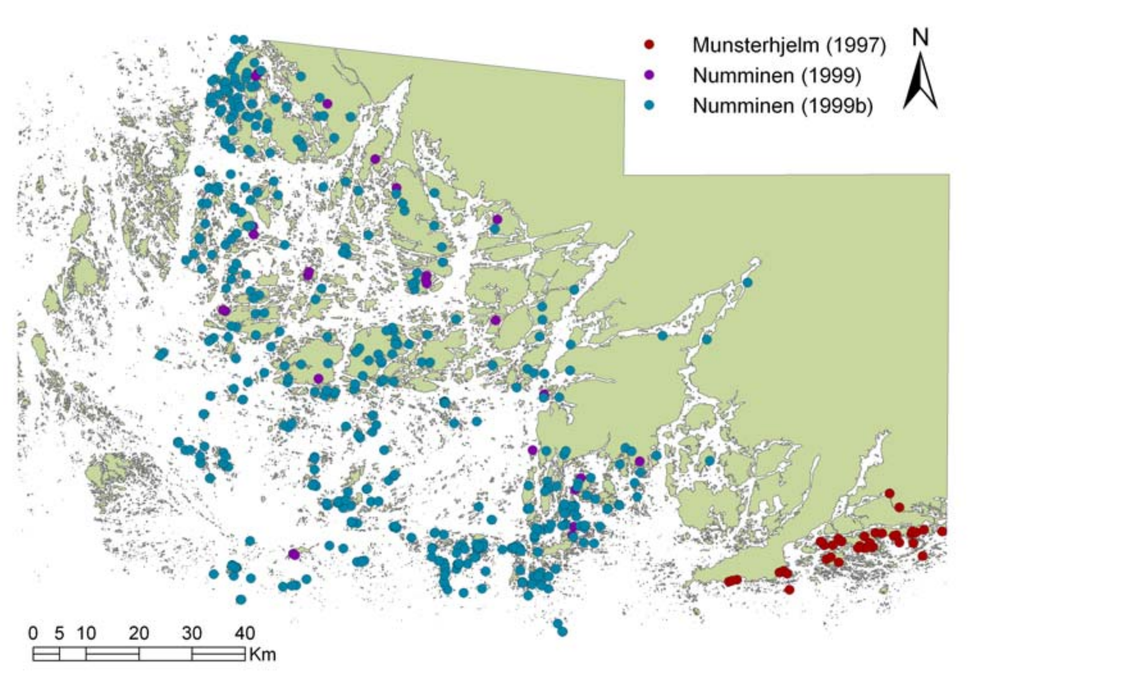

Fig. 5. *Flads and gloes in the Archipelago Sea reported in literature before 2003.*

2.3.2 Finland

The only dataset available for validation of the GIS analyses run on the Finnish side of the pilot area, at the time of this study, was a point dataset of flads and gloes. The dataset was collated from literature produced before 2002 as part of a national project aiming to produce a GIS database of potential marine and coastal Annex I habitats around the Finnish coast (figure 5). The project combined GIS analyses with field records from available literature sources.

3 GIS ANALYSIS OF NATURA 2000 HABITATS

The methods are based on tools in ArcGIS with the Spatial Analyst extension. Sweden also used the model maker in ERDAS Imagine and Finland used the Benthic Terrain Modeller extension from NOAA. The resulting layers are presence maps of the Annex I habitats.

The GIS-analyses are different for each habitat and described separately. For some habitats the analyses also differ between the countries, described as approaches. The table below gives an overview of the data used to map each habitat. The numbers in the table and of approaches links to the countries.

Table 3. Predictions layers used in each model. The scale of the input data and and information used in each layer are described in each habitat model.

Prediction layer	1110	1130	1150	1160	1170	1610	1620
Sea	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2
Lakes			1, 2				
Rivers		1, 2	1	1, 2			
Land		1, 2	1, 2	1, 2		1, 2	1, 2
Elevation			1, 2				
Depth model	1, 2	1, 2	1, 2	1, 2	1	1	1, 2
Terrainmodel/BPI	2				1, 2	2	
Wave exposure					1. 2		1, 2
Bottom substrate	1, 2						
Subsurface and surface rocks					1, 2		
Exposed bedrock shores					2		
Soil type					1, 2	1	
Land cover: forest							1, 2
Land cover: wetlands		2					
Land cover: estuaries		1					
Land cover: lagoons			1				
Coastal exploitation			1				
Satellite images /aerial photos		1					
Photic depth model					2	2	2
River flow		2					

1) Approach 1 Sweden, 2) Approach 2 Finland

3.1 Sublittoral sandbanks (1110)

3.1.1 Input data

- Bottom substrate [S6], [F7]

- Benthic Terrain Model [F16]

3.1.2 GIS selection criteria

- Areas classified as sand and with a maximum depth of 30 meters (approach 1)
- Areas consisted of > 70% sand elevated from the seafloor and partly located above 20m depth (approach 2)

3.1.3 GIS analysis

Approach 1: Selection of areas classified as sand and with a maximum depth of 30 meters. The information needed was available in the attribute table in the input shape-file.

Approach 2: The Benthic Terrain Model was used to select cells that were clearly elevated above their surrounding seafloor. The extracted cells were grouped into continuous patches, or "mounds". The total area and the area of sandy substrate on each mound were calculated. Mounds larger than three pixels that consisted of a minimum of 70% sand and were at least partly located above 20m depth were selected as sandbanks.

3.1.4 Results

The prediction maps are one vector file per coutry outlining presens of the habitat. The objects may overlap all other mapped habitats.

3.2 Estuaries (1130)

3.2.1 Input data

- Land and sea [S2], [F12]
- Rivers [S3], [F2]
- Depth [S5], [F11]
- Estuaries from Swedish Land Cover [S4]
- Wetlands from CORINE [F5]
- Satellite images and aerial photos[S9], [S10]

3.2.2 GIS selection criteria

- Sheltered areas with a freshwater influx from a river with a watershed > 1 km^2 where sedimentaions can occure. Only sea is included in the habitat (approach 1)
- Embayments or basins surrounded by land or shallow water of a depth of 3 metres or less, with an input of fresh water and sediment from at least one river with an average flow of 2 m^3/s or above. Shallow sea and and surronding wetlands (if present) are included in tha habitat (approach 2)

Estuaries have priority over the other enclosed water body types, areas mapped as estuaries are not mapped as any other type (both approaches).

3.2.3 GIS analysis

Approach 1: Sheltered areas with a freshwater influx (from a river with a watershed > 1 km^2) are a by-product of the analyses of 1150 and 1160. These areas of potential estuaries, are visually classified with reference data from satellite images, aerial photos and maps. Objects were deselected if there is no natural conditions for sedimentation, they are artificial pools, if the river mouth is located on an exposed coast or in waters deeper than 3 m. The selecte remaining objects are manually outlined in GIS. The outline towards the river is at the point of the river mouth.

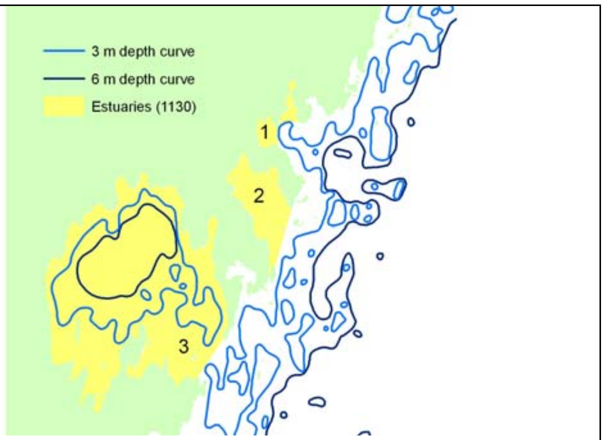

***Fig. 6** Three examples of how the outline of estuaries towards the sea was drawn (se text).*

The outline towards the open sea is either at a threshold (Fig 6:3) or the 3 meter depth curve (Fig. 6:1) but not further out than were “sheltering land” ceases (Fig. 6:2). Boundaries were drawn with special emphasis on placing the inner border up stream and the outer border towards the sea. 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 Land Cover are included.

Approach 2: Embayments or basins surrounded by land or shallow water of a depth of 3 metres or less, with an input of fresh water and sediment from at least one river with an average flow of 2 m^3/s or above and with wetlands present were selected using the following methodology. Separate reed lined shallow "basins" were extracted by initially splitting the depth data into two categories: <= 3m and > 3m. The waters deeper than 3m were reclassified into the same class as land. The land and "deep" water class was expanded, resulting in many separate bodies of shallow water. Wetlands were extracted from Corine 2000 landcover data and added to the shallow waters to help define the edges. Potential estuaries were selected from the shallow reed lined basins based on rivers running into them.

***Fig. 7a.** Estuaries Photo: NN, Affiliation.*

***Fig. 7b.** Coastal lagoons. Photo: NN, Affiliation.*

3.2.4 Results

The prediction maps are one vector file outlining the presence of the habitat. The results are shallow sheltered areas at the moth of rivers. The objects do not overlap mapped Large shallow inlets and bays or Lagoons.

3.3 Coastal lagoons (1150)

3.3.1 Input data

- Land, lakes and sea [S1], [S12], [F1], [F12]
- Rivers [S3], [F2]
- Depth [S5],[F6]
- Elevation [S2],[F3]
- Lagoons from Swedish Land Cover [S4]
- Exploitation index of the coast line [S9]

3.3.2 GIS selection criteria

The criteraia and analysis separate between coastal lagoons that area wholly separated from the sea (gloes) and those that are partially separated from the sea.

