BALANCE Interim Report No. 13

Harmonizing marine geological data with EUNIS habitat classification

Baltic Sea Region INTERREG III B

BALANCE

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0 PREFACE

This report is a BALANCE product, aiming at the harmonisation of surficial geological data for usage in marine benthic habitat mapping.

For habitat classification purposes, surficial marine geology is a crucial variable together with e.g. depth, current, salinity and wave exposure. Marine geological mapping involves a range of hydro-acoustic and ground-truthing methods. However, the scope and scale of marine geological surveying is different from biological investigations. To overcome this inconsistency, a framework for reclassification of marine geological information to align with the requirements for habitat mapping is under development.

The background data in this report derives from marine geological investigations from two areas in Sweden, carried out by the Swedish Geological Survey (SGU).

Please note that this working document is intended for internal use within the BALANCE project. The framework for harmonisation of primary data will be developed and revised throughout the project. More information about BALANCE can be found at http://www.balance-eu.org.

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1 INTRODUCTION

There is a growing pressure on the marine environment and therefore also an increasing demand of marine environmental data, e.g. to meet the requirements of EU habitats directive (92/43/EEG) and Water framework directive (2000/60/EC). Habitat classification is an import tool for management of human exploitation of natural resources (fishing, oil, gas, wind power) and nature conservation (monitoring, protection, species distribution and location of marine reserves).

A reliable benthic habitat classification requires data concerning hydrography (bathymetry, slope, wind exposure, currents), seabed characteristics (primary sediments, surficial substrates) and species distribution. Many benthic species can only be mapped using very detailed survey techniques, which often makes it is impossible to map larger areas due to coasts. This has made that a major goal for habitat mapping is to predict distribution and abundance of species (and resources), from physical and biotic parameters, which can be sampled with cost-effective remotely techniques (Bretz *et al*., 1999). The immense lack of habitat data in Sweden not only arises from coasts but also from national security issues.

The Geological survey of Sweden (SGU) has carried out seafloor mapping using hydroacoustic methods since 1969, when surveying the Öresund. During the years since, methods and equipment has improved considerably. The early surveys were performed with one-channel seismic and ground-truthing (grain size analysis, video- and photo documentation). At present, a combination of side-scanning sonar, 6-channel seismic and chirp techniques are used, which allows for a much more detailed interpretation of collected material (Lindeberg 2006, pers. comm.). Another important factor is the development of GPS (Global Positioning Systems), which has significantly enhanced the spatial accuracy.

Geological and biological mapping
Detailed seabed maps are one of the most important variables for describing the marine environment. However, mapping of seabed sediments can be done different depending on the purpose of the survey. Geologists are traditionally more interested in *primary deposits* and generally involves a more broad-scale approach to seafloor mapping, based on hydro-acoustical methods covering large areas. In a biological perspective, detailed mapping of *surficial substrates* and species distribution is most important – since substrate characteristics (hardness, mobility, grain size and composition) affects the probability to find specific species. Biological investigations are often carried out using expensive and time-consuming methods as diving, ROV (Remotely Operated Vehicle) and close distance sampling – techniques which are necessary for describing habitats (i.e. physical location or type of environment in which a biological community lives or occurs).

Lack of standards
New techniques has resulted in many descriptions of benthic habitats, but these descriptions can vary from one investigator to another, making it difficult to compare habitats and associated biological communities among geographic regions (Greene *et al*., 1999). Methods for collection, analysis and visualisation of data are often so briefly described, that these methodologies can not be employed by others (Andrews, 2003). Other problems are that data often are presented at different scales with different definitions. This has caused an urgent need to develop an internationally useful standard, which can be used by several scientific disciplines at appropriate scales, in order to integrate and visualise marine habitat data.

European classification standard
A large effort to develop a European habitat classification standard has been made through EUNIS (European Nature Information System) by ETC/NPB in Paris (the European Topic Centre for Nature Protection and Biodiversity) for EIONET (the European Environmental Information Observation Network) and EEA (the European Environment Agency). EUNIS web application provides searchable information of species, habitats and sites. *EUNIS habitat classification* (Davies *et al*., 2004) consists of a hierarchical key, which identifies water and land habitats at six different levels of detail.

The marine key is based on *structuring factors* as: (1) substrate material, composition and mobility, (2) depth (including light penetration), (3) anoxic conditions, (4) wave exposure, currents and tidal streams and (5) species occurrence. A disadvantage is that the key has a far too broad approach regarding definitions and use of abiotic structuring factors (e.g. substrate composition, energy level and exposure) already at the first generalised levels (level 2-3). And also that these levels requires very detailed information of flora and fauna occurrence, which seldom exists. At present, there is fortunately a lot of ongoing work with the development of this classification (see EUNIS web application, web reference).

The Oslo Paris Commission (OSPAR, web reference) regulates marine pollution in the Northeast Atlantic. One part of the OSPAR strategy (the Convention for the Protection of the Marine Environment of the northeast Atlantic) is to protect biological diversity and ecosystem, including marine habitats. OSPAR habitats (web reference) have when possible been given equivalent codes as in EUNIS habitat classification. The Helsinki Commission (HELCOM, web reference) works with the protection of the marine environment in the Baltic Sea (including Kattegatt in Sweden). HELCOM is also involved in habitat classification through the Nature Protection and Biodiversity Group (HELCOM HABITAT, web reference), which works to ensure that suitable information on habitats, species and the conservation of biodiversity is available.

Biological and Geological survey purposes

The main structure in a marine habitat is provided by the type of substrate, which is one of the most important factors influencing species composition (Connor *et al*., 2003). From a biological point of view is often only the uppermost surficial substrate relevant (the surficial layer on top of seabed sediments), since animal and algae are attached to or lives in it. This surficial material can consist of the original primary sediment (unaffected by erosion), but also of sediment, rock and bedrock which been left after erosion or fine material which been transported. This means that surficial substrates can differ from the original primary sediment at erosion and transport bottoms, while it should match the primary sediment at accumulation bottoms (Elhammer 2006, pers. comm.). Due to a different scope and scale of marine geological survey methodology, the substrate information can not always be directly obtained from marine geological maps. Geological nomenclature is partly based on genesis and age of the sediment (c.f. glacial- and postglacial clay), which is not relevant in a biological context. Also marine geological mapping takes into consideration and generalises approximately the topmost meter of sediments. Therefore a reclassification of surficial layers in the Marine geological map is needed to meet the requirements of habitat mapping. It is also desirable that the reclassification results in a product, which harmonises with common definitions of substrate information and habitat types.

1.1 Aim and objectives

The purpose with this study is to establish a classification system, enabling predictions of surficial substrates directly from the Marine geological map – in a mode were geological data and Swedish conditions harmonises with EUNIS habitat classification.

The work was performed by biological analysis of geological field data – by comparing predictions of surficial material with detailed video- and photo interpretations from Skagerrak, Kattegatt and the Baltic Sea. Individual predictions (Mattisson 2005) have been tested and modified (Lindeberg and Elhammer 2006, pers. comm.) for ten categories of the seabed sediments presented in the Marine geological map.

2 DEFINITIONS

2.1 Habitat versus Biotope

The term habitat is often used for describing only physical characters, but also more widely used to include communities of species, which makes it synonymous with *biotope* (an area with uniform environmental conditions, supporting a characteristic assemble of organisms). Most EUNIS habitats are in effect biotopes, except for e.g. glaciers and artificial non-saline standing waters with only microbes (Davies *et al*., 2004). In this study a marine habitat has been considered as: "*a physical location formed by its substrate* (*rock or sediment*) *and other physical factors* (e.g. depth, topography, wave exposure, salinity and temperature)*, in which communities of species occur together*". Which communities that will occur together are decided by the physical characteristics and species interaction in the particular habitat.

The importance of physical structuring factors and scale, is brought up in EUNIS habitat classification – were a habitat is defined as: "*a place where plants or animals normally live, characterised primarily by its physical features* (topography, plant or animal physiognomy, soil characteristics, water quality etc.) *and secondarily by the species of plants and animals that live there*. *Important is that these habitats are defined at a given scale*."

2.2 Scale

Spatial and habitat scales are fundamental concepts in habitat mapping, since they constitute a base from which methodology should be chosen. The significance of these two scales and tidal scale is pointed out by WGMHM (the Working Group on Marine Habitat Mapping, web reference). They define a habitat as a: "*A particular environment which can be distinguished by its abiotic characteristics and associated biological assemblage*, *operating at particular but dynamic spatial and temporal scales in a recognisable geographic area*" (ICES, 2006).

Spatial scale

Spatial scale is a map scale used for describing the resolution of maps (the ratio between maps units and real units), were *large-scale maps* refers to one which shows greater detail (1:10 000-1:50 000) and *small-scale maps* refers to one with less detail (1:250 000-1:7 500 000). Those between 1:50 000-1:250 000 are maps with an intermediate scale (Rosenberg, web reference). Maps with a very small ratio are considered as "small-scale" maps (NOAA Coastal Services Center, web reference), while "large-scale maps" has a large ratio. These terms should not be mixed up with common expressions concerning large-scale and small-scale habitat mapping, which refer to the size of the area being investigated. One important rule concerning spatial scale and resolution of data (high or low) is to use an appropriate scale, which enables visualisation of the mapped data. SGU (the Geological survey of Sweden) produces both local (1:100 000) and regional (1:500 000) Marine geological maps.

Habitat scale

Habitat scale is used for describing the geographical extent of habitats as an area. EUNIS works on a scale enabling identification of large invertebrates and small vertebrates were a habitat could be distinguished if it occupies more than 25 m^2 (Connor 2006, pers. comm.). Despite that most EUNIS habitats are at least 100 m^2 and that many *habitat complexes* (e.g. X31-X33) usually occupies 10 ha, there are also a few *microhabitats* which occupies ≤1 m^2. The difficulty in distinguishing individual habitats, depends on that they can extend over several habitat scales and do not always have distinct boundaries (i.e. transitions of sediment grain size), and due to temporal processes which affects the seabed substrates. It is however important to try to identify these boundaries, the geographic limit of species distribution results among other from the barriers to migration, reproduction and survival (Bretz *et al*., 1999).

Temporal scale

Temporal scale is important since seasonal changes and sudden fluctuations will affect mapped habitat data. This scale can reach from regular hour-long processes as the tide and day-long occasionally occuring storms, to month-long temperature variations due to the change of seasons.

2.3 Seafloor mapping and benthic habitat mapping

Seafloor mapping and benthic habitat mapping are two different mapping approaches, often operating at different scales and with different purposes. *Seafloor mapping* and *habitat mapping* involves both identification of geological features and morphology, but *habitat mapping* involves also identification and collection of detailed information of biological communities, oceanographic- and chemical features.

Multidisciplinary techniques

Today, increased use of multidisciplinary techniques (broad remote sensing techniques and detailed *in situ* ROV-techniques) has made it possible to describe all benthic habitats (shallow to very deep habitats) from many different sorts of data at different scales. Since it seems that benthic habitats primarily are defined by its geology, geophysical techniques (sidescan sonar, swath bathymetry, backscatter imagery and seismic reflection profiles) are essential in determining sediment and rock type. But *in situ* biological, geological- and oceanographic techniques as grab, photo documentation and CTD (measurement of conductivity, temperature and depth) are needed for validation of interpreted remote sensing and hydroacoustic data in order to enable detailed habitat classification. This has lead to an urgent need of developing standard definitions and nomenclature, which can be used by all multidisciplinary actors. A solid review of these techniques in a mode harmonising with EUNIS has been done by MESH (Mapping European Seabed Habitats, web reference), resulting in the development of a set of internationally agreed protocols and standards for seabed habitat mapping (Bultat *et al*., 2005).

Structuring factors

The marine environment can be mapped and described at many habitat scales (e.g. from ocean- and habitat-level to species-level). The corresponding classification uses different detailed geological-, oceanographical-, biological- and chemical- structuring factors for characterisation of each scale. Some important structuring factors controlling species distribution and abundance in benthic habitats are shown in Figure 1.

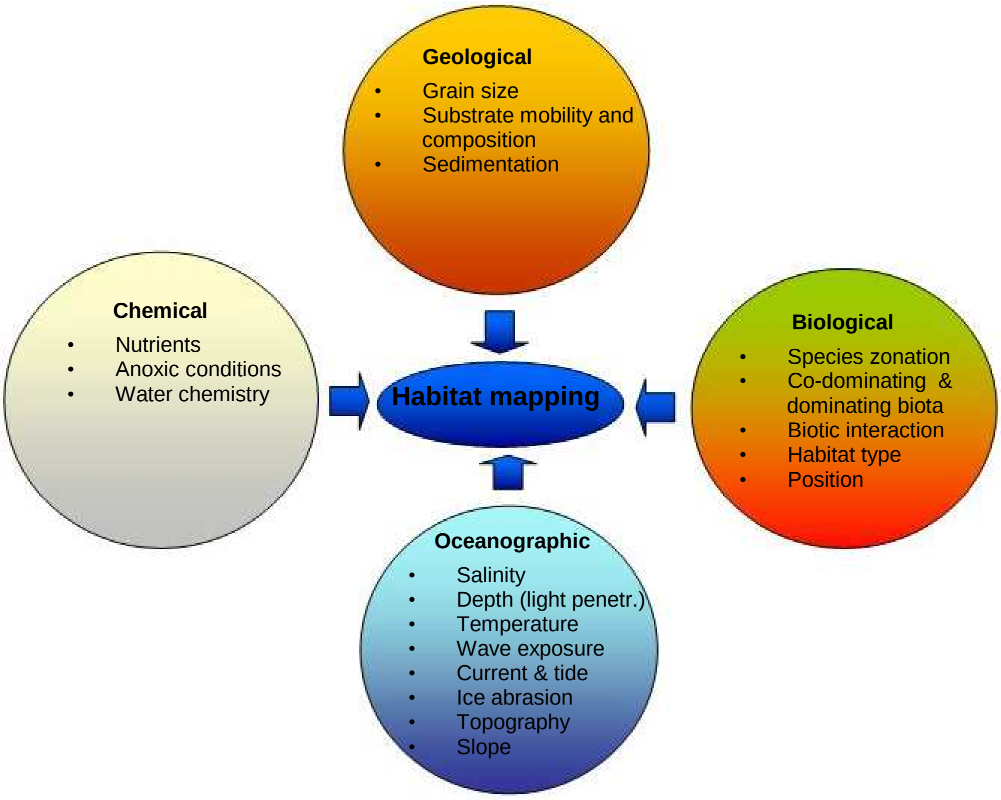


Figure 1. *Important geological, oceanographic, biological and chemical structuring factors controlling species distribution and abundance in benthic habitats.*

Species-environment relations

For a successful ocean´s management a systematic approach is required to define relationships between benthic infauna and physical properties which is not well established (Post, 2006). Sediment properties enable characterization of surficial sediments and ecosystem heterogeneity (Smith & Wiedicke-Hombach, 2001). Some *abiotic* structuring factors and their relationship to species are listed below.

- *Substrate firmness* is among others related to *grain size*, *water content* (porosity) and *compaction*. Cohesive substrates resist erosion and resuspension, while bioturbation (mixing of sediment by burrowing or boring organisms) alters the overall cohesiveness of the substrate (Gingras *et al*., 2000).

- *Grain size and distribution*. The particle size is important for organism since epibenthic organisms (mobile or sessile) can attach on hard surfaces, while crevices between gravel, cobbles and boulders may provide shelter from predators. The distribution is also important, since mixed biogenic sediments provide a diversity of habitats and therefore also of organisms (Post *et al*., 2006).

- *Water content and Porosity*. The amount of water (weight % of the sediment) in a porous medium is associated with *porosity* (volyme % pore space), which is affected by compaction (see below) and the flow of pore water from and below the seawater-sediment interface. The water content increases rapidly in materials smaller than about 0.02 mm (silt and clay). After standing or after the superposition of additional material the water content decreases (Sverdrup *et al*., 1942). A high water content reduces the effort burrowing organisms need to penetrate the sediment surface (Gingras *et al*., 2000) and facilitates organisms vertical movement (Smith & Wiedicke-Hombach, 2001). Processes in the sediment-water interface control among other food avaibility and pore water flow (Post, 2006).

- *Compaction* is the loss of water from a sediment layer. This compression process reorients and reshapes the grains of a sediment in response to the weight of overlying deposits (Gingras *et al*., 2000), resulting in a more firm sediment.

- *Sediment age* is related to water depth, since *relict sediments* sedimented before present (McManus, 1975), while *recent sedimentation* must have been well established continuously during >150 years (Elhammer, pers. com. 2006). Seabed sediments are affected by theirs *hydrodynamic balance* (particle supply and distribution) and by *compaction* (recently deposited material has a greater pore space and water content than "*aged*" that has been subjected to pressure, Sverdrup *et al*., 1942). Relict sediments which are no longer in hydrodynamic balance therefore create a very different environment than sediments in hydrodynamic balance, even if they have similar grain size. *Recently* deposited muddy sediments tend to have high water content and are characterized by deposit feeders and unstable burrows, while hard relict muddy sediments are associated with suspension feeders and permanent burrows (Post *et al*., 2006).

- *Shear strength*, the ability of a sediment to resist deforming and moving forces, results from cohesion and friction between soil particles. Shear strength is extremely important for burrowing animals (Gingras *et al*., 2000), which are dependent of the sediments nutrients and pores as shelter.

According to Kenny *et al*. (2003) *grain size*, *porosity*, *shear strength* and *sediment dynamics* are most important in controlling benthic communities of marine sands and gravel. Post (2006) however suggest that *sediment stability and age* might be of greater importance (than grain size itself), since granulometric properties most likely only account for maximum 45% of the variability found in the biological component – which also is affected by water depth, temperature, light intensity and food supply. Currents are important in defining grain size and by the distribution of larvae, which may reflect passive sorting of larvae – rather than selective preference.

Abiotic and biotic relationships may vary between regions and also depending on scale. Even if grain size is the most important influence on community composition can organic carbon content be more important on a broader scale and surface production on an even larger scale (Post, 2006).

2.4 Substrates and sediments

Surficial substrates

Bottom substrates have a fundamental significance on the type of fauna which can be found at a site (Blomqvist *et al*., 2006) and therefore habitat mapping should include a detailed classification of *surficial substrates* (the thin surface on or in organisms and biological communities are attached or burrow). These data are often overlooked since biologists often are most interested in describing species and a geologic interpretation may include and generalise the topmost meter of sediments, since geologists aim at describing material not directly affected by recent processes (*primary sediments*).

In a geological point of view, surficial substrates can originate from three categories of bottom sediment, depending on how the erosion process has affected the sediment:

Primary sediment

- original material (unaffected by erosion)

Secondary sediment

- residual material (left after erosion)
- transported and redeposited material

Erosion and sediment transport

The seabed is divided into three bottom types: *erosion bottoms, transportation bottoms* and *accumulation bottoms*. The interaction between these bottoms depends on the grade of impact from wind, depth, currents and bottom substrate characteristics. But sediment transport is a complex process, resulting in that sediment on steep slopes can be moved by currents too weak to move the same sediment on a flat surface, while mussels and algae can stabilise fine sediment through reducing the energy from waves and currents (Morelock, 2006).

Water movement affects the type of sediment, resulting in coarse sediment in exposed areas and fine mud in sheltered areas. Most of the sediments are deposited at great depth (without strong currents and waves), while only a few are deposited shallow. Old deposited sediments are eroded due to the land elevation (land uplift) process typical for the Baltic Sea. No fine material is permanently deposited on the shallow erosion bottoms (UMESC, web reference), since current- and wave action will move the material further down to transportation bottoms were it can settle down temporary. Finally the material will settle down at accumulations bottoms, were very old sediments can be found. At erosion and transport bottoms the surficial substrate may differ from the primary sediment, while it should match the primary sediment at accumulation bottoms (Elhammer 2006, pers. comm.).

Bedrock

In this study two types of bedrock has been studied: the older crystalline bedrock and the younger sedimentary bedrock. In areas where wave actions and strong currents prevents sedimentation, bedrock outcrops may occur.

Glacial sediments

Glacial clay is a very fine material with less than 1% organic content (Table 2), composed of many different fractions (from consolidated clay and sand to boulders). The more unsorted *till* might include fractions from clay to boulders but is often dominated by sand (*boulder clay* is till deposits with >15% clay). *Glaciofluvial deposits* forms distinct layers with sorted material as sand and gravel, and also rounded stones and boulders. These deposits may also ocur as distinct esker features outcropping the seabed.

Postglacial sediments

Postglacial clay, gyttja clay and clayey gyttja consist of eroded fine minerogenic material (clay and silt) and organic content (Table 2). Occasionally these sediment types are laminated due to seasonal oxygen deficiency. *Postglacial fine sand* and *postglacial silt* are both well sorted fine material, which often are transported and deposited on top of other more stable sediments and rocks. Surge sediments as *postglacial sand and gravel* is mainly composed of fractions from sand to gravel, but can also include pebbles and cobbles.

2.5 EUNIS definitions

The seabed consists of substrates with different grain size, organic- and water content, composition (well or poorly sorted) and stability, which directly or indirectly affects species distribution (i.e. grazers, predators, deposit- and filter feeders). These characteristics must be defined and intergrated with EUNIS habitat classification. Proposal of definitions that can be used and how to use EUNIS marine habitat classification in practice has been done by among others MESH (Connor, web reference), but many abiotic structuring factors are still not integrated in EUNIS (see 2.3 "Species-environment relations").

Grain size and organic content

Sediments physical properties can be described according to their clay and silt content (Table 1), which requires particle size analysis (PSA). PSA is a commonly used method for groping fractions from clay to boulders. Terms and definitions in accordance with the Atterberg scale were used in the Marine geological map, while EUNIS used Connor & Hiscock (1996). One difference is that the clay and silt fractions in the marine geological map are grouped together as mud in EUNIS (Table 9). In the Marine Geological Map physical properties of sediments are described according to their organic content (Table 2), while EUNIS only briefly mentions "*organically-enriched sediment*" without any definition.

Table 1. *Sediment classification based on clay* (*SGU, 2002*) and *silt content* (*Davies et al., 2004*).

Clay content (%)	Nomenclature (Marine geological map)	Silt content (%)	Nomenclature (EUNIS)
<5	non-clayey or poorly clayey	<30	fine sand or muddy sand
5–15	clayey sediment		
15–25	coarse clay	>30	mud
>25	fine clay		

Table 2. *Sediment classification based on organic content* (*SGU, 2002*).

Organic content (%)	Nomenclature (Marine geological map)
<2	non-muddy sediment
2–6	muddy sediment (e.g. gyttja clay)
6–20	muddy sediment (e.g. clay-gyttja)
>20	gyttja

Substrate mobility

The stability of rock and sediments, which depends on the grain size in combination with the degree of exposure to waves and currents, are important factors for algae and animals which live on the substrate surface (epifauna) or within sedimentary deposits (infauna). Only a few attached organisms can survive on mobile cobbles – they are fast growing, disturbance-tolerant species that settle rapidly or that grow readily from remaining parts after abrasion finishes (Hiscock *et al*., 2006). In EUNIS substrates have been divided into three groups (Table 3) regarding mobility:

- *non-mobile substrates*
- *mobile substrates*
- *mosaics of non-mobile and mobile substrates*

Table 3. *EUNIS classification of rock and sediment according to substrate mobility: Non-mobile substrates, mobile substrates and mosaics of non-mobile and mobile substrates.*

Non-mobile substrates	Mobile substrates	Mosaics of non-mobile and mobile substrates
bedrock and boulders	-	”Complex” [3] X 31: A1 and A2 X 32: A3 and A5 X 33: A4 and A5 (see Annex 2)
cobbles and pebbles	cobbles, pebbles and shingle[1]	
-	gravel	
-	sand	
compact soft mud or peat	mud	
rock overlaid by deposited sediments	"Mixed sediments" [2]	

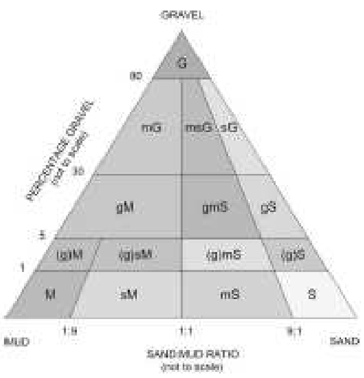
[1] highly mobile pebbles and cobbles

[2] combination of poorly sorted heterogeneous mobile substrates with different grain size (mud-cobbles)

[3] mixtures of mobile and non-mobile substrates with different grain size (mud-bedrock)

Sediment mixtures

To define if a site with mixtures of *surficial sediments* (mud, sand and gravel) is truly mixed or heterogeneous, EUNIS recommend the BGS trigon. The BGS (British Geological Survey) trigon is based on the ”*Folk triangle*” (Long, 2006) by Folk (1954), in which 15 sediment classes could be distinguished based on the relative proportions of mud, sand and gravel. The original Folk triangle, which has been used in BGS 1:250 000 maps are shown in Figure 2 (left). In BGS 1:250 000 maps were the original 15 sediment classes used but in the BGS 1:100 000 maps were only 11 classes used (Figure 2 to the right), after removal of the 1% gravel boundary (Long, 2006). A weakness with the BGS approach is that large non-mobile cobbles and boulders are treated as fine mobile gravel (Rees, 2004).



M	Mud
SM	Sandy mud
(g)M	Slightly gravelly mud
(g)sM	Slightly gravelly sandy mud
gM	Gravelly mud
S	Sand
mS	Muddy sand
(g)S	Slightly gravelly sand
(g)mS	Slightly gravelly muddy sand
gmS	Gravelly muddy sand
gS	Gravelly sand
G	Gravel
mG	Muddy gravel
msG	Muddy sandy gravel
sG	Sandy gravel

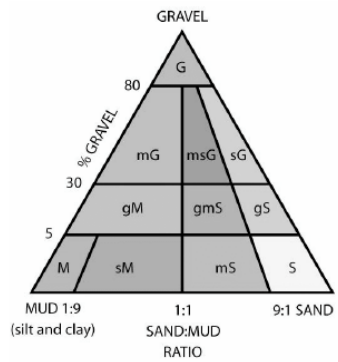
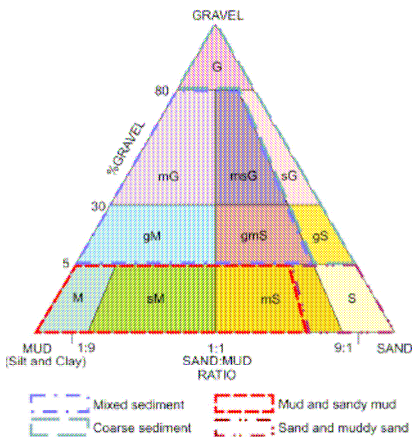


Figure 2. *Folk triangle used in BGS 1:250 000 maps with the original 15 sediment classes (left) and modified Folk triangle used in BGS 1:1000 000 maps with 11 sediment classes (right), after removal of the 1 % gravel boundary (after Long 2006).*

A sediment classification system more adapted to EUNIS has been developed for the *UKSeaMap project*, (web reference) through the grouping of the 11 classes into four main groups (Long, 2006):

- *mixed sediment*
- *coarse sediment*
- *sand and muddy sand*
- *mud and muddy sand*

Other adaptions to EUNIS were made through the creation of a fifth group, *rock outcrop*, and also by dividing the Folk gravel class (gravel, pebbles, cobbles and boulders) into two classes, since cobbles and boulders support significantly different biological communities (Connor *et al*., 2006). More detailed information of how these two classes with non-mobile substrates were defined or how cobble mobility should be handled (can be both mobile and non-mobile), were however not specified. The main difference from the original Folk classification is that the boundary between ”muddy sands” and ”sandy mud” is set to 4:1 (sand to mud ratio) instead of 9:1 (Figure 3). In Figure 3 (to the right) is also an even more simplified system shown, with only the four main groups based on the 5% and 80% gravel boundaries and the 4:1 and 9:1 sand to mud ratio.



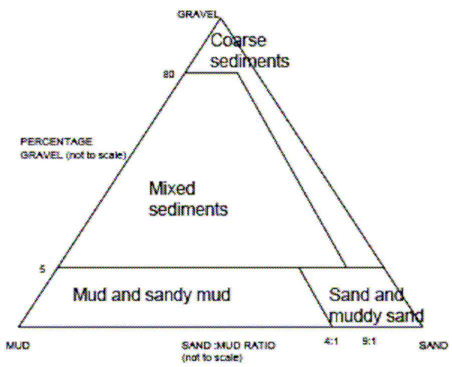


Figure 3. *BGS trigon adapted to EUNIS in* the *UKSeaMap, with four major sediment classes (left). The sediment classes and the 4:1 boundary between “muddy sands” and “sandy mud” is shown to the* right (after Long, 2006).

Criteria for marine habitats (level 1-2)

In EUNIS marine habitats at the first level (A) are defined as saline, brackish or almost fresh – which are directly or indirectly connected to the oceans. At the second level (A1-A6) benthic habitats (rock and sediments at the seabed) are further classified and named after if the habitats are permanently water-covered, if the habitats are situated at the shelf or not, if the substrates are mobile or non-mobile and if macro algae are dominating (Figure 4). These criteria are mainly grouped based on *depth zones*.

- *Hydrolittoral* habitats can be found at shores of non-tidal waters below the mean water level (MWL), which regularly or occasionally are exposed by the action of wind. According to Backer *et al*. (2004) the shores of the Baltic Sea are hydrolittoral (0-0,5 meters below the mean water level).

- *Littoral rock* (A1) *and littoral sediment* (A2) includes habitats occurring in the intertidal zone (the area of the shore between high and low tides) and the splash zone. These habitats might be found in shallow areas in the Skagerrak and Kattegatt where the tidal differences are up to 30 cm (Bohuslän), but not in the micro-tidal Baltic Sea were the tidal influence is negligible (EUROSION, 2004).

- *Infralittoral rock* (A3) habitats in the shallow subtidal zone are dominated by seaweed, while animals dominate the deeper occurring *circalittoral rock* (A4) habitats. These two rock habitats can only be distinguished if detailed information of algae and animal abundance is available (light penetration dependent). In a study of Swedish offshore banks were this boundary established at approximately 15-20 m in the Baltic Sea and 20 m in Kattegatt and Skagerrak (Naturvårdsverket, 2006), while Mattisson (2005) used 25 m for areas in the Baltic Sea.

- *Sublittoral sediments* (A5) cover both the infralittoral- and the circalittoral zones at the continental shelf, i.e. the area from the shore to the shelf break at approximate 200 meters (including the Baltic Sea which is a shelf sea).

- The *deep-sea bed* (A6), which is generally found at depth greater than 200 meters, starts at the edge of the shelf and continuous beyond the shelf break.
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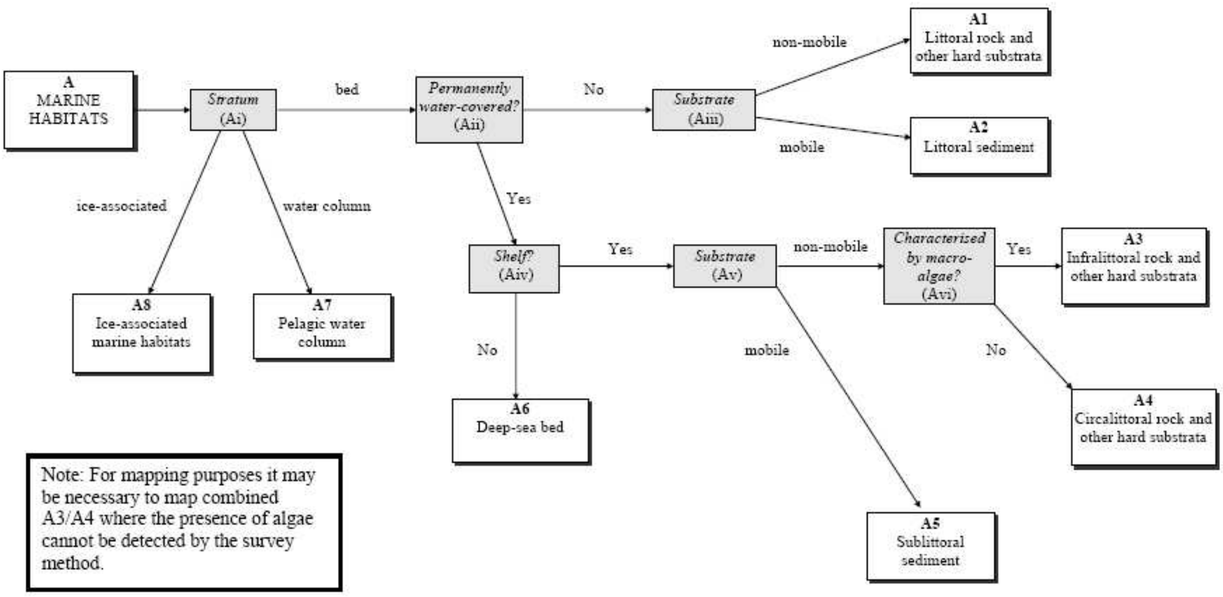


Figure 4. *EUNIS habitat classification*: *criteria for marine habitats to level 2, were combination of letters refers to explanatory notes to the key* (*see EUNIS habitat classification by Davies et al., 2004*).

Exposure

Infralittoral- (A3.4-A3.6) and circalittoral rock (A4.4-A4.6) in the Baltic are classified after *exposure status* (caused by waves, currents and ice scouring) – based on *effective fetch*[1] (Annex 1 – Table 1). A large *fetch window*[2] generates greater waves than a small (Howes *et al.*, 1999). The classes: (1) *Exposed* (>25 km), (2) *Moderately exposed* (5-25 km) and (3) *Sheltered* (<5 km) – are shown in Figure 5-6.

