BALANCE Interim Report No. 31

Marine landscapes and benthic habitats in the Archipelago Sea

Baltic Sea Region INTERREG III B

BALANCE

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Anu Reijonen, Anna Nöjd, Heta Rousi and Aarno Kotilainen</td><td colspan="4">Date
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CONTENTS

0 PREFACE

This report describes the validation of local scale marine landscapes and EUNIS habitats of the Archipelago Sea, in the BALANCE Pilot area 3. Marine landscapes are an approach to classify the marine environment on the basis of available geophysical and hydrographical parameters to represent ecologically valid assemblages. First, we describe the identification of the Archipelago Sea local scale marine landscapes and the EUNIS habitats and study their distribution. Then we examine the accuracy and confidence of the datasets and lastly analyse the biological relevance of the landscapes and the habitats identified. Validation was accomplished with statistical analyses on the basis of benthic grab samples and underwater video.

The Archipelago Sea forms a heterogeneous natural environment, where wave exposure, topography and seabed substrates among other environmental parameters vary within a small area. It is a high interest area for many uses, e.g. recreational activities, fishing and shipping routes. Many studies have been conducted in the area and as a consequence there is generally a good availability of data. In addition to the BALANCE, the Archipelago Sea has served as a pilot area for the Finnish Inventory Programme for the Underwater Marine Environment, VELMU.

Local scale marine landscapes, which we present here, give insight to what the archipelago consists of and more importantly enable validation of the available datasets. Marine landscapes have to include ecological relevance in order to be useful proxies of biological diversity in a management context. Thus the knowledge of what can be drawn from them, in relation to biological values, is vital for informed planning and management. In addition, the work was undertaken in order to bridge the gap between marine sciences, especially between biologists and geologists. We aimed to identify the communication gaps and to highlight the need for multidisciplinary work.

The work should be seen as an initial step to assess the ecological value of marine landscape as well as to find targets for further development. Results from the study are promising but should be taken as first steps. Current marine landscapes are not yet inclusive, but a good start for developing ecosystem-based tools for marine management.

The results, products and recommendations presented do not represent any official national viewpoints of the involved research institutes or governmental agencies but represent the experiences of an independent partnership. The work has been financed by the European development fund BSR INTERREG IIIB Neighbourhood Programme, The Finnish Ministry of Environment and partly by the involved partners.

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

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1 INTRODUCTION

The EU -co-funded BALANCE-project (Baltic Sea management – Nature conservation and sustainable development in the marine ecosystem through marine spatial planning) set out to develop transnational marine spatial planning tools, as well as an agreed template for marine management planning and decision-making (http://balance-eu.org). Marine Landscapes for the Baltic Sea and habitat maps in selected areas are a central outcome of the BALANCE project. Marine landscapes (Seascapes) have been put forward as proxies of biological and ecological variables (Roff and Taylor, 2000; Golding et al. 2004; Connor et al., 2006; Heap, 2006). They are seen as a cost-effective means to guide environmental managers in ecosystem based decision-making. In order to be able to use them in management, we must assess their accuracy, confidence and biological relevance to ensure their validity and to avoid pitfalls. In addition, we must be aware of their faults and advantages to make suggestions on how the said maps could be used in management and planning.

1.1 The study area – Archipelago Sea

The Archipelago Sea is located in the junction of the Baltic Proper, the Gulf of Finland and the Gulf of Bothnia (Fig. 1). It is a shallow sea area with over 40 000 rocky islands and islets (larger than ½ ha) extending from Hanko peninsula in the east to the large Åland islands in the west. Continuous land uplift (3-4 mm/year) has had a strong impact on the nature of the area (Mäkinen & Saaranen 1998); small islets are transformed into big islands and finally to parts of the growing mainland. New bays are formed, and existing shallow sheltered bays are turned into lakes eventually cut off from the sea. The water depth, exposure of the shore, sea bottom type and other environmental factors vary within small areas. Together with the strongly meandering shoreline this results in an archipelago of extremely varied natural environments.

The Archipelago Sea is of high interest for many users. It has large shipping routes and substantial leisure boat traffic. The area is important for professional fishermen and leisure fishing activities alike. The archipelago is a very popular holiday location, with a high number of summer houses. The area is known to be very heterogeneous and has good data availability for biological data as well as local scale geophysical and hydrographical data. The development of marine landscapes and high level habitat maps of the Archipelago Sea has focused on areas where local scale (1: 20 000/1: 100 000) substrate data exists (Häkkinen A., in prep.) (Fig. 1). The Archipelago Sea is also a military interest area, which has complicated study by restricting free data distribution. The difficulties with data distribution can hopefully be avoided in the future with better guidance from defence forces.

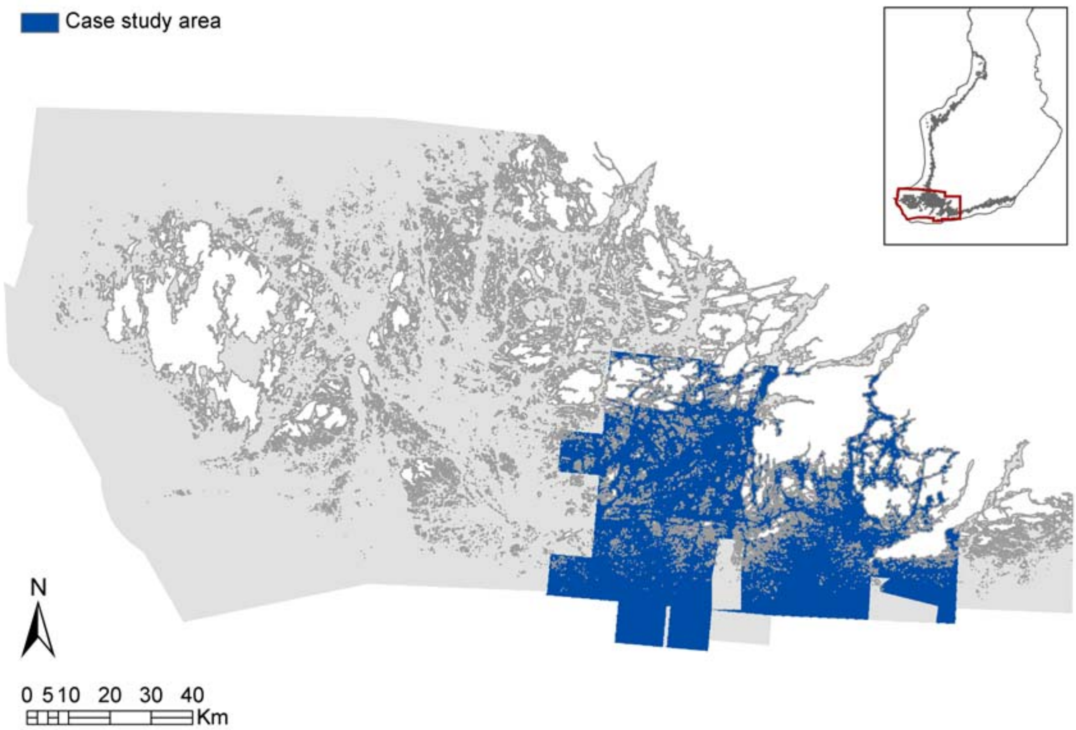

***Figure 1**. The Archipelago Sea (Baltic Sea) case study area in BALANCE pilot area 3.*

1.2 Aims and Objectives of the report

This report explains the procedure behind the detailed scale marine landscapes and EUNIS habitat maps, identified from the Finnish side of BALANCE pilot area 3, the Archipelago Sea. Marine landscapes have already been identified for the whole Baltic Sea basin (Al-Hamdani, Z. and Reker, J. (eds.) 2007; Al-Hamdani et al., 2007; Reijonen et al., submitted). This detailed study gives an insight to the true heterogeneity of landscapes in the archipelago area and more importantly enables biological validation and confidence assessment of habitats and landscapes identified. It also presents an opportunity to compare the landscapes and habitats classified according to the European Nature Information System (EUNIS) marine habitat classification. The input datasets from the area are more synchronous than for the Baltic Sea landscapes, which ease confidence analysis and comparison. Aims and objectives of this report are:

- Describe detailed scale marine landscapes and EUNIS habitats
- Assess the accuracy and confidence of background datasets to evaluate usefulness of the landscape and habitat maps
- Study biological relevance of the landscape and habitat maps
- Improve communication between geologists and biologists
- Provide suggestions for future development of marine landscapes

2 BACKGROUND DATASETS

Marine landscapes and EUNIS habitats have been developed based on available geological, geophysical and hydrographical data. With the marine landscapes, we started the identification process by gathering data and harmonising it to BALANCE classification schemes (Al-Hamdani and Reker (eds.), 2007). Data was received from various sources and in different formats. Majority of the datasets were in raster/vector format and only a few had to be interpolated from point data. Each dataset used was classified to biologically relevant classes to limit the number of possible landscapes (Table 1). The same classification, as in the landscapes for the whole Baltic Sea, has been used, unless otherwise mentioned. Below we describe each dataset shortly. A more detailed description of the biological justification behind the chosen classification can be found in BALANCE interim report no. 10 "Towards marine landscapes in the Kattegat and Baltic sea" (Al-Hamdani and Reker (eds.), 2007).

Table 1. The parameters and their classification used to identify Marine Landscapes and EUNIS habitats for the Archipelago Sea

Parameter	Data holder	Original format	Classification for marine landscapes	Classification for EUNIS habitats
Substrates	GTK	Vector	1. Bedrock 2. Complex 3. Sand, gravel 4. Hard clay 5. Clay, mud	1. Rock (Bedrock) 2. Mixed sediment (complex and hard clay) 3. Sand/coarse substrate (sand, gravel) 4. Mud (clay and mud)
Bathymetry	FMA/ SYKE	Point/ Grid	1. Photic zone 2. Intermediate zone (< 50 m) 3. Deep zone (> 50 m)	1. Infralittoral (photic zone) 2. Circalittoral (aphotic zone)
Salinity	SYKE	Point	1. Fresh water 0.0 – 5.0psu 2. Oligohaline 5.0 – 7.5psu 3. Mesohaline I 7.5 – 11 psu 4. Mesohaline II 11 – 18 psu 5. Polyhaline 18 – 30 psu 6. Euhaline > 30 psu	
Wave Exposure[1)]	SYKE	Grid		1. Sheltered (0 – 100,000) 2. Moderately exposed (100,000 – 500,000) 3. Exposed (500,000 – 2,000,000)
Coastline	NLS/ SYKE	Line	no classification	
River flow data	SYKE	Point	1. River run-off < 2 ^{m3}/s 2. River run-off ≥ 2 ^{m3}/s	

[1)] Wave exposure values are relative index values from a Simplified Wave Model, see Isaeus (2004)

2.1 Substrate

Marine substrate data from the Archipelago Sea distributed by the Geological Survey of Finland (GTK) is one of the datasets used in the BALANCE marine landscape development. GTK has produced local scale substrate maps (1: 100 000, 1: 20 000) since the 1970's using data from echo-sounding, side-scan sonar imaging and continuous seismic profiling. Survey lines are situated approximately 500 m apart and geological interpretations have been verified by sampling. Technology has improved throughout the years. For example, the side scan sonar has been used from about 1983 and positioning has improved from the 1970's Decca positioning ($^+$/- 300 m). DGPS ($^+$/- 2 m) positioning has been used since 1995. The major part of the marine geological data from the Archipelago Sea has been acquired before 1983.

The original local scale substrate maps from the Archipelago Sea (e.g. Häkkinen, in prep.) were reclassified to BALANCE substrate classes (Al-Hamdani and Reker (eds.), 2007) and transformed from vector to grid data (Fig. 3a). The BALANCE substrate classification scheme includes 5 substrate classes (Table 1). The substrate classes are amalgamations of more varied substrate types and hence do not correspond to individual habitats; the same habitat may occur in several of the substrate categories. For example, complex substrates include both boulders and clays, which serve differing organisms, and as a consequence typical clay habitat may appear beside/with boulder habitat. It is likely that there are habitats that occur in only one and habitats that appear in several of the identified substrate types (Fig. 2). This is reflected also in landscapes; they do not individualise each habitat, but a combination of habitats can be attributed to a certain landscape.

Substrates defined as modern mud/gyttja were extracted from original maps and further interpreted as sediment accumulation areas. Besides accumulation, they indicate areas without strong wave and current activity/bed-stress. The raster size of the substrate dataset was kept at a coarse 100 m resolution mainly due to military issues.

The BALANCE classification of substrates, described above, was found appropriate for use in the EUNIS habitat maps. The only modification made to the substrate map, that differentiated it from the map used in landscape development was to combine the hard bottom complex and hard clay into the EUNIS sediment class: mixed sediment. Consequently only four substrate classes are used in the EUNIS maps.

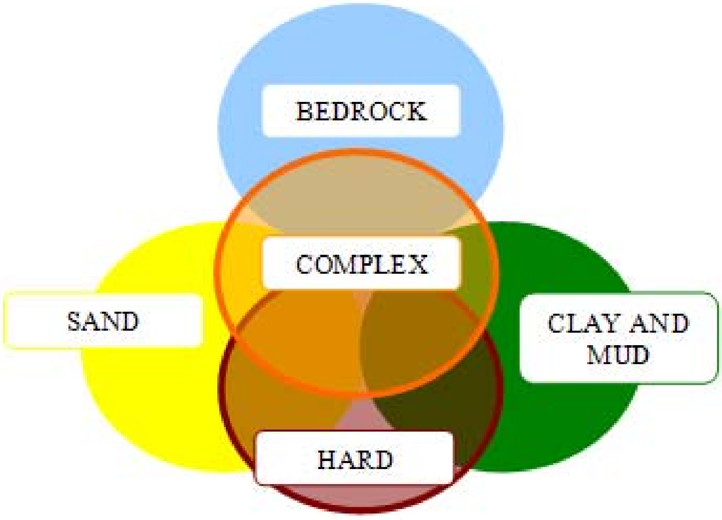

Figure 2. *The BALANCE substrate classification has ecologically overlapping substrates. There exist 3 homogeneous substrates: bedrock, sand and mud&clay and 2 composite, heterogeneous substrates: hard clay and complex substrates. similar overlapping is most likely seen in habitats as well*

2.2 Bathymetry

2.2.1 Depth models

The marine landscape maps were made using a depth model with a 50 metre cell size. The model was created at the Finnish Environment Institute (SYKE) using digital bathymetric point data, and the depth isolines from the coastal 1:50,000 nautical charts. Depth data was interpolated to a bathymetric raster map using a triangulated irregular network (TIN). Nautical chart data are collected and distributed by the Finnish Maritime Administration (FMA) who conducts acoustic-seismic soundings in marine areas that are interpolated to charts. Charts present depth points from the soundings at approximately 500 m intervals. Depth points are somewhat unevenly distributed, the main interests of the FMA being in the shipping routes.

A bathymetric model with a 25 metre cell size was used in the EUNIS habitat maps. The model was based on the same nautical chart data as the 50 m depth described above, but also incorporated elevation isolines from the National Land Survey's topographic database to improve results in the very shallow waters. The bathymetric map was interpolated using the ArcGIS Spatial Analyst Topo to Raster – procedure.

2.2.2 Depth zonation

For the marine landscapes we classified bathymetry to 3 depth categories: photic, intermediate and deep (Fig. 3b). Photic depth data used in the Archipelago Sea marine landscapes is the same as used in the whole Baltic Sea scale landscape maps (Al-Hamdani and Reker (eds.), 2007). It is modelled from Secchi depth data from the Baltic Sea, stored at the International Council for the Exploration of the Seas (ICES). The data is available through the ICES website: http://www.ices.dk/Ocean/project/secchi/ (Aarup, 2002). In BALANCE we have only applied Secchi disc data from 1980-1998 collected between March and October in the Photic depth model. Photic depth was approximated as 1.9 times the Secchi depth and was interpolated to a 617*617 m^2 grid. Measurements are unevenly distributed. We did not found information on positioning systems used in the field.