- Gloes are lakes less than 30 meters from the shoreline and located lower than 5 meter a.s.l. (apporach 1 and 2).
- Partially separated lagoons are inlets with a mouth towards the sea less than 30 meters wide. Maximum depth is 6 meters (approach 1 and 2).
- None of the lagoon-types have a freshwater influx from rivers and are smaller than 30 hectares (approach 1 and 2).
- The results are divided into those whith physical exploitation along the shore line and those without (apprioach 1).

3.3.3 GIS analysis

Approach 1: For gloes, lakes were selected from the older map ([S1] date from 1990-1996). A buffered shoreline was produced by expanding the sea surface one pixel up towards land ([S12], 15 m pixel size). Lakes that intersect with the new shoreline and located between the 5 meter elevation curve and the shoreline were selected.

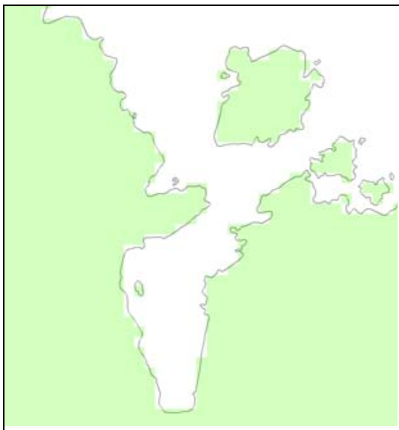

Fig. 8a. The analysis of lagoons area based on a raster (Land in green).

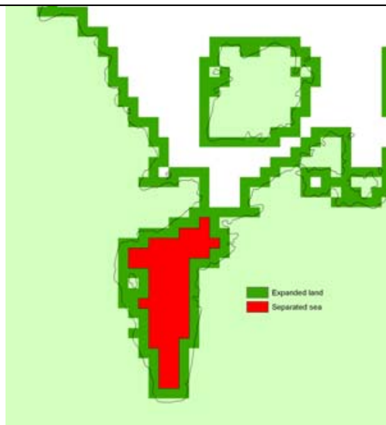

Fig. 8b. Step 1 and two in the analysis area identical in both countries (se text for details)

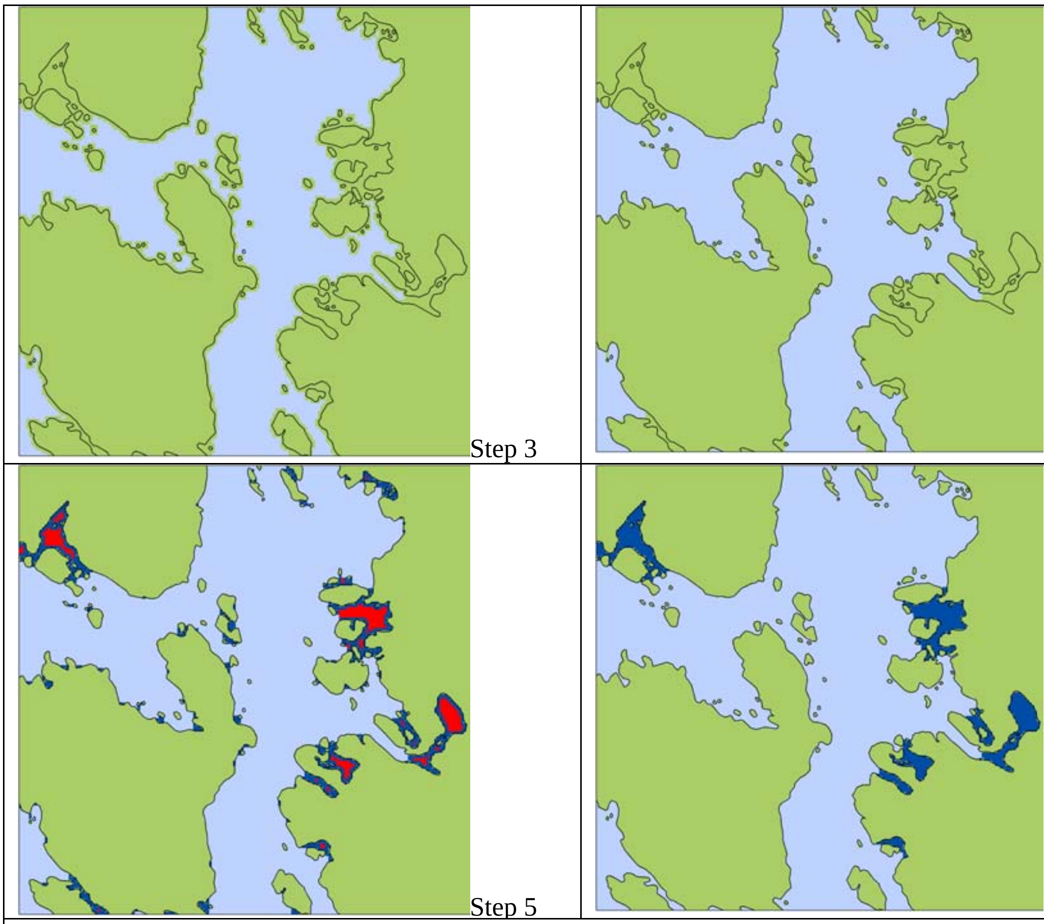

***Fig. 9.** Steps 3-6 in the selection of bays almost separated from the surrounding sea in Finland. (See the text for details on the steps.). Steps 1 and 2 as in Sweden*

To analyse lagoons partially separated from the sea, 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 (figure 8a and b). Sea-areas that had become separated from the “larger” sea were identified, rasterised and expanded one pixel back to its original outline. From the results three more selections were made (figure 9); 1) the lagoons are less than 6 m deep, 2) the lagoons do not have rivers running into them 3) they are smaller than 30 hectares. The operation is done on two generations of 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 less than 30 hectares from the Swedish Land Cover were included. Finally the result was divided into two layers based on the exploitation along the coastline. Coastal lagoons with no exploitation were separated from those with some exploitation.

Approach 2: For gloes, lakes were selected that intersected a 30m buffer of the shoreline and were in a zone below 5m elevation that intersected the sea. The gloes dataset was rasterised into 10m cells.

The analysis of partially seprated lagoons was done for both the 10m and 15m rasters [F12]. *Step 1 and 2* are the same as in the Swedish analysis (figure 8a and b): land was expanded one pixel and the separated "lagoons" were extracted. *Step 3*. The "lagoons" and the expanded land were reclassified into the same class. *Step 4*: the land (and "lagoon") was shrunk back by one pixel. *Step 5*: "lagoons" were extracted into a separate raster layer using a sea mask. This results in many small errors caused by the expand and shrink operations. *Step 6*: to remove the errors only those resulting enclosed bays that were more than 3 pixels in size and had a corresponding bay in the results of the original expand analysis were included in the final potential lagoons dataset (figure 7). Finally, partially separated lagoons were selected if they have a maximum depth of six metres and are no larger in size than 30 hectares.

3.3.4 Results

The prediction maps are two vector files outlining the presence of goes and Coastal lagoons partly separated from the sea. The results are shallow, sheltered water bodies that are wholly (gloes) or partially separated from the sea. The objects may overlap all other habitats except for Estuaries.

3.4 Large shallow inlets and bays (1160)

3.4.1 Input data

- Land and sea from maps [S2], [S12], [F1] [F12]
- Rivers [S3], [F2]
- Depth [S5], [F6]

3.4.2 GIS selection criteria

- Sheltered areas with land (> 1 hectare) within 1 km in 5 of 8 directions (approach 1).
- Sheltered areas with land (> 1 hectare) within 1 km in 7 of 8 directions (approach 2).
- They do not have a freshwater influx from a river and less than 20 % of their area is deeper than 15 meters. They are larger than 20 hectares (approach 1 and 2).

- A subset of areas larger than 100 hectares less than 6 m depth was made to meet the Finnish criteria of the habitat (approach 2).

	
Fig. 10a. *Large shallow inlets and bays Photo: NN, Affiliation.*	***Fig. 10b.*** *Large shallow inlets and bays. Photo: Sandra Wennberg.*

3.4.3 GIS analysis

The analysis is based on a raster with land and sea in 25m pixelsize. The number of directions out of eight (N, NE, E, SE, S, SW, W, and NW) in which sea pixels in are within 1 km of land was analysed (see figure 11 for approach 1 and figure 12 for approach 2). In this part of the analysis land areas smaller than 1 hectare are classified as sea, due to that their sheltering effect was considered too small. The output “bays” is sheltered areas defined by the number of directions with presence of land. Patches of open water surrounded by “bays” were identified and included in the bays. The “bays” were shrinked 4 pixels to remove small strings of “bays” along the shoreline. Areas intersecting with rivers were deselected. The “lagoons” that were too large or too deep to be Coastal lagoons were included. 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.

Approach 1: In Sweden areas with land in 5 of 8 directions were accepted as sheltered.

Approach 2: In Finland the analysis was done using a wedge shaped neighbourhood specified with a one degree difference in the start and end angles to achieve as thin a wedge as possible. Land had to be found in at least 7 directions. Out of the first set of bays a subset was further defined that conformed to the Finnish criteria of larger than 100 hectares and less than 20 percent of area deeper than 6 metres.

