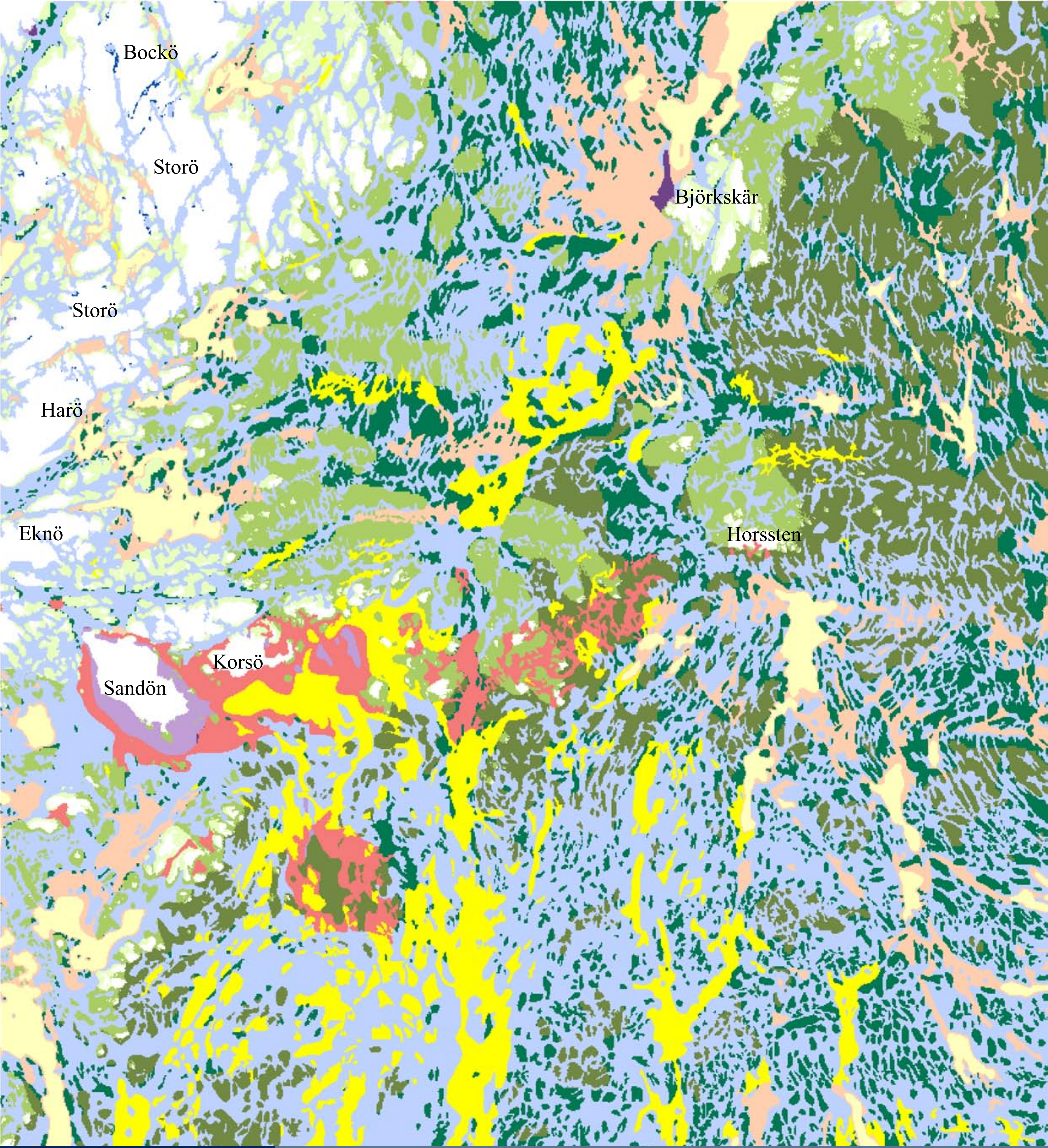

Report 2005:21

LÄNSSTYRELSEN
I STOCKHOLMS LÄN

Mapping Marine Habitats

Pilot study for the coastal areas of the Stockholm County

Author:
Annelie Mattisson

Mapping marine habitats
with the help of existing information and
the European Nature Information System (EUNIS).
Pilot study for the coastal areas of Stockholm County.

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LÄNSSTYRELSEN
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Mapping Marine Habitats

Pilot study for the coastal areas of the Stockholm County

Cover: Map of different marine environments in the archipelago of Stockholm, EUNIS level 3.

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Preface

Marine conservation has long been neglected in Sweden, and most environmental work has been done on land. One reason for this is a lack of knowledge about what lies under the surface of the water in our coastal areas. Another is that natural assets that we cannot see are easier to neglect. There is a growing awareness, however, that the need to conserve and manage our aquatic environments is becoming more and more pressing.

We hope that this report will go some way towards remedying the present situation. It presents a method that uses existing geographical information to map and describe the seabed in the Stockholm archipelago. By combining information on depth, degree of wave exposure and bottom substrate, it is to a certain extent possible to predict the types of habitats that may occur in a given area.

We have used the European Nature Information System (EUNIS) to classify the marine habitats in our coastal areas. EUNIS is a hierarchical classification system for all European habitats, both natural and artificial. It aims to coordinate and harmonise the description and collection of data, with the help of common criteria for habitat identification. The classification system is linked to and compatible with other systems used to classify European habitats. Since the Baltic Sea lacks a coherent classification system, it seemed wise to use EUNIS to map the seabed of the Stockholm archipelago.

The result is a set of digital maps showing the predicted natural habitats of the seabed in the county of Stockholm. The overall accuracy of these predictive maps has not yet been verified. We therefore emphasize that they should be used in combination with field investigations and/or other sources of information. We hope that the maps will enable us to identify marine areas that may need to be considered for protection and conservation.

Stockholm, September 2005

Lars Nyberg

Environment and Planning Director

Contents

Summary

On a broad scale, little has been known about the marine underwater environments of the county of Stockholm. This report shows how existing information such as data on depth, bottom substrate and degree of wave exposure can be combined to produce maps of the physical environment of the seabed of the Baltic proper. The maps have been produced using Geographical Information Systems (GIS).

The European Nature Information System (EUNIS) is a hierarchical classification system with several habitat levels, which is used to classify European natural biotopes at different general levels. This study focuses on the upper three levels of the EUNIS system (levels 1–3). The first level was used to identify and geographically delimit the marine environment of Stockholm county. The second and third levels were used to identify different combinations of physical factors that define the basic conditions for flora and fauna.

Another aim of this study was to test whether EUNIS was appropriate for the marine benthic habitat types of Stockholm county. I conclude that the EUNIS classification is suitable for many purposes, but that the system has certain weaknesses and gaps. For instance, EUNIS levels 2 and 3, which are very generalised levels, require highly detailed information about the flora and fauna. This type of information rarely exists, which means that it is simply not possible to create a generalised large-scale map at EUNIS level 3. One way of improving the present system would be to work more with the physical prerequisites for biota, e.g. produce more detailed combinations of structuring factors such as depth and degree of wave exposure.

The study also produced an expanded list including additional marine habitats for the county of Stockholm. This is an expansion of the existing EUNIS habitats, in which physical data (e.g. EUNIS substrate type) were further combined to identify unique habitats (e.g. glaciofluvial material at different depths and with different degrees of exposure). This material should provide a basis for further work on the conservation and management of marine environments in the county.

Some basic information, for example regarding bottom material (Geological Survey of Sweden) and degree of wave exposure (Isæus 2004), was easily accessible. The available data had been produced by experts and had a high resolution. However, it was difficult to gain access to all the existing depth information for some areas, owing to their military importance. The resolution of the data on depth was therefore lower than in the case of bottom substrate and wave exposure.

The results are presented in the form of maps, diagrams showing the proportions of different habitats, and tables of identified and delimited habitats at EUNIS levels 1, 2 and 3. The results also include the expanded list of additional (non-EUNIS) marine habitats for Stockholm county.

This work will hopefully give rise to further discussion about the kind of information that is needed for the management and conservation of marine environments. This would improve the next generation of habitat maps and make them more relevant.

One of the conclusions of this report is that there is a great deal of uncollated information on the marine underwater habitats of Stockholm county. If appropriately collated, this information could form the basis for practical measures to achieve the Swedish environmental quality objective *A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos*. Such measures would include the management, protection and conservation of valuable and representative marine environments.

The different parts of this report are outlined briefly below.

Main report

The main report is comparatively technical and detailed. It describes the underlying geographical information, together with how and why it was used. It also presents the background and conditions for this study, the EUNIS system, and the methods used to produce the maps.

The results section includes maps, diagrams showing the proportions of different habitats, and tables of identified and delimited habitats at EUNIS levels 1, 2 and 3. The results also include the expanded list of additional (non-EUNIS) marine habitats in Stockholm county.

The discussion section deals with how information should be chosen and combined in order to define habitat types and create maps; advantages and shortcomings of the EUNIS classification system; and general problems that have to be dealt with in this type of mapping.

The main report is aimed at people with a special interest in the methods used to produce the maps.

Appendix 1. Reclassifying the marine geological map for biological applications

This is a short report that describes the process of reclassifying the marine geological map, first in terms of probable surficial materials and subsequently in terms of EUNIS substrate classes.

Appendix 2. Criteria diagrams with explanatory notes for EUNIS habitat classification

Appendix 2 presents the EUNIS "criteria diagrams", along with explanations of the criteria. For each diagram there are notes describing how the criteria were interpreted and applied to identify and delimit different EUNIS habitats in Stockholm county.

Appendix 3. Descriptions of EUNIS habitats

Appendix 3 presents the original descriptions of the EUNIS habitats discussed in this study.

Appendix 4. A short review of the basic conditions for marine flora and fauna in the county of Stockholm

Appendix 4 presents the animal and plant communities that may occur in the marine habitats identified in Stockholm county. The information has mainly been obtained from the book *Under ytan i Stockholms skärgård* (*Below the surface in the Stockholm archipelago*) (L. Kautsky *et al.* 2000). There are also tables presenting where the marine benthic habitats identified in Stockholm county fit into the EUNIS system.

Appendix 4 is aimed at users, and describes what information can be shown in the maps. It also includes photographs of some of the different marine habitats in Stockholm county.

Swedish summary

Svenskt namn: *Kartläggning av marina naturtyper med hjälp av befintlig information och European Nature Information System (EUNIS). En pilotstudie i Stockholms län.* Finns även som svensk rapport med samma namn (Mattisson 2005).

Stockholms läns undervattensmiljöer har ur ett storskaligt perspektiv länge varit dåligt kända. Detta arbete är ett första steg mot att förändra denna bild. Här presenteras hur det går att använda sig av existerande information som djup, bottenmaterial och vågexponeringsgrad för att ta fram unika kombinationer av fysiska faktorer som tillsammans skapar förutsättningar för olika typer av naturtyper för organismsamhällen på och i länets Östersjöbottnar.

Till min hjälp har jag tagit ett klassificeringssystem som har tagits fram centralt inom EU: EUNIS (EUropean Nature Information System). EUNIS är ett hierarkiskt klassificeringssystem med flera naturtyps- eller habitatnivåer där nivåerna presenteras med olika generaliseringsgrad. Denna studie fokuserar sig på de tre översta nivåerna. Den första nivån innebär att geografiskt avgränsa den marina miljön i länet medan nivå 2 och 3 mycket handlar om att ta fram olika kombinationer av de fysiska faktorer som skapar förutsättningarna för bottnarnas flora och fauna.

Naturtyp och *habitat* ses i denna studie som synonyma. Ordet *naturtyp* kommer emellertid fortsättningsvis endast att användas för den utökade habitat- eller naturtypslistan för Stockholms län och *habitat* kommer att användas för de delar av rapporten som behandlar EUNIS-systemet.

Projektet har aktualiserat frågan huruvida EUNIS-systemet passade för Stockholms läns marina bottentyper. Kortfattat är svaret på den frågan att EUNIS klassificering för Östersjön räcker långt för många syften men att systemet fortfarande har svagheter och luckor för Stockholms havsområden som förhoppningsvis kommer att lösas i framtiden. Bland annat krävs mycket detaljerad information om djur- och växtliv på starkt generaliserade nivåer. Denna typ av information finns ofta inte för större områden vilket leder till att en generaliserad kartering på nivå 3 som följer EUNIS till 100 procent inte kan fullföljas.

Förutom en EUNIS-klassificering på nivå 1-3 har en naturtypslista för länet tagits fram. Den innehåller unika kombinationer av olika fysiska faktorer och är i princip en utökning av de EUNIS-habitat som behandlats i denna studie. Förhoppningsvis kommer detta material att utgöra en bas när kommuner och länsstyrelse jobbar vidare med exempelvis skydd av marina områden.

Tillgången på grundläggande material såsom bottenmaterial (SGU) och vågexponeringsgrad (Isæus 2004) har varit god. Upplösningen på den ingående informationen har ofta varit hög och framtaget av experter inom respektive område. Den information som har haft sämst upplösning har varit djupinformationen. Bättre information finns visserligen för vissa områden men är inte tillgänglig på grund av militärstrategiska skäl.

Resultaten består av digitala kartor samt arealer över olika identifierade marina habitat/naturtyper.

Förhoppningsvis kan detta arbete skapa en diskussion om vilka andra typer av kombinationer eller tillägg av information som behövs för framtida skötsel och skydd av marina områden. På det sättet kan nästa generation habitat- och naturtypskartor bli bättre och mer relevanta.

En av slutsatserna med detta arbete är att det finns en hel del modeller och kunskap om länets marina miljöer som ännu inte sammanställts. Kombinerad bör denna kunskap räcka för att sätta igång ett reellt arbete fokuserat mot miljömålen och bevarande av värdefulla och representativa marina miljöer.

Nedan presenteras innehållet i rapportens olika delar:

Huvudrapport

Huvudrapporten är förhållandevis teknisk och detaljerad. Här beskrivs bland annat hur ingående geografiskt material har använts samt varför det har använts på olika sätt. Här tas också bakgrund och förutsättningar för studien upp. Metodik och bakomliggande idé för kartläggningen beskrivs och EUNIS klassificeringssystem beskrivs kortfattat.

Resultatdelen redovisar olika habitat/naturtypsarealer, kartexempel och tabellöversikter på identifierade och avgränsade habitat på EUNIS nivå 1, 2 och 3 i Stockholms län. Samma typ av resultat presenteras för den utökade naturtypslistan för Stockholms län.

I diskussionen behandlas bland annat informationsval, EUNIS klassificeringssystem samt generella svårigheter med kartläggningar av denna typ.

Huvudrapporten är framför allt riktad mot de som har ett specialintresse av hur kartläggningen gick till rent praktiskt och hur och varför visst material, modeller och definitioner användes.

Bilaga 1. Reclassifying the marine geological map for biological applications

En kort rapport som beskriver hur omklassificeringen av maringeologiska kartan till att bättre spegla ytsubstraten gjordes. Rapporten är skriven på engelska.

Bilaga 2. Kriteriediagram med kriterieförklaringar för EUNIS-habitatklassificering

I bilaga 2 presenteras EUNIS så kallade kriteriediagram samt kriterier för olika EUNIS-habitat. I varje diagram finns författarens kommentarer eller hänvisningar till text där beskrivningar av hur kriterierna har tolkats och utnyttjats för identifiering och avgränsning av olika habitat hittas.

Bilaga 3. Beskrivningar av EUNIS-habitat

I bilaga 3 hittas engelska originalbeskrivningar av de EUNIS-habitat som tas upp i denna studie.

Bilaga 4. Lite om förutsättningar för flora och fauna i Stockholms läns marina undervattensmiljöer

I bilaga 4 beskrivs grovt vilka olika växt- och djursamhällen som kan förekomma i och på de olika naturtyperna och EUNIS-habitaten i Stockholms skärgård. Där inget annat är angett är informationen hämtad från *Under ytan i Stockholms skärgård* (Kautsky, L. m. fl. 2000). En lista efter varje bottentyp anger var de ligger sorterade i EUNIS-systemet och i den utökade naturtypslistan för Stockholms län. Det är tänkt att denna bilaga ska kunna hjälpa tjänstemän och andra intresserade att bättre förstå vad de framtagna kartorna visar. I denna del finns även bildexempel på några av de olika miljöerna.

Background

Early in 2004 there was much discussion about how the Stockholm County Administrative Board could identify and take appropriate action to conserve different types of valuable marine biotopes. It was understood that, in order to achieve these objectives, the Board needed not only to have access to knowledge about the habitats of the Baltic Sea, but also to determine the geographical location of those habitats. At the time it was concluded that a basic map of the marine habitats of the Stockholm archipelago was very much needed, but not yet available. Such a map was required not only to identify hitherto unknown valuable marine biotopes, but also as a background for more detailed biological knowledge of geographically limited areas, and as a basis for decision making. In short, it was concluded that a basic map of this kind would be an important tool and a source of knowledge for the subsequent management and conservation of the county's marine environments. As a result of this discussion, it was decided that an attempt should be made to produce a basic map of marine underwater environments.

The approach chosen involved attempting to predict the flora and fauna at certain scales, using existing geographical data, models and general knowledge about the sea.

This type of mapping, or predictive modelling, is being used to a growing extent, although this was the first large-scale effort for the Baltic proper. The aims of other similar studies have been more or less the same, to produce basic information for the planning of management and conservation measures (e.g. Ekebom and Erkkilä 2002; Roff *et al.*2003; Day and Roff 2000; Bekkby *et al.* 2002; Bekkby and Rosenberg 2004; Rinde *et al.* 2004; Axelsson 2003; Cato *et al.* 2003).

Within the European Union, work is in progress on a description of the European natural environment based on the European Nature Information System (EUNIS), which is a hierarchical classification system for all European habitats, natural and artificial (EEA 2004). It is being developed and managed by the European Topic Centre for Nature Protection and Biodiversity (ETC/NPB in Paris) for the European Environment Agency (EEA) and the European Environmental Information Observation Network (EIONET). The purpose of the EUNIS habitats classification is to facilitate harmonised description and collection of data, with the help of criteria for habitat identification. EUNIS is linked to and compatible with other habitat systems used in Europe.

Since a comprehensive classification system was needed for the Swedish basic map and the EUNIS system had been used in other studies (e.g. Bekkby and Rosenberg 2004; Rinde *et al.* 2004), and often in combination with Natura 2000 work, it was decided that this study should use and test the EUNIS classification that existed for the Baltic Sea.

Aim and objectives

The aim of this study was to develop a method to produce basic marine habitat maps for the whole of Stockholm county.

Objectives included

- Exploring the quality, quantity and availability of necessary marine geographical data.
- Exploring existing marine methods and knowledge.
- Identifying the best way to use the above-mentioned data, methods and knowledge together to produce marine habitat maps.
- Validation of the maps produced.
- Testing the criteria-based identification of marine EUNIS habitats in the Baltic Sea.

Material and study area

Material

Table 1 lists the information used in the habitat identification process and table 2 the information that has so far been used to validate the habitat maps produced.

Geographical information	Source
Geographical Sweden Data (GSD) Fastighetskartan 2004	National Land Survey of Sweden
Geographical Sweden Data (GSD) Ekonomiska kartan 1996	National Land Survey of Sweden
Marine geological map	Geological Survey of Sweden (SGU)
Depth model	Geological Survey of Sweden (SGU)
Wave exposure model	Isæus 2004
Black and white orthophotos 2000	National Land Survey of Sweden

Table 1. *Geographical information used in the identification of different marine habitats.*

Geographical information	Source
Black and white orthophotos 2000	National Land Survey of Sweden
Geo-coded video samples of bottom material	Geological Survey of Sweden (SGU)

Table 2. *Geographical information used to validate the habitat maps produced.*

Study area

The study area, shown in figure 1, is identical with the extent of the marine geological map of Stockholm county and covers most of the coastal waters of the county. Several marine surveys and inventories, together with other marine and coastal research projects, have been performed in this area (e.g. Schreiber 2003; Axelsson 2003; Isæus 2004; Nitzelius 2003, personal communication; Engquist 2002; Cato *et al.* 2003; Philipson and Lindell 2003; Jonsson (ed.) 2003). These may hopefully be of help in the future validation process or in further analyses of selected areas.

The unique archipelago dominates the coastal areas of Stockholm county (L. Kautsky *et al.* 2000). It continues eastwards all the way to Finland. The archipelago is approximately 200 kilometres long and 100 kilometres wide. It comprises 30 000 islands, islets and skerries, and along with the mainland coast the shoreline totals an impressive 10 000 kilometres. Between the islands lie hard and soft bottom areas with great potential for rich biodiversity. Postglacial crustal uplift, now proceeding at a rate of 4 millimetres per year, constantly changes the landscape. The aquatic environment of the archipelago is strongly influenced by the outflow of the freshwater lake Mälaren, as well as by brackish water from the Bothnian Sea and the Baltic proper. This creates a gradient from the inner to the outer archipelago, as well as from the north to the south. Along with the salinity gradient from shallow to deep waters, these factors create an environment with plant and animal communities with rare characteristics.

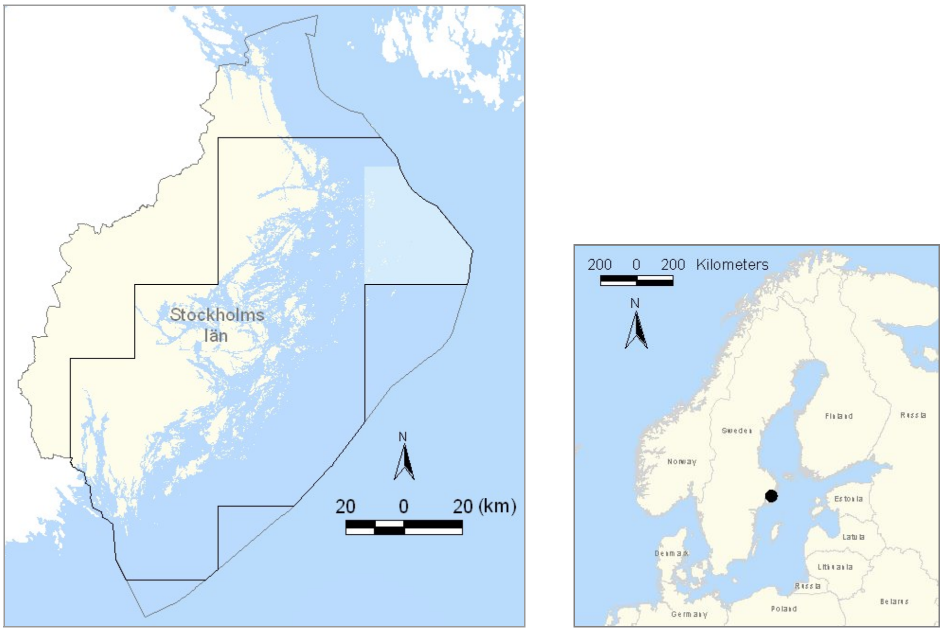


Figure 1. *The marine geological map delimits the area studied (black outline) in the county of Stockholm (Stockholms län). The area shaded a lighter blue in the north-eastern corner has been mapped at a more generalised level compared with the rest of the area. The map to the right shows where the study was performed in the Baltic Sea.*

Methods

Since the methods and reasoning involved in the identification and geographical delimitation of different habitats are described in more detail in the discussion section, I will confine myself here to a basic outline of the mapping method used.

The type of habitat modelling or mapping attempted here will in principle show little more than different combinations of physical factors (such as bottom substrate, depth, and degree of wave exposure), which will then be assigned to different EUNIS habitat types. However, the flora and fauna of the Baltic Sea are strongly affected by these different physical factors (H. Kautsky 1988), which are often described as structuring. Different combinations of physical factors such as *sand–gravel bottom + moderate wave exposure* or *hard bottom + high wave exposure* constitute different prerequisites for the biota and result in our finding different sets of flora and fauna in different geographical areas. It is not possible to guarantee that given organisms will definitely be found in a certain physical environment that has been mapped. Nor is it possible to establish sharp delimitations between, for example, different degrees of wave exposure. The results, in the form of maps, will nevertheless show that there exist basic conditions for certain types of organisms, associated with the particular combination of physical factors that is mapped. It will be impossible to decide for sure, however, without undertaking field inventories, for example. It is my hope that these maps will give a broad-scale picture of where we are more or less likely to find, say, eelgrass meadows, common mussel beds or belt-forming bladderwrack.

Geographical delimitation of EUNIS habitats

The website http://eunis.eea.eu.int/habitats.jsp provides extensive information about the EUNIS habitat classification system. Different habitats and criteria diagrams or keys for their identification (see figure 2) are presented, for example. These keys have been developed at the first three hierarchical levels, which were my primary concern. The general idea was to find or produce the geographical information needed for each criterion, in order to be able to confirm or reject different paths in the keys. An example of the method is given in figure 3, where the EUNIS habitat *Sublittoral sediment* (A5) is identified with the help of EUNIS criteria and digital geographical information.

I have used the EUNIS report *EUNIS Habitat Classification. Marine habitat types: Revised classification and criteria, September 2004* (Davies and Moss 2004) to classify the habitats in the county. The criteria diagrams that have been used are to be found in appendix 2, along with the explanatory notes on how to interpret and use the criteria. For each criterion, it is noted how the criterion has been interpreted and applied in Stockholm county.

As far as scale (time and space), quality, quantity etc. are concerned, the geographical information needed for the classification exists in different forms. In addition, this information has been collected from several disciplines, such as geology, oceanography, biology etc. Although certain concepts exist in several of these fields, they may have different definitions. It was therefore essential to thoroughly analyse each data set and to collect and systematically save metadata. The combination of different data sets of differing scale, quality etc. was critical, and to avoid or minimize bias and errors it was vital that each data combination was carefully considered.

Descriptions of the different EUNIS habitats are found in appendix 3. These are quoted from *EUNIS Habitat Classification Revised 2004* (Davies, Moss and Hill 2004), which is a final report that appeared a month after the report (mentioned above) that I used for the classification. According to Dorian Moss (2005, personal communication), the two reports should be in agreement with each other at least at the more generalised levels I have used.