The intermediate depth was defined to range from the photic depth limit to 50 m. This zone was determined according to Virtasalo et al. (2005), where it was concluded that anoxic bottoms are typical to these depths. This depth zone should be regarded as indicative (approximate) as Virtasalo et al. (2005) did not have measurements from the whole study area and the amount of measurement points was rather low. The area was classified as deep if depth exceeded 50 metres.

The EUNIS classification divides the sublittoral into infralittoral and circalittoral. Generally the infralittoral is defined from the low water mark to 20 m depth and the circalittoral from 20 m to the shelf edge (200 m). This loosely corresponds to the lower limit of the photic zone. In the Archipelago Sea the depth of the photic zone varies greatly depending on among other things on the location and on the gradient from the inner to the outer archipelago. Hence, infralittoral and circalittoral were considered synonymous to photic and aphotic, respectively, in the development of EUNIS habitat maps for the Archipelago Sea. A photic depth layer was created using a modelling approach that linked secchi depth to the openness of the archipelago.

A 50 m raster dataset separating land and sea was used in a neighbourhood analysis to determine the percentage of land within a five kilometre radius of and including each cell. A linear regression model of Secchi depth against the percentage of land in the neighbourhood was used to predict Secchi depth for the study area. Photic depth was estimated at twice the Secchi depth.

2.3 Salinity

Randomly distributed salinity point measurements from the years of 1995 to 2005 were received from SYKE. SYKE also offered data on river mouths. To create salinity models for landscape development we placed salinity value of 0 psu to each river mouth and combined them with bottom and surface salinity points. On the basis of these points we interpolated both bottom and surface salinity maps to the Archipelago Sea. Interpolations were done by ArcGIS function Kriging. The resulting maps are not accurate, but one is able to get the overall salinity conditions in the Archipelago Sea (Fig. 3c and 3d). However, the roughness of the salinity model causes difficulties in delineating coastal landscapes. Salinity was classified to zones according to boundaries determined within the BALANCE for the Baltic Sea (Al-Hamdani and Reker (eds.) 2007). It is most likely that classification should be modified to suit better detailed scale study.

2.4 River flow

There are several rivers running to the Archipelago Sea (Paimionjoki, Aurajoki etc., Fig. 3e). SYKE has point data from each river mouth where factors like the average river flow are reported. Average flow was used instead of current velocity in defining estuaries.

2.5 Wave exposure

Wave exposure was available in a 25 metre cell size raster for the study area (Fig. 3f). Wave exposure has been calculated using the Simplified Wave Model (SWM) (Isæus, 2004). The method incorporates fetch and average wind speed over 10 years from 16 directions into an index of wave exposure for each cell. The fetch calculations have been made to include the effects of wave diffraction and refraction around islands and skerries. The method is described in detail in Isaeus (2004). Fetch calculations were made using the National Land Survey's 1:20,000 vector shoreline.

2.6 Coastline

The coastline data that originates from National Land Survey of Finland (NLS) Topographic database was received from SYKE. It was scaled to 1: 20 000 with raster size 10 m. However, the data layers used in seabed marine landscape (bathymetry, substrates) had different coastlines, thus the resulting coastline is combination of them all.

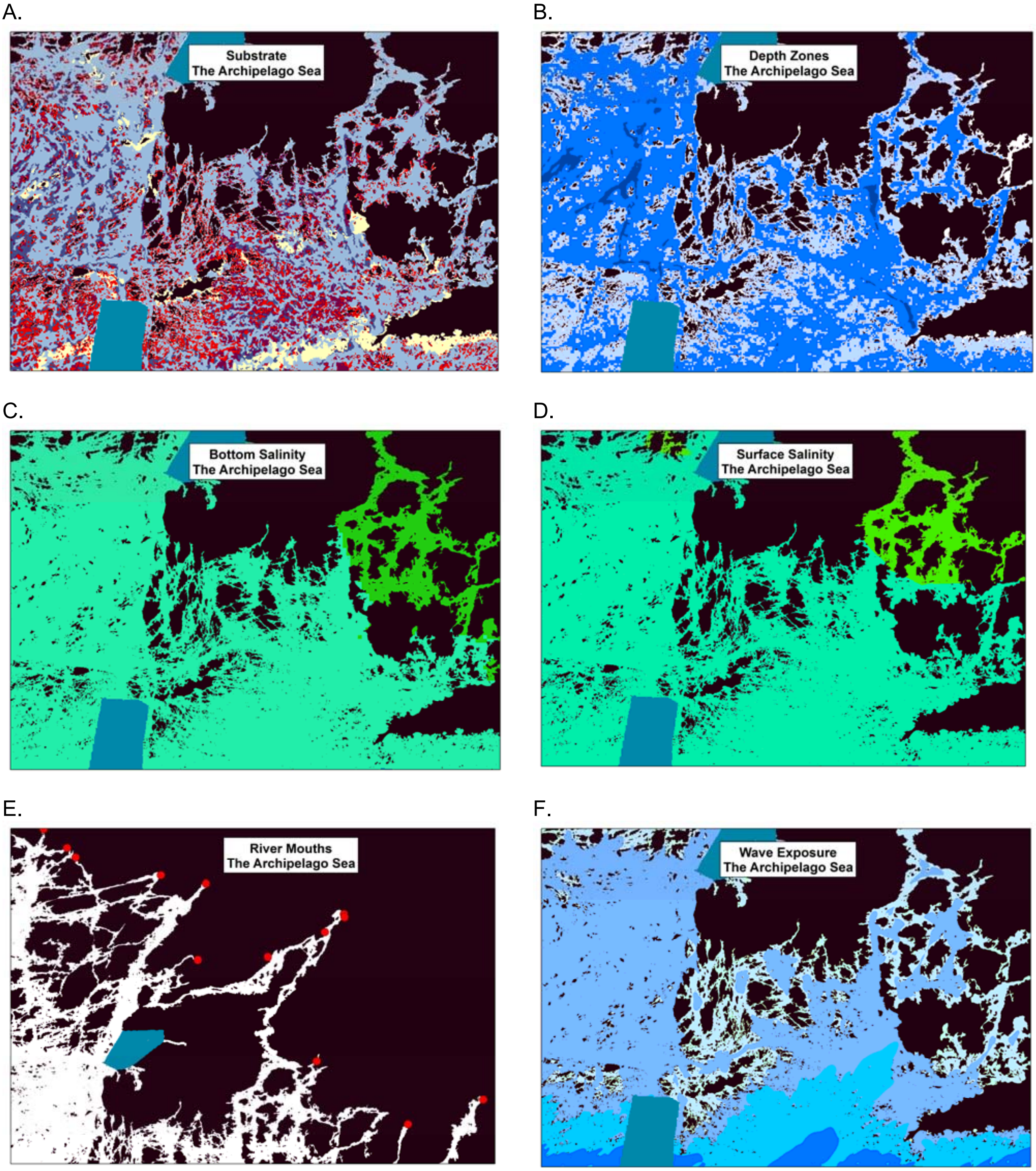

Figure 3. *The Archipelago Sea is a heterogeneous natural environment, where etc. seabed substrates (A), bathymetry (B), salinity (C,D), and wave exposure (F) vary within a small area. The coastline is very complex and there are several rivers (E) running to area. Blue areas are restricted by military reasons. Permission: Pääesikunta, Operatiivinen osasto, Lupa AE2352, 1.2.2008, Helsinki; Shoreline: National Land Survey of Finland 13/MML/08.*

3 MARINE LANDSCAPES AND HIGH LEVEL HABITATS

We have studied the marine landscapes of the Archipelago Sea from 3 different aspects correspondingly to the Baltic Sea study (Al-Hamdani and Reker (eds.) 2007). Marine landscapes are regarded as a generic approach, which also include features similarly to the UKSeaMap project (Connor et al., 2006). Benthic marine landscapes were identified by their physio-chemical characteristics. Seabed topographic features (landscapes) were studied by conceptualising the topographic layout and recognising bedforms. Both the benthic marine landscapes and the sea topographic features comprise the seabed and the water at the substrate/water interface (Golding et al., 2004). Coastal physiographic features were defined by studying the transition zone from land to sea. They cover areas where the seabed and water body are closely interlinked (Golding et al. 2004). Both the seabed and the overlying water are included within this landscape type. These three marine landscape types together offer a spatial overview on the complexity and diversity of the marine environment in the Archipelago Sea.

The identification of the landscapes has concentrated on areas where detailed scale marine geological data is available (Fig. 1) covering 3465 km^2. The raster size used in marine landscape definition is 50 m. Study is first of its kind in the Archipelago Sea and among firsts in the world. Landscape determination is ongoing process and current landscapes identified should not be regarded as final rather than first steps. It is likely that they will be altered after we have more experience and get feedback from the users.

3.1 Benthic marine landscapes

3.1.1 Methods

Benthic marine landscapes include areas with resembling physio-chemical characteristics. Similarly to the Baltic Sea scale Al-Hamdani and Reker (eds.), 2007) they base on overlay analysis of the following datasets:

I. BALANCE classified substrate data, at 100 m cell size
II. Depth zone data, at 50 m cell size
III. Bottom salinity, at 50 m cell size

These three parameters were regarded as most relevant from datasets available in context to benthic communities' distribution. Benthic marine landscapes include no further modelling, they base on the input data. Substrate was considered to describe seabed. Depth zones and bottom salinity describe waterbody at the interface.

3.1.2 Results

Altogether there are 26 different benthic marine landscapes forming 32578 seafloor patches (Fig. 4, Table 2). The average size of the benthic marine landscape is about 130 km^2. Benthic marine landscapes based on mud and clay cover large areas of the Archipelago Sea; mud and clay substrates in intermediate depth and oligohaline conditions being the biggest group in the study area (1190 km^2, 34 %). If studied by number of patches bedrock dependent benthic landscapes become dominant. In consequence, oligohaline bedrock in intermediate and photic depths covers 37 % of the patches. Fresh water and sand dependent benthic marine landscapes are rare in general (< 3 %).

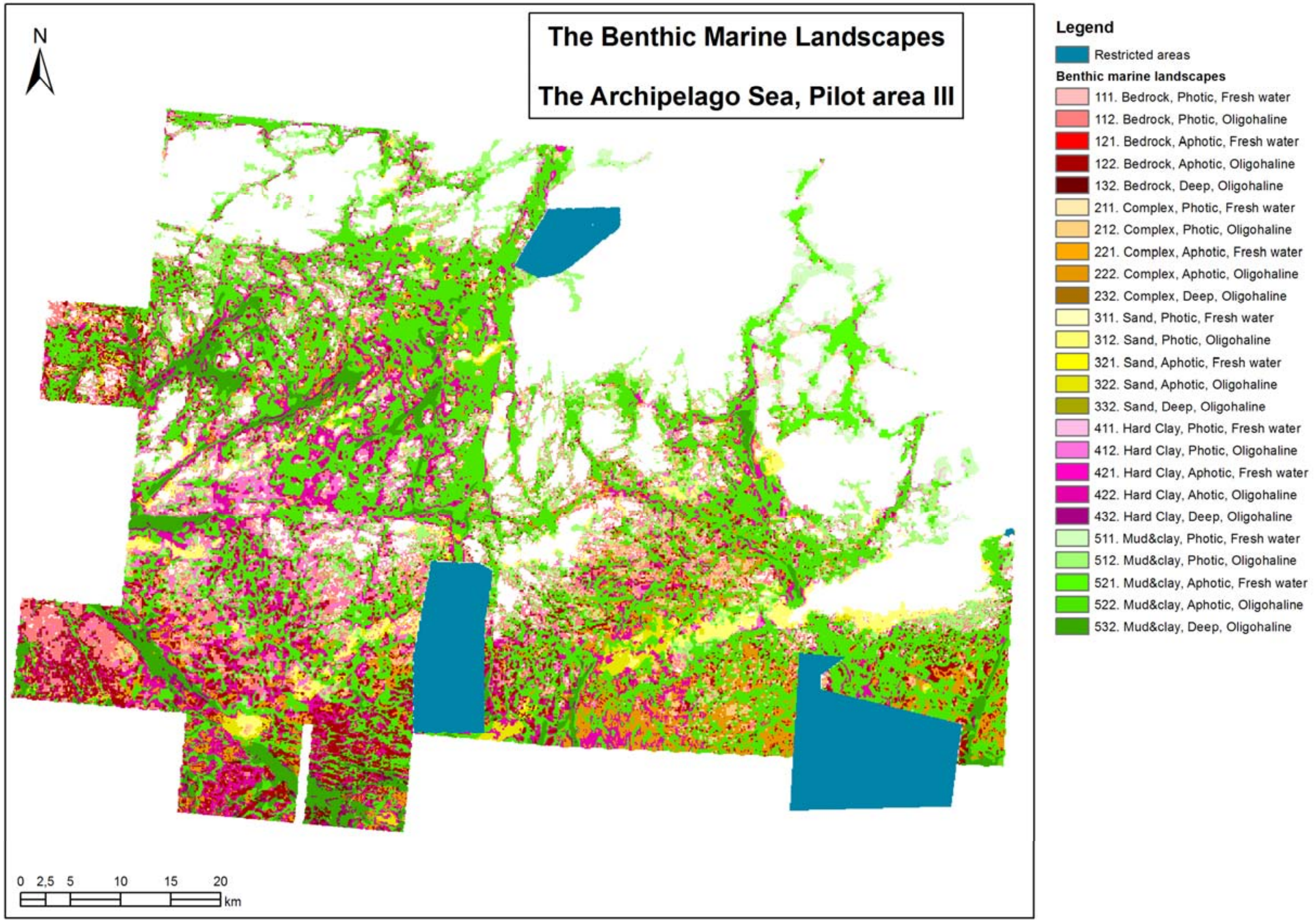

Figure 4. *The benthic marine landscapes of the Archipelago Sea. Blue areas are restricted by military forces. Permission: Pääesikunta, Operatiivinen osasto, Lupa AE2352, 1.2.2008, Helsinki; Shoreline: National Land Survey of Finland 13/MML/08.*

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Table 2. The distribution of the benthic marine landscapes in the study area. Percentages are calculated against total values.					
Seabed benthic landscape	**Cells**	**Area(Km2)**	**Area (%)**	**Patches**	**Patch (%)**
Bedrock, photic, fresh	2867	7	0	316	1
Bedrock, photic, oligohaline	113814	285	8	5887	18
Bedrock, intermed., fresh	615	2	0	112	0
Bedrock, intermed., oligohaline	110531	276	8	6089	19
Bedrock, deep, oligohaline	3733	9	0	359	1
Complex, photic, fresh	1706	4	0	145	0
Complex, photic, oligohaline	40501	101	3	2163	7
Complex, interemed., fresh	346	1	0	49	0
Complex, intermed., oligohaline	88983	222	6	2662	8
Complex, deep, oligohaline	1852	5	0	163	1
Sand, photic, fresh	181	0	0	12	0
Sand, photic, oligohaline	37020	93	3	527	2
Sand, intermed., fresh	20	0	0	4	0
Sand, intermed., oligohaline	23833	60	2	594	2
Sand, deep, oligohaline	265	1	0	34	0
Hard clay, photic, fresh	2649	7	0	202	1
Hard clay, photic, oligohaline	53648	134	4	2859	9
Hard clay, intermed., fresh	1335	3	0	102	0
Hard clay, intermed., oligohaline	157689	394	11	4028	12
Hard clay, deep, oligohaline	9419	24	1	648	2
Mud and clay, photic, fresh	27693	69	2	197	1
Mud and clay, photic, oligohaline	140370	351	10	3382	10
Mud and clay, intermed., fresh	23028	58	2	65	0
Mud and clay, intermed., oligohaline	475391	1188	34	1688	5
Mud and clay, deep, fresh	9	0	0	3	0
Mud and clay, photic, oligohaline	68463	171	5	288	1
Sum	1385961	3465	100	32578	100
Average	53306	133	4	1253	4
Min	9	0	0	3	0
Max	475391	1188	34	6089	19

3.2 Seabed topographic features

3.2.1 Methods

Seabed topographic features aim to give insight to physical complexity of the seafloor. They emphasize the importance of topography. Here, bedforms and substrates are regarded as data describing the seabed and water/seabed interface is described by depth. Datasets used in the seabed topographic feature identification are:

I. BALANCE classified substrate data, at 100 m cell size
II. Bathymetry, at 50 m cell size

There was no topographical/bedform map available for the project, thus bedforms were modelled from the bathymetry. Modelling method resembles that of Baltic Sea scale seabed topographic features in general, only limiting values were modified to suit detailed scale study.