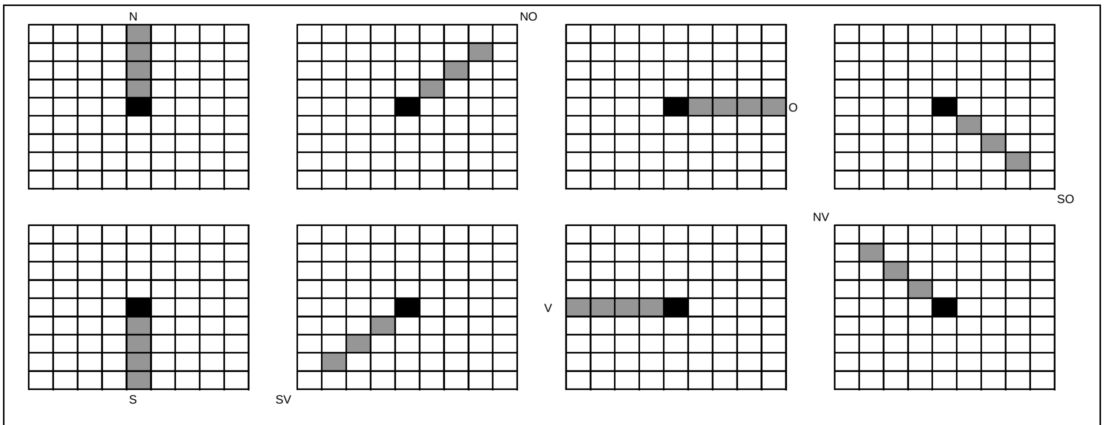

Fig. 11. *The figure shows a sketch of the GIS-model that identifies sheltered sea. The neighbourhood (gray) around each pixel (black) is searched eight times, once for each direction. The analysis returns the maximum value to the centre pixle that equals 1 if land is within the neighbourhood and 0 otherwise. The eight results are then summarized. In approach 1 the analysis was done in ERDAS Model builder and thergray area is 1 km long and one pixel wide Approach 2 used ArcGIS and the gray area was wedge shaped and 1 km long (se figure 11).*

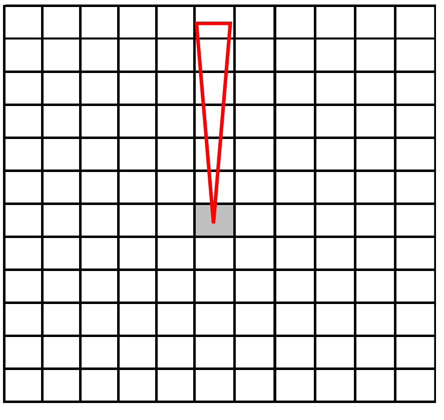

Fig. 12a. *Wedge shaped neighborhood analysis in ArcGIS*

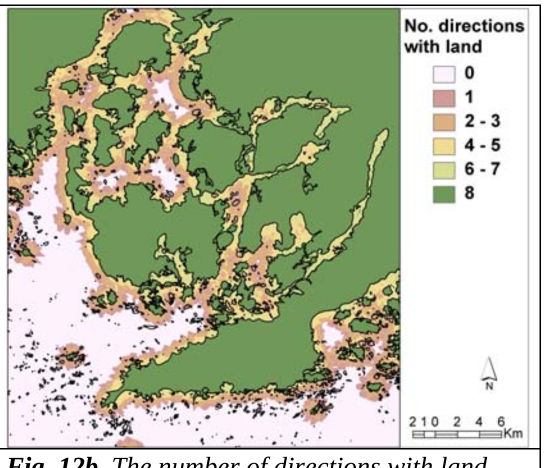

Fig. 12b. *The number of directions with land.*

3.4.4 Results

The prediction maps are a vector file outlining the presence of the habitat. The results are shallow, sheltered water bodies; the outline is somewhat artificial, based on a raster analysis and may appear strange. The objects may overlap all other mapped habitats except for Estuaries.

3.5 Reefs (1170)

Fig. 13a. *Fucus vesiculosus at reef Photo: Martin Isæus*

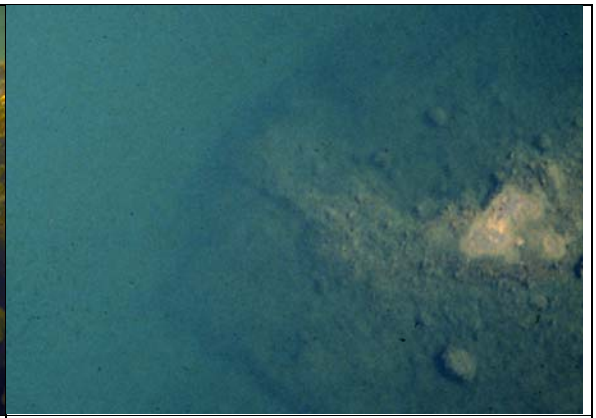

Fig. 13b. *Reefs. Photo: NN, Affiliation.*

3.5.1 Input data

- Depth surfaces and terrain model [S11], [S13], [F11], [F16]
- Surfs and sub surface rocks from nautical charts [S5], [F6]
- Soil type on land [F8]
- Land and sea [S1], [F1]
- Wave exposure [S8], [F9]
- Photic depth [F10]

3.5.2 GIS selection criteria

- Areas with potentially hard substrate that rise from the surrounding seafloor and have exposures within in a range from very sheltered to exposed (4,000-1,000,000 m^2/s) (approach 1 and 2).
- Maximum depth is photic depth (approach 2)
- Maximum depth is 10 m (approach 1)

3.5.3 GIS analysis

Approach 1: Potential hard bottoms were selected from two sources. First depth areas between 0 and 6 meters that intersect with wave exposure class “sheltered” or higher was selected (overlay of raster). Second, surfs and sub surface rocks were converted to a 25 m raster. This were analysed in “Neighbourhood Statistic” sum for a circle with a 150 radius. Values larger than 1 (having surfs or subsurface rocks in the neighbourhood) together with the shallow areas in exposed positions were merged to “potential hard bottom”. A layer of “potential reefs” was created by selecting peaks in the benthic terrain model overlapping with potential hard bottom areas. Areas deeper than 10 m were excluded because the input depth model was considered too inaccurate. Finally, the results are converted to a vector layer, objects intersecting land are saved as a separate layer 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.

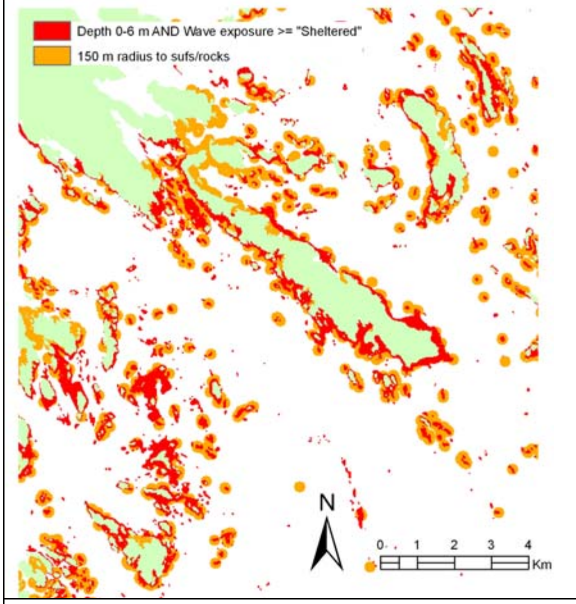

Fig. 14a. The selection of potential hard bottoms is a combination of shallow exposed areas (red) and the neighbourhood of 150 m around surfs and subsurface rocks in nautical charts (orange).

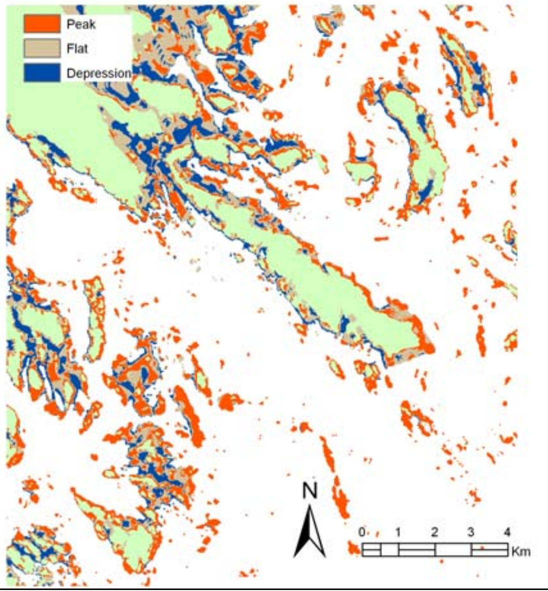

Fig. 14b. Peeks were separated from depressions and flat areas by subtracting the actual depth from an average depth within a 300 m radius. Reefs are peeks that overlap with potential hard bottoms.

Approach 2: Surfs and subsurface rocks were analysed using the Point Density tool. The density of rocks within a circular 150m search radius was calculated for a 50m raster dataset. A similar dataset was made for the length of rocky shoreline within a 150m search radius using the Line density tool. The results were merged to “potential hard bottom”. Potential reefs were created by extracting “mounds” from the Benthic terrain model, i.e. areas rising above their surroundings intersecting with “potential hard bottom”. Finally, areas that does not exceed photic depth and within wave exposure range 4,000-1,000,000 m^2/s were selected. Rocky elevations that intersect land are assigned to a separate subclass.

