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Ecotopes in the Dutch Marine Tidal Waters

**A proposal for a classification of ecotopes
and a method to map them**

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Summary

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In order to predict the effects of intended steps and measures on aquatic ecosystems, the use of ecotope maps and habitat maps has increased in the past decade. Recently, in the Netherlands, a GIS-method has been developed for the marine tidal waters to define the ecotopes and habitats that occur there and to depict them in maps. This method, HABIMAP, uses the relations between communities or species and their abiotic environment. These relations are determined and they are mapped, using an 'accumulation' of the various parameter maps leading to the eventual ecotope and habitat maps. Apart from the rendering of current ecotopes and habitats the HABIMAP-method makes it possible to test the effects on ecotopes and habitats (situation, extent) of measures taken by man and to work retrospectively as well. The HABIMAP-method, in fact, can be viewed as a spatial model, that can be a part of a larger Decision Support System, if desired.

In this report workable definitions are given for the ecotope and habitat concepts and the method used to create the maps in question is illustrated. Consequently a proposal is presented for an ecotope classification of the North Sea (Dutch Continental Shelf) and for the marine coastal tidal waters, respectively. Both are illustrated by maps. To conclude some other application possibilities of the HABIMAP-method are discussed and some important future activities are given in this respect.

1 Introduction

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In the Dutch coastal waters and the North Sea many activities take place aimed at construction and management, e.g. dredging activities in channels leading to ports and waterways, construction of port facilities and conservation measures. In order to evaluate these activities as well as to carry out research more efficiently, the demand has arisen for an ecological classification of the Dutch marine tidal waters as a coherent ecotope system: an ecosystem classification. Such a classification may also play an important part in the use of Decision Support Systems (DSS) and the set up of Environmental Impact Assessments (EIA). Internationally the need for a general ecological classification is becoming increasingly larger as well, e.g. in the perspective of the implementation of the EU-Habitats-directive, the designation of Marine Protected Areas (MPA' s), OSPAR and ICES.

A nationwide classification system for terrestrial ecosystems in the Netherlands has been developed by CML[1] and IBN-DLO[2] (a.o. Runhaar et al, 1987; Stevers et al, 1987; Klijn, 1988), which is suitable for ecological effect predictions. Subsequently a number of, interrelating classifications were developed for larger rivers and larger bodies of fresh water by RWS-RIZA[3] and SC-DLO[4] (Rademakers and Wolfert, 1994; van der Meulen, 1997; Wolfert, 1996; Maas, 1998). These classifications have all been based on a hierarchic structure of systems which in their turn were based on dominantly affecting factors.

By analogy with this a classification for the Dutch marine tidal waters has been worked out RWS-RIKZ[5] in co-operation with IBN-DLO and RIVM[6]. A distinction has been made between a classification for the Dutch part of the North Sea (Hartholt, 1998) and the marine coastal tidal waters (de Jong et al, 1999, Leewis et al, 1999). This work, primarily, consisted of a method using GIS to create ecotope maps in a simple and reproducible way. This method is universally applicable and also offers application possibilities for the production of other kinds of ecological maps, e.g. habitat maps.

Reading guide
To start with this report describes the concepts of ecotope and habitat which have been elaborated in workable descriptions. Subsequently the GIS-method that is used to map ecotopes and habitats is described. Two ecotope classifications are presented, respectively for the North Sea Dutch Continental Shelf and the marine coastal tidal waters, as well as the mapping results of this GIS-method. Finally several other forms of ecological maps that can be produced using the HABIMAP-method are discussed in short and some important future activities within this framework are indicated.