In order to identify bedforms, slope and Bathymetric Position Index (BPI) were calculated from the bathymetry. Unlike in the Baltic Sea examination, slope was calculated in degrees to classify slope according to standards of detailed geomorphological mapping (Demek, 1972): 0° – 0°30' (plain), 0°30' – 2° (slightly sloping), 2° – 5° (gently inclined), 5° – 15° (strongly inclined), 15° – 35° (steep, very steep), 35° – 55° (precipitous) and > 55° (vertical). In the BPI analysis we used inner radius (~neighbourhood) of 1 cell in both BPI scales and outer radius of 10 cells (500 m) in fine scale and 100 cells (5 000 m) in broad scale. This combination seemed coarse enough to identify broad features but accurate enough to create realistic seabed structures. There is enough difference in local and broad scale to result in complementary features. The radius size by cell number was similar in the Baltic Sea study even though the cell size here is smaller. Classification of BPI standardized values to BPI structures/units is modified from Lundblad (2004). We identified 5 BPI structures on the basis of slope, broad and fine scale BPI values: narrow depression, basins, crests, flat and slope.

BPI structures were combined with substrate data and depth zonation to identify seabed topographic features (Table 3). Again, combinations were done by ArcMap™ Raster calculator tool by adding grid values together. The definitions of seabed topographic features are adopted (whenever feasible) from "The Standardization of the Undersea Feature Names"-guideline (The International Hydrographic Organization, 2001). Also the Irish Sea pilot (Golding et al., 2004) was used as a guideline to keep results globally comparable. Features identified indicate changes in sea bottom physical environment and thus probably changes in biota.

In identifying seabed topographical features BPI structures were regarded as dominating factors. This leads to the fact, that for example regarding mound with sand, sand is not necessarily the main substrate type covering the whole mound but a part of it (Fig. 5). In addition, for example sandbanks are included to class mound with sand but there are other combinations included as well. At present, the proportion of certain substrate type in a certain feature has not been examined.

Table 3. The seabed topographic features identified from the Archipelago Sea. Also depth zones (photic, intermediate and deep) are included to each feature type.		
Feature / lands-cape	**Definition**	**BPI structu-re**
Plains	Large areas where relief stays low. Largely uniform and seabed conditions are homogeneous. In addition to bathymetry, plains were divided into accumulation plains, mud and clay plains and coarse substrate plains (hard clay, sand, complex, bedrock).	Flat
Basins	A depression in the seafloor, more or less equidimensio-nal in plain and of variable extent (IHO 2001). They were divided into accumulation basins, mud and clay basins and coarse substrate basins (hard clay, sand, complex, bedrock).	Large de-pression, narrow de-pression
Troughs	Troughs are steep sided, long depressions of the seafloor. Often associated with deep-water currents. Troughs were further classified to accumulation troughs, mud and clay troughs and coarse substrate troughs (hard clay, sand, complex, bedrock).	Narrow de-pression, where lope of the sides ≥ 5°.
Mounds	Elevations of seafloor. Include plateaus as well as hills, banks and sills. In local scale mounds were divided ac-cording to substrates to mounds with bedrock, mounds with complex substrates, mounds with sand, mounds with hard clay, mounds with clay and to mound with accumu-lation.	Crest
Slopes	Areas where slope exceeds values of flat (0-2°) and that did not fall to any other group were kept as their own group. This is very small group and it was not further classified on the basis of substrates.	Slope

There is no internationally agreed standard on how to model bedforms and therefore they were identified for this project only (internally). We have not conducted any field-work relating to the accuracy of the bedforms. They were validated trough visual ex-amination; bedforms were compared to well-known features and to depth contours.

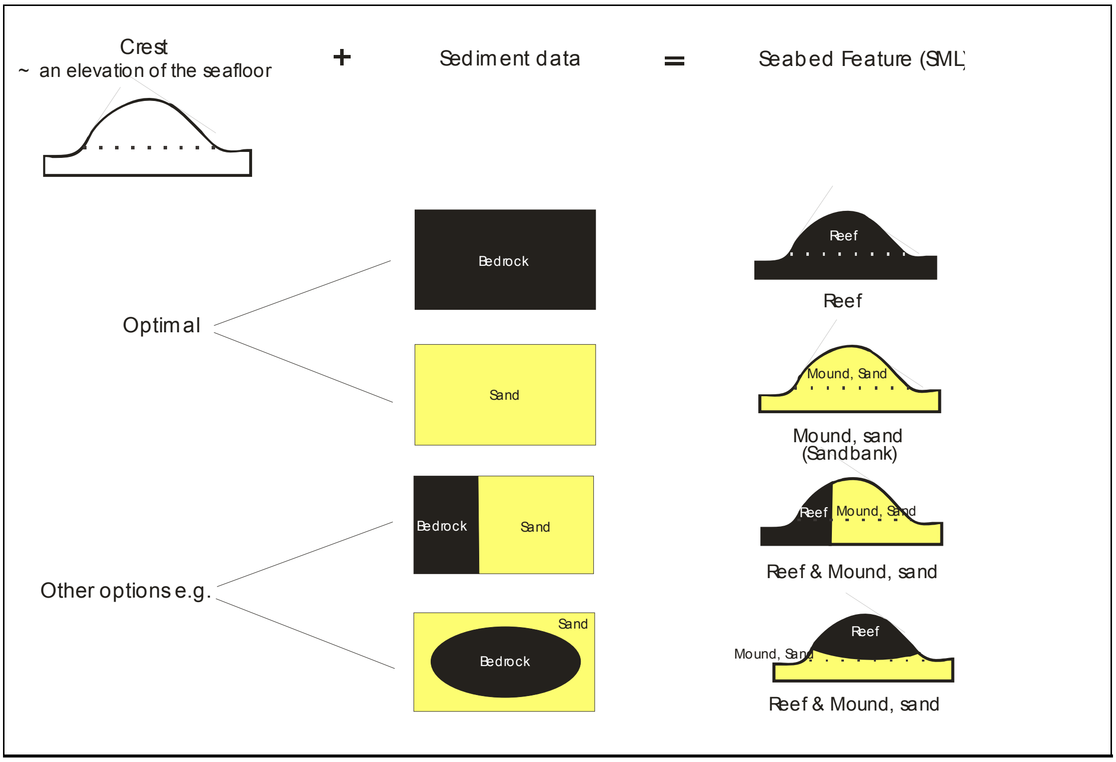

Figure 5. *Seabed topographic features were identified first by shape (crest) and second by substrate. This leads to variety of resulting options. Optimal features are BPI structures covered by single substrate type, for example mound covered by sand only is most likely sandbank. However, if there are other substrates as well, result is more complex.*

3.2.2 Results

Seabed topographic features consist on substrate, BPI structures and depth. Altogether there are 49 topographic landscapes describing seabed (Fig. 6; Table 4). Topographic features are smaller than benthic landscape identified, average size, 71 km^2, being nearly half of that of benthic landscape (Table 2). According to topographic study basin with mud and clay in intermediate depths has largest coverage (540 km^2, 15 %). Also coarse substrate basins have large coverage, 380 km^2, including 11 % of the seafloor. In addition to basins, bedrock mounds in photic depth include comparatively large areas, 250 km^2 (7 %).

When studied by number of patches, intermediate depth basins with coarse substrate come first (9%). Also some mound landscapes have relatively high frequency, like mounds with bedrock on photic conditions (8 %) and mounds with clay in photic depth (7 %). Mounds with sand are few in number (2 %) and areally small (3 %). In general basins cover large areas of the Archipelago Sea, but different mounds are the most frequent feature types. Trough and slope features are rare (< 2 %). The low occurrence of plain landscape types (< 5 %) supports the idea of topographically complex Archipelago Sea. In regional scale plain landscapes were one of the major seabed topographic features in the entire Baltic Sea (Reijonen et al., submitted).

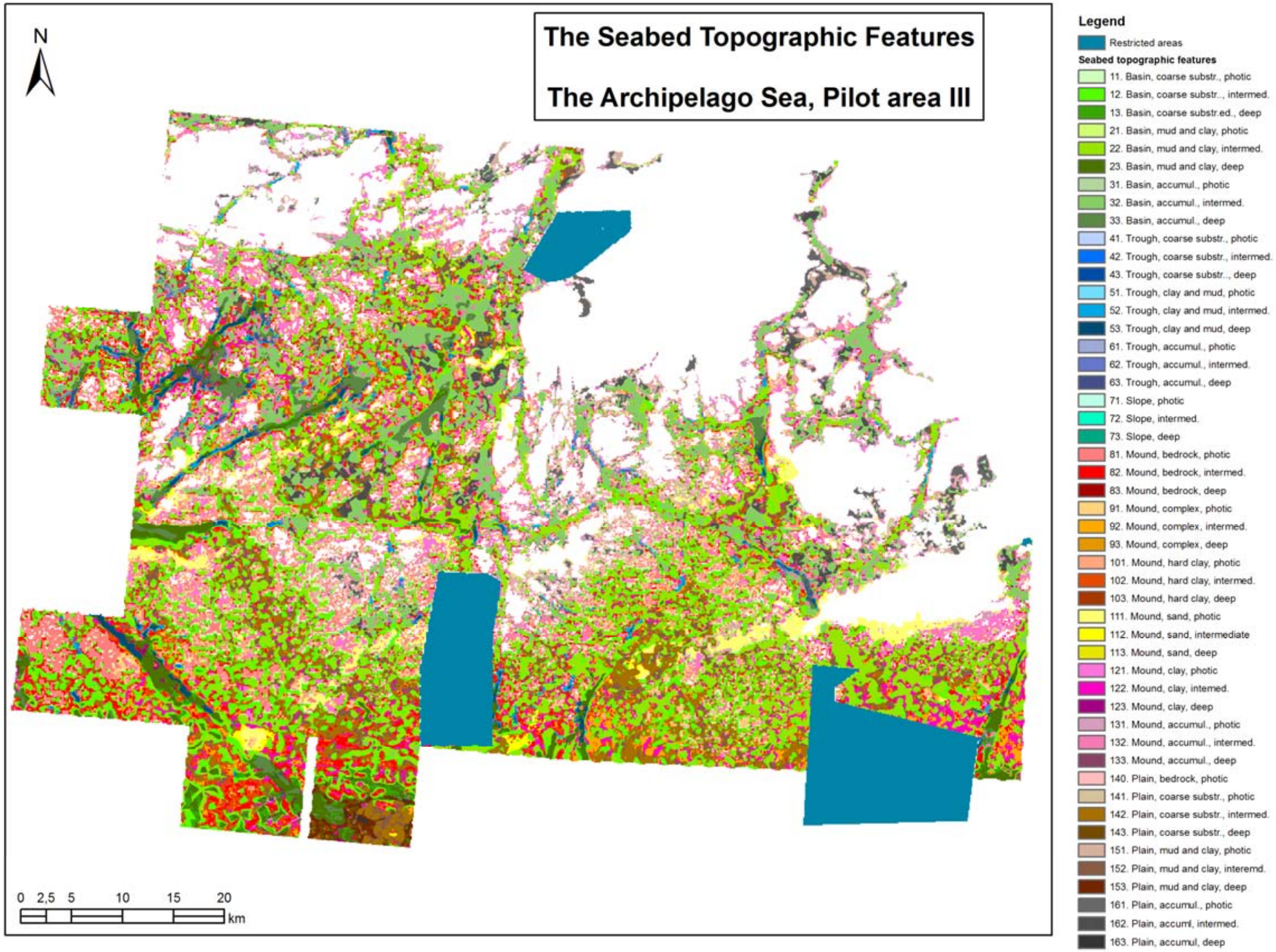

Figure 6. *The seabed topographic features of the Archipelago Sea. Blue areas are restricted by military reasons. Permission Pääesikunta, Operatiivinen osasto, Lupa AE2352, 1.2.2008, Helsinki; National Land Survey of Finland 13/MML/08.*

Table 4. The distribution topographic seabed marine landscapes of the Archipelago Sea. Percentages are calculated against total values.					
Topographic ML	**Cells**	**Area (km2)**	**Area (%)**	**Patches**	**Patch (%)**
Basin, coarse sed., photic	29728	74	2	3608	6
Basin, coarse sed., intermed.	151955	380	11	5586	9
Basin, coarse sed., deep	9699	24	1	246	0
Basin, mud and clay, photic	27760	69	2	3058	5
Basin, mud and clay, intermed.	214804	537	15	4030	6
Basin, mud and clay, deep	33215	83	2	280	0
Basin, accum., photic	14101	35	1	1437	2
Basin, accum., intermed.	111436	279	8	1515	2
Basin, accum., deep	18996	47	1	152	0
Trough, coarse sed., photic	1020	3	0	315	0
Trough, coarse sed., intermed.	6626	17	0	989	2
Trough, coarse sed., deep	2048	5	0	188	0
Trough, clay and mud, photic	1172	3	0	293	0
Trough, clay and mud, intermed.	11153	28	1	953	1
Trough, clay and mud, deep	7973	20	1	209	0
Trough, accum., photic	495	1	0	117	0
Trough, accum., intermed.	5160	13	0	490	1
Trough, accum., deep	2751	7	0	135	0
Slope, photic	497	1	0	260	0
Slope, intermed.	1797	4	0	410	1
Slope, deep	20	0	0	0	0
Mound, bedrock, photic	97886	245	7	5499	8
Mound, bedrock, intermed.	58680	147	4	3261	5
Mound, bedrock, deep	142	0	0	5	0
Mound, complex, photic	31887	80	2	1843	3
Mound, complex, intermed.	35931	90	3	1344	2
Mound, complex, deep	52	0	0	3	0
Mound, hard clay, photic	39623	99	3	2600	4
Mound, hard clay, intermed.	51254	128	4	3001	5
Mound, hard clay, deep	537	1	0	36	0
Mound, sand, photic	30842	77	2	559	1
Mound, sand, intermed.	8925	22	1	402	1
Mound, sand, deep	1	0	0	0	0
Mound, clay, photic	65187	163	5	4715	7
Mound, clay, intermed.	62311	156	4	4285	7
Mound, clay, deep	1239	3	0	45	0
Mound, accum., photic	21148	53	2	1906	3
Mound, accum., intermed.	17151	43	1	1691	3
Mound, accum., deep	511	1	0	38	0
Plain, bedrock, photic	7979	20	1	1405	2
Plain, coarse sed., photic	12181	30	1	1173	2
Plain, coarse sed., intermed.	66918	167	5	1864	3
Plain, coarse sed., deep	2729	7	0	0	0
Plain, clay and mud, photic	17314	43	1	1721	3
Plain, clay and mud, intermed.	54211	136	4	1975	3
Plain, clay and mud, deep	3415	9	0	0	0
Plain, accumul., photic	21629	54	2	917	1
Plain, accumul., interemed.	23468	59	2	977	1
Plain, accumul., deep	413	1	0	0	0
Sum	1385970	3465	100	65536	100
Average	28285	71	2	1337	2
Min	1	0	0	0	0
Max	214804	537	15	5586	9

3.3 Coastal physiographic features

3.3.1 Methods

Coastal physiographic features include coastal areas where physical conditions are considered to differ from the surrounding environment. Change in physical environment is most likely reflected to ecology as well. Coastal physiographic features describe the transition from land to sea; their coverage area represents the area with the highest concentration of human activities and interests. Coastal physiographic features cover areas where the seabed and water body are closely interlinked (Golding et al. 2004); both the seabed and the overlying water are included. The following datasets were used in the analysis:

I. Coastline, at 10 m cell size
II. Surface salinity, at 50 m cell size
III. River mouth data

Coastal physiographic features defined in context are channels, bays and estuaries (Table 5). In the Baltic Sea scale also archipelagos, lagoons and fjords were defined, but they were considered irrelevant in this detailed scale study. In addition archipelagos at least are regional scale features. In general, the limiting values were determined/reasoned by visual examination and based on existing data (e.g. Kotilainen et al. 2005).