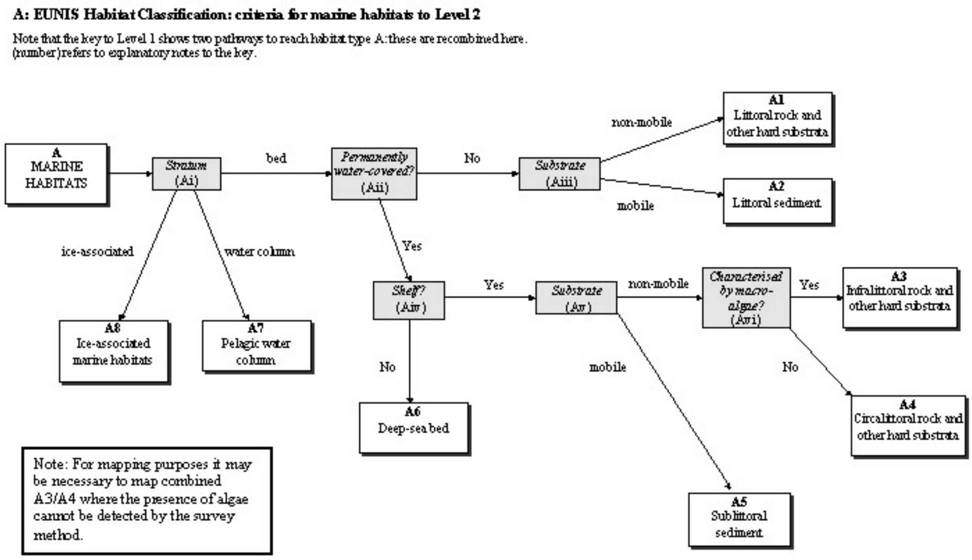
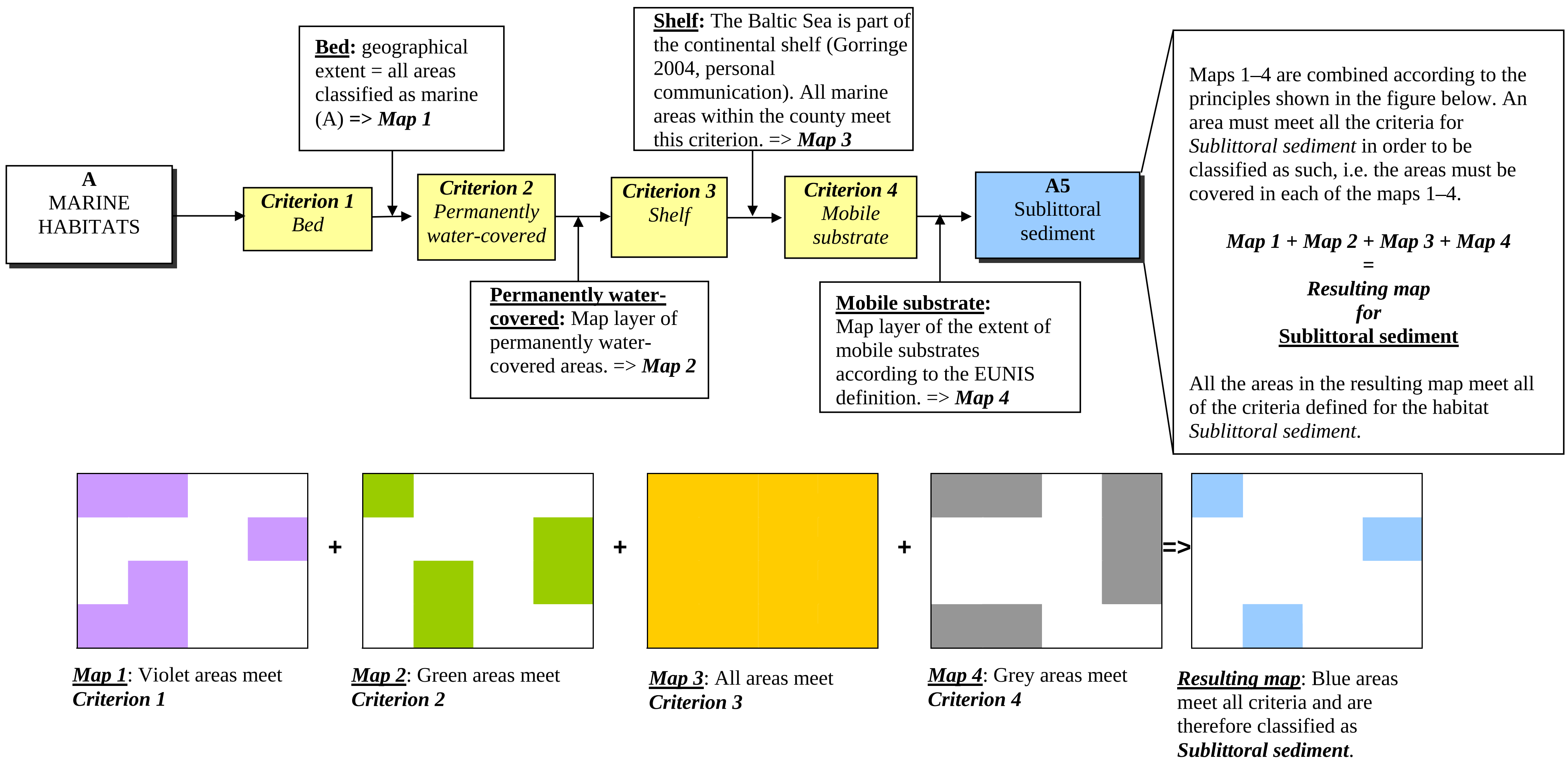


Figure 2. *Criteria diagram for marine habitats to level 2. For each decision box (grey) there are explanatory notes that explain how the box is to be applied. These notes form an integral and essential part of the criteria (Davies and Moss 2004).*

Figure 3. *The methodological principle of this work is presented below. In this example, the EUNIS habitat* Sublittoral sediment *is geographically delimited or identified and presented in a map of its own. Areas are identified using the defined EUNIS criteria. Digital maps presenting areas that meet each of the criteria in turn are produced. These digital criteria maps are then combined so that areas that fulfil ALL the criteria for this EUNIS habitat can be identified and presented in a resulting map of the habitat* Sublittoral sediment*.*



More detailed habitat analysis for Stockholm county

Since the EUNIS system is fairly coarse even at level 3, and I was in the possession of information that permitted the identification of additional unique combinations of structuring physical factors, I decided to draw up an expanded habitat list for the county. Basically I continued to work from the classification made at level 3. This list is not intended to replace or compete with the EUNIS system in any way. It should be seen more as a brainstorming exercise. It will only be possible to know whether the combinations are relevant when people at the County Administrative Board or elsewhere actually start working with them. In a dialogue with users it will hopefully be possible to produce a second generation of more relevant maps.

Working in geographical information systems (GIS)

The practical work involved in this study has predominantly been undertaken with the help of digital maps in two GIS environments, vector- and raster-based. Some of the input data maps have been delivered in vector format and some in raster format. A short explanation of the two formats is given below.

Vector

Most GIS maps used in this study were delivered in vector format. This means that the maps are made up of several unique objects that are stored using x- and y-coordinates. Points are stored as simple coordinate pairs, while lines and surfaces (polygons) are stored as series of coordinate pairs each representing a break point or the beginning/end of a line (ESRI 1996; ESRI 1992–99). Analysis in vector environments often involves the analysis of separate geographical objects and their characteristics in terms of place, size, shape etc. In this study I have mostly used vector analysis to search for specific types of objects.

Raster

In a raster-based GIS such as the *ArcView Spatial Analyst*, the geographical information is stored in a regular grid system organised in a number of columns (fields) and rows. Each square, or raster cell, has a certain value (ESRI 1996; ESRI 1992–99). The raster system is well suited to geographical characteristics that extend and vary over large surfaces, such as elevation or land use data. The size of the raster cell is decided on the basis of the resolution of the input data, the question to be addressed or the analysis to be undertaken. In raster systems it is easy to perform different mathematical, logical and statistical manipulations or combinations of one or more map layers with different types of variables. These operations are often performed using what is known as a map calculator.

The delimitation and identification of different habitats has primarily been carried out in a raster environment.

Results

The resulting areas of different habitats identified are valid for Stockholm county. They are presented as areas (km^2), map examples and tables of identified and delimited habitats at EUNIS levels 1, 2 and 3, as well as from the expanded list of non-EUNIS habitats for the county.

EUNIS Habitat Level 1 – *Marine environment* (A)

Classified area: 9456 km^2

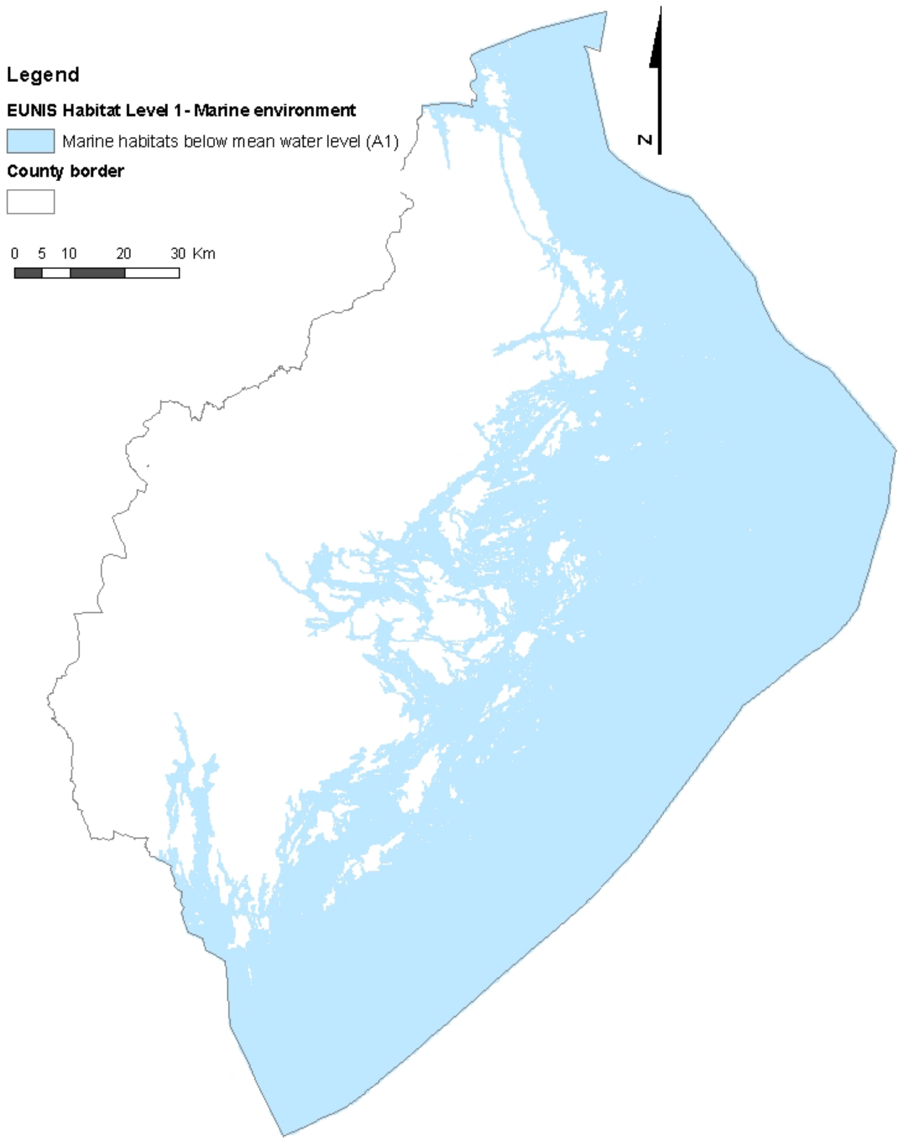


Figure 4. *EUNIS habitat level 1 (A).* Marine environment.

EUNIS Habitat Level 2 – Broad habitats

Classified area: 6913 km^2 (73 per cent of the county's marine areas)

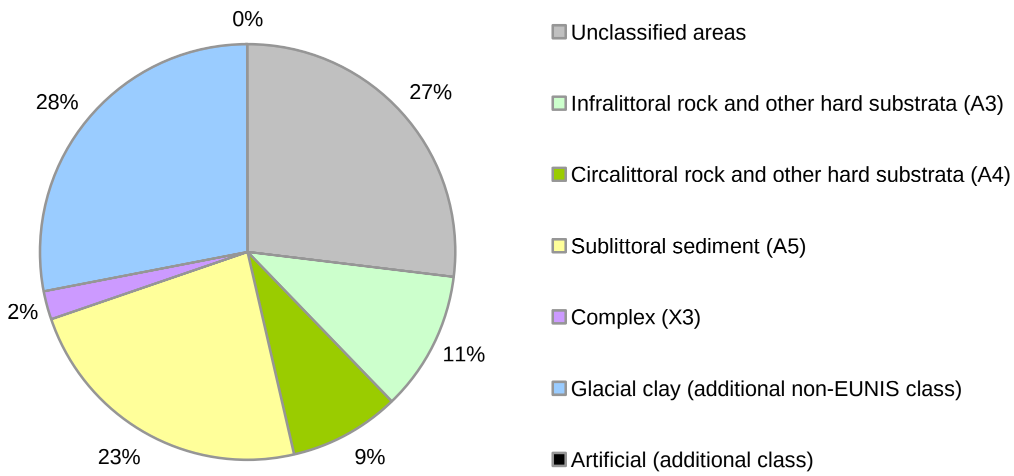


Figure 5. *Relative distribution of unclassified and classified EUNIS level 2 habitats. The areas involved are presented in table 3.*

Overview of level 2 habitats

EUNIS code	EUNIS scientific habitat name	Area (km^2)	Comments
A3	Infralittoral rock and other hard substrata	1018.0	Not fully matched with EUNIS. The infralittoral and circalittoral were distinguished using a maximum depth of 25 metres for infralittoral habitats.
A4	Circalittoral rock and other hard substrata	823.3	Not fully matched. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres and below for circalittoral habitats.
A5	Sublittoral sediment	2198.9	Sublittoral macrophyte-dominated sediment (A5.5) identified outside the area of the marine geological map was added.
X3	Mosaics of mobile and non-mobile substrata	215.4	–
–	Glacial clay	2656.0	**Glacial clay**. Additional habitat class, due to the great diversity of surface substrate in the marine geological category glacial clay. It can consist of everything from hard consolidated clay to mosaics of mobile and non-mobile substrata.
–	Artificial	1.2	**Artificial**. Since this habitat is variable and may contain both mobile and non-mobile material it was assigned to a class of its own.
–	Unclassified areas	2543.1	–

Table 3. *Areas of unclassified and classified EUNIS level 2 habitats. Note that, owing to limited data, compromises with EUNIS definitions and additional non-EUNIS habitats were necessary. It is important to stress that this classification and delimitation is* ***not*** *complete. It should be seen as an initial step pending the availability of further information of use in the classification.*

Map example showing EUNIS level 2 habitats

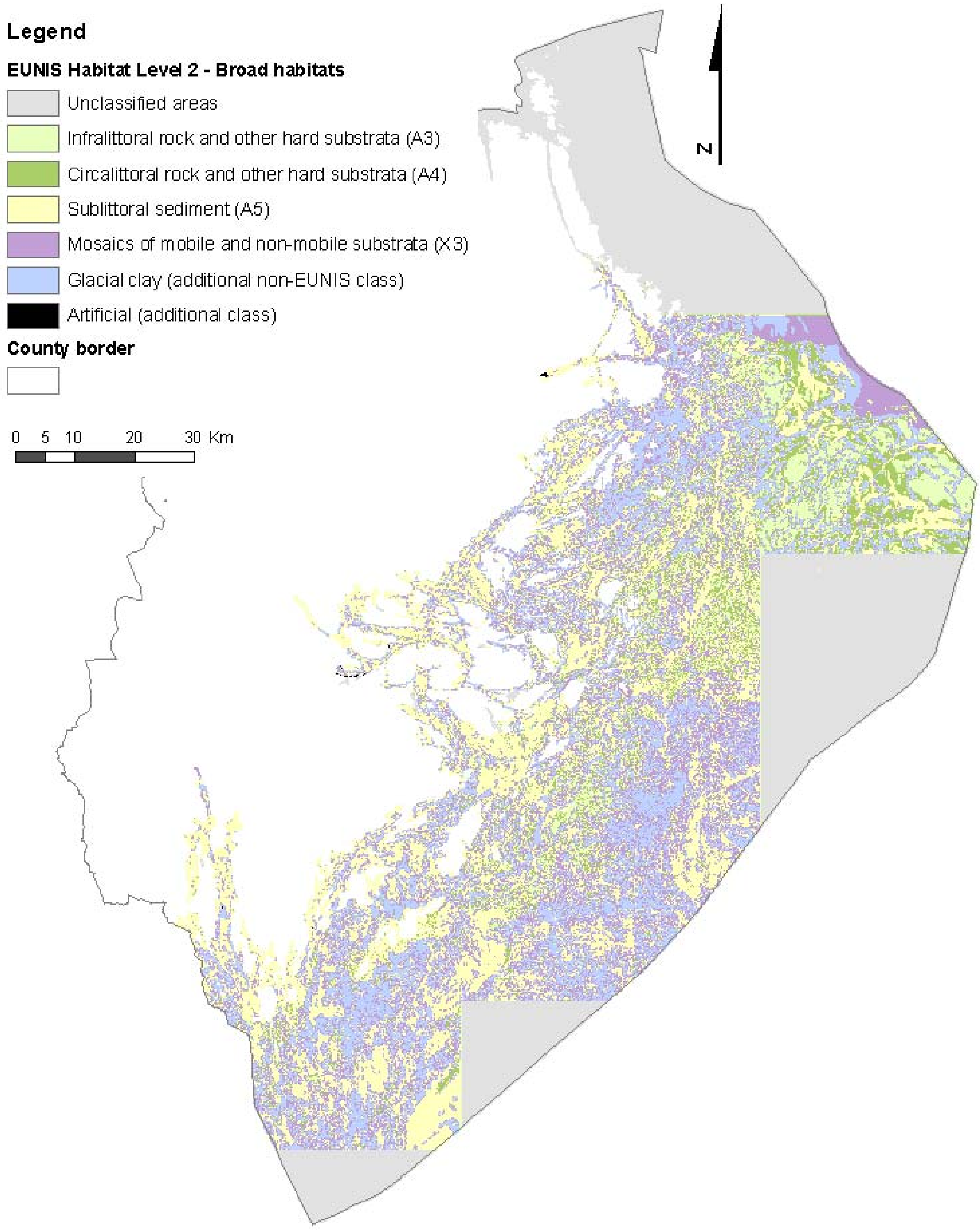


Figure 6. *EUNIS habitat level 2. Distribution of broad habitats in coastal waters of Stockholm county.*

EUNIS Habitat Level 3 – Main habitats

Classified area: 6913 km^2 (73 per cent of the county's marine areas)

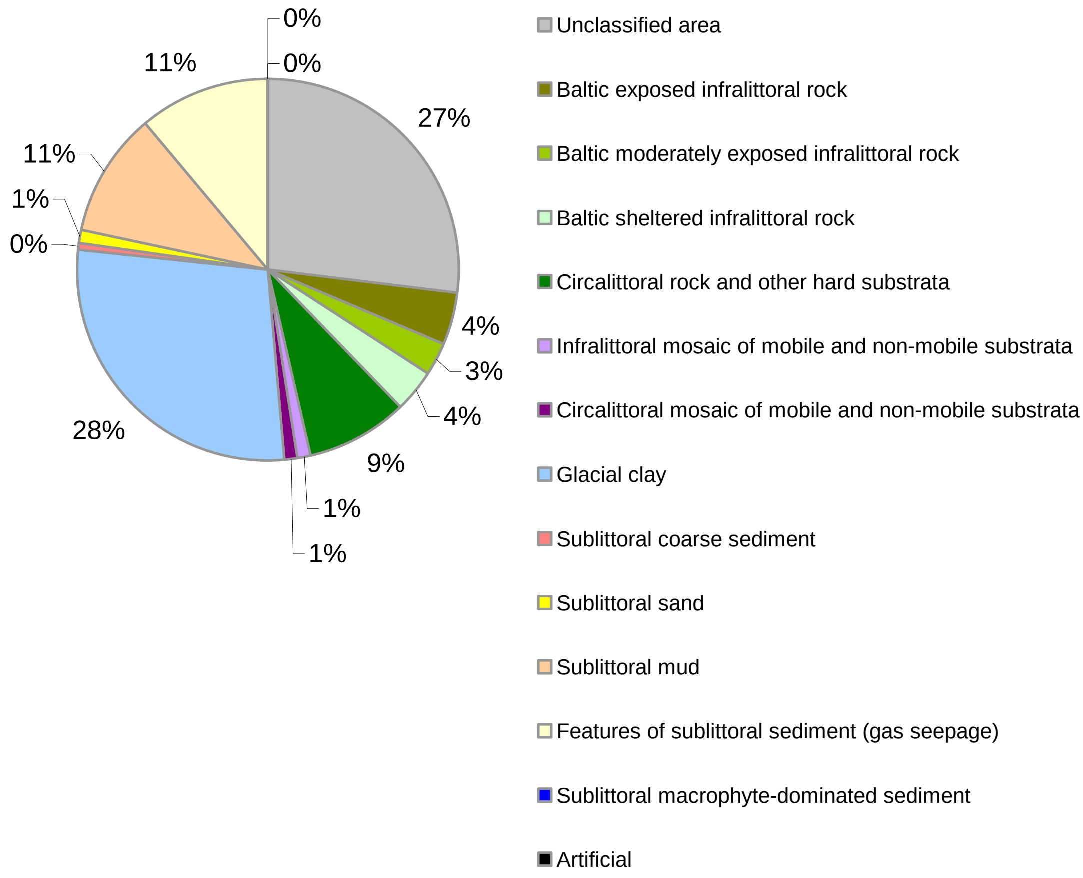


Figure 7. *Relative distribution of unclassified and classified EUNIS level 3 habitats. The areas involved are presented in table 4.*

Overview of level 3 habitats

EUNIS code	EUNIS scientific habitat name	Area (km^2)	Comment
A3.4	Baltic exposed infralittoral rock	416.0	
A3.5	Baltic moderately exposed infralittoral rock	268.7	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
A3.6	Baltic sheltered infralittoral rock	333.3	
A4.4	Baltic exposed circalittoral rock	823.3	A4.4–A4.6 will be presented at level 2 since no information was available on exposure to currents in deeper waters.

A4.5	Baltic moderately exposed circalittoral rock		
A4.6	Baltic sheltered circalittoral rock		
A5.1 or A5.5	Sublittoral coarse sediment	44.6	Not enough information to distinguish A5.1 from A5.5.
A5.2 or A5.5	Sublittoral sand	109.8	Not enough information to distinguish A5.2 from A5.5.
A5.3 or A5.5	Sublittoral mud	999.0	Not enough information to distinguish A5.3 from A5.5.
A5.5	Sublittoral macrophyte-dominated sediment	11.0	Dense reeds modelled from National Land Survey data (A5.54).
A5.7	Features of sublittoral sediments	1034.4	Only areas with probable gas seepage (predominantly methane).
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	101.7	Not fully matched habitat. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats. Certain areas may consist of pure substrates.
X33	Mosaics of mobile and non-mobile substrata in the circalittoral zone	113.7	Not fully matched habitat. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres and below for circalittoral habitats. Certain areas may consist of pure substrates.
–	Glacial clay	2656.0	**Glacial clay**. Additional habitat class, due to the great diversity of surface substrate in the marine geological map category glacial clay. It can consist of everything from hard consolidated clay to mosaics of mobile and non-mobile substrata.
–	Artificial	1.2	**Artificial**. Since this habitat is variable and may contain both mobile and non-mobile material it was assigned to a class of its own.
–	Unclassified areas	2543.1	–

Table 4. *Areas of unclassified and classified EUNIS level 3 habitats. Note that, owing to limited data, compromises with EUNIS definitions and additional non-EUNIS habitats were necessary. It is important to stress that this classification and delimitation is* ***not*** *complete. It should be seen as an initial step pending the availability of further information of use in the classification.*

Map example showing EUNIS level 3 habitats

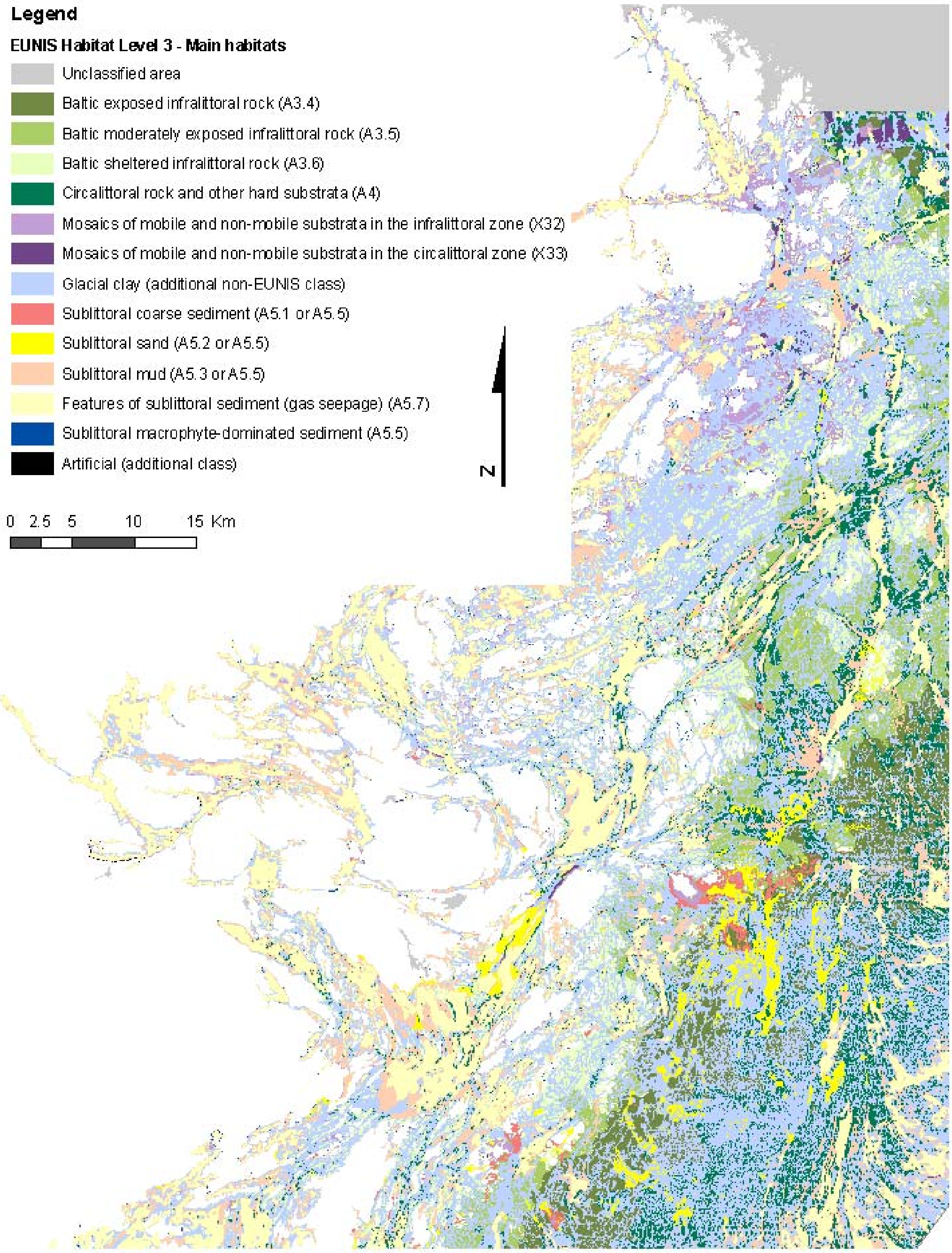


Figure 8. *EUNIS habitat level 3. Main habitats in coastal areas of Stockholm county.*

Expanded non-EUNIS habitat list for Stockholm county

Classified area: 6913 km^2 (73 per cent of the county's marine areas)

Overview – Distribution of different habitats in the expanded list

EUNIS code	**EUNIS scientific habitat name** (To the lowest level possible. Many higher level habitats have, however, been used as "umbrella habitats".)	Name in expanded list	Area (km^2)	%	Comment on EUNIS classification
	Unclassified area	Unclassified area	2543.14	26.9	
A3.4	Baltic exposed infralittoral rock	Shallow exposed hard bottom (–6 metres)	18.09	0.2	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
A3.5	Baltic moderately exposed infralittoral rock	Shallow moderately exposed hard bottom (–6 metres)	75.47	0.8	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
A3.6	Baltic sheltered infralittoral rock	Shallow sheltered hard bottom (–6 metres)	166.03	1.8	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
A3.4	Baltic exposed infralittoral rock	Exposed hard bottom (6–25 metres)	397.87	4.2	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
A3.5	Baltic moderately exposed infralittoral rock	Moderately exposed hard bottom (6–25 metres)	193.27	2.0	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
A3.6	Baltic sheltered infralittoral rock	Sheltered hard bottom (6–25 metres)	167.31	1.8	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
A4.4	Baltic exposed circalittoral rock				
A4.5	Baltic moderately exposed circalittoral rock	Deep hard bottom (25 metres and below)	823.32	8.7	Not fully matched habitats. The infralittoral and circalittoral were distinguished using a depth minimum of 25 metres for circalittoral habitats. A4.4–A4.6 will be presented at level 2 since no information was available on current exposure in deeper waters.
A4.6	Baltic sheltered circalittoral rock				