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[1] Centre for Environmental Studies University of Leiden
[2] DLO-Institute for Forestry and Nature Conservation
[3] National Institute for Inland Water Management and Waste Water Treatment
[4] DLO-Institute Staring Centre
[5] National Institute for Coastal and Marine Management/RIKZ
[6] National Institute for Public Health and the Environment

2 Description of the ecotope and habitat concepts

Many terms are circulating within the theme of 'ecological maps'. Especially the concepts of 'ecotope' and of 'habitat' are frequently used in this respect, but also terms such as 'biotope' and 'physiotope' regularly occur, in certain case completed with the addition of '-complex' or 'sub-' for higher or lower levels respectively. Furthermore, the concept of 'habitat' is frequently used as a synonym for 'ecotope'. This confusing use of concepts lead to all sorts of communication problems among scientists themselves and among them, policy makers and managers. As, apart from that, it is frequently forgotten that basically all of these 'topes' must be reasonably similar as well as reproducibly mapable (in almost all of the definitions the term 'mapable' occurs), the situation as a whole is not becoming more practicable.

In order to be able to get some concrete ecological maps for the marine tidal waters, a pragmatic approach was taken here. The problem was approached from the angle of the general purpose: ecological relevant data are required in a simple and reproducible way, in order to use them for policy purposes and research purposes. Depicting the data in one or more maps is an important tool in such an approach. Two types of ecological maps can be distinguished, grouped around the concepts 'ecotope' and 'habitat'. The distinction is based on the usual distinction in the areas where respectively communities and individual species live. This distinction also leads to different methods in the production of the maps as well.

The following descriptions are used to describe the ecotope and habitat concepts:

⇒ an **'ecotope'** is an area/environment in which a community lives, e.g. a zoobenthos community with accompanying birds and fishes. This means that communities are basically depicted on an ecotope map. In practice these communities are not or hardly area-wide mapable, unless they are visible at the surface, such as musselbeds or seagrass beds. However, there are all sorts of area-wide abiotic maps available. Departing from the assumption that quantifiable relations exist between the communities that are to be mapped and the various abiotic parameters, these abiotic maps can be used to map the communities. This will be further elaborated in Chapter 3. Within this framework an ecotope is based on a combination of relevant abiotic parameters, such as water depth, salinity, current velocity, waves, soil composition and geomorphology, completed with, where necessary, biotic information, such as musselbeds, seagrass beds, but also human use of the area etc.

A methodical starting point in this is that ecotopes are discrete units; which means that in a certain part of a water system only one ecotope can occur. The relations between ecotopes and parameters are here given as discrete class boundaries.

⇒ a **'habitat'** is an area in which a certain species lives in a certain zone. A species, however, may need various habitats in the course of one year and/or its life cycle, either in the same zone, e.g. high tidal flat - low tidal flat, or in different zones, e. g. 'tundra' - 'Wadden Sea' - 'West Africa' or 'upriver' - 'estuary' - 'open sea'. A habitat is also distinguished based on a combination of the relevant abiotic data for the species in question and a habitat map gives a map image on which for that species the relative importance (suitability) for each part is indicated.

A methodical starting point here is that with relations between a species and the relevant abiotic parameters there is always the concept of being more or

less suitable. This can be expressed by feedback curves. In the final maps the areas are distinguished gradually into potential suitability for one species, in this case with extremes of 100% and 0 % suitability, the 'habitat suitability maps'.

The following can be remarked on the other frequently used terms mentioned above, 'physiotopes' and 'biotopes': a 'physiotope' is described generally as an area that can be discerned based on abiotic characteristics, in addition to which ecological relevant boundaries are taken. It therefore resembles the above described concept of 'ecotope'. Here the term 'ecotope 'is preferred, as it is a concept that is more current in (Dutch) policy making. The term 'biotope' is much used internationally, and is more or less a synonym for 'ecotope'. It is usually used, however, for both community levels and species levels. For this reason biotope is less unambiguous than is preferred for policy use. As a consequence it has become a less workable term in practice.
The additions '-complex' and 'sub-' are more or less a matter of map scale. When on a large scale, e.g. 1: 10,000 or 1: 5,000, ecotopes are indicated, they can be subdivided into smaller units, if preferred to the level of the 'sub-s'. When a smaller map scale is used, e.g. 1: 50,000 or 1:25,000, ecotopes need to be combined into larger units, which can be called the '- complexes'.