We determined coastal zone as an area where the width of open water cannot exceed 1000 m. We identified coastal zone with raster size 10 m and started identification by excluding islands less than 100 cells (1 km^2) from the examination. We regarded them too small to form landscapes and thus to skew the results of the analysis. Original land area is nevertheless shown in results.

Table 5. The coastal physiographic features identified from the Archipelago Sea.

Feature / landscape	Definition	Other
Channels (small sounds)	Areas with unstable physical conditions. Longitudinal water-areas between lands that serve as water passages. Comparatively small (vs. sound).	Nutrient distributors, reflect to the marine ecology.
Bays	Sheltered water areas that often have only one open connection to sea. Stable environments.	Includes saline lagoons, flads and gloes.
Estuaries	A river mouth, where brackish water mixes with fresh water. River whose run-off exceeds 2 ^{m3}/s was considerer cause significant mixing of fresh and brackish water. Area from river mouth to point, where salinity exceeds the fresh water boundary (5 psu) was classifies as an estuary.	In reality the Baltic Sea forms one big estuary, but in small scale the brackish water estuaries of the Baltic Sea, where there is no tidal action, can be kept as separate sub-type of estuaries.

Coastal physiographic features defined here do not cover the whole coastal area. Only features that were considered most relevant were determined. More features and further classification can be accomplished in future, if needed. Also the standards and methods used should not be regarded as final, but initial moves to define this concept. The parameter limits chosen have a major effect on the size of the resulting landscapes, for instance some large bays are not identified. In future the practical size of the coastal physiographic feature should be studied. It is most likely that features/landscapes will be altered after we get more information and feedback from the users.

3.3.2 Results

We identified three different coastal marine physiographic features: channels, bays and estuaries (Fig. 7). They cover together 440 km^2, which is about 13 % of the study area (3470km^2) (Table 6). Channels cover largest area (45%) and bays are most frequent coastal landscapes (63%). In relation to whole study area channels cover about 6 %. Estuaries identified are unrealistically large (Fig. 7). In fact, only two estuaries reach up to the study area, but when resampling them to 50 m grid from 10 m used in the analysis they have been split into 26 patches (Table 6). The false size is due to the salinity data; there are not enough measurements to create reliable scaled salinity map and to delineate the real size of an estuary. Also the salinity range 0 - 5 ‰ is wide for the Archipelago Sea, where overall salinity is only 5 - 7 ‰. Estuary landscapes should be improved when detailed salinity data is available and also the salinity categorization of the Archipelago Sea should be reconsidered.

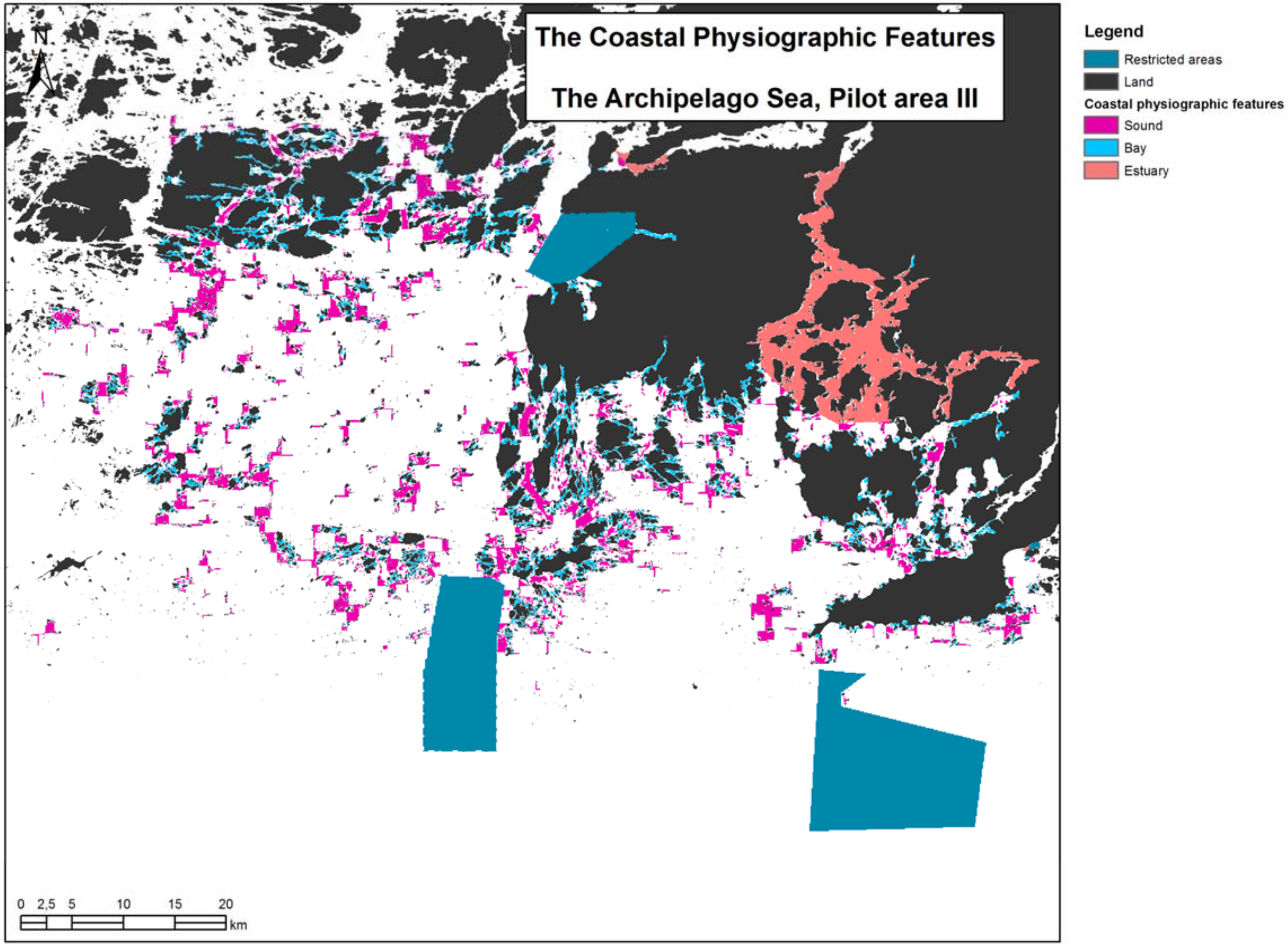

Figure 7. *The coastal physiographic features of the Archipelago Sea. Blue areas are restricted by military reasons. Permission Pääesikunta, Operatiivinen osasto, Lupa AE2352, 1.2.2008, Helsinki;Shoreline: National Land Survey of Finland 13/MML/08.*

Table 6. The distribution of the coastal features of the Archipelago Sea						
Coastal ML	Cells	Area (km2)	Area (%)	Area* (%)	Patches	Patch (%)
Channel	79447	199	45	6	2206	36
Bay	46689	117	26	3	3853	63
Estuary	51362	128	29	4	26	0
Sum	**177498**	**444**	**100**	**13**	**6085**	**100**
Average	**59166**	**148**	**33**	**4**	**2028**	**33**
Min	**46689**	**117**	**26**	**3**	**26**	**0**
Max	**79447**	**199**	**45**	**6**	**3853**	**63**

*compared to total study area 3465 km^2

3.4 Benthic habitats

Maps of benthic habitats were made covering the same area as the benthic marine landscapes and topographic seabed features. The habitat distinction used is at a very coarse level, utilising only the abiotic datasets available for the analysis. The high level habitats produced are comparable to the marine landscapes/features in detail, but the classes determined by the analysis have been based on the European Nature Information System (EUNIS) classification of marine habitats (Davies and Moss, 2004).

<table>
<tr><th colspan="4">Table 7. EUNIS Habitats on levels 2 and 3 in the study area</th></tr>
<tr><th colspan="2">Level 2</th><th colspan="2">Level 3</th></tr>
<tr><td rowspan="3">A3</td><td rowspan="3">Infralittoral rock and other hard substrata</td><td>A3.4</td><td>Baltic exposed infralittoral rock</td></tr>
<tr><td>A3.5</td><td>Baltic moderately exposed infralittoral rock</td></tr>
<tr><td>A3.6</td><td>Baltic sheltered infralittoral rock</td></tr>
<tr><td rowspan="3">A4</td><td rowspan="3">Circalittoral rock and other hard substrata</td><td>A4.4</td><td>Baltic exposed circalittoral rock</td></tr>
<tr><td>A4.5</td><td>Baltic moderately exposed circalittoral rock</td></tr>
<tr><td>A4.6</td><td>Baltic sheltered circalittoral rock</td></tr>
<tr><td rowspan="7">A5</td><td rowspan="7">Sublittoral sediment</td><td>A5.1</td><td>Sublittoral coarse sediment</td></tr>
<tr><td>A5.2</td><td>Sublittoral sand</td></tr>
<tr><td>A5.3</td><td>Sublittoral mud</td></tr>
<tr><td>A5.4</td><td>Sublittoral mixed sediments</td></tr>
<tr><td>A5.5*)</td><td>Sublittoral macrophyte dominated sediments</td></tr>
<tr><td>A5.6*)</td><td>Sublittoral biogenic reefs</td></tr>
<tr><td>A5.7*)</td><td>Features of sublittoral sediments</td></tr>
<tr><td colspan="4">*)Not included in the map here, as would have required information on biological attributes, or a bottom oxygen layer which was no available</td></tr>
</table>

The EUNIS habitat classification system has a hierarchical structure with increasing detail at the lower levels. Level 1 divides nature into larger domains, including the whole marine environment. The marine part of the habitat classification system divides the benthos according to a biologically derived framework. The highest levels in the hierarchy have only abiotic attributes, and can thus be mapped using the same methods as for the landscapes and seabed features. At level 2, the marine environment is split into classes using depth and substrate, level 3 adds new abiotic factors (wave exposure and anoxia) to further define habitats in more detail. Level 3 also includes certain biological factors, namely cover of macrophytes and mussels (Table 7). An increasing amount of biology is included at the lower levels.

The level chosen for analysis in this report is level 3. The decision was made based on the fact that level 2 does not bring any additional information relative to the marine landscapes. Wave exposure, included at EUNIS level 3, does introduce a new element.

3.4.1 Methods

The classes used in the analysis of benthic habitats follow as closely as possible the EUNIS classes on level three that are applicable to the study area (Davies and Moss, 2004). However, the classes that include information on macrophytes, biogenic reefs and features of the sublittoral sediments have not been included in this analysis, because the required information was not available (Table 7). The following three GIS raster layers were used in the analysis:

I. BALANCE classified substrate data, at 100 m resolution.
II. The photic layer, at 25 m resolution.
III. Wave exposure index, at 25 m resolution.

The BALANCE classified substrate has previously been compared to substrate classes used in EUNIS (Erlandsson and Lindeberg, 2007). Here the five BALANCE substrate classes have been combined into the four classes of the EUNIS classes relevant to the study area (Table 7). The wave exposure index was classified into categories relevant to EUNIS using the cut-off values derived from an analysis distribution of lichens and algae on shores (Isaeus and Rygg, 2005). This scale has more detail than needed so the classes were further combined into the classes (sheltered, moderately exposed and exposed) needed for the analysis. The source figures and corresponding classes, for both datasets have been set out in table 1.

The reclassified input rasters were combined using map algebra in ArcMap, and the results were further reclassified to fit into the categories in table 7.

3.4.2 Results

78% of the study area consists of sublittoral mud (i.e. clay and mud) and mixed sediments. Sublittoral mud is found all over the study area and is generally present in very large patches, whilst mixed sediments are present in larger numbers of smaller patches (Fig. 8). A very small portion (5%) of the study area consists of sublittoral sands. Rocky bottoms together cover 22% of the study area. Sheltered infralittoral and circalittoral rock have the largest numbers of patches. Rocky habitat patches are also in general smaller than sediment patches. Exposed rocky patches are somewhat larger than sheltered patched, which is likely because of the higher sedimentation rates in sheltered areas (Table 8).

Table 8. EUNIS Habitats on levels 2 and 3 in the Study Area						
Habitat class		**Area (km^2)**	**% of study area**	**No. patches**	**Patch size (km^2)**	
					min	**max**
A3.4	Baltic exposed infralittoral rock	27	1 %	737	0.1	3.50
A3.5	Baltic moderately exposed infralittoral rock	50	1 %	1470	0.1	3.76
A3.6	Baltic sheltered infralittoral rock	168	5 %	6643	0.1	2.44
A4.4	Baltic exposed circalittoral rock	185	5 %	2177	0.1	26.14
A4.5	Baltic moderately exposed circalittoral rock	61	2 %	2264	0.1	0.99
A4.6	Baltic sheltered circalittoral rock	170	5 %	12779	0.1	1.96
A5.1/2	Sublittoral sand /coarse sediment	170	5 %	537	1.0	17.77
A5.3	Sublittoral mud	1939	53 %	862	1.0	709.26
A5.4	Sublittoral mixed sediments	920	25 %	4366	1.0	66.47
Total		3692	100 %	31835		

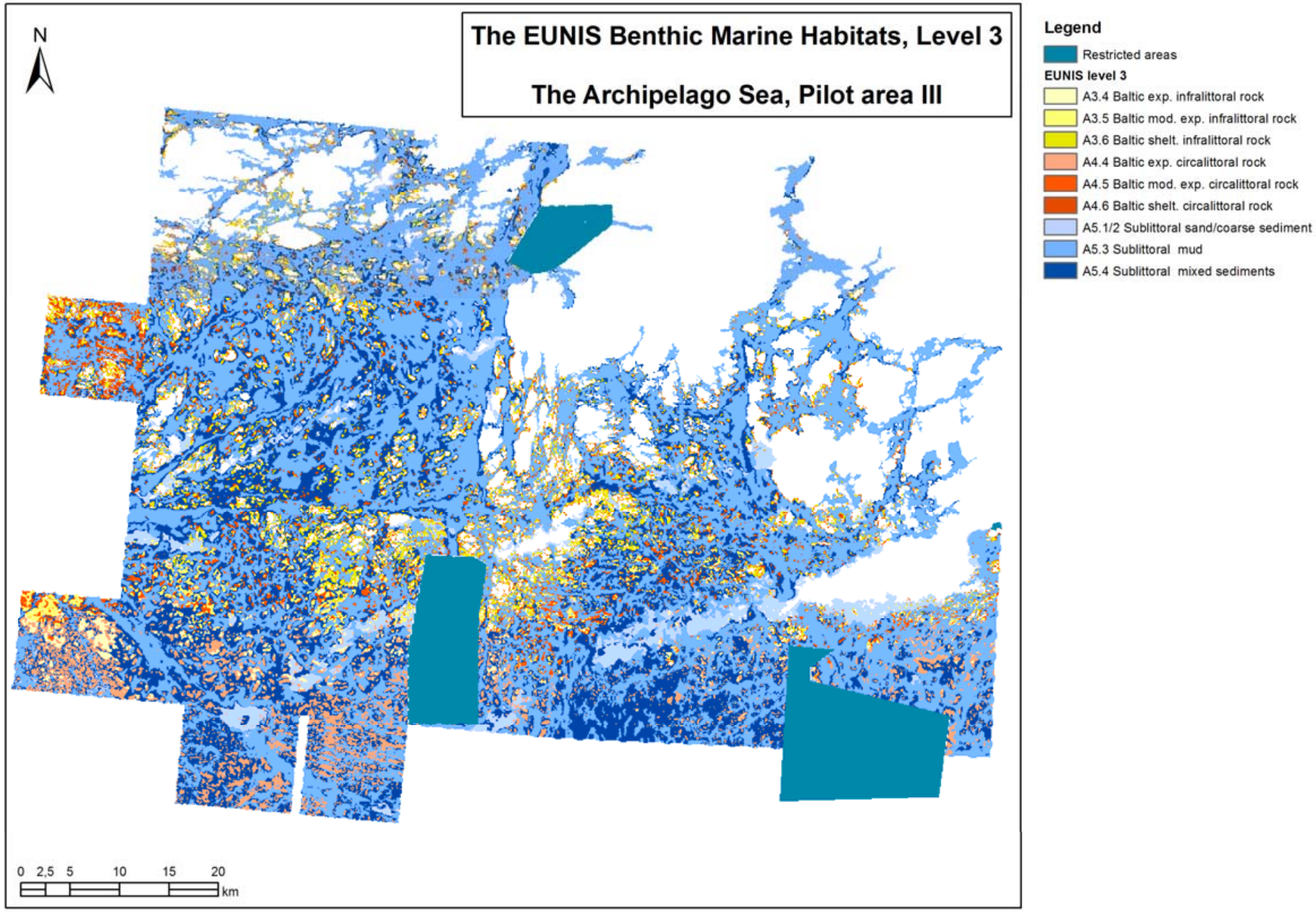

Figure 8. *EUNIS level 3 classified benthic marine habitats. Blue areas are restricted by military reasons. Permission Pääesikunta, Operatiivinen osasto, Lupa AE7278, 9.4.2008, Helsinki; shoreline: National Land Survey of Finland 13/MML/08.*

4 ACCURACY OF SOURCE DATASETS AND CONFIDENCE ASSESSMENT

Ultimately, the applicability of the marine landscapes and habitat maps is scale dependent. One very important factor when evaluating these very general and coarse resolution maps is the input data they are based on. The source GIS data used in both the landscape and habitat maps is based on data gathered for other uses. The geological data was not originally collected to depict surficial substrate and the categories in the source dataset have been calibrated to coincide with classifications in the other BALANCE countries, losing some of their specificity in the process. The depth models used in the work are based on nautical charts and inherit the inaccuracies in the reported depths, which are only meant for safe navigation, as well as adding on the inaccuracies of the modelling process.