A5.1	Sublittoral coarse sediment	Shallow exposed gravel–sand bottom (–6 metres)	0.82	0.0
A5.1	Sublittoral coarse sediment	Shallow moderately exposed gravel–sand bottom (–6 metres)	5.22	0.1
A5.1	Sublittoral coarse sediment	Shallow sheltered gravel–sand bottom (–6 metres)	8.91	0.1
A5.1	Sublittoral coarse sediment	Shallow exposed gravel–sand bottom (6–25 metres)	12.22	0.1
A5.1	Sublittoral coarse sediment	Moderately exposed gravel–sand bottom (6–25 metres)	9.68	0.1
A5.1	Sublittoral coarse sediment	Sheltered gravel–sand bottom (6–25 metres)	3.60	0.0
A5.1	Sublittoral coarse sediment	Deep gravel–sand bottom (25 metres and below)	4.20	0.0
A5.2	Sublittoral sand	Shallow exposed fine sand bottom (–6 metres)	0.06	0.0
A5.2	Sublittoral sand	Shallow moderately exposed fine sand bottom (–6 metres)	3.62	0.0
A5.2	Sublittoral sand	Shallow sheltered fine sand bottom (–6 metres)	11.16	0.1
A5.2	Sublittoral sand	Exposed fine sand bottom (6–25 metres)	14.76	0.2
A5.2	Sublittoral sand	Moderately exposed fine sand bottom (6–25 metres)	10.29	0.1
A5.2	Sublittoral sand	Sheltered fine sand bottom (6–25 metres)	7.54	0.1
A5.2	Sublittoral sand	Deep fine sand bottom (25 metres and below)	62.30	0.7
A5.2	Sublittoral sand	Shallow exposed muddy fine sand bottom (–6 metres)	0.00	0.0
A5.2	Sublittoral sand	Shallow moderately exposed muddy fine sand bottom (–6 metres)	0.00	0.0
A5.2	Sublittoral sand	Shallow sheltered muddy fine sand bottom (–6 metres)	0.00	0.0

A5.2	Sublittoral sand	Exposed muddy fine sand bottom (6–25 metres)	0.00	0.0	
A5.2	Sublittoral sand	Moderately exposed muddy fine sand bottom (6–25 metres)	0.00	0.0	
A5.2	Sublittoral sand	Sheltered muddy fine sand bottom (6–25 metres)	0.05	0.0	
A5.2	Sublittoral sand	Deep muddy fine sand bottom (25 metres and below)	0.01	0.0	
A5.3	Sublittoral mud	Shallow exposed mud bottom (–6 metres)	0.02	0.0	
A5.3	Sublittoral mud	Shallow moderately exposed mud bottom (–6 metres)	0.41	0.0	
A5.3	Sublittoral mud	Shallow sheltered mud bottom (–6 metres)	122.88	1.3	
A5.3	Sublittoral mud	Exposed mud bottom (6–25 metres)	5.20	0.1	
A5.3	Sublittoral mud	Moderately exposed mud bottom (6–25 metres)	16.60	0.2	
A5.3	Sublittoral mud	Sheltered fine mud bottom (6–25 metres)	387.88	4.1	
A5.3	Sublittoral mud	Deep fine mud bottom (25 metres and below)	1500.27	15.9	
A5.5	Sublittoral macrophyte-dominated sediment	Dense reed belts	11.03	0.1	Dense, emergent vascular vegetation modelled from National Land Survey data (A5.54). The classification should ***not*** be seen as comprehensive.
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Shallow exposed glaciofluvial deposits (–6 metres)	0.00	0.0	Not fully matched. Judging from the few locations for which video films are available, glacio-fluvial material seems to be a diverse class that can include hard bottoms, sediments and mosaics. Until more is known, these habitats are placed in EUNIS class X32. Once again, the infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Shallow moderately exposed glaciofluvial deposits (–6 metres)	1.00	0.0	
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Shallow sheltered glaciofluvial deposits (–6 metres)	1.95	0.0	
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Exposed glaciofluvial deposits (6–25 metres)	0.27	0.0	

X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Moderately exposed glacio-fluvial deposits (6–25 metres)	0.80	0.0	Not fully matched. Judging from the few locations for which video films are available, glacio-fluvial material seems to be a diverse class that can include hard bottoms, sediments and mosaics. Until more is known, these habitats are placed in EUNIS class X32. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Sheltered glaciofluvial deposits (6–25 metres)	1.58	0.0	
X33	Mosaics of mobile and non-mobile substrata in the circalittoral zone	Deep glaciofluvial deposits (25 metres and below)	1.22	0.0	Not fully matched habitat. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres and below for circalittoral habitats.
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Shallow exposed mosaics (–6 metres)	0.00	0.0	Not fully matched. Judging from the few locations for which video films are available, glacio-fluvial material seems to be a diverse class that can include hard bottoms, sediments and mosaics. Until more is known, these habitats are placed in EUNIS class X32. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Shallow moderately exposed mosaics (–6 metres)	1.07	0.0	
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Shallow sheltered mosaics (–6 metres)	43.25	0.5	
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Exposed mosaics (6–25 metres)	10.73	0.1	Not fully matched. Judging from the few locations for which video films are available, glacio-fluvial material seems to be a diverse class that can include hard bottoms, sediments and mosaics. Until more is known, these habitats are placed in EUNIS class X32. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres for infralittoral habitats.
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Moderately exposed mosaics (6–25 metres)	3.14	0.0	
X32	Mosaics of mobile and non-mobile substrata in the infralittoral zone	Sheltered mosaics (6–25 metres)	37.90	0.4	
X33	Mosaics of mobile and non-mobile substrata in the circalittoral zone	Deep mosaics (25 metres and below)	112.44	1.2	Not fully matched habitat. The infralittoral and circalittoral were distinguished using a depth limit of 25 metres and below for circalittoral habitats.
–	–	Shallow exposed glacial clay (–6 metres)	2.31	0.0	The surficial material glacial clay can be everything from hard consolidated clay to mosaics of mobile and non-mobile substrata.
–	–	Shallow moderately exposed glacial clay (–6 metres)	13.91	0.1	
–	–	Shallow sheltered glacial clay (–6 metres)	193.87	2.1	
–	–	Exposed glacial clay (6–25 metres)	225.69	2.4	The surficial material Glacial clay can be everything from hard consolidated clay to mosaics of mobile and non-mobile substrata.

–	–	Moderately exposed glacial clay (6–25 metres)	195.69	2.1	
–	–	Sheltered glacial clay (6–25 metres)	442.71	4.7	
–	–	Deep glacial clay (25 metres and below)	1581.82	16.7	The surficial material glacial clay can be everything from hard consolidated clay to mosaics of mobile and non-mobile substrata.
–	–	Artificial	1.17	0.0	No depth delimitation.

Table 5. *Combinations of different physical factors. It is important to note that this expanded habitat list is* ***not*** *to be seen as something fixed and complete. It is only a first step. It is also important to note that it is in no way intended to replace the EUNIS system. It is simply a way to make greater and more detailed use of existing data than EUNIS permits.*

Map example showing habitats from the non-EUNIS list

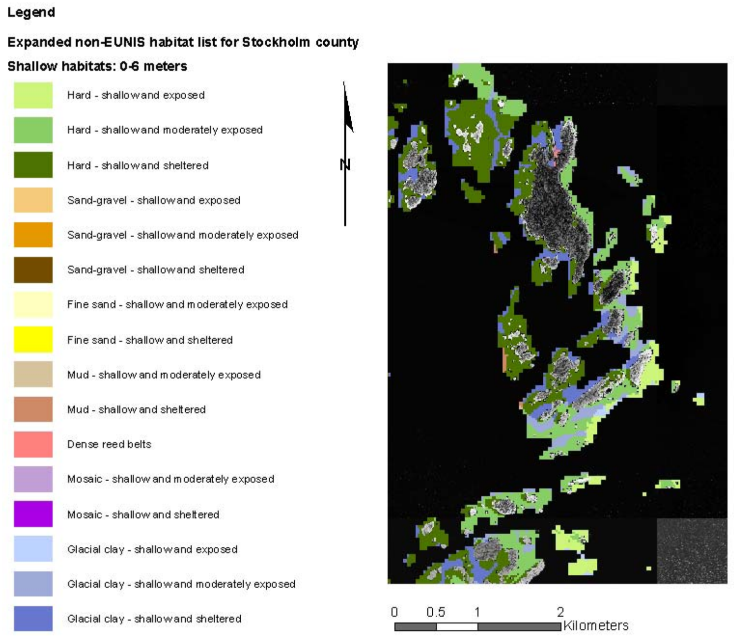


Figure 9. *Example showing identified combinations of physical factors in coastal waters of Stockholm county.*

Discussion

Since the classification used has as far as possible followed the EUNIS system, this discussion focuses on the criteria and conditions laid down within that system.

Choice of geographical resolution for raster analysis

Before any work could begin, it was necessary to decide the geographical resolution, or cell size, of the GIS raster analyses. The Geological Sweden Data (GSD) map (wetlands and water), which is in vector format (J. Sjöhed 2004, personal communication), has a high level of detail. Cell size (see *Methods*) was therefore limited more by computer capacity than by data resolution. The marine geological map (vector format) can, according to Anders Elhammer (personal communication 2004), be used with a cell size of 25 x 25 metres. There are areas for which the data are detailed enough for a cell size of 10 x 10 metres, but the Geological Survey of Sweden (SGU) is restricted from providing information about these areas for military reasons. The digital map of wave exposure also has a resolution of 25 x 25 metres.

Depth information was supplied by SGU with a 50 x 50 metre cell size and constituted the coarsest data used in this study. Since habitats are very dependent on bottom material, I did not want to lose information regarding them in order to match the depth resolution. I therefore decided to continue to use a cell size of 25 x 25 metres even for analyses involving depth data. This will most likely produce errors in some or many of the depth delimitations. It is therefore a good idea to first seek out the combination of, for example, EUNIS substrate and wave exposure and then use the depth delimitation with a degree of caution.

EUNIS Habitat Level 1 – *Marine environment* (A)

The areas classified as marine include water according to the GSD Fastighetskartan and modelled aquatic vegetation assumed to lie below the mean water level, i.e. below the shoreline (see *Mean water levels and digital shorelines*).

Littoral habitats above mean water level were excluded from this study (see discussion below).

The most relevant EUNIS criteria for the marine environment, from a Baltic Sea perspective, were:

1. Habitats must not be constructed, extremely artificial or regularly tilled.
2. They must not be subterranean (marine caves excluded).

3. They must be *marine*, i.e.

   a) directly connected to the oceans,

   b) influenced by saltwater (fully saline, brackish or almost fresh),

   c) geographically located from mean water level and below,

   d) waterlogged saltmarsh habitats and saline or brackish pools above the mean water level of non-tidal waters (parts of the geolittoral).

The more problematic criteria and questions and other problems concerning the geographical delimitation of marine habitats are discussed below.

Constructed, regularly tilled and artificial habitats

Artificial habitats could not be properly delimited in this study. In the inner archipelago and around the city of Stockholm, however, there are numerous and widespread human structures and other disturbed areas (Aneer 2004, personal communication) which would most likely end up in this category. In the future, such structures will probably have to be treated differently. Examples include concreted shorelines and large concrete foundations for different kinds of structures, such as bridges, harbours etc. (See also *Artificial habitats* under *Additional habitats and habitat compromises* in the discussion on EUNIS habitat levels 2–3.)

Saltwater influence

The Baltic Sea is brackish, with mean salinities for surface water between about 10 psu (practical salinity units) (southern parts of the Baltic proper) and about 2 psu (northern part of the Gulf of Bothnia) (H. Kautsky 1995). A proper separation of upstream coastal freshwater habitats and brackish or almost freshwater habitats, based on the EUNIS salinity criteria, would require salinity tests. Since this would have been too expensive and time-consuming, an indirect demarcation was undertaken instead, by means of GIS identification of all connected water bodies and areas of aquatic vegetation. Further delimitations were then made with the help of black and white orthophotos and a few simple criteria. The resultant delimitation is perhaps somewhat generous with respect to landward areas. I decided that it was better to risk including a few freshwater lakes, rather than omit saltwater-influenced areas. The more or less subjectively defined criteria for this process were:

- Open areas of water separated from brackish waters by a channel or stream shorter than 100 metres were classified as marine. These areas are assumed to be saltwater-influenced.

- Open areas of water that are connected with brackish water areas through areas of aquatic vegetation identified as lying below mean water level were classified as marine. These were assumed to be saltwater-influenced.

- Networks of open water, aquatic vegetation identified as lying below mean water level and channels or streams that connect to two or more brackish water areas were classified as marine even if the channel or stream was longer than 100 metres (see example in figure 10).
- Streams that do not lead to open areas of water classified as marine were excluded from the study.

With the help of high-resolution digital elevation data it would have been easier to delimit fresh water from marine water with the help of the topography of the landscape. Such information, however, is not available at present.

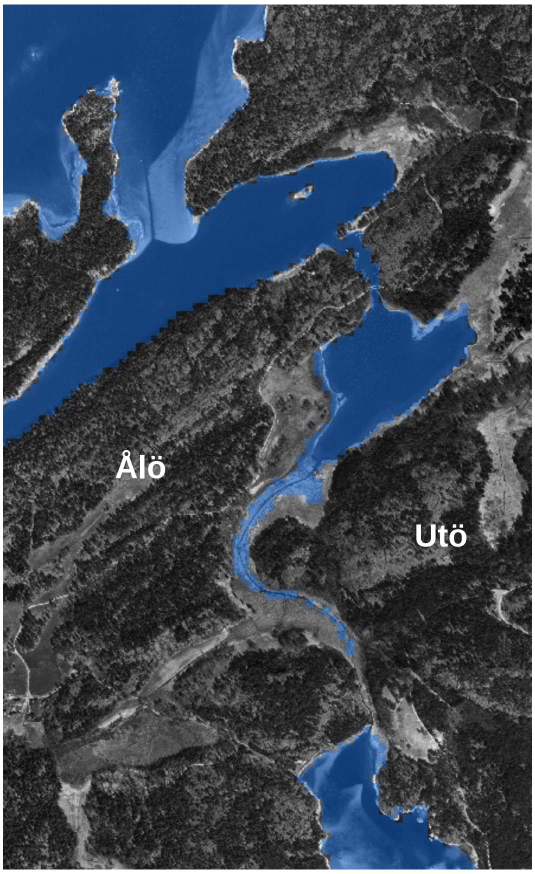


Figure 10. *Blue areas were classified as marine. The northern bay is directly connected to the Baltic Sea, as is the southern one. As a result, the intermediate parts of the network were also classified as marine.*

The picture also illustrates the resolution limitations. The narrow channel (less than 25 metres in width) was not automatically recognised all the way by the GIS with a raster resolution of 25 x 25 metres.

Mean water level and digital shorelines

The shoreline defined in the Geographical Sweden Data (GSD), provided by the National Land Survey of Sweden, is often acceptably precise and accurate. Large jetties and piers, however, have been unsystematically digitised as terrestrial in certain areas. This results in marine areas not being classified as marine as they are defined as terrestrial in the GSD maps. It would be easy but time-consuming to correct these errors.

The latest land use map, on which the shoreline is also based, includes several classes of wetlands, among them rough or impassable wetlands. These areas, however, often stretch from land into water with no indication of where the shoreline is located. This is a serious problem since emergent macrophytes are important habitats for fish reproduction (Casselman and Lewis 1996), for example, and it was important that they did not end up being classified as terrestrial habitats. With the help of an old shoreline, an attempt was made to model this aquatic vegetation (see below).

The reason why the GSD definition of the shoreline was chosen, rather than that of the Swedish Maritime Administration for example, was that the Stockholm County Administrative Board mainly uses digital maps created by the National Land Survey. When the Board wishes to combine information about the terrestrial and marine habitats, things are made much easier if the same shoreline definition is used. This approach is of course more pragmatic than scientific.

For this kind of work a clearly defined shoreline was needed. The National Land Survey and the Swedish Maritime Administration are currently working towards a mutual definition of the shoreline. Hopefully this cooperation will remedy some of the current problems with different definitions.

Modelling of aquatic vegetation in areas below mean water level

In 1996 the National Land Survey produced a land use map. At that time the possibility of dividing wetlands into different classes did not exist. According to Jan Sjöhed (2004) at the Land Survey, the purpose of the land use map was partly to delimit areas of real estate on land from those in water. The latest land use map incorporates several classes of wetlands, including rough or impassable wetlands. These areas, however, often stretch from land into water with no indication of where the shoreline is.

Since I needed both these types of information in a combined form, my general approach was to partition open (non-forested) rough or impassable wetland areas using the 1996 shoreline, in order to differentiate wetland areas below the mean water level from those above it. When this approach was discussed with Sjöhed (2004), he made a rough estimate that it would enable 80–90 per cent of this aquatic vegetation below the mean water level to be included.

The aerial photographs on which the 1996 land use map was based were taken on 9 July 1991 (Almgren 2004, personal communication), when the water level was 6–7 centimetres below normal (Gorringe 2004, personal communication). For the 2000 Fastighetskartan map the water level was 25–31 centimetres below normal. This might result in a smaller than normal area below mean water level. Interpretation of shoreline in areas with aquatic vegetation, however, is based more on indirect indicators such as vegetation structure and composition. The deviation from normal water level in the aerial photographs and the between-year difference in water level will therefore hopefully have a limited effect on the total area. Furthermore, this analysis should not be seen as complete, since it mostly only covers very dense aquatic vegetation such as reed belts.

Validation

Some validation of the geographical extent of level 1 marine habitats was performed in connection with the identification of lower level habitats. There is no doubt that most of the marine areas of Stockholm county are covered. The problems lie in the shoreline definition discussed above.
A really thoroughgoing demarcation of marine habitats would of course require sampling of salinity, in order to distinguish completely fresh from almost fresh water. Apart from areas with emergent macrophytes, harbours and other constructed areas, the shoreline definition is nevertheless precise enough for the aim of this study. Further validation is of course needed, but should be focused on habitats at lower levels.

EUNIS Habitat Levels 2–3 – Broad and main habitats

The subdivision of permanently water-covered habitats at level 2 is based largely on the mobility of the bottom substrate. To perform this subdivision, the marine geological map, which provides information about bottom material, was needed. Before using this map for the EUNIS habitat classification, I checked whether the EUNIS definition of a substrate matched that used by SGU for benthic material. It clearly did not. While the marine geological map categories are based on a stable state during a geologically short period of 50–100 years and focus on the dominant material in the upper sediment, which must be *at least* 50 centimetres deep, the EUNIS definition of the term *substrate* is “the mineral or organic matter forming a surface in or on which organisms can grow or attach” (Davies 2004, personal communication). To be able to classify EUNIS habitats, I firstly needed a knowledge of the biologically relevant surficial materials.

With the assistance of Anders Elhammer and Greger Lindeberg (SGU), therefore, I proposed a reclassification. Its aim was to make the map more useful for biological applications, presenting the most likely surficial material for each location, and then to reclassify these surficial materials in terms of the EUNIS substrates (see table 6). It emerged that, in some cases, the surficial material differs from the marine geological map category, especially in deeper areas. The EUNIS substrate classes, however, were more closely in accordance with the marine geological map, since some deposited material on substrates classed as hard is accepted.

It is important to note that this reclassification only indicates the potential surficial material or EUNIS substrate class, and that it is based on the assumption that the bottom surface has been exposed to energies in the form

Category according to marine geological map	Code	Generalised surficial material	Proportion correctly classified	Leads to EUNIS or comple-mentary substrate	Other EUNIS substrates found	Comments
Postglacial clay, gyttja clay and clay gyttja	1	mud	**1.0**	mud	–	–
Postglacial silt	2	silt/mud	**0.7**	mud	Non-mobile (hard) substrate (2)	–
Postglacial fine sand	3	fine sand	**0.8**	fine sand	Complex – mixed substrates (1) Mobile (sediment) substrate (possibly mud) (2)	–
Postglacial sand–gravel (mainly sand)	4	sand–gravel	**0.7**	sand–gravel	Non-mobile (hard) substrate (2). Complex – mixed substrates (3)	–
Glacial clay	5	sand–boulders	**0.9**	glacial clay	Mobile (sediment) substrate (possibly mud) (2)	Rather than concealing the diversity of this category I decided to create a separate *Glacial clay* class which is expected to cover the most common surface substrates found in the videos: Complex (mosaics of mobile and non-mobile substrates) (10) Sand and/or gravel (4) Non-mobile (hard) substrate – consolidated clay (7)
Glacial fine sand and silt	6	fine sand–silt (mud)	no estimate	muddy sand	-	No videos of this category found.
Glaciofluvial deposits	7	sand–boulders	**1.0**	complex (mosaics of mobile and non-mobile substrates)	–	Only four videos were found of this category. Until further validation has been done it must be expected that pure forms of substrates may also be found, although I will continue to use the complex class. Materials found: Complex (mosaics of mobile and non-mobile substrates) (2) Sand (1). Non-mobile (hard) substrate (boulder bottom) (1)
Till	8	sand–boulders	**0.8**	complex (mosaics of mobile and non-mobile substrates)	Mobile (sediment) substrate (possibly mud) (1)	–
Older sediments	9	mud–boulders in deeper areas (>15 metres)	no estimate	complex (mosaics of mobile and non-mobile substrates)	–	No older sediments exist in the county of Stockholm. It is most likely, however, that other deposited material ranging from mud to boulders in grain size will overlie the older sediments in deeper areas.
Artificial fill	10	–	no estimate	artificial	–	No videos of this category found.
Sedimentary bedrock	11	till	no estimate	sedimentary bedrock	–	No videos of this category found.
Crystalline bedrock	12	mud–boulders in deeper areas (>15 metres)	**1.0**	crystalline bedrock	–	Deposited material found: Boulders, cobbles, pebbles, gravel, sand and thin layers of deposited mud. The deposited material was sometimes pure and sometimes comprised mosaics of mobile and non-mobile substrates.

Table 6. *Reclassification scheme showing estimated accuracy. Some information about the basis for certain reclassifications is also given in the table. For more information about the reclassification see appendix 1.*

of waves or currents, for example, and that there is no ongoing sedimentation (except in areas where the marine geological map states this to be the case). This will not be true for all areas. But since information on exposure at greater depths is not available, the reclassification was used as presented.

For more information on how the reclassification was undertaken, see appendix 1.

Before reclassification, the marine geological map was interpolated 50 metres towards land in order to fill the gaps between land and water resulting from the use of different shoreline definitions. The interpolated areas are therefore probably not as accurate as the non-interpolated areas. All other areas not covered by the marine geological map, with the exception of the modelled aquatic vegetation (A5.5), lack the information required for a classification at EUNIS levels lower than 1. These areas have been presented as unclassified or unknown in the results.

Level 2 is further discussed in connection with the discussion of level 3 below.

Littoral habitats (A1 and A2)

No littoral habitats were classified in this study. Littoral habitats pose a special problem in the Baltic Sea. This is mainly because the tide in the Baltic proper (the part of the Baltic Sea where Stockholm county lies) only amounts to a couple of centimetres (L. Kautsky *et al.* 2000) and therefore this sea area has practically no littoral zone. The water level is, in fact, affected more by air pressure and winds (L. Kautsky *et al.* 2000), and the county has what is termed a hydrolittoral zone. This zone is defined by Davies and Moss (2004) as the "shores of non-tidal water which are regularly or occasionally exposed by the action of wind, and which lie below the mean water level". In a newly produced classification system for Baltic marine biotopes, Backer *et al.* (2004) define the hydrolittoral as the "periodically or occasionally emerging shoreline", extending approximately 0–0.5 metre below the mean water level.

The hydrolittoral is thus a diffuse boundary that is geographically limited along steep shorelines and increasingly wide, the flatter the shoreline is. Since highly resolved topographical data are lacking for this particular zone, it was impossible to identify the exact area. These habitats were also difficult to handle because of the resolution used. I used a 25-metre cell size and my guess is that that few, if any, hydrolittoral zones in the county of Stockholm are that wide.

This left a number of hydrolittoral habitats that were impossible to identify with GIS methods. A possible compromise could have been to buffer the shoreline with one cell that was defined and classified in terms of hydrolittoral habitats. Because of the 25-metre cell size, however, this would in most cases have grossly overestimated the extent of the hydrolittoral zone. On account of this, I chose to view the spatially limited hydrolittoral zone as part of the sublittoral zone and for the time being not to classify it as a separate zone.

There are, however, exceptions in both A1 and A2 which could and should be separately classified and which could quite easily have been identified with the help of either previous inventories, GSD or aerial photographs. These habitats are discussed below.

Features of littoral rock (A1.4)

Rockpools are found under *Features of littoral rock*. Rockpools could probably quite easily be identified from aerial photographs. And with the help of geological maps and photographs from more than one year it would most likely be possible to distinguish freshwater lakes from brackish rockpools dependent on water input from the sea. Aerial photograph interpretation, however, is time-consuming and additional resources would have been needed for a study of this type.

Coastal saltmarshes and saline reedbeds (A2.5)

The areas that could be identified as *Coastal saltmarshes and saline reedbeds* are mainly wetlands connected to the sea which either have a high water table or are periodically flooded due to changes in water level, i.e. they do not properly fit under the definition of the hydrolittoral zone, which states that the areas should be below the mean water level. It was therefore decided to leave these habitats for now and instead identify them in connection with a possible future classification of coastal habitats.

Infralittoral (A3) and *circalittoral* (A4) *rock and other hard substrata*

According to the criteria that distinguish *Infralittoral rock and other hard substrata* from *Circalittoral rock and other hard substrata*, it is necessary to know which areas are characterised by macroalgae. In order to obtain this information, a detailed field inventory of all coastal areas would have been necessary. For resource reasons, this was unfortunately impossible. Instead, a compromise approach was adopted. The infralittoral and circalittoral zones were schematically distinguished on the basis of maximum depths of 20–30 metres for macroalgae (H. Kautsky 2004, personal communication; Wallentinus 1976). The infralittoral was defined as comprising depths of 0–25 metres and the circalittoral depths of 25 metres or deeper. This schematic division of course exaggerates the extent of infralittoral habitats, since no account was taken of local Secchi depths or actual presence of macroalgae. The lack of long time series of Secchi depth data, however, made it difficult to assess whether the data that exist (KVVF 2004) are representative over longer periods of time or not. Rather than use short-term Secchi depth measurements, therefore, it was decided that the schematic approach should be adopted.

Crystalline bedrock, sedimentary bedrock and boulder bottoms identified by SGU make up the hard or non-mobile substrates that were identified in this study.

Level 3

Features of infralittoral (A3.7) and *circalittoral* (A4.7) *rock and other hard substrata*

Seeps, recently colonised artificial substrata, caves, overhangs, vertical rocks and surge gullies are included in the habitats *Features of infralittoral* (A3.7) and *circalittoral* (A4.7) *rock and other hard substrata*. It is probably possible to find overhangs, vertical rocks and surge gullies with the help of existing geographical information.

The surge gully effect, for example, with a back-and-forth or multi-directional water movement of great force may, according to Elhammer (2004, personal communication) arise between close-lying islands in the archipelago of Stockholm. These channels could be modelled with the help of data on topography, water depth and wave exposure. Unfortunately there was not enough time to explore these identification possibilities in this study.

According to Elhammer, there are no caves in the area.