Energy level

Infralittoral- (A3.1-A3.3) and circalittoral rock (A4.1-A4.3) in the Atlantic & Mediterranean are classified after *energy levels* (caused by waves, currents and tidal streams): (1) *High*, (2) *Moderate* and (3) *Low to negliglible* (Figure 5-6). These levels are subdivided according to *grade of wave exposure* and *strenght of tidal streams and currents*. These definitions are among other things based on: fetch[1], open water window[2] and swell[3], offshore breaks and deep-water distance from shore (Annex 1 – Table 2).

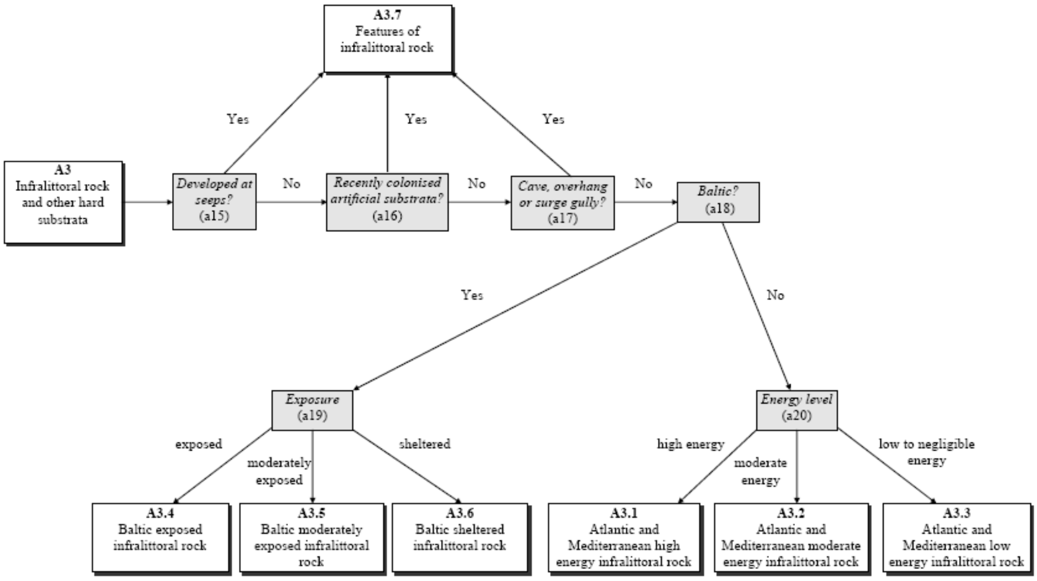


Figure 5: *Infralittoral rock* (A3) *classified by exposure and energy level* (*after Davies et al., 2004*).

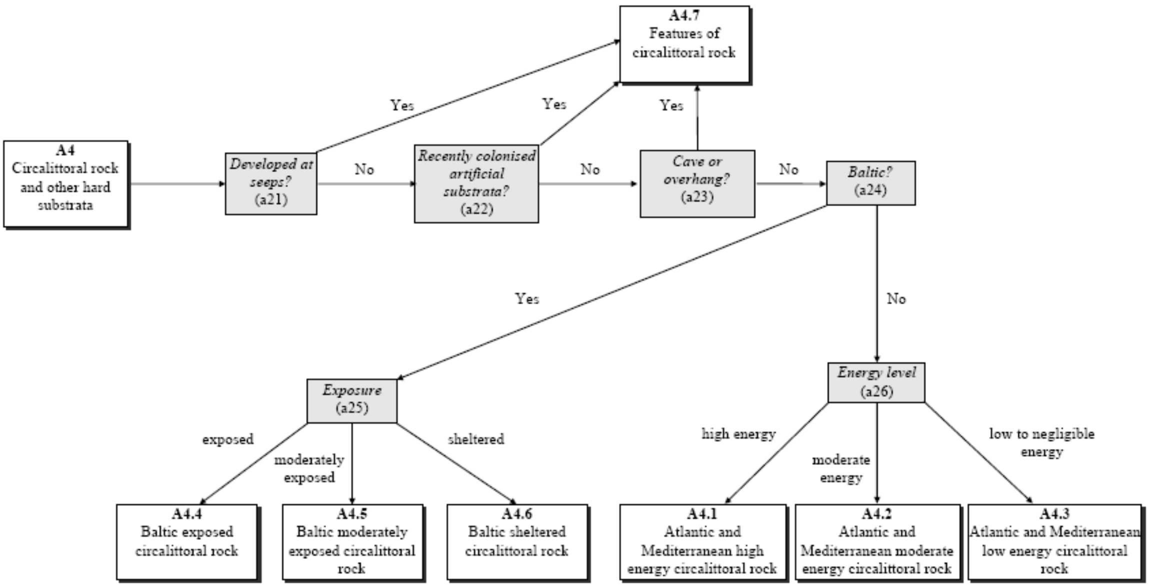


Figure 6: *Circalittoral rock* (A4) *classified by exposure and energy level* (*after Davies et al., 2004*).

[1] i.e. effective fetch, distance along several directions from a given point from the shore

[2] i.e. fetch window, the open-water area offshore from the shore over which waves can be generated by winds (Howes *et al*., 1999)

[3] waves generated remote from the shore

3 MATERIAL

3.1 Geological data

This study is based on existing geological data (the uppermost 0.5 m) of the seabed surface (classified as glacial- or postglacial sediments and bedrock), and also of videos and photos of surficial substrates from Skagerrak, Kattegatt and the Baltic Sea in Sweden. The Marine geological maps which been used in this study (Table 4), are based on interpretations of hydro acoustic data (side-scanning sonar, sediment profiles and 6-channel seismic), which been ground-truthed through sediment sampling, grain size analysis and interpretation of video- and digital photo material.

Table 4. *Geological material used in this study.*

Nr	Data	Nr	Owner	Year
1	Marine geological map (digital vers.).	4-5, 6A, 7A-B, 8A, 9A, 10A	(Geological Survey of Sweden) SGU	2006
2	Marine geological map	5B Lilla Middelgrund-Varberg	(Geological Survey of Sweden) SGU	2002
3	Geological field protocols	-	(Geological Survey of Sweden) SGU	1991-2001, 2003-2005
4	Video films (VHS)	-	(Geological Survey of Sweden) SGU	1991-2001
4	Photos (digital)	-	(Geological Survey of Sweden) SGU	2003-2005

Sites controlled

All samples were collected and documented by the Swedish Geological Survey (SGU) during 1991-2001 and 2003-2005 (Table 5) at S/V Ocean Surveyor. Video sequences from a total of 136 sampling sites in Skagerrak/Kattegatt had sufficient quality for video interpretation. From the Baltic Sea photos from 123 sites were investigated, including 8 sites in Öresund. In total 259 sample sites were controlled (Table 5).

Table 5. *Sea area, year and month of documentation and number of sites controlled.*

Nr	Sea area	Year	Month	Controlled sites	Material	Total
1	Skagerrak and Kattegatt	1999	June	136	Videos (VHS)	259
		2000	August-September			
		2001	April			
2	Öresund	2005	July	8	Photos (digital)	
3	Baltic Sea	2003	July-September	115	Photos (digital)	
		2004	July-August			
		2005	May-August			

Primary sediments and rock

Taking the Marine geological map as a starting point, videos and photos from 10 sediment- and rock categories were investigated (Table 6).

Table 6. *Primary sediments and rock investigated in this study.*

Nr	Postglacial sediments	Nr	Glacial sediments and rock	Nr	Bedrock
1	clay	5	clay	9	crystalline bedrock
2	silt	6	till	10	sedimentary bedrock
3	fine sand	7	boulder clay	-	-
4	sand and gravel	8	glaciofluvial deposits	-	-

3.2 Biological data

In order to harmonise geological definitions and nomenclature with biological, were the marine part of *EUNIS habitat classification* (Davies *et. al*., 2004) used, which is a European classification developed for benthic-, pelagic- and ice-associated habitats.

4 STUDY AREA

4.1 Skagerrak and Kattegatt

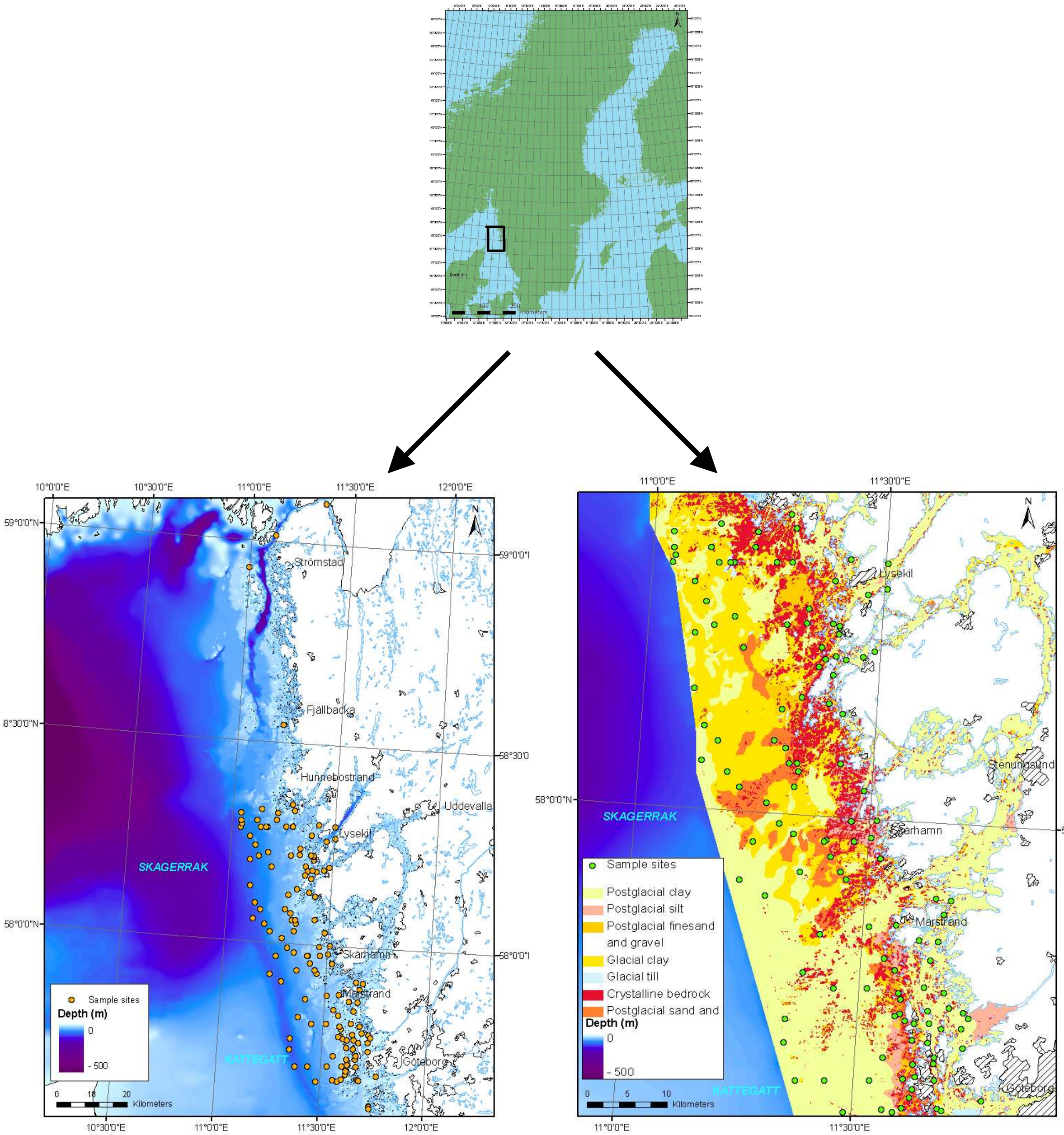


Figure 7. *Study area at the Swedish West Coast* (*left*) *with sample sites* (*center*) *and primary sediments* (*right*).

The study area at the Swedish West Coast covers the southern part of Skagerrak and northern part of Kattegatt. Sampling sites were located at 4-115 m depth, from south east of Hunnebostrand to the north east of Gothenburg. Sampling sites and sediments from the digital version of the Marine geological map are shown in Figure 7.

Skagerrak is our deepest sea (700 m), which very seldom is covered by ice and is characterised by large areas of accumulation bottoms. The connection to the northeast Atlantic makes the deep-water salinity conditions almost oceanic (33 psu). Kattegatt is shallow with an average depth of 25 m, characterised by few depositional areas and less salinity (25 psu). In Skagerrak and Kattegatt approximately 1500 and 800 macro-invertebrates have been found (BOING, web reference).

4.2 Baltic Sea and Öresund

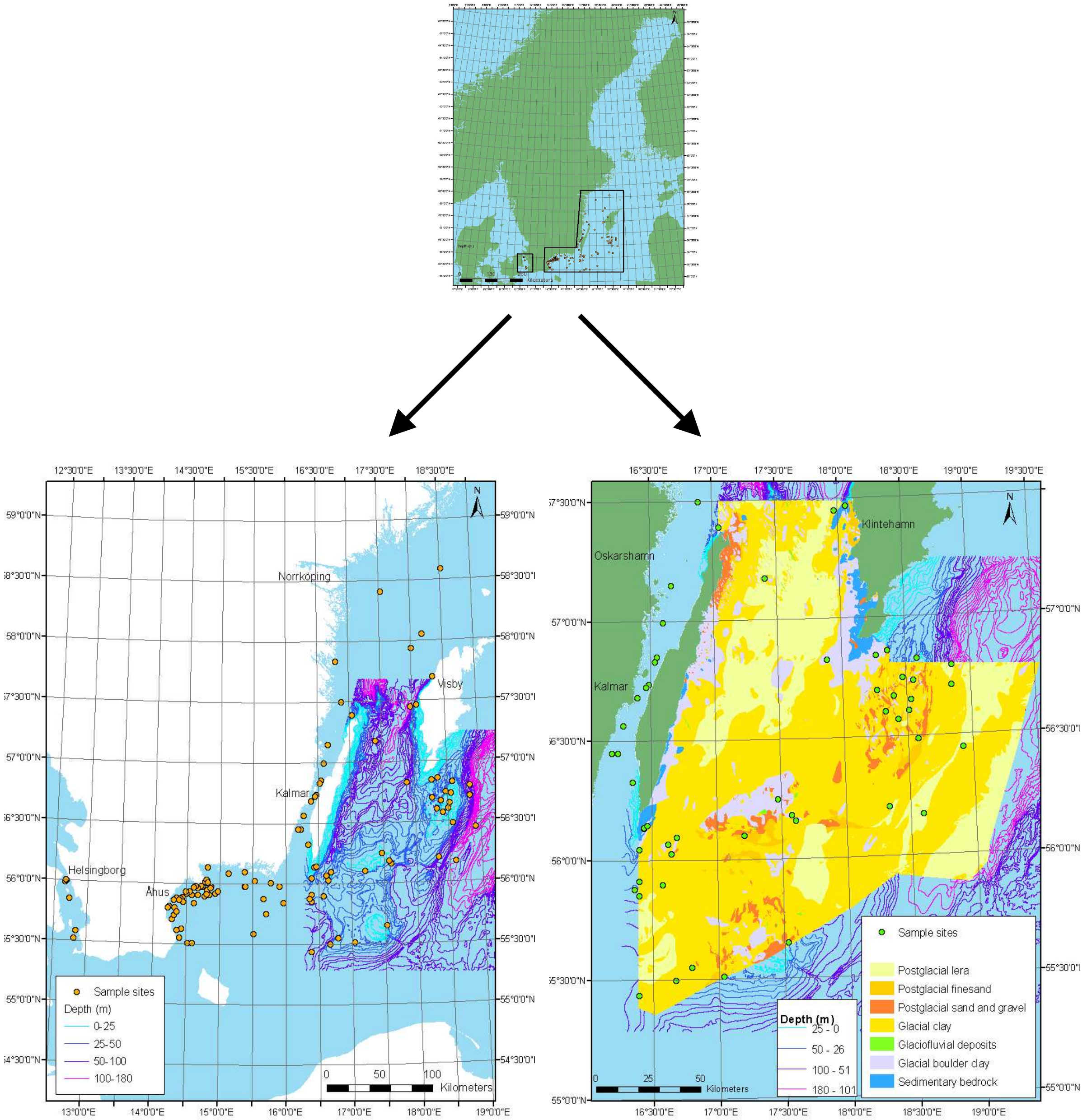


Figure 8. *Study area at the Swedish East Coast* (*left*) *with sample sites* (*center*) *and primary sediments* (*right*).

The main study area at the Swedish East Coast reaches from the area outside Åhus in the Hanöbay to the southern part of Gotland. Sampling sites and primary sediments from the digital version of the Marine geological map are shown in Figure 8. Most sampling sites were located within a depth range of 17-173 m (7-28 m in Öresund).

The salinity gradient decreases from 6 psu in southern Baltic Sea to 1-2 psu in Bothnian bay. Areas in the Bothnian- and Baltic Sea are often covered by ice during shorter periods, while Bothnian bay is covered from November to May. The Baltic Sea is shallow. The average depth is 55 m, but there are also many deep basins (250-460 m), which are separated by sills as shallow as 18 m. In the southern Baltic Sea and in the Bothnian bay, around 77 and 67 different macro-invertebrates have been found (BOING, web reference).

5 METHODS

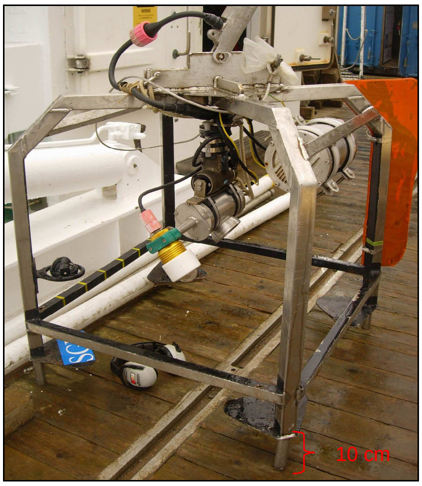


Figure 9. *SGU´s Photo equipment* (*red text shows one of the 10-cm sticks*).

5.1 Video and photo interpretation

The video material had been documented during 1999-2001 with a 50-kilo equipped cage, consisting of a frame with four weights and a 10-cm measure scale. Each weight had a 10-cm long stick (Figure 9). Most videos show a close-up of sediments and weights, and also a 360° panning view. A total of 136 video sequences (1-3 minutes long) were selected for analysis. The photographs from 2003-2005 were documented with a similar but heavier (50-75 kilo) cage. Photos from a total of 123 sites were analysed.

Substrate structure and condition

The observed surficial material constituents, structure and condition were estimated through observing factors as: *grain size*, *substrate structure*, *hardness* and *colour*, *anoxic conditions*, *sedimentation*, *depth* and the occurrence of *animal* and *algae*. Grain size of coarser sediments was estimated with aid of the measure scale (according to EUNIS), while animal and algae were noted as being present or dominating. Hardness was assessed based on how deep the photo equipment sank into the sediments according to SGU´s 6-graded scale:

1.	*very loose material*	(covered camera)	4.	*firm*	(only sticks are penetrating)
2.	*loose*	(frame covered)	5.	*hard*	(cage standing on sticks)
3.	*soft*	(weights squeeze into sediment)	6.	*very hard*	(cage is sliding on sticks)

Cobble mobility

Erosion of the sea floor (caused by waves hitting the coast) takes place in surf zone, i.e. between shoreline and breakers (Figure 10). Waves break at depths between 1-1.5 times wave height, thus for 6 m tall waves, rigorous erosion of sea floor can take place in up to 9 m of water (Nelson, 2003). Since no slope, current- or wave exposure data were available, cobbles (64-256 mm) were considered as mobile at <10 meters water depth (Elhammer, pers. comm., 2006).

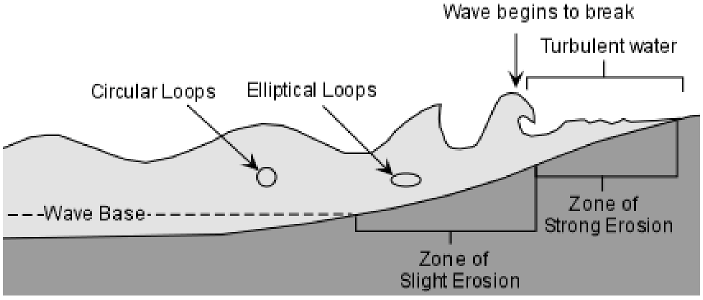


Figure 10. *Erosion of the sea floor, caused by waves, takes place inbetween shoreline and breakers* (*after Nelson 2003*).

5.2 Adaptation to EUNIS

Substrate composition

The composition of observed surficial substrates at each site were defined according to grain size and mobility. The definitions used to distinguish these three composition groups are listed below and in Table 7. Three main groups were created at the same level, comparable with EUNIS level 3, (Annex 2), which consisted of a:

- *single dominating substrate type*
- *mixture of mobile substrates* (mixed sediments)
- *mixture of mobile and non-mobile substrates* (complex).

Dominating substrate type

Individual substrates (mobile or non-mobile) with approximately more than 90% coverage were considered as dominating (see Alleco Ltd., 2005, web reference), except from gravel which were regarded as dominating with 80% coverage (see Long, 2006).

Mixed sediments

Sites with *mobile substrates with different particle size* (mud-cobbles) have been described as "*mixed sediments*", comparable with EUNIS *mixed sediment* at level 3 (A2.4 and A5.4). For describing the composition was a modified version of the EUNIS-adapted reclassified Folk triangle (Long, 2006) used (Figure 3), in which the relative percentage depend on the grain size of one or more mobile fractions (mud, sand and gravel) with at least >5% coverage. In EUNIS, there is no definition or description of how to handle the two largest fractions (mobile pebbles and cobbles) but according to Connor *et al*. (2006) they should be a part of Folk gravel class. Therefore were mobile pebbles or cobbles with ≥10 % coverage included.

Complex

In this study has the term "*complex*" been used to describe sites consisting of a *combination of mobile- and non-mobile substrates* at the same scale as "*mixed sediments*", not as in EUNIS were it refer to large habitat complexes (X31, X32 and X33). Since there were no available definition (similar to the Folk triangle) for how to handle mixtures of mobile- and non-mobile substrates, were sites with these mixtures considered as complex when the individual fractions had ≥10 % coverage.

In practice, "*mixed sediment*" and "*complex*" were only defined when a single or several fractions had ≥10 % coverage, but all fractions with ≥5 % coverage were presented within parenthesis (Annex 3).

Table 7. *Modified definitions* (*from UKSeaMap by Long 2006, Backer et al. 2004 and EUNIS habitat classification*) *of substrate types used in this study.*

Substrate types	Nomenclature	Definitions (modified by Erlandsson 2006)		
Dominating (homogeneous mobile substrates)	mud and sand	> 90% coverage		
	gravel and shell gravel	> 80% gravel		
	pebbles and cobbles[1]	> 90% coverage		
Dominating (homogeneous non-mobile substrates)	compact clay, cobbles[2] and boulders	> 90% coverage		
Mixed sediments (heterogeneous mobile substrates)	"Mixed sediments"	10% mud	with:	< 90% sand > 5% but < 80% gravel
		90% sand	with:	> 10% mud > 5% but < 80% gravel
		5-80% gravel	with:	< 90 % sand > 10 % mud
		≥10 % pebbles or cobbles		
Complex (mosaics of mobile and non-mobile substrates)	"Complex"	≥ 10% non-mobile substrates	with:	≥ 10% mobile substrates

[1] Mobile cobbles at <10 m

[2] Non-mobile cobbles at >10 m

Predicted surficial material

Reclassifications of predicted surficial substrates (Mattisson, 2005) were modified (Elhammer & Lindeberg, pers. comm., 2006) by adding, "*consolidated clay*" as predicted surficial substrate in the "*Glacial clay*" sediment category. (Table 8). The resulting "*modified predicted surficial substrate*" were tested on observations from the west coast (Skagerrak/Kattegatt) and the East Coast (the Baltic sea/Öresund). The proportions of correct and non-correct observations are shown in Annex 4 (Table 1A and 2A).

Table 8. *Sediment categories in the Marine geological map with predicted surficial material.*

Nr	Sediment categories (according to Marine Geological Map)	Predicted surficial substrate (Mattisson, 2005)	Modified predicted surficial substrate (Elhammer & Lindeberg, pers. comm. 2006)
1	Postglacial clay, gyttja clay, clayey gyttja	clay, gyttja clay, clayey gyttja	clay, gyttja clay, clayey gyttja
2	Postglacial silt	clayey silt (seldom pure silt)	clayey silt (seldom pure silt)
3	Postglacial fine sand	fine sand	fine sand
4	Postglacial sand and gravel (mainly sand)	sand-gravel	sand-gravel
5	Glacial clay	sand-boulders	sand-boulders consolidated clay
6	Glacial fine sand and silt	fine sand-silt (mud)	-
7	Glaciofluvial deposits	sand-boulders	sand-boulders
8	Till	sand-boulders	sand-boulders
9	Older deposits (glacial/interglacial)	mud-boulders (>15 m)	-
-	Boulder clay	-	sand-boulders
10	Artificial filling	-	-
11	Sedimentary bedrock	till	bedrock outcrop (<15 m) *overlaid by*: sand-boulders (overlaid by clay, gyttja clay, clayey gyttja at >15 m)
12	Crystalline bedrock	mud-boulders (>15 m)	bedrock outcrop (<15 m) *overlaid by*: stone-boulders (overlaid by clay, gyttja clay, clayey gyttja at >15 m)

Grain size adjustment and reclassification of predicted surficial substrates

Since predicted surficial material was defined according to the Marine Geological Map (after Atterberg) and observed substrate according to EUNIS (Connor & Hiscock 1996), the grain size was investigated. Different definitions used for the same fractions are marked with different colours in Table 9. Modified predicted surficial substrates were reclassified, resulting in "*new predicted substrate*" and defined with EUNIS terms. The proportion of correct and non-correct observations were calculated in per cent for Skagerrak and Kattegatt, the Baltic Sea and for the two areas together (Annex 4 - Table 1B, 2B and 3).

Table 9. *Definitions of grain size and fractions, used in the Marine Geological Map* (*Atterberg scale*) *and in EUNIS habitat classification* (*Connor & Hiscock 1996*).

Marine Geological Map (Atterberg scale)			EUNIS vers. 2004 (Connor & Hiscock 1996)		
Fraction	Subdivision	Grain size (mm)	Fraction	Subdivision	Grain size (mm)
bedrock	-	-	bedrock	-	-
boulders	-	>600	boulders	very large	> 1024
	-	-		large	512 – 1024
	-	-		small	256 – 512
stone	coarse	200 – 600	stone	cobble/shingle[1]	64 – 256
	medium	60 – 200		pebble/shingle[1]	16 – 64
gravel	coarse	20 – 60	gravel	-	4 – 16
	medium	6 – 20	-	-	-
	fine	2 – 6	-	-	-
sand	coarse	0.6 – 2	sand	coarse	1 – 4
	medium	0.2 – 0.6		medium	0.25 – 1
	fine	0.06 – 0.2		fine	0.063 – 0.25
silt	coarse	0.02 – 0.06	mud	-	< 0.063
	medium	0.006 – 0.02	-	-	-
	fine	0.002 – 0.006	-	-	-
clay	-	< 0.002	-	-	-

[1] Shingle = highly mobile pebbles and cobbles

Mapping observed substrates

The coordinates from each sample site were transformed from WGS 84 (degrees, minutes, seconds) to RT 90 (2,5 gon W, Transverse Mercator). For each sediment category in Skagerrak and Kattegatt maps were produced showing the distribution of observed substrates. No sediment maps were produced for the Baltic, due to the prevailing lack of comprehensive digital data.

Using the hierarchical key

The hierarchical key in EUNIS habitat classification (level 1 to 6) which leads to more specific habitats by using structuring factors, were simplified (Table 10) and adapted to Swedish conditions. Modified predicted surficial layers were classified as far as possibly (Table 11). Graphic figures showing possible surficial substrates for each sediment category are shown in Annex 5.

Table 10. *Simplified overview of structuring factors and codes according to EUNIS habitat classification* (*after Backer et al., 2004 - modified by Erlandsson).*

Affecting factors	Example of characteristics	Level	Code[1]
Type of environment?	**Marine**	Level 1	A Marine habitats
1. Stratum? 2. Water-covered? 3. Depth zone (shelf)? 4. Substrate mobility?	Benthic Littoral Sublittoral/Deep-sea Rock/Sediment/Complex	Level 2	A1 Littoral rock and other hard substrata A2 Littoral sediment A5 Sublittoral sediment A6 Deep-sea bed
5. Light (occurrence of macroalgae)?	Circalittoral Sublittoral		A3 Infralittoral rock and other hard substrata A4 Circalittoral rock and other hard substrata
6. Substrate material?	Mud Fine/Muddy/Coarse Sand Gravel Pebbles/cobbles/Shingle Boulders Bedrock Limestone rock Compact clay Mixed substrates	Level 3	A2.1 Littoral coarse sediment A2.2 Littoral sand and muddy sand A2.3 Littoral mud A2.4 Littoral mixed sediments A5.1 Sublittoral coarse sediment A5.2 Sublittoral sand and muddy sand A5.3 Sublittoral mud A5.4 Sublittoral mixed sediments A6.1 – A6.6 Deep-sea rock, mixed sub., sand, muddy sand, mud)[1]
	Sabellaria reefs Mussel beds		A2.7 Littoral biogenic reefs A5.6 Sublittoral biogenic reefs
7. Standing water, cave, overhang, annual and opportunistic species?	Rockpools Cave/Overhang Opportunistic species		A1.4 Features of littoral rock
8. Cave, overhang, artificial substrata or developed at seeps?	Cave/Overhang Artificial Seeps		A3.7 Features of infralittoral rock A4.7 Features of circalittoral rock
9. Seepage, organically enriched or anoxic conditions?	Anoxic/Organically enriched Seepage		A2.8 Features of littoral sediments A5.7 Features of sublittoral sediments
10. Chemical conditions or canyons?	Chemical/Canyons		A6.7 – A6.9 Deep-sea canyons, vents, seeps and anoxic habitats[1]
11. Energy level? (caused by wave action, currents or tidal stream)	High Moderate Low		A1.1 High energy littoral rock A1.2 Moderate energy littoral rock A1.3 Low energy littoral rock
	Not Baltic!		A3.1 Atlantic and Mediterranean high energy infralittoral rock A3.2 Atlantic and Mediterranean moderate energy infralittoral rock A3.3 Atlantic and Mediterranean low energy infralittoral rock A4.1 Atlantic and Mediterranean high energy circalittoral rock A4.2 Atlantic and Mediterranean moderate energy circalittoral rock A4.3 Atlantic and Mediterranean low energy circalittora rock
12. Exposures (wave action, currents or ice scouring)?	Baltic!		A3.4 Baltic exposed infralittoral rock A3.5 Baltic moderately exposed infralittoral rock A3.6 Baltic sheltered infralittoral rock A4.4 Baltic exposed circalittoral rock A4.5 Baltic moderately exposed circalittoral rock A4.6 Baltic sheltered circalittoral rock
13. Community type?	Algae, Mussel beds	Level 4	AX.XX Sandy bottoms with vascular plants
14. Dominate species?	Potamogeton pectinatus	Level 5	AX.XXX Sandy bottoms with [Potamogeton pectinatus]
15 Co-dominant species?	P. peftinatus, [Z. major]	Level 6	AX.XXXX Sandy bottoms with [P. pectinatus], [Zannichellia major]

[1] from level 3 are codes for the deep-sea bed (A6) generalised, while ice-associated marine habitat (A8) and the pelagic water column (A7) are excluded.

Table 11. *Geological sediment categories and modified predicted surficial layers, with corresponding substrates and codes according to EUNIS habitat classification.*

Nr	Sediment categories in Marine Geological Map	Modified predicted surficial layer (substrate)	Corresponding substrate in EUNIS	Substrate mobility (M=mobile, NM=non-mobile)	Corresponding codes in EUNIS (with deep-sea bed excluded)
1	Postglacial clay, gyttja clay, clayey gyttja	clay, gyttja clay, clayey gyttja	mud	M	A2 Littoral sediment A2.3 Littoral mud A5 Sublittoral sediment A5.3 Sublittoral mud
2	Postglacial silt	clayey silt (seldom pure silt)	mud	M	
3	Postglacial fine sand	fine sand	fine sand	M	A2 Littoral sediment A2.2 Littoral sand A5 Sublittoral sediment A5.2 Sublittoral sand
4	Postglacial sand and gravel (mainly sand)	sand-gravel	sand-cobbles[1] ([1] After adaptation to EUNIS grain size were gravel changed into pebbles & cobbles)	M	A2 Littoral sediment A2.1 Littoral coarse sediment A2.2 Littoral sand A2.4 Littoral mixed sediments A5 Sublittoral sediment A5.1 Sublittoral coarse sediment A5.2 Sublittoral sand A5.4 Sublittoral mixed sediments *Also including non-mobile cobbles at <10 m*: A1 Littoral rock A1.1-A1.3 (see below) A3 Infralittoral rock and other hard substrata A3.1- A3.6 (see below) A4 Circalittoral rock and other hard substrata A4.1- A4.6 (see below)
5	Glacial clay	sand-boulders consolidated clay	sand-boulders compact soft clay	M and NM NM	"Complex" X31 (mosaics of A1 and A2) and "Complex" X32/X33 (mosaics of A5 and A3 and/or AA4) A2 Littoral sediment A2.1 Littoral coarse sediment A2.2 Littoral sand A2.4 Littoral mixed sediments A5 Sublittoral sediment A5.1 Sublittoral coarse sediment A5.2 Sublittoral sand A5.4 Sublittoral mixed sediments A1 Littoral rock A1.1 High energy littoral rock A1.2 Moderate energy littoral rock A1.3 Low energy littoral rock A3 Infralittoral rock and other hard substrata A3.1 Atlantic and Mediterranean high energy infralittoral rock A3.2 Atlantic and Mediterranean moderate energy infralittoral rock A3.3 Atlantic and Mediterranean low energy infralittoral rock A3.4 Baltic exposed infralittoral rock A3.5 Baltic moderately infralittoral rock A3.6 Baltic sheltered infralittoral rock A4 Circalittoral rock and other hard substrata A4.1 Atlantic and Mediterranean high energy circalittoral rock A4.2 Atlantic and Mediterranean moderate energy circalittoral rock A4.3 Atlantic and Mediterranean low energy circalittoral rock A4.4 Baltic exposed circalittoral rock A4.5 Baltic moderately circalittoral rock A4.6 Baltic sheltered circalittoral rock
6	Glaciofluvial deposits	sand-boulders	sand-boulders	M and NM	(as category Glacial clay)
7	Till				
8	Boulder clay				
9	Sedimentary bedrock	bedrock outcrop (<15 m) (at >15 m) - *overlaid by*: sand-boulders clay, gyttja clay, clayey gyttja	mud-bedrock	M and NM	(as category Glacial clay)
10	Crystalline bedrock				

6 RESULTS

6.1 Geological substrate categories

More than half of the 259 samples were derived from equal amount of the Marine geological map substrate categories *postglacial clay*, *postglacial sand and gravel* and *glacial clay* (58%), while one third were derived from equal amount of *till*, *boulder clay* and *postglacial fine sand* (30%). Around 10% of the samples were consisted of *postglacial silt* and *glaciofluvial deposits*, while less than 5% were represented by *crystalline*- and *sedimentary bedrock* (Figure 11).