3.5.4 Results

The prediction maps are a vector file outlining the presence of the habitat. The results are peaks, with a high probability to be constituted of hard substrates. Biogenic reefs are not mapped. The objects may overlap all other mapped habitats.

3.6 Baltic esker islands (1610)

3.6.1 Input data

- Land and sea [S1], [F1]
- Depth [S5]
- Soil type [S7] [F8]

- Esker survey [F13]
- Photic depth [F10]
- Benthic terrain model [F16]

3.6.2 GIS selection criteria

- Islands with glacio-fluvial material. Surrounding sea areas in a 200 meter buffer zone is included, down to a maximum depth of 6 meters (approach 1).
- Esker islands and islands with > 50 % glacio-fluvial material. Surrounding sea areas in a 200 meter buffer zone is included, down to a maximum depth equal to photic depth (approach 2).

3.6.3 GIS analysis

Approach 1: Islands intersecting with glacio-fluvial 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.

Approach 2: Islands identified in the Finnish esker survey run in the 70s and 80s were automatically included as were islands digitised by the Nature Division at the Finnish Environment Institute as a part of their investigation into esker islands (Suutari et al, 2002 unpublished report). The soil map was reclassified to contain only what could potentially be "esker deposits" (classes: sand, gravel and till). Each "esker deposit" was assigned to a particular island and the percentage area of esker deposits on each island was calculated. Islands with > = 50 % of "esker deposits" were selected as esker islands. The submerged part of the islands was determined by including the "mounds" in the benthic terrain model that the island was the top of, limited by photic depth and a buffer of 200m.

3.6.4 Results

The prediction maps are a vector file outlining the presence of the habitat, the land and sea part separated. The results are islands of glacio-fluvial origin and the surrounding sublittoral environment in a 200 m buffer. The objects may overlap all other mapped habitats.

Fig. 15a. *Esker islands Photo: NN, Affiliation.*

Fig. 15b. *Boreal Baltic islets and skerries. Photo: NN, Affiliation.*

3.7 Boreal Baltic islets and small islands (1620)

3.7.1 Input data

- Land and sea [S1], [F1]
- Depth [S5]
- Photic depth [F10]
- Benthic terrain model [F16]
- Archipelago zones [F15]
- Wave exposure [S8]
- Forest cover from Swedish Land Cover [S4]
- Exposed bedrock [F4]

3.7.2 GIS selection criteria

- Islands without forest in exposed areas. Surrounding sea areas is included within a 200 meter buffer down to 6m depth. Reefs intersecting the areas are included (approach 1).

- Islands without forest in the outer archipelago. Surrounding sea areas in a 200 meter buffer zone is included, down to a maximum depth equal to photic depth (approach 2).

3.7.3 GIS analysis

Approach 1: Islands with no forest cover were selected. A majority filter operation is executed on the classified wave exposure data in order to exclude single pixels values. Islands intersecting with exposure class "sheltered" or higher (>4,000 m^2/s) are then selected. The submerged part of the habitat is determined as a buffer of 200 meters around the selected islands down to 6 meters depth. Reefs in contact with the buffer zone are included in the habitat.

Approach 2: Islands were selected if they were located in the outer archipelago zone (> 50% water) with no forest cover and no forested island within a 200m buffer in their neighbourhood. The submerged part of the island is defined according to it being topographically distinct from the surrounding seafloor (mound), down to the photic depth within a 200m buffer.

3.7.4 Results

The prediction maps are a vector file outlining the presence of the habitat, the land and sea part separated. The results are islands in exposed location with little or no trees and the surrounding waters within a 200 m buffer. The objects may overlap all other mapped habitats but reefs.

3.8 Summary of results

The results show potential areas of the Natura 2000 habitats, one map per habitat. The habitats may overlap each other. The total area mapped as either one of the habitats is 108,000ha and covers 7% of the sea area of the Swedish part of pilot area 3.

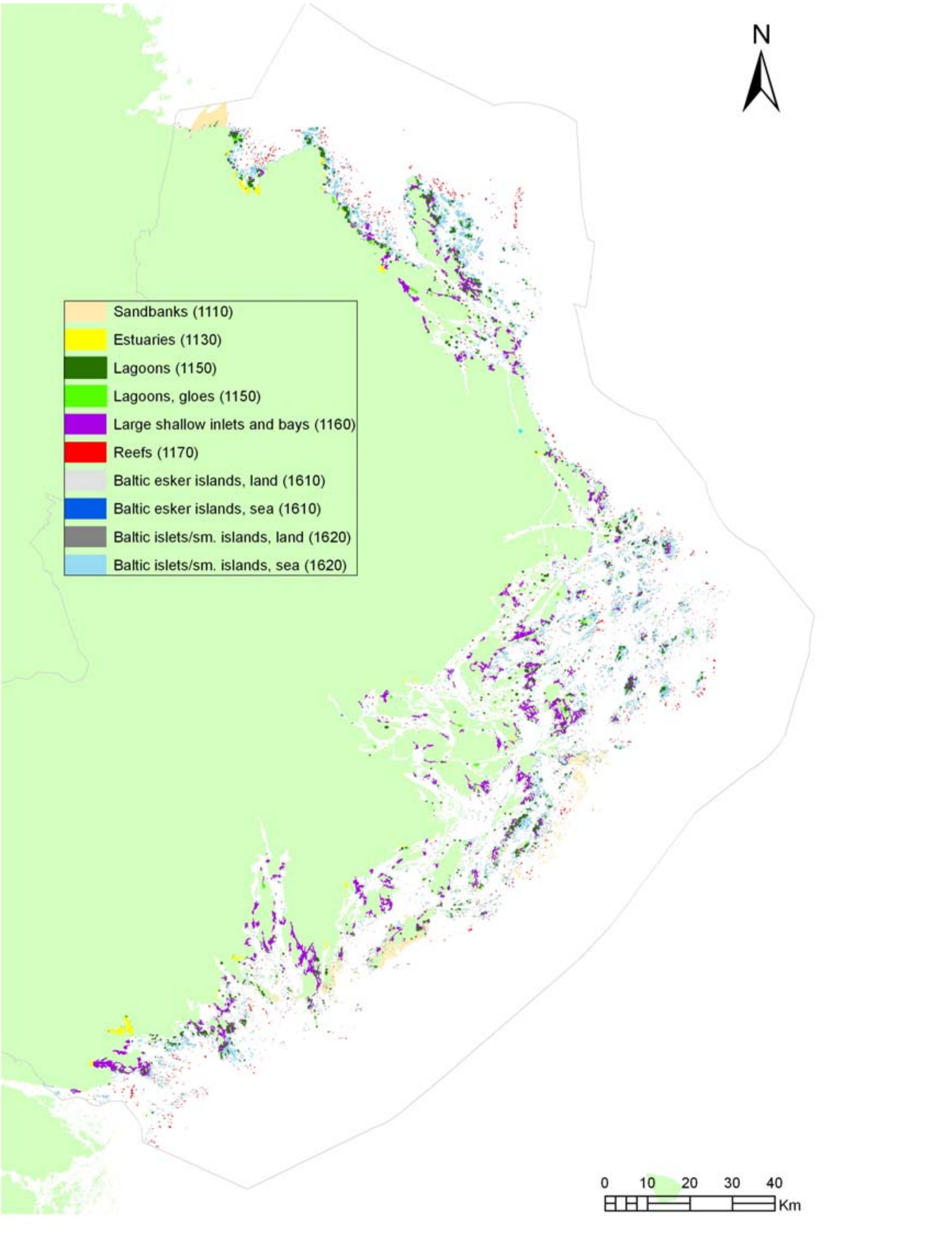

Fig. 16. *The distribution of Natura 2000 habitats according to the habitat directive Annex 1(the Swedish part of Pilot area 3). The habitats may overlap each other, in total the maps covers 7% of the sea (108 000 ha)*