Baltic exposed (A3.4), *moderately exposed* (A3.4) and *sheltered* (A3.6) *infralittoral rock and other hard substrata*

With the help of Martin Isæus (2005, personal communication), a subdivision of the EUNIS system's exposure classes *exposed, moderately exposed* and *sheltered* was undertaken. This subdivision should be considered preliminary, since a correct classification of the different areas requires an exposure classification that is more closely correlated with the biota. Isæus (2005, personal communication) intends to produce such a classification during 2005.

The land–sea maps which the wave exposure model used as input for calculating degrees of exposure were based on a more generalised National Land Survey map (Terrängkartan) than the one used for this study (Fastighetskartan). This may cause discrepancies between the two datasets and therefore constitute a source of error. The map on which the model was based also contained errors in certain areas. For example, some land areas were missing around the islands of Ornö and Fjärdlång in the municipality of Haninge in the southern part of the archipelago. This means that the degree of exposure is overestimated in these areas (Axelsson 2004, personal communication). Furthermore, the whole Södertäljeviken is missing. Judging from the surrounding areas, however, I have assumed this area to belong to the EUNIS class sheltered.

Baltic exposed (A3.4), *moderately exposed* (A3.4) and *sheltered* (A3.6) *circalittoral rock and other hard substrata*

Since information about currents in the study area is lacking and the wave exposure model is more likely to be relevant at shallower depths (Isæus 2004, personal communication), it was decided not to divide the circalittoral (25 metres and below) habitats into different exposure classes. At level 3 as well, therefore, these areas will be presented as at level 2, i.e. *Circalittoral rock and other hard substrata* (A4).

Validation

No validation was undertaken apart from the interpretation of video films of surficial material carried out in connection with the reclassification of the marine geological map categories (see appendix 1). This showed that some of the hard material, in all cases crystalline bedrock, was overlain by deposited material. This material could be everything from thin layers of mud – possibly temporary – to boulders, sometimes pure and sometimes mixed–complex. All of the video samples, however, were collected from depths of between 15 and 121 metres. Bare rock is probably more likely to be found above these depths, where wave erosion is more active (Elhammer and Lindeberg 2004, personal communication). However, in the EUNIS system (Davies and Moss 2004), non-mobile rock which is overlain by some deposited sediments follows the non-mobile (hard) path. Crystalline bedrock will therefore continue to be classified as non-mobile. Although no video samples of sedimentary rock were found, the same principle applies to this type of bedrock, which was consequently also assigned to the non-mobile (hard) substrates.

From a biological point of view, it would be interesting to distinguish bare rock from rock covered by deposits, since the different surficial materials most likely affect the basic conditions for organisms.

An analysis of both wave exposure and slope would be helpful in deciding whether or not the bedrock is likely to be overlain by deposited material. A generalised solution could be to divide the class into one shallow and one deeper category, the latter being more prone to be overlain by deposited material than the former. Since no videos from shallower areas were analysed, however, it was difficult to attempt such a division.

Sublittoral sediment (A5)

All mobile substrates according to the reclassified marine geological map were assigned to the habitat class *Sublittoral sediment*. Modelled aquatic vegetation below mean water level was also classified as sediment, since this vegetation is assumed to grow in soft substrates.

Since no division into infralittoral and circalittoral is necessary at level 2, the classification was quite straightforward once reclassification of the marine geological map had been performed.

Level 3

Animal-dominated sublittoral sediment (A5.1–A5.3) and *Macrophyte-dominated sublittoral sediment* (A5.5)

To demarcate the animal-dominated habitats (A5.1–A5.3) from the macrophyte-dominated habitat (A5.5), information about the occurrence of both macrophytes and animals is needed. Such information is unfortunately lacking, and the animal-dominated sediment habitats were therefore consolidated with the ones dominated by macrophytes. It is likely, however, that there exist areas classified as animal- or macrophyte-dominated which lack both flora and fauna. The different *Sublittoral sediment* habitats were classified according to the reclassification of the marine geological map (presented in table 6). Only aquatic vegetation identified in connection with the criterion permanently water-covered (see discussion of level 1 above) was classified as *Sublittoral macrophyte-dominated sediment*. When more information about the presence of macrophytes and animals is available, a better classification will be possible.

Sublittoral mixed sediment (A5.4)

Although combinations of substrates (A5.4) no doubt exist in the area (on some geographical scale), the information needed to identify the habitat *Sublittoral mixed sediment* is lacking and consequently no such identification could be attempted.

*Sublittoral biogenic structure*s (A5.6)

No information about biogenic reefs (A5.6) is available at present. *Sublittoral biogenic structures* therefore could not be analysed.

Features of sublittoral sediments (A5.7)

With the help of SGU and the marine geological map I was able to identify areas that seep gas. They are, according to Elhammer (2004, personal communication), more or less the same areas as those with ongoing sedimentation and the gas seeping is predominantly methane.

Organically enriched areas with permanent or periodic anoxia will be analysed during 2005, but their identification will not be complete before this report is finished.

Validation

No validation was undertaken apart from the interpretation of videos of surficial material carried out in connection with reclassification of the marine geological map (see appendix 1). The substrate class mud showed high accuracy in the video samples, although only a few could be interpreted for postglacial silt, which was also translated to the EUNIS class mud.

The EUNIS class fine sand could only be checked for the translation of postglacial fine sand. Of 20 videos interpreted 80 per cent were decided to be correct. No video samples of glacial fine sand and silt were found for the coastal waters of Stockholm county.

The sand or gravel class (coarse) was accurate in 70 per cent of the videos interpreted. This was decided to be good enough for our purposes.

A preliminary field visit was undertaken to check a very limited number of *Sublittoral macrophyte-dominated sediments*. In these areas dense reeds grew from land out into the water. The extent of the modelled sublittoral reeds may not be exact, but some of this habitat is definitely caught using the model and it may highlight areas that require further analysis.

Complex (X)

Three of the categories used in the marine geological map were reclassified as mixtures of mobile and non-mobile substrata according to EUNIS (see table 6): till, older sediments and glaciofluvial deposits. This resulted in their being assigned to X, *Complex habitats*. The infralittoral and circalittoral zones were distinguished in the same schematic manner as with *Rock and other hard substrata* (see discussion above).

Glaciofluvial deposits, however, are interesting in themselves since they seep freshwater (Elhammer 2004, personal communication). They should therefore be highlighted.

Validation

No validation was undertaken apart from the interpretation of videos of surficial material performed in connection with reclassification of the marine geological map (see appendix 1). Of the category glaciofluvial deposits, only four videos were viewed. The surficial material was predicted to be sand–boulders and this was found to be true in all the videos. However, only two showed a mixture of materials, while the other two showed pure sand or boulders. Until further videos have been interpreted it must be expected that pure forms of the materials involved may also be found in this category. In the meantime, the habitat class *Complex* (X) will be used.

Additional habitats and habitat compromises

Glacial clay

Glacial clay was the most problematic marine geological map category, since it showed a high diversity of surficial materials at different sampling locations (see appendix 1). Everything from soft bottoms to hard boulder bottoms was included within this class. Non-mobile and mixed mobility habitats clearly predominated, however. Rather than concealing this considerable diversity by placing glacial clay in either non-mobile or mixed mobility (i.e. complex) classes, it was decided to compromise and simply classify it as *Glacial clay* and explain that these areas can consist of just about anything from *Rock and other hard substrata* (mainly consolidated clay) to *Complex* (X).

The diversity of glacial clay is rather unfortunate, as this material makes up the seabed of at least 28 per cent of the marine areas of Stockholm county. Some of these areas are likely to include *Complex habitats* that may be of special interest from a conservation point of view. It is therefore important to see whether there is any means of further dividing this category into habitats made up of consolidated clay and those that are overlain by other deposited material.

Validation

No validation was undertaken apart from the interpretation of video samples (see appendix 1). This work is described above.

Artificial habitats

Since artificial habitats can be made up of more or less any type of surficial material, they will continue to be classified as artificial. According to the EUNIS system, artificial substrates with semi-natural aquatic flora or fauna should be integrated in either mobile (sediment) or non-mobile (hard) natural substrata (Davies and Moss 2004) and classified accordingly. Since data on substrate mobility and occurrence of biota in these artificial habitats are lacking, it seemed wise to highlight and keep track of them. Rather than place them somewhere in the habitat hierarchy on the basis of guesswork, the decision was made to classify them as *Artificial habitats*.

In the city of Stockholm, for example, there are a number of artificial habitats that will not feature in this classification project. This is unfortunate and I hope to be able to add this information at a later stage. Until then users may for example be able to use my study of shoreline development in Stockholm county (Mattisson 2004) to get a rough idea of the degree of artificiality.

Validation

No validation has been undertaken as yet.

Expanded EUNIS-inspired habitat list for Stockholm county

Since the EUNIS classification is rather coarse even at level 3, I decided to make a further subdivision based on the information available. This resulted in 58 different combinations of the physical factors used for the EUNIS classification. All the combinations have been used and presented, which means that classes such as *Shallow exposed mud* have also been created. These are highly unlikely to exist in reality. The areal extent of such combinations can, however, be seen as a pointer to how large such artefacts may be (see *Results*).

The large number of classes, though, may seem a little overambitious, and they certainly could not be presented in a thematic regional habitat map. This is not the intention, however. The expanded list is intended to work as a smorgasbord, from which it is possible to select the habitats which the user is especially interested in. If someone wishes to locate potential eelgrass areas, for example, it should be possible to seek out habitats containing sand in an appropriate depth interval and then look more closely at these areas. It is thus largely up to the user to search for the habitat or habitats that may contain the flora or fauna of interest. The hope is that the habitats I have chosen to highlight (see table 5) are relevant for the management and conservation of our marine habitats. If they are not, however, the list is easy to adjust, as long as there is a dialogue with map users. In appendix 4 a short review of the basic conditions for flora and fauna in the Stockholm archipelago can be found. That appendix also includes an explanation of roughly where each habitat belongs in the EUNIS system.

Validation

No validation was undertaken apart from the validation of EUNIS habitats.

Time, resource and availability limitations

Some of the EUNIS criteria were harder to map than others. For example, modelling or inventories of surge gullies, overhangs or presence of macro-algae were challenges in themselves and needed to be the subject of separate studies. Owing to the limited time and resources available, every idea and possibility in terms of identifying geographical information for each and every criterion could not be investigated. I have chosen to examine some of the criteria more thoroughly than others. The choices have been compromises between time/resource use and the importance of the criteria.

I have chosen to work more with criteria at higher levels, in order to be able to then work further down into the hierarchies. I have also focused on geographical information that is used for different habitats or at more levels than one (with different degrees of generalisation), e.g. EUNIS substrate classes.

Geographical information involving a cost has also been avoided, since this project had very limited scope for such outlays.

On account of the strategic importance of the Stockholm archipelago, all the existing geographical information was not available. The Stockholm County Administrative Board requested permission to use classified depth information from the Swedish Maritime Administration. At length, we were asked to withdraw the request pending a user availability classification of all Swedish marine areas. One of the classes will most likely be strictly non-available. This process will probably start in September 2005 and end in November of the same year (Moe 2005, personal communication). Because of this I had little choice but to continue working with less accurate data. Even if we are finally allowed to use certain classified data, there will probably be tight restrictions on how the results derived from them can be handled, used and presented. This restriction on availability and use is a major problem. At the same time, according to the head of security (Sjöquist 2004, personal communication), requests for depth and other information for use in environmental applications are becoming increasingly common. There is, in other words, a great need for this kind of information for environmental purposes.

EUNIS and habitat criteria

The EUNIS habitat criteria are intended to serve as keys for the identification of habitats. As well as the various criteria diagrams, there are explanatory notes. These notes explain how the criteria are to be applied and form an integral and essential part of the criteria (Davies and Moss 2004).

Definition of terms

It is important to read the explanatory notes, as they contain exceptions and explanations of the meaning of the criteria. There are additional dimensions to consider when using the criteria, however. Definitions of terms are extremely important, and it is essential that the information we use is in accordance with the definitions presented in the glossary at the EUNIS habitat application website. If it is not, there is a great risk of errors and confusion.

The term *substrate* can serve to illustrate the importance of well-defined terms. When I started working with the EUNIS substrates, a definition of this term was still lacking (there is one now). Since most marine geological information comes from marine geologists who have different objectives than biologists, it was important to find out what different people meant by the term *substrate*. SGU defines the bottom material (*substrate*) as the material that is considered to give the bottom its dominant character. The depth of this characteristic material must be more than 50 centimetres (Elhammer 2004, personal communication). This definition mirrors what a marine geologist considers it important to analyse. It is less interesting, though, for a marine biologist who is more concerned with the surface and the upper few centimetres of the substrate (H. Kautsky 2004, personal communication; Cederwall 2004, personal communication). This is reflected in the EUNIS definition of the term *substrate,* which is “the mineral or organic matter forming a surface in or on which organisms can grow or attach” (Davies 2004, personal communication). With the help of marine geologists, I examined and attempted to reclassify the marine geological substrates in terms of what biologists mean by substrates, i.e. the surficial material, and then to reclassify them once more in terms of the EUNIS substrate classes. If terms are not clearly defined for all the individuals involved, from different disciplines, there is a great risk of information being used incorrectly and consequently of the wrong habitats being identified. In this case it was apparent that the EUNIS substrate classes agreed fairly closely with the original marine geological map categories, even thought the surficial material did not. This is due to the fact that EUNIS accepts some deposited material on hard substrates such as crystalline and sedimentary bedrock.

Top–down and bottom–up

When using the EUNIS criteria for different habitats, we need to be clear about what it is we want to identify and on what scale we want to identify it. For example, when asking whether a substrate is mobile or not, we need to know what kind of environment we want to identify by using this criterion. It is essential to look down the hierarchy and check whether the “right” habitat results at the lower levels when we use a certain classification of *mobile* and *non-mobile*. This is especially important, given that the classification of the lower levels for the Baltic is far from complete. If the “right” habitat does not emerge, then either the habitat is placed in the wrong branch or we have used the information in the wrong way or else misunderstood the definition of the criterion.

Reuse and transformation of the marine geological map

Reclassification of the categories used for the marine geological map into probable surficial materials and EUNIS substrates was undertaken on the basis that surficial material is what is most relevant to organisms (H. Kautsky 2004, personal communication). However, this gives us only the probable distribution, based on the dominant bottom material from a marine geologist's point of view. It also presupposes erosion, which is not necessarily occurring in all areas. In addition, all areas with ongoing sedimentation have not been identified. It is only those with sedimentation from 1850 onwards (Elhammer 2004, personal communication) that have been classified as areas with recent sedimentation. It must be stressed therefore that the map of surficial materials is a map showing the *potential* distribution. Information about exposure (waves, currents) and bottom topography would answer more questions, but much of this information is limited in either availability or resolution, or both. It is necessary to make these types of uncertainties clear in the maps that are produced. An understanding of the limitations of such maps is fundamental to any use of them. It would therefore be beneficial to prepare uncertainty maps for the habitat maps produced.

In *Context sensitive transformation of geographic information* by Ola Ahlqvist (2000), methodological approaches for this type of transformation and reuse of geographical data are presented. It would be of interest to investigate whether these methodologies might be of assistance in analysing and presenting spatial, temporal and thematic uncertainties.

Spatial uncertainty

A map of spatial uncertainty could be more or less complicated. The basic idea is to classify the degree of certainty with which the classification has been made. If interpolated values have been used, for example, the accuracy of the map is greater the closer you come to the sampling locations on which the interpolation was based.

The marine geological map is less accurate in shallow areas (Elhammer 2004, personal communication). In future SGU plans to attach maps that show with what certainty an area has been classified. This will also benefit the habitat maps created.

Scale

Spatial scale

The aim of this project was to develop a method of making maps of marine habitats, in order to begin work on the identification of valuable marine areas. In order not to drown in detail, we needed to keep to the big picture and stick to the upper levels of the EUNIS hierarchy, at least to begin with. But what scale is really needed? And what is it that we need to capture and represent in our digital maps? Is it individual habitats? Or might it in some cases be complexes of habitats?

For example, in the Stockholm archipelago there are plenty of small islands, islets and skerries. Some areas are therefore mosaics of patches of water and skerries, for example. These can be captured as individual features, but perhaps it is the mosaic land/seascape we are interested in, rather than the individual habitats. We also have a mosaic landscape on the seabed – what is known as patchiness (Elhammer 2004, personal communication). This mosaic is probably interesting in itself and it would be beneficial to be able to identify it. It will be difficult, however, to identify mosaics of features smaller than 25 metres, since this is the resolution used for the present project.

But perhaps the 25 metre resolution is higher than we need for our long-term overall aim of identifying and conserving valuable marine areas of the Baltic Sea. How highly resolved data do we need for this? For Stockholm county, high-resolution marine geological data are available; for most other parts of the country, only coarse data exist. It would be interesting to see what is lost if we use a coarser scale in the county of Stockholm. In that way we would know more about the limitations for areas for which only coarse data are available.

Timescale and dynamic seascapes

In this type of project, where the aim is to conserve marine natural areas in the long term, it is crucial to consider the question of timescale. This is not easy, however, given that the information we are using can often be based on one sample or a short time series. It is thus almost impossible not to mix information with different timescales. If we cannot compensate for these differences, through transformation or some such procedure, we must at least try to analyse and be aware of the effects that might arise from this mixture.

What will be the consequences, for example, if we use single samples instead of long time series and then use the habitat classification maps to set aside marine protected areas (MPAs)? Will the MPAs still be consistent with our current goals in 50–100 years’ time? How much can future habitats potentially differ from existing ones?

Other questions relating to time include:

- How are we to handle ephemeral habitats? Is there a need to highlight these types of habitats? Are they spatially stable and do they appear at certain intervals or are they completely random?
- Is there some kind of succession in marine habitats that needs to be acknowledged and identified? And in what way are such successions to be presented and handled?

- Should the best-case or worst-case scenario be modelled? Or should we use both? For example, it is suggested that anthropogenic eutrophication and increased phytoplankton concentrations are indirectly responsible for observed losses of macrophyte cover, as a result of reduced light levels (Domin *et al.* 2004.). How do we handle this? Should we try to model pristine depth limits for macrophytes or should we use present depth limits? If we model more pristine depths we will arrive at the potential but not the actual macrophyte cover. But if we use the current depth limits we are restricting ourselves to present conditions which, hopefully, might change for the better, with less eutrophication and a recovery of macrophyte cover in the future.

Improvements and refinements

Several ways of improving the habitat maps produced exist. The models used may be refined; more accurate and precise data that only exist for certain areas may be used. The sky is the limit. This work is a test of whether this type of modelling is worthwhile and whether the EUNIS system works in the archipelago areas of the Baltic proper. If validation of this study shows that new knowledge about our marine habitats can be obtained by combining different types of information, it is my opinion that complementary studies should be undertaken to improve the model as a whole. As it is now, I have given certain habitats priority over others which may very well be identified with further effort (such as surge gullies, overhangs etc.).

To my present knowledge, realistic areas for improvement and refinement include:

- Complementing the identification of habitats:
    - in shallow shoreline areas, using the soil map (SGU),
    - with investigations of the seafloor of Baltic Sea archipelagos (Jonsson (ed.) 2003),
    - with shoreline information based on satellite imagery (Philipson and Lindell 2003),
    - with data on identified marine Natura 2000 habitats (Axelsson 2003; Cato *et al.* 2003),
    - with information about the surficial structure of the bottom (if it is possible to access this kind of information),
    - with information on existing currents (if it is possible to access this kind of information),
    - with information on bottom topography and bottom diversity (from a morphological point of view) (if it is possible to access this kind of information),
    - with slope models, to improve the classification of surficial material (if it is possible to access this kind of information),
    - etc.

- Producing models/methods to identify
  - surge gullies,
  - overhangs,
  - potential presence of macroalgae,
  - etc.
- Interpreting and identifying hydrolittoral and certain sublittoral habitats (some of them macrophyte-dominated) with the help of aerial photographs.
- Investigating how spatial, temporal and thematic uncertainties might be analysed and presented. Fuzzy GIS is a possible means.
- A more scientific approach involving detailed reviews of the literature.
- Greater attention to conservation objectives, timescales and dynamic marine seascapes.
- Identifying and classifying coastal habitats using the same methodological approach, to complement the overall picture.
- Increased cooperation with specialists in relevant fields.

Concluding discussion

The primary aim of this study was to find a method to produce a basic map of the underwater marine environments of Stockholm county. This has been achieved. I have produced three digital maps in as close accordance as possible with the top three habitat levels of EUNIS. I have also produced an expanded list of different combinations of physical factors structuring the flora and fauna of the Baltic.

Sources of errors and a time for validation

There are of course quite a few sources of errors and I have referred to many of them when discussing particular habitats, the reuse of geographic information, spatial uncertainties and different types of scale. Some of these errors might be reduced by the actions suggested in the *Improvements and refinements* section.

At a more general level, the original errors in the geographical data used will of course also remain in the maps presenting my results. Many of them might even have been amplified by the procedures employed. Some of these errors are known and have been discussed in relevant parts of this report, but there are, I am sure, other artefacts, errors and shortcomings which at present are unknown.

All of the above shows just how important a thorough validation is. Unfortunately, there has been almost no time for this. It is my hope that some validation will be performed during 2005, although this is not certain at the time of writing. It is therefore important that the maps are used in combination with other information and that no conservation decisions regarding these areas are made on the basis of the results before field inventories have been carried out. It is also important to bear in mind that the depth delimitations are more generalised, compared with EUNIS substrates and degree of wave exposure, since the resolution of the depth data was coarser and in many areas inadequate.

Knowledge about the sea

Access to absolutely essential data such as bottom material and degree of wave exposure has been good. For depth data the situation has been less favourable. Highly resolved data do exist for many areas, but for military reasons access to them is often completely restricted.

The resolution of the data used has nevertheless been high, and they have been produced by experts in different fields. Depth information naturally had a lower resolution (50 x 50 metres) than other data. This is a major problem, as depth has a decisive influence on the type of organisms to be found on the Baltic seabed. Accurate, highly resolved depth data would permit further analysis of bottom complexity, i.e. it would be possible to perform topographic analyses and identify areas with high bottom diversity, which may harbour high biodiversity.

EUNIS and the coastal waters of Stockholm

So far, the upper three levels of EUNIS (1–3) have worked well, although some compromises have been necessary, mainly owing to lack of data.

In my opinion, though, it is not ideal to require detailed biological information at the more general levels. I had good access to marine geological information and was therefore able to produce a detailed subdivision of substrates at level 3, whereas, in a large-scale perspective, almost no information was available about organisms. My guess is that this situation is fairly common as regards other areas as well.

For hard substrates, the problem with the criterion *macrophyte-dominated*, which distinguishes the infralittoral from the circalittoral, was solved by a compromise whereby the maximum depth for algae was chosen to schematically separate the two. For sediment bottoms, each *animal-dominated* substrate class was consolidated with *Macrophyte-dominated sediments* (A5.5), i.e. it was stated that, for example, a sand bottom in the sublittoral zone could be either animal- or macrophyte-dominated, but we do not know which. Since the EUNIS system does not use depth ranges, there is no way to simply look at the EUNIS map and say that an area is more likely to be dominated by animals rather than macrophytes. This is a pity, since being able to do so would greatly enhance the informative value of the maps.

In view of this experience, I believe that it would be better to make more use of the basic conditions for biota, to work with more detailed combinations of structuring factors such as substrate, depth range and degree of wave exposure, rather than asking questions about organisms that often cannot be answered without extensive field surveys. The knowledge about physical factors available at the Stockholm County Administrative Board, for example, is good, and it enabled a more detailed non-EUNIS subdivision of habitats to be made, based on physical parameters alone.

Since the EUNIS classification of the lower levels has yet to be finalised for the Baltic Sea, it is difficult to say whether the upper ones are functional or not. The lower habitat classes have to be placed under the higher classes, and it does not go without saying that all habitat classes will fit neatly into existing higher ones. It is not entirely clear, for example, whether seeping methane actually affects organisms in any way (Cederwall 2004, personal communication). If they are not affected at all, it may be inappropriate that areas with ongoing sedimentation and/or animal-dominated communities are hidden in the diverse class *Features of sublittoral sediment* at level 3.

Conclusions

Since almost no validation of the results has been undertaken, it is difficult to conclude whether I have done a good job or not. This material is not to be regarded as the final word, however. There are, for example, additional methods and models that can be used to identify potential areas for eelgrass meadows. At the moment, though, it seems wisest to focus mapping on a fairly general level, working with existing data on physical factors. The more models and predictions that are added, the more uncertain the maps are likely to become, at least given the relatively coarse data we possess and the scale that I have used.

However, the County Administrative Board now has at its disposal a comparatively reliable map showing general patterns and conditions for flora and fauna in different areas of the Stockholm archipelago. On the basis of this material, it will be possible to explore further various more or less specialised questions or issues, whether it be bladderwrack belts or the occurrence of eelgrass meadows.

Hopefully this work will contribute to a discussion about what types of physical factor combinations or additional information are needed for the identification, management and conservation of marine areas in the county of Stockholm. This will make the next generation of habitat maps better and more relevant.

The final conclusion of this work is that a great deal of information and knowledge and a range of different models exist concerning the underwater marine areas of Stockholm county. Combined, this knowledge should be sufficient to embark on a practical endeavour focused on achieving the Swedish environmental quality objective *A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos* and on securing the management, protection and conservation of valuable and representative marine environments.

Appendices 1–4

1. Reclassifying the marine geological map for biological applications
2. Criteria diagrams with explanatory notes for a EUNIS habitat classification
3. Descriptions of relevant EUNIS habitats down to level 3
4. A short review of the basic conditions for marine flora and fauna in the county of Stockholm

Appendix 1. Reclassifying the marine geological map for biological applications

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Abstract

With the help of marine geological expertise, an attempt was made to predict the surficial material of each of the marine geological map categories for the county of Stockholm.

The predicted surficial materials were checked against video films that had been shot at most of the sampling locations. Most of the predictions showed a high level of accuracy. Correction and additional information were necessary, however, for some of the categories, namely *Postglacial silt* and *Crystalline bedrock*. Owing to its high diversity, ranging from mobile to non-mobile surficial materials, *Glacial clay* was given a class of its own. For the categories *Glacial fine sand and silt*, *Older sediments*, *Artificial fill* and *Sedimentary bedrock* no video samples were found in the area. Possible reclassification classes are discussed for each of them, however.

For some categories, e.g. *Glaciofluvial deposits*, video samples were so few in number that a trend could not be recognised for the predicted surficial material. These categories will be highlighted as unique classes and/or thorough reclassification descriptions, in order to avoid misunderstandings of the maps.

The most likely surficial materials were then reclassified, as far as possible, according to the substrate classes used in the EUNIS (European Nature Information System) classification system, in order to arrive at a habitat classification of the marine areas of the county of Stockholm. Interestingly, the EUNIS substrate classes were more in accordance with the original categories of the marine geological map, since some deposited material is accepted for hard substrate classes.

Background

The Stockholm County Administrative Board is currently attempting to prepare a predictive map of the marine habitats to be found within the county borders. This geographical information is of great importance in identifying valuable marine areas that may be potential candidates for marine protected areas, which the County Administrative Board is required to designate in the near future.

The habitat classes that were used for the predictive habitat map originate from EUNIS. EUNIS is a hierarchical classification system for all European habitats, natural and artificial (EEA 2004). Its purpose is to facilitate harmonised description and collection of data, with the help of criteria for habitat identification. The classification system is linked to and compatible with other habitat systems used in Europe. Since the Baltic Sea lacks a coherent classification system, it seemed wise to try to use this pan-European system as a basis for classifying the marine areas of the county.