Any model or representation simplifies reality and is only representation of mapped phenomenon. Landscapes as well as other representations omit details and smooth irregularities. The inevitable discrepancy between the modelled and real worlds constitutes inaccuracy and uncertainty, which in turn may turn spatial decision making sour (Zhang and Goodchild, 2002). Consequently, the assessment of the accuracy and confidence in the source datasets is the first step towards establishing the reliability, biological relevance and suitability of different uses of the landscape and habitat maps to be produced. What the map does not reveal about the world is sometimes as important as what it does reveal, especially when important decisions have to be made based on maps (Zhang and Goodchild, 2002).

Here confidence is as an assessment of the reliability of the map given its purpose, similarly to MESH project (Foster-Smith et al., 2007). It is regarded to involve judgement of the relative importance of many contributing factors, such as level of information, how near the map is to reality, how relevant to the purpose etc. Uncertainty is explained to be an assessment of the doubt as to map's reliability. Accuracy on the other hand is regarded as a measure of the predictive power of a map to represent world as measured against reality. Measure of inaccuracy is error. It is mathematical measure that describes departure of map from reality based on hits and misses. Accuracy could be used as one of the criteria for assessing confidence. (Foster-Smith et al., 2007).

4.1 Depth and surface substrate data accuracy

The spatial and thematic accuracy of substrate and depth datasets was quantified by comparing values of the GIS datasets to substrate and depth observations obtained from the field at a total of 966 sites.

4.1.1 Methods

Field data
Two field observation datasets were available for the verification of the spatial accuracy of the substrate maps and depth models (Fig. 9). A benthic fauna dataset with 149 sta-

tions sampled between 1991 - 2005 with either an Ekman grab or a Van Veen grab was extracted from the Finnish Environmental Administration's POHJE-database. Six additional sites were obtained from the VALKO project's 2004 survey (Kotilainen et al. 2005). The bottom fauna dataset included depth and a visual approximation of the substrate from the sampling site (hard, soft, mixed). No particle size analyses were available.

A second dataset included a total of 991 sites sampled by drop-video. The dataset comprises observations from three Natural Heritage Service field campaigns between 2004 and 2006. Percent cover of predefined soil types has been recorded from the video where possible. Depth has been recorded at each sampling site. The video data is concentrated in two clusters sampled using a 100 m grid. After removing those sites from the video dataset that lacked the required data, 810 video sites remained to be included in the analysis.

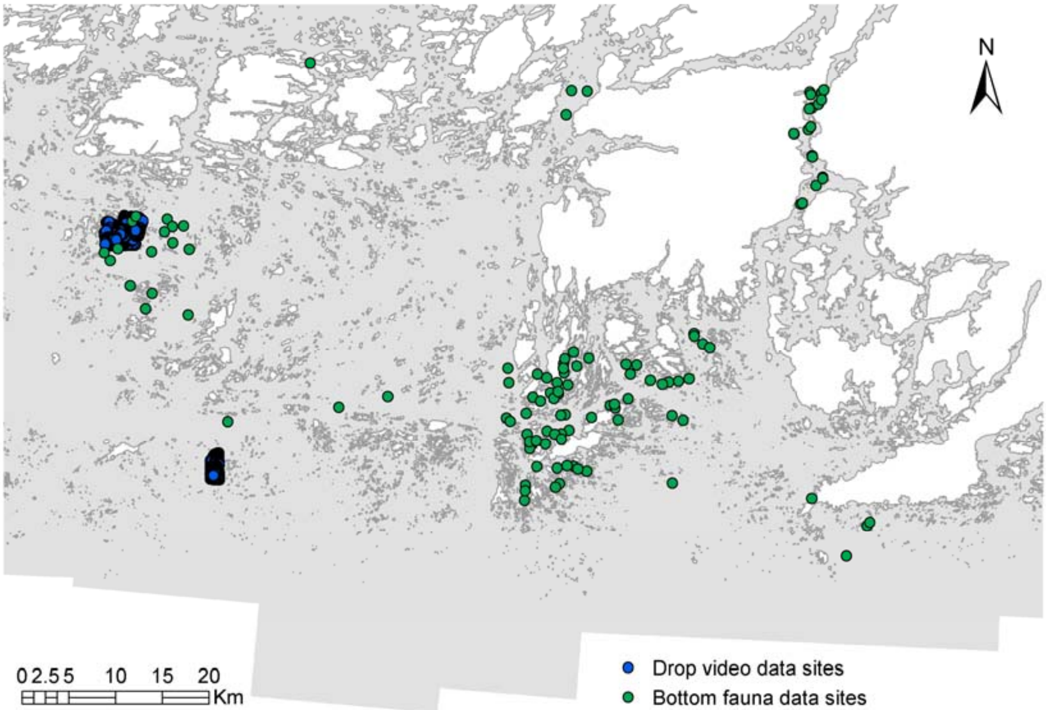

Figure 9. *Field data available for testing the accuracy of substrate and depth GIS data*

Substrate accuracy

In order to make the comparison of surface substrates recorded in the drop-down video observations and the substrate at the same location in the GIS dataset, the percent cover of soil types at the video sites had to be classified according to the BALANCE substrate categories. In the video data, surface substrates are documented as percent cover of ten predefined substrate types: rock, boulders, large stones, small stones, mixed substrate, gravel, sand, fine sand, clay and soft substrate. First, we harmonised the substrate records from video data to BALANCE categories (Table 9). The harmonisation was made on the basis of ecological validity. We considered that there had to exist at least 50 % ecologically relevant material to be classified to certain substrate category. For example, we have classified as category 1 (hard bottom, bedrock and boulders) those video samples where rock, boulders and large stones (> 60 mm) together consist over 50 % of sample and more than 10 % of sample is reported to consist of rock. The same approach was carried through to all of the BALANCE substrate classes. Video observation may include several substrates in same patch, like 30 % of rock and 70 % soft material, which complicates the harmonisation.

Table 9. Harmonisation of video samples to BALANCE substrate classification.

BALANCE category	Predicted surficial material	Substrate in drop video
1. Hard bottom, Bedrock (crystalline and sedimentary), Bedrock covered with boulders.	Bedrock, boulders	Rock ≥ 10 % and (rock + boulders + large stones ≥ 50%)
2. Hard bottom, Complex, patchy hard surface, coarse sand (sometimes also clay) to boulders.	Complex, almost everything except bedrock or gyttja	Mixed ≥ 50 % or (rock < 10% and (rock + boulders + large stones ≥ 50%)) or ((clay + soft) < 10 and (small stones + gravel + sand + fine sand) < 50)
3. Sand	Fine to coarse sand (gravel)	(Small stones + gravel + sand + fine sand) ≥ 50 and (clay + soft) < 10
4. Hard clay	Thin layer of sand, clay, clay with coarse sed. (varved clay, glacial clay)	(Small stones + gravel + sand + fine sand + clay + soft) ≥ 50 and 10 ≤ (clay + soft) < 50
5. Mud, Gyttja	Mud, gyttja clay to silt	(Clay + soft) ≥ 50

Substrate in the bottom fauna dataset from the POHJE database was originally defined as hard, mixed, sand or soft and these were considered to fall into the BALACE classes hard bottom (1, 2), hard clay (4), sand (3) and mud and gyttja (5), respectively.

The BALANCE classified observed substrates from video sites and benthic fauna sites were compared to the class for that location in the substrate GIS data. Confusion matrices with producers and users accuracy were built for each dataset to assess the percentage of sites with a correct bottom substrate and to highlight which substrates were mostly mistakes for others.

Accuracy of depth models

The recorded depths from the video and bottom fauna sites were compiled into one dataset consisting of 966 observations. The depths recorded in the field were compared to the depths presented in the 50 metre and 25 metre depth models for those locations. Scatter plots with linear regression were created to compare the measured depth to modelled depth. Root-mean-squared-error (RMSE) was calculated for both models based on the field data. The distribution of the residuals in comparison to depth was also plotted to test the hypothesis that error in the model depths increases with depth.

4.1.2 Results and discussion

Substrate data

The results of the substrate comparisons done on drop video and grab samples are reported in tables 10 and 11, respectively. The tables comprise a confusion matrix of the substrate GIS data compared to the BALANCE classified bottom substrate data from drop-video observations and grab samples, with the probability that areas placed in a certain class are truly of that class (users accuracy) and the probability of classifying an area into a correct class (producers accuracy) for each substrate class as well as the overall accuracy, in other words, the percentage of all samples classified correctly.

The overall accuracy for video data, at 28 percent, was very unsatisfactory (Table 10). BALANCE substrate class 1 (hard bottom, bedrock and boulders) had the highest producers accuracy, whereas class 5 (mud and gyttja) had the highest users accuracy. Other substrates had accuracies well below 50 percent. Half of the bottoms falling in one of the two hard bottom classes in the map were classes as soft bottoms in the drop video observations. There were also a large number of sites classified as sand on the map, whilst only 3 sites with sand were recorded from video.

Table 10. A confusion matrix of the GIS data substrate compared to BALANCE classified bottom substrate data from drop-video observations

Class in substrate map	Observed class						Users accuracy (%)
	1	2	3	4	5	total	
1	**195**	103	0	0	272	570	**34.2**
2	11	**11**	0	0	54	76	**14.5**
3	18	19	**1**	0	25	63	**1.6**
4	21	9	1	**0**	36	67	**0**
5	9	4	1	0	**20**	34	**58.8**
total	254	146	3	0	407	**810**	
Producers accuracy (%)	**76.8**	**7.5**	**33.3**	**0**	**6.1**		**Overall accuracy 28%**

1) Hard bottom, bedrock and boulders, 2) hard bottom, complex, 3) sand, 4) hard clay, 5) mud and gyttja

Grab samples are gathered from soft bottoms so the large majority of samples are from mud and clay bottoms. Both producer's and user's accuracies for soft bottoms are high, and the overall accuracy of 72 percent can be considered good (Table 11). All but one site classified as mud and clay in the substrate map were from soft bottoms. The few observations of sand from the field samples also fall mainly in classes sand and hard clay, which often has a high percentage of sand.

Table 11. A confusion matrix of the GIS data substrate compared to BALANCE classified bottom substrate data from bottom fauna samples.							
Class in substrate map	**Observed class**						**Users accuracy (%)**
	1	**2**	**3**	**4**	**5**	**total**	
1	**1**	0	1	0	15	17	**5.9**
2	0	**0**	0	0	4	4	**0**
3	1	0	**3**	0	5	9	**33.3**
4	1	0	2	**0**	13	16	**0**
5	1	0	0	0	**109**	110	**99.1**
total	4	0	6	0	146	**156**	
Producers accuracy (%)	**25**	**0**	**50**	**0**	**74.7**		**Overall accuracy 72%**

1) Hard bottom, bedrock and boulders, 2) hard bottom, complex, 3) sand, 4) hard clay, 5) mud and gyttja

The data used to build the substrate map was gathered for a geological mapping purpose, which is intended to give an overview of the seafloor. Maps produced for this purpose cannot be expected to be fully accurate at the scale of benthic sampling. Borders between substrate classes are originally fuzzy and dependent on subjective decisions by the person interpreting field data. Part of the substrate data is relatively old and has low positioning accuracy (± 300 m).

Furthermore, the surface substrate may not be the same as the geological substrate documented in the map. The use of multibeam bathymetry and backscatter data would ease in some cases the interpretation of surface substrate. Better approximations of surface substrate can also be obtained using the original geological map together with other factors that affect the stability of substrates, such as depth, wave exposure and current strength in a predictive model based on field observations of surface substrate.

The geological data was also converted from a vector dataset to a raster with a 100 metre cell size. The rasterisation process has added further error as the value of each cell was based on the vector value at the centre of the cell. Accuracy could be improved by basing the cell value on the dominant class within the cell. We suggest it should be tested whether assigning the cell value to the class with highest percent area within the cell would be a more appropriate approach.

There are several factors contributing to the much poorer substrate accuracy found in the drop video dataset. Video data is limited to depths of 25 metres and shallower, where geological mapping has not always been done acoustically, but has often been extrapolated from the surroundings, making it more uncertain. The shallower depths also tend to be more complex compared to the fairly homogenous soft substrates in the deeper basins, which have a much better accuracy score. Substrate has been visually assessed from the video image, with no sampling. It is possible that some bias towards identifying soft bottoms, although the soft sediment may only form a thin layer on a harder substrate. This needs further attention.

The video samples include several substrate patches, which complicates harmonisation to the BALANCE classes used in the substrate map. Sites with high coverages of soft bottom and rock, for example, are very difficult to place in one BALANCE class. The harmonisation and classification to substrate classes of video data has here been done optimising the harmonisation rules from the viewpoint of habitats. Further work is needed to examine the optimal way to harmonise visual observations of surface substrate into simplified classes.

Depth models

Both depth models (50 m and 25 m cell size) are fairly accurate overall. The depth values in both models clearly correlate with the measured depths (Fig. 10). Linear regressions result in r^2 values of 0.68 for the 50 m cell size model and 0.76 for the 25 m cell size model. The error in the model depths ranges from almost 0 to 40 m (Fig. 11), with root-mean-squared-error (RMSE) of 5.7 m for the 50 m model and 5.0 m for the 25 m model. An error of 5 m is acceptable at the scale of the landscapes and high level habitats. The error in modelled depths increases with depth (Fig. 11). This is likely due to the lower density of depth points in the nautical charts in deeper waters. Depth is also more accurately portrayed in nautical charts in shallow areas.

There is not a large difference between the accuracy of the two models, which is expected as they are largely based on the same data. Preferred use of one model over another would not greatly affect results of the GIS process. Although an error of 5 metres is acceptable at the coarse level of marine landscapes and high level benthic habitats, it will have a noticeable effect on the biological assemblages recorded from a site. The errors at the highest end of the range (40 m) are unacceptable and can have a large effect how the area is classed in a marine landscape of habitat GIS analysis. The large errors, however, were rare and occur in deep areas. Still, the assessment of overall accuracy of the depth models may be influenced by the fact that most of the field measurements used here are from shallow waters (up to 25 m), which are more thoroughly mapped.

The accuracy of depth models could be improved by including a higher number of point measurements of depth into the model, especially from very shallow and deep areas.