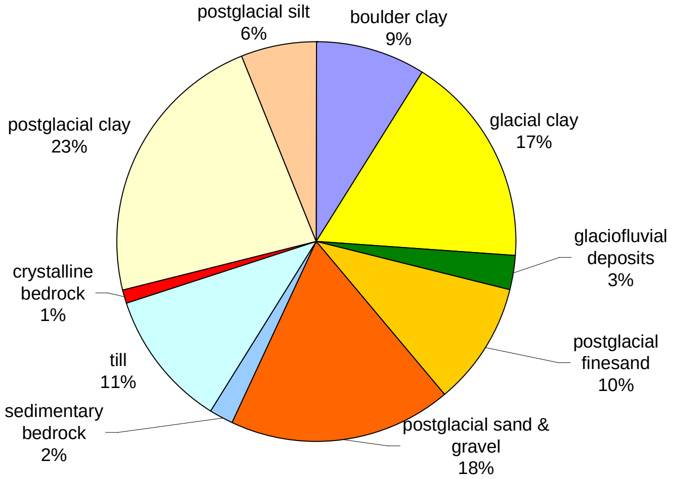


Figure 11. *The origin of the 259 samples from ten sediment categories presented in the Marine geological map.*

6.2 Observed surficial substrates

Surficial substrate categories

A total of 12 substrate categories were observed: *mud*, *anoxic mud*, *sand* (fine to coarse), *gravel* (shell gravel), *mixed sediment* (mud-cobbles), *complex* (mud-boulders), *consolidated mud* (compact clay), *pebbles*, *cobbles and boulders*, *boulders*, *boulders and bedrock outcrop* and *bedrock outcrop* (see photos in Annex 6 and substrate composition in Annex 3). Most substrates (31%) consisted of *mud* or *anoxic mud*, 56% were derived from equal amount of *sand*, *mixed sediment* and *complex*, 8% from equal amounts of *consolidated mud*, *gravel* (shell gravel), *pebbles*, *cobbles and boulders*, *boulders and bedrock outcrop* and *bedrock outcrop* and 5% were *boulders* (Figure 12).

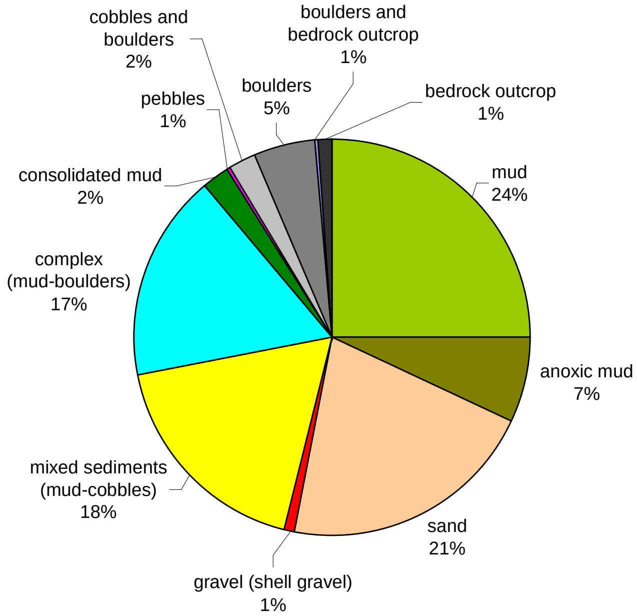


Figure 12. *Observed surficial substrates from 259 samples of the ten sediment categories in Figure 11.*

Structure and composition

The substrates structure and composition varied from soft pure mud (or mixtures of mud and shells) and smooth fine sands, through heterogeneous mixtures of mobile substrates (mixed sediment) or mobile and non-mobile substrates (complex), to hard consolidated mud (compact clay) and hard bottoms with cobbles, boulders and bedrock outcrop. Most sediment had a quite light colour, but some anoxic had black crusts and were covered by beggiatoa spp. (sulphur-oxidizing bacteria), which are associated to the layer between oxygen rich and anoxic environments and occur in areas with high organic load as during decomposition (Karlsson, 2002). Beggiatoa indicates periodic anoxic conditions (Hiscock *et al*., 2005) and anoxic bottoms which have expanded rapidly in the Stockholm Archipelago (Boesch *et al*., 2006).

Mobility

Most substrates (73%) were mobile mud, sands, pebbles or mixed sediment (mixtures of mud, sand, gravel pebbles and cobbles. Only 17% were mosaics of both mobile and non-mobile substrates (complex) as mud, sand, gravel, pebbles, cobbles, boulders, bedrock outcrop and consolidated mud and 10% were non-mobile (consolidated mud, cobbles, boulders and bedrock outcrop).

Depth distribution

Several *mud* (75%) were found at 10-70 m and 90-100 m, while *anoxic mud* (74%) were found at either <15 m or >65 m. *Sand* were equally distributed down to 40 m, as 76% of all *mixed sediment*. G*ravel* (shell gravel) was found at 8 m water depth while most *complexes* (84%) were found at <40 m. Four of five *consolidated mud* were found at <33 m, while one sample with *pebbles* was found at 64 m. B*oulders* (77%) were found in-between 10-20 m. Most *cobbles and boulders*, the only *boulders and bedrock outcrop* and two of the tree *bedrock outcrop* – were found at <20 m (Table 12).

Table 12. *Observed surficial substrates versus depth* (marked squares with *yellow colour represent depth with the main* distribution and blue colour represents depth with ≤ 3 samples).

Observed substrates / Depth (m)		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	> 110
Mobile substrates													
1	mud												
2	anoxic mud												
3	sand												
4	gravel (shell gravel)												
5	mixed sediment (mud-cobbles)												
Non-mobile and mobile substrates													
6	complex (mud-boulders)												
Non-mobile substrates													
7	consolidated mud												
8	pebbles												
9	cobbles and boulders												
10	boulders												
11	boulders and bedrock outcrop												
12	bedrock outcrop												

Geographic distribution of substrates

The observed surficial substrates and their distribution for each of the seven geological substrate categories from Skagerrak and Kattegatt are shown in Annex 7.

6.3 Predictions

Correct predictions

The proportions of correct predictions were 26-100% for Skagerrak/Kattegatt and 38-96% for the Baltic Sea. The most problematic categories (<85% correct predictions) in Skagerrak/Kattegatt were *postglacial sand and gravel*, *postglacial silt* and *glacial clay*, with 30%, 53% and 57% correct predictions respectively (anoxic mud were accepted as correct for pg clay/silt, see Annex 4 – Table 1).

In the Baltic Sea were *postglacial sand and gravel* and *glacial clay* problematic categories, with 67% and 38% correct predictions respectively. *Glaciofluvial deposit* and *sedimentary bedrock* were also two problematic groups, with 75% and 83% correct predictions respectively (Annex 4 – Table 2).

Correct predictions after reclassifications

After adaptation to EUNIS grain size and after reclassification of some predicted substrates, the correct predictions varied between 53-100% for Skagerrak and Kattegatt and 75-100% for the Baltic Sea. *Postglacial silt* and *postglacial sand and gravel* were still problematic categories in Kattegatt and Skagerrak, with 53% and 83% correct predictions respectively (Annex 4 – Table 1a). Also in the Baltic Sea *postglacial sand and gravel* was still a problematic category and also *glaciofluvial deposits*, with 79% and 75% correct predictions respectively (Annex 4 – Table 2a). After adding data from both Skagerrak and Kattegatt together with data from the Baltic Sea, the correct predictions varied from 53% to 100%. The three problematic categories were *postglacial silt*, *postglacial sand and gravel* and *glaciofluvial deposits* – with 53%, 81% and 75% correct predictions respectively (Annex 4 – Table 3).

Prediction changes

The prediction of mud as surficial material for both postglacial clay and postglacial silt, was changed to also include *anoxic mud* which was found at <15 meters depth. The prediction of sand-gravel as surficial material for postglacial sand and gravel, was changed to also include *pebbles and cobbles* (medium to coarse stones). To the category glacial clay were the substrate categories *mud* and *anoxic mud* added as predicted surficial substrate, while sedimentary bedrock was changed to also include *mud* (Table 13).

Table 13. *Sediment categories in the Marine geological map with predicted surficial material* (after *Mattisson, 2005 – modified by Elhammer & Lindeberg, 2006*) and corresponding "New predicted substrate" – described with geological- and EUNIS definitions.

Nr	Geological sediment categories	Predicted surficial substrate (Mattisson, 2005)	Modified predicted surficial substrate (Elhammer & Lindeberg, pers. comm. 2006)	New predicted surficial substrate (geological definitions)	New predicted surficial substrate (EUNIS definitions)
1	Postglacial clay, gyttja clay, clayey gyttja	clay, gyttja clay, clayey gyttja	clay, gyttja clay, clayey gyttja	clay, gyttja clay, clayey gyttja anoxic clay (<15 m)	mud anoxic mud (<15 m)
2	Postglacial silt	clayey silt (seldom pure silt)	clayey silt (seldom pure silt)		
3	Postglacial fine sand	fine sand	fine sand	fine sand	fine sand
4	Postglacial sand and gravel (mainly sand)	sand-gravel	sand-gravel	sand-stones (medium-coarse)	sand-cobbles mixed sediment (sand-cobbles) complex (sand-cobbles)
5	Glacial clay	sand-boulders	sand-boulders consolidated clay	sand-boulders consolidated clay clay (pure at >45 m) anoxic clay (<15 or >65 m)	sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders) consolidated clay mud (pure at >45 m) anoxic mud (<15 or >65 m)
6	Glaciofluvial deposits	sand-boulders	sand-boulders	sand-boulders	sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)
7	Till	sand-boulders	sand-boulders		
8	Boulder clay	-	sand-boulders		
9	Sedimentary bedrock	till	bedrock outcrop (<15 m) (*at >15 m*) - *overlaid by*: sand-boulders clay, gyttja clay, clayey gyttja	bedrock outcrop (<20 m) (*at >15 m*) - *overlaid by*: sand-boulders clay, gyttja clay, clayey gyttja	bedrock outcrop (<20 m) (*at >15 m*) - *overlaid by*: sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders) mud
10	Crystalline bedrock	mud-boulders (>15 m)	bedrock outcrop (<15 m) (*at >15 m*) - *overlaid by*: stone-boulders clay, gyttja clay, clayey gyttja	bedrock outcrop (<15 m) (*at >15 m*) - *overlaid by*: sand-boulders clay, gyttja clay, clayey gyttja	bedrock outcrop (<15 m) (*at >15 m*) - *overlaid by*: sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders) mud

6.4 Harmonisation with EUNIS

Reached classification levels

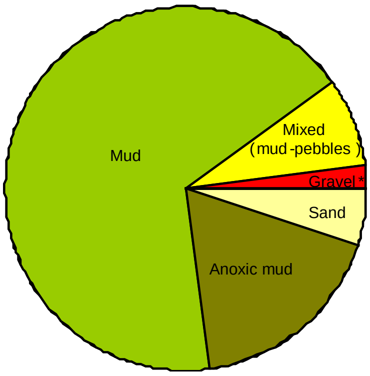
The observed substrates were classified as far as possible in the EUNIS hierarchy, leading mainly to habitats at level 1-3. Most samples have been classified as sublittoral sediments, except for some non-mobile consolidated mud (compact soft clay), cobbles, boulders and bedrock outcrops – which were classified as infralittoral or circalittoral rock. Levels 4-6 were only reached through special observations of the sulfur-oxidizing bacteria "*beggiatoa spp. on anoxic mud*" and "*organically enriched or anoxic sediments*". Graphic figures showing observed substrates and corresponding codes in EUNIS for each of the ten sediment categories presented in the Marine geological map, are shown in Annex 5 (Figure 1-10).

7 DISCUSSION

7.1 Accuracy of predicted substrates

* S= Skagerrak, K= Kattegatt and B= the Baltic Sea

Postglacial clay, gyttja clay and clay gyttja



Correct predictions
- 85%

*Sites controlled**
- 60 (from S/K)

New predicted substrate
- mud
- anoxic mud (<15 m)

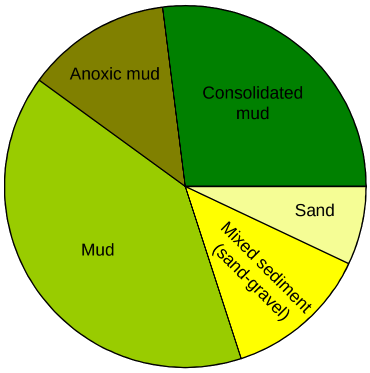
* Shell gravel

This category had 85% correct predictions of mud and anoxic mud. A white bacterial mat (Beggiatoa spp.) covered this dark anoxic mud, found at 5-13 meter depth.

The most shallow (8 m) other substrate found was shell gravel. Three sands were also observed. Of five "*mixed sediment*" were three mainly composed of mud and some gravel and two of sand and gravel.

The new predicted substrate will still encompass the original predicted substrate mud, but with the addition of anoxic mud (at <15 m), since 51 of 60 observed substrates were mud or anoxic mud.

Postglacial silt



Correct predictions
- 53%

*Sites controlled**
- 15 (from S/K)

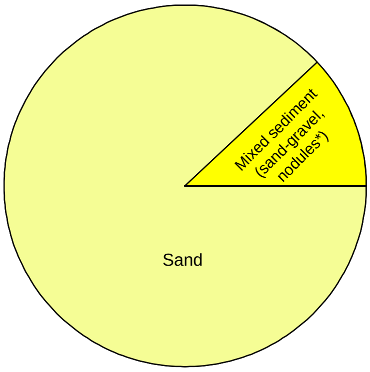
New predicted substrate
- mud
- anoxic mud (<15 m)

This category is one of three with most incorrect observations – only 53% of the observed substrates were interpreted as mud, of which two shallow (<12 m) were anoxic.

Other substrates were one sand, two "*mixed sediment*" (mainly sand but also gravel, pebbles and cobbles) and four consolidated mud (compact soft clay). Consolidated clay occur in the littoral- and sublittoral zone at places with high energy due to currents, where sandy sediments have been permanently removed (Bouma *et al*., 2006).

There is a need for further analysis with more samples and information of currents and wave exposure, before it is possible to make any conclusions. The predicted substrate will therefore remain as mud, with the addition of that anoxic mud can be found at depth <15 meters.

Postglacial fine sand



Correct predictions
- 89%

*Sites controlled**
- 26 (9 from S/K, 17 from B)

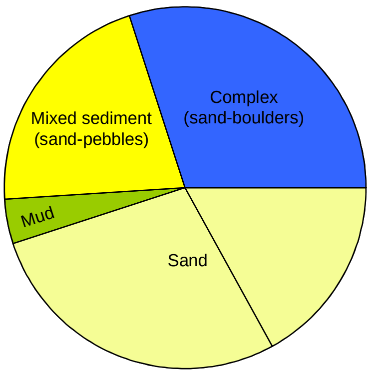
New predicted substrate
- fine sand

For the category fine sand 89% of the predictions were correct. Sometimes it was impossible to distinguish between medium sand and fine sand, but corresponding geological samples showed that these samples actually consisted of fine sand.

The three observed "mixed sediment" consisted mainly of sand (65-90%) and gravel, but also of pebble-sized nodules (30%). These nodules, which were found at 40 meters depth, probably originates from the 15 centimetre thick glacial clay layer situated just beneath the layer of fine sand. A nodule is a rounded mineral concretion, usually harder than the surrounding rock or sediment. Fe/Mn nodules are frequently found in the deep non-depositional areas in the Baltic Sea, and they may act as traps of heavy metals in non-deposition areas (Perttilä, 2001).

Due to the high accuracy of correct predictions the predicted substrate fine sand were not changed.

Postglacial sand and gravel



Correct predictions
- 81%

*Sites controlled**
- 47 (23 from S/K, 24 from B)

New predicted substrate
- sand-cobbles
- mixed sediment (sand-cobbles)
- complex (sand-cobbles**)

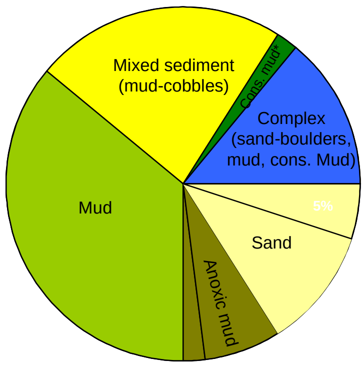
** Cobbles at depth >10 m were considered as non-mobile

This is the second problematic category, with 81% correct predictions. Most observed substrates were either pure sands or mixtures (mixed sediments) which mainly consisted of sand. Half of the observed "complexes" with non-mobile cobbles (at depth >10 m) were considered correct.

The largest group of other observed substrates than the predicted, were "complexes" with 5-30% boulders. One of these was composed of 70% boulders and two other shallows were hard to distinguish due to many growing algae. In these areas scattered areas with many boulders have been observed, but this will not affect the predictions since there is impossible to explain these observations on the basis of only geological data. Apart from these complexes two mud were also observed.

Since the definition of gravel, with geological terms, was defined as pebble in EUNIS (Table 9), the original prediction "sand-gravel" was changed to also include cobbles – since both large pebbles and small cobbles can be 60 mm.

Glacial clay



Correct predictions
- 100%

*Sites controlled**
- 44 (23 from S/K, 24 from B)

New predicted substrate
- sand-boulders
- consolidated mud
- mud (pure at >45 m)**
- anoxic mud (<15 or >65 m)**
- mixed sediment (sand-cobbles)
- complex (sand-boulders)

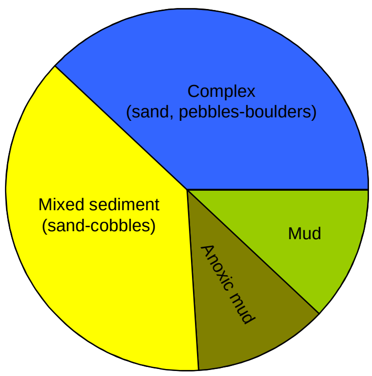
** The proposed depth interval reflects result from this study only

Glacial clay is one of six sediment categories (also glaciofluvial deposits, till, boulder clay, sedimentary- and crystalline bedrock) which had everything from sand to boulders as predicted surficial layer. After the addition of mud as predicted substrate was 100% of the predictions correct.

Nearly half of the observed substrates were mud at 48-98 meters depth (of which four were anoxic and one was composed of consolidated mud) and the rest consisted of mixed sediment (sand-cobbles but mainly sand), complexes (mud-boulders but mainly mud, sand or pebbles/cobbles) or pure sands. Pure mud were found at >65 m in Skagerrak and Kattegatt and at >45 m in the Baltic Sea. This result shows that mud often can be found as surficial substrate at glacial clay sediments in low energy areas.

After the addition of mud as predicted substrate glacial clay, sedimentary- and crystalline bedrock is the three sediment categories with the broadest predicted surficial substrate, from mud to boulders.

Glaciofluvial deposits



Correct predictions
- 75%

*Sites controlled**
- 8 (from B)

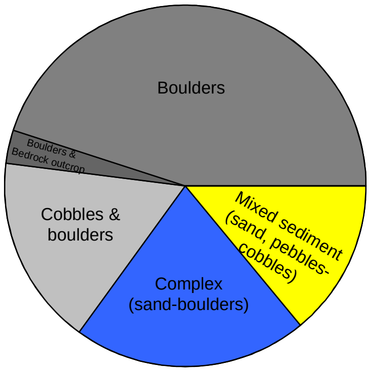
New predicted substrate
- sand-boulders
- mixed sediment (sand-cobbles)
- complex (sand-boulders)

This category has all fractions from sand to boulders as predicted surficial substrates, as the two following sediment categories till and boulder clay. Out of these few samples from the Baltic Sea, were 75% of the predictions correct. The three complexes were mainly composed of sand, cobbles and/or boulders and the three mixed sediments consisted mainly of coarse sand and/or cobbles.

The only other observed substrate mud (two), of which the deepest (95 m) was anoxic.

More samples are needed in order to draw conclusions about expected surficial substrates.

Till



Correct predictions
- 98%

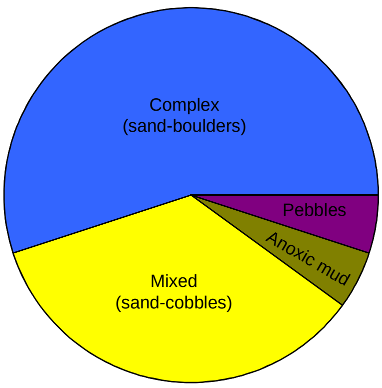
*Sites controlled**
- 29 (4 from S/K, 25 from B)

New predicted substrate
- sand-boulders
- mixed sediment (sand-cobbles)
- complex (sand-boulders)

At this category (98% correct predictions) is it most likely to find boulders, since boulders were found at 23 of 29 sampling sites. At more than half of the sites were the bottom composed of non-mobile boulders or mixtures of boulders and non-mobile cobbles. Apart from these was one fifth of the sample mosaics of both non-mobile and mobile substrates. These complexes were mainly composed of sand or boulders, but also of smaller proportions of gravel, pebbles and cobbles.

The only other observed substrate was bedrock outcrop, mixed with a small proportion of boulders at 14 meters depth. The prediction was not changed, but it would be valuable to investigate more samples from the till category – since hard bottoms are important recruitment surfaces for many animals and algae. More samples are needed, since it was hard to distinguish the substrate composition at 10 sample sites in the Baltic Sea (due to mussel and algae at 8-23 meters depth).

Boulder clay



Correct predictions
- 98%

*Sites controlled**
- 22 (from B)

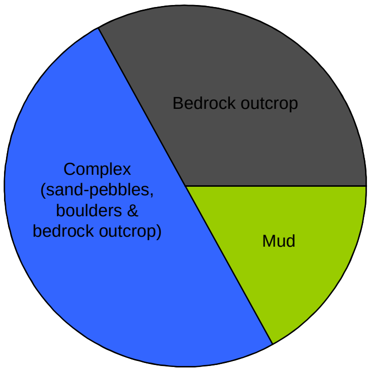
New predicted substrate
- sand-boulders
- mixed sediment (sand-cobbles)
- complex (sand-boulders)

In this category, with 98% correct predictions, consisted most sites of mixtures or complexes. More than half of the samples were complexes, dominated by all fractions from sand to boulders. One third were mixed sediments, dominated by sand, pebbles or cobbles. The only two observed homogeneous samples were one with rounded pebbles was covered by organic ooze and one anoxic mud found at 122 m.

The only other observed substrate was an anoxic mud at 122 meters depth, which also was the only pure substrate.

It seems like the category boulder clay is composed of mixtures and mosaics, rather than homogeneous fractions. It would be interesting to investigate more samples from the three categories which has “sand-boulders” as predicted surficial substrate (glaciofluvial deposits, till and boulder clay), in order to resolve the composition of the expected substrates.

Sedimentary bedrock



Correct predictions
- 100%

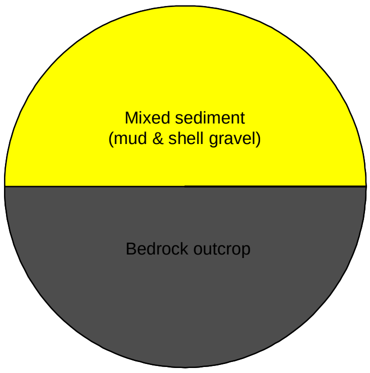
*Sites controlled**
- 6 (from B)

New predicted substrate
- bedrock outcrop (<20 m)
  at >15 m - overlaid by:
- mud
- sand-boulders
- mixed sediment (sand-cobbles)
- complex (sand-boulders)

Out of these six samples from the Baltic Sea 100% was correct. Half of these samples were complexes, dominated by bedrock outcrop or coarse sand at 14-20 meters depth. Of the two bedrock outcrops at 17 and 42 meters depth, a thin layer of mud covered the deepest one. The deepest mud was observed at 73 meters depth.

No direct conclusions can be drawn due to few samples. It would be interesting to include more data, concerning the affection of currents and wave action.

Crystalline bedrock



Correct predictions
- 100%

*Sites controlled**
- 2 (from S/K)

New predicted substrate:
- bedrock outcrop (<20 m)
  at >15 m - overlaid by:
- mud
- sand-boulders
- mixed sediment (sand-cobbles)
- complex (sand-boulders)

Only 2 samples were found in this category, but both were classified as correct. Bare rock was found very shallow (11 m), while shell gravel, individual pebbles and cobbles (overlaid by mud) were found deepest (80 m).

The prediction was not changed, but more samples should be investigated in further analysis.

7.2 Problematic predictions

After adaptation to EUNIS grain size and reclassification of predicted surficial substrates three categories were problematic (<85% correct predictions):

- postglacial silt
- glaciofluvial deposits
- postglacial sand and gravel

Postglacial silt from Skagerrak/Kattegatt was the most problematic category with only 53% correct predictions. The main reason was that non-mobile consolidated mud (with shells), sand and mixed sediments (sand-cobbles) were found, although mud was the predicted substrate. But more than these 15 samples are needed to make any further conclusions.

Only 8 samples of *glaciofluvial deposits* from the Baltic Sea were investigated, of which 75% were correct. The incorrect predictions consisted of 2 mud. But in this case is the number of samples also to few, in order to make any further conclusions.

From 44 samples of *postglacial sand and gravel*, 81% of the predictions were correct. Other substrates found (than the predicted) included boulders (7 samples) and also two relatively deep found mud.

7.3 Using EUNIS hierarchical key

This is an attempt to describe how EUNIS habitat key was used for reaching the different levels and codes. Observed substrates and corresponding codes for each of SGU´s ten sediment categories are shown in Annex 5. Abiotic factors (depth, substrate mobility, substrate material, current and wave strength) are most important at level 1-3, except for deciding the border between infralittoral and sublittoral – when observations of fauna and algae are required. At level 4-6 occurrence of communities, species and co-dominating species are most important (Table 10).

Level 1

The first level in EUNIS habitat classification define marine habitats (A Marine habitats) as not subterranean but marine.

Level 2

At level 2 is *stratum* deciding if the habitat is ice-associated, pelagic (water column) or benthic (bed). In this case we are working with benthic beds. Next choice leads into two main paths, depending on if the substrates are *permanently water-covered or not*. Covered leads to Littoral rock (A1) if they are non-mobile, to Littoral sediment (A2) if they are mobile and to complex X31 if they are mosaics of both mobile and non-mobile substrates. Since all samples are from sites, which are permanently water-covered, is the littoral not the right choice.

Next criteria, if the habitat is *located on the shelf* separates Infralittoral rock (A3), Circalittoral rock (A4) and Sublittoral rock (A5) from the deep-sea bed below 200 meters. Since we are not dealing with depth > 100 meters is the deep-sea bed not the right way.

Next choice is about *substrate mobility*, leading to Infralittoral rock (A3) or Circalittoral rock (A4) if they are non-mobile and to Sublittoral sediment (A5) if they are mobile. The observed "consolidated mud" will fit A3 and A4, since it is a non-mobile compact substrate consisting of clay (Annex 5 –Figure 2 and 5). Complex (mosaics with both mobile and non-mobile substrates) are X32 and X32, depending on if they are mixtures of A3/A5 or A4/A5 (Annex 5 – Figure 4-9).

The separation of A3 and A4 is determined by the *occurrence of flora and fauna*. Macro algae dominated substrate leads to A3, while animal dominated habitat leads to A4 (depending on if it is sufficient with light). This dividing will not be able to do in this study, since the data of flora and fauna is not detailed enough. But A3 and A4 can be reached through special observations as "consolidated mud". So, mobile substrates at shelf will lead to mobile Sublittoral sediment (A5) and to complex X32 and X33.

In this study were 16% of the observed substrates determined to level 2, depending on the lack of information of wave exposure and currents, which are critical when dealing with these non-mobile substrates. *Consolidated mud* was observed at postglacial clay and glacial clay, *bedrock outcrop* was observed at till, sedimentary bedrock and crystalline bedrock, while *cobbles* and *boulders* were observed at till (Annex 5 – Figure 2, 5, 7, 9, 10).

Level 3

At level 3, the *energy level* (wave actions, current or tidal stream) divides Littoral rock (A1) into high-energy littoral rock (A1.1), moderate (A1.2) or low (A1.3). Here are depth profile of water adjacent to the coast and fetch (distance to nearest land) important, in order to estimate wave exposure. Since no data was available, dividing can not be done in this study.

Littoral sediment (A2) is divided into five groups depending on the dominating *type of substrate*: gravel or coarse sand (A2.1), fine sand or muddy sand (A2.2), mud (A2.3), combination of substrate (A2.4) and biogenic (A2.5). The same dividing as above are done for Infralittoral rock (A3) and Circalittoral rock (A4), but with another criteria for if the substrates are *Baltic or not*.

Sublittoral sediment (A5), leads to "Features of sublittoral sediments" (A5.7), if the sediments are organically enriched or anoxic (here will the observed anoxic mud fit in). Sublittoral sediment (A5) is divided exactly as Littoral sediment A2 (see above). Gravel or coarse sand (including rounded shingle and cobbles) leads to Sublittoral coarse sediment (A5.1), while fine sand or muddy sand leads to Sublittoral sand (A5.2), mud leads to Sublittoral mud (A5.3) or to Sublittoral mixed sediments (A5.4) if the substrate is mobile (mixtures of mobile substrates with different particle size). A5.5 refers to macrophyte-dominated substrates and Sublittoral biogenic reefs (A5.6) refers to biogenic substrates.

Most observed substrates (68%) were determined to level 3 (Annex 5 – Figure 1-10). Among these were most mixed sediment, many were complexes (X32/X33) or mud, while some were sand or coarse sand.

Level 4-6

Level 4, 5 and 6 are not really possible to reach with the data from this study, since there is not enough information about *community type* (aggregates of species), *dominating species* and *co-dominating species*.

Level 4 was only reached through special observations of "organically-enriched or anoxic sublittoral habitats " (A5.72). These two observations represented 5% of the observed substrates (Annex 5 – Figure 1 and 5). No observed substrates were possibly to determine at level 5, which requires information of dominating species. Level 6 were only reached through the observation of the white sulphide-oxidiseing bacteria " [*Beggiatoa*] spp. on anoxic sublittoral mud (A5.7211), which represented 11% of all observed substrates (Annex 5 – Figure 1, 2, 5, 6 and 8).

8 EVALUATION AND RECOMMENDATIONS

Different scales

In this study focus has been on the *substrate* forming the habitat, rather than at the occurrence of animals and algae. The use of terms describing observed substrates as "*complex*" will therefore not be comparable with "*habitat complexes*" as they are defined in EUNIS (>25 m^2), but they will still reflect which surficial substrates we can expect to find on top of the different defined marine sediment classes. When considering temporal scale, was probably many of the shallow mud anoxic due to decomposing, since all samples were collected during the end of April to the beginning of September.

Ambiguos definitions

Apart from definitions of *grain size*, *organic content*, *sediment mixtures*, *substrate mobility, exposure* and *energy levels* – are physical characteristics only mentioned briefly in EUNIS. The definitions of these physical factors are however sometimes ambiguously termed, hard to find or just missing. For example is the use of "*consolidated cobbles*" in EUNIS unfortunate, since the original geological term "*consolidated*" refers to processes whereby loosely aggregated (soft or liquid) earth materials become firm and coherent. But "*consolidated cobbles*" probably only refers to that these cobbles are non-mobile, which easily could have been solved by having a definition in the glossary. The use of different definitions of *grain size* complicates geological and biological data integration and point out how important it is to use common definitions. Another uncleariety is how the proportion of mobile pebbles and cobbles should be defined within "*mixed sediments*". According to EUNIS can the BGS trigon be used to define mixed sediments, but only mixtures of mud, gravel and sand (what about pebbles and mobile cobbles?). The exposure levels for infralittoral- and circalittoral rock in the Atlantic & Mediterranean were hard to find, since they only were defined in the glossary. Another example of diffuse expressions is the use of "*organically-enriched sediment*" (sublittoral), without any definitions, which might be useful since organically enriched sediments are usually associated with density (high) and biodiversity (low) of macrofauna (Martin & Grémare, 1997).