Appendix 1

One important source of information was the marine geological map produced by the Geological Survey of Sweden (SGU). In order to use this map for a EUNIS habitat classification, I needed to check whether the EUNIS definition of a substrate matched that used by SGU. It clearly did not. While the marine geological map classification is based on a stable state during a geologically short period of 50–100 years and focuses on the dominant upper part of the sediment that is at least 50 centimetres deep, the EUNIS definition of *substrate* is: “the mineral or organic matter forming a surface in or on which organisms can grow or attach” (Davies 2004, personal communication). In other words, what I needed for the habitat classification was the biologically relevant surficial material, which in many cases may differ from the marine geological category.

In the Baltic Sea three main types of bottom exist: erosion bottoms (zones of erosion), transport bottoms (zones of sediment transport) and accumulation bottoms (zones of accumulation) (Kautsky *et al.* 2000). Currents sweep fine material from erosion bottoms and leave behind a coarser material. The fine material is transported and settles temporarily on transport bottoms, before being swept away to accumulation bottoms, where it settles for good. Zones of accumulation are found in calm areas, often in deep depressions. They represent the commonest type of bottom in the archipelago below a depth of 15 metres (Kautsky *et al.* 2000). The marine geological map contains information about where the majority of accumulation bottoms occur, and it is therefore likely that the other areas are zones of either transport or erosion. Accumulation bottoms on the marine geological map should have a surficial material that matches the category to which they are assigned, while transport and erosion bottoms may have a different surficial material. The surficial material of erosion bottoms is called residual. The marine geological map does not incorporate any classification based on residual material. However, according to Elhammer (2004, personal communication), it is possible to generalize the residual material from the category of benthic material.

The residual material consists of larger particles that are left after the finer sediment has been eroded from the original or primary sediment (Elhammer 2004, personal communication). The size of the residual particles depends on the composition of the primary sediment and the type of energy they have been exposed to. On transport bottoms the primary sediment may be overlain by a thin layer of transported material, e.g. fine sand.

On the basis of the above, an attempt was made to predict the surficial material for each marine geological map category. The results are presented in table 1 under *Method*. The aim of this study was to see how correct these predictions were and then to try to reclassify them according to the EUNIS substrate classification.

Material and study area

Material

- SGU's digital marine geological map – locally and regionally mapped areas (see figure 1).
- Underwater videos filmed by SGU at its sampling locations in the county of Stockholm (see figure 1) and at one in the county of Södermanland.
- Field notes for the videos.

Study area

The study area has the same extent as the marine geological map and covers most of the coastal waters of the county of Stockholm, as well as a small northern part of the county of Södermanland. The study area and the sampling locations (triangles) are shown in the left-hand map in figure 1.

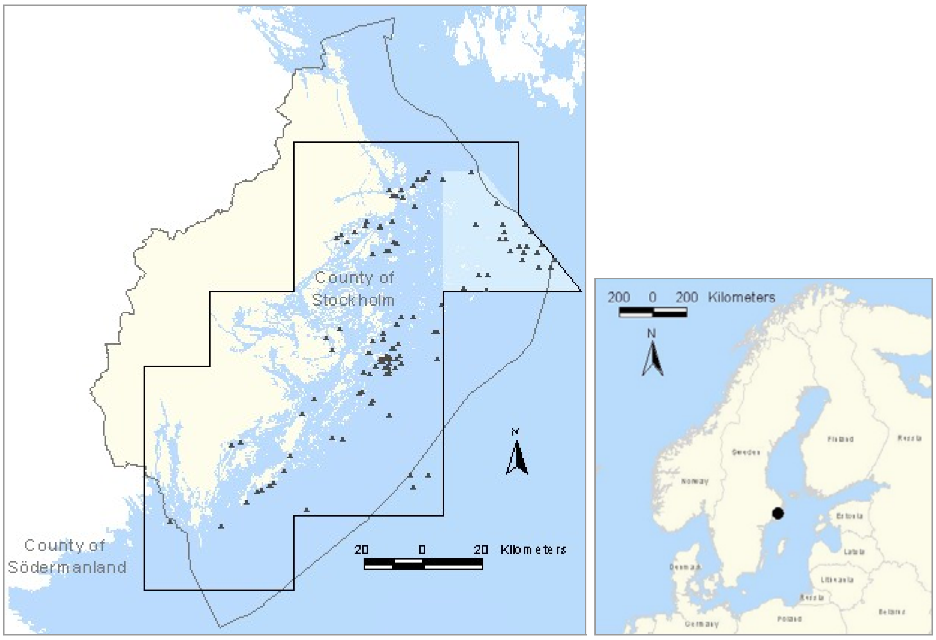

Figure 1. *The study area is outlined in black in the left-hand map and marked as a dot in the location map to the right. The sampling locations used are marked as triangles on the map to the left. The lighter area in the north-eastern part of the study area has been regionally mapped at a higher level of generalisation than the rest of the area, which has been locally mapped.*

Appendix 1

Method

The surficial materials associated with each of the marine geological map categories were predicted by Anders Elhammer of SGU (2004, personal communication). These predicted materials were then reclassified in terms of the EUNIS substrate classes, which are also classified as either mobile (sediment) or non-mobile (hard) substrates. According to Elhammer (2004, personal communication), bottoms with *Till*, *Glaciofluvial deposits* and *Older sediments* can have all grain sizes between sand and boulders. These classes were reclassified as habitat complexes according to the EUNIS system. Habitat complexes are defined as mosaics of both mobile and non-mobile substrates.

Predicted surficial materials and the EUNIS substrate reclassification are presented in table 1.

Category according to marine geological map	Predicted surficial material	Leads to EUNIS substrate
Postglacial clay, gyttja clay and clay gyttja	mud	mud (mobile)
Postglacial silt	silt/mud	mud (mobile)
Postglacial fine sand	fine sand	fine sand (mobile)
Postglacial sand–gravel (mainly sand)	sand–gravel	sand–gravel (mobile)
Glacial clay	sand–gravel	sand–gravel (mobile)
Glacial fine sand and silt	fine sand–silt (mud)	muddy sand (mobile)
Glaciofluvial deposits	sand–boulders	complex (mosaics of mobile and non-mobile substrates)
Till	sand–boulders	complex (mosaics of mobile and non-mobile substrates)
Older sediments	sand–boulders	complex (mosaics of mobile and non-mobile substrates)
Artificial fill	–	artificial (mobile or non-mobile)
Sedimentary bedrock	sand–boulders (till)	sedimentary bedrock (non-mobile)
Crystalline bedrock	possibly cobbles–boulders	crystalline bedrock (non-mobile)

Table1. *Marine geological map categories reclassified in terms of probable surficial materials according to Elhammer (2004, personal communication). The surficial materials have subsequently been reclassified as EUNIS substrates.*

The aim was to interpret at least ten videos for each category, spread over the study area in order to be geographically representative of the county. This did not prove possible, however. For several of the categories few video recordings were available, some videos were of poor quality and some categories only existed in certain areas in the county. In addition, if a given category showed a high diversity of surficial materials, more videos were watched in order to try to find a trend by increasing the number of samples.

The videos were viewed on a television screen and the surficial material was interpreted and subjectively classified according to the classes in table 1. SGU field notes, which provided additional information about both the surface and the underlying material, were a helpful source for the interpretation. The scale of the pictures was shown by decimetre markers on the camera stand. These were not always in the picture, however. The accuracy of prediction was then calculated in a simple manner, as the number of correct reclassifications divided by the total number of reclassifications for each category.

Results

The results and proportions of accurate predictions for each of the marine geological map categories are found in table 2.

Appendix 1

Category according to marine geological map	Code	Predicted surficial material	Leads to EUNIS substrate	Number of determinable sites checked	Correct (number)	Incorrect (number)	Proportion correctly classified	Other EUNIS substrates found	Comments
Postglacial clay, gyttja clay and clay gyttja	1	mud	mud	15	15	0	**1.0**	–	
Postglacial silt	2	silt/mud	mud	6	4	2	**0.7**	Non-mobile substrate (2)	Only six videos of this category were found.
Postglacial fine sand	3	fine sand	fine sand	15	12	3	**0.8**	Complex (1). Mobile substrate (possibly mud) (2)	
Postglacial sand–gravel (mainly sand)	4	sand–gravel	sand–gravel	17	12	5	**0.7**	Non-mobile (hard) substrate (2). Complex (mosaics of mobile and non-mobile substrates) (3)	
Glacial clay	5	sand–gravel	sand–gravel	23	4	19	**0.2**	Complex (10). Mobile substrate (possibly mud) (2). Non-mobile substrate – consolidated clay (7)	
Glacial fine sand and silt	6	fine sand–silt (mud)	muddy sand	–	–	–	no estimate	–	No videos of this category found.
Glaciofluvial deposits	7	sand–boulders	complex (mosaics of mobile and non-mobile substrates)	4	4	0	**1.0**	–	Only four videos of this category were found: two of the locations had mixed (complex) substrates, the other two were pure forms, one sand and the other boulders.
Till	8	sand–boulders	complex (mosaics of mobile and non-mobile substrates)	12	11	1	**0.9**	Mobile substrate (possibly mud) (1)	
Older sediments	9	sand–boulders	complex (mosaics of mobile and non-mobile substrates)	–	–	–	no estimate	–	No older sediments exist in the county of Stockholm.
Artificial fill	10	–	artificial (9)	–	–	–	no estimate	–	No videos of this category found.
Sedimentary bedrock	11	sand–boulders (till)	sedimentary bedrock	–	–	–	no estimate	–	No videos of this category found.
Crystalline bedrock	12	possibly cobbles–boulders	crystalline bedrock	23	16	7	**0.7**	Relatively firm bottom (3) Sand bottom (3) Firm bottom (1)	Deposited material observed: Boulders, cobbles, pebbles, gravel, sand and thin layers of deposited mud. The deposited material was sometimes pure and sometimes complex.

Table 2. *Results. Predicted surficial materials. Number of video samples viewed, proportion correctly predicted for each category, and other surficial materials found at sites in each category.*

Appendix 1

Discussion

Postglacial clay, gyttja clay and clay gyttja showed the highest accuracy of prediction, the predicted surficial material and EUNIS substrate class being mud. Of the 15 videos watched, all were interpreted as mud.

Only six videos were viewed for the category *Postglacial silt*, and four of these were interpreted as silt/mud and two as having a hard surficial material. This is hardly a sufficient number to calculate accuracy. However, since four out of six were interpreted as silt/mud, we will continue to use this class for the reclassification of *Postglacial silt*.

Twenty videos were watched for the category *Postglacial fine sand*, which had been predicted as having a surficial material of fine sand. Of the videos, five were indeterminable because of what were most likely temporary mud layers or poor video quality. Grainy pictures also made it difficult to decide whether or not the bottom material was made up of sand. Of the 15 videos that could be interpreted, 12 were interpreted as correct and three as incorrect. The proportion of accurate reclassifications was calculated as 0.8, which was decided to be satisfactory. The EUNIS substrate class was also determined to be fine sand.

The accuracy for *Postglacial sand–gravel (mainly sand)*, with the surface prediction of sand–gravel, was calculated as 0.7. Of the 18 videos viewed, five were interpreted as other material, while one could not be determined. The degree of accuracy was decided to be good enough for our purposes. The relevant EUNIS substrate class was determined to be sand–gravel.

Glacial clay was the most problematic category, since the surficial materials found at different sampling locations varied considerably. The surficial material had been predicted to be sand–gravel, but this category was found to include everything from mobile (sediment) substrates to non-mobile (hard) boulder bottoms. Of the 23 videos viewed, ten were interpreted as complexes (mosaics of mobile and non-mobile materials), four as sand and/or gravel and seven as consolidated clay. Two were constituted of finer material; these two did not form the basis for any amendment of the reclassification, however. Rather than concealing the great diversity of this category by placing it in either a mobile or a non-mobile surficial material class, I decided to simply classify it as *Glacial clay* and explain that these areas can consist of just about anything from consolidated clay to boulder bottoms, but that the EUNIS class complex (mosaics of mobile and non-mobile substrates) best fitted the surficial materials found.

For the category *Glaciofluvial deposits*, only four videos were found in the study area. The surficial material was predicted to be sand–boulders and this was found to be true for all four video samples. However, only two showed a mixture of substrates, whereas the other two were pure forms of either sand or boulders. Until further videos have been interpreted it must therefore be expected that pure forms of the surficial materials involved may also be found in this category. For now, however, I will continue to reclassify the surficial material of *Glaciofluvial deposits* as the EUNIS class complex (mosaics of mobile and non-mobile substrates).

The reclassification of *Till* as sand–boulders gave an accuracy of 0.9. Of 13 video samples, one showed this reclassification to be incorrect and one could not be interpreted. The EUNIS substrate class was set to complex (mosaics of mobile and non-mobile substrates).

Crystalline bedrock also proved to be a highly diverse category. The surficial material had been predicted as either bare rock or possibly cobbles to boulders. Of the 23 sites interpreted, only one showed bare rock surrounded by deposited material overlying the rest of the bedrock. The deposited material observed in the videos consisted of everything from thin layers of mud – possibly temporary – to boulders, sometimes pure and sometimes complex (mosaics of mobile and non-mobile surficial materials). All of the samples, however, were from depths between 15 and 121 metres. Bare rock is more likely to be found above these depths, where wave erosion is more active (Elhammer and Lindeberg 2004, personal communication). However, according to the EUNIS system (Davies and Moss 2004), non-mobile rock which is overlain by some deposited sediments follows the non-mobile (hard) path. *Crystalline bedrock* will therefore continue to be classified as non-mobile crystalline bedrock, with the explanation that in many cases it will be overlain by deposited mud–boulders in low energy areas, which are often the deeper areas. An analysis of slope and wave and current exposure would help to decide whether the bedrock is more or less likely to be overlain by deposited material.

Non-sampled categories

Of the 12 categories included in the marine geological map, four were not documented by videos from the study area: *Glacial fine sand and silt*; *Older sediments*; *Artificial fill* and *Sedimentary bedrock*.

Since artificial can include more or less any type of material, we will continue to classify it as artificial. According to the EUNIS system, artificial substrates with semi-natural aquatic flora or fauna should be integrated in either mobile (sediment) or non-mobile (hard) natural substrata (Davies and Moss 2004) and classified accordingly. Since we have no knowledge about either the mobility or the biota of these artificial habitats, it seems wise to highlight and keep track of them and we will therefore show them as artificial habitats, rather than guess where they belong in the habitat hierarchy.

Older sediments do not exist in the study area and are therefore no problem for the county of Stockholm, although they still need to be verified for the rest of Sweden.

For the marine geological map category *Sedimentary bedrock* the predicted surficial material was till, i.e. sand–boulders. In the EUNIS system (Davies and Moss 2004), however, non-mobile rock which is overlain by some deposited sediments follows the non-mobile (hard) path. *Sedimentary bedrock* will therefore, like *Crystalline bedrock* (see discussion above), be classified as non-mobile sedimentary bedrock, with the explanation that in many cases it will be overlain by till.

The predicted surficial material fine sand–silt (mud) for the category *Glacial fine sand and silt* should, according to Elhammer (2004, personal communication), be a correct reclassification in most cases and I will therefore not change it at present. This links it to the EUNIS substrate class muddy sand.

Sources of errors

Several factors made interpretation of the videos difficult. The picture was often grainy, which in some cases made it difficult to impossible to determine the grain size of the surficial material. This was especially the case for fine sand. The scale of the pictures was shown by decimetre markers on the camera stand, but these were not always in the picture. The scale of the picture could also be difficult to assess when the objects observed were far from the camera stand. It was also a very subjective decision whether pebbles or cobbles were to be classified as mobile, and thus defined as sediment according to the EUNIS system, or non-mobile, which would make the substrate non-mobile (hard) (Davies and Moss 2004).

In many areas it is common to find a thin layer of mud that is deposited during shorter or longer periods of low water movement. Such layers, however, are to be considered as temporary and could be swept away in a matter of days if water movements increase due to increased wind speed or current activity (Lindeberg 2004, personal communication). When viewing the videos, though, it could at times be difficult to assess whether a mud layer was thin or not.

Due to a lack of marine geological training, the interpreter (in this case Annelie Mattisson, a biologist) may have made more or less serious misjudgements concerning the interpretation of the surficial material. It is also important to stress that when it comes to image interpretation we are dealing with precisely that, *interpretation*. And interpretation will always be subject to the knowledge or lack of knowledge of the interpreter. He or she will look at the picture and colour the results with his or her background. This may in many cases be a good thing, bringing new angles to traditional knowledge, but there will always be situations when things are overlooked because of it.

Regional mapping compared to local mapping

Of more than 120 videos viewed, 24 came from the regionally mapped north-eastern area of the coastal waters of the county of Stockholm. Since this study is based on individual SGU sampling locations, it probably makes little difference whether an area has been regionally or locally mapped. This is because the individual samples were used to prepare the marine geological map. The classification of each individual sampled location is therefore more likely to be correct than that of areas far from it (depending on the type of interpolation of results from sampling sites).

The videos were also shot in the same manner, regardless of whether an area was investigated regionally or locally. The overall accuracy of the regional map is of course a different matter, but that was not what was being tested in this study.

Other areas

This study was mainly performed in marine areas of the county of Stockholm. According to Elhammer (2004, personal communication), the trends shown in this study are most likely to be valid for other marine areas of Sweden. A statistically more thorough investigation of all categories, spread over all marine areas of Sweden, should however be performed.

Suggested reclassification scheme

The reclassification scheme set out in table 2 was changed in the light of the results and the discussion above. This produced the amended reclassification scheme found in table 3. Until further validation has been performed, this scheme will be what the county of Stockholm will use for further work on the classification of marine habitats.

Appendix 1

Category according to marine geological map	Code	Generalised surficial material	Number of determinable sites checked	Correct (number)	Incorrect (number)	Proportion correctly classified	Leads to EUNIS or complementary substrate	Other EUNIS substrates found	Comments
Postglacial clay, gyttja clay and clay gyttja	1	mud	15	15	0	**1.0**	mud	–	–
Postglacial silt	2	silt/mud	6	4	2	**0.7**	mud	*Non-mobile (hard) substrate* (2)	–
Postglacial fine sand	3	fine sand	15	12	3	**0.8**	fine sand	*Complex – mixed substrates* (1). *Mobile (sediment) substrate bottom* (possibly mud) (2)	–
Postglacial sand–gravel (mainly sand)	4	sand–gravel	17	12	5	**0.7**	sand–gravel	*Non-mobile (hard) substrate* (2). *Complex – mixed substrates* (3)	–
Glacial clay	5	sand–boulders	23	21	2	**0.9**	glacial clay	*Mobile (sediment) substrate* (possibly mud) (2)	Rather than concealing the diversity of this category, we decided to create a separate Glacial clay class which is expected to cover the most common surface substrates found in the videos: *Complex* (mosaics of mobile and non-mobile substrates) (10) *Sand and/or gravel* (4). *Non-mobile (hard) substrate* – consolidated clay (7)
Glacial fine sand and silt	6	fine sand–silt (mud)	–	–	–	no estimate	muddy sand	–	No videos of this category found.
Glaciofluvial deposits	7	sand–boulders	4	4	0	**1.0**	complex (mosaics of mobile and non-mobile substrates)	–	Only four videos of this category were found. Until further validation has been undertaken, it must be expected that pure forms of substrates may also be found, even though we will continue to use the complex class. Materials found: *Complex* (mosaics of mobile and non-mobile substrates) (2) *Sand* (1) *Non-mobile (hard) substrate* (boulder bottom) (1)
Till	8	sand–boulders	12	11	1	**0.8**	complex (mosaics of mobile and non-mobile substrates)	*Mobile (sediment) substrate* (possibly mud) (1)	–
Older sediments	9	mud–boulders in deeper areas (>15 metres)	–	–	–	no estimate	complex (mosaics of mobile and non-mobile substrates)	–	No older sediments exist in the county of Stockholm. It is most likely, however, that other deposited material ranging from mud to boulders in grain size will overlie the older sediments in deeper areas.
Artificial filling	10	–	–	–	–	no estimate	artificial	–	No videos of this category found.
Sedimentary bedrock	11	till	–	–	–	no estimate	sedimentary bedrock	–	No videos of this category found.
Crystalline bedrock	12	mud–boulders in deeper areas (>15 metres)	23	23	0	**1.0**	crystalline bedrock	–	Deposited material found: Boulders, cobbles, pebbles, gravel, sand and thin layers of deposited mud. The deposited material was sometimes pure and sometimes comprised mosaics of mobile and non-mobile substrates.

Table 3. *Amended reclassification scheme with new accuracy figures. Information about the basis for each classification is also given in the table.*

Appendix 1

Conclusion

Concerning surficial material, this study showed that in some cases it differs from the marine geological map category, especially in deeper areas. The EUNIS substrate classes, however, were more closely in accordance with the original categories of the marine geological map, since some deposited material is accepted for hard substrate classes.

It is essential to remember that this reclassification only shows the potential surficial material and EUNIS substrate class, and that it is based on the assumption that certain bottom areas are exposed to some kind of energy and are therefore not subject to sedimentation. This will not be true for all areas. But since we lack sufficient information about where exposure occurs, we will use the reclassification as it is in this study.

For shallow areas, the reclassification can probably be improved by integrating existing wave exposure models. For deeper areas it is probably a good idea to create some kind of slope model to rule out sedimentation on steeper surfaces.

For some of the categories the number of videos has clearly been too few to draw definite inferences about surficial materials. However, I hope that this small study has shown that for some categories it will almost certainly be possible to make assumptions with quite a good degree of accuracy. More validation is needed, however, in order to improve the overall reclassification, both for the county of Stockholm and for Sweden as a whole.

Acknowledgements

Without the kind assistance of Anders Elhammer and Greger Lindeberg at Marine Geology and Geophysics at the Geological Survey of Sweden, this work simply could not have been done. Thank you.

Appendix 1

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Appendix 2. Criteria diagrams with explanatory notes for a EUNIS habitat classification

Criteria for marine habitats (A)

1. Habitat A to level 2
2. Habitat A3 to level 3
3. Habitat A4 to level 3
4. Habitat A5 to level 3

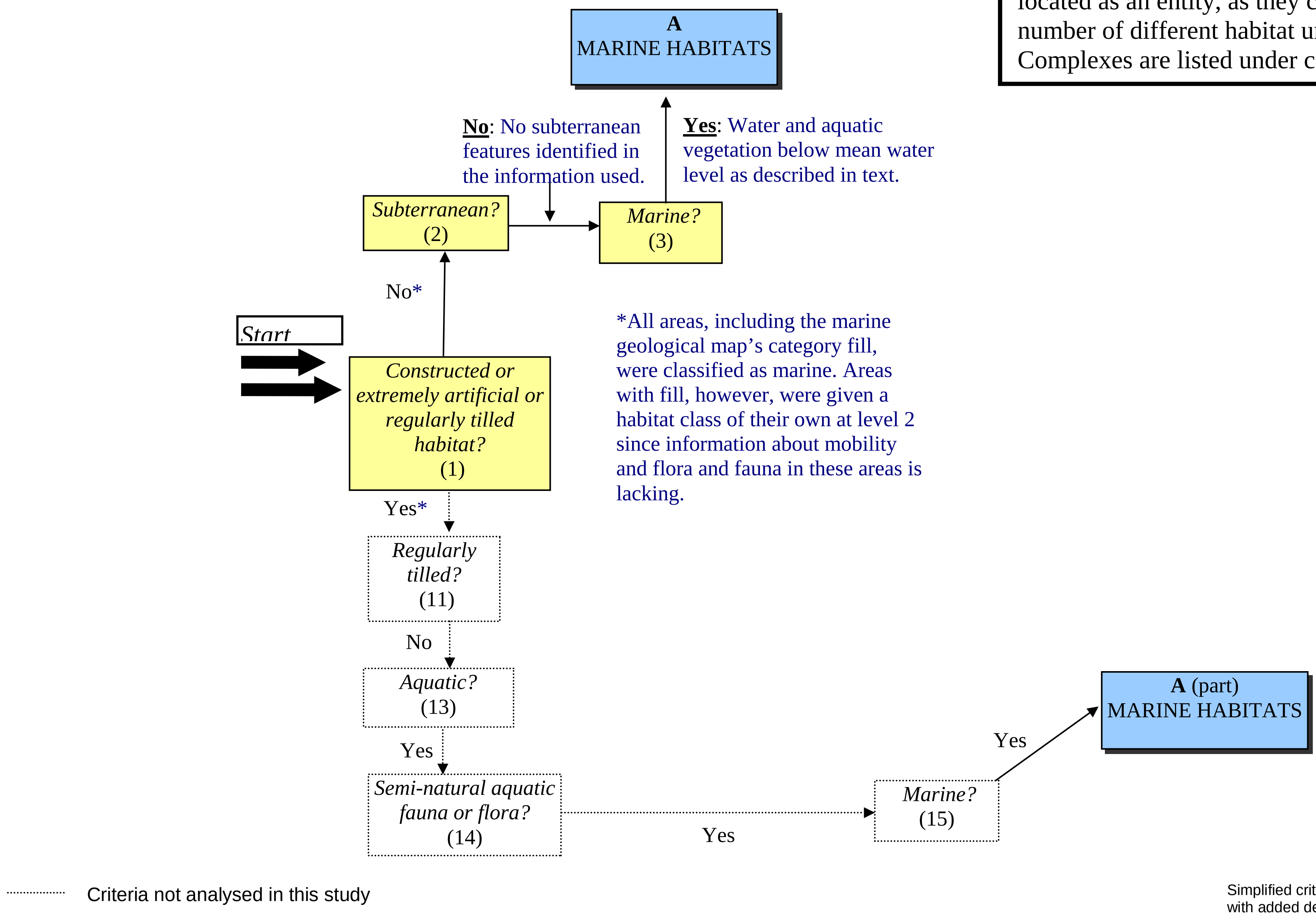
Comments or references to text on how the criteria have been interpreted and used in this study are given in blue in the criteria diagrams (simplified from Davies and Moss 2004).

For more information about the EUNIS system, its habitats, criteria and definitions, see the EUNIS web application: http://eunis.eea.eu.int/habitats.jsp

Appendix 2

1. EUNIS Habitat Classification: criteria for Level 1

(Number) refers to explanatory notes



Note: Complex habitats may not readily be located as an entity, as they comprise a number of different habitat units. Complexes are listed under code X.

Simplified criteria diagrams after Davies and Moss 2004 with added definitions (by Mattisson) for the archipelagic waters of Stockholm.