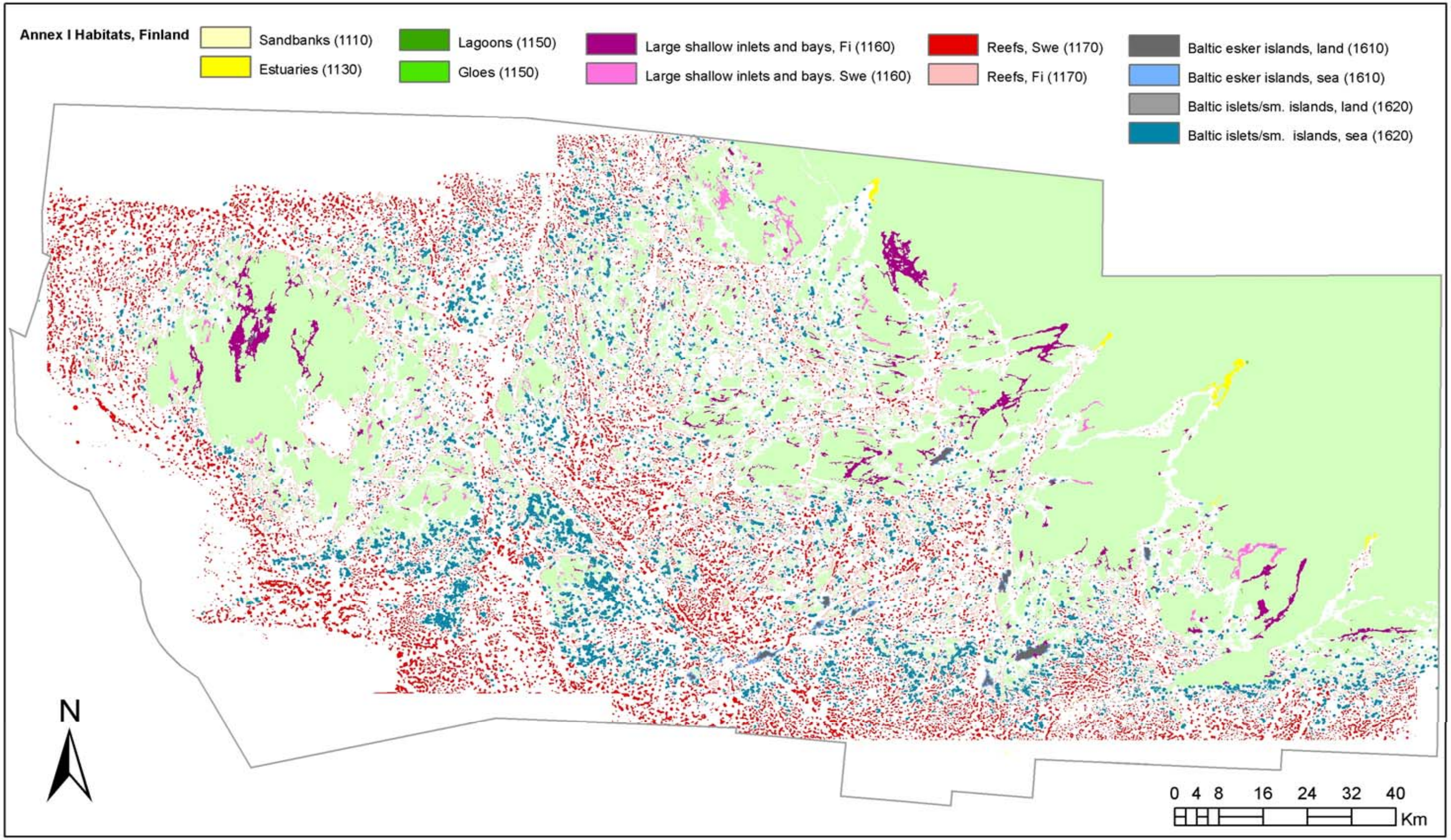

Fig. 17. *The distribution of Natura 2000 habitats according to the habitat directive Annex 1(the Finnish part of Pilot area 3*

4 VALIDITY OF THE IDENTIFIED HABITATS

There is not enough information to independently validate the majority of maps resulting from the GIS analyses. Validation is, therefore, presented here mainly as a discussion of the methods and criteria used and the effect they will have. Each habitat layer is discussed in chapter 4.1. A comparison between the mapped habits and known areas of high nature value in the Stockholm archipelago has been done. This gives some insights to how the result may find these areas, although it won't answer the question if the habits are well outlined or if the area is over estimated (chapter 4.2.1). A comparison between the habitat type Coastal Lagoons and the flads and gloes reported in literature, laid out in chapter 4.2.2, will give a similar account of one habitat type from the Finnish side of the pilot area. Again, this will show how well the GIS analysis for lagoons has been able to represent the known sites, but as the list from literature is not complete, it cannot be used to estimate how many sites are falsely identified.

4.1 Evaluation of maps, data and 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. Basic data that outlines water and land have enough quality. They are available in very detailed resolution (scale 1:20,000) that is needed to identify small habitats like small islands and lagoons, although maps in scale 1: 50,000 may well suite the purpose for most habitat modelling. The data on wave exposure and land cover have also enough quality to be used in these type of analyses. Better data on water flow from small rivers are wanted, as well as data on water quality. The main datasets required to produce high-quality detailed habitat maps are a high resolution map of the sediment characteristics and depth (e.g. multi beam surveys). Besides resolution, the current depth and substrate data available has two major problems; 1) There are quite large areas with very limited or no information available due to military restrictions and 2) the shallow areas of 0-6 meter are not well mapped.

Sublittoral sandbanks: 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. The results have very varied quality over the pilot area (figure 18).

Estuaries: Boundaries are set somewhat arbitrary regarding the actual water mixing and reeds are not always included in the habitat. In Sweden 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. In Finland the basins considered estuaries were defined by deciding on an artificial depth criterion to approximate the potential extent of freshwater influence. The actual extent is affected by both the flow of the river(s) and geographical attributes. In both cases 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.

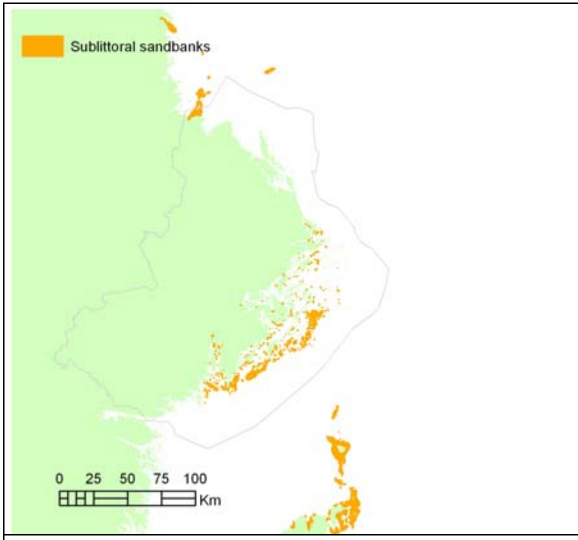

Fig. 18a. Occurrence of sublittoral sandbanks on the Swedish side of pilot area 3 based on geological maps.

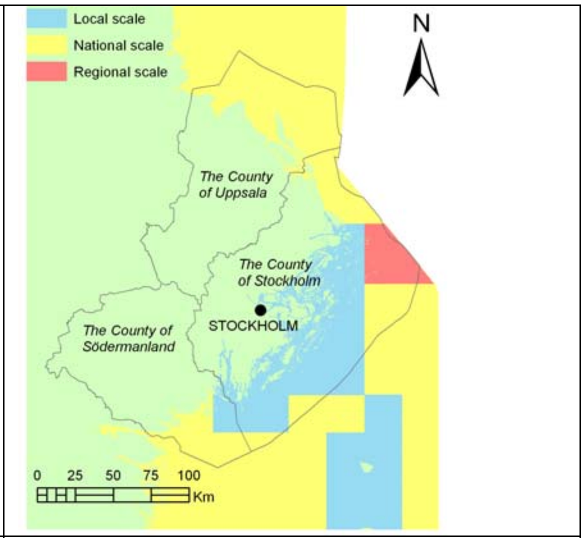

Fig. 18b. The knowledge of where sandbanks occur is correlated to the scale of the geological survey.

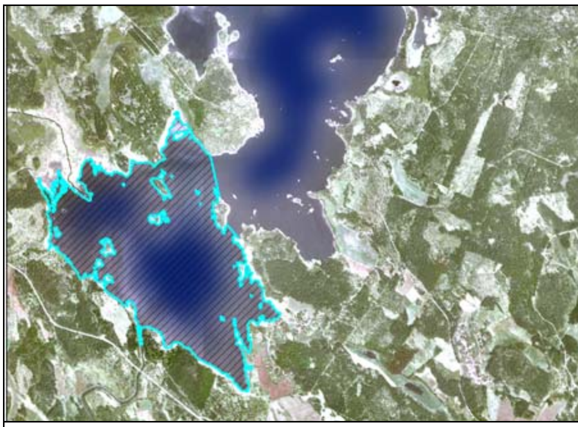

Fig. 19a. The estuary boundary towards the sea is drawn in line with the 3 m depth curve. This seems to lead to an overestimation rather than an underestimation of the area, especially in the shallow archipelago of Uppland.

Fig. 19b. 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). One estuary can have more than one river mouths.

Coastal lagoons: Resulting gloes 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). Some actual gloes identified in the field, were also not picked out by the analysis. This may be due to the uncertainty in the elevation model and its scale. The partially separated lagoon-analysis also leaves out lagoons smaller than 30m x 30m and lagoons that are narrower than 30m. The analysis may also miss and/or under estimate objects that are outlined by submerged thresholds towards the sea as depth information of an adequate resolution is not available. 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 20). These sites are, however, potential lagoons in the future with continuing land uplift. Artificial pools (harbours, piers) are not included in the Swedish results where the exploitation index is used to only include unexploited areas.