Different use of substrates and biota in EUNIS hierarichal key

The degree of importance of each habitat-structuring factor varies for different communities, but substratum and the vertical zonation of species appears to play a highly significant role in all communities (JNCC, web reference). According to EUNIS habitat classification should mapped areas without detailed biota be classified as "Sublittoral" sediment or rock. This is of course obvious, seeing that a habitat in EUNIS mainly is defined by the presence of organisms and/or biological communities – while substrates, which are directly related to the possibility to find certain biota, are treated very vaguely. This had led to that the first levels (level 1-3) in EUNIS hierarichal key, which are characteristizied by abiotic factors, are very broad. Then there is an enormous gap between level 3 and 4, with a drastic change into very detailed descriptions of the habitats at the highest levels (level 4-6), due to the identification of certain species and biological communities. More details should be implemented at level 1-3 in EUNIS habitat classification, dealing with *classification of surficial substrates* in relation to basic factors as depth, current, slope and biota occurrence. This would enable the use of using modelling methods in order to for example estimate the mobility of substrates correct.

Approximations

Important to remember is that the photo interpretations and SGU:s marine geological maps (based on samples along transects 1-13 km from each other) - are approximations. The main problem in this study has been to bring together data sampled with different techniques at different scales. In other words to incorporate SGU: s interpreted field data from small sampling sites (1 m^2) and from marine geological maps at local (1:100 000) and regional (1:500 000) scales, with EUNIS requirements of very detailed information of biota occurrence. The lack of bathymetric-, exposure- and current data led to the assumption that cobbles (64-256 mm) at <10 m water depth were mobile, which might be misleading since Backer *et al*. (2004) defined large stones (<100 mm) as mobile (depending on exposure). But hopefully can this attempt to develop a classification system for predicting surficial substrates directly from Marine geological maps, also enable predictions of species and biological communities.

Recommendations

- Increased number of samples from each marine geological seabed sediment category
- Samples should be chosen at random from specific depth interval, since the vertical depth gradient affects the mobility of substrates and the possibility to find certain biological communities (due to light penetration and feeding behaviour). Knowledge of depth is also important since the effect of wind exposure decreases with increasing depth
- More details should be implemented at level 1-3 in EUNIS habitat classification, dealing with classification of surficial substrates in relation to depth, current, wave exposure and slope
- Detailed systematic tables with clear definitions (turn to experts from different scientific fields) should be incorporate into EUNIS, in order to investigate detailed aspects of physical characters and define standard terms – which also will simplify interdisciplinary mapping and data exchange
- To be able to estimate the mobility of substrates using modelling methods and 3D-visualization, it is necessary with detailed data of surficial substrates, depth, slope, wave exposure, current and biological communities
- In order to to meet the requirements of EU habitats directive (92/43/EEG), the Water framework directive (2000/60/EC) and commercial interest as wind power – scientist are in urgent need of bathymetric data! These data should be used for creating basic maps of seabed topography and substrates before planning any mapping projects
- Bathymetric data is also needed in order to identify seascapes (underwater landscapes as EUNIS habitat complexes) as estuaries and seamounts, which are defined by their physiographic features (Costello, web reference).
- Extended use of photo material of the seabed and sampling during acoustic mapping (ground-truthing)

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ANNEX 1
Tables: Exposure and Energy levels in rocky habitats according to EUNIS

Table 1. *Exposure classes for infralittoral- and circalittoral rock in the Baltic, based on effective fetch* (*after Davies and Moss, 2004*).

Area	Exposure status (caused by waves, currents and ice scouring)	Effective fetch (Fe) [3]	
Baltic	1. High	-	>25 km
	2. Moderately exposed	-	5-25 km
	3. sheltered	-	<5 km

Table 2. *Energy levels for infralittoral- and circalittoral rock in the Atlantic & Mediterranean, based on grade of wave exposure and strenght of tidal streams and currents* (*after Davies and Moss, 2004*).

Energy level	Wave exposure classes	Coastline	Swell[1]	Offshore breaks	Open water window[2]	Deep water (50 m) distance from shore	Fetch[3]		OR	Tidal streams/current classes	Stream/current strenght[4]	
High												
	1. extremely exposed	few open	x	>1000 km	-	<300 m	-	-		1. very strong	>6 knots	>3 m/sec
	2. very exposed	open	x	>1000 km	-	>300 m		-		2. strong	3-6 knots	1.5-3 m/sec
	3. exposed	open (facing away from winds or shelter)	not generally strong or regular	extensive shallow areas	>90°	-	long (frequent strong wind)	-		-	-	-
Moderate												
	1. moderately exposed	open (facing away from winds)	-	-	-	-	short (strong winds can be frequent)	-		1. moderately strong	1-3 knots	0.5-1.5 m/sec
Low to negliglible												
	1. sheltered	can face prevailing wind	-	extensive shallow areas	-	-	short	<20 km		1. weak	<1 knots	<0.5 m/sec
	2. very sheltered	facing away from prevailing wind or have obstructions	-	x	>30°	-	short	<20 km		2. very weak	(negligible)	
	3. extremely sheltered	fully enclosed	-	-	-	-	short	<3 km		3. without tidal stream/current	-	-
	4. ultra sheltered	-	-	-	-	-	very short	<100 m		-	-	-

[1] waves generated remote from the shore

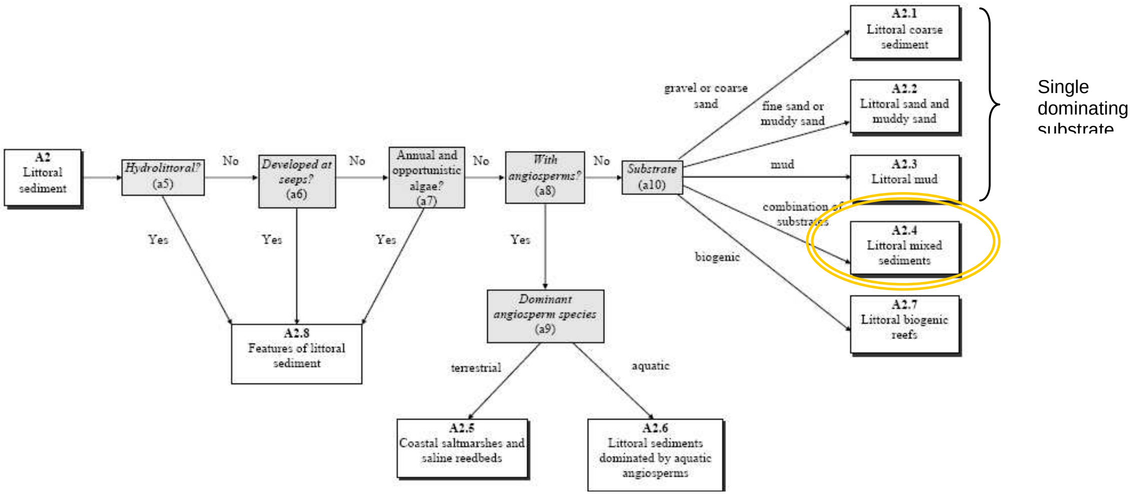
[2] i.e. *fetch window*, the open-water area offshore from the shoreunit over which waves can be generated by winds (Howes *et al*., 1999)

[3] i.e. *effective fetch* (distance along several directions from a given point from the shore)

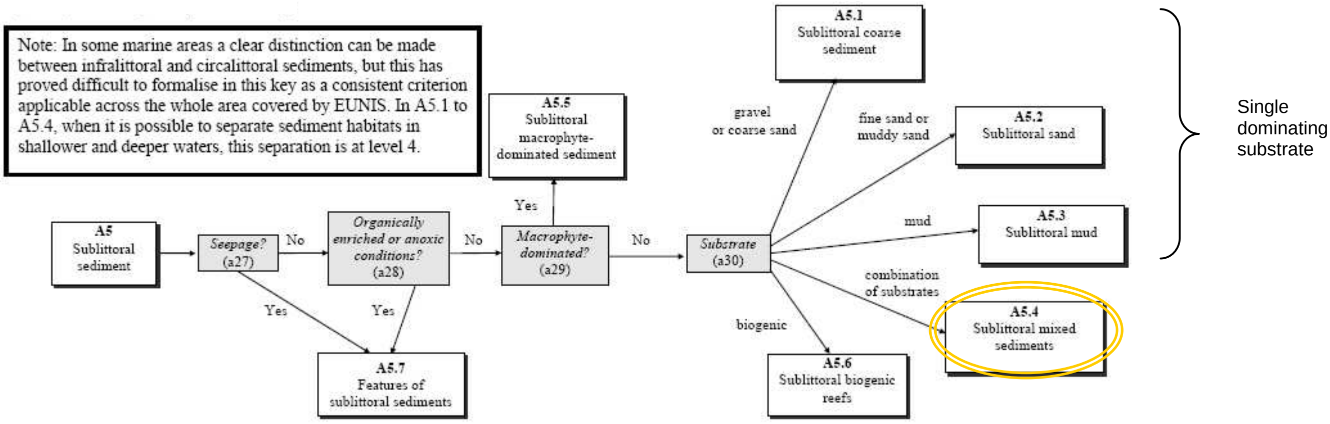
[4] may differ considerable from tidal streams nearby

ANNEX 2
Figure*: *EUNIS-level of "Complex" and "Mixed sediments" used in this study

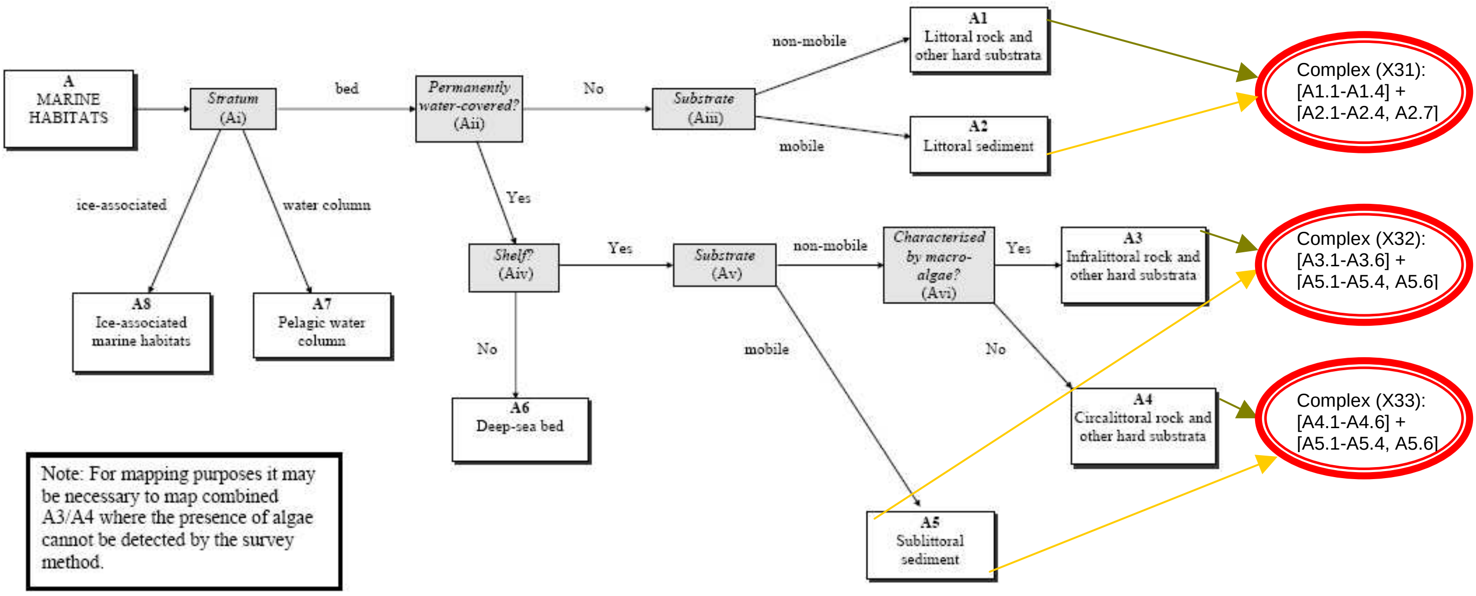
Mixed sediments: (1) *littoral*



Mixed sediments: (1) *sublittoral*



Complex: (1) *littoral*, (2) *circalittoral* and (3) *infralittoral*



ANNEX 3

Table: Geological sediments, observed substrates and substrate composition (based on particle size)

Projection: RT 90 2.5 gon V0: -15

Nr	Id	Area	Sediment category in marine geological map	Observed surficial substrate	Substrate composition	Other Geological Substrate (x=individual, xx=many individual, xxx=<5%)					Shell			Z	X	Y	Date
						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
1	10A0003	w	crystalline bedrock	bedrock outcrop	100% bedrock outcrop (against sand area).									10,8	6561927	1245334	2000-08-26
2	08A0101	w	crystalline bedrock	mixed sediment (mud and gravel)	90% mud and 10% shell gravel.			x	x					79,5	6469634	1223469	2001-04-21
3	07A0091	w	glacial clay	complex (mud, pebbles-boulders)	85% mud, 5% pebbles, 5% cobbles and 5% boulders (a bit messy).							x	x	81,9	6442981	1235970	2001-04-22
4	07A0092	w	glacial clay	complex (mud, pebbles-boulders)	85% mud, 5% pebbles, 5% cobbles and 5% boulders (a bit messy).		x					x	x	44,2	6472000	1226589	2001-04-21
5	08A0100	w	glacial clay	complex (sand, pebbles-boulders)	75% sand, 10% pebbles, 10% cobbles and 5% boulders.									52,6	6464000	1225886	2000-08-23
6	08A0072	w	glacial clay	mixed sediment (sand-gravel)	90% sand and 10% gravel.			xxx	xxx			x	x	36,4	6441000	1232498	2000-09-11
7	07A0065	w	glacial clay	mixed sediment (sand-cobbles)	80% fine sand with 10% gravel, 5% pebbles and 5% cobbles.									51,0	6472120	1220741	2000-08-27
8	08A0064	w	glacial clay	mixed sediment (sand-cobbles)	80% sand, 10% pebbles, 5% cobbles and 5% shell gravel.							x	x	57,1	6435997	1230768	2000-09-11
9	07A0063	w	glacial clay	mixed sediment (sand and pebbles)	85% sand (coarse) with 15% pebbles.		xxx							27,8	6462700	1241579	2000-09-06
10	08A0057	w	glacial clay	mud	100% mud with individual pebbles/cobbles and individual small shells.									70,3	6449005	1226387	2001-04-22
11	07A0068	w	glacial clay	mud	100% mud.						xxx		x	73,5	6451004	1224717	2001-04-22
12	08A0068	w	glacial clay	mud	100% mud.							x	x	86,4	6443006	1229072	2001-04-23
13	07A0089	w	glacial clay	mud	100% mud.			x				x		90,2	6409921	1252719	1999-06-18
14	08A0069	w	glacial clay	mud	100% mud.		xxx					x	x	91,7	6471979	1228444	2001-04-21
15	08A0117	w	glacial clay	mud	100% mud.			x	x			x		98,1	6465002	1228562	2000-08-23
16	07A0095	w	glacial clay	mud	100% mud.				x			x		65,7	6462966	1223470	2000-08-23
17	07B0087	w	glacial clay	mud (anoxic)	100% dark bacteria (beggiatoa) layer (thick, lichen-like, covering all area).									6,7	6423004	1254013	2000-09-07
18	07B0031	w	glacial clay	sand	100% sand.			x	x			x	x	26,8	6447995	1234892	2000-09-11
19	08A0098	w	glacial clay	sand	100% sand.		x					x		52,2	6467005	1224976	2000-08-23
20	08A0055	w	glacial clay	sand	100% sand (muddy).						xxx	x	x	71,7	6473004	1221080	2000-08-27
21	08A0053	w	glacial clay	sand	100% sand (muddy).		x							88,2	6445000	1227555	2001-04-22
22	07A0067	w	glacial clay	sand	100% sand (coarse).			xxx				x	x	50,8	6473989	1225578	2000-08-27
23	08A0056	w	glacial clay	sand	100% sand (medium).							x		58,3	6473987	1220949	2000-08-27
24	08A0116	w	glacial clay	mixed sediment (sand-gravel)	90% sand (ridges) with 10% shell gravel inbetween.									33,9	6438280	1234049	2000-09-11
25	08A0070	w	glacial clay	mixed sediment (sand-gravel)	30% sand and 70% shell gravel.			x					x	98,8	6453009	1234408	2001-04-22
26	08A0044	w	postglacial clay	mixed sediment (sand-pebbles)	60% coarse sand, 30% shell gravel and 10% pebbles.									29,8	6476390	1236336	2000-08-22
27	07A0018	w	postglacial clay	mud	100% mud.						xxx			-	6405109	1245305	1999-06-17

Nr	Id	Area	Sediment category in marine geological map	Observed surficial substrate	Substrate composition	Other Geological Substrate (x=individual, xx=many individual, xxx=<5%)					Shell			Z	X	Y	Date
						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
28	07A0025	w	postglacial clay	mud	100% mud.						xxx			-	6416998	1245106	1999-06-17
29	07B0024	w	postglacial clay	mud	100% mud (slightly dark).						xxx			5,8	6413765	1257174	1999-06-15
30	07B0089	w	postglacial clay	mud	100% mud.									9,4	6426501	1254713	2000-09-08
31	07B0022	w	postglacial clay	mud	100% mud.						xxx			11,2	6414402	1255348	1999-06-15
32	07B0040	w	postglacial clay	mud	100% mud.		x					x	x	12,0	6411721	1256920	1999-06-18
33	08A0075	w	postglacial clay	mixed sediment (mud and gravel)	90% mud (silty) and 10% gravel.			x	x			x	x	12,6	6459720	1244611	2000-09-06
34	07B0017	w	postglacial clay	mud	100% mud (slighly dark).									14,5	6417098	1252201	1999-06-15
35	08A0108	w	postglacial clay	mud	100% mud.							x	x	15,0	6472376	1243112	2001-04-22
36	07B0092	w	postglacial clay	mud	100% mud.									15,3	6428246	1255617	2000-09-08
37	08A0078	w	postglacial clay	mud	100% mud (* rolling).		xxx*						x	15,5	6453728	1240308	2000-09-06
38	07B0036	w	postglacial clay	mud	95% mud and 5% gravel (fine).							x	x	17,6	6401427	1253828	1999-06-18
39	07A0083	w	postglacial clay	mud	100% mud.			x					x	18,1	6438682	1246318	2001-04-20
40	08A0043	w	postglacial clay	mud	100% mud.							x	x	19,7	6478170	1235711	2000-08-22
41	08A0081	w	postglacial clay	mud	100% mud.							x		20,0	6468505	1247712	2000-09-08
42	07B0094	w	postglacial clay	mud	100% mud.			x	x			x	x	27,0	6401129	1254372	2000-09-12
43	07A0084	w	postglacial clay	mud	100% mud (* packed).							x*	x	27,7	6442444	1244684	2001-04-20
44	08A0104	w	postglacial clay	mud	100% mud.			x	x	x				30,5	6471811	1247729	2001-04-22
45	07A0032	w	postglacial clay	mud	100% mud.		xxx				xxx			32,8	6424955	1245345	1999-06-17
46	07A0019	w	postglacial clay	mud	100% mud.						xxx			34,2	6408006	1247088	1999-06-17
47	07A0010	w	postglacial clay	mixed sediment (mud and gravel)	90% mud with 10% shell gravel.									35,2	6401004	1248196	1999-06-14
48	07A0012	w	postglacial clay	mud	100% mud with shell gravel (sediment ontop of gravel).		xxx					x		38,9	6401278	1246868	1999-06-14
49	08A0109	w	postglacial clay	mud	100% mud (slope).									39,2	6469609	1241174	2001-04-22
50	08A0105	w	postglacial clay	mud	100% mud.		x	x				x		40,7	6467847	1245242	2001-04-22
51	08A0058	w	postglacial clay	mud	100% mud.						xxx		x	42,8	6475963	1231448	2000-08-23
52	08A0048	w	postglacial clay	mud	100% mud.		x					x		43,7	6464004	1235063	2000-08-23
53	07A0024	w	postglacial clay	mud	100% mud.			x	x					48,1	6417007	1240847	1999-06-17
54	08A0061	w	postglacial clay	mud	100% mud.						xxx	x		50,2	6471992	1235776	2000-08-23
55	08A0065	w	postglacial clay	mud	100% mud (sandy).			xxx				x		52,3	6476993	1226853	2000-08-27
56	07A0048	w	postglacial clay	mud	100% mud (silty).		x					x		54,8	6431992	1236659	2000-09-07
57	07A0093	w	postglacial clay	mud	100% with shell gravel.									60,3	6436972	1235897	2001-04-22

Nr	Id	Area	Sediment category in marine geological map	Observed surficial substrate	Substrate composition	Other Geological Substrate (x=individual, xx=many individual, xxx=<5%)						Shell		Z	X	Y	Date
						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
58	07A0102	w	postglacial clay	mud	100% mud.									62,0	6418996	1236985	2001-04-23
59	07A0013	w	postglacial clay	mud	100% mud with shell gravel (sediment ontop of gravel).		xxx					x		64,5	6401001	1242002	1999-06-14
60	07A0016	w	postglacial clay	mud	100% mud.						xxx			66,1	6405107	1239717	1999-06-14
61	07A0070	w	postglacial clay	mixed sediment (mud and gravel)	90% mud and 10% gravel (fine).									74,5	6423997	1239143	2000-09-11
62	08A0067	w	postglacial clay	mud	95% mud with 5% shell gravel.								x	85,3	6476013	1220904	2000-08-27
63	07A0100	w	postglacial clay	mud	100% mud with small shells (ridges).									90,1	6428995	1232299	2001-04-23
64	07A0022	w	postglacial clay	mud	100% mud.						xxx			91,6	6409998	1234595	1999-06-17
65	07A0099	w	postglacial clay	mud	100% mud with gravel (fine) and small shells.									92,5	6431008	1229044	2001-04-23
66	07A0023	w	postglacial clay	mud	100% mud.						xxx			93,6	6413004	1234756	1999-06-17
67	08A0040	w	postglacial clay	mud	100% mud.		xxx					x	x	95,8	6455788	1223458	2000-08-22
68	07A0015	w	postglacial clay	mud	100% mud (* long).						xxx*	x	x	96,4	6405112	1236081	1999-06-14
69	07A0090	w	postglacial clay	mud	100% mud.							x	x	114,8	6446549	1224274	2001-04-22
70	07B0021	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer.			x	x					7,3	6416339	1254778	1999-06-15
71	07B0019	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer.						xxx			10,6	6420549	1253037	1999-06-15
72	07B0016	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer.			x	x			x	x	12,9	6414060	1252644	1999-06-15
73	07B0015	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer.						xxx		x	10,8	6412406	1252883	1999-06-15
74	07B0037	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark (beggiatoa) layer (thick, patchy).		x					x		5,0	6409163	1257066	1999-06-18
75	07B0093	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer (thick, lichen-like).									6,0	6413081	1257785	2000-09-12
76	07B0086	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer (thick, lichen-like).									7,0	6423156	1251629	2000-09-07
77	08A0080	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer (thick, covering all area).									8,0	6452444	1242044	2000-09-06
78	07B0095	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer (thick, lichen-like).									9,3	6402381	1259359	2000-09-12
79	08A0074	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer (thick, covering all area).									9,8	6459383	1242490	2000-09-06
80	07B0014	w	postglacial clay	mud (anoxic)	100% mud (anoxic). Slightly dark bacteria (beggiatoa) layer (thick, lichen-like, covering all area)									8,3	6411671	1254349	1999-06-15
81	07B0012	w	postglacial clay	sand	100% sand.						xxx	x	x	16,7	6407186	1253427	1999-06-15
82	08A0047	w	postglacial clay	sand	100% sand (* Nearly < 10%).						xxx*		x	31,2	6464150	1237598	2000-08-23
83	08A0045	w	postglacial clay	mixed sediment (sand-gravel)	90% sand (coarse) with 10% shell gravel (large).								x	39,9	6471994	1233771	2000-08-22
84	07B0088	w	postglacial clay	sand	100% sand (fine).			x	x			x	x	17,0	6428486	1253743	2000-09-08
85	08A0076	w	postglacial clay	gravel (shell gravel)	100% gravel (shell gravel).			x	x				x	8,3	6460498	1246074	2000-09-06
86	07B0035	w	postglacial fine sand	sand	100% sand.			x	x			x	x	15,7	6402882	1250381	1999-06-18
87	07A0033	w	postglacial fine sand	sand	100% sand.		x					x	x	20,7	6425115	1248709	1999-06-17
88	08A0112	w	postglacial fine sand	sand	100% sand (with ripples).									24,5	6461008	1239410	2001-04-22

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						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
89	08A0113	w	postglacial fine sand	sand	100% sand.			x				x		31,1	6459497	1239863	2001-04-22
90	08A0103	w	postglacial fine sand	sand	100% sand (with ripples).							x		32,5	6466005	1237821	2001-04-21
91	08A0115	w	postglacial fine sand	sand	100% sand (muddy).		x					x	x	32,7	6454566	1236902	2001-04-22
92	08A0114	w	postglacial fine sand	sand	100% sand.		x	x	x					36,6	6458523	1239117	2001-04-22
93	07B0034	w	postglacial fine sand	sand	100% sand.		x	x	x			x		8,6	6403894	1250717	1999-06-18
94	07A0085	w	postglacial fine sand	mixed sediment (sand-gravel)	85% sand and 15% shell gravel (ridges).									24,3	6445989	1241780	2001-04-20
95	07A0087	w	postglacial sand and gravel	complex (gravel and cobbles)	70% cobbles and 30% gravel.					x				24,5	6446024	1235322	2001-04-20
96	07A0028	w	postglacial sand and gravel	complex (gravel-cobbles)	60% shell gravel with 15% pebbles, 15% cobbles and 10% gravel.					x				15,1	6415532	1249329	1999-06-17
97	07A0082	w	postglacial sand and gravel	complex (gravel-cobbles)	60% gravel, 15% pebbles, 15% cobbles, and 10% shell gravel (hard packed).					x				23,8	6434010	1240502	2001-04-20
98	07A0034	w	postglacial sand and gravel	mixed sediment (sand and pebbles)	85% coarse sand and 15% pebbles.				x	x		x	x	18,9	6413693	1249177	1999-06-18
99	07A0104	w	postglacial sand and gravel	complex (sand-boulders)	40% pebbles, 40% cobbles, 10% boulders, 5% gravel and 5% sand.									23,1	6420858	1247202	2001-04-23
100	07A0047	w	postglacial sand and gravel	complex (sand-cobbles)	40% pebbles, 40% cobbles, 10% gravel and 10% sand (coarse).									25,1	6431009	1242496	2000-09-07
101	07A0046	w	postglacial sand and gravel	complex (sand, pebbles-boulders)	85% sand (coarse), 5% pebbles, 5% cobbles and 5% boulders.		x					x	x	30,2	6432008	1241758	2000-09-07
102	07A0094	w	postglacial sand and gravel	complex (sand, pebbles-cobbles)	80% sand, 10% pebbles and 10% cobbles.					x	xxx			34,5	6436103	1239960	2001-04-23
103	07A0088	w	postglacial sand and gravel	complex (sand-gravel, cobbles)	60% cobbles, 30% gravel and 10% sand.					x				39,6	6448987	1233452	2001-04-20
104	07B0032	w	postglacial sand and gravel	mixed sediment (gravel-pebbles)	20% pebbles, 70% gravel, 10% shell gravel.								x	14,1	6407096	1250768	1999-06-18
105	07A0029	w	postglacial sand and gravel	mixed sediment (sand-cobbles)	70% sand, 20% gravel, 5% pebbles and 5% cobbles.							x	x	4,0	6416311	1248978	1999-06-17
106	07A0011	w	postglacial sand and gravel	mixed sediment (sand-pebbles)	75% sand and 25% pebbles.		x		x					23,6	6401531	1249405	1999-06-14
107	07A0036	w	postglacial sand and gravel	mixed sediment (sand-pebbles)	70% sand, 15% pebbles, 10% shell gravel and 5% gravel.							x	x	20,1	6405212	1249556	1999-06-18
108	08A0097	w	postglacial sand and gravel	mud	100% mud.		x					x	x	52,2	6473975	1231110	2001-04-21
109	08A0049	w	postglacial sand and gravel	mud	100% mud.		xxx					x	x	52,8	6461004	1229632	2000-08-23
110	06B0606	w	postglacial sand and gravel	sand	100% sand.		x	x				x	x	14,5	6394038	1257222	1999-06-16
111	06B0605	w	postglacial sand and gravel	sand	100% sand.							x		15,2	6393831	1257194	1999-06-16
112	06B0604	w	postglacial sand and gravel	sand	100% sand.							x	x	16,7	6393392	1257130	1999-06-16
113	07B0013	w	postglacial sand and gravel	sand	100% sand.							x		21,8	6407988	1253465	1999-06-15
114	07A0081	w	postglacial sand and gravel	sand	100% sand (hard packed).							x	x	23,6	6433744	1246809	2001-04-20
115	07A0064	w	postglacial sand and gravel	sand (coarse)	100% sand (small ripple-like structures).							x		4,0	6444987	1236520	2000-09-11
116	09A0001	w	postglacial sand and gravel	mixed sediment (sand-pebbles)	50% sand, 40% gravel and 10% pebbles.							x	x	24,7	6500441	1233074	2000-08-25
117	07A0035	w	postglacial sand and gravel	mixed sediment (sand-gravel)	70% shell gravel and 30% sand (ridges).			xxx					x	9,3	6412753	1249837	1999-06-18
118	08A0073	w	postglacial silt	consolidated mud	100% consolidated mud (compact).			x	x				x	13,5	6459844	1241236	2000-09-06

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						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
119	07A0043	w	postglacial silt	consolidated mud	100% consolidated mud (compact and sandy).							x		22,5	6436393	1245590	2000-09-07
120	08A0071	w	postglacial silt	consolidated mud	100% consolidated mud (compact with fine shell gravel).			x	x			x	x	30,7	6463629	1241719	2000-09-06
121	08A0110	w	postglacial silt	consolidated mud	100% consolidated mud (compact and sandy).							x		32,9	6463799	1241699	2001-04-22
122	08A0077	w	postglacial silt	mixed sediment (sand-gravel)	80% sand, 15% gravel and 5% shell gravel.			xxx	xxx					14,3	6457465	1240865	2000-09-06
123	07A0044	w	postglacial silt	mixed sediment (sand-gravel)	85% coarse sand, < 5% pebbles, < 5% cobbles and 5% gravel with individual large shells.									28,6	6435983	1243464	2000-09-07
124	07B0011	w	postglacial silt	mud	100% mud.						xxx			21,2	6405040	1253455	1999-06-15
125	07A0027	w	postglacial silt	mud	100% mud (quite compact).							x	x	25,0	6413393	1248574	1999-06-17
126	07A0105	w	postglacial silt	mud	100% mud (sandy).									25,9	6419351	1248554	2001-04-23
127	07A0059	w	postglacial silt	mud	95% mud (silty) and 5% small shells.			x						30,1	6438570	1243156	2000-09-11
128	08A0111	w	postglacial silt	mud	100% dark mud (with white stripes).			x				x		13,7	6464049	1240852	2001-04-22
129	09A0012	w	postglacial silt	mud	100% mud.			x				x		33,2	6544505	1223337	2000-08-26
130	07B0033	w	postglacial silt	mud (anoxic)	100% mud (anoxic). Dark bacteria (beggiatoa) layer (thin).		x					x	x	12,4	6405537	1251055	1999-06-18
131	07B0029	w	postglacial silt	mud (anoxic)	95% mud (anoxic). Slightly dark (beggiatoa) layer with 5% shell gravel.			x	x					7,4	6412423	1250981	1999-06-18
132	07B0030	w	postglacial silt	sand	100% sand.			x				x		22,6	6410268	1250757	1999-06-18
133	07A0086	w	till	complex (gravel, cobbles, boulders)	60% boulders (large), 35% cobbles och 5% gravel.									30,0	6446025	1236325	2001-04-20
134	07A0045	w	till	complex (sand-cobbles)	70% sand (coarse) , 15% pebbles, 10% cobbles and 5% gravel.					x			x	33,3	6435979	1239754	2000-09-07
135	08A0099	w	till	complex (sand-cobbles)	80% sand, 10% pebbles, 5% cobbles and 5% gravel.					x				33,5	6472000	1227974	2001-04-21
136	10A0008	w	till	mixed sediment (sand-pebbles)	10% pebbles, 20% gravel and 70% sand.					x		x		87,5	6553272	1230981	2000-08-26
137	04_0071	b	boulder clay	mixed sediment (sand-pebbles)	85% sand, 5% gravel and 10% pebbles.				x					62,3	6290487	1686507	2004-07-25
138	04_0082	b	boulder clay	mud (anoxic)	100% dark mud (covered by a thick, cotton-like white bacteria, beggiatoa, layer).									121,7	6261718	1692123	2004-07-25
139	04_0173	b	boulder clay	complex (sand, pebbles-boulders)	80% sand (coarse), 5% pebbles, 10% cobbles and 5% boulders.								x	31,1	6302902	1669738	2004-08-04
140	04_0175	b	boulder clay	complex (gravel-boulders)	60% gravel, 10% pebbles, 15% cobbles and 15% boulders.								xx	26,9	6293778	1663112	2004-08-04
141	04_0235	b	boulder clay	complex (sand, pebbles-cobbles)	60% pebbles, 25% cobbles and 15% sand.									40,1	6226998	1612062	2004-08-09
142	04_0255	b	boulder clay	mixed sediment (sand-pebbles)	70% pebbles, 20% gravel and 10% sand.				x					39,2	6152226	1554723	2004-08-12
143	04_0256	b	boulder clay	complex (sand-cobbles)	30% sand, 30% gravel, 30% pebbles and 10% cobbles.					x				35,1	6158309	1562328	2004-08-12
146	04_0161	b	boulder clay	complex (gravel, cobbles and boulders)	75% boulders, 20% cobbles and 5% gravel.									18,3	6274300	1660964	2004-08-04
147	04_0162	b	boulder clay	mixed sediment (sand-cobbles)	70% sand, 20% gravel, 5% pebbles and 5% cobbles.									22,8	6278369	1666064	2004-08-04
148	04_0228	b	boulder clay	mixed sediment (sand-cobbles)	65% sand (coarse), 20% gravel, 10% pebbles and 5% cobbles.					x				23,6	6236636	1603567	2004-08-08
149	04_0229	b	boulder clay	complex (gravel-cobbles)	50% gravel, 30% cobbles and 20% pebbles.					x				28,0	6229551	1610041	2004-08-08
150	04_0301	b	boulder clay	complex (gravel-boulders)	70% pebbles, 20% cobbles, 5% gravel and 5% boulders.									27,2	6211148	1552588	2004-08-29