3 The HABIMAP-method for mapping

3.1 General procedure

3.1.1 The ecotope map

Basic starting point in the making of ecotope maps is the hypothesis that the presence of a community mainly is determined by a combination of a number of (a)biotic parameters. Between the communities and the relevant abiotic and biotic parameters relations can be determined, i. e. ranges in which the community in question is present. These relations can be translated into map images.
A distinction in these determining abiotic parameters (the different layers of information) can be made between primary parameters, such as period of flooding or period of emergence, current velocity, wave action, salinity and turbidity on the one side and parameters resulting from them such as geomorphology (the shape of the soil surface) and soil composition (especially silt content) on the other side. Relevant biotic parameters may be for example the presence of one or several dominant species (musselbeds or seagrass beds) or certain human activities (trawling, discharge of toxic substances, recreation).

Basically only those parameters are suitable that can be somehow rendered into a map. This can be the result of direct mapping (geomorphology, seagrass, mussel beds) or of indirect mapping, i.e. via interpolation of measurements on (sample) points (soil maps, water depth maps, maps of emergence periods). But such maps may also be derived from model calculations (wave action, current velocity, salinity). If possible maps should be used with a continuous legend scale, in order to get an optimum fit with certain relations. Furthermore, some parameter maps will need further adjustments. E. g. in the littoral the absolute height with respect to a reference level is of no importance, however the period of flooding or of emergence is. Such a derived map can be made by converting the water depth map by means of the tidal curve (amplitude and shape) into the map required. Generally recent maps will be used, but of course it is possible to use maps of future situations or historical maps for respectively prognostic or retrospective research.

On behalf of the making of an ecotope map relations are established between the presence of the distinguished communities and the relevant parameters by indicating discrete class boundaries per relevant parameter. These relations can be available from literature or from field data, but if necessary they can be based on intrinsic knowledge (so-called 'expert-judgement').
The set up class boundaries are linked with the parameter maps concerned, the individual information layers, into monoparametric ecotope maps. Consequently these can be linked into the final product, the ecotope map. The whole procedure is indicated schematically in figure 1.
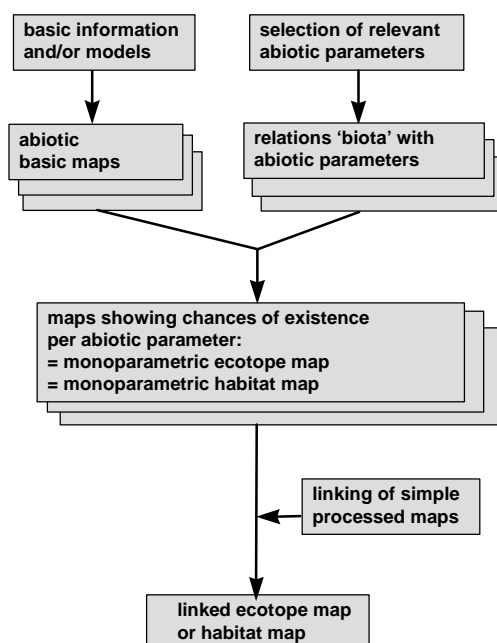
Figure 1. Diagram of the production of an ecotope map or a habitat map

3.1.2 The habitat map

In almost the same way a habitat map, a (potential) distribution map for one species, can be made. The relations between a species and the relevant parameters are indicated by way of feedback curves. The deduction of a feedback curve from the field data is done by drawing an enveloping line around the points in a graph (see figure 2).
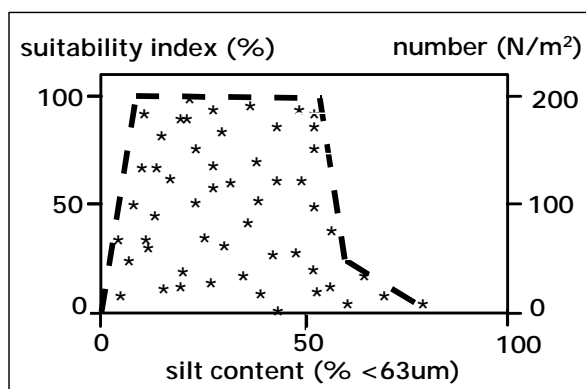
Figure 2. Drawing of a feedback curve on behalf of a habitat map