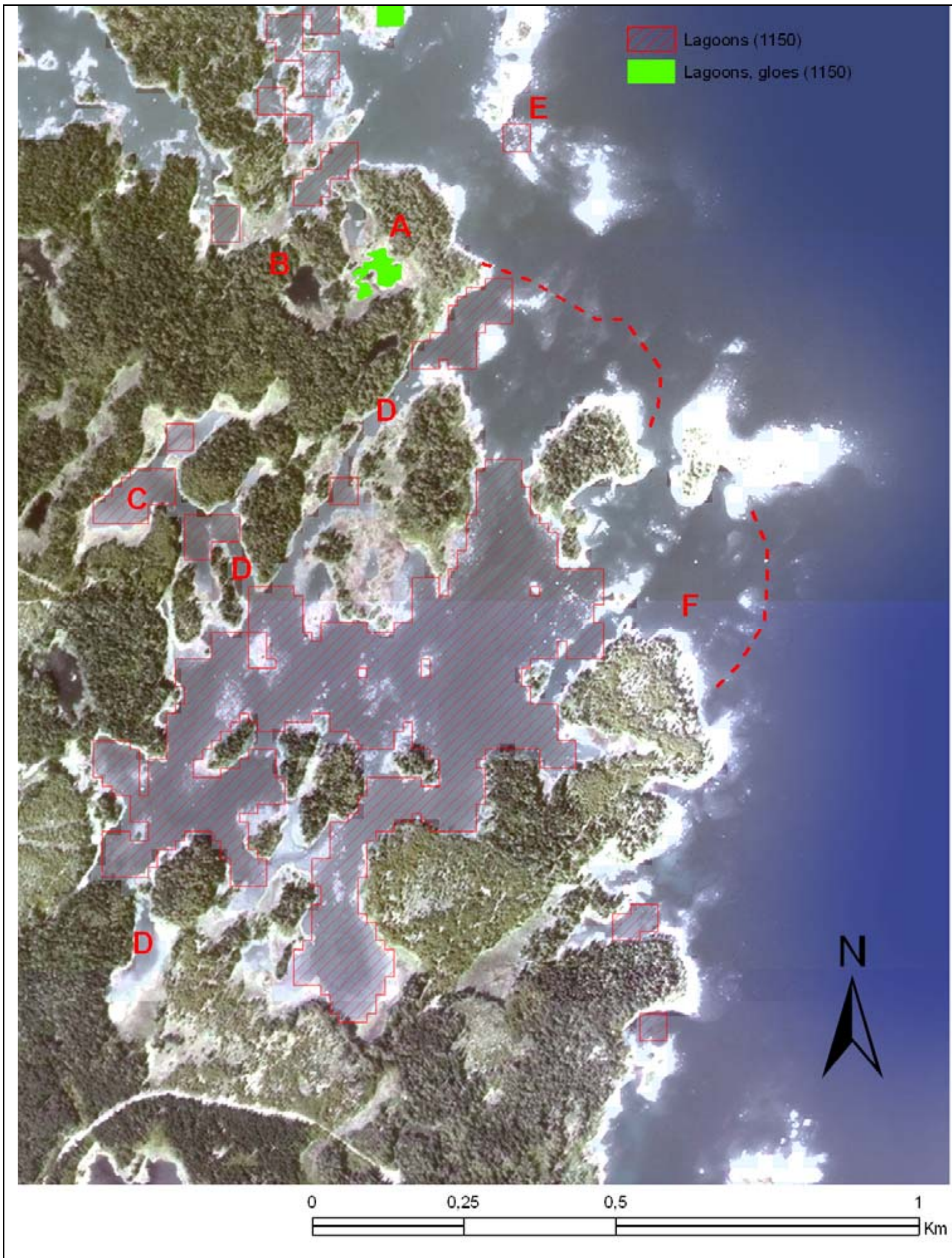

Fig. 20 *Results from the Coastal lagoon analysis. The analysis of gloes identifies lakes (according to maps) that are within 15 meter to the shore line (A). In the flat topography of Uppland, lakes even further from the shore (B) may be recently separated from the sea. The analysis misses these objects. The analysis of partially separated lagoons identifies shallow areas that have an opening towards the sea more narrow than 30 meters (C). The analysis miss areas more narrow than 30 meters (D) and false lagoons can be created when small skerries are close to each other, forming a pool (E). The analysis identifies important locations but probably underestimate the area of lagoons. 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 could most probably be included (F) as several thresholds are present (red lines).*

Large shallow inlets and bays: The results are shallow, sheltered water bodies. No information weather the object does have high biodiversity or a well developed zonation exists. The analysis excludes areas smaller than 20 ha and may miss areas that have a freshwater inflow, although of minor effect on the habitat. The analysis also creates rather irregular shaped edges toward the sea, and often includes areas where there are large numbers of islands in close proximity.

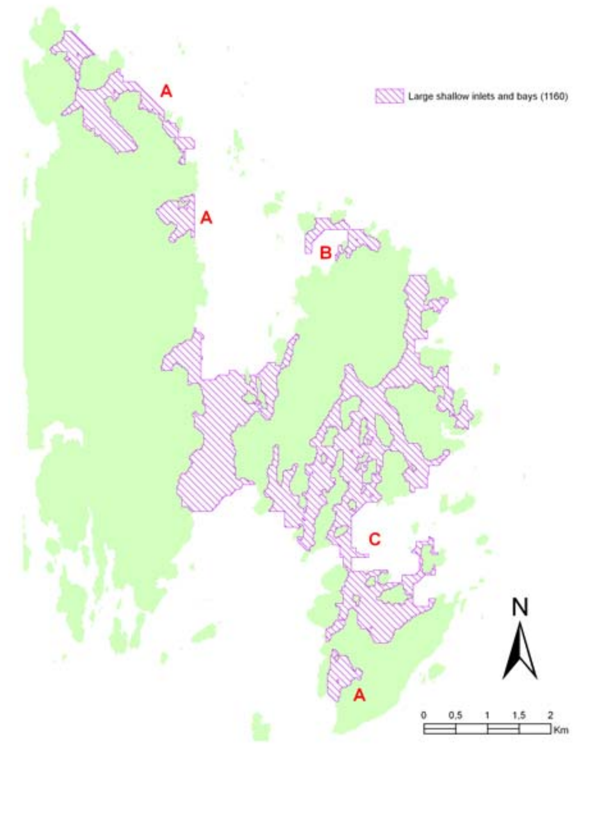

Fig. 21a *Mapped 1160 in the County of Stockholm. The outline is usually good (A). The analysis is based on each pixels proximity to land in a raster, this can lead to that only areas closest to land are included (B) or to outcrops of the bay into open sea (C).*

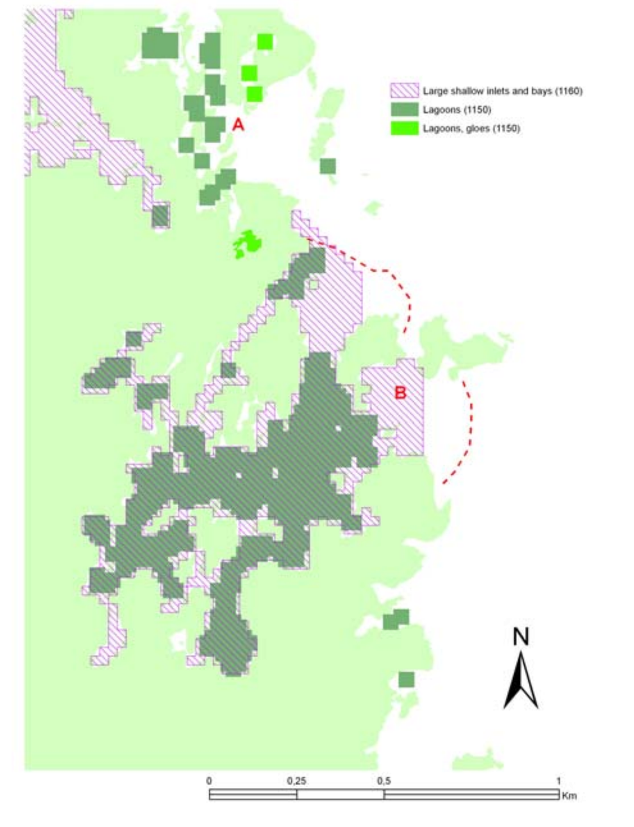

Fig. 21b *Mapped 1160 on top of 1150. The results overlap to some extent when the objects are between 20-30 ha and more shallow than 6 m. The majority of the mapped lagoons are small separated objects (A) while the objects mapped as Large shallow bays are large and captures the whole sheltered area of the bays (B). Both results are shallow sheltered areas with a high potential of having high nature value.*

Reefs: The method produced potential locations for reefs. However, the presence of a hard substrate is postulated from the presence of rocks marked on nautical charts. This attribute is the generalised to an entire elevated area. Whilst the rock often correspond to submerged bedrock formations, they may also be boulders in a till formation. The accuracy of the selection process would improve with better depth data. With better depth data in deeper areas, more deep reefs could be found. 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 extent of the selected areas may differ some, depending on how certain selection criteria is set, such as the radius of the neighbourhood, when selecting peak areas or extrapolating hard substrate from rocks.

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 hard bottom substrates according to the detailed geological information. The area cover of the EUNIS-classes within the mapped reefs shows that besides hard bottoms, about 15 % are glacial clays and 4 % are mixed bottoms.

Baltic esker islands: The results have major uncertainties, and better geological information is needed to perform GIS-analysis. Mapping by interpretation of aerial photos may be a better approach. In Sweden only islands with glacio-fluvial material are selected, although eskers forming a spit could be included in the habitat, having the same type of environment. The map of soil types does not cover the whole pilot area. In Finland the entire island was selected even if only part of it was esker. No data was available on macrophyte vegetation. An approximation of the photic depth is used as a proxy for the presence of sublittoral vegetation. The extent of the formation below the surface is represented by a 200m buffer, which may either underestimate or overestimate the actual formation Often an esker will form a chain of several islands. The presence of glacio-fluvial material in the buffer zone is not included in the analysis as this data was considered too uncertain, and was not available for the whole area. Better data on depth and glacio-fluvial deposits below water would improve the analysis, by allowing the determination of the entire esker formation both above and below the surface.

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.