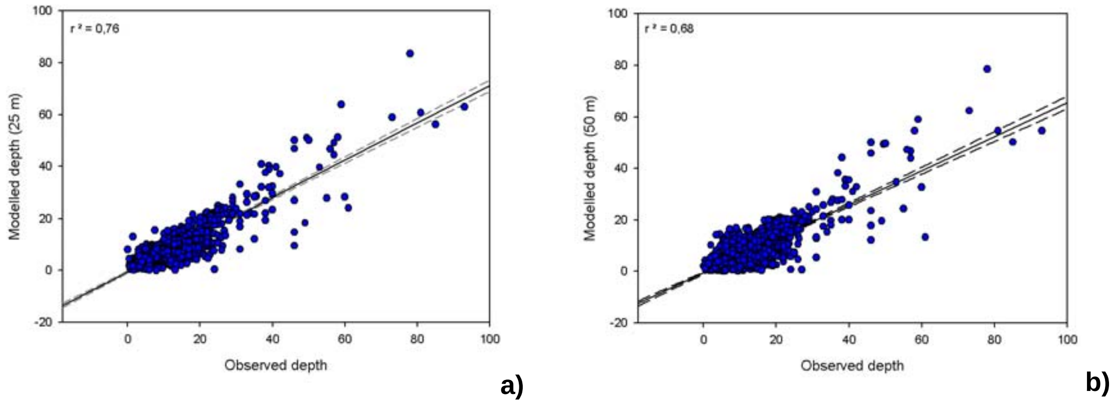

Figure 10. Modelled depths a) 25 m cell size, b) 50 m cell size plotted against the measured values with a linear regression.

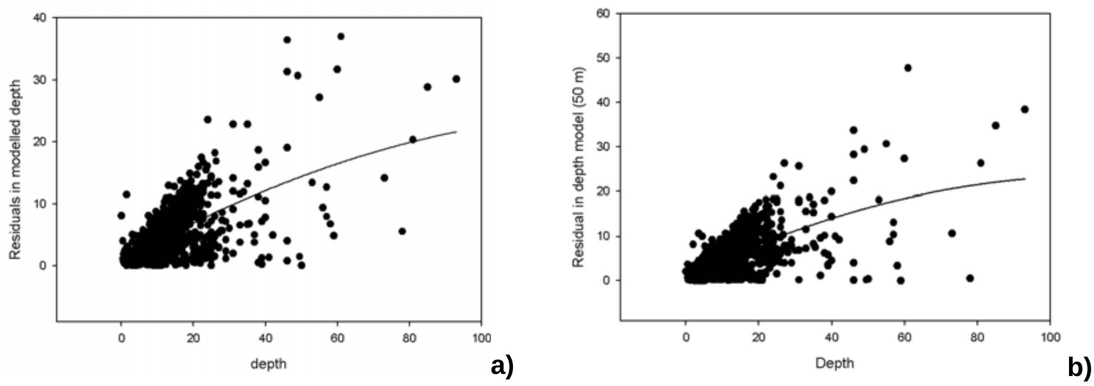

Figure 11. A scatter plot of residuals from the comparison of measured depths and depth models, a) 25 m cell size, b) 50 m cell size.

4.2 Confidence assessment

The marine landscape concept is a recent approach to marine management. The reports and articles about marine landscapes focus on describing the methods of identification, whilst confidence assessments have rarely been tackled. The UKSeaMap –project took the confidence of the landscapes in consideration (Connor et al., 2006). In addition, confidence assessment tools for habitat-mapping purposes have been developed within the Mapping European Seabed Habitat – Interreg project (MESH) (Foster-Smith et al., 2007). Results and methods from these projects have been utilized in the confidence assessment of the BALANCE landscape maps and the EUNIS habitat maps of the Archipelago Sea.

4.2.1 Methods

We have assessed the marine landscapes and EUNIS habitats of the Archipelago Sea against a number of criteria to indicate the overall confidence level using a scoring system developed in MESH (Foster-Smith et al., 2007). We consider the approach simple and general enough to assess data gathered over a large number of years by different surveys and persons. The scoring is possible to complete from metadata alone, which is a great advantage and therefore can be carried out for the Archipelago Sea landscapes.

The MESH confidence assessment is based on a questionnaire developed for habitat mapping (Foster-Smith et al., 2007). Originally the evaluation included three main questions to be addressed to assess the habitat map: How good is the remote sensing? How good is the ground truthing? How good is the interpretation? Each section (main question) contained a number of criteria that were scored separately from 0 to 3 and were afterwards combined to form a score for each section. These section scores were combined into a final overall score. We have slightly modified the questionnaire in order to make it applicable for landscape purposes and to assess confidence of the input data. No ground-truthing or remote sensing is connected to landscape identification itself. The aim was to use existing models and datasets. The same applies to the approach taken to identify EUNIS habitats in this study. Thus, it is essential to asses also the confidence of the input data.

At present, the confidence assessment questionnaire is divided into three sections. The first two sections are about field methods (remote sensing and ground truthing) and address only the input data. Both sections include 5 questions aiming to evaluate the methods used in data gathering and also the age of the data. Questions focus on acoustic-seismic soundings, photographs, satellite images and sampling methods, among others. In cases, only one of the method questionnaires has been appropriate, e.g. Secchi disc data is based on field measurements and no remote sensing has been done in this case. The last section in the questionnaire, interpretation, has 4 questions about how the field measurements or models were interpreted into a map. This last section pertains not only to the input datasets but to the resulting marine landscape and EUNIS habitat maps as well.

Each section has relevant questions scored from 0 to 3 (whole numbers). Similarly to MESH (Foster-Smith et al., 2007) scores are as follows: 0 = task is not carried out (inadequate), 1 = carried out at low standards or to an unknown standard (tolerable), 2 = carried out to a moderate standard (fair/satisfactory) and 3 = carried out to a high standard (excellent). The section score is the average of scores in that section. Finally, section scores are again averaged to present the final score. At this point we have done no weightings between questions or sections. Final scores are presented in scale from 0 - 3 (with decimals). Percentages were considered, but regarded misleading as they might be confused with accuracy. An example questionnaire is presented in Annex 1.

UKSeaMap (Connor et al. 2006) took the following approach to confidence assessment of the marine landscapes:

- For each underlying data set provide good metadata to indicate the source of the data, how the data were processed and the resolution of the dataset
- Consider whether the resolution of the data sets, individually or combined, could be represented on a map
- For each marine landscape type, express the amount of ground-truth validation data available and the degree of consistency in habitat type (compared to expected character of the landscape type)

- For each area for particular landscape type, express the amount of ground-truth data available and the degree of consistency of habitat type (compared to the expected character of the landscape type). This may be best expressed via maps.

In this study, we have taken the first two points of the above into consideration. Metadata of the marine landscapes has been reported and used as a basis of the confidence assessment. The second point has been slightly modified. We have decided to present the confidence level of landscapes on a map instead of the resolution of the dataset. Biological validation (the last two points) of the landscape and EUNIS habitat maps is addressed in the next chapter.

4.2.2 Results and discussion

Each marine landscape map, as well as the EUNIS habitat map, was scored to be in confidence level 2 (Table 13; Fig. 12), corresponding to level fair. The resembling confidence ratings are due to the use of largely the same input data both in landscape and EUNIS identification analyses. Confidence ratings alter inside landscape and habitat models; there are areas that are more confident than others. This derives from uneven bathymetry and substrate datasets. Field methods and sample point density might vary substantially inside a dataset resulting to differing confidence in areas (Table 12). For example, the main part of the substrate data has been mapped before 1983, when positioning was poor and side scan sonar unavailable and only a small portion with more modern techniques afterwards. Thus a confidence assessment was conducted separately for the substrate data finished before and after 1983.

The confidence levels of the different landscape types alter slightly if decimals are taken into account (Table 13, Fig. 12). Coastal physiographic features and EUNIS habitats get the highest confidence level, 2.4. Range of the section scores involved in coastal physiographic features is 1.8 - 3.0. Range of the sections scores for EUNIS habitats is 1.8 - 2.4. Maximum confidence of the seabed topographic features is 2.3 and the benthic marine landscapes get the score of 2.2 in maximum. They include section scores from 1.8 to 2.4 (Table 12).

Tools developed in the MESH –project to assess the confidence of marine habitats proved to be useful in BALANCE marine landscape and EUNIS habitat context (with some modifications), and also when studying the confidence of input data. However, the resulting confidence assessment system is very complicated, as landscapes result from different datasets and models. In future assessment should be rethought and find ways to simplify it. Ideally the data producer should include the confidence assessment to a dataset. However, confidence analysis are generally lacking especially from old/historical datasets. In these cases existing metadata is the only source of information available for confidence assessment. Here we have assessed confidence on the basis of the metadata only.

Confidence analysis reveals the weaknesses of the marine landscapes by studying uncertainties throughout the production process. The ICES Working Group of Marine Habitat Mapping (WGMHM) discussed the confidence analysis developed in MESH (ICES, 2007). They point out that as the scoring system is transparent, and the aspects that reduce the overall confidence can be identified, it is possible to increase the confidence of the final map by adding more reliable data when available. This is valid also for landscapes; the confidence of the landscapes could easily be enhanced by more reliable input data and interpretation. Weak points of landscape determination can be identified and they can be given more effort in future work. At present, more effort should be put on input data, especially to its validation, accuracy and coverage, to raise the confidence to good levels (>2.5). To highlight the importance of field measurements, a weighting system should be examined. The interests to use marine data are expanding all the time and it is vital to have a valid confidence assessment for the data - even if very overall - to assure that users understand the strengths and weaknesses of the data.

Polygonised landscapes might mislead a user to consider that landscapes have high precision due to the smooth boundaries between polygons (Connor et al., 2006). The marine landscapes of the Archipelago Sea are presented in pixels of cell size of 50 m. This reflects also the grid size of the bathymetry data; the grids of the substrate and salinity data used were even coarser.

Table 12. Confidence scores for each contributing input dataset and section scores.

Input data	Confidence				
	Section Scores			Overall score	
	Remote sensing	Ground truthing / field measurements	Interpretation	Min.	Max.
Substrate					
Before 1983	1.8	1.8	1.8	1.8	2.4
After 1983	2.6	2.4	2.3		
Bathymetry and its derivatives					
Model	2.8		2.0 / 2.5	2.4	2.7
Secchi depth – *landscapes*		2.0	1.8	1.9	
Secchi depth – *EUNIS maps*		2.6	2.0	2.3	
Depth zones – *landscapes*			2.0	2.1	2.2
Depth zones – *EUNIS maps*			2.3	2.3	2.4
Bedforms – *landscapes*			2.0	2.2	2.4
Salinity					
Model		2.6	1.5	2.1	
Salinity zones			2.3	2.2	
Wave Exposure					
Wind data		2.8			
Wave exposure			2	2.4	

Table 13. Confidence scores for the Archipelago Sea marine landscapes and EUNIS habitat. Each landscape identification method was scored as 2.0.		
Output Model	**Final Confidence**	
	Min.	**Max.**
Seabed topographic features		
Substrate + Depth zone + Bedforms + Identification	2.0	2.3
Benthic marine landscapes		
Substrate + Depth zone + Salinity + Identification	2.0	2.2
Coastal physiographic features		
Substrate + Bathymetry model + Coastline + Salinity zones + Identification	2.3	2.4
EUNIS level 3 habitats		
Substrate + Depth zone (EUNIS) + Wave exposure	2.2	2.4

A. B. C. D.

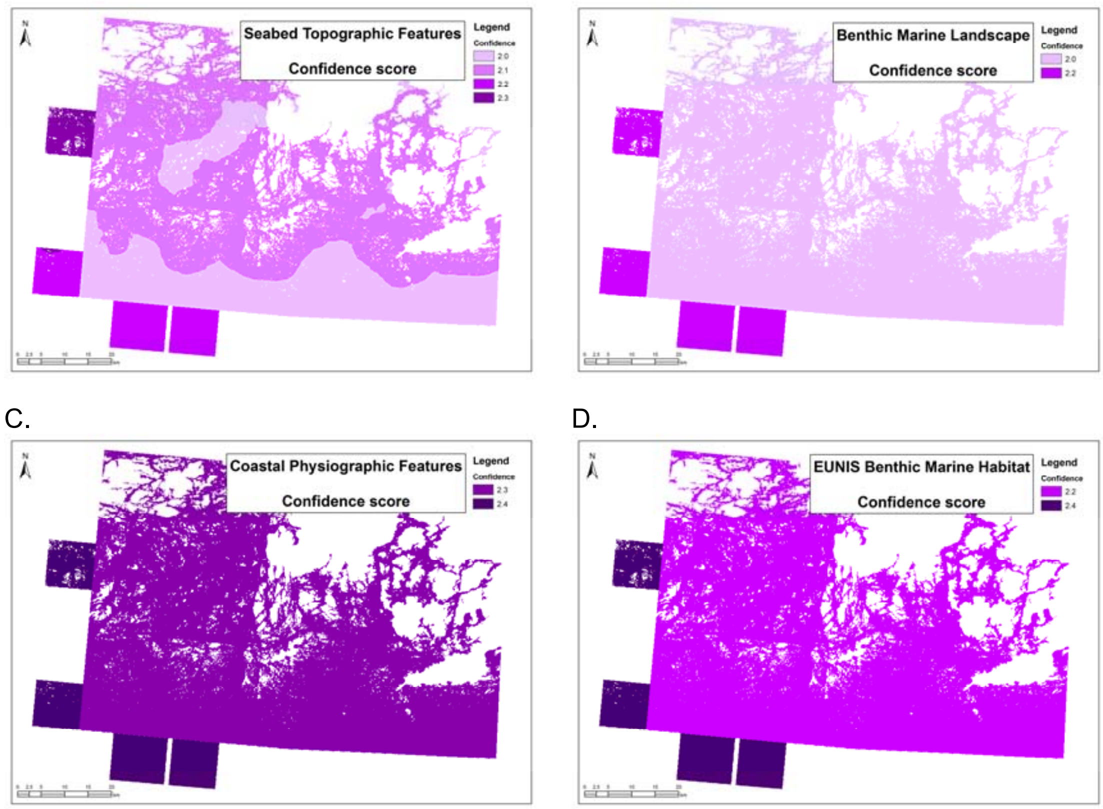

Figure 12. *The confidence ratings for the Marine landscapes from the Archipelago Sea study area. They are scored to be in confidence level 2. Coastal physiographic features are rated highest (C) and benthic marine landscapes lowest (B).*

The results indicate the finest level of confidence reachable in the study area also within the BALANCE landscapes covering the entire Baltic Sea. The confidence of the Baltic scale landscapes cannot exceed the confidence of the local Archipelago Sea landscapes due to the latter having a finer resolution of input data. The Baltic Sea data is combined from different sources and as a consequence data original gathering methods and interpretation may alter significantly inside data layer (Al-Hamdani and Reker (eds.) 2007). The original input data from the Archipelago Sea derives from certain Finnish surveys/organisations with somewhat resembling field and interpretation methods.

This is among the first confidence assessments of marine landscapes. The maps developed in this study have not been used in marine spatial planning yet. In the future, when we get more feedback and suggestions from users, also the confidence assessment will be improved. There are additional issues that should be taken into consideration and the scoring system could potentially be modified as well. Also, meaningfulness of this kind of assessment should be discussed. A potential user of marine landscape and habitat maps will also be interested in the spatial and thematic accuracy of the maps; the actual certainty associated to the map. However, this kind of confidence assessment describes the confidence associated with the input data used and the interpretation method and data used in identification. Confidence and accuracy measures compliment each other to give a potential user of a map the best information available on the applicability of a map to their purpose.

5 BIOLOGICAL RELEVANCE

The biological relevance of marine landscapes and higher level habitats is defined by their ability to determine species associations. The landscapes are not expected to correspond to one habitat in particular, but to include certain habitat types. The following analyses aimed to establish a connection between certain species and combinations of species (or communities) and habitat types, benthic marine landscapes, and seabed topographic features. The coastal physiographic features were not tested due to clustering of habitat sites to small specific areas, lack of detailed input data (e.g. salinity) and very overall feature classification.

Three complimentary approaches were used to assess the correspondence between the biological organisation of the sites into groups and the 3 classifications (benthic marine landscapes, seabed topographic features and EUNIS habitats). MRPP and indicator species analyses were used to test the biological meaningfulness of the “artificial” classes resulting from the GIS analyses, which used cut-off values determined by consensus rather than biological data. Ordination gave an overview of organisation into groups based on biological communities and a visual check on the distribution of sites relative to the classifications.