Appendix 2

Explanatory notes to the criteria used for the identification of marine habitats – level 1

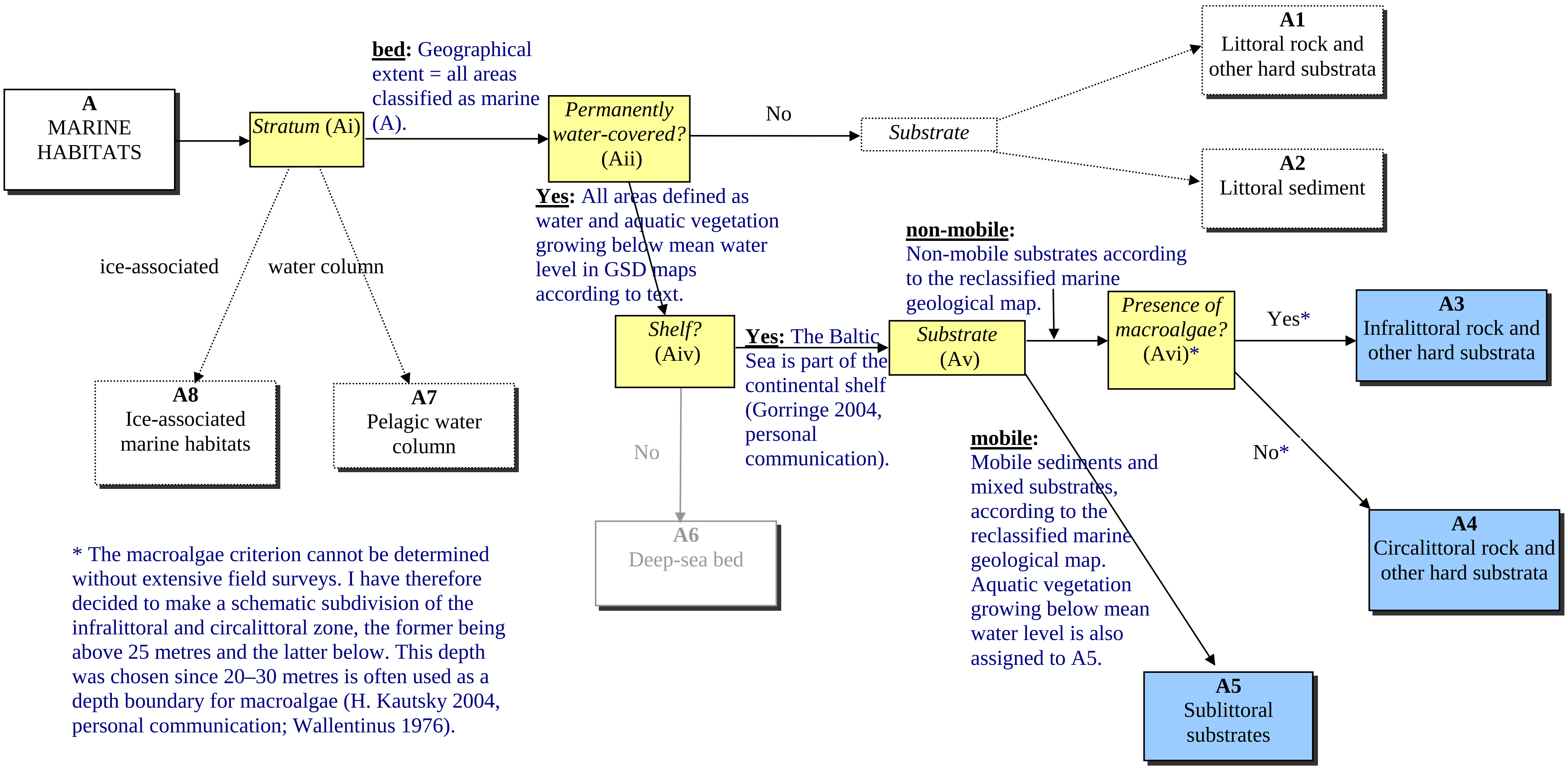
1. Is the habitat highly artificial, i.e. either constructed or with a man-made substrate; industrial; maintained solely by frequent tilling; or pioneer and ruderal communities arising from recent abandonment of previously tilled or constructed habitats (path = *Yes*)? All other habitats follow path = *No.* Note that habitats which originated through extractive industries (quarries, mines, peat diggings etc) but which have been colonised by natural or semi-natural plant and/or animal communities (other than pioneer or ruderal communities) follow path = *No*.
2. The criterion separates subterranean non-marine caves and passages and underground waters (path = *Yes*).
3. Marine habitats including marine littoral habitats (path = *Yes*) are distinguished. Note that marine habitats are directly connected to the oceans, i.e. part of the continuous body of water which covers the greater part of the earth's surface and which surrounds its land masses. Marine waters may be fully saline, brackish or almost fresh. Marine habitats include those below spring high tide limit (or below mean water level in non-tidal waters), coastal saltmarshes, and also enclosed coastal saline or brackish waters, without a permanent surface connection to the sea but either with intermittent surface or sub-surface connections (as in lagoons). Waterlogged littoral zones of the sea above the spring high tide limit in tidal waters are included with marine habitats (path = *Yes*). Rockpools in the supralittoral zone are considered as enclaves of the marine zone and follow the marine path. Waterlogged saltmarsh habitats and saline or brackish pools above the mean water level of non-tidal marine waters (parts of the geolittoral) are included with marine habitats and follow path = *Yes*; non-saline habitats above the mean water level in non-tidal waters follow path = *No*. Free-draining supralittoral habitats adjacent to marine habitats normally only affected by spray or splash and old strandlines characterised by terrestrial invertebrates follow path = *No*.

(From: Davies C. E. & Moss, D.: EUNIS Habitat Classification. Marine Habitat Types: Revised Classification and Criteria, September 2004. Report to the European Topic Centre on Nature Protection and Biodiversity, European Environment Agency. September 2004. 82 pp.)

Appendix 2

2. A: EUNIS Habitat Classification: criteria for marine habitats to Level 2

Note that the key to level 1 shows two pathways to reach habitat type A: these are recombined here. (Number) refers to explanatory notes.



——— Habitats not identified for the archipelagic waters of Stockholm, according to the EUNIS criteria and the author's interpretation.

········ Habitat/criterion not analysed in this study.

Simplified criteria diagrams after Davies and Moss 2004, with added definitions (by Mattisson) for the archipelagic waters of Stockholm.

Appendix 2

Explanatory notes to the criteria used for the identification of marine habitats down to level 2

Ai. The criterion distinguishes between strata: the sea *bed* of non-tidal, inter-tidal and sub-tidal waters; the *water column* of shallow or deep sea, or enclosed coastal waters; and ice or *ice-associated* marine habitats.

Aii. Is the bed permanently covered by water (path = *Yes*), or either regularly exposed at some stage in the tidal cycle (littoral / inter-tidal), subjected to frequent non-tidal change in water level, or above the high water mark but with a high water table (path = *No*)? Note that under extreme conditions the uppermost fringe of the ‘permanently water-covered’ zone may be exposed. Note that saltmarsh pools, rock-pools (filled by splash and spray) located in the supralittoral and permanent brackish pools affected by spray in the waterlogged Baltic geolittoral zone follow path = *No*.

Aiii. – (Mattisson’s remark: This criterion relates to the littoral zone and will not be analysed in this study.)

Aiv. This criterion separates sublittoral zones of the shelf (including infralittoral and circalittoral zones) (path = *Yes*), from the deep seabed, beyond the shelf break (path = *No*). The shelf break occurs at variable depth, but is generally over 200 metres. The upper limit of the deep-sea zone is marked by the edge of the shelf. The Baltic Sea is a shelf sea and follows path = *Yes*. Areas of the Mediterranean Sea which are deeper than 200m follow path = *No*. Note that all sublittoral caves follow path = *Yes* irrespective of depth.

Av. *Non-mobile* substrates include continuous hard and soft bedrock and also non-mobile boulders, rocks and consolidated cobbles, non-mobile artificial substrates and compacted soft substrates such as clay and peat; *mobile* substrates include substrates such as mobile cobbles, pebbles, sand and mud. Non-mobile rock which is overlain by some deposited sediments follows path = *non-mobile*. Biogenic reefs on sub-littoral sediment follow path = *mobile*. Sub-littoral mosaics of mobile and non-mobile substrates should be considered as complex X32 or X33 comprising units from A5 and A3 and/or A4.

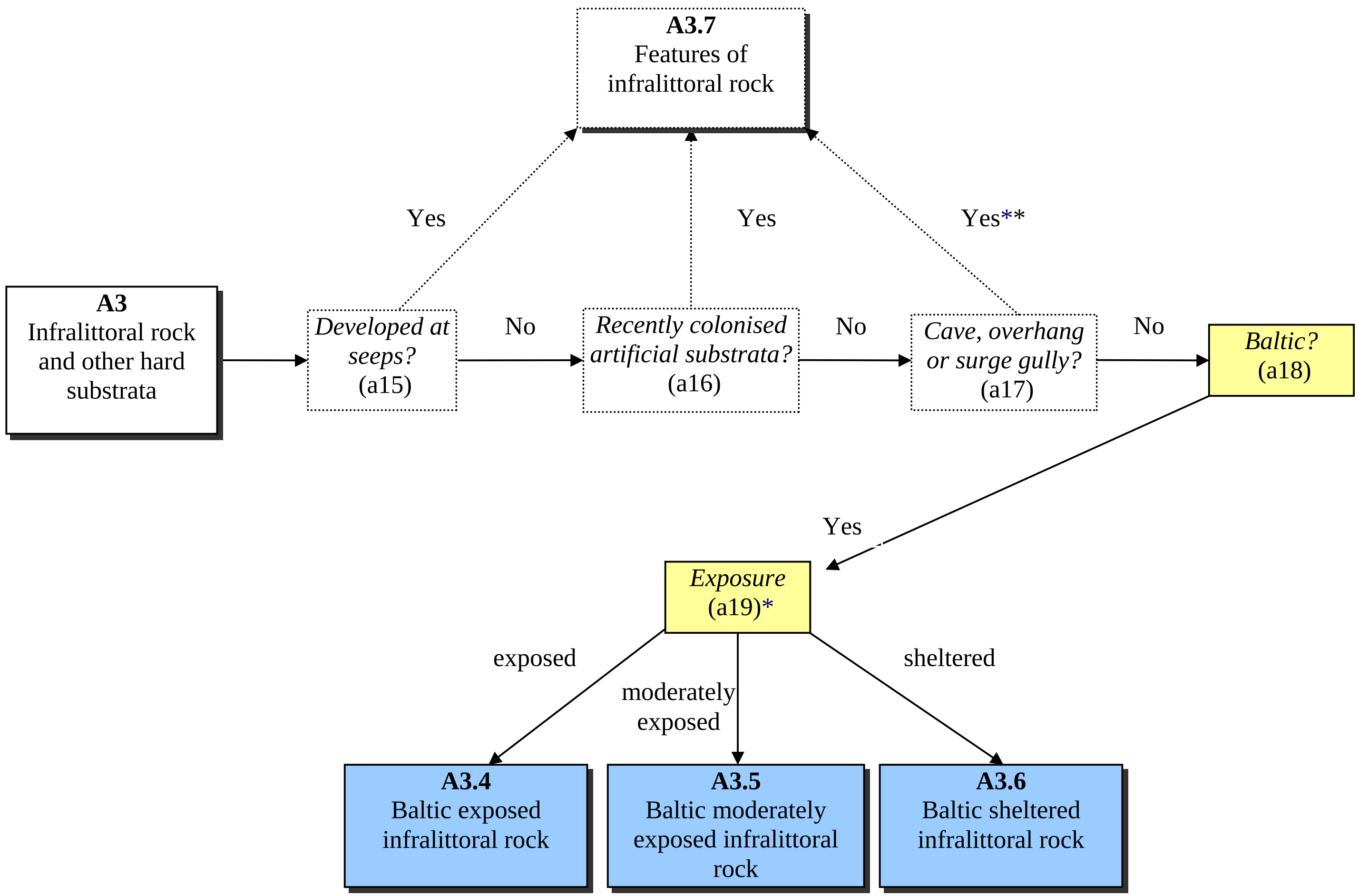
Avi. Infralittoral zones characterised by foliose or filamentous macro-algae, within the euphotic zone in relatively shallow sub-tidal or non-tidal water, are separated (path = *Yes*) from deeper animal-dominated circalittoral zones (path = *No*). Circalittoral zones are below deeper sub-tidal or non-tidal water with insufficient light penetration to allow algae to dominate; however encrusting algae and very sparse foliose or filamentous algae may be present in the upper circalittoral. Note that habitats in the euphotic zone, normally dominated by foliose or filamentous macro-algae but which as a result of storm damage or heavy grazing are characterised by encrusting algae, follow path = *Yes*. Note also that sublittoral caves or overhangs physically located within the infralittoral zone but where conditions are the same as at deeper levels of the seabed (i.e. total darkness, no hydrodynamic action and constant temperature) should follow path = *No*. Note: for mapping purposes it may be necessary to map combined A3/A4 where the presence of algae cannot be detected by the survey method.

(From: Davies C. E. & Moss, D.: EUNIS Habitat Classification. Marine Habitat Types: Revised Classification and Criteria, September 2004. Report to the European Topic Centre on Nature Protection and Biodiversity, European Environment Agency. September 2004. 82 pp.)

Appendix 2

3. A3: EUNIS Habitat Classification: criteria for infralittoral rock and other hard substrata (A3) to Level 3

(Number) refers to explanatory notes to the key



*A GIS-based wave exposure model for the Swedish coast (Isæus 2004) was, with the help of Martin Isæus (2005, personal communication), divided on a preliminary basis into the different EUNIS exposure classes.

** There was no time for the identification of recently colonised artificial substrata, habitats developed at seeps, surge gullies and overhangs. No caves exist in the area (Elhammer 2004, personal communication).

··········· Habitat/criterion not analysed in this study

Simplified criteria diagrams after Davies and Moss 2004 with added definitions (by Mattisson) for the archipelagic waters of Stockholm.

Appendix 2

Explanatory notes to the criteria used for the identification of marine A3 habitats down to level 3

a15. Habitats in hard substrata in the infralittoral zone characterised by the presence of seeping or bubbling gases, oils or water are distinguished (path = *Yes*).

a16. Recently colonised artificial hard substrata in the infralittoral zone are distinguished (path = *Yes*).

a17. Habitats developed in rock caves, underneath wave or tide-disturbed overhangs in the infralittoral zone or in wave-scoured surge gullies are separated (path = *Yes*).

a18. Infralittoral habitats in the Baltic Sea (as defined by the Helsinki Convention, from and including the Kattegat eastward to the Bothnian Bay, Gulf of Finland and Gulf of Riga) are separated (path = *Yes*) from other geographical sea areas. The Baltic Sea is effectively a vast estuary with sills, characterised by a stable reduced salinity gradient, lack of tides and reduced fetch energy.

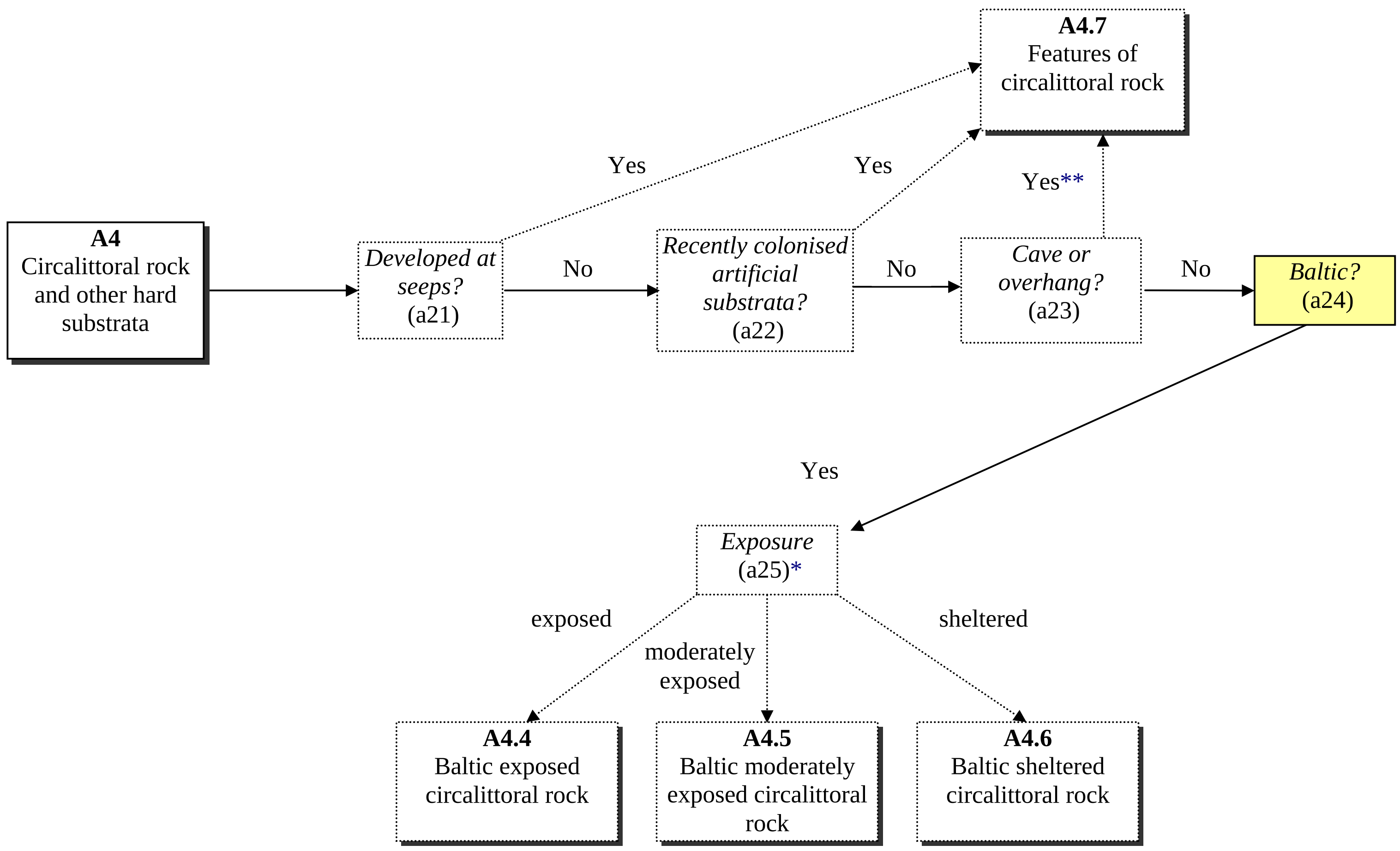
a19. The criterion separates out habitats in the Baltic infralittoral zone which are *exposed* to wave action, currents or ice scouring from those only *moderately exposed* or *sheltered*. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation in relief (e.g. steeper rock in more moderately exposed or even sheltered areas). Note that '*exposed*' has an effective fetch of greater than 25 km; '*moderately exposed*' has an effective fetch of 5–25 km; and '*sheltered*' has an effective fetch less than 5 km.

(From: Davies C. E. & Moss, D.: EUNIS Habitat Classification. Marine Habitat Types: Revised Classification and Criteria, September 2004. Report to the European Topic Centre on Nature Protection and Biodiversity, European Environment Agency. September 2004. 82 pp.)

Appendix 2

4. A4: EUNIS Habitat Classification: criteria for circalittoral rock and other hard substrata (A4) to Level 3

(Number) refers to explanatory notes to the key



* Since I lack information about currents in the study area and the wave exposure model is more likely to be relevant at shallower depths (Isaeus 2004, personal communication), I have decided not to divide the circalittoral (25 metres and below) habitats into different exposure classes.

** There was no time for the identification of recently colonised artificial substrate, habitats developed at seeps and overhangs. No caves exist in the area (Elhammer 2004, personal communication).

Habitat/criterion not analysed in this study

Simplified criteria diagrams after Davies and Moss 2004 with added definitions (by Mattisson) for the archipelagic waters of Stockholm.

Appendix 2

Explanatory notes to the criteria used for the identification of marine A4 habitats down to level 3

a21. Habitats in hard substrata in the circalittoral zone characterised by the presence of seeping or bubbling gases, oils or water are distinguished (path = *Yes*).

a22. Recently colonised artificial hard substrata in the circalittoral zone are distinguished (path = *Yes*).

a23. Habitats developed in rock caves or underneath overhangs in the circalittoral zone are separated (path = *Yes*).

a24. Circalittoral habitats in the Baltic Sea (as defined by the Helsinki Convention, from and including the Kattegat eastward to the Bothnian Bay, Gulf of Finland and Gulf of Riga) are separated (path = *Yes*) from other geographical sea areas. The Baltic Sea is effectively a vast estuary with sills, characterised by a stable reduced salinity gradient, lack of tides and reduced fetch energy.

a25. The criterion separates out habitats in the Baltic circalittoral zone which are *exposed* to wave action or currents from those only *moderately exposed* or *sheltered*. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation in relief (e.g. steeper rock in more moderately exposed or even sheltered areas). Note that ‘exposed’ has an effective fetch of greater than 25 km; ‘moderately exposed’ has an effective fetch of 5–25 km; and ‘sheltered’ has an effective fetch less than 5 km.

(From: Davies C. E. & Moss, D.: EUNIS Habitat Classification. Marine Habitat Types: Revised Classification and Criteria, September 2004. Report to the European Topic Centre on Nature Protection and Biodiversity, European Environment Agency. September 2004. 82 pp.)

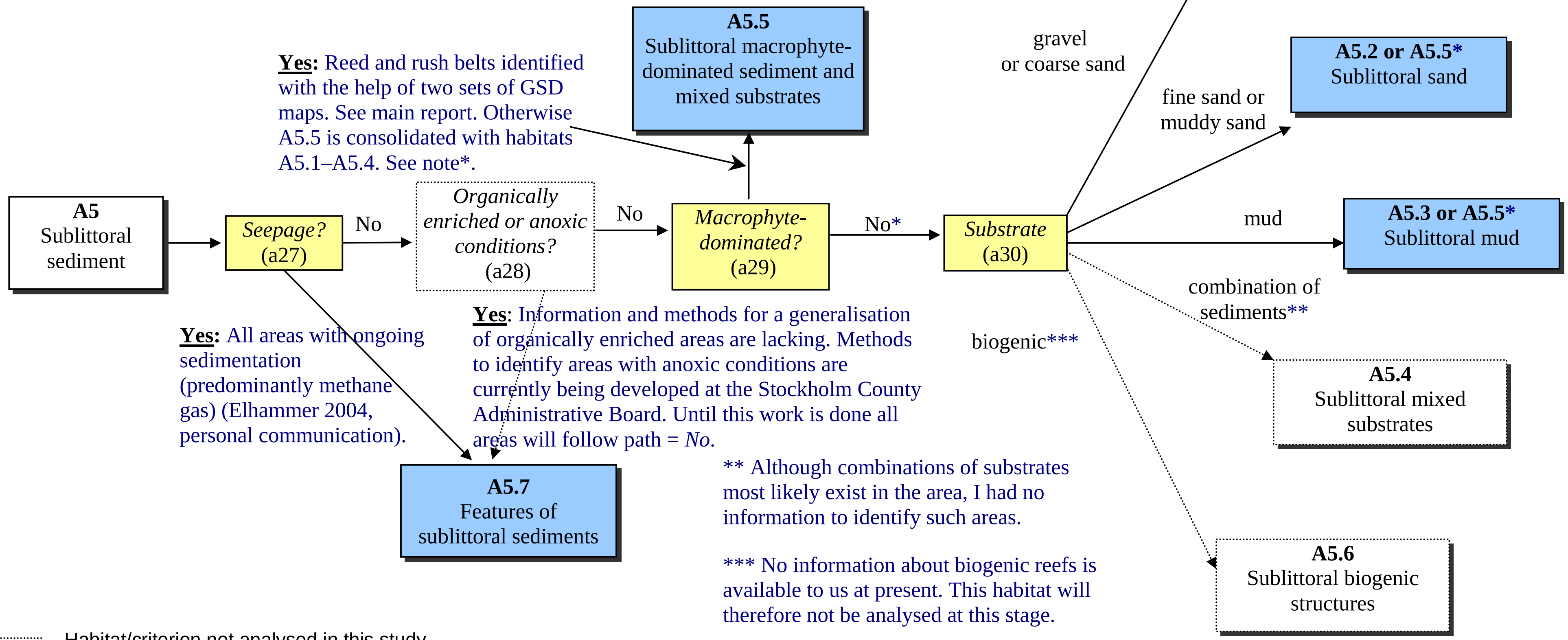
Appendix 2

5. A5: EUNIS Habitat Classification: criteria for sublittoral sediment (A5) to Level 3

(Number) refers to explanatory notes **Revision 2004**

Note: In some marine areas a clear distinction can be made between infralittoral and circalittoral sediments, but this has proved difficult to formalise in this key as a consistent criterion applicable across the whole area covered by EUNIS. In A5.1 to A5.4, when it is possible to separate sediment habitats in shallower and deeper waters, this separation is at level 4.

* Owing to a lack of information about presence of macrophytes, *Animal-dominated* (A5.1–A5.4) and *Macrophyte-dominated* (A5.5) *sublittoral substrates* have been consolidated.



······ Habitat/criterion not analysed in this study

Simplified criteria diagrams after Davies and Moss 2004 with added definitions (by Mattisson) for the archipelagic waters of Stockholm.

Appendix 2

Explanatory notes to the criteria used for the identification of marine A5 habitats down to level 3

a27. Sublittoral habitats characterised by the presence of gases or liquids bubbling or seeping through sediments are distinguished (path = *Yes*).

a28. Sublittoral sediments which are organically-enriched or permanently or periodically anoxic are separated (path = *Yes*).

a29. Habitats dominated by aquatic angiosperm or algal macrophytes (path = *Yes*) are distinguished from those dominated by animal communities, with or without algae.

a30. Habitats are divided on the basis of the dominating particle size of the substrate. *Gravel or coarse sand* > 1 mm grain size (including shingle and mobile cobbles); *fine sand or muddy sand* <= 1 mm with <=30% silt (less than 0.063 mm grain size); *mud* >30% less than 0.063 mm grain size; *combination of substrates* – veneers or intimate mixtures of mobile substrates with different particle size; or *biogenic* structures on sediment. Note that sublittoral mosaics of mobile and non-mobile substrates are considered as complex X32 or X33 comprising units from A5 and A3 and/or A4.

(From: Davies C. E. & Moss, D.: EUNIS Habitat Classification. Marine Habitat Types: Revised Classification and Criteria, September 2004. Report to the European Topic Centre on Nature Protection and Biodiversity, European Environment Agency. September 2004. 82 pp.)

Appendix 3. Descriptions of relevant EUNIS habitats down to level 3

The following text and EUNIS habitat descriptions are copied from the report *EUNIS Habitat Classification Revised 2004* by Cynthia E. Davies, Dorian Moss and Mark O. Hill.

Habitat definitions and factsheets

The EUNIS Habitat Classification database contains definitions of the habitat types and parameters used to define and distinguish them. The following pages contain extracts from that database, for marine habitats to level 4 in the hierarchy, and for terrestrial habitats to level 3. For each habitat type, the following information is given:

- Scientific name (i.e. using scientific names of species), and English name where different;
- Description of the habitat;
- Source of the description;
- Legal instruments which include the habitat type;
- Descriptive or diagnostic parameters, under several headings;
- Related phytosociological units, from Rodwell et al (2002).

The legal instruments included are Annex I of the EU Habitats Directive (92/43/EEC) as amended in 2003 (European Commission 2003) and Bern Convention Resolution No. 4 (1996) listing endangered natural habitats requiring specific conservation measures (Council of Europe, 1996). When a legal instrument is given, the EUNIS habitat type either includes, is included within, or overlaps the legally designated habitat(s) mentioned. The parameters given relate to the key to the classification (Chapter 2), and therefore are primarily the parameters which separate the given habitat type from similar habitats. Although other descriptive parameters are included, these are not exhaustive. For example, “Characteristics of wetness or dryness: Dry” is not repeated for all dry terrestrial habitats, only for those which must be distinguished from wet habitats. More complete information, including all habitat types in the classification, and equivalents in a number of international and national habitat classifications, is available on the EUNIS website, http://eunis.eea.eu.int/index.jsp.

Appendix 3

A MARINE HABITATS

Description

Marine habitats are directly connected to the oceans, i.e. part of the continuous body of water which covers the greater part of the earth's surface and which surrounds its land masses. Marine waters may be fully saline, brackish or almost fresh. Marine habitats include those below spring high tide limit (or below mean water level in non-tidal waters) and enclosed coastal saline or brackish waters, without a permanent surface connection to the sea but either with intermittent surface or sub-surface connections (as in lagoons). Rockpools in the supralittoral zone are considered as enclaves of the marine zone. Includes marine littoral habitats which are subject to wet and dry periods on a tidal cycle including tidal saltmarshes; marine littoral habitats which are normally watercovered but intermittently exposed due to the action of wind or atmospheric pressure changes; freshly deposited marine strandlines characterised by marine invertebrates. Waterlogged littoral saltmarshes and associated saline or brackish pools above the mean water level in non-tidal waters or above the spring high tide limit in tidal waters are included with marine habitats. Includes constructed marine saline habitats below water level as defined above (such as in marinas, harbours, etc) which support a semi-natural community of both plants and animals. The marine water column includes bodies of ice.