4.2 Validation with field data

4.2.1 Sweden

A comparison between known shallow areas with high nature value (107 locations) and the mapped results was done to validate how the different steps in the methods include or exclude areas from the results (table 4). The known areas were mapped as center points of the bay. An overlap analysis (intersect) was made between the locations and the habitat layers of Lagoons (gloes included), Estuaries, Large shallow inlets and bays, Islets and small islands and Esker islands. For the analysis of lagoons (gloes incl.) a query weather the point was in the neighborhood (distance of 500 m) to a mapped lagoon was also done as the mapped lagoons are very small and the point location sometimes was indicating larger areas with several shallow fladas or gloes.

77 of the locations are described as either one of the succession stages flada, gloflada or glo. The most accurate description among the Natura 2000 habitats would then be lagoons or Long and narrow bays, although the identified location is often a centre point in a larger bay whereas the different stages form a complex. The majority of the location was captured in one or several of the analysis (60 locations, 78 %). 50 (65 %) were mapped as large shallow inlets and bays, 27 (35 %) were mapped as lagoons and 5 (6 %) were mapped as Estuaries. The reason why the remaining 17 or 22 % of the locations was not mapped as either one of the habitats where:

- Ten locations had been discharges from the analysis of Large shallow inlets and bays due to freshwater inflow.
- Three was lagoons that had physical exploitation.
- Two lagoons were influenced by rivers in the analysis
- Two bays had openings towards the open sea that were too wide to be captured in any analysis, although described as having thresholds in the openings.

20 of the locations were described as a preface to a flada. The most accurate description among the Natura 2000 habitats is either Large shallow inlets and bays, Lagoons or Long and narrow bays. 14 of the locations (70 %) were mapped as either one of the habitats. The reason why the remaining 6 or 30 % of the locations was not mapped as either one of the habitats where:

- Two were influenced by rivers in the analysis
- Four bays had openings towards the open sea that were too wide to be captured in the lagoon analysis, and were too small to be captured as Large shallow inlets and bays.

Table 4. Evaluation of the maped habitats against locations of shallow areas with high nature value (the Conty administrative boeard of Stockholm 2003)

Type of location	No.	% in maps	No. as 1130	No. as 1150	No. as 1160	No. as 1610	No. as 1620
Flada/glo	77	78%	5	27	50	N/A	N/A
Preface to flada	20	70%	0	4	11	N/A	N/A
Varied	5	80%	1	0	3	0	1
Exposed	5	100%	0	0	3	1	2
Sum	**107**	**78%**	**6**	**31**	**67**	**1**	**3**

Five locations were described as exposed, all captured in the maps. Two were Islets and small islands, one was an Esker island and two were Large shallow inlets and bays. Five locations were described as varied, all but one captured in the maps. Three were Islets and small islands, one was an Estuary and one had an opening towards the sea that was too open to be captured in anal analysis.

The second evaluation was done by using the 66 river moths that had been identified in the inventory of shallow areas with high nature value, although not inventoried. Only rivers on the mainland were included in the inventory. An overlap analysis was made between estuaries on the mainland and the identified locations. 42 of the 66 locations (64%) were mapped as estuaries. Of the 69 Estuaries on the mainland, 33 (48%) locations were identified as river moths with a high probability of having high nature values.

The last evaluation was done by using in the inventory of bays with a threshold towards the open sea (the County administrative board of Stockholm 1991). The inventory identified 85 locations. Of the 85, locations 45 (53 %) were mapped as one of the habitats, 31 as Large shallow inlets and bays, 11 as Lagoons and 6 as Estuaries. Of the remaining 40 bays not mapped were:

- 29 discharges from the analysis of large shallow bays due to freshwater inflow

- Six discharges from the analysis of lagoons due to exploitation
- Three discharges from the analysis of lagoons due to freshwater inflow
- Two were too open to be captured in the analysis of lagoons and to small to be a Large shallow inlets and bays

The raster analyses that captures sheltered shallow areas that are the basis for the later selection of lagoons, large shallow bays or estuaries together with the depth selection works very good. Of the 182 locations that were either fladas/gloes, preface to flada or bays with thresholds towards the sea only two (1%) were not identified in this stage of the analyses.

In order to get a selection of areas that are close to the definitions of the habitats fresh water inflow from rivers were used to exclude areas from the analysis of lagoons and large shallow inlets and bays. Not all of these areas became mapped as Estuaries as not all have sedimentation at the river mouth. The freshwater criteria had the largest impact on the selection of Large shallow inlets and bays. 46 of the known locations, or 25 % was not in the resulting maps due to the criteria. Rather large areas become deselected due to one river at one end, although others may not fulfill the definition of a Natura 2000 habitat. Almost half of the area of Large shallow inlets and bays became deselected due to the criteria of freshwater inflow (29 000 ha of 63 000 ha). In the lagoon analysis the freshwater criteria did not effect the results so much, and as the mapped lagoons are much smaller water bodies, a river into the bay will have a larger impact.

Nine (5%) of the locations had been deselected from the lagoon results due to the degree of physical exploitation along the coastline. This criterion affects the analysis of lagoons partially separated from the sea. Former analysis of lagoons in Sweden identified that the largest problem with the results were presence of small harbors and marinas in the resulting maps of lagoons. It does have a large effect in the pilot area; about half of the objects and area becomes deselected due to the criterion.

4.2.2 Finland

The success of the 1150 Lagoons datasets on the Finnish side was tested using a number of field observations of flads and gloes collated from literature. The available field dataset is not exhaustive and thus cannot be used to estimate the number of areas the lagoons analysis falsely identifies as lagoons (commission error). This could only be done if a comprehensive survey of flads and gloes was available covering the entire survey area. Consequently only omission error (existing lagoons that the analysis did not identify) can be quantified. In this case all of the phases of flad development (juvenile flad, flad, and glo-flad) were grouped under flads, whereas gloes were kept separate. There were 385 flads and 83 gloes in total identified from the study area, of which just under half (40%) of the flads and a minor fraction of the gloes (8%) were identified as lagoons by the analysis (table 5).

Over half of the flads (47%) were not recognised by the analysis. Some of the flads (14%) fell into the areas classified as large bays by the bays analysis, which is to be expected as the analyses identified very similar areas. In both cases the error was likely due to depth and size, which were set according to existing criteria in descriptions of the habitat type. Flads identified in the field do not however follow these criteria strictly, there are many amending features.

The majority of gloes (86%) was not identified by the analysis. It was difficult to separate gloes from coastal lakes using a GIS analysis bases solely on distance from shore and elevation from sea level. A more detailed analysis including detailed elevation data and data on small streams and ditches is needed, to analyse flow direction under various sea levels (also higher sea levels during storm events) to elucidate which coastal lakes have a potential irregular connection to the sea.

Table 5. Evaluation of the mapped lagoon habitats against the known locations of lagoons and gloes from literature

	Total count	No. as 1130	% as 1130	No. as 1150	% as 1150	No. as 1160	% as 1160	No. as other	% as other
Flads	385	0	0%	153	40%	52	14%	180	47%
Gloes	83	1	1%	7	8%	4	5%	71	86%

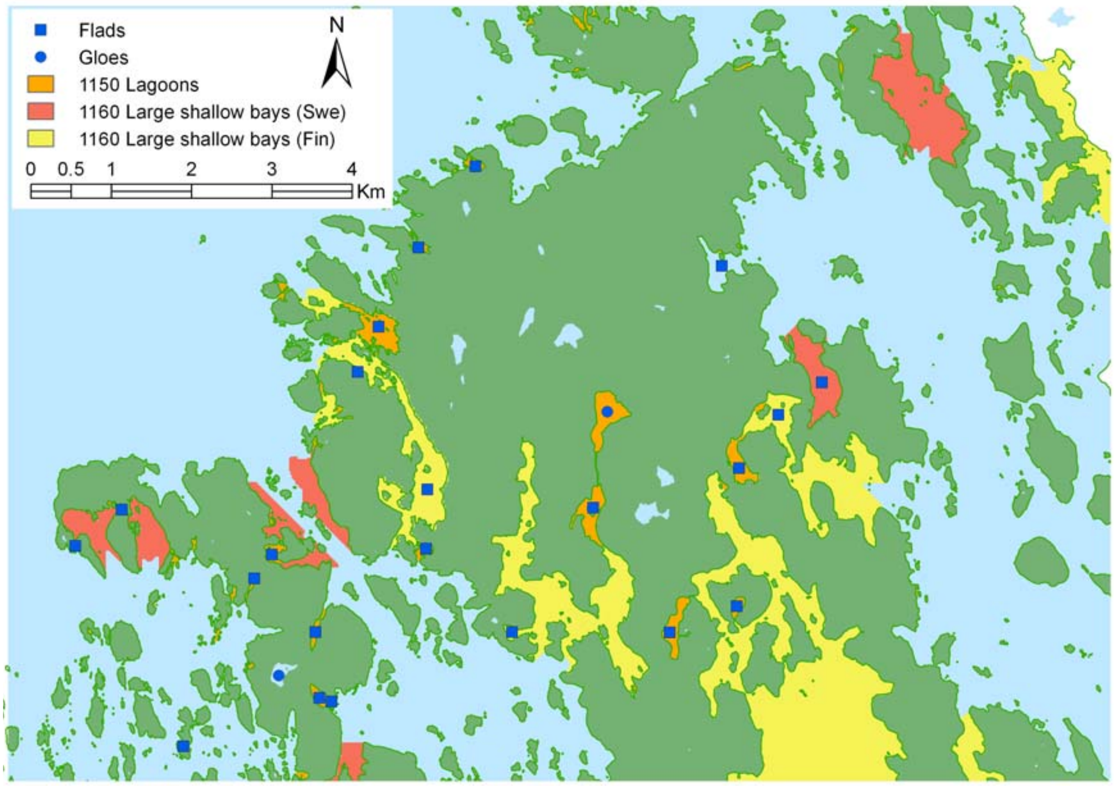

Fig. 22. *A close up of one area in the flads and gloes dataset, with the observed flads (squares) and gloes (circles) from the literature sources overlaid.*