We chose to approach the task from the point of view of assessing the biological relevance of the actual maps, rather than the landscape and habitat classes represented on the maps. We did not only want to know if the classes were biologically relevant the way they have been put forward in this work, but also the applicability of the existing GIS datasets in representing the biological and ecological factors they have been postulated to stand as proxies for. Thus, we did not test sites classified into the landscape classes based on the real environmental data accompanying the biological field samples as Dienesen et al (in prep.) did in the Danish straits, but extracted the landscape, feature or habitat class for each site in the analysis from the maps.

The more specific aims are set out below:

1 Test for agreement between the source GIS-datasets and measured values in the biological datasets.

2 Check if the Archipelago Sea marine landscape and habitat classifications coincide with biologically distinct units.

3 Test the biological relevance of the currently used cut-off points in the depth and substrate classes selected for landscape and habitat classifications.

4 See if some of the landscape or habitat classes could be merged to produce more meaningful classes.

5 Determine any potential indicator species for particular landscapes and habitats.

5.1 Biological data used

The same field observation datasets used in accuracy analysis were used to assess the biological validity of benthic marine landscapes, seabed topographic features and high level EUNIS-habitats (see chapter 3.1.1). Only those sites from each dataset (drop-video and grab samples) where the substrate in the GIS dataset used to produce the landscape and habitat maps matched the BALANCE classified substrate observed in the field were included in this part of the analysis. The datasets were further selected to include only sites with at least one species record.

The benthic fauna dataset from grab samples that was used in the analyses consisted of observations of the density of species (individuals/m^2) from 57 sites. The drop video dataset comprised 202 sites with percent cover estimates of macrobenthic species that are identifiable from the video image. Taxa were identified to the highest level possible from a video image and percent cover was estimated from the field of vision.

5.2 Methodology

Values for the following categorical variables were extracted in ArcGIS for each video and benthic fauna site included in the analysis:

1. BALANCE substrate classification (5 substrate classes);
2. A classification to 3 depth zones: photic, aphotic and deep;
3. BALANCE benthic marine landscape classification;
4. BALANCE seabed topographic features (without depth);
5. Modified EUNIS habitat classification level 3 habitats;
6. Photic depth from the model used in EUNIS habitats;
7. Wave exposure classes used in the EUNIS habitats.

The Baltic seabed topographic features with depth zones were also considered, but brought no additional information as all seabed feature classes were within the same depth zones. Before the analyses datasets were prepared for each analysis. For the community analyses, five occurrences of a class from each of the classifications were required to be included in the analysis. For the MRPP and indicator species analyses, which were performed for each of the above eight classifications separately, five occurrences of a class in that particular classifying variable were required for the class to be included. In each case, only species, which occurred at least in 5 of the remaining sites, were kept in the analyses. All analyses were done using PC-ORD software version 4 (McCune and Mefford 1999). Bray-Curtis distance was used in all analyses, as it is the most appropriate distance measure for biological community data (McCune et al. 2002).

5.2.1 Testing the landscape and habitat classifications

Differences in communities within the marine landscape/habitat classes

The ability of each of the eight classification variables to characterise differences in biological communities was tested with the Multiresponse Permutation Procedure (MRPP). MRPP is a nonparametric procedure to test for a significant difference between two or more groups of entities. The method requires pre existing groups defined based on some other criteria than the data used to test them. MRPP has the advantage of not requiring distributional assumptions and it is increasingly used with community data (Mielke 1984, Mielke & Berry 2001).

Indicator species for marine landscape and habitat classes

The Indicator value method (IndVal) of Dufrene and Legendre (1997) was used to establish characteristic species for classes in each of the eight classification variables. The method is based on the comparison of relative abundances and frequencies of occurrence of species in different predefined groups of sites. The method identifies species that vary more between groups than expected by chance. The method specifies an indicator value of each species for each class of the classification being tested based on within-species comparisons of abundance and frequency of occurrence in each group. The indicator values range from zero (no indication) to 100 (perfect indication). The significance of each species as an indicator for a class was tested using Monte Carlo tests with 1000 permutations.

Biological diversity in marine landscape/habitat classes

Box-plots of the number of species and the total abundance were produced for a visual comparison of biological diversity between classes of benthic marine landscapes and topographic seabed features.

5.2.2 Community analysis

Non-metric multidimensional scaling (NMDS) was used to create ordinations of the sites in the video and bottom fauna datasets, based on their community composition. NMDS performs an iterative search for the optimal spatial configuration of sites in a dataset in multidimensional space. In effect, NMDS produces a map with the distances between data points as closely matched by their dissimilarity in species space as possible. NMDS is based on ranked distances between samples, does not assume normality and is highly suitable for ecological data that typically contains numerous zero values. (Kruskal 1964, Mather 1976, Minchin 1987).

The video data with percentage coverage values was arcsine-squareroot transformed before conducting the analysis. Untransformed data was used for the benthic fauna dataset. An initial analysis was run for both datasets using the autopilot set up mode, where the default configuration suggested by the program was used. For benthic fauna, the final analysis was run using the three dimensions recommended in the autopilot analysis. For the video data the recommended number of dimensions was two. Standard deviation of 0.0001 in the stress value over 10 iterations was used as a criterion of stability in the final solution of both ordinations. Monte Carlo tests performed with a number of runs of the analysis with randomised data were used to ensure that a better than random result was achieved.

5.3 Results and discussion

5.3.1 Goodness of the landscape/habitat classifications

Differences in communities within the marine landscape/habitat classes
Different classifying factors work best for the two datasets. The benthic marine landscapes are significant classifiers for the benthic fauna dataset (Table 14), whereas the EUNIS level 3 habitats are the best classification for the drop video dataset (Table 15). In both cases the chance corrected within-group agreement (A) is satisfactory. In ecological datasets 0.3 is considered a good A value (McCune et al. 2002). The A value for benthic marine landscapes with the benthic fauna dataset is 0.13 and the A value for the EUNIS habitats with drop video data is 0.1. The seabed topographic features seem to have a small indication of grouping the sites in both datasets (A = 0.05). Both in the marine landscapes and EUNIS habitats, the classification groups sites better than the component parts of the classification. This suggests that there is indeed added value to the combinations of abiotic factors to stand as proxies of the types of habitats and communities present.

The difference in the grouping power of the classifications on the two different datasets may be influenced by the fact that benthic fauna data is largely collected from fairly deep waters whilst the video data is all from relatively shallow waters. In the shallow waters the exposure element included in the EUNIS classification will play a more significant role. The more locally optimised photic depth model used in the EUNIS habitats may also give this classification an advantage in the shallow waters. Another difference to consider is the lack of variation in salinity in between the locations of the video dataset, whereas fauna data is available from both salinity categories. Hence, the salinity element in the marine landscapes can be seen to increase their ability to class benthic fauna communities.

Table 14. MRPP results for the bottom fauna dataset

Classification	No. sites	Average within group distance	A*	p**
Substrate	92		0.01	0.11
Sand	6	0.31		
Mud and clay	86	0.51		
Depth zone	96		0.04	0.00
Photic	37	0.38		
Aphotic	54	0.56		
Deep	5	0.41		
Benthic Marine Landscapes	82		0.13	0.00
Mud and clay, photic freshwater	10	0.41		
Mud and clay, photic, oligohaline	23	0.28		
Mud and clay, aphotic, freshwater	10	0.53		
Mud and clay, aphotic, oligohaline	39	0.51		
Seabed Topographic Features	85		0.05	0.00
Basin, coarse substrate	6	0.20		
Basin, mud and clay	20	0.48		
Basin, accumulative	30	0.59		
Mound, clay	7	0.46		
Plain, mud and clay	8	0.36		
Plain, accumulative	14	0.42		
EUNIS level 3	96		0.00	0.14
Sublittoral sand / coarse sediment	5	0.32		
Sublittoral mud	85	0.52		
Sublittoral mixed sediments	6	0.35		
Photic depth model	96		0.01	0.08
Infralittoral	11	0.38		
Circalittoral	85	0.51		
Exposure class	96		0.01	0.05
Sheltered	91	0.49		
Moderately exposed	5	0.62		

* Chance corrected within-group agreement, ** Probability of smaller or equal delta

Table 15. MRPP results for the benthic community data from drop-video.

Classification	No. sites	Average within group distance	A*	p**
Substrate	217		0.02	0.00
Hard bottom, bedrock	192	0.47		
Hard bottom, complex	11	0.66		
Mud and clay	14	0.50		
Depth zone	219		0.03	0.00
Photic	186	0.49		
Aphotic	33	0.45		
Benthic Marine Landscapes	215		0.05	0.00
Bedrock, photic, oligohaline	173	0.48		
Bedrock, aphotic, oligohaline	20	0.30		
Complex, photic, oligohaline	8	0.68		
Mud and clay, photic, oligohaline	5	0.35		
Mud and clay, aphotic, oligohaline	9	0.55		
Seabed Topographic Features	212		0.05	0.00
Basin, coarse substrate	19	0.38		
Basin, mud and clay	9	0.50		
Mound, bedrock (reef)	177	0.48		
Mound, complex	7	0.61		
EUNIS level 3	216		0.10	0.00
Baltic moderately exp. infral. rock	12	0.63		
Baltic sheltered infralittoral rock	134	0.48		
Baltic sheltered circalittoral rock	45	0.22		
Sublittoral mud	14	0.50		
Sublittoral mixed sediments	11	0.66		
Photic depth model	219		0.07	0.00
Infralittoral	157	0.51		
Circalittoral	62	0.33		
Exposure class	219		0.02	0.00
Sheltered	180	0.45		
Moderately exposed	39	0.64		

* Chance corrected within-group agreement, ** Probability of smaller or equal delta

Each of the classifying variables had an indicator species in at least one class in both datasets. None of the classifying variables had an indicator species for all classes within the classification. The species found to have n significant indicator value ($p \leq 0.05$) are set out in table 16. In most cases the indicator species are ecologically valid, with species commonly found in the shallow sublittoral indicating photic classes and e.g. mussels indicating deeper hard bottoms. The only inconsistent indicator species is filamentous algae which indicated aphotic soft bottoms, but this may be due to the algae observed at these sites being drifting algal mats.

Table 16. Indicator species analysis results for video data

Classification	Bottom fauna indicator species	Video data indicator species
Substrate		
1. Hard bottom, bedrock 2. Hard bottom, complex 3. Sand and gravel 5. Mud and clay	*Pontoporeia femorata; Gammarus* -	*Mytilus trossulus*
Depth zone		
1. Photic 2. Aphotic 3. Deep	*Hydrobia sp.; Prostoma obscurum* *Pontoporeia femorata*	*Pilayella littoralis*
Benthic Marine Landscapes		
112. Bedrock, photic oligohaline 122. Bedrock, aphotic, oligohaline 212. Complex, photic, oligohaline 511. Mud and clay, photic, freshwater 512. Mud and clay, photic, oligohaline 521. Mud and clay, aphotic, freshwater 522. Mud and clay, aphotic, oligohaline	*Prostoma obscurum* *Macoma balthica; Mysidae* *Monoporeia affinis; Harmothoe sarsi; Halicryptus spinulosus; Pontoporeia femorata; Macoma balthica*	*Mytilus trossulus* *Cladophora glomerata* Filamentous algae spp.
Seabed Topographic Features		
1. Basin, coarse substrate 2. Basin, mud and clay 3. Basin accumulative 8. Mound, bedrock (reef) 9. Mound, complex 12. Mound, clay 15. Plain, mud and clay 16. Plain, accumulative	*Pontoporeia femorata* *Potamopyrgus antipodarum; Marenzelleria viridis* *Mysidae*	*Mytilus trossulus* *Cladophora glomerata*
EUNIS level 3		
2. Baltic moderately exp. infral. rock 3. Baltic sheltered infralittoral rock 6. Baltic sheltered circalittoral rock 7. Sublittoral sand /coarse sediment 8. Sublittoral mud 9. Sublittoral mixed sediments	*Pontoporeia femorata* *Gammarus*	*Pilayella littoralis* *Mytilus trossulus*
Photic depth model		
10. Infralittoral 0. Circalittoral		*Pilayella littoralis* *Mytilus trossulus*
Exposure class		
1. Sheltered 2. Moderately exposed	*Chironomidae* *Oligochaeta; Ostracoda; Pygospio elegans; Mytilus trossulus*	*Mytilus trossulus; Chorda filum*

5.3.2 Community analysis

In the community analysis of bottom fauna all of the samples fell into the substrate class mud and clay (5.). At level 3 in the EUNIS classification that was used here, classes including sublittoral sediments are not split according to any other factor, so the only EUNIS class that was present was sublittoral mud (8.). Consequently these two classifications were not considered in the benthic fauna community analysis results.

The bottom fauna ordination had a stress value of 12.4 with a stable solution in three dimensions. A good ordination is considered to have a stress, value between 5 and 10, but values between 10 and 20 are acceptable, although ordinations with stress values closer to 20 can potentially be misleading (Clarke 1993, McCune et al. 2002). The ordination image is essentially a map of the distances of the studied sites determined on their dissimilarity calculated from a community matrix. The result shows a structure to the communities, which is ecologically appropriate.

In NMDS, which is an unconstrained ordination method, the axes in the figure do not represent specific environmental factors. Although based on a visual evaluation of species abundances across the ordination, the main factors that seem to determine the ordination structure are depth and bottom oxygen conditions. There is a grouping of sites with species typically found in deeper waters in fairly good oxygen conditions, such as *Monoporeia* and *Pontoporeia*. Another grouping of sites appears to include species that are tolerant to low oxygen conditions, such as Chironomids and the polychaete *Marenzelleria viridis*. There is also a cluster of sites that appears to include species common at medium depth with good oxygen conditions, such as Oligochaetes and Mysids. There is also an indication of a shallow water group with *Hydrobia* and *Protostoma* (Fig. 13).

The best ordination achieved with the drop video data had a stress value of 17.1 but the solution did not fulfil the stability criterion. Most runs kept oscillating between competing local minima. Consequently the drop video ordination results must be interpreted with caution. A usable ordination was difficult to achieve from the data for several reasons. The data consisted of a very low number of species, with observations collected very close to each other. Most video locations were very similar. It is, however, clear that the main factor structuring the communities in the video dataset was depth (Fig. 14).