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Descriptive or diagnostic parameters
Parameter Value(s)

Altitude zones (terrestrial and marine): Bathyal; Offshore circalittoral; Circalittoral (marine); Infralittoral (marine); Littoral (marine)

Human activities and impacts: Urbanised areas, human habitation, constructed artificial surfaces; Other industrial / commercial areas; Port areas

Geomorphology or landform: Beach; Coastal flat; Lagoon; Reef; Submerged flanks of oceanic islands; Open sea; Sea cave; Marine overhang; Surge gully; Submarine channels;

Deep ocean trenches; Elongated submarine ridges; Submarine gas, oil or water vents and seeps; Isolated raised seabed features; Rockpools

Characteristics of wetness or dryness: Aquatic; Frequently submerged

EUNIS habitat **code and names** A1 Littoral rock and other hard substrata

Description

Littoral rock includes habitats of bedrock, boulders and cobbles which occur in the intertidal zone (the area of the shore between high and low tides) and the splash zone. The upper limit is marked by the top of the lichen zone and the lower limit by the top of the laminarian kelp zone. There are many physical variables affecting rocky shore communities – wave exposure, salinity, temperature and the diurnal emersion and immersion of the shore. Wave exposure is most commonly used to characterise littoral rock, from 'extremely exposed' on the open coast to 'extremely sheltered' in enclosed inlets. Exposed shores tend to support faunal-dominated communities of barnacles and mussels and some robust seaweeds. Sheltered shores are most notable for their dense cover of fucoid seaweeds, with distinctive zones occurring down the shore. In between these extremes of wave exposure, on moderately exposed shores, mosaics of seaweeds and barnacles are more typical.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Littoral (marine)

Depth zones (for marine habitats): Upper shore; Mid-shore; Lower shore

Human activities and impacts: Urbanised areas, human habitation, constructed artificial surfaces; Other industrial / commercial areas; Port areas

Exposure characteristics: Extremely exposed to wind action; Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Extremely exposed to wave action; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action

Geomorphology or landform: Coastal flat; Lagoon; Reef; Sea cave; Marine overhang; Rockpools

Characteristics of wetness or dryness: Aquatic; Frequently submerged

Substrate types: Bedrock; Clay; Chalk; Hard; Artificial hard; Boulders (undefined); Very large non-mobile boulders; Large non-mobile boulders; Small non-mobile boulders; Non-mobile cobbles; Mixed

Salinity levels: Fully saline; Reduced salinity; Variable salinity

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EUNIS habitat **code and names** A1.4 Features of littoral rock

Description

Littoral rock features include rockpools (A1.41, A1.42), ephemeral algae (A1.45) and caves (A1.44) in the intertidal zone (the area of the shore between high and low tides). These features are present throughout the littoral rock zone from the upper limit at the top of the lichen zone and the lower limit by the top of the laminarian kelp zone. These features can be found on most rocky shores regardless of wave exposure. Lichens can be found in the supralittoral zone on shores with suitable substratum. The lichen band is wider and more distinct on more exposed shores. Rockpools occur where the topography of the shore allows seawater to be retained within depressions in the bedrock producing 'pools' on the retreat of the tide. As these rockpool communities are permanently submerged they are not directly affected by height on the shore and normal rocky shore zonation patterns do not apply allowing species from the sublittoral to survive. Ephemeral seaweeds occur on disturbed littoral rock in the lower to upper shore. The shaded nature of caves and overhangs diminishes the amount of desiccation suffered by biota during periods of low tides which allows certain species to proliferate. In addition, the amount of scour, wave surge, sea spray and penetrating light determines the unique community assemblages found in upper, mid and lower shore caves, and on overhangs on the lower shore. Non-tidal areas irregularly exposed by wind action (hydrolittoral) with hard substrata are also included here. Note that lichens and algae crusts in the supralittoral zone are coastal habitats (B3.11).

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)

Legal instruments

Legal instrument Legally designated habitat Code

EU Habitats Directive Annex I Estuaries 1130

Large shallow inlets and bays 1160

Reefs 1170

Submerged or partially submerged sea caves 8330

Descriptive or diagnostic parameters

Parameter Value(s)

Altitude zones (terrestrial and marine): Littoral (marine); Driftline

Depth zones (for marine habitats): Upper shore; Mid-shore; Lower shore

Exposure characteristics: Extremely exposed to wind action; Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Tidal action; Extremely exposed to wave action; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action

Geomorphology or landform: Coastal flat; Sea cave; Marine overhang; Rockpools

Substrate types: Bedrock; Clay; Boulders (undefined); Very large non-mobile boulders; Large non-mobile boulders; Small non-mobile boulders; Non-mobile cobbles

Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

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EUNIS habitat **code and names** A2 Littoral sediment

Description

Littoral sediment includes habitats of shingle (mobile cobbles and pebbles), gravel, sand and mud or any combination of these which occur in the intertidal zone. Littoral sediment is defined further using descriptions of particle sizes – mainly gravel (16-4 mm), coarse sand

(4-1 mm), medium sand (1-0.25 mm), fine sand (0.25-0.063 mm) and mud (less than 0.063 mm) and various admixtures of these (and coarser) grades – muddy sand, sandy mud and mixed sediment (cobbles, gravel, sand and mud together). Littoral sediments support communities tolerant to some degree of drainage at low tide and often subject to variation in air temperature and reduced salinity in estuarine situations. Very coarse sediments tend to support few macrofaunal species because these sediments tend to be mobile and subject to a high degree of drying when exposed at low tide. Finer sediments tend to be more stable and retain some water between high tides, and therefore support a greater diversity of species. Medium and fine sand shores usually support a range of oligochaetes, polychaetes, and burrowing crustaceans, and even more stable muddy sand shores also support a range of bivalves. Very fine and cohesive sediment (mud) tends to have a lower species diversity, because oxygen cannot penetrate far below the sediment surface. A black, anoxic layer of sediment develops under these circumstances, which may extend to the sediment surface and in which few species can survive. Some intertidal sediments are dominated by angiosperms, e.g. eelgrass (*Zostera noltii*) beds on the mid and upper shore of muddy sand flats, or saltmarshes which develop on the extreme upper shore of sheltered fine sediment flats. Situation: Littoral sediments are found across the entire intertidal zone, including the strandline. Sediment biotopes can extend further landwards (dune systems, marshes) and further seawards (sublittoral sediments). Sediment shores are generally found along relatively more sheltered stretches of coast compared to rocky shores. Muddy shores or muddy sand shores occur mainly in very sheltered inlets and along estuaries, where wave exposure is low enough to allow fine sediments to settle. Sandy shores and coarser sediment (gravel, pebbles, cobbles) shores are found in areas subject to higher wave exposures. Temporal variation: Littoral sediment environments can change markedly over seasonal cycles, with sediment being eroded during winter storms and accreted during calmer summer months. The particle size structure of the sediment may change from finer to coarser during winter months, as finer sediment gets resuspended in seasonal exposed conditions. This may affect the sediment infauna, with some species only present in summer when sediments are more stable. These changes are most likely to affect sandy shores on relatively open shores. Sheltered muddy shores are likely to be more stable throughout the year, but may have a seasonal cover of green seaweeds during the summer period, particularly in nutrient enriched areas or where there is freshwater input.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)

Descriptive or diagnostic parameters

Parameter Value(s)

Altitude zones (terrestrial and marine): Littoral (marine)

Depth zones (for marine habitats): Upper shore; Mid-shore; Lower shore

Exposure characteristics: Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action

Geomorphology or landform: Beach; Coastal flat; Lagoon

Characteristics of wetness or dryness: Aquatic; Frequently submerged

Substrate types: Mobile; Mobile cobbles; Pebbles; Gravel; Mobile shingle; Sand; Muddy sand; Mud, Silt; Biogenic; Peat; Shells; Mixed; Rock, Sand, Gravel; Pebbles, Cobbles; Sand, Gravel; Mud, Sand, Gravel; Mud, Gravel; Mud, Sand; Sand, Organic

Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

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EUNIS habitat **code and names** A2.5 Coastal saltmarshes and saline reedbeds

Description

Angiosperm-dominated stands of vegetation, occurring on the extreme upper shore of sheltered coasts and periodically covered by high tides. The vegetation develops on a variety of sandy and muddy sediment types and may have admixtures of coarser material. The character of the saltmarsh communities is affected by height up the shore, resulting in a zonation pattern related to the degree or frequency of immersion in seawater.

Appendix 3

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Estuaries 1130
Coastal lagoons 1150
Large shallow inlets and bays 1160
Salicornia and other annuals colonizing mud and sand 1310
Spartina swards (Spartinion maritimae) 1320
Atlantic salt meadows (Glauco-Puccinellietalia maritimae) 1330
Mediterranean salt meadows (Juncetalia maritimi) 1410
Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea 1420
fruticosi)
Boreal Baltic coastal meadows 1630
Descriptive or diagnostic parameters
Parameter Value(s)

Altitude zones (terrestrial and marine): Littoral (marine); Driftline

Depth zones (for marine habitats): Upper shore; Mid-shore; Lower shore

Exposure characteristics: Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Tidal action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action

Geomorphology or landform: Coastal flat; Lagoon

Dominant life forms: Angiosperms (in aquatic habitats); Terrestrial angiosperms (in aquatic habitats); Halophile species

Characteristics of wetness or dryness: Aquatic; Frequently submerged

Substrate types: Muddy sand; Mud, Silt; Mud, Sand, Gravel; Mud, Gravel; Mud, Sand

Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

Related phytosociological units: *Aegopodion podagrariae; Agropyrion pungentis; Agropyro-Artemision coerulescentis; Armerion maritimae; Arthrocnemion glauci; Atriplicion littoralis; Caricion fuscae; Crypsidetalia aculeatae; Cypero-Spergularion salinae;Eleocharition uniglumis; Frankenion pulverulentae; Glauco maritimae-Juncion maritimi; Glauco-Puccinellietalia; Honckenyo-Crambion maritimae; Hordeion marini; Juncion maritimi; Limoniastrion monopetali; Limonion ferulacei; Plantaginion crassifoliae; Puccinellion limosae; Puccinellion maritimae; Puccinellion phryganodis; Puccinellio-Spergularion salinae; Romulion; Saginetalia maritimae; Saginetea maritimae; Saginion maritimae; Salicornietalia fruticosae; Salicornion fruticosae; Salicornion herbaceae; Salicornion patulae; Salicornio-Puccinellion; Spartinion maritimae; Suaedion braun-blanqueti; Suaedion verae; Thero-Atriplicion; Thero-Salicornietalia; Thero-Salicornietea; Thero-Salicornion; Thero-Suaedion; Trifolion squamosi*

EUNIS habitat **code and names** A3 Infralittoral rock and other hard substrata

Description
Infralittoral rock includes habitats of bedrock, boulders and cobbles which occur in the shallow subtidal zone and typically support seaweed communities. The upper limit is marked by the top of the kelp zone whilst the lower limit is marked by the lower limit of kelp growth or the lower limit of dense seaweed growth. Infralittoral rock typically has an upper zone of dense kelp (forest) and a lower zone of sparse kelp (park), both with an understorey of erect seaweeds. In exposed conditions the kelp is *Laminaria hyperborea* whilst in more sheltered habitats it is usually *Laminaria saccharina*; other kelp species may dominate under certain conditions. On the extreme lower shore and in the very shallow subtidal (sublittoral fringe) there is usually a narrow band of dabberlocks *Alaria esculenta* (exposed coasts) or the kelps *Laminaria digitata* (moderately exposed) or *L. saccharina* (very sheltered). Areas of mixed ground, lacking stable rock, may lack kelps but support seaweed communities. In estuaries and other turbid-water areas the shallow subtidal may be dominated by animal communities, with only poorly developed seaweed communities.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
Council of Europe Bern Convention Sublittoral rocky seabeds and kelp forests 11.24

Appendix 3

Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Infralittoral (marine)

Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m; 20 - 30m

Human activities and impacts: Urbanised areas, human habitation, constructed artificial surfaces; Other industrial / commercial areas; Port areas

Exposure characteristics: Extremely exposed to wind action; Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Tidal action; Very strong tidal stream; Strong tidal stream; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Extremely exposed to wave action; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action

Geomorphology or landform: Coastal flat; Reef; Open sea; Sea cave; Marine overhang; Surge gully; Submarine gas, oil or water vents and seeps

Substrate types: Bedrock; Clay; Hard; Artificial hard; Boulders (undefined); Very large nonmobile boulders; Large non-mobile boulders; Small non-mobile boulders; Nonmobile cobbles; Cobbles (undefined); Mixed

Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

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EUNIS habitat **code and names** A3.4 Baltic exposed infralittoral rock

Description

Rock habitats in the Baltic infralittoral zone which are exposed to wave action, currents or ice scouring. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation in relief (e.g. steeper rock in more moderately exposed or even sheltered areas). Note that it has been proposed that 'exposed' has an effective fetch of greater than 25 km: this requires verification across the Baltic.

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Reefs 1170
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Infralittoral (marine)

Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m

Exposure characteristics: Exposed to wind action; Moderately exposed to wind action; Exposed to wave action; Moderately exposed to wave action

Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic

Substrate types: Bedrock; Clay; Hard; Artificial hard; Boulders (undefined); Very large nonmobile boulders; Large non-mobile boulders; Small non-mobile boulders; Nonmobile cobbles

Salinity levels: Reduced salinity; Low salinity

EUNIS habitat **code and names** A3.5 Baltic moderately exposed infralittoral rock

Description

Rock habitats in the Baltic infralittoral zone which are moderately exposed to wave action, currents or ice scouring. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation in relief (e.g. steeper rock in sheltered areas). Note that it has been proposed that 'exposed' has an effective fetch of 5 – 25 km: this requires verification across the Baltic.

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code

Appendix 3

EU Habitats Directive Annex I Reefs 1170
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Infralittoral (marine)

Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m

Exposure characteristics: Moderately exposed to wind action; Sheltered from wind action; Moderately exposed to wave action; Sheltered from wave action

Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic

Substrate types: Bedrock; Clay; Hard; Artificial hard; Boulders (undefined); Very large nonmobile boulders; Large non-mobile boulders; Small non-mobile boulders; Nonmobile cobbles

Salinity levels: Reduced salinity; Low salinity

EUNIS habitat **code and names** A3.6 Baltic sheltered infralittoral rock

Description
Rock habitats in the Baltic infralittoral zone which are sheltered from wave action, currents or ice scouring. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation in relief (e.g. sheltered areas within exposed or moderately exposed areas). Note that it has been proposed that 'exposed' has an effective fetch less than 5 km: this requires verification across the Baltic.

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Reefs 1170
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Infralittoral (marine)

Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m

Exposure characteristics: Very sheltered from wind action; Extremely sheltered from wind action; Ultra sheltered from wind action; Very sheltered from wave action; Extremely sheltered from wave action; Ultra sheltered from wave action

Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic

Substrate types: Bedrock; Clay; Hard; Artificial hard; Boulders (undefined); Non-mobile cobbles

Salinity levels: Reduced salinity; Low salinity

EUNIS habitat **code and names** A3.7 Features of infralittoral rock

Description
Includes surge gulleys (A3.71), which are found throughout the infralittoral rock zone, and usually consist of vertical bedrock walls, occasionally with overhanging faces, and support communities, which reflect the degree of wave surge they are subject to and any scour from mobile substrata on the cave/gully floors. The larger cave and gully systems, such as found in Shetland, Orkney, the Western Isles and St Kilda, typically show a marked zonation from the entrance to the rear of the gully/cave as wave surge increases and light reduces. Also includes habitats in hard substrata in the infralittoral zone characterised by the presence of seeping or bubbling gases, oils or water (A3.73) and recently colonised artificial hard substrata in the infralittoral zone (A3.72).

Source
Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Estuaries 1130
Large shallow inlets and bays 1160
Reefs 1170
Submerged or partially submerged sea caves 8330

Appendix 3

Council of Europe Bern Convention Sea-caves 12.7
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Infralittoral (marine)

Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m

Exposure characteristics: Extremely exposed to wind action; Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Extremely exposed to wave action; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action

Geomorphology or landform: Reef; Sea cave; Marine overhang; Surge gully
Light intensity (when used in criteria): beyond limit of light

Substrate types: Bedrock; Clay; Hard; Boulders (undefined); Non-mobile cobbles
Salinity levels: Fully saline

EUNIS habitat **code and names** A4 Circalittoral rock and other hard substrata

Description
Circalittoral rock is characterised by animal dominated communities (a departure from the algae dominated communities in the infralittoral zone). The circalittoral zone can itself be split into two sub-zones; upper circalittoral (foliose red algae present but not dominant) and lower circalittoral (foliose red algae absent). The depth at which the circalittoral zone begins is directly dependent on the intensity of light reaching the seabed; in highly turbid conditions, the circalittoral zone may begin just below water level at mean low water springs (MLWS). The biotopes identified in the field can be broadly assigned to one of three energy level categories: high, moderate and low energy circalittoral rock (used to define the habitat complex level). The character of the fauna varies enormously and is affected mainly by wave action, tidal stream strength, salinity, turbidity, the degree of scouring and rock topography. It is typical for the community not to be dominated by single species, as is common in shore and infralittoral habitats, but rather comprise a mosaic of species. This, coupled with the range of influencing factors, makes circalittoral rock a difficult area to satisfactorily classify; particular care should therefore be taken in matching species and habitat data to the classification.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
Council of Europe Bern Convention Sublittoral rocky seabeds and kelp forests 11.24
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Circalittoral (marine)

Depth zones (for marine habitats): 5 - 10m; 10 - 20m; 20 - 30m; 30 - 50m

Human activities and impacts: Urbanised areas, human habitation, constructed artificial surfaces; Other industrial / commercial areas; Port areas

Exposure characteristics: Extremely exposed to wind action; Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Very strong tidal stream; Strong tidal stream; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Extremely exposed to wave action; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action

Substrate types: Bedrock; Clay; Hard; Artificial hard; Boulders (undefined); Very large nonmobile boulders; Large non-mobile boulders; Small non-mobile boulders; Nonmobile cobbles; Cobbles (undefined); Mixed

Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

Appendix 3

EUNIS habitat **code and names** A4.4 Baltic exposed circalittoral rock

Description
Rock habitats in the Baltic infralittoral zone which are exposed to wave action, currents or ice scouring. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation in relief (e.g. steeper rock in more moderately exposed or even sheltered areas). Note that it has been proposed that 'exposed' has an effective fetch of greater than 25 km: this requires verification across the Baltic.

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Reefs 1170
Council of Europe Bern Convention Sublittoral rocky seabeds and kelp forests 11.24
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine)
Depth zones (for marine habitats): 5 - 10m; 10 - 20m; 20 - 30m; 30 - 50m
Exposure characteristics: Exposed to wind action; Moderately exposed to wind action; Exposed to wave action; Moderately exposed to wave action
Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Bedrock; Clay; Hard; Boulders (undefined); Non-mobile cobbles
Salinity levels: Reduced salinity; Low salinity

EUNIS habitat **code and names** A4.5 Baltic moderately exposed circalittoral rock

Description
Rock habitats in the Baltic infralittoral zone which are moderately exposed to wave action, currents or ice scouring. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation in relief (e.g. steeper rock in sheltered areas). Note that it has been proposed that 'exposed' has an effective fetch of 5 – 25 km: this requires verification across the Baltic.

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Reefs 1170
Council of Europe Bern Convention Sublittoral rocky seabeds and kelp forests 11.24
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine)
Depth zones (for marine habitats): 10 - 20m; 20 - 30m; 30 - 50m
Exposure characteristics: Moderately exposed to wind action; Sheltered from wind action; Moderately exposed to wave action; Sheltered from wave action
Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Bedrock; Clay; Hard; Boulders (undefined); Non-mobile cobbles; Mixed
Salinity levels: Reduced salinity; Low salinity

EUNIS habitat **code and names** A4.6 Baltic sheltered circalittoral rock

Description
Rock habitats in the Baltic infralittoral zone which are sheltered from wave action, currents or ice scouring. The exposure status is that impacting on the area concerned at the relevant scale. Thus there may be enclaves of different exposure status caused by localised variation

in relief (e.g. sheltered areas within exposed or moderately exposed areas). Note that it has been proposed that 'exposed' has an effective fetch less than 5 km: this requires verification across the Baltic.

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Reefs 1170
Council of Europe Bern Convention Sublittoral rocky seabeds and kelp forests 11.24
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine)
Depth zones (for marine habitats): 5 - 10m; 10 - 20m; 20 - 30m
Exposure characteristics: Very sheltered from wind action; Extremely sheltered from wind action; Ultra sheltered from wind action; Very sheltered from wave action; Extremely sheltered from wave action; Ultra sheltered from wave action
Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Bedrock; Clay; Hard; Boulders (undefined); Non-mobile cobbles
Salinity levels: Reduced salinity; Low salinity

EUNIS habitat **code and names** A4.7 Features of circalittoral rock

Description
Circalittoral rock features include circalittoral fouling communities (A4.72) and circalittoral caves and overhangs (A4.71). These features are present throughout the circalittoral zone in a variety of wave exposures and tidal streams. Two fouling subtypes have also been identified: A4.722 has been recorded from disused fishing nets and other artificial substrata, and is characterised by aggregations of *Ascidiella aspersa* whilst A4.721 has been recorded from steel wrecks, and is characterised by dense aggregations of *Alcyonium digitatum* and *Metridium senile*. Habitats in hard substrata in the circalittoral zone characterised by the presence of seeping or bubbling gases, oils or water are also included (A4.73).

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Large shallow inlets and bays 1160
Reefs 1170
Submerged or partially submerged sea caves 8330
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine)
Depth zones (for marine habitats): 10 - 20m; 20 - 30m; 30 - 50m
Exposure characteristics: Extremely exposed to wind action; Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal
stream; Extremely exposed to wave action; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action; Sheltered from
wave action
Geomorphology or landform: Sea cave; Marine overhang
Light intensity (when used in criteria): Beyond limit of light
Characteristics of wetness or dryness: Aquatic
Substrate types: Bedrock; Clay; Hard; Artificial hard; Boulders (undefined); Non-mobile cobbles
Salinity levels: Fully saline

EUNIS habitat **code and names** A5 Sublittoral sediment

Description
Sediment habitats in the sublittoral near shore zone (i.e. covering the infralittoral and circalittoral zones), typically extending from the extreme lower shore down to the edge of the bathyal zone (200 m). Sediment ranges from boulders and cobbles, through pebbles and

shingle, coarse sands, sands, fine sands, muds, and mixed sediments. Those communities found in or on sediment are described within this broad habitat type.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
Council of Europe Bern Convention Sublittoral soft seabeds 11.22
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine); Infralittoral (marine)
Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m; 20 - 30m; 30 - 50m; 50 - 100m
Exposure characteristics: Very exposed to wind action; Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Strong tidal stream; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Very exposed to wave action; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action
Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Mobile; Mobile rock; Cobbles (undefined); Mobile cobbles; Pebbles; Gravel; Sand; Muddy sand; Mud, Silt; Biogenic; Peat; Shells; Mixed; Rock, Sand, Gravel; Pebbles, Cobbles; Sand, Gravel; Mud, Sand, Gravel; Mud, Gravel; Mud, Sand; Sand, Organic
Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

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EUNIS habitat **code and names** A5.1 Sublittoral coarse sediment

Description
Coarse sediments including coarse sand, gravel, pebbles, shingle and cobbles which are often unstable due to tidal currents and/or wave action. These habitats are generally found on the open coast or in tide-swept channels of marine inlets. They typically have a low silt content and a lack of a significant seaweed component. They are characterised by a robust fauna including venerid bivalves.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Sandbanks which are slightly covered by sea water all the time 1110
Estuaries 1130
Coastal lagoons 1150
Large shallow inlets and bays 1160
Council of Europe Bern Convention Sublittoral soft seabeds 11.22
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine); Infralittoral (marine)
Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m; 20 - 30m
Exposure characteristics: Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Strong tidal stream; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action
Geomorphology or landform: Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Mobile; Mobile rock; Cobbles (undefined); Mobile cobbles; Pebbles; Gravel; Mobile shingle; Sand; Shells
Salinity levels: Fully saline; Variable salinity

EUNIS habitat **code and names** A5.2 Sublittoral sand

Description
Clean medium to fine sands or non-cohesive slightly muddy sands on open coasts, offshore or in estuaries and marine inlets. Such habitats are often subject to a degree of wave action or tidal currents which restrict the silt and clay content to less than 15%. This habitat is characterised by a range of taxa including polychaetes, bivalve molluscs and amphipod crustacea.

Appendix 3

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Sandbanks which are slightly covered by sea water all the time 1110
Estuaries 1130
Coastal lagoons 1150
Large shallow inlets and bays 1160
Council of Europe Bern Convention Sublittoral soft seabeds 11.22
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine); Infralittoral (marine)
Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m; 20 - 30m; 30 - 50m
Exposure characteristics: Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action
Geomorphology or landform: Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Mobile; Sand; Muddy sand; Mixed
Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

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EUNIS habitat **code and names** A5.3 Sublittoral mud

Description

Sublittoral mud and cohesive sandy mud extending from the extreme lower shore to offshore, circalittoral habitats. This biotope is predominantly found in sheltered harbours, sealochs, bays, marine inlets and estuaries and stable deeper/offshore areas where the reduced influence of wave action and/or tidal streams allow fine sediments to settle. Such habitats are often by dominated by polychaetes and echinoderms, in particular brittlestars such as *Amphiura* spp. Seapens such as *Virgularia mirabilis* and burrowing megafauna including *Nephrops norvegicus* are common in deeper muds. Estuarine muds tend to be characterised by infaunal polychaetes and oligochaetes.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Estuaries 1130
Coastal lagoons 1150
Large shallow inlets and bays 1160
Boreal Baltic narrow inlets 1650
Council of Europe Bern Convention Sublittoral soft seabeds 11.22
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine); Infralittoral (marine)
Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m; 20 - 30m
Exposure characteristics: Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Ultra sheltered from wind action; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action; Ultra sheltered from wave action
Geomorphology or landform: Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Muddy sand; Mud, Silt
Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

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EUNIS habitat **code and names** A5.4 Sublittoral mixed sediments

Description

Sublittoral mixed (heterogeneous) sediments found from the extreme low water mark to deep offshore circalittoral habitats. These habitats incorporate a range of sediments including heterogeneous muddy gravelly sands and also mosaics of cobbles and pebbles embedded in or lying upon sand, gravel or mud. There is a degree of confusion with regard nomenclature within this complex as many habitats could be defined as containing mixed sediments, in part depending on the scale of the survey and the sampling method employed. The BGS trigon can be used to define truly mixed or heterogeneous sites with surficial sediments which are a mixture of mud, gravel and sand. However, another 'form' of mixed sediment includes mosaic habitats such as superficial waves or ribbons of sand on a gravel bed or areas of lag deposits with cobbles/pebbles embedded in sand or mud and these are less well defined and may overlap into other habitat or biological subtypes. These habitats may support a wide range of infauna and epibiota including polychaetes, bivalves, echinoderms, anemones, hydroids and Bryozoa. Mixed sediments with biogenic reefs or macrophyte dominated communities are classified separately in A5.6 and A5.5 respectively.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Sandbanks which are slightly covered by sea water all the time 1110
Estuaries 1130
Coastal lagoons 1150
Large shallow inlets and bays 1160
Council of Europe Bern Convention Sublittoral soft seabeds 11.22
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine); Infralittoral (marine)
Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m; 20 - 30m; 30 - 50m
Exposure characteristics: Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Ultra sheltered from wind action; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action; Ultra sheltered from wave action
Geomorphology or landform: Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Mobile; Shells; Mixed; Rock, Sand, Gravel; Pebbles, Cobbles; Sand, Gravel; Mud, Sand, Gravel; Mud, Gravel; Mud, Sand; Sand, Organic
Salinity levels: Fully saline; Reduced salinity; Low salinity; Variable salinity

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EUNIS habitat **code and names** A5.5 Sublittoral macrophyte-dominated sediment

Description

This habitat type includes maerl beds, seaweed dominated mixed sediments (including kelps such as *Laminaria saccharina* and filamentous/foliose red and green algae), seagrass beds, and lagoonal angiosperm communities. These communities develop in a range of habitats from exposed open coasts to lagoons and are found in a variety of sediment types and salinity regimes.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Sandbanks which are slightly covered by sea water all the time 1110
Posidonia beds (Posidonion oceanicae) 1120
Estuaries 1130
Coastal lagoons 1150
Large shallow inlets and bays 1160
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Infralittoral (marine)
Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m
Exposure characteristics: Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Extremely sheltered from wind action; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action; Extremely sheltered from wave action
Geomorphology or landform: Open sea
Dominant life forms: Aquatic angiosperms
Characteristics of wetness or dryness: Aquatic

Substrate types: Mobile; Cobbles (undefined); Gravel; Sand; Muddy sand; Mud, Silt; Biogenic; Peat; Shells; Mixed
Salinity levels: Fully saline; Reduced salinity; Variable salinity
Related phytosociological units: *Charion canescentis; Cymodoceion nodosae; Posidonion oceanicae; Ruppietea maritimae; Ruppion maritimae; Zannichellion pedicellatae; Zosterion marinae*

EUNIS habitat **code and names** A5.6 Sublittoral biogenic reefs

Description
This habitat type includes polychaete reefs, bivalve reefs (e.g. mussel beds) and cold water coral reefs. These communities develop in a range of habitats from exposed open coasts to estuaries, marine inlets and deeper offshore habitats and may be found in a variety of sediment types and salinity regimes.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Estuaries 1130
Coastal lagoons 1150
Large shallow inlets and bays 1160
Reefs 1170
Council of Europe Bern Convention Sublittoral soft seabeds 11.22
Res. No. 4 1996
Sublittoral rocky seabeds and kelp forests 11.24
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Circalittoral (marine); Infralittoral (marine)
Depth zones (for marine habitats): 0 - 5m; 5 - 10m; 10 - 20m; 20 - 30m; 30 - 50m; 50 - 100m
Exposure characteristics: Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Strong tidal stream; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action
Geomorphology or landform: Reef; Open sea
Characteristics of wetness or dryness: Aquatic
Substrate types: Biogenic; Peat; Shells
Salinity levels: Fully saline; Variable salinity

EUNIS habitat **code and names** A5.7 Features of sublittoral sediments

Description
Features of sublittoral sediments include sublittoral habitats characterised by the presence of gases or liquids bubbling or seeping through sediments (A5.71) and sublittoral sediments which are organically-enriched or permanently or periodically anoxic (A5.72).