The basic idea here is that the maximums in the presence of one species are determined by the parameter in question; lower values of the presence in that parameter value are the result of the 'negative' effects of one (or more) other parameter(s). The feedback curves are linked with the parameter maps into the so-called monoparametric habitat maps and these are linked into the habitat map. This linking is done in a habitat map (processed as a grid map) by making the lowest value determining for every grid cell; taking into account

that there is always one parameter somewhere that is restrictive (similarly as with the drawing of the feedback curves).

3.2 The application

For the production of the maps a GIS- application has been developed (in ARC/INFO under UNIX), called HABIMAP. This application consists basically of two modules, a processing module and a presentation module (see Figure 3).
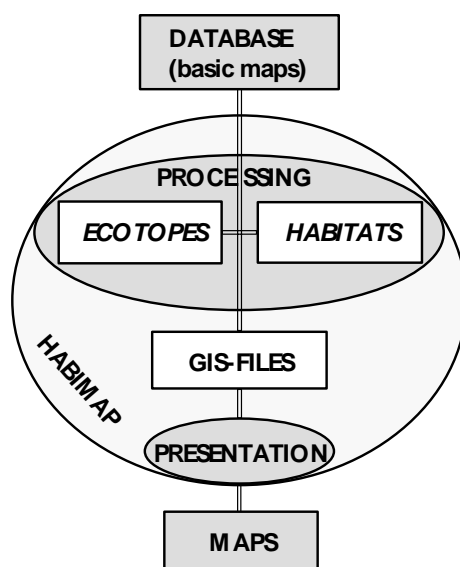

Figure 3. Schematic structure of the GIS-application HABIMAP

The actual processing happens in the **processing module**. i. e. the parameters are selected and the corresponding class boundaries and feedback curves are adjusted. Then the chosen adjustments are linked into a multiparametric map, the eventual ecotope map or habitat map. The result is a series of map files, that can all be printed.

The **presentation module** presents the results of the conducted processing into maps. In the case of ecotope maps one can personally determine which parameters and which class boundaries will eventually be used in the map. This offers for example, the once-only opportunity to calculate a large series of detailed class boundaries for a number of parameters, after which the relevant parameters and class boundaries can be selected and printed per problem. In case of the habitat maps the monoparametric as well as the multiparametric 'suitability' maps can be printed. This offers e.g. the opportunity to analyse the importance of the individual parameters to the final result.

3.3 Some pros and cons of the chosen procedure.

Of course, the procedure for the mapping of ecotopes and habitats described above has, its pros and cons, a few of which will be described in short.

The 'cons' for an important part have to do with the lack of information, as a result of which the final product has not yet the quality one would wish. Some important points are:

⇒ the quality and the extent of detail of the parameter maps are to a large extent determining for the accuracy of the final product. An important point of attention in this is the mode of interpolation in case of sample point data.

Generally, this is due to the fact that it is not possible to tell what is happening on the level of hectares. The remedy is to use parameter maps that are as accurate as possible and if necessary to invest in (the development of) better techniques to map certain parameters (field observations and interpolation techniques).

⇒ In most cases the relations between the parameters and the communities are based on empirical knowledge (field data, whether or not from literature, or intuition) instead of understanding the processes. This could be improved with well-aimed experiments. This is important if knowledge about one region is used in other regions.

⇒ in the current version of HABIMAP the interactions between the parameters is not taken into account; i.e. the feedback of one species to one parameter depends on the value of another parameter. Concrete data in this matter are relatively scarce. In a future version of HABIMAP this can possibly be dealt with.