5 CONCLUSIONS

5.1 General conclusions

The methods are direct and very useful for habitat modelling of Natura 2000- habitats and are possible to harmonise over national boarders. In this study, changes of some of the criteria due to differences in input data and in geomorphology resulted in more comparable results. In other cases definitions were interpreted differently or an input was missing in one of the countries, whereas the methodology made it possible to have national subsets of the common result. 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 in Sweden and Finland. Due to lack of data the following areas are known to be lacking in the results:

- Deeper reefs (shallowest part deeper than 6 m) and the deepest part of the reefs identified (> 10 m of depth)
- Lagoons with wider openings than 30 m, separated from the open sea by sub-merged sills
- Sublittoral sandbanks outside the geologically surveyed areas
- A separation between large shallow inlets and bays and Long narrow inlets

In general the modelled layers satisfy the needs of large scale planning of the coastal sea. All maps shows the potential of the occurrence of the habitats and can be used to derive habitat complexity maps, estimate the proportion of protected versus unprotected areas of the habitats and can be used as a first selection of areas to be of interest for more detailed surveys. The Natura 2000 habitats do not cover deeper habitats or shallow hard bottom habitats that may have high nature value.

5.2 Future recommendations

To get a more complete overview for management these results could be complemented with models showing:

- Vegetation cover in shallow soft bottoms
- Vegetation cover around islands
- Shallow hard bottoms with zonal vegetation
- Deeper hard bottoms with zonal vegetation
- Deeper soft bottoms separated into sandy/muddy areas without oxygen depletion
- Areas with high values for fish

Some of the part results from the analyses could be used to fulfill the overview for managers:

- The part result from the reef analysis when sloping sea beds are excluded due to the connection to land are most probably hard substrates with zonal vegetation

- The part result of Large shallow inlets and bays influenced by fresh water inflow can still have high nature values depending on water exchange.
- The part result of lagoons with exploitation can have high nature values or be possible to restore.

The results show potential areas of the Natura 2000 habitats, one map per habitat. The habitats may overlap each other. This can be used to find complex areas with a potential of having high nature values. To be able to separate the habitats from each other in such a heterogeneous area as the archipelago, field visits are probably needed in combination with a discussion of the definitions and priority between habitats.

6 REFERENCES

Aaltojen alla, 2006. A web site describing the Baltic Sea and its underwater life. Accessed on 7.2.2006 at http://www.aaltojenalla.fi/.

Airaksinen, O. and Karttunen, K. 1998: Natura 2000 - luontotyyppiopas. Ympäristöopas 46. Suomen ympäritökeskus, Helsinki.

Axelsson, S. 2003: Kartering av vissa kustbiotoper som utpekas i EU:s habitatdirektiv. Rapport för Naturvårdsverket. Metria Miljöanalys.

Cato, I., Kjellin, B. och Zetterlund, S. 2003: Förekomst och utbredning av sandbankar, berg och hårdbottnar inom svenskt territorialvatten och svensk ekonomisk zon (EEZ).SGU Rapport 2003:1. Sveriges Geologiska Undersökning (SGU). Uppsala.

Coastal Guide to Europe, 2006. Archipelago Sea Biosphere Reserve, a web page of the Coastal Guide to Europe. Accessed on 7.2.2006 at http://www.coastalguide.to/archipelago/main.html.

European Comission, dg Environment 1999: Interpretation manual of European Union Habitats. EUR 15/2

Häkkinen, A. 1990: Saaristomeren vedenalaisten maa-ainesvarojen kartoitus Gullkronan selällä 1989. Varsinais-Suomen seutukaavaliitto, Turku. 58 p. In Finnish.

Isæus, M. 2004: A GIS-based wave exposure model calibrated and validated from vertical distribution of littoral lichens. In thesis: Factors structuring Fucus communities at open and complex coastlines in the Baltic Sea. Doktorsavhandling vid Botaniska Institutionen, Stockholms Universitet: Stockholm.

Mattisson, A. 2005: Mapping Marine Habitats. Pilot study for the coastal areas of the Stockholm County. County administrative Board of Stockholm. Available at http://www.ab.lst.se/upload/dokument/publikationer/M/Rapportserien/2005/R2005_21_Marine_mapping.pdf

Munsterhjelm, R. 1997: The aquatic macrophyte vegetation of flads and gloes, S coast of Finland. Acta Botanica Fennica 157

Mäkinen, J. and Saaranen, V. 1998: Determination of post-glacial land uplift from the three precise levellings in Finland. Journal of Geodesy 72, 516–529.

Numminen, S. 1999: Fladat ja Kluuvijärvet Saaristomerellä. Suomen ympäristö 339. Lounais-Suomen Ympäristökeskus

Philipson, P. och Lindell, T. 2003: Nationell kartering från satellitbilder av strandtyper längs svenska havskusten. Rapport för Naturvårdsverket. Centre for Image Analysis, Swedish University of Agricultural Sciences, Uppsala University. (in Swedish)

Seinä, A. et al., 2001. Ice seasons 1996-2000 in Finnish sea areas. MERI – Report Series of the Finnish Institute of Marin Research, No. 43.

Smedberg, E. 2006: Brygginventering i flygbilder längs Sveriges kust. Report for the Swedish Environmental and Protection Agency (in Swedish). Metria Miljöanalys.

Swedish environmental protection agency 2006: Sammanställning och analys av kustnära undervattenmiljö. Report no. 5591 (in Swedish)

The county administrative board of Stockholm 1991: Trösklade havsvikar. Rapport nr 1991:9 (in Swedish)

The county administrative board of Stockholm 2003: Skyddsvärda grundområden I Svealands kärgårdar. Rapport nr 2003:05 (in Swedish)

Virtasalo, J.J., Kohonen, T., Vuorinen, I., Huttula, T., 2005: Sea bottom anoxia in the Archipelago Sea, northern Baltic Sea - Implications for phosphorus remineralization at the sediment surface. Marine Geology 224, 103-122.

About the **BALANCE** project:

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

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

The **BALANCE Report Series** includes:

BALANCE Interim Report No. 1	Delineation of the BALANCE Pilot Areas
BALANCE Interim Report No. 2	Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea – an interim strategy
BALANCE Interim Report No. 3	Feasibility of hyperspectral remote sensing for mapping benthic macroalgal cover in turbid coastal waters of the Baltic Sea"
BALANCE Interim Report No. 4	Literature review of the "Blue Corridors" concept and its applicability to the Baltic Sea
BALANCE Interim Report No. 5	Evaluation of remote sensing methods as a tool to characterise shallow marine habitats I
BALANCE Interim Report No. 6	BALANCE Cruise Report – The Archipelago Sea
BALANCE Interim Report No. 7	BALANCE Cruise Report – The Kattegat
BALANCE Interim Report No. 8	BALANCE Stakeholder Communication Guide
BALANCE Interim Report No. 9	Model simulations of blue corridors in the Baltic Sea
BALANCE Interim Report No. 10	Towards marine landscapes of the Baltic Sea
BALANCE Interim Report No. 11	Fish habitat modelling in a Baltic Sea archipelago region
BALANCE Interim Report No. 12	Evaluation of remote sensing methods as a tool to characterise shallow marine habitats II
BALANCE Interim Report No. 13	Harmonizing marine geological data with the EUNIS habitat classification
BALANCE Interim Report No. 14	Intercalibration of sediment data from the Archipelago Sea
BALANCE Interim Report No. 15	Biodiversity on boulder reefs in the central Kattegat
BALANCE Interim Report No. 16	The stakeholder – nature conservation's best friend or its worst enemy?
BALANCE Interim Report No. 17	Baltic Sea oxygen maps
BALANCE Interim Report No. 18	A practical guide to Blue Corridors
BALANCE Interim Report No. 19	The BALANCE Data Portal
BALANCE Interim Report No. 20	Pelagic habitat mapping: A tool for area-based fisheries management in the Baltic Sea
BALANCE Interim Report No. 21	Mapping of marine habitats in the Kattegat
BALANCE Interim Report No. 22	E-participation as tool in planning processes
BALANCE Interim Report No. 23	The modelling of *Furcellaria lumbricalis* habitats along the Latvian coast
BALANCE Interim Report No. 24	Towards a representative MPA network in the Baltic Sea
BALANCE Interim Report No. 25	Towards ecological coherence of the MPA network in the Baltic Sea
BALANCE Interim Report No. 26	What's happening to our shores?
BALANCE Interim Report No. 27	Mapping and modelling of marine habitats in the Baltic Sea
BALANCE Interim Report No. 28	GIS tools for marine planning and management
BALANCE Interim Report No. 29	Essential fish habitats and fish migration patterns in the Northern Baltic Sea
BALANCE Interim Report No. 30	Mapping of Natura 2000 habitats in Baltic Sea archipelago areas
BALANCE Interim Report No. 31	Marine landscapes and benthic habitats in the Archipelago Sea
BALANCE Interim Report No. 32	Guidelines for harmonisation of marine data
BALANCE Interim Report No. 33	The BALANCE Conference

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