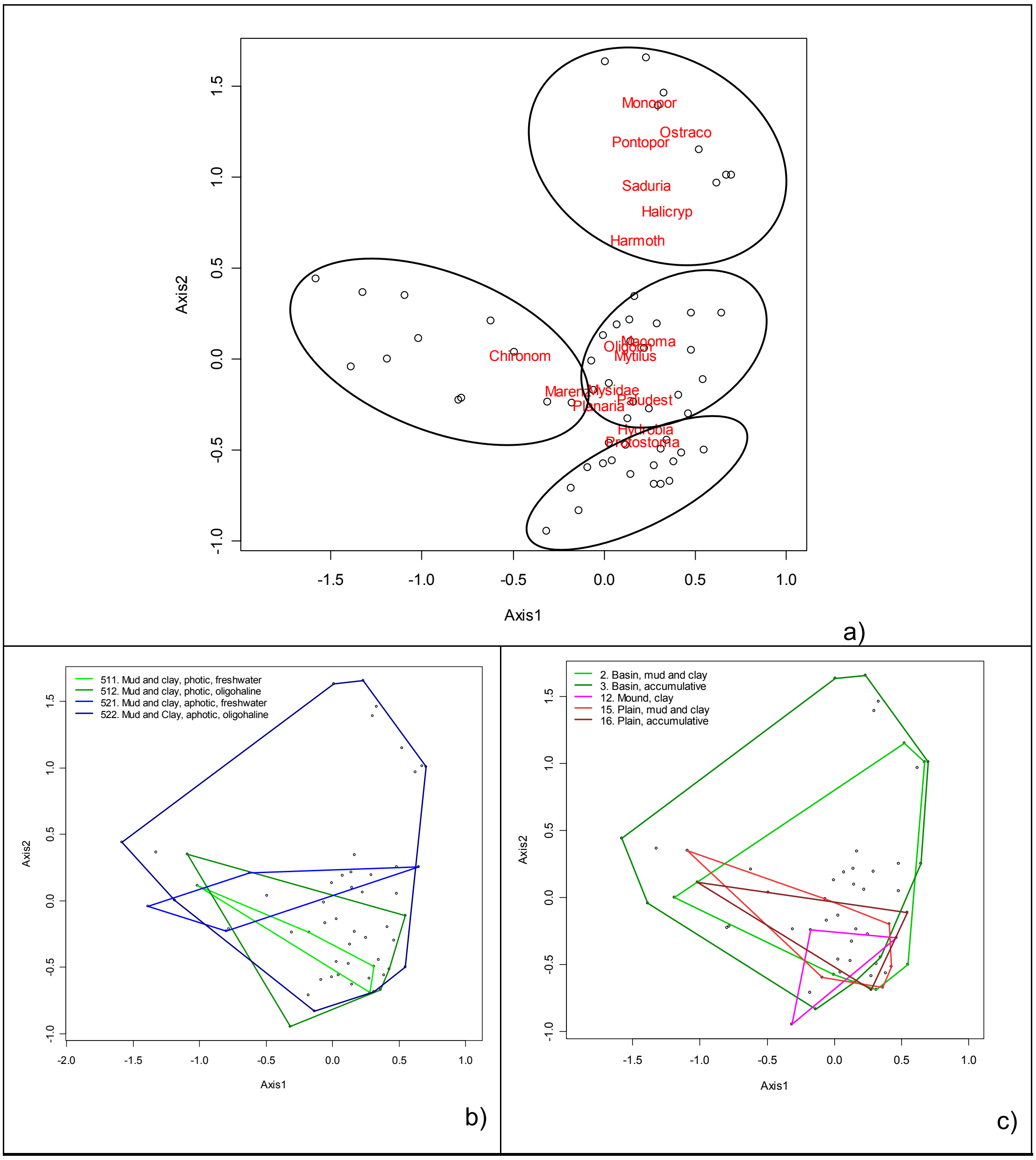

Figure 13. NMDS ordination plots of bottom fauna: a) ordination results with weighted means of species, b) benthic marine landscape, c) seabed topographic features

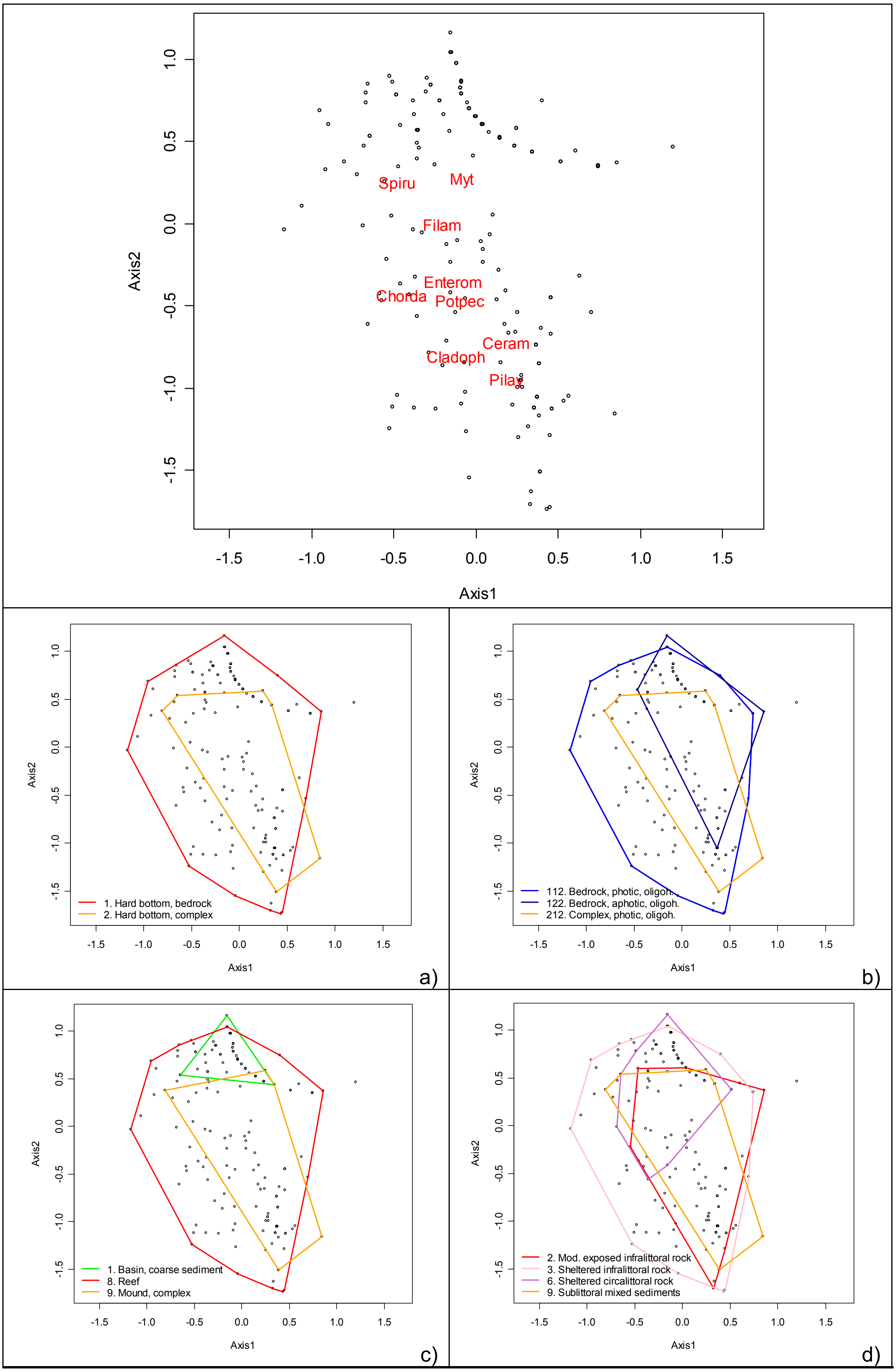

Figure 14. *NMDS ordination plots of the drop video data for a) BALANCE substrate classification, b) Benthic marine landscapes, c) seabed topographic features and d) EUNIS level 3 habitats.*

There is no clear separation according to with the grouping variables from the seabed topographic features, benthic marine landscapes or EUNIS habitat classes for either ordination. There is a large overlap between many classes. The overlap itself does not, however, mean that the groupings are meaningless. A certain amount of overlap is expected between landscape classes. The ordination is based purely on comparison of the biological community at each site. Landscapes, on the other hand, are larger entities consisting of several habitats and consequently communities. Similar communities can exist in several landscape types. Some landscape types are also more diverse than others. This aspect of the biological relevance of marine landscapes requires further attention.

In the benthic fauna ordination all sites are of mud and clay substrate type, so variation in the marine landscapes is defined by depth zones and salinity. The overlap in photic zone groups is partially the result of error in the depth model. Some sites actually in the photic layer have been classed as aphotic in the landscape and vice versa. The group of deep sites is, however, clearly in the aphotic class. The fact that sites in the freshwater group are nested within the corresponding oligohaline groups suggests that the oligohaline groups include a larger variety of sites.

The seabed topographic feature classes in the benthic fauna ordination separate by being on a mound, basin or plain. The basins encompass the largest number of different types of sites, which is acceptable, as no depth separation has been used. However, it must be noted that the landscape/feature types with the largest number of sites also encompass the larges variation in types of sites. Both types of plain (mud and clay, as well as accumulative) are very similar and could be joined together. It is logical that the mounds, with theoretically the higher energy environment do not include any of the low oxygen sites, and also that they have a more limited type of communities.

The grouping power of the benthic marine landscapes and seabed topographic features on the benthic fauna ordination would likely be improved by the addition of a variable that would represent the oxygen conditions. Improved accuracy in depth zones could also make a difference.

No clear groupings can be made out of the video ordination. We believe this is due to the fact that the sites are located in two tight clusters (Fig. 9), and hence are very similar. Most sites have hard bottoms and bedrock found in sites located all over the ordination. The aphotic sites are grouped together inside the photic sites, which would suggest that there is a depth gradient, but the depth zones are not entirely appropriately represented by the landscape and habitat maps. It must also be noted that the video data are collated from two different locations, both containing large number of sites. Although spatially located apart, both locations are biologically very alike and no grouping by location can be seen in the ordination. More widely distributed data is required to make a clear distinction between bottom types.

6 CONCLUSIONS

6.1 General conclusion

We have defined EUNIS habitats and three different sets of marine landscapes from the Archipelago Sea with the raster size of 50 m. The raster size does not, however, reflect accuracy in the map, as some source data have much coarser cell size. The overall aim was to give insight what archipelago and its seafloor consists of: the diversity of the small-scale landscapes that create archipelago and also enable biological validation. On this we have succeeded.

The benthic marine landscapes include altogether 26 landscapes. They were identified from substrate, bathymetry and salinity datasets. Areally dominant benthic marine landscape found is clay and mud areas in aphotic depth and oligohaline environment. The most frequent benthic marine landscape is bedrock in aphotic depth and oligohaline condition. Substrate, BPI structures and bathymetry define altogether 49 seabed topographic features. Here, areally dominant topographic features are basins, especially mud and clay basins in aphotic depths. If studied by number of patches aphotic basins with coarse substrate are most frequent. Coastal landscapes cover 13 % of the whole study area. Channels include largest coastal area (45 %) and bays are most frequent (63%).

The dominance of mud and clay is also reflected in the EUNIS level 3 habitats with over half of the study area falling in the class sublittoral mud. The larger expanses of mud are dotted with smaller patches of sublittoral mixed sediments. Rocky bottoms occur in a large number of small sized patches. Exposed rocky patches were found to be somewhat larger than sheltered patches, which is likely because of the higher sedimentation rates in sheltered areas.

The accuracy of depth and substrate data was assessed with an extensive dataset of over 900 sites. Bottom substrate classification was more accurate in the sediment bottoms. In the shallow sublittoral substrate accuracy was poor. The poor accuracy in shallow waters may result both from the fact that geological survey does not extend all the way to the shoreline, and in these areas the map is extrapolated, and also because the substrate in shallow water is more variable and this variability cannot be captured in such coarse raster grid size. One important factor to consider is the conversion from percent cover of substrate identified from video to the BALANCE substrate classes, which is itself a source of error. The depth model was found adequate for mapping at this scale, with an average error of 5 metres. However, the error increases with increasing depth.

Confidence assessment was conducted successfully for the Archipelago Sea marine landscapes and EUNIS habitats. The confidence levels of different landscapes were scored as fair (<2.5). The result indicates the finest level of confidence reached within BALANCE marine landscapes, because the confidence of the Baltic scale landscapes (Al-Hamdani & Reker (eds.), 2007) cannot exceed the confidence of the local scale landscapes due to finer resolution of input data. Confidence assessment shows that we are able to assess maps based on metadata. Assessments like this give insight also to validity of the metadata, thus the importance of metadata should be emphasized for the users and for mappers. Even though we are able to conduct confidence assessment based on metadata, it is recommendable that data producers would assess the confidence of datasets.

The biological relevance of the landscape and habitat maps was tested with two field datasets, a grab sampled soft-bottom fauna dataset with 57 sites and an underwater video dataset with 202 sites. The benthic marine landscapes were found to group the bottom fauna data better than the other classifications, whilst with the video data the EUNIS habitat classification outperformed the other classifications. The seabed topographic features showed some ability to group communities in both dataset. Each of the classifications was found to group the community data better than their component parts.

Each of the classifying variables was found to have one or more indicator species in at least one class in both datasets. None of the classifying variables had an indicator species for all classes within the classification. In most cases the indicator species were considered ecologically correct for the type of environment the landscape or habitat class represented.

The benthic fauna dataset produced a stable and well interpretable ordination. Depth and oxygen concentration seemed to be the factors affecting community composition. The video dataset did not produce a stable ordination, which was attributed to the dominance of *Mytilus trossulus* in the dataset and the fact that all of the sites in the dataset were very close to each other. The ordination images had no clear structure attributable to the classes of seabed topographic features, benthic marine landscapes or EUNIS habitats. Classes were found to have large overlaps. However, a certain amount of overlap is expected between landscape classes. Landscapes are by definition larger entities consisting of several habitats and consequently a range of communities. Similar communities can exist in several landscape types. Some landscape types may potentially also have a more diverse combination of communities (e.g. complex mounds), whilst others will largely equal one type of community (e.g. mud and clay plains). This aspect requires further attention.

Further work is needed to assess the types of abiotic factors to include in marine landscape and habitat maps to ensure the abiotically determined classes best represent biological communities. Classification boundaries for landscape variables should be examined on a local basis, because they may vary between regions. The relevance factors such as current stress, wave exposure and oxygen conditions should also be examined where appropriate. Linkage between diversity in landscapes and biodiversity should be studied more closely to benefit the ecosystem approach. Types of habitats found in each landscape should also be elucidated.

Work was done in close co-operation between biologists and geologists. Purpose was to enhance the communication between marine scientists and ensure the data transferability. Problems arose especially from mapping scale, substrate classification and sampling. Traditionally marine geologists work in broader scale than biologists. Tendency is to find broad patterns in substrate distribution instead of small traits. From the ecological point of view the surface material is vital in shaping the habitat assemblage. Geologically, however, uppermost centimetres are almost irrelevant and also difficult to identify with methods used. Substrate classifications differ as well, biologist often mark the percentage coverage of substrates as geologists classify area to certain class on the basis of dominant substrate. Issues rose especially from biological video sample data harmonisation. More effort should be placed to harmonise/connect biological sampling to marine geological datasets. Studies on distribution of surface substrates on the basis of marine geological datasets and other environmental parameters should be encouraged to enhance utility value for different user groups.

This study is first of its kind in the Archipelago Sea. We have used "top to bottom" approach, i.e. we have first identified broad concepts (landscapes), made hypothesis and then validated them on basis of biological data. In future it might be regarded that we need more data to define landscapes or more landscape types; data classification scheme and marine landscape types are not final. There is yet neither standard on how to identify marine landscapes, on their limiting values and definitions. At present, limiting values were mainly determined from the general appearance. In future more emphasis should be put on creating internationally agreed standard on marine landscapes and how to define them by GIS to keep landscapes comparable. Marine landscapes are targeted for the marine spatial planning, but they might aid also in studying geological processes (sedimentation) and marine resources among others.

6.2 Marine landscapes in planning and management

At this stage, the results look very promising. Marine landscapes have some ecological value, even though not very clear. They give the broad description of the distribution patterns in the seafloor on the basis the best available data. Nevertheless the results should be handled with caution. Marine landscape approach is in developmental stage. It is likely that they will be modified with more experience and feedback. The marine landscapes are not yet validated with field work. In addition, the accuracy analysis of input datasets are lacking in most cases.

Current marine landscapes can be used as background information to guide investigations to most interesting areas. At this point, however, there are too many uncertainties involved with the landscapes to execute management decisions based on them.

6.3 Future recommendations

We have following recommendations with respect to marine landscape development:

- A list of internationally agreed broad-scale marine landscapes for the shelf areas should be developed in multidisciplinary co-operation with marine scientists. Also strict definitions should be identified to keep marine landscapes similar and comparable.

- Local conditions should be acknowledged in the local scale in the marine landscape hierarchy. The datasets required to supplement basic landscapes in different areas may vary.

- Ecologically relevant class boundaries should be defined regionally and locally for both basic and locally important input datasets.

- The practical ecological dimensions of the marine landscapes should be studied (e.g. ecological boundaries between plain and basin)
- The advantages of the marine landscape approach should be studied in context to marine nature conservation, especially study importance of diversity conservation.
- Assessing accuracy and confidence should be encouraged and be part of the whole modelling and communication process. Confidence assessment methods should be further developed.
- Metadata including spatial information, such as the density of field measurements used to produce a map, are essential and should be a requirement for everyone producing spatial datasets.
- Biological validation of datasets and limiting values should be studied
- Guidance from the National Defense Forces to identify areas where data can be freely distributed

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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

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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
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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
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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
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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.