Source Hill, M.O., Moss, D. & Davies, C.E. (2004b)
Legal instruments
Legal instrument Legally designated habitat Code
EU Habitats Directive Annex I Submarine structures made by leaking gases 1180
Council of Europe Bern Convention Sublittoral soft seabeds 11.22
Res. No. 4 1996
Descriptive or diagnostic parameters
Parameter Value(s)
Altitude zones (terrestrial and marine): Offshore circalittoral; Circalittoral (marine); Infralittoral (marine)
Geomorphology or landform: Reef; Open sea; Submarine gas, oil or water vents and seeps
Chemical attributes: Anoxic/Hypoxic
Substrate types: Mobile; Mobile cobbles; Pebbles; Gravel; Sand; Muddy sand; Mud, Silt; Biogenic; Peat; Shells; Mixed; Rock, Sand, Gravel; Pebbles, Cobbles; Sand, Gravel; Mud, Sand, Gravel; Mud, Gravel; Mud, Sand; Sand, Organic

Appendix 4. A short review of the basic conditions for marine flora and fauna in the county of Stockholm

The modelling or mapping that has been performed in this study shows little more than different combinations of physical factors such as bottom substrate, depth, wave exposure etc. However, these factors, often referred to as structuring, determine to a great extent the distribution of flora and fauna in the Baltic Sea (H. Kautsky 1988). Different combinations of structuring factors, e.g. *mobile substrate + very exposed to wave action*, constitute the basic conditions for biological communities and therefore result in different organisms being found in areas with different combinations of physical factors.

It is not possible to guarantee that particular types of organisms will be present at sites with the different combinations of factors that have been identified for the coastal waters of Stockholm. Nor is it possible to make clear-cut distinctions between, for example, different degrees of wave exposure. What the maps convey is the existence of basic conditions for certain types of organisms, tied to a specific combination of physical factors identified in a specific area. To confirm that those organisms are indeed present, it is necessary to study the site in the field. I nevertheless hope that these maps will give a general picture of where prerequisites exist for, for instance, eelgrass meadows, mussel beds or bladderwrack belts.

It is important to bear in mind that sunlight penetrates to different depths, depending on the turbidity of the water. The maximum depth for macrophyte-dominated bottoms will therefore differ for different areas in the archipelago. Bladderwrack (*Fucus vesiculosus)* will be able to grow down to 9 metres in areas with very clear water, but be unable to grow beyond 5 metres in others. The inner parts of the Stockholm archipelago are generally more turbid than the outer areas. This is due to eutrophication, which in general means that vegetation cannot grow to greater depths than 5 metres in the areas closest to the city of Stockholm (L. Kautsky *et al.* 2000).

Below I give a general description of the types of animals and vegetation that can be expected in the different habitats identified for the coastal waters of Stockholm. Except where otherwise stated, the information is obtained from the book *Under ytan i Stockholms skärgård* (*Below the surface in the archipelago of Stockholm*) (L. Kautsky *et al.* 2000). After each of the main substrate types, there is a list showing where the habitats fit into the EUNIS system and the expanded habitat list prepared in this study.

Non-mobile substrates – hard bottoms

A belt of filamentous algae grows at the boundary between land and water and stretches down to about one metre. During the summer this is an important nursery environment for amphipods, isopods and small gastropods. Algal species vary depending on the season. During late spring and early summer two brown algae are common, *Pilayella littoralis* and maiden's hair (*Ectocarpus siliculosus*). In summer the intensively green *Cladophora glomerata* dominates the hard substrates in this zone. And in the autumn and early winter *Cladophora glomerata* makes way for red algae of the genus *Ceramium*.

Bladderwrack usually dominates below the shallow filamentous belt. This is a large, perennial brown alga that creates an important belt in which around 70 per cent of the Baltic Sea's larger organisms (> 1 millimetre) can be found. This belt provides an important nursery, reproductive and growth environment for many fish species, since it offers both protection from predators and food opportunities. Depending on degree of wave exposure and currents, different species are found. The largest number of species is found in sheltered bays and inlets, mainly because they harbour more fresh-water species alongside the marine ones. At more exposed sites many of the freshwater species disappear and the abundance of the bay barnacle (*Balanus improvisus*) increases instead.

Red algae start to take over at about four metres. If the water is clear, however, bladderwrack may grow down to depths of 11 metres (observations from the 1940s) (Aneer 2004, personal communication). Otherwise red algae or common mussels (*Mytilus edulis*) are more likely to dominate hard bottoms at these depths. *Furcellaria fastigiata* and *Phyllophora brodiaei* are among the more common red algae.

At about 25 metres it is normally too dark for algae. Hard bottoms at these depths are instead dominated by the common mussel (*Mytilus edulis*). This mussel is important in purifying the water. It also releases nutrients and is thus an important link between the biota of the water column and that of the seabed. Bacteria and sediment feeders use the excreta which the mussels produce. The nutrients (phosphorus and nitrogen) which they release are used by algae and phytoplankton. The mussel larvae are also an important food resource for small fish and herring, while the adult mussels are important for eider and flatfish.

Main habitats in the EUNIS system and in the expanded list for Stockholm

EUNIS level 2	EUNIS level 3	Expanded habitat list
Infralittoral rock and other hard substrata (A3)	Baltic exposed infralittoral rock (A3.4)	Shallow exposed hard bottom (–6 metres)
Circalittoral rock and other hard substrata (A4)	Baltic moderately exposed infralittoral rock (A3.5)	Shallow moderately exposed hard bottom (–6 metres)
	Baltic sheltered infralittoral rock (A3.6)	Shallow sheltered hard bottom (–6 metres)
	Circalittoral rock and other hard substrata (A4)	Exposed hard bottom (6–25 metres)
		Moderately exposed hard bottom (6–25 metres)
		Sheltered hard bottom (6–25 metres)
		Deep hard bottom (25 metres and deeper)

Appendix 4

***Picture 1**. Bladderwrack (Fucus vesiculosus) on a hard bottom.*

Photo: Martin Isæus.

Mobile substrates – soft bottoms

Three main types of soft bottom exist: erosion bottoms (zones of erosion), transport bottoms (zones of sediment transport) and accumulation bottoms (zones of accumulation). Currents sweep fine material from erosion bottoms and leave behind a coarser material. The fine material is transported and settles temporarily on transport bottoms, before it is swept away to accumulation bottoms, where it settles for good. Zones of accumulation are found in calm areas, often in deep depressions in the seabed. They represent the commonest type of bottom in the archipelago below a depth of 15 metres.

On shallow bottoms where there is enough light, rooted vegetation can grow. This vegetation is important for many fish species, which use it for shelter, food supplies, and as a spawning and nursery environment. Large or small areas of reed (*Phragmites australis*) and sedges (*Scirpus* spp.) are often found in shallow and sheltered bays. These areas are important, for example, as nurseries for fish (Casselman and Lewis 1996).

Various submerged and free-floating vegetation, such as duckweeds (*Lemna* spp.), takes over outside the reed belts. Common species in more or less sheltered bays and inlets are fennel pondweed (*Potamogeton pectinatus*), perfoliate pondweed (*P. perfoliatus*), brackish water crowfoot (*Ranunculus baudotii*) and spiked water milfoil (*Myriophyllum spicatum*).

Appendix 4

Freshwater animal species are found along with brackish-water and fully marine species on the soft mobile substrates of the archipelago. The marine species are, among others, Baltic tellin (*Macoma baltica*), cockles (*Cerastoderma* spp.), the amphipod *Monoporeia affinis*, estuary ragworm (*Nereis diversicolor*), the mud shrimp *Corophium volutator*, the priapulid worm *Halicryptus spinulosus* and the isopod *Saduria entomon*. The freshwater species are mud bithynia (*Bithynia tentaculata*) and the genus *Chironomus*. The species composition of benthic communities is dependent on the quantities of organic matter and oxygen present . Most animals are deposit feeders, that is, they eat the surface material and use the energy available in the bacteria and organic particles present in the bottom material. The Baltic tellin (*Macoma baltica*) and the genera *Lumbriculus* and *Chironomus* are favoured by large amounts of organic material.

Gastropods of the genera *Lymnea* and *Hydrobia*, *Chironomus* larvae, Baltic tellin (*Macoma baltica*), cockles (*Cerastoderma* sp.), sand gaper (*Mya arenaria*), the mud shrimp *Corophium volutator* and various fish species are common on shallow soft bottoms.

Only a few animal species are found on deep sediment bottoms. They may, however, occur in large numbers, and the commoner species include *Monoporeia affinis* and the Baltic tellin.

Drifting mats made up of dead and living filamentous algae can also be found on soft bottoms. Below these mats, oxygen deficits may occur (Aneer 2004, personal communication). Many of the soft bottoms of the archipelago suffer from periodic oxygen deficits, and consequently in large areas close to the city of Stockholm no higher life is found.

Sand bottoms

Pure sand bottoms are a sign of good water turnover. In these habitats only very specialised species occur. Eelgrass (*Zostera marina*) is found on shallow sandy bottoms, which become more common the further out into the archipelago you go. The stonewort *Chara aspera* and fennel pondweed (*Potamogeton pectinatus*) are also found on shallow sandy bottoms (HELCOM 1998). Animal species such as sand gaper (*Mya arenaria*), brown shrimp (*Crangon crangon*) and cockles (*Cerastoderma* spp.) are common in this type of environment. Deep sandy bottoms are fairly unusual in the archipelago. Flatfish such as turbot (*Psetta maxima*) use these habitats for spawning.

Sand–gravel bottoms

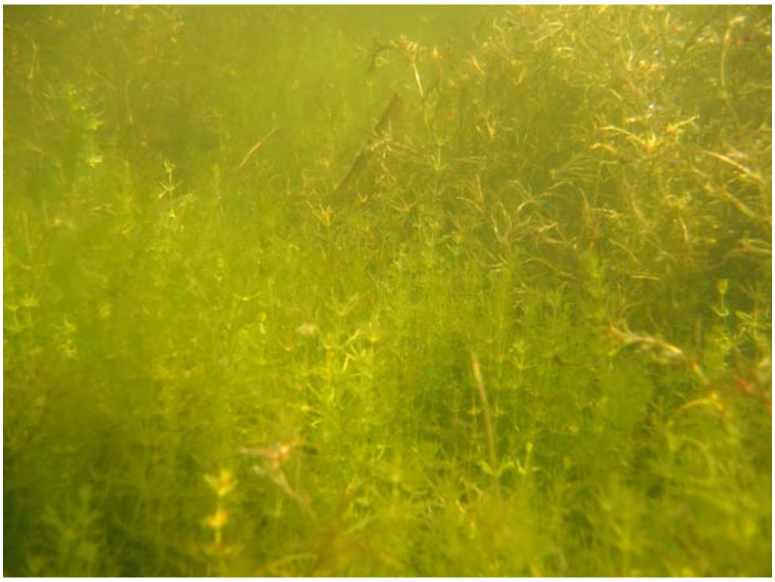
Few animals can live on pure gravel bottoms. There are nevertheless a few fish species that use this substrate for egg-laying (HELCOM 1998).

Appendix 4

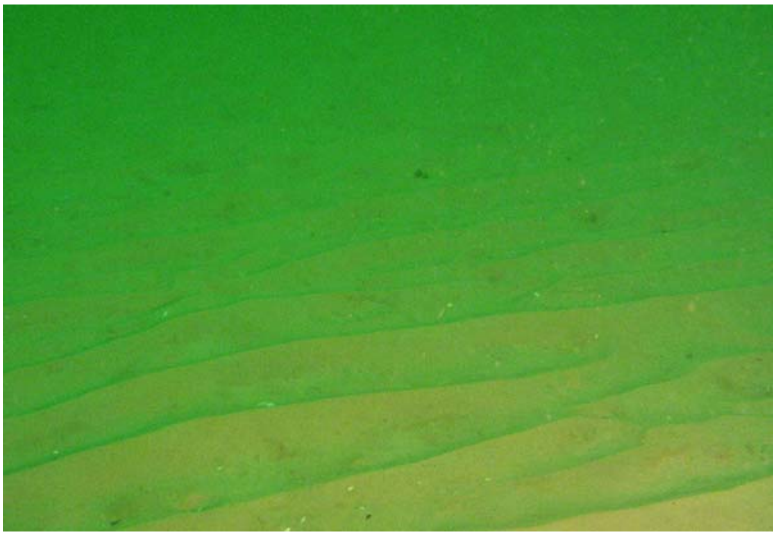
Main habitats in the EUNIS system and in the expanded list for Stockholm

EUNIS level 2	EUNIS level 3	Expanded habitat list
Sublittoral sediment (A5)	Sublittoral coarse sediment (A5.1)	Shallow exposed sand–gravel bottom (–6 metres)
	Sublittoral sand (A5.2)	Shallow moderately exposed sand–gravel bottom (–6 metres)
	Sublittoral mud (A5.3)	Shallow sheltered sand–gravel bottom (–6 metres)
	Sublittoral macrophyte-dominated sediment (A5.5)	Exposed sand–gravel bottom (6–25 metres)
	Features of sublittoral sediments (A5.7)	Moderately exposed sand–gravel bottom (6–25 metres)
		Sheltered sand–gravel bottom (6–25 metres)
		Deep sand–gravel bottom (25 metres and deeper)
		Shallow exposed fine sand bottom (–6 metres)
		Shallow moderately exposed fine sand bottom (–6 metres)
		Shallow sheltered fine sand bottom (–6 metres)
		Exposed fine sand bottom (6–25 metres)
		Moderately exposed fine sand bottom (6–25 metres)
		Sheltered fine sand bottom (6–25 metres)
		Deep fine sand bottom (25 metres and deeper)
		Shallow exposed muddy fine sand bottom (–6 metres)
		Shallow moderately exposed muddy fine sand bottom (–6 metres)
		Shallow sheltered muddy fine sand bottom (–6 metres)
		Exposed muddy fine sand bottom (6–25 metres)
		Moderately exposed muddy fine sand bottom (6–25 metres)
		Sheltered muddy fine sand bottom (6–25 metres)
		Deep muddy fine sand bottom (25 metres and deeper)
		Shallow exposed mud bottom (–6 metres)
		Shallow moderately exposed mud bottom (–6 metres)
		Shallow sheltered mud bottom (–6 metres)
		Exposed mud bottom (6–25 metres)
		Moderately exposed mud bottom (6–25 metres)
		Sheltered mud bottom (6–25 metres)
		Deep mud bottom (25 metres and deeper)
		Dense reed belt

Appendix 4

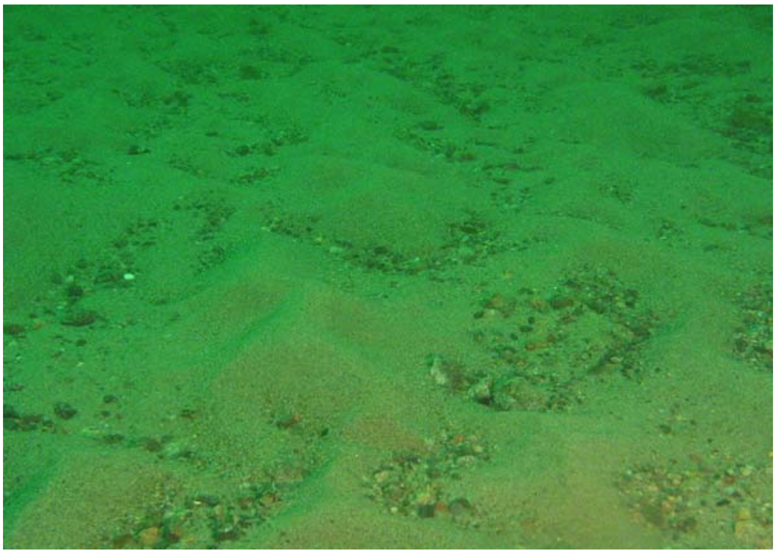


Picture 2. *Chara meadow on soft bottom. Photo: Martin Isæus.*



Picture 3. *Fine sand.*

Photo: SGU.



Picture 4. *Sand and gravel bottom. Photo: SGU.*

Appendix 4

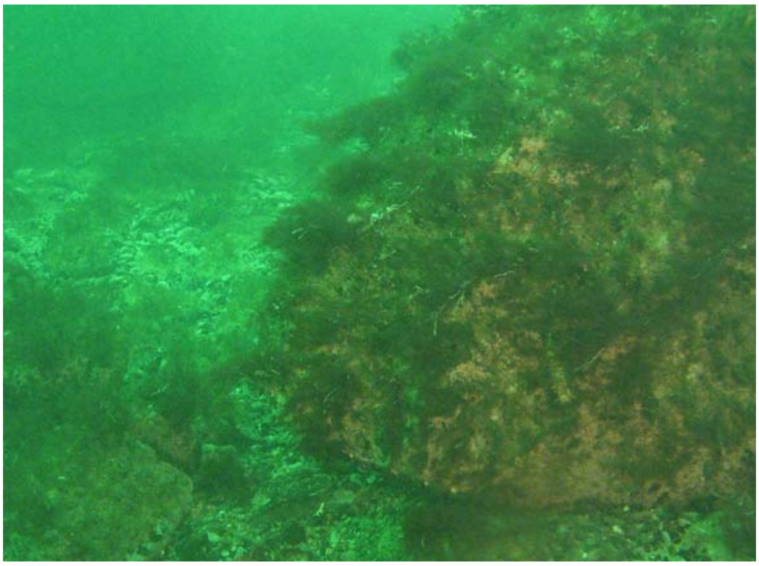
Mosaics

Bottoms with a mixture of many materials, from soft sediments to boulders, create good habitats for both soft- and hard-bottom organisms. As a consequence, these areas may sustain relatively high biodiversity (HELCOM 1998).

For descriptions of the flora and fauna found on soft and hard bottoms, see *Non-mobile substrates – hard bottoms* and *Mobile substrates – soft bottoms*.

Main habitats in the EUNIS system and in the expanded list for Stockholm

EUNIS level 2	EUNIS level 3	Expanded habitat list
Mosaics of mobile and non-mobile substrata (X3)	Mosaics of mobile and non-mobile substrata in the infralittoral zone (X32)	Shallow exposed glaciofluvial material (–6 metres)
	Mosaics of mobile and non-mobile substrata in the circalittoral zone (X33)	Shallow moderately exposed glaciofluvial material (–6 metres)
		Shallow sheltered glaciofluvial material (–6 metres)
		Exposed glaciofluvial material (6–25 metres)
		Moderately exposed glaciofluvial material (6–25 metres)
		Sheltered glaciofluvial material (6–25 metres)
		Deep glaciofluvial material (25 metres and deeper)
		Shallow exposed mosaics (–6 metres)
		Shallow moderately exposed mosaics (–6 metres)
		Shallow sheltered mosaics (–6 metres)
		Exposed mosaics (6–25 metres)
		Moderately exposed mosaics (6–25 metres)
		Sheltered mosaics (6–25 metres)
		Deep mosaics (25 metres and deeper)



Picture 5. *Mosaics in the infralittoral zone.*

Photo: SGU.

Appendix 4

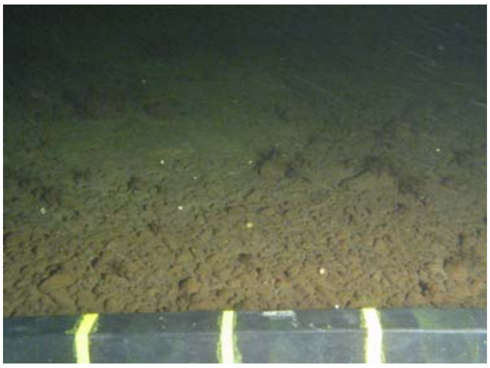
Glacial clay

The surficial material in areas that have been classified as glacial clay in the marine geological map differs greatly from one site to another and may consist of anything from soft bottoms to hard boulder bottoms, and such areas are therefore presented as *Glacial clay*. There is a lack of knowledge as to which surficial material is to be found at which location. It seems, however, that most areas have a surficial material of either consolidated clay (hard) or a mixture (*Complex*) of mobile (soft) and non-mobile (hard) substrates (see appendix 1).

Main habitats in the EUNIS system and in the expanded list for Stockholm

EUNIS level 2	EUNIS level 3	Expanded habitat list
Glacial clay (additional class)	Glacial clay (additional class)	Shallow exposed glacial clay (–6 metres)
		Shallow moderately exposed glacial clay (–6 metres)
		Shallow sheltered glacial clay (–6 metres)
		Exposed glacial clay (6–25 metres)
		Moderately exposed glacial clay (6–25 metres)
		Sheltered glacial clay (6–25 metres)
		Deep glacial clay (25 metres and deeper)

***Pictures 6**, **7** and **8**. Different surficial materials classified as Glacial clay. Photo: SGU.*



Appendix 4

Artificial bottoms

Artificial bottoms may of course be made up of many things. Such habitats may also support a semi-natural flora and fauna. The artificial bottoms that are presented in this study consist of fill material and are copied from the marine geological map. Several other unidentified artificial bottoms exist in Stockholm county. This is of course something that needs to be addressed if we are to use the maps for conservation and protection purposes. Meanwhile, additional material, such as the shoreline development study (Mattisson 2004), is recommended to provide an overall idea of anthropogenic impact in different areas.

Main habitats in the EUNIS system and in the expanded list for Stockholm

EUNIS level 2	EUNIS level 3	Expanded habitat list
Artificial (additional class)	Artificial (additional class)	Fill

Additional information – bottom features

Freshwater seepage from glaciofluvial material

Freshwater seeps from glaciofluvial deposits (Elhammer 2004, personal communication) might give bottom areas a different salinity compared to their immediate surroundings. This might mean that they sustain a flora and fauna differing from that of the local area, and it may therefore be interesting to highlight them.

Main habitats in the EUNIS system and in the expanded list for Stockholm

EUNIS level 2	EUNIS level 3	Expanded habitat list
Mosaics of mobile and non-mobile substrata (X3)	Mosaics of mobile and non-mobile substrata in the infralittoral zone (X32)	Shallow exposed glaciofluvial material (–6 metres)
	Mosaics of mobile and non-mobile substrata in the circalittoral zone (X33)	Shallow moderately exposed glaciofluvial material (–6 metres)
		Shallow sheltered glaciofluvial material (–6 metres)
		Exposed glaciofluvial material (6–25 metres)
		Moderately exposed glaciofluvial material (6–25 metres)
		Sheltered glaciofluvial material (6–25 metres)
		Deep glaciofluvial material (25 metres and deeper)

Ongoing sedimentation

Certain areas in the archipelago of Stockholm have ongoing sedimentation. These areas also seep gases, mainly methane (Elhammer 2004, personal communication).

Main habitats in the EUNIS system and in the expanded list for Stockholm

EUNIS level 2	EUNIS level 3	Expanded habitat list – feature
Sublittoral sediment (A5)	Features of sublittoral sediments (A5.7)	Mud bottom with methane seepage = area with ongoing sedimentation

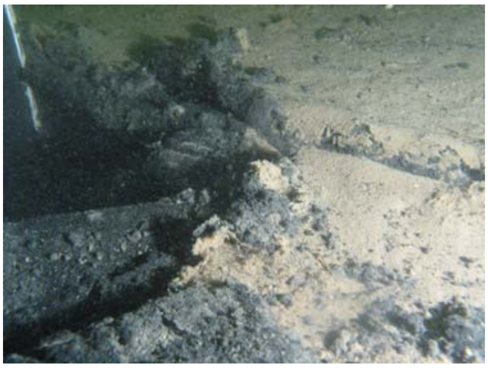
Appendix 4

Periodically or permanently anoxic conditions

An analysis of periodically or permanently anoxic bottoms will hopefully be completed during 2005.

Expanded habitat list – feature

EUNIS level 2	EUNIS level 3	Expanded habitat list – feature
Sublittoral sediment (A5)	Features of sublittoral sediments (A5.7)	Periodically or permanently anoxic mud bottom



***Pictures 9** and **10.** Soft and anoxic marine bottoms. In the picture to the right, the SGU sampling device has cut through the surface and into the black, “dead” sediments. Photo: SGU.*

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21. Kartläggning av marina naturtyper - en pilotstudie i Stockholms län, *miljö- och planeringsavdelningen*. Finns endast som pdf. Även på engelska med titeln: Mapping marine habitats - pilot study for the coastal areas of the Stockholm county.

This report presents a method that uses existing geographical information to map and describe the seabed in the Stockholm archipelago. By combining information on depth, degree of exposure and bottom substrate, the types of flora and fauna that may occur in a certain area can be predicted. We have used the European Nature Information System (EUNIS) system to classify the marine habitats in our coastal areas. The result is a set of digital maps that show the predicted natural habitats of the seabed in Stockholm County.

More information about this report is found at the County Administrative Board's Nature Conservation Section or Environmental Information Section, tel: 08- 785 52 94
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