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						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
151	04_0310	b	boulder clay	complex (sand, pebbles-cobbles)	70% pebbles, 20% sand and 10% cobbles.					x				33,2	6218935	1555007	2004-08-29
152	04_0322	b	boulder clay	complex (pebbles-boulders)	70% pebbles, 20% boulders and 10% cobbles.									13,1	6223051	1539316	2004-08-30
153	04_0210	b	boulder clay	mixed sediment (sand-cobbles)	60% sand (coarse), 20% gravel, 15% pebbles and 5% cobbles.					x				30,0	6287740	1650747	2004-08-06
154	04_0215	b	boulder clay	complex (sand-boulders)	40% gravel, 20% sand (coarse), 15% pebbles, 20% cobbles and 5% boulders.									21,4	6304117	1650196	2004-08-07
155	04_0179	b	sedimentary bedrock	complex (gravel-pebbles, boulders and bedr. outcrop)	40% bedrock outcrop, 30% gravel, 20% boulders and 10% pebbles.									17,7	6292573	1668246	2004-08-04
156	04_0279	b	sedimentary bedrock	mud	100% mud (dark surface).									72,9	6339552	1597058	2004-08-18
157	04_0145	b	sedimentary bedrock	bedrock outcrop	100% bedrock outcrop.							x		17,4	6373455	1635337	2004-08-01
158	04_0323	b	sedimentary bedrock	complex (gravel and bedrock outcrop)	85% bedrock outcrop with 15% gravel and.					x				14,3	6223229	1539525	2004-08-30
159	04_0324	b	sedimentary bedrock	complex (sand and bedrock outcrop)	70% coarse sand and 30% bedrock outcrop.					x				19,8	6224172	1541024	2004-08-30
160	04_0125	b	postglacial fine sand	sand (fine)	100% sand (fine).								x	32,1	6219804	1587380	2004-07-30
161	04_0185	b	postglacial fine sand	sand (fine)	100% sand (fine).									20,1	6265353	1670623	2004-08-05
162	04_0200	b	postglacial fine sand	sand (fine)	100% sand (fine).							x	x	36,6	6277938	1655099	2004-08-06
163	04_0262	b	postglacial fine sand	sand (fine)	100% sand (fine).								x	32,3	6154239	1577909	2004-08-12
164	04_0164	b	postglacial fine sand	sand (fine)	100% sand (fine).							x		32,5	6283502	1667305	2004-08-04
165	04_0288	b	postglacial fine sand	mixed sediment (sand and nodules)	70% sand (fine) and 30% round nodules (pebble size).									47,5	6196897	1548201	2004-08-26
166	04_0205	b	postglacial fine sand	sand (fine)	100% sand (fine).							x	x	49,6	6285204	1658999	2004-08-06
167	04_0214	b	postglacial fine sand	sand (fine)	100% sand (fine).								x	37,1	6306436	1655519	2004-08-07
168	04_0038	b	glacial clay	mud	100% mud.			xxx					x	51,5	6191507	1537002	2004-07-22
169	04_0073	b	glacial clay	mud (anoxic)	100% mud (anoxic). Dark, covered by a thin cotton-like white bacteria (beggiatoa) layer.									105,5	6300008	1686338	2004-07-25
170	04_0087	b	glacial clay	complex (pebbles-cobbles)	90% pebbles and 10% cobbles.		xxx						x	36,8	6213018	1537005	2004-07-27
171	04_0092	b	glacial clay	mixed sediment (sand-pebbles)	80% sand, 15% gravel and 5% pebbles (slightly anoxic patches).				x					104,6	6230499	1673287	2004-07-28
172	04_0095	b	glacial clay	consolidated mud (nodules)	100% consolidated mud (hard with nodules).									56,2	6233651	1656902	2004-07-28
173	04_0250	b	glacial clay	mud	100% mud (with dark surface and beginning beggiatoa).									64,4	6145240	1536995	2004-08-11
174	04_0267	b	glacial clay	mud	100% mud.									47,5	6198233	1537000	2004-08-13
175	04_0307	b	glacial clay	complex (sand, pebbles-cobbles)	60% sand, 30% pebbles and 10% cobbles.									46,3	6215689	1550932	2004-08-29
176	04_0325	b	glacial clay	sand	100% sand (coarse).			x						30,3	6170123	1608476	2004-09-03
177	05_0130	b	boulder clay	mixed sediment (sand-pebbles)	90% sand (coarse), 5% gravel and 5% pebbles.								x	50,1	6166698	1413571	2005-06-08
178	05_0131	b	boulder clay	complex (sand, cobbles-boulders)	80 % sand, 15% boulders and 5% cobbles.		x	x					x	26,5	6165926	1408948	2005-06-08
179	05_0221	b	boulder clay	mixed sediment (sand, pebbles-cobbles)	70% cobbles, 20% sand and 10% pebbles.					x				8,3	6289856	1541508	2005-06-19
180	05_0232	b	boulder clay	mixed sediment (sand and pebbles)	80% pebbles and 20% sand.				x					21,3	6336047	1552203	2005-06-19

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						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
181	05_0134	b	sedimentary bedrock	bedrock outcrop	100% bedrock outcrop (with a thin mud layer, * 2 examples).					x*				42,1	6153804	1418775	2005-06-08
182	05_0055	b	glacial clay	mixed sediment (sand and pebbles)	90% sand and 10% pebbles.		x		x					28,7	6202549	1438283	2005-05-27
183	05_0157	b	glacial clay	mud	100% mud.								x	45,0	6205730	1473536	2005-06-11
184	05_0173	b	glacial clay	mud	100% mud.									50,9	6180036	1493669	2005-06-15
185	05_0178	b	glacial clay	mud (anoxic)	100% mud (anoxic). Dark with some beggiatoa.									67,3	6161955	1481736	2005-06-16
186	05_0243	b	glacial clay	mixed sediment (sand and gravel)	90% sand and 10% gravel.			x					xx	45,1	6375040	1564891	2005-06-20
187	05_0188	b	glacial clay	mud	100% mud.			x	x				xx	49,9	6194347	1534961	2005-06-17
188	05_0193	b	glacial clay	mud	100% mud.								x	55,8	6190132	1510145	2005-06-17
189	05_0291	b	glacial clay	complex (consolidated mud and pebbles)	90% consolidated mud and 10% pebbles.				x					98,6	6425268	1630352	2005-07-02
190	05_0317	b	glacial clay	mud (anoxic)	100% mud (anoxic). Dark.									172,9	6498432	1658411	2005-07-06
191	05_0162	b	glacial clay	mixed sediment (mud, pebbles-cobbles)	90% mud, 5% pebbles and 5% cobbles (* thin layer).	x*				x			x	38,6	6210355	1483106	2005-06-14
192	05_0262	b	glacial clay	mud	100% mud (slightly dark).									69,4	6477265	1601374	2005-06-28
193	05_0158	b	glacial clay	mud	100% mud.									45,3	6205734	1474369	2005-06-11
194	05_0297	b	glaciofluvial deposits	mud (anoxic)	100% mud (anoxic). Dark with some beggiatoa with round hilly-like topography.									95,2	6438256	1640516	2005-07-03
195	05_0242	b	glaciofluvial deposits	mixed sediment (sand-pebbles)	70% coarse sand (low broad clean ripples) with 20% gravel and 10% pebbles.									29,9	6363458	1575043	2005-06-20
196	05_0251	b	glaciofluvial deposits	mixed sediment (sand-pebbles)	70% coarse sand (low broad clean ripples) with 20% gravel and 10% pebbles.									16,8	6412416	1559032	2005-06-21
197	05_0218	b	glaciofluvial deposits	complex (cobbles and boulders)	50% cobbles and 50% boulders. Hard to see substrate due to all green algaes (fintrådiga).									8,2	6270789	1529499	2005-06-18
198	05_0202	b	glaciofluvial deposits	mixed sediment (sand, pebbles-cobbles).	70% cobbles, 20% pebbles and 10% sand.									9,4	6258042	1526721	2005-06-18
199	05_0061	b	glaciofluvial deposits	complex (sand, pebbles-boulders)	70% sand, 15% cobbles, 10% pebbles and 5% boulders.								x	23,6	6205631	1442141	2005-05-28
200	05_0169	b	glaciofluvial deposits	complex (sand, pebbles-cobbles)	70% cobbles, 20% sand and 10% pebbles.									32,7	6194324	1490948	2005-06-15
201	05_0225	b	glaciofluvial deposits	mud	100% mud.				x	x			x	18,0	6302926	1545377	2005-06-19
202	05_0024	b	till	boulders	100% boulders (hard to see substrate due to mussels and algaes).									16,2	6204280	1440917	2005-05-25
203	05_0025	b	till	boulders	100% boulders (hard to see substrate due to mussels and algaes).									17,0	6201146	1447930	2005-05-25
204	05_0027	b	till	boulders	100% boulders (hard to see substrate due to mussels and algaes).									18,0	6199446	1445595	2005-05-25
205	05_0028	b	till	boulders	100% boulders (hard to see substrate).									23,4	6197837	1439775	2005-05-25
206	05_0035	b	till	cobbles and boulders	90% boulders and 10% cobbles.									16,7	6198062	1429054	2005-05-26
207	05_0039	b	till	boulders	100% boulders (hard to see substrate).									14,7	6197718	1423797	2005-05-26
208	05_0044	b	till	boulders	100% boulders (hard to see substrate).		x		x			x		11,4	6196280	1414400	2005-05-26
209	05_0045	b	till	boulders	100% boulders (hard to see substrate).									8,4	6194718	1412440	2005-05-26
210	05_0046	b	till	boulders	100% boulders (hard to see substrate).									13,1	6201391	1421883	2005-05-27

Nr	Id	Area	Sediment category in marine geological map	Observed surficial substrate	Substrate composition	Other Geological Substrate (x=individual, xx=many individual, xxx=<5%)					Shell			Z	X	Y	Date
						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
211	05_0048	b	till	cobbles and boulders	90% boulders and 10% cobbles.									13,9	6199331	1418655	2005-05-27
212	05_0052	b	till	complex (sand, pebbles-boulders)	80% finesand, 10% boulders, 5% pebbles and 5% cobbles.									28,4	6196786	1435462	2005-05-27
213	05_0053	b	till	cobbles and boulders	85% boulders, 10% cobbles and 5% pebbles.							x		23,1	6198366	1437360	2005-05-27
214	05_0057	b	till	boulders and bedrock outcrop	80% bedrock outcrop and 20% boulders.									13,6	6205201	1425221	2005-05-28
215	05_0062	b	till	boulders	100% boulders.									11,6	6201304	1417705	2005-05-28
216	05_0122	b	till	boulders	100% boulders.									19,1	6201403	1448031	2005-06-06
217	05_0201	b	till	mixed sediment (sand, pebbles-cobbles)	90% coarse sand, 5% cobbles and 5% pebbles. * many					x			x	12,1	6258045	1524041	2005-06-18
218	05_0214	b	till	cobbles and boulders	(hard to see substrate due to all green algaes).									12,2	6244363	1533874	2005-06-18
219	05_0219	b	till	mixed sediment (sand-cobbles)	40% cobbles, 30% pebbles, 20% gravel and 10% sand.									8,1	6283841	1536237	2005-06-19
220	05_0223	b	till	complex (sand, pebbles-boulders)	60% sand, 10% pebble, 10% cobbles and 20% boulders.		x							14,6	6300492	1544547	2005-06-19
221	05_0229	b	till	mixed sediment (pebbles-cobbles)	(hard to see substrate due to all green algaes).									9,1	6318846	1548361	2005-06-19
222	05_0196	b	till	cobbles and boulders	60% boulders and 40% cobbles.	x		x						30,7	6205726	1506477	2005-06-17
223	05_0005	b	till	boulders	100% boulders.									15,5	6205490	1433725	2005-05-22
224	05_0198	b	till	complex (sand-boulders)	40% boulders, 20% gravel, 20% coarse sand, 15% pebbles and 5% cobbles.									15,9	6208412	1498099	2005-06-17
225	05_0004	b	till	boulders	100% boulders.									15,1	6205970	1432200	2005-05-22
226	05_0008	b	till	boulders	100% boulders.									8,6	6209836	1436305	2005-05-22
227	05_0003	b	postglacial fine sand	sand (fine)	100% sand (fine) with ripples and thin darker mobile sedimentation layer.							x		22,0	6204250	1428991	2005-05-22
228	05_0010	b	postglacial fine sand	sand (fine)	100% sand (fine) with ripples.								x	20,5	6210981	1437892	2005-05-22
229	05_0012	b	postglacial fine sand	sand (fine)	100% sand (fine) with darker sedimentation layer and (* patches).							x*		20,2	6212117	1437356	2005-05-22
230	05_0014	b	postglacial fine sand	mixed sediment (sand-gravel)	90% sand (fine) and 10% gravel.			x					x	27,2	6208812	1438483	2005-05-22
231	05_0032	b	postglacial fine sand	sand (fine)	100% sand (fine).								x	16,1	6206228	1427371	2005-05-26
232	05_0132	b	postglacial fine sand	sand (fine)	100% sand (fine). * many								x	32,1	6158996	1411415	2005-06-08
233	05_0135	b	postglacial fine sand	sand (fine)	100% sand (fine).									45,0	6153581	1423325	2005-06-08
234	05_0153	b	postglacial fine sand	sand (fine)	100% sand (fine).								x	24,4	6219054	1473300	2005-06-10
235	05_0294	b	postglacial fine sand	sand (fine)	100% sand (fine) with non-regular ripples.							x	x	17,4	6398965	1650970	2005-07-03
236	05_0013	b	postglacial sand and gravel	sand	100% sand (silty).							x	x	26,2	6209624	1438711	2005-05-22
237	05_0058	b	postglacial sand and gravel	sand (coarse)	95% sand (coarse) with ridges and 5% cobbles (in one corner).								x	14,7	6205172	1425110	2005-05-28
238	05_0067	b	postglacial sand and gravel	mixed sediment (sand-pebbles)	75% coarse sand, 20% pebbles and 5% gravel.				x				xx	12,8	6195112	1409191	2005-06-01
239	05_0071	b	postglacial sand and gravel	sand (fine)	100% sand (fine) with mediumhigh ripples (* patches).			x			xxx*			15,7	6193219	1406511	2005-06-01
240	05_0079	b	postglacial sand and gravel	sand (fine)	95% sand (fine) and 5% boulders.				x					14,0	6191524	1415307	2005-06-01
241	05_0080	b	postglacial sand and gravel	sand	100% sand.								x	11,0	6193423	1411374	2005-06-02

Nr	Id	Area	Sediment category in marine geological map	Observed surficial substrate	Substrate composition	Other Geological Substrate (x=individual, xx=many individual, xxx=<5%)					Shell			Z	X	Y	Date
						Sand	Gravel	Pebble	Cobble	Boulder	gravel	Small	Large				
242	05_0084	b	postglacial sand and gravel	complex (sand and boulders)	90% sand (fine) and 10% boulders.							x		16,9	6187973	1401879	2005-06-02
243	05_0085	b	postglacial sand and gravel	sand	100% sand (with non-regular mediumhigh ripples).								x	17,7	6186759	1400888	2005-06-02
244	05_0090	b	postglacial sand and gravel	sand (coarse)	100% sand (coarse) with non-regular ripples.									22,4	6176073	1404318	2005-06-02
245	05_0096	b	postglacial sand and gravel	mixed sediment (sand and pebbles)	90% sand and 10% pebbles.		x							23,1	6179800	1406652	2005-06-02
246	05_0109	b	postglacial sand and gravel	sand (coarse)	100% sand (coarse). Long and regular with high ripples.								x	14,3	6186286	1406982	2005-06-04
247	05_0116	b	postglacial sand and gravel	sand (coarse)	100% sand (coarse) with small, non-regular ripples.			x						15,9	6182686	1409053	2005-06-04
248	05_0119	b	postglacial sand and gravel	complex (sand and cobbles)	75% sand and 25% cobbles (hard to see substrate due to algaes).								x	20,7	6222983	1438496	2005-06-05
249	05_0124	b	postglacial sand and gravel	sand (coarse)	100% sand (coarse).		x			x			x	27,9	6190131	1425329	2005-06-06
250	05_0149	b	postglacial sand and gravel	sand	100% sand. * many			x	x				x	34,1	6217629	1458596	2005-06-10
251	05_0220	b	postglacial sand and gravel	sand (coarse)	100% sand (coarse) with high sharp ripples.								xx	10,6	6288574	1540196	2005-06-19
252	05_0328	ö	postglacial sand and gravel	complex (sand and boulders)	70% boulders and 30% sand (coarse).									7,3	6158501	1311682	2005-07-16
253	05_0329	ö	postglacial sand and gravel	complex (sand and boulders)	70% sand (coarse) with some non-regular small hills and 30% boulders.								xx	8,3	6158728	1311671	2005-07-16
254	05_0330	ö	postglacial sand and gravel	complex (cobbles and boulders).	(hard to see substrate due to all green algaes).									8,0	6165388	1313113	2005-07-16
255	05_0331	ö	postglacial sand and gravel	complex (cobbles and boulders).	(hard to see substrate due to all green algaes).									7,3	6165387	1313120	2005-07-16
256	05_0333	ö	postglacial sand and gravel	mixed sediment (sand-gravel)	70% coarse sand, 15% gravel and 15% large shells (M. edulis).									11,4	6195719	1307603	2005-07-16
257	05_0336	ö	postglacial sand and gravel	sand (coarse)	100% sand (coarse) with non-regular small hills.							x		10,9	6210538	1303633	2005-07-16
258	05_0337	ö	postglacial sand and gravel	sand (fine)	100% sand (fine) with thin muddy layer.									27,4	6211690	1304955	2005-07-16
259	05_0338	ö	postglacial sand and gravel	sand (fine)	100% sand (fine) with thin muddy layer (* 1 example).			x*		x*		x		23,3	6212535	1304447	2005-07-16

ANNEX 4
Tables: Correct predictions of surficial substrates

Table 1. *Modified predicted surficial substrates (Skagerrak and Kattegatt).*

Nr	Sediments categories according to Marine geological map	Modified redicted surficial substrate (after Mattisson 2005, modified by Elhammar and Lindeberg 2006)	Observed substrate	Sites controlled (number)	Correct substrate (number)	Other substrate (number)	Correct (%)	Depth of correct substrate (m)	Other substrates found	Mobility (mobile or non-mobile)	Depth of other substrates (m)	Comment
1	Postglacial clay, gyttja clay and clayey gyttja	clay, gyttja clay, clayey gyttja	mud, mud (anoxic), sand gravel (shell gravel) mixed sediments (mud-pebbles[1])	60	51	9	**85**	7-13/6-115	(5) mixed sediment (mud and gravel[1]) (sand-shell gravel) (sand-pebbles)	M	13-40, 74	Mainly mud and sand. Anoxic mud defined as correct substrate.
									(3) sand	M	17-31	Fine to coarse with shells.
									(1) gravel (shell gravel*)	M	8	*Mussels and polychaetes.
2	Postglacial silt	clayey silt (seldom pure silt)	mud, mud (anoxic), sand consolidated mud mixed sediment (sand-cobbles[1])	15	8	7	**53**	7-12/14-33	(2) mixed sediment (sand-cobbles) (sand-cobbles[1])	M	14/29	Mainly sand. Anoxic mud defined as correct substrate.
									(1) sand	M	23	-
									(4) consolidated mud	NM	14-33	Hard packed (compact) mud with small and/or large shells.
3	Postglacial fine sand	fine sand	sand* mixed sediment (sand-gravel[1])	9	8	1	**89**	9-33	(1) mixed sediment (sand and shell gravel)**	M	24	Mainly sand. * Corresponding samples showed that the observed substrates were fine sand. ** Ridges.
4	Postglacial sand and gravel (mainly sand)	sand-gravel	mud, sand boulders (individual) mixed sediments (sand-cobbles) complex (sand-boulders[1])	23	7	16	**30**	4-24	(8) complex (gravel and cobbles) (gravel[1]-cobbles) (sand-gravel, cobbles) (sand, pebbles-cobbles) (sand, pebbles-boulders)	M/NM	15-40	A lot of pebbles and cobbles were found at >15 m (and also individual boulders).
									(2) mud	M	53	Mud at >50 m.
									(6) mixed sediment (sand-pebbles) (sand and pebbles) (gravel-pebbles) (sand-cobbles)	M	4-25	Mainly sand and gravel.
5	Glacial clay	sand-boulders consolidated clay	mud, mud (anoxic), sand mixed sediment (sand-cobbles[1]) complex (mud-sand, pebbles-boulders)	23	13	10	**57**	27-99	(2) complex (mud, pebbles-boulders)	M/NM	44/82	Mainly mud but also pebbles, cobbles, boulders and shells (messy).
									(7) mud	M	65-98	Mud at >65 m.
									(1) mud (anoxic)	M	7	-
-	Glaciofluvial deposits	-	-	-	-	-	**-**	-	-	-	-	No videos found
6	Till	sand-boulders	mixed sediment (sand-pebbles) complex (sand-boulders)	4	4	0	**100**	33-34/88	-	-	-	Mainly sand.
-	Boulder clay	-	-	-	-	-	-	-	-	-	-	No videos found
-	Sedimentary bedrock	-	-	-	-	-	-	-	-	-	-	No videos found
7	Crystalline bedrock	bedrock outcrop (<15 m) *overlaid by*: sand-boulders (>15 m) clay, gyttja clay, clayey gyttja (>15 m)	bedrock outcrop mixed sediment (mud and shell gravel)	2	2	0	**100**	11/80	-	-	-	Bare rock at 11 m. Mixed sediment consisted mainly of mud at 80 m.
	Total			136	92	44	**26-100**				-	

[1] including shell gravel

ANNEX 4
Tables: Correct predictions of surficial substrates

Table 1a. *New predicted surficial substrates (Skagerrak and Kattegatt).*

Nr	Sediments categories according to Marine geological map	New predicted surficial Substrate[2]	New predicted surficial substrate (with definitions used in EUNIS)[2]	Sites controlled (number)	Correct substrate (number)	Other substrate (number)	Correct (%)	Depth of correct substrate (m)	Other substrates found	Mobility (mobile or non-mobile)	Depth of other substrates (m)	Comment
1	Postglacial clay, gyttja clay and clayey gyttja	clay, gyttja clay, clayey gyttja + anoxic clay* (at <15 m)	mud + anoxic mud (<15 m)	60	51	9	**85**	7-13*/6-115	(5) mixed sediment (mud and gravel[1]) (sand-shell gravel) (sand-pebbles)	M	13-40, 74	* Eleven anoxic mud found at 5-13 m.
									(3) sand	M	17-31	Fine to coarse and shells.
									(1) gravel (shell gravel)	M	8	-
2	Postglacial silt	clayey silt (seldom pure silt) + anoxic clay* (at <15 m)	mud + anoxic mud (<15 m)	15	8	7	**53**	7-12*/14-33	(2) mixed sediment (sand-cobbles) (sand-cobbles)[1]	M	14/29	* Two anoxic mud found at 7 and 12 m.
									(1) sand	M	23	-
									(4) consolidated mud	NM	14-33	Mattisson (2005) also found compact soft substrates.
3	Postglacial fine sand	fine sand	fine sand	9	8	1	**89**	9-33	(1) mixed sediment (sand and shell gravel)	M	24	-
4	Postglacial sand and gravel (mainly sand)	sand-gravel + medium stones* + coarse stones**	sand-cobbles + pebbles + cobbles mixed sediments (sand-cobbles) complex (sand-cobbles***)	23	19	4	**83**	4-40	(2) complex (sand-boulders) (sand, pebbles-boulders)	M/NM	23/30	* Grain size adjustment resulted in that pebbles were included (see table 9). ** 8 complex and 1 mixed sediment with cobbles were observed (5-70% coverage). *** Cobbles considered as non-mobile at >10 m.
									(2) mud	M	53	-
5	Glacial clay	sand-boulders consolidated clay + clay (>65 m) + anoxic clay (at<15 m)	sand-boulders consolidated mud + mud (pure at >65 m) + anoxic mud (<15 m) mixed sediment (sand-cobbles) complex (sand-boulders)	23	23	0	**100**	7-99	-	-	-	Seven pure mud were found at 65-98 m, two complex with mud at 44/82 m and one anoxic mud at 7 m. This category is the most diverse regarding predicted substrate.
-	Glaciofluvial deposits	-	-	-	-	-	**-**	-	-	-	-	No videos found
6	Till	sand-boulders	sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)	4	4	0	**100**	33-34/88	-	-	-	-
-	Boulder clay	-	-	-	-	-	-	-	-	-	-	No videos found
-	Sedimentary bedrock	-	-	-	-	-	-	-	-	-	-	No videos found
7	Crystalline bedrock	bedrock outcrop (<15 m) *overlaid by*: sand-boulders (>15 m) clay, gyttja clay, clayey gyttja (>15 m)	bedrock outcrop (<15 m) *overlaid by*: mixed sediment (sand-cobbles) at >15 m complex (sand-boulders) at >15 m mud at >80 m	2	2	0	**100**	11*/80**	-	-	-	Other samples indicate that mud often is found much deeper than 15 m.
Total				136	115	21	**53-100**	-				

[1] including shell gravel [2] added new substrates are marked with +

ANNEX 4
Tables: Correct predictions of surficial substrates

Table 2. *Modified predicted surficial substrates (the Baltic Sea).*

Nr	Sediments categories according to Marine geological map	Modified predicted surficial substrate (after Mattisson 2005, modified by Elhammer and Lindeberg 2006)	Observed substrate	Sites controlled (number)	Correct substrate (number)	Other substrate (number)	Correct (%)	Depth of correct substrate (m)	Other substrates found	Mobility (mobile or non-mobile)	Depth of other substrates (m)	Comment
1	Postglacial clay, gyttja clay and clayey gyttja	-	-	-	-	-	**-**	-	-	-	-	No photos found
2	Postglacial silt	-	-	-	-	-	**-**	-	-	-	-	No photos found
3	Postglacial fine sand	fine sand	sand (fine) mixed sediment (sand-gravel, nodules)	17	15	2	**88**	16-50	(2) mixed sediment (sand-gravel) (sand and nodules*/[1])	M	27/48*	Mainly fine sand. * Round and pebble sized nodules[1].
4	Postglacial sand and gravel (mainly sand)	sand-gravel	sand mixed sediments (sand-pebbles) complex (sand, cobbles, boulders)	24	16	8	**67**	11-34	(2) mixed sediment (sand-pebbles) (sand and pebbles)	M	13/23	Mainly sand.
									(6) complex (sand and cobbles) (sand and boulders) (cobbles & boulders)	NM/M	7-8/17-21	Mainly sand.
5	Glacial clay	sand-boulders consolidated clay	mud, mud (anoxic), sand consolidated mud with nodules* mixed sediment (mud-cobbles) complex (sand-cobbles) complex (consolidated clay** & pebbles)	21	8	13	**38**	29-56, 99-105	(1) mixed sediment (mud, sand-cobbles)		39	Mainly mud. * Disc-formed compact mud with round (pebble sized) non-mobile nodules[1]. ** Consolidated mud and mobile pebbles at 99 m.
									(9) mud	M	48-70	-
									(3) mud (anoxic)	M	67/106/173	Only slightly anoxic at 65
6	Glaciofluvial deposits[2]	sand-boulders	mud, mud (anoxic) mixed sediment (sand-cobbles) complex (sand, pebbles-boulders)	8	6	2	**75**	8-9, 17-33	(1) mud	M/NM	18	With individual cobbles and boulders).
									(1) mud (anoxic)		95	-
7	Till	sand-boulders	boulders and bedrock outcrop mixed sediment (sand-cobbles) complex (sand-boulders)	25	24	1	**96**	8-31	(1) bedrock outcrop and boulders	NM	14	Mainly bedrock outcrop.
8	Boulder clay[2]	sand-boulders	mud, mud (anoxic) consolidated pebbles* mixed sediment (sand-cobbles) complex (sand-boulders)	22	21	1	**95**	8,13-63, 96	(1) mud (anoxic)	M	122	* Non-mobile pebbles (rounded) covered by a very thin (cm) layer of compact soft material, were found at 63 m.
9	Sedimentary bedrock[2]	bedrock outcrop (<15 m) *overlaid by*: sand-boulders (>15 m) clay, gyttja clay, clayey gyttja (>15 m)	mud bedrock outcrop complex (sand-gravel, bedrock outcrop)	6	5	1	**83**	14-20, 73	(1) bedrock outcrop	NM	40	Bedrock outcrop (bare bedrock) found at 14-20 and 42 m. Bedrock outcrop found at depth <20 m were defined as correct. Mud was found at
10	Crystalline bedrock	-	-	-	-	-	**-**	-	-	-	-	No photos found
	Total			123	95	28	**38-96**			-		

[1] A rounded mineral concretion consisting chiefly of oxide minerals; formed in oceans as a result of pelagic sedimentation or precipitation.
[2] Sediment category with samples only from the Baltic Sea

ANNEX 4
Tables: Correct predictions of surficial substrates

Table 2a. *New predicted surficial substrates (the Baltic Sea).*

Nr	Sediments categories according to Marine geological map	New predicted surficial Substrate[1]	New predicted surficial substrate (with definitions used in EUNIS)[1]	Sites controlled (number)	Correct substrate (number)	Other substrate (number)	Correct (%)	Depth of correct substrate (m)	Other substrates found	Mobility (mobile or non-mobile)	Depth of other substrates (m)	Comment
1	Postglacial clay, gyttja clay and clayey gyttja	-	-	-	-	-	**-**	-	-	-	-	No photos found
2	Postglacial silt	-	-	-	-	-	**-**	-	-	-	-	No photos found
3	Postglacial fine sand	fine sand	fine sand	17	15	2	**88**	16-50	(2) mixed sediment (finesand-gravel) (finesand and nodules*)	M	27/48	Mainly sand.
4	Postglacial sand and gravel (mainly sand)	sand-gravel + medium stones* + coarse stones	sand-cobbles + pebbles + cobbles mixed sediments (sand-cobbles) complex (sand-cobbles**)	24	19	5	**79**	11-34	(5) complex (cobbles and boulders) (sand and boulders)	M/NM	7-8/17	Mainly sand. * Grain size adjustment (see table 1B in app. 3). ** Non-mobile cobbles at depth >10 m.
5	Glacial clay	sand-boulders consolidated clay + clay (>40 m) + anoxic clay (<15 m)	sand-boulders consolidated mud + mud (pure, >45 m) + anoxic clay (>65 m) mixed sediment (sand-cobbles) complex (sand-boulders)	21	21	0	**100**	29-67, 99-106, 172	-	-	-	-
6	Glaciofluvial deposits	sand-boulders	sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)	8	6	2	**75**	8-9, 17-33	(1) mud	M/NM	18	With individual cobbles and boulders.
									(1) mud (anoxic)		95	-
7	Till	sand-boulders	sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)	25	24	1	**96**	8-31	(1) boulders and bedrock outcrop	NM	14	-
8	Boulder clay	sand-boulders	sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)	22	21	1	**95**	8-96	(1) mud (anoxic)	M/NM	122	-
9	Sedimentary bedrock	bedrock outcrop (+ <20 m) *overlaid by*: sand-boulders (>15 m) clay, gyttja clay, clayey gyttja (>15 m)	bedrock outcrop (+ <20 m) overlaid by: mixed sediment (sand-cobbles) complex (sand-boulders) mud (>15 m)	6	6	0	**100**	14-20, 40, 73	-	-	-	-
10	Crystalline bedrock	-	-	-	-	-	**-**	-	-	-	-	No photos found
	Total			123	112	11	**75-100**		-			

[1] added new substrates are marked with +

ANNEX 4
Tables: Correct predictions of surficial substrates

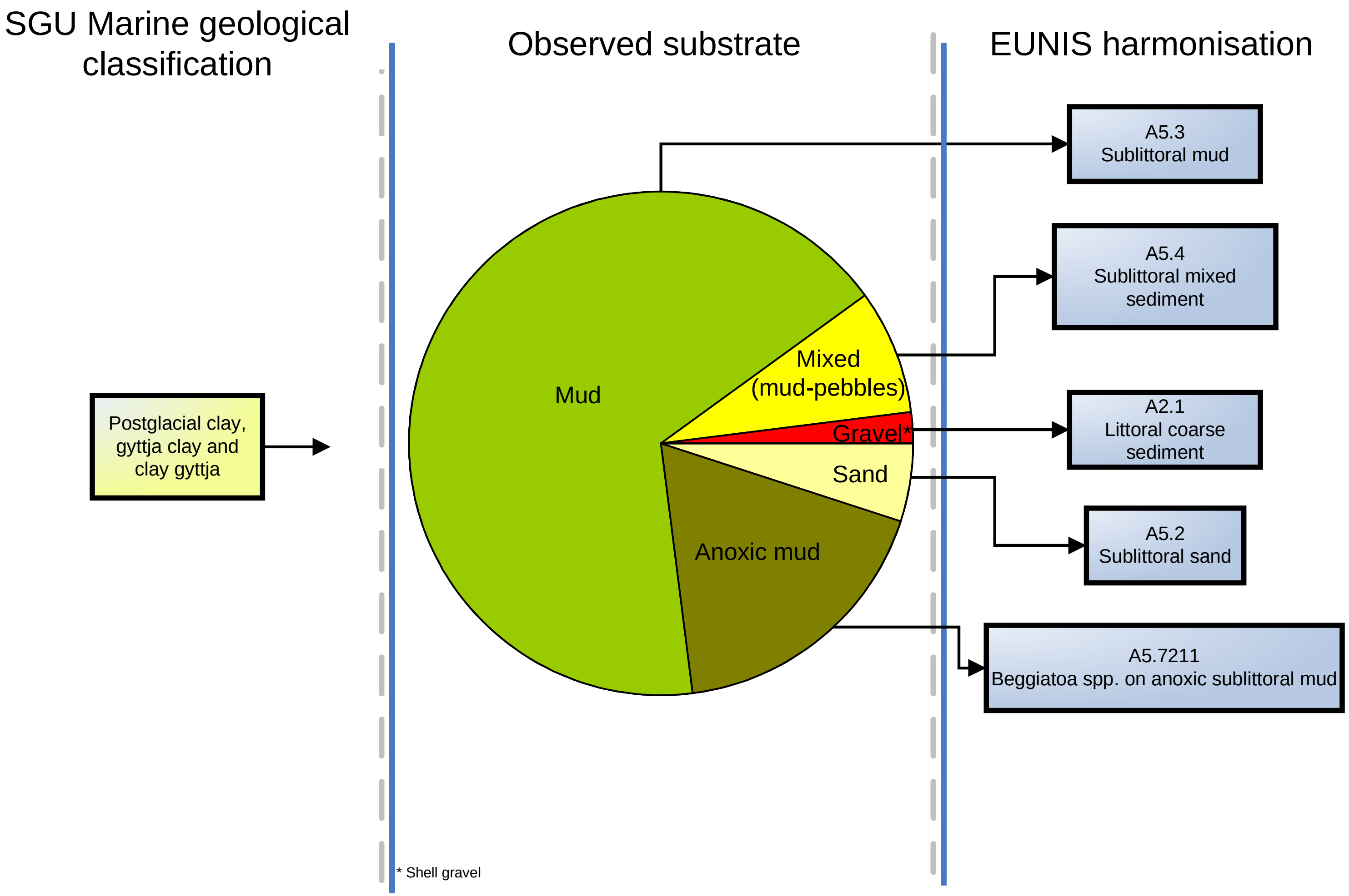
Table 3. *New predicted surficial substrates (Skagerrak, Kattegatt and the Baltic Sea).*

Nr	Sediments categories according to Marine geological map	New predicted surficial layer (substrate)	New predicted substrate (surficial layer) with definitions used in EUNIS	Sites controlled (number)	Correct substrate (number)	Other substrate (number)	Correct (%)	Depth of correct substrate (m)	Other substrates found	Mobility (M= mobile N= non-mobile)	Depth of other substrates (m)	Comment
1	Postglacial clay, gyttja clay and clayey gyttja[1]	clay, gyttja clay, clayey gyttja anoxic clay (<15 m)	mud anoxic mud (<15 m)	60	51	9	**85**	7-13*/6-115	(5) mixed sediment (mud and gravel[1]) (sand-shell gravel) (sand-pebbles)	M	13-40, 74	* Anoxic mud
									(3) sand	M	17-31	-
									(1) gravel (shell gravel)	M	8	-
2	Postglacial silt[2]	clayey silt (seldom pure silt) anoxic clay (<15 m)	mud anoxic mud (<15 m)	15	8	7	**53**	7-12*/14-33	(2) mixed sediment (sand-cobbles) (sand-cobbles)[1]	M	14/29	* Anoxic mud
									(1) sand	M	23	-
									(4) consolidated mud	NM	14-33	-
3	Postglacial fine sand	fine sand	fine sand	26	23	3	**89**	9-50	(3) mixed sediment (finesand-gravel) (sand and shell gravel) (finesand & nodules)	M	24, 27, 48	Nodules probably originate from Glacial clay under the thin finesand layer (15-cm).
4	Postglacial sand and gravel (mainly sand)	sand-stones (medium-coarse)	sand-cobbles mixed sediments (sand-cobbles) complex (sand-cobbles*)	47	38	9	**81**	4-40	(7) complex (sand, pebbles-boulders) (sand and boulders) (sand-boulders) (cobbles-boulders)	M/NM	7-8, 17-23, 30	-
									(2) mud	M	52/53	-
5	Glacial clay	sand-boulders consolidated clay clay (pure at >45 m) anoxic clay (<15 or >65 m)	sand-boulders consolidated mud mud (pure at >45 m) anoxic mud (<15 or >65 m) mixed sediment (sand-cobbles) complex (sand-boulders)	44	44	0	**100**	7-105	-	-	-	-
6	Glaciofluvial deposits[3]	sand-boulders	sand-boulders mixed sediments (sand-cobbles) complex (sand-boulders)	8	6	2	**75**	8-33	(1) mud	M	18	With individual cobbles and boulders.
									(1) mud (anoxic)	M	95	-
7	Till	sand-boulders	sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)	29	28	1	**98**	8-34, 88	(1) boulders and bedrock outcrop	NM	14	-
8	Boulder clay[3]	sand-boulders	sand-boulders mixed sediments (sand-cobbles) complex (sand-boulders)	22	21	1	**95**	8-96	(1) mud (anoxic)	M/NM	122	14 complex and 7 mixed sediments were found.
9	Sedimentary bedrock[3]	bedrock outcrop (<20 m) (*at >15 m*) - *overlaid by*: sand-boulders clay, gyttja clay, clayey gyttja	bedrock outcrop (<20 m) (*at >15 m*) - *overlaid by*: mud and sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)	6	6	0	**100**	14-73	-	-	-	Bare rock at 14, 18 and 42 m. Mud (dark) at 73 m.
10	Crystalline bedrock[2]	bedrock outcrop (<15 m) (*at >15 m*) - *overlaid by*: sand-boulders clay, gyttja clay, clayey gyttja	bedrock outcrop (<15 m) (*at >15 m*) - *overlaid by*: mud and sand-boulders mixed sediment (sand-cobbles) complex (sand-boulders)	2	2	0	**100**	11/80	-	-	-	-
	Total			259	216	43	**53-100**			**-**		

[1] Including shell gravel [2] Sediment category with samples only from Skagerrak and Kattegatt [3] Sediment category with samples only from the Baltic sea

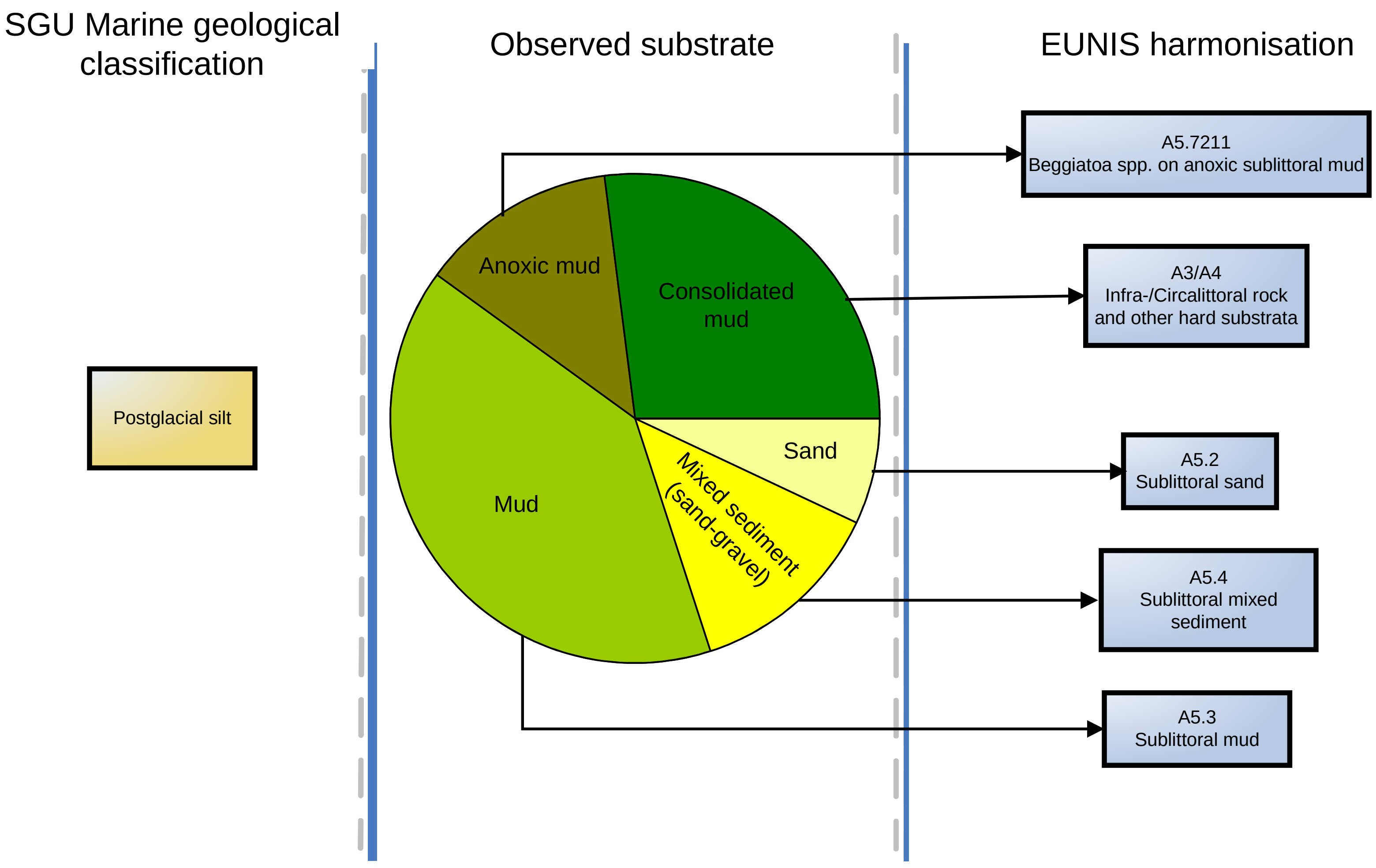
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (Skagerrak, Kattegatt and the Baltic Sea).

Figure 1. *Postglacial Clay.*



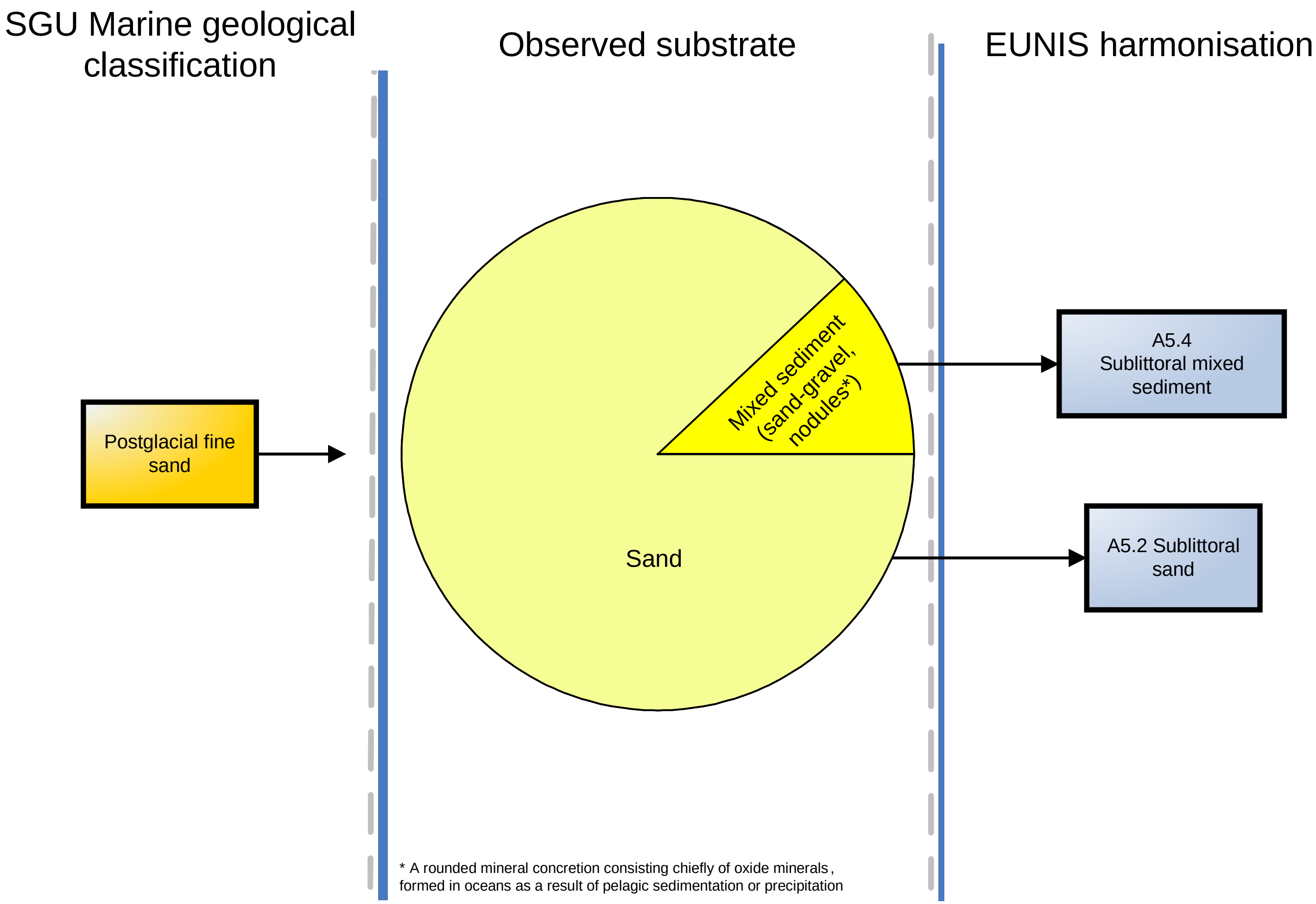
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (*Skagerrak, Kattegatt and the Baltic Sea*).

Figure 2. *Postglacial Silt.*



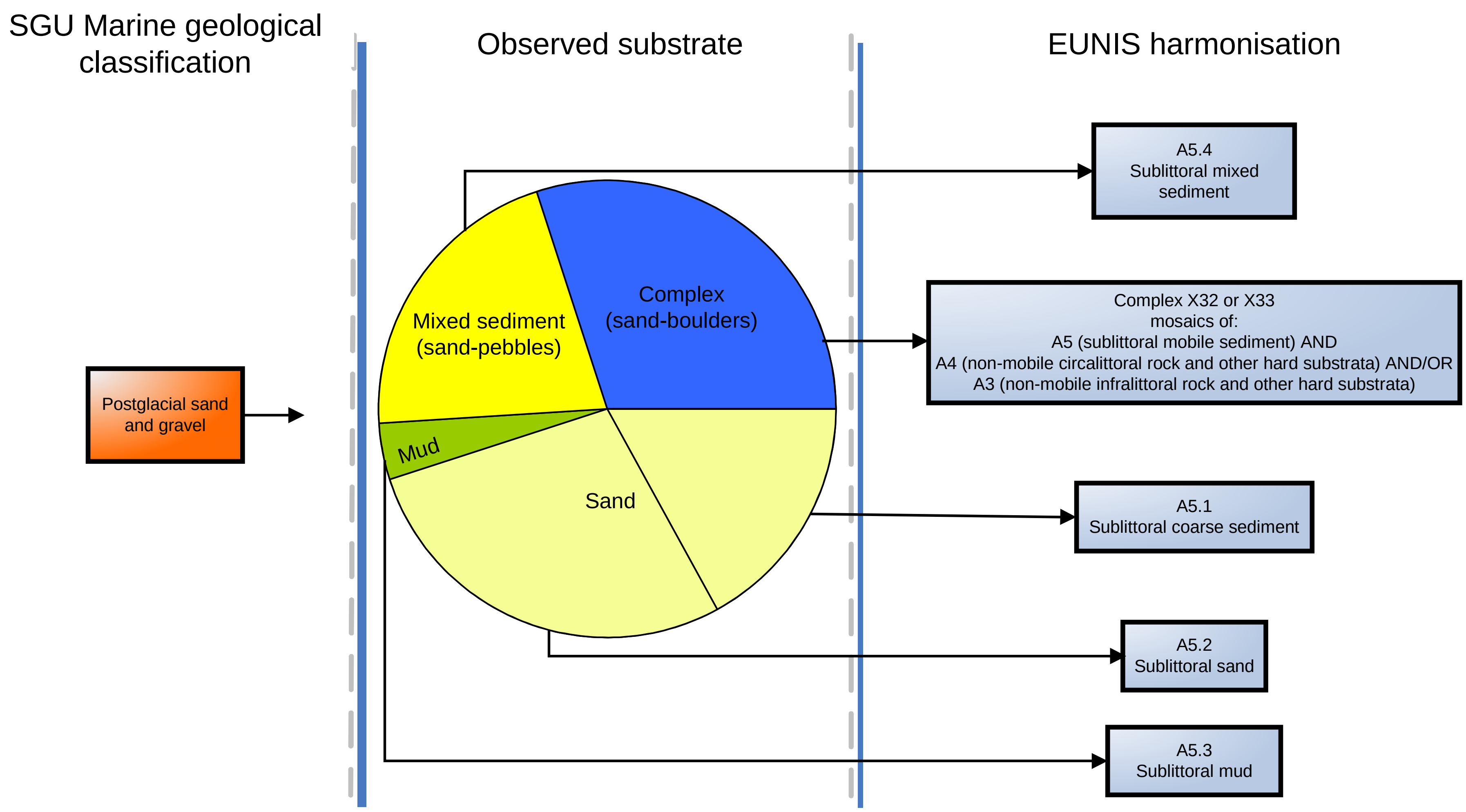
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (*Skagerrak, Kattegatt and the Baltic Sea*).

Figure 3. *Postglacial Fine Sand..*



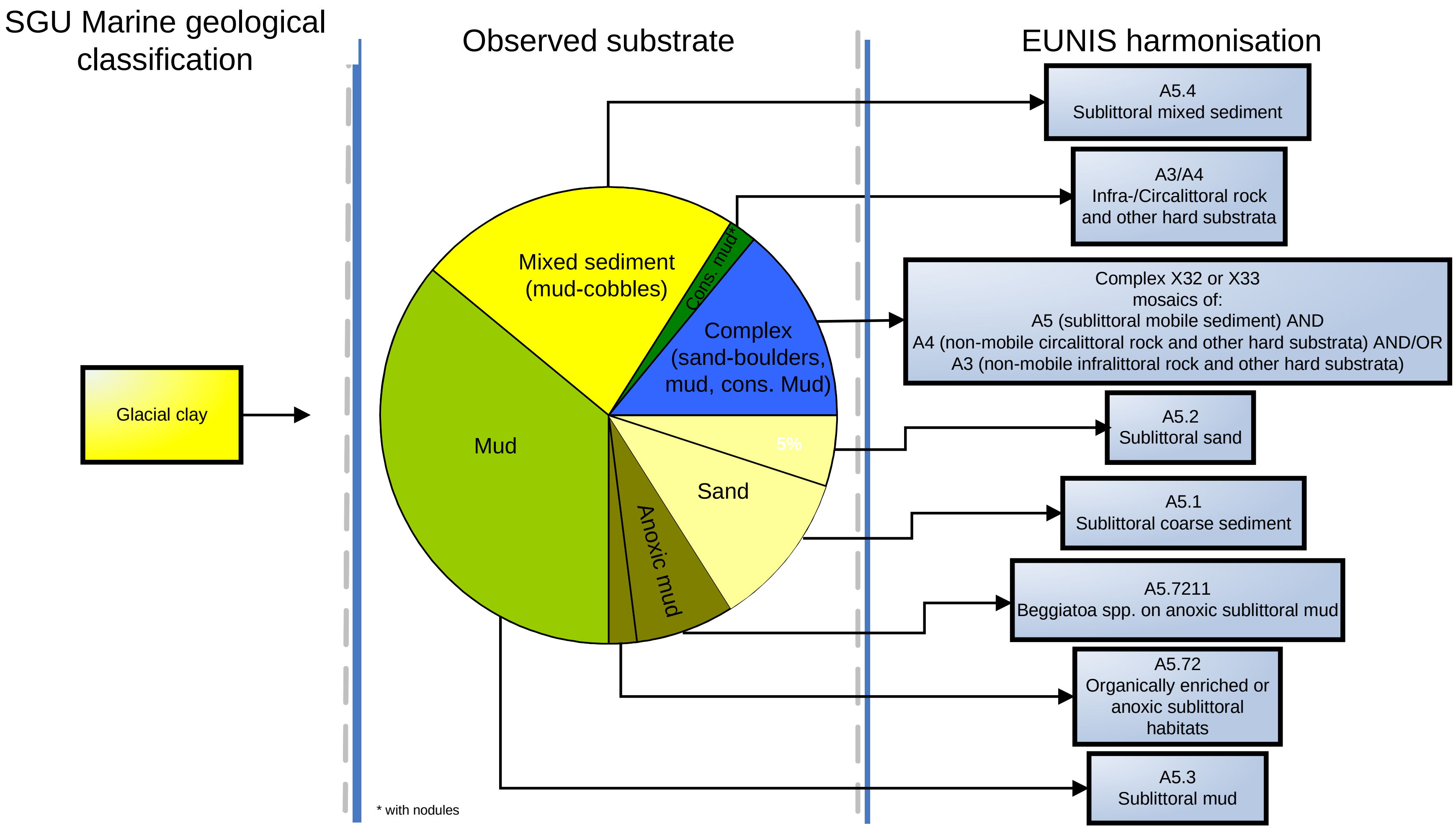
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (*Skagerrak, Kattegatt and the Baltic Sea*).

Figure 4. *Postglacial Sand and Gravel.*



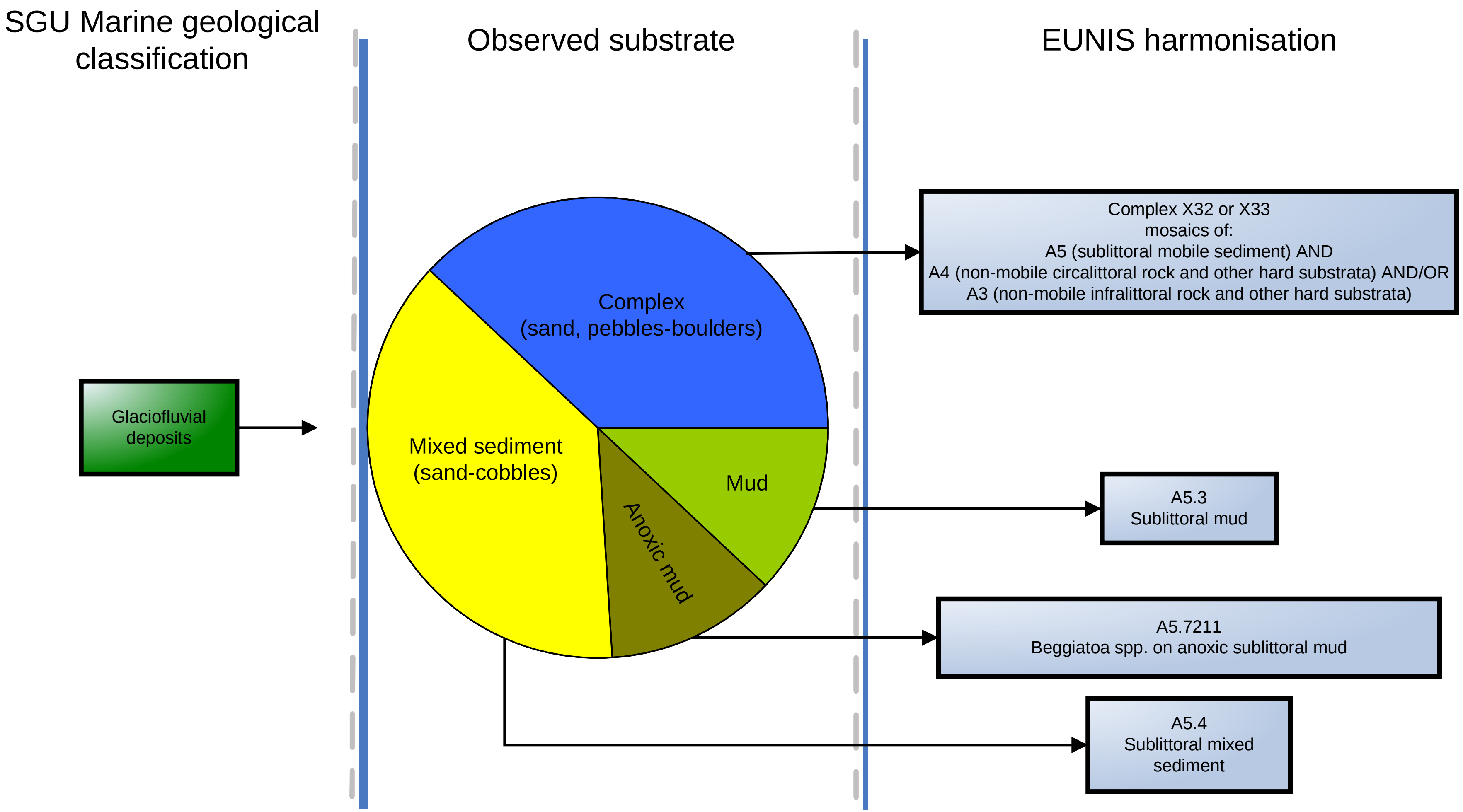
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (Skagerrak, Kattegatt and the Baltic Sea).

Figure 5. *Glacial Clay.*



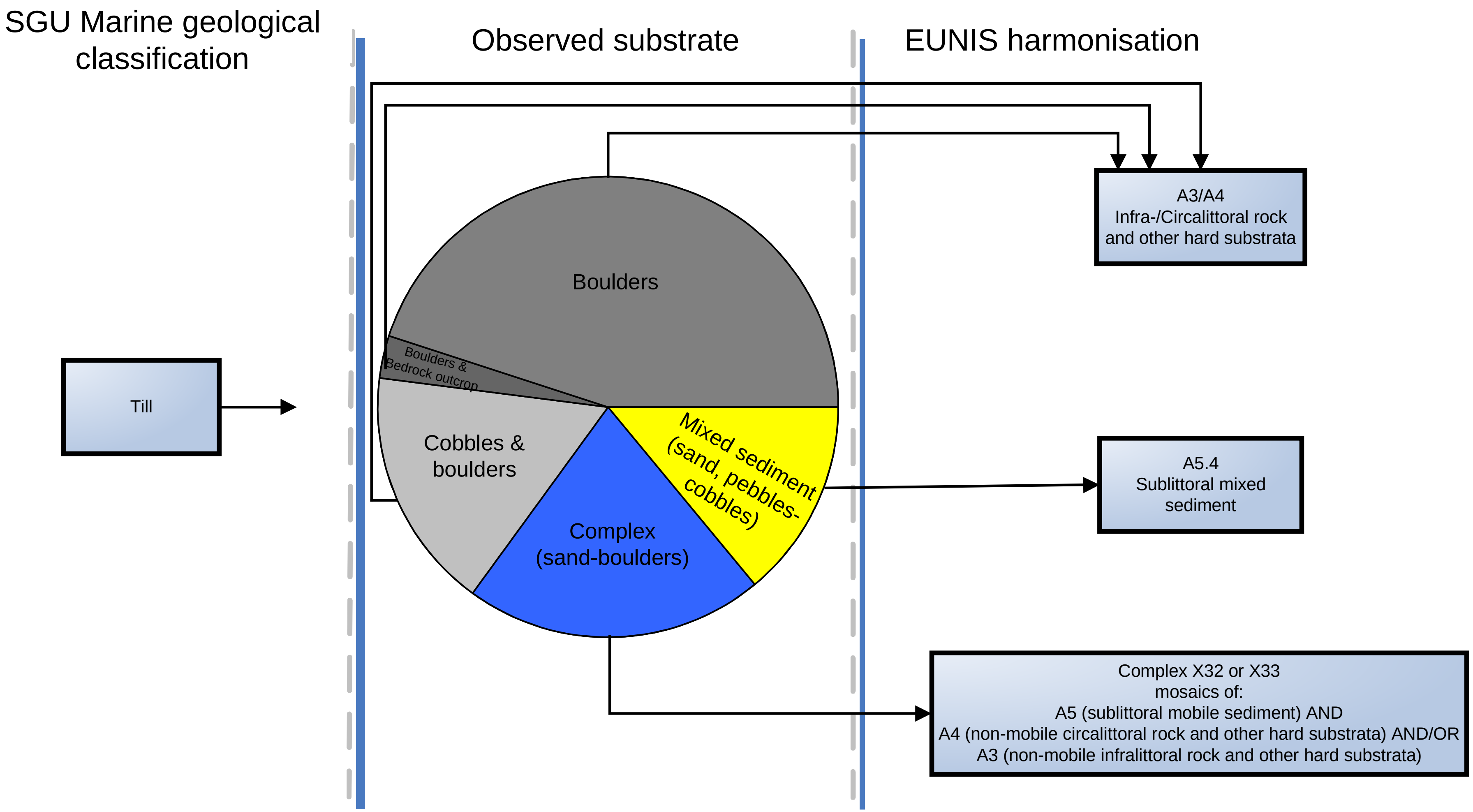
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (Skagerrak, Kattegatt and the Baltic Sea).

Figure 6. *Glaciofluvial Deposits.*



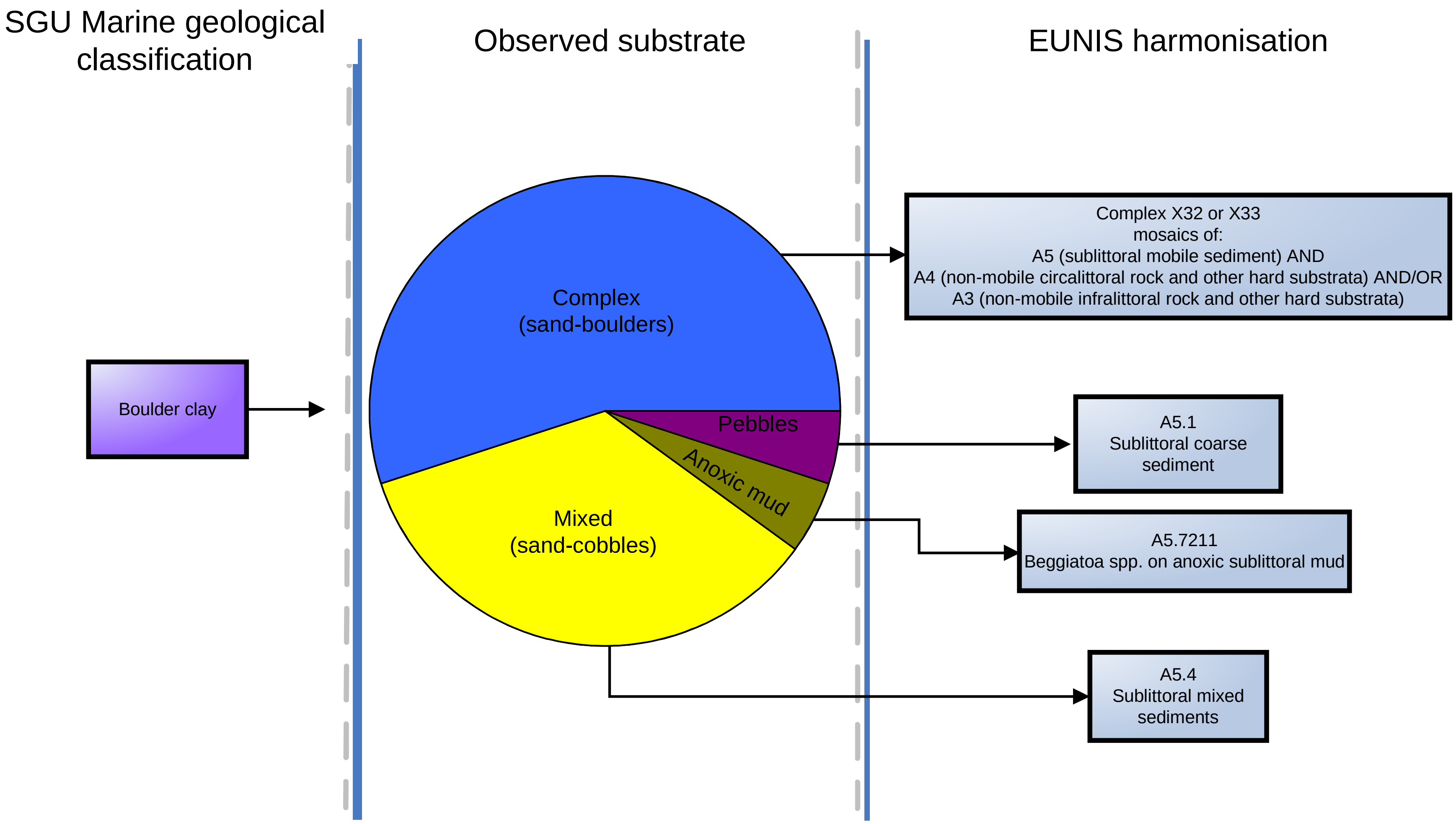
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (Skagerrak, Kattegatt and the Baltic Sea).

Figure 7. *Glacial Till.*



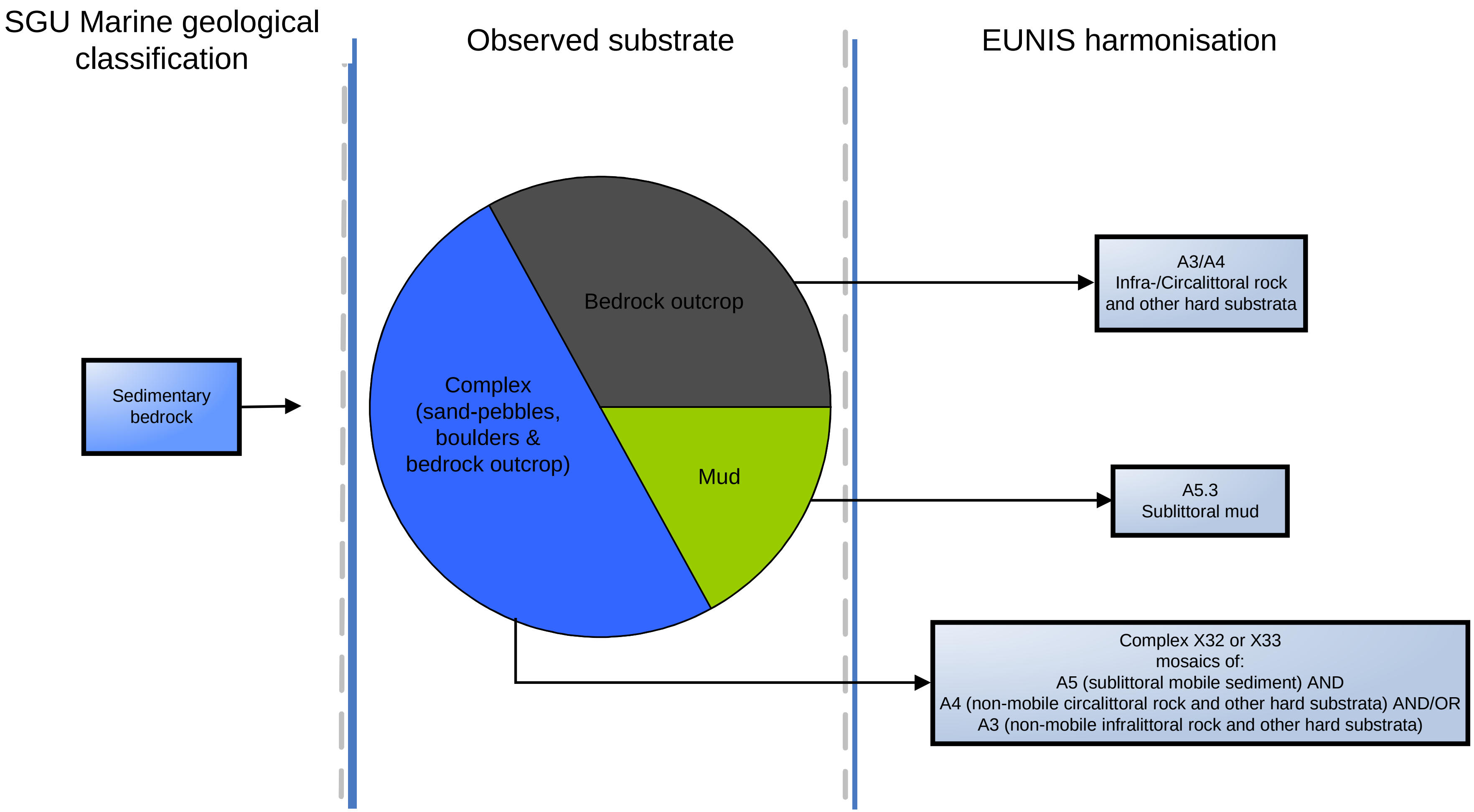
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (*Skagerrak, Kattegatt and the Baltic Sea*).

Figure 8. *Glacial Boulder Clay.*



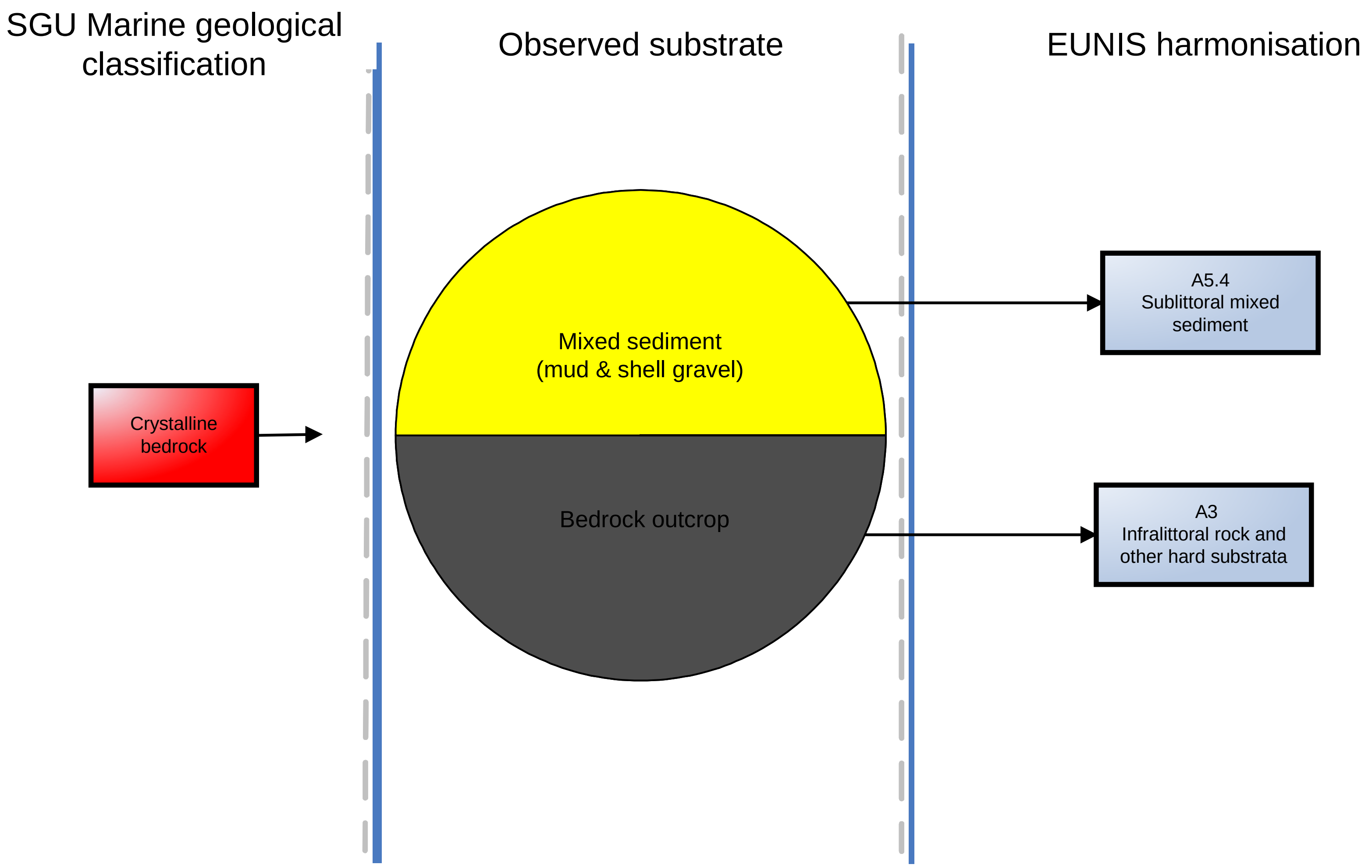
ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (Skagerrak, Kattegatt and the Baltic Sea).

Figure 9. *Sedimentary Bedrock.*



ANNEX 5
Figures: Geological classification, observed substrates and EUNIS harmonisation (Skagerrak, Kattegatt and the Baltic Sea).

Figure 10. *Crystalline Bedrock.*



ANNEX 6
Photos of observed surficial substrates (12 categories)

Photo 1. *Mud*

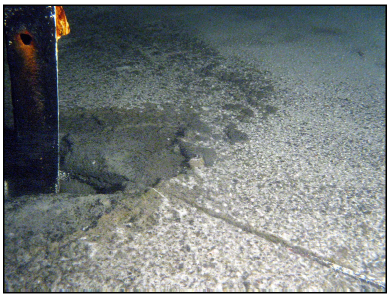


Photo 2. *Anoxic mud* [1]

Photo 3. *Sand*

Photo 4. *Gravel* (*shell gravel*)

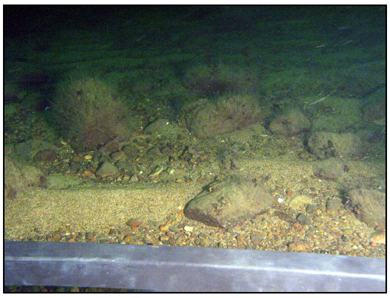


Photo 5. *Mixed sediment* (*sand-cobbles*)[2]

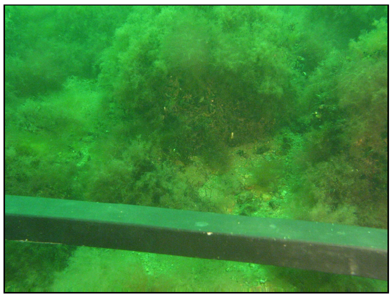


Photo 6. *Complex* (*sand-boulders*)[3]

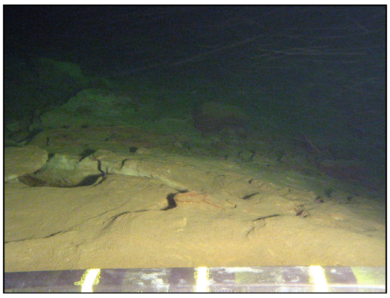


Photo 7. *Consolidated mud*

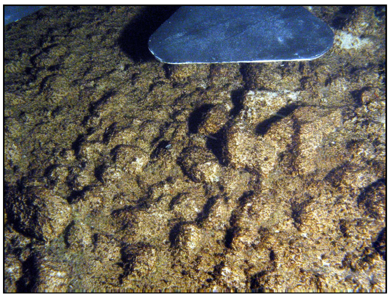


Photo 8. *Pebbles*

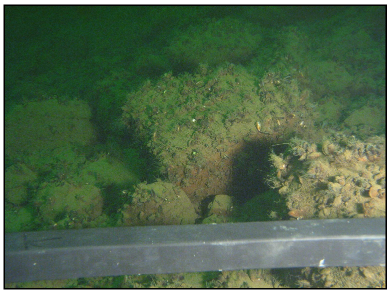


Photo 9. *Cobbles and boulders*

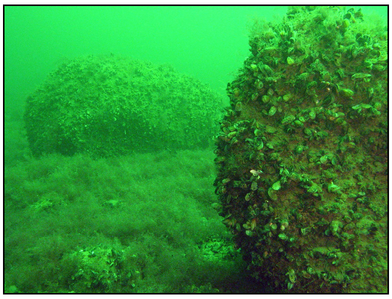


Photo 10. *Boulders*

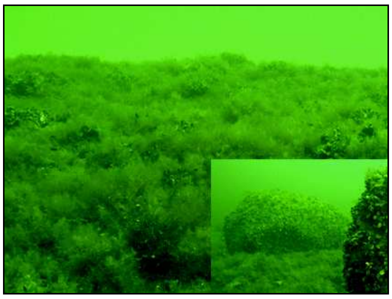


Photo 11. *Boulders and bedrock outcrop*

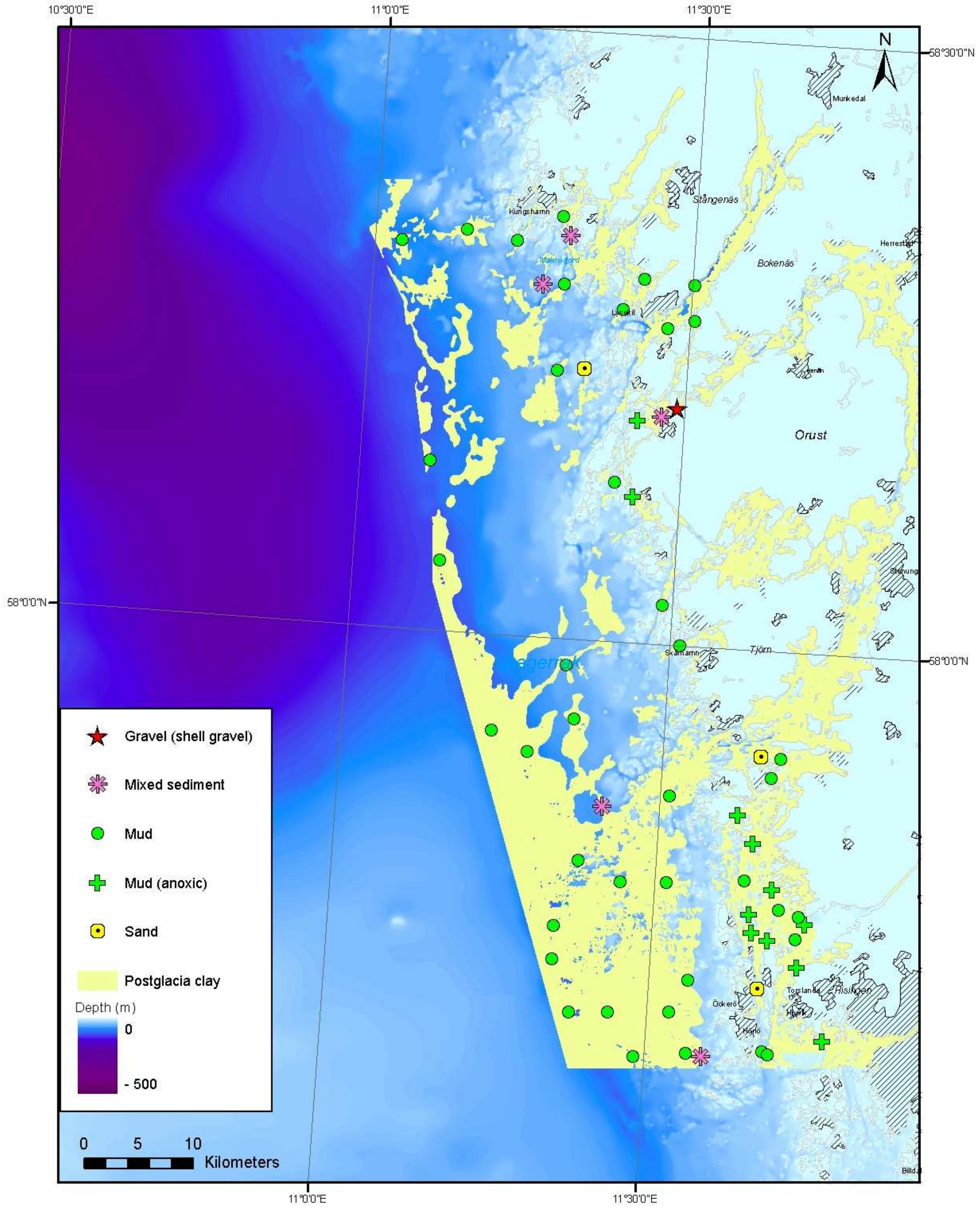
Photo 12. *Bedrock outcrop*

[1] with [Beggiatoa spp.]
[2] can also consist of mobile mud
[3] can also consist of mobile mud or non-mobile mud

ANNEX 7

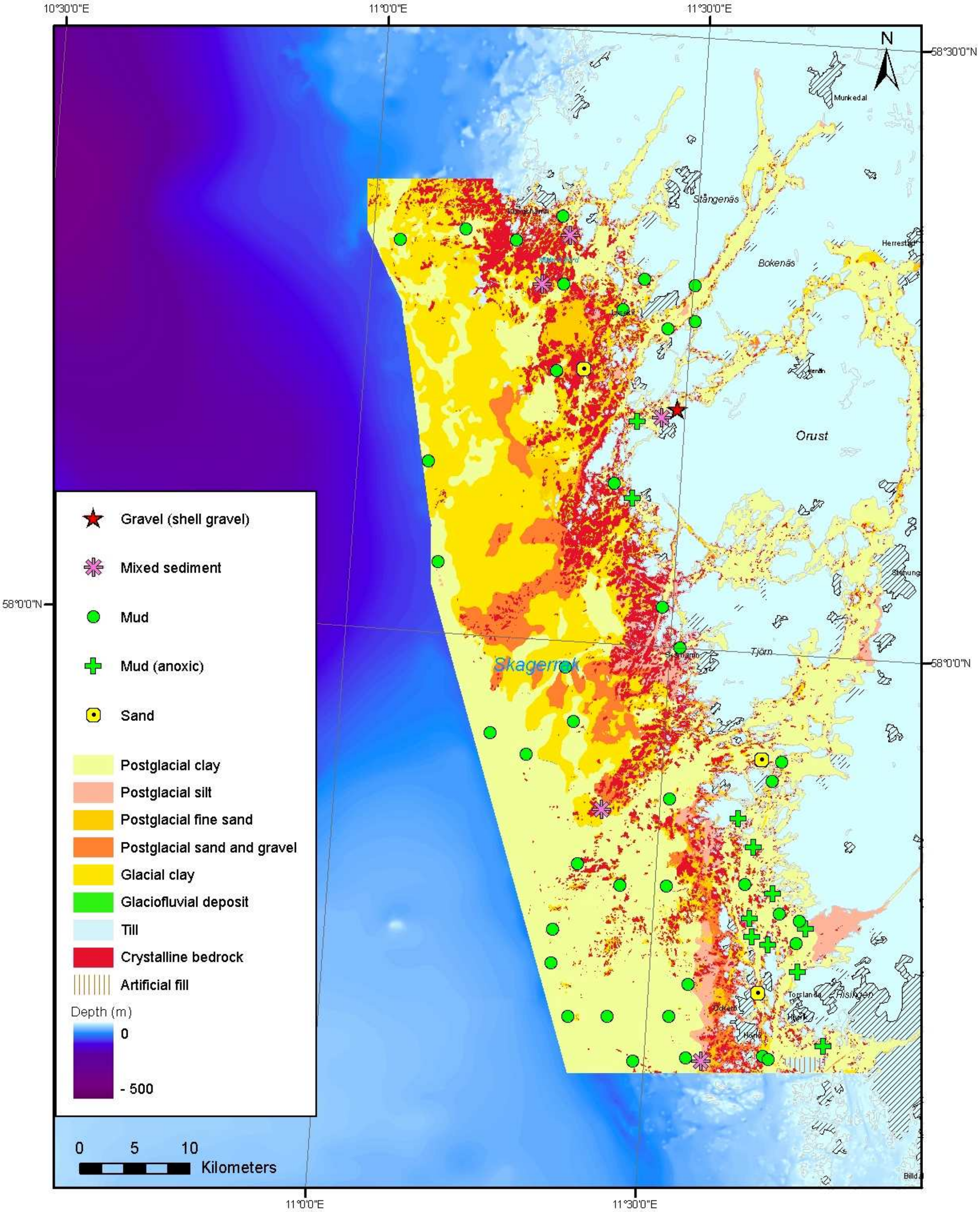
Maps: Observed surficial substrates (according to EUNIS) at sediments (classified by SGU) in Skagerrak and Kattegatt.

Figure 1. *Observed surficial substrates at* ***Postglacial Clay****.*



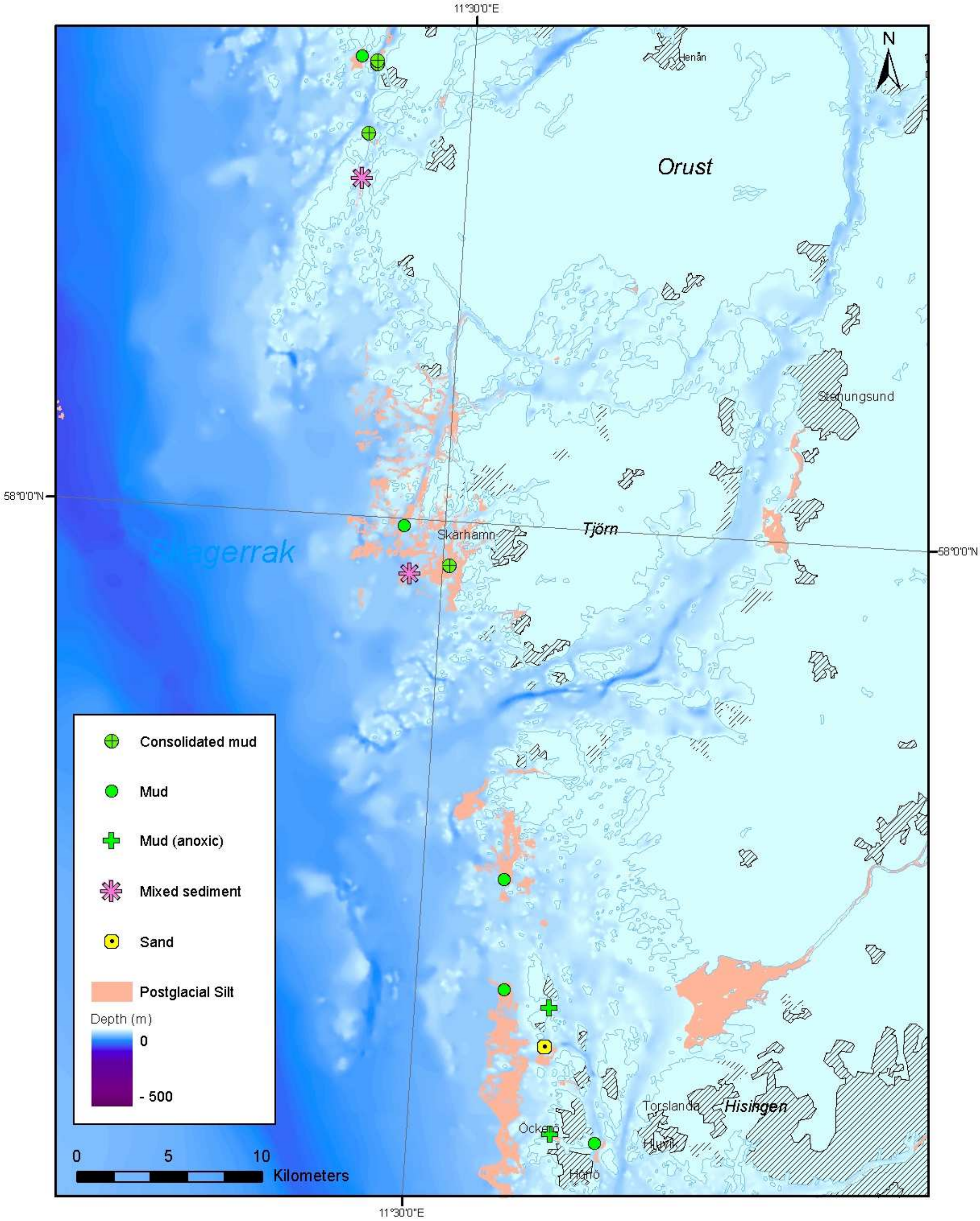
ANNEX 7

Figure 1a. *Observed surficial substrates at* ***Postglacial Clay*** *(including other geological sediments).*



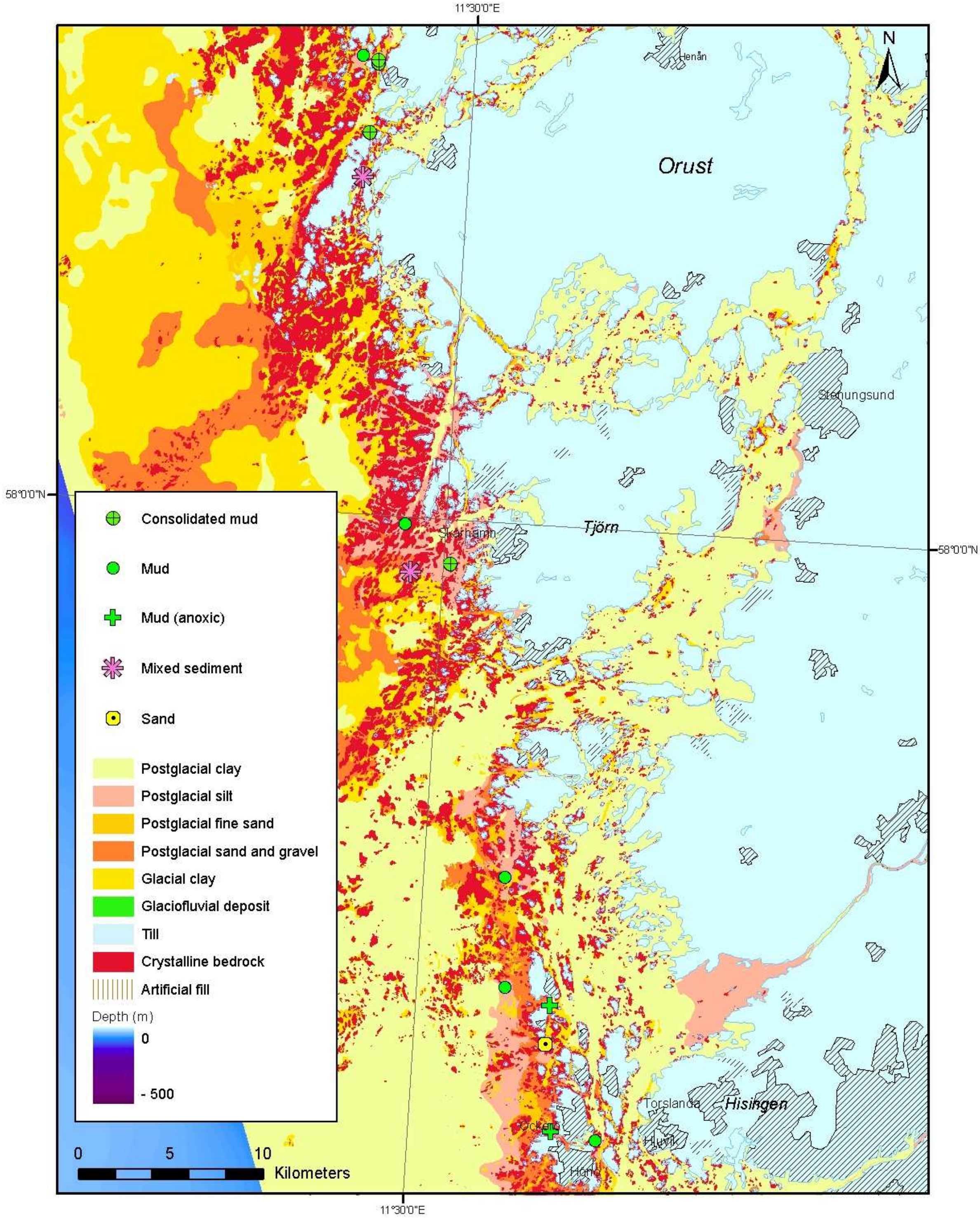
ANNEX 7

Figure 2. *Observed surficial substrates at* ***Postglacial Silt.***



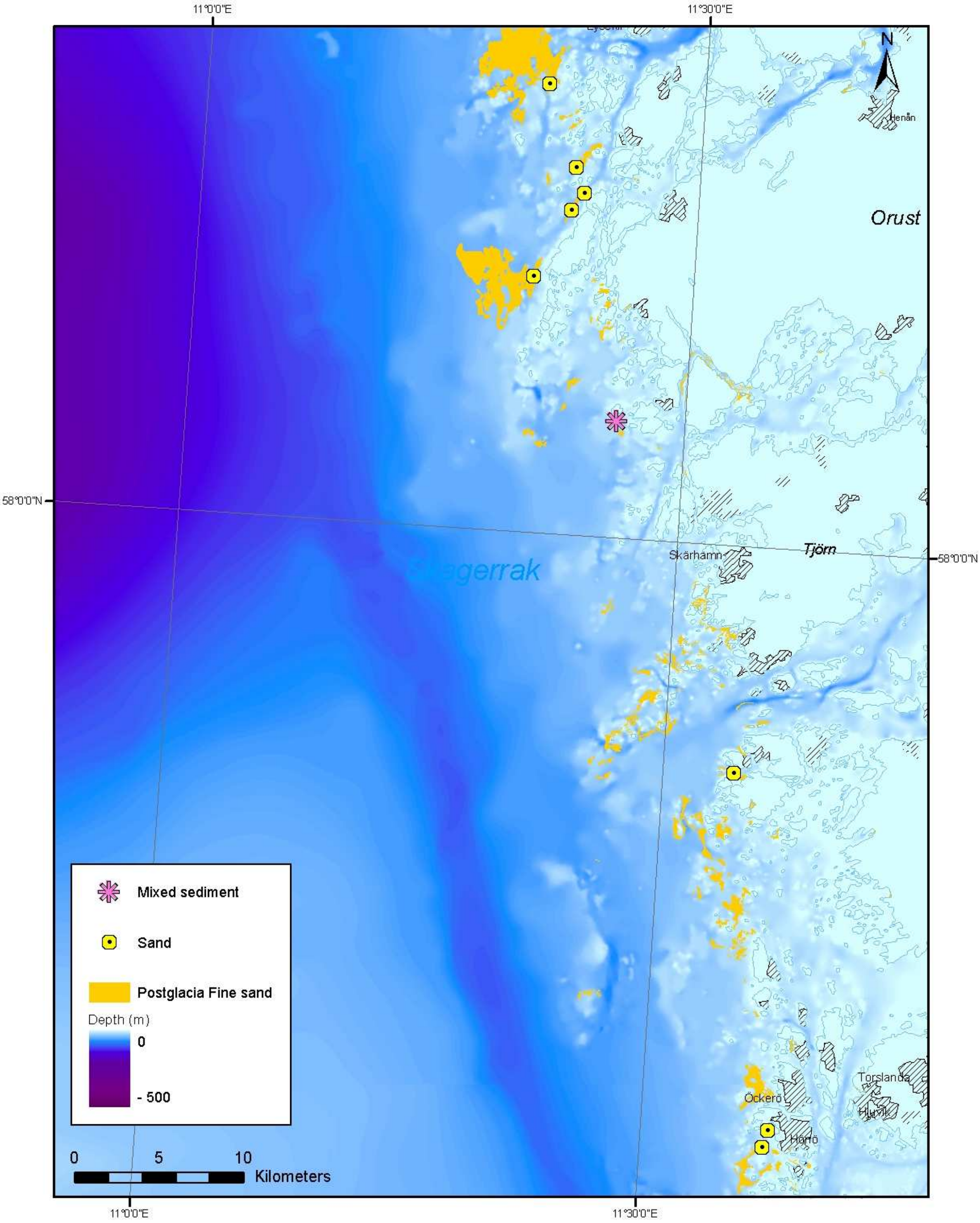
ANNEX 7

Figure 2a. *Observed surficial substrates at* ***Postglacial Silt*** *(including other geological sediments).*



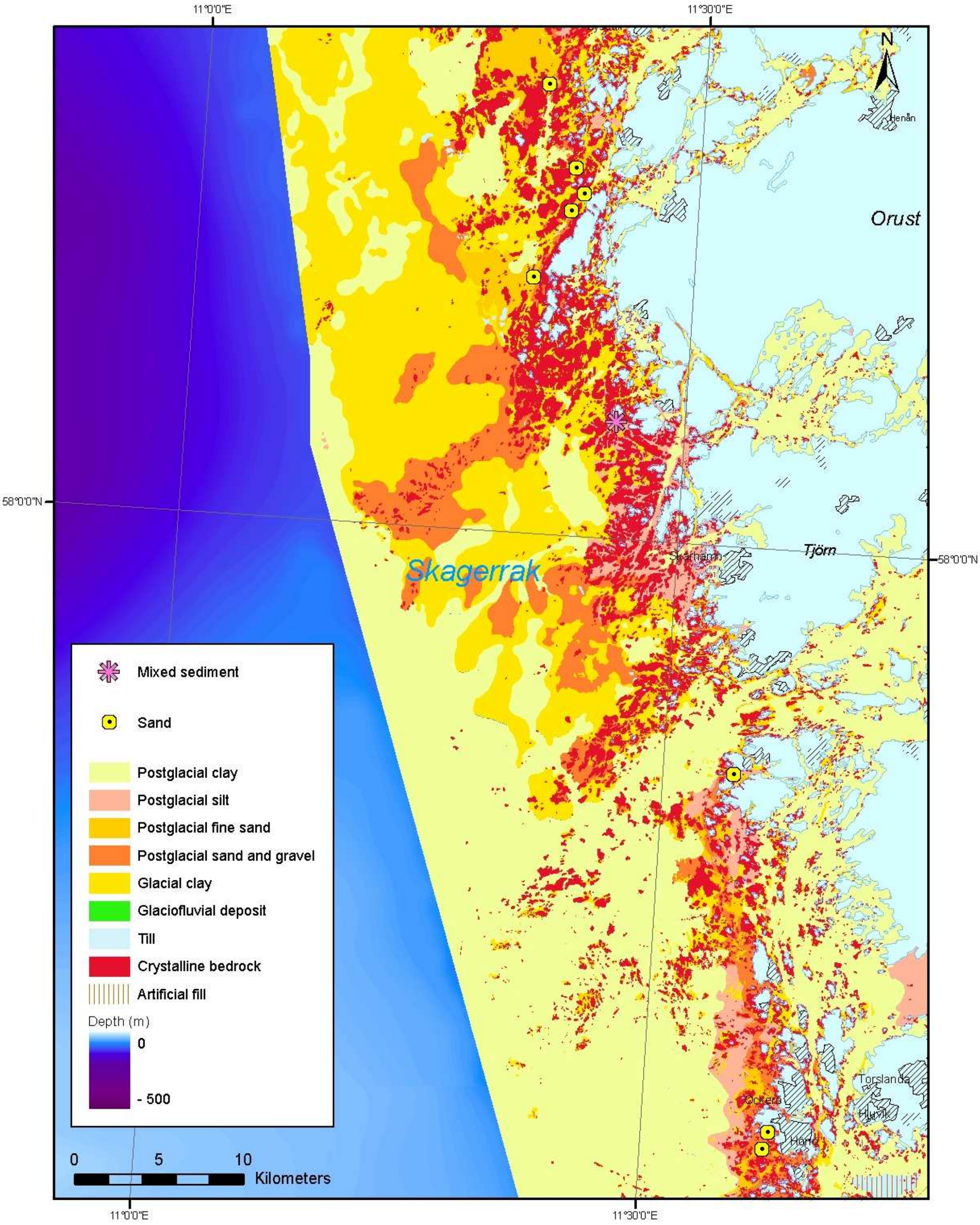
ANNEX 7

Figure 3. *Observed surficial substrates at **Postglacial Fine Sand.***



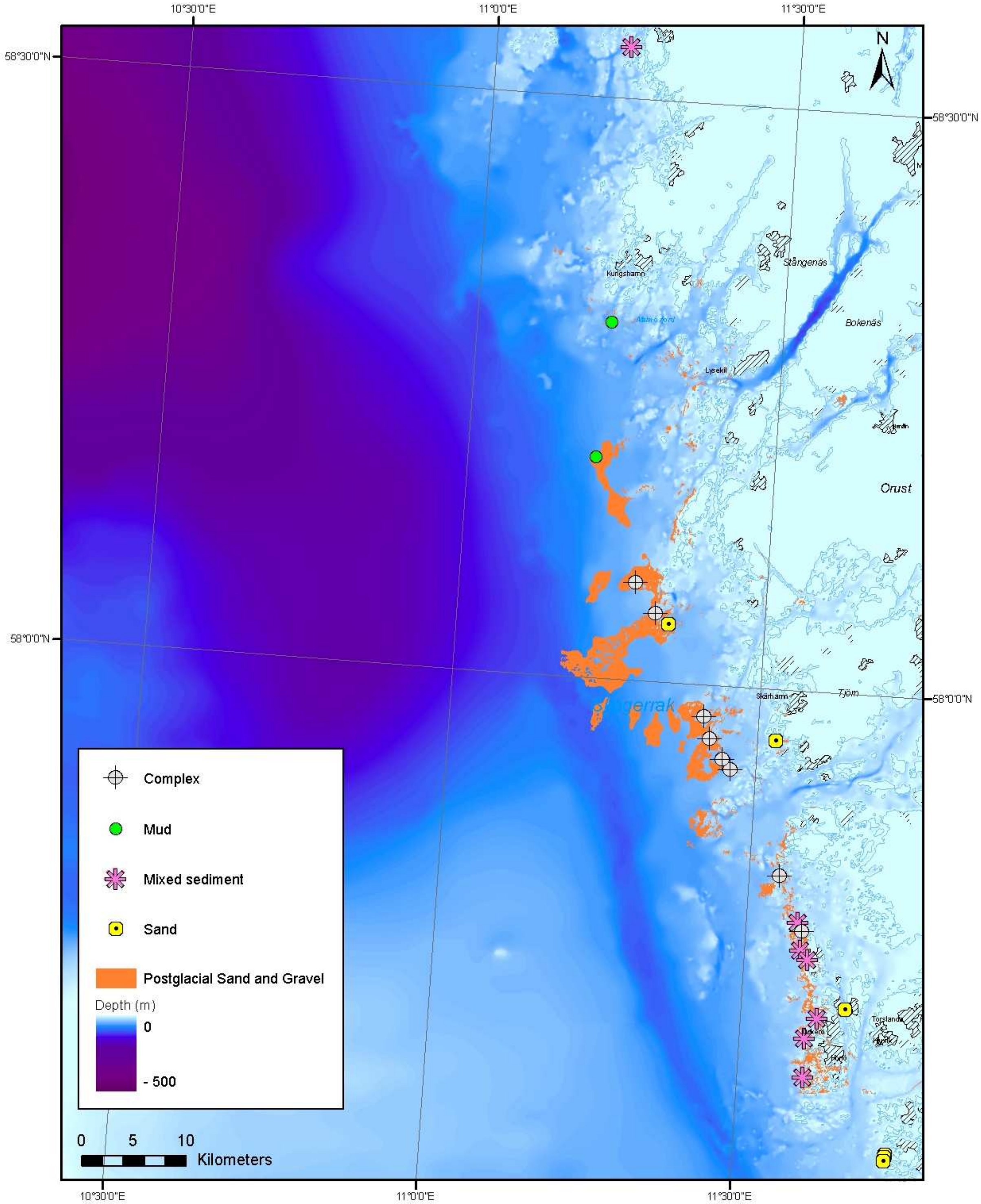
ANNEX 7

Figure 3a. *Observed surficial substrates at* ***Postglacial Fine Sand*** *(including other geological sediments).*



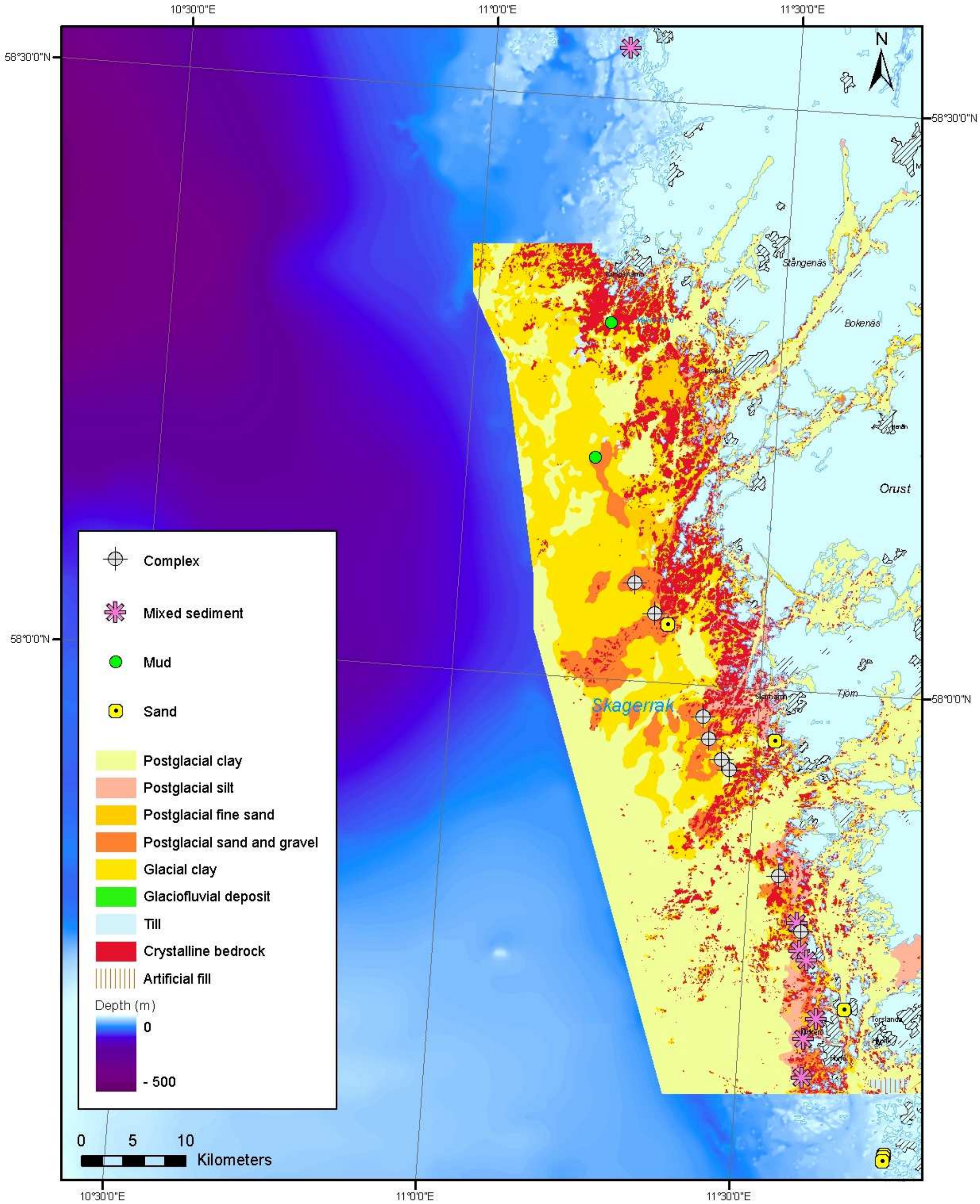
ANNEX 7

Figure 4. *Observed surficial substrates at* ***Postglacial Sand and Gravel.***



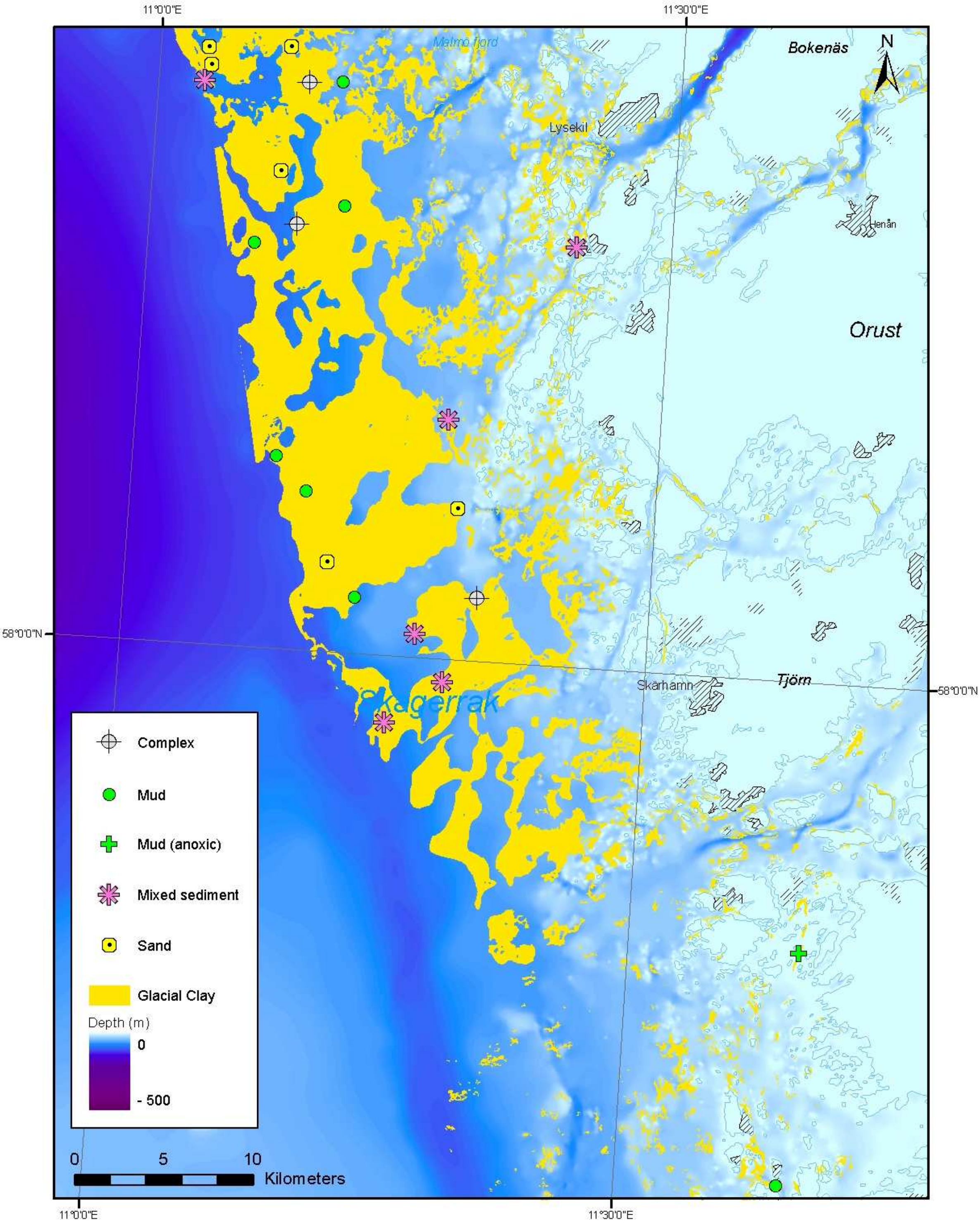
ANNEX 7

Figure 4a. *Observed surficial substrates at* ***Postglacial Sand and Gravel*** *(including other geological sediments).*



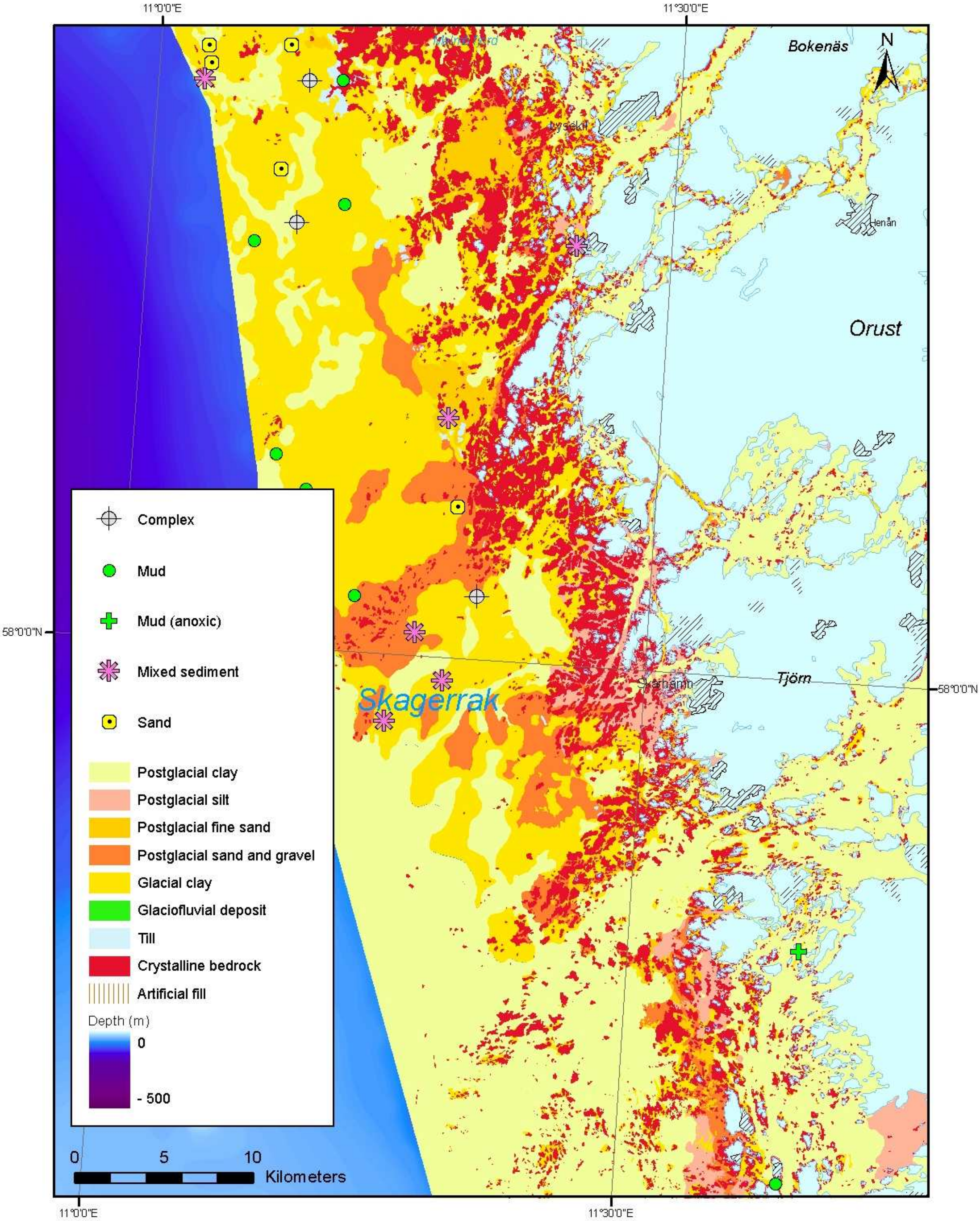
ANNEX 7

Figure 5. *Observed surficial substrates at **Glacial Clay.***



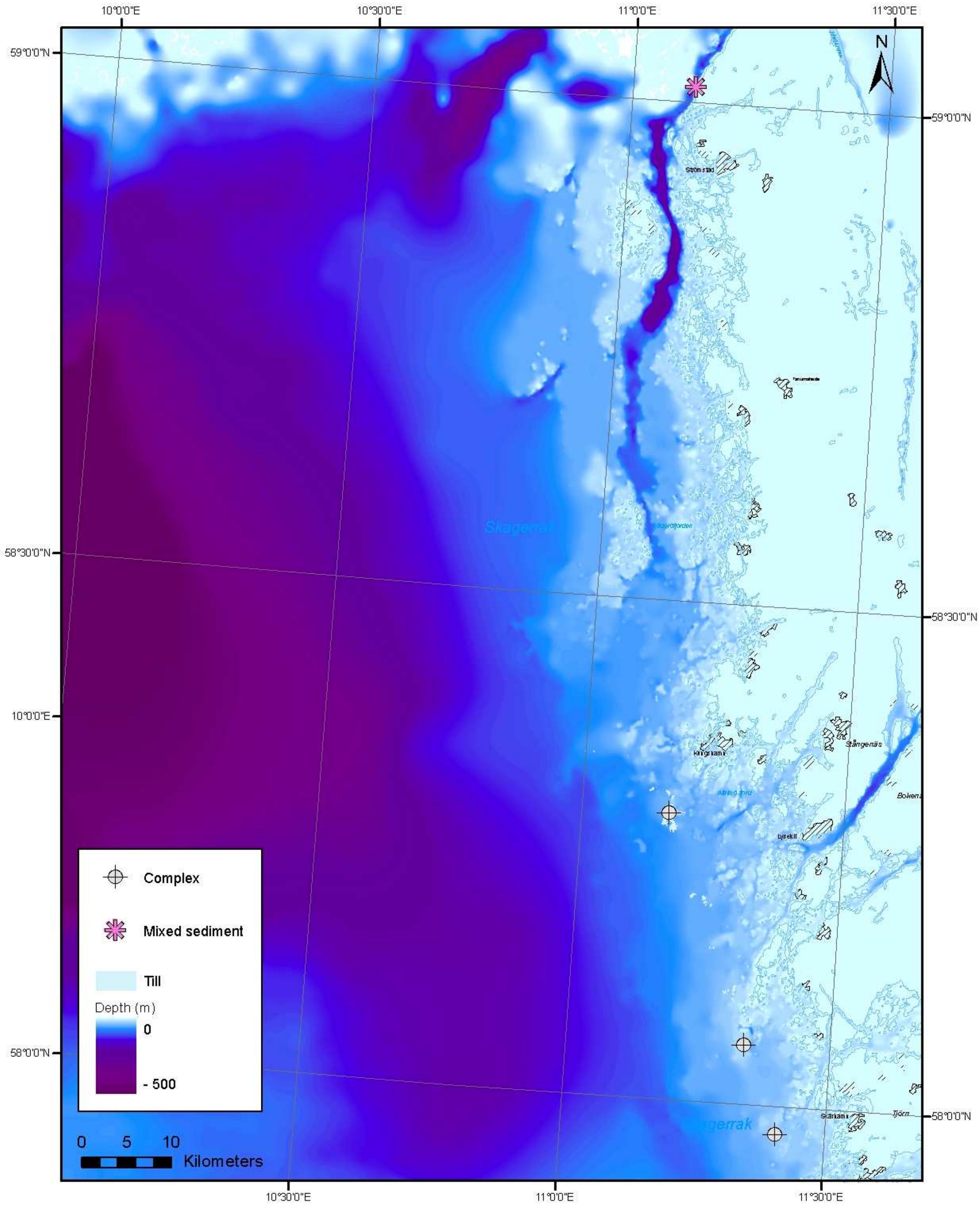
ANNEX 7

Figure 5a. *Observed surficial substrates at* ***Glacial Clay*** (*including other geological sediments).*



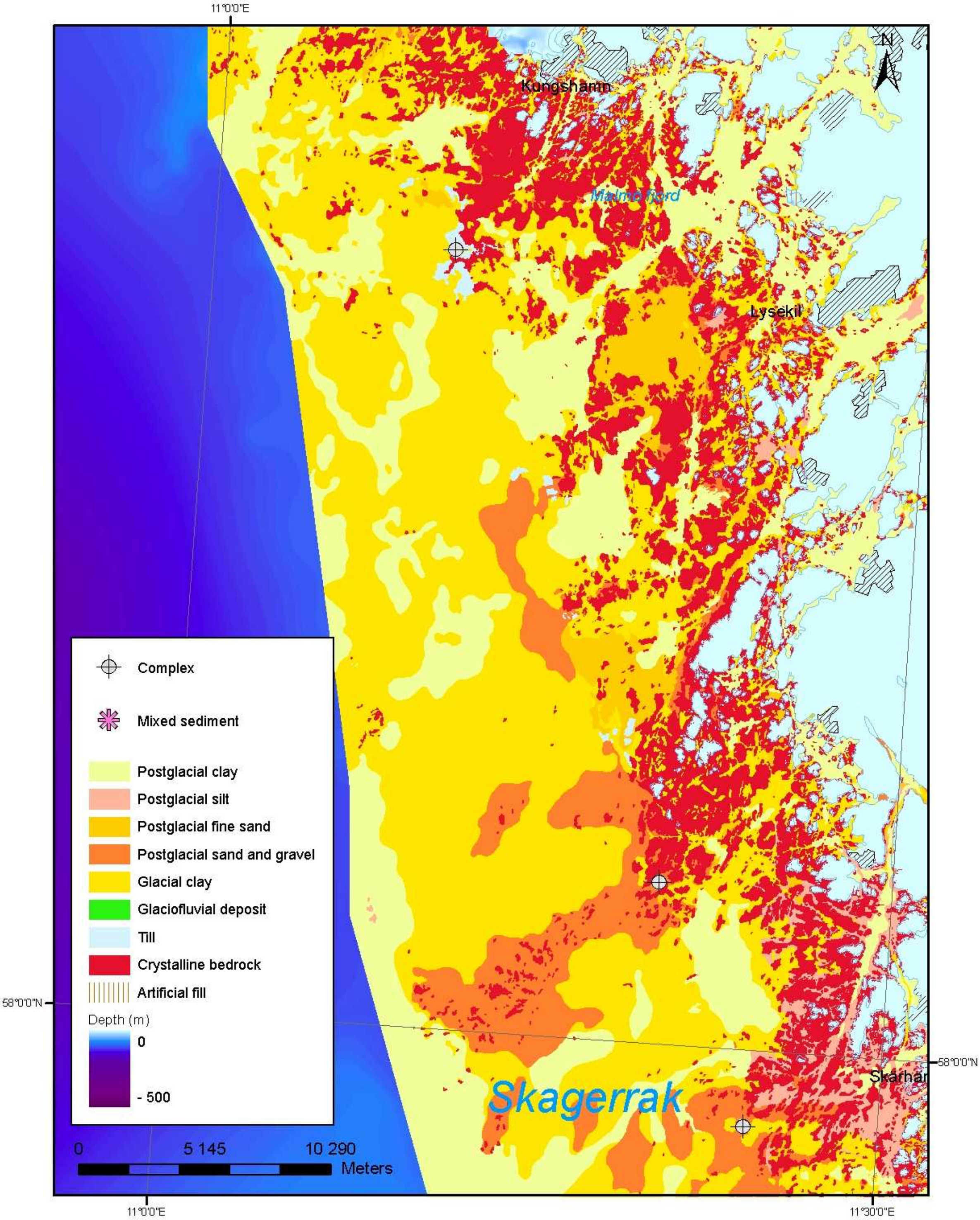
ANNEX 7

Figure 6. *Observed surficial substrates at* ***Till.***



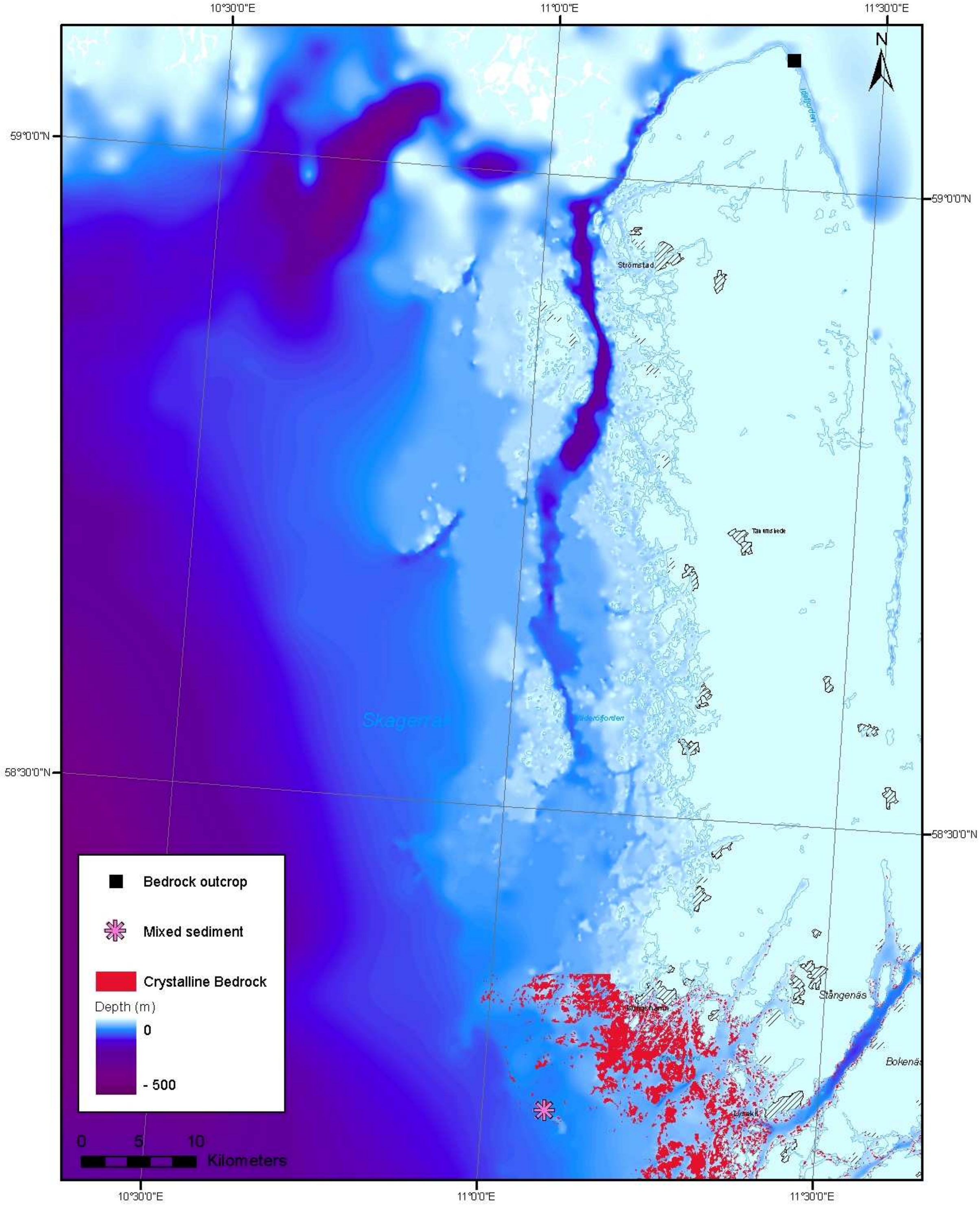
ANNEX 7

Figure 6a. *Observed surficial substrates at **Till** (including other geological sediments).*



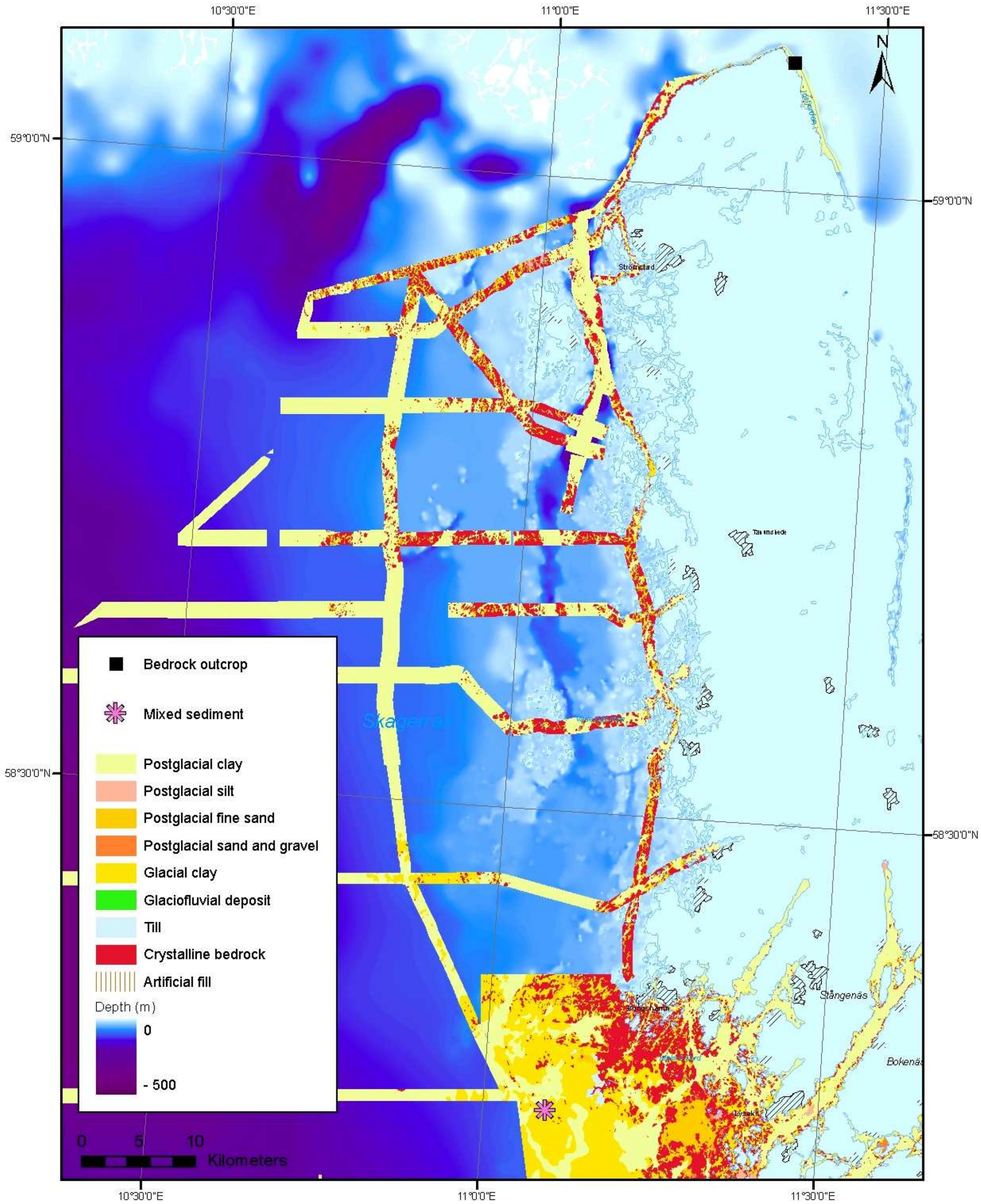
ANNEX 7

Figure 7. *Observed surficial substrates at* ***Crystalline Bedrock****.*



ANNEX 7

Figure 7a. *Observed surficial substrates at* ***Crystalline Bedrock*** *(including other geological sediments).*



About the BALANCE project

This report is a product of the BSR INTERREG IIIB project "BALANCE".

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 BALANCE partnership is composed of the following institutions based in 10 countries: The Danish Forest and Nature Agency (Lead), The Geological Survey of Denmark and Greenland, The National Environmental Research Institute/University of Aarhus, The Danish Institute for Fisheries Research, WWF Denmark, WWF Germany, Institute of Aquatic Ecology at University of Latvia, Estonian Marine Institute at University of Tartu, Coastal Research and Planning Institute at Klaipeda University, Metsähallitus Natural Heritage Service, The Finnish Environment Institute, The Geological Survey of Finland, WWF Finland, The Swedish Environmental Protection Agency, The National Board of Fisheries – Department of Research and Development, The Geological Survey of Sweden, County Administrative Board of Stockholm, Department of Marine Ecology at Gothenburg University and WWF Sweden.

The following institutes contribute as consultants to the partnership: The Geological Survey of Norway, Norwegian Institute for Water Research, DHI Water & Environment, The Leibniz Institute of Marine Sciences, The Sea Fisheries Institute, The Finnish Game and Fisheries Research Institute, Metria Miljöanalys and The Nature Conservancy.

The **BALANCE Report Series** included on 1th of July 2007:

BALANCE Interim Report No. 1 "Delineation of the BALANCE Pilot Areas".
BALANCE Interim Report No. 2 "Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea - an interim strategy".
BALANCE Interim Report No. 3 "Feasibility of hyperspectral remote sensing for mapping benthic macroalgal cover in turbid coastal waters of the Baltic Sea".
BALANCE Interim Report No. 4 "Literature review of the "Blue Corridors" concept and its applicability to the Baltic Sea".
BALANCE Interim Report No. 5 "Evaluation of remote sensing methods as a tool to characterise shallow marine habitats I".
BALANCE Interim Report No. 6 "BALANCE Cruise Report - The Archipelago Sea".
BALANCE Interim Report No. 7 "BALANCE Cruise Report - The Kattegat"
BALANCE Interim Report No. 8 "BALANCE Stakeholder Communication Guide"
BALANCE Interim Report No. 9 "Model simulations of blue corridors in the Baltic Sea"
BALANCE Interim Report No. 10 "Towards marine landscapes of the Baltic Sea (June 2007)"
BALANCE Interim Report No. 11 "Fish habitat modelling in the Archipelago Sea"
BALANCE Interim Report No. 12 "Evaluation of satellite imagery as a tool to characterise shallow habitats in the Baltic Sea"
BALANCE Interim Report No. 13 "Harmonizing marine geological data with the EUNIS habitat classification"
BALANCE Interim Report No. 14 "Intercalibration of sediment data from the Archipelago Sea"
BALANCE Interim Report No. 15 "Marine spatial planning in the Baltic Sea – an interim report"
BALANCE Interim Report No. 16 "The stakeholder - nature conservation's best friend or its worst enemy?"

For more information please see www.balance-eu.org and http://maps.sgu.se/Portal.