⇒ the dynamics in the course of time are not directly taken into account, e.g. seasonal changes in salinity or seasonal patterns in the distribution of organisms. This can be dealt with by working with parameter maps that vary with the seasons.

The pros have generally to do with the large flexibility of the method and the extensive freedom of use:

⇒ in a relatively simple manner new or other views can be tested by applying a set of new class boundaries or feedback curves instead of the old ones; in addition the new classification can also be applied retrospectively. This way e.g. an earlier assessed T_0 (point of departure) can be adapted to the new classification in order to be able to soundly compare the developments. Other ecotope classifications (e.g. from abroad) can easily be translated in an adjusted map image.

⇒ it is relatively easy to renew ecotope and habitat maps by applying new information layers (e.g. more recent or one of better quality). In the same way retrospective maps can be made, by adding old maps to the data base, e.g. in order to map an old reference situation.

⇒ hierarchic classifications (the '-complexes' and 'sub-'s') are easily made by coarsening or refining class boundaries. However, it must be kept in mind that the scales and error rates of the parameter maps should not be overlooked, so as to avoid that one is working in too detailed a manner with respect to the basic maps.

⇒ intrinsic knowledge can be tested in habitat maps and wherever needed be adjusted; in this way information can be gathered
d on the importance of parameters and on the relations between the species and a particular parameter.

⇒ for new, hypothetical situations (after conservation measures) 'new' parameter maps can be produced with the help of model calculations or on the basis of expert judgement, after which these new situations can be calculated for a comparison with for example the point of departure or a historical reference.

4 Proposal for the ecotope classification

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4.1 General

Because the Dutch part of the North Sea continental shelf as a system differs considerably from the Dutch marine coastal tidal waters of the Wadden Sea, the Westerschelde and the Oosterschelde, an individual ecotope classification system has been developed for each type of water system. Here both classifications are explained elaborately and are presented in the form of an example map. Class boundaries for the parameters used in both types of classifications have been proposed, but they should be considered as preliminary. Further research will have to indicate whether the chosen parameters are the correct ones as well as the exact boundaries in the classification.

4.2 Proposal for an ecotope classification system on the North Sea Dutch Continental Shelf

4.2.1 The parameters used

As most important determining factor for the choice of the parameters and class boundaries for a classification of ecotopes the benthic fauna was taken. This group's existence is mainly determined by local abiotic circumstances. Birds and fish are mainly guided by the presence and the availability of food and the existence of these groups may mainly be derived from the presence of benthic fauna. Furthermore many fish in the North Sea show an obvious migrating behaviour through the whole of the North Sea (and sometimes the adjacent shallow waters).
With regard to the benthic fauna important parameters of the Dutch Continental Shelf (DCS) are the water depth with respect to MSL, salinity and soil composition. The gradients of salinity and water depth are strongly parallel as the salinity gradient is a consequence of the fresh water discharge of the rivers Rhine, Meuse and Scheldt into the North Sea, after which this water mass moves north parallel to the coast. For this reason primarily only water depth has been taken into account.
In addition e.g. summer and/or winter temperature and stratification as well can play important parts. However, it did not work out to find clear relations between the benthic fauna and these parameters. Therefore in the setting up of this ecotope classification, these parameters were left out.

Water depth
Only a few classes were distinguished:
= *shallow*   *MLW - MSL -20m*
        (salinity here is lowest as a rule: about <32 g/l)
= *moderately deep*   *MSL -20 - -30m*
        (salinity here is somewhat higher as a rule: about 33 - 35 g/l)
= *deep*   *MSL -30 - -50m*
        (salinity here is highest as a rule: about >35 g/l)
(= *very deep*   *> MSL -50m*
        *(this class hardly occurs on the DCS and has been combined
         with deep)*

Soil

With regard to the soil the parameter grain size is used. Based on this the following classes can be distinguished:

= *muddy sand*   rich in silt > 10 %
= *fine sand*   < 10% silt and a median grain size < 250 μm
= *coarse sand*   < 10% silt and a median grain size > 250 μm
= *gravel*   > 30 % gravel

4.2.2 Proposal for a hierarchic ecotope classification

An ecotope classification has been set up based on the two parameters mentioned and the class boundaries described. In figure 4 this is worked out.
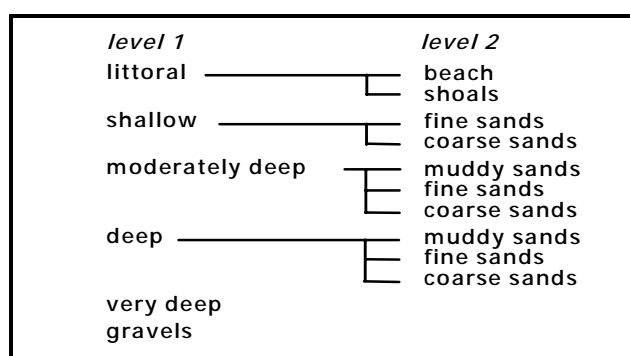

Figure 4. Proposal for the ecotope classification of the Dutch Continental Shelf in the North Sea

4.2.3 Ecotope map

An ecotope map for the Dutch Continental Shelf has been made, based on the described parameters and the proposed class boundaries. This map can be found in Appendix 1. This map does not show the types littoral - beach/shoals, because the basic map data do not yet offer the opportunity.

4.3 Proposal for an ecotope classification of the marine coastal tidal waters

4.3.1 The parameters used

Here also the benthic fauna has been taken as the determining factor for the choice of parameters and class boundaries. The group's existence is mainly defined by the local abiotic circumstances. Birds and fish are mainly guided by the presence of benthic fauna.
The basic parameters used for the ecotope classification are salinity, water depth (with respect to MSL and period of emergence) and hydrodynamics. These can be completed, if necessary, with e.g. biotic parameters such as musselbeds, seagrass beds, salt marsh vegetation etc. Per parameter a description is given how it can be divided into classes, after which a proposal is made for the class boundaries, as to be used in the Dutch marine coastal tidal waters. It should be noted that there are not yet enough data to verify these class boundaries. They are only suggestions. The parameter 'human use/ influences' has not (yet) been taken into account in this classification, because this parameter is more likely to bring about a variation on an ecotope that will occur somewhere else by nature, than it is to form an ecotope on its own.

Salinity

Five classes can be distinguished: fresh, oligohaline, mesohaline, polyhaline, and marine. The latter three are of importance to the coastal zone. The class boundaries can be derived from the internationally used boundaries:

> *mesohaline: 5.4-18.0 gNaCl/l*
> *polyhaline: 18.0-30.6 g NaCl/l*
> *marine: > 30.6 g NaCl/l*

An important problem is which situation is normative: the annual average salinity or the annual minimum or maximum salinity or the spring average (start of the new growing season) or the summer average etc.

Water depth

An important boundary is the Mean Low Water Line (MLW). Below this boundary absolute water depths with respect to MLW can be used. Above this boundary the absolute depth is not so important, but instead the period of emergence/ period of flooding is important. This is a function of the soil height above MLW and the tidal curve in the area concerned.
Below MLW a broad distinction can be made into two zones:
⇒ the deeper channels,
⇒ the flat shallow water areas between the channels and MLW.
The motivation for this distinction is that the shallow water areas are the zones in which tidal migrating species play an important part and in which the nursery function is pre-eminently expressed. The boundary between both zones varies per water system, but for the Dutch coastal waters is about MSL -4 à -5 m as a rule.

Above MLW a broad distinction can be made from below upward into:
⇒ the zone in which musselbeds can occur as a co-structuring factor,
⇒ the zone in which no mussels occur but still other filter feeders (e.g. the cockle) do and in which the benthic fauna still has a high biomass,
⇒ the zone in which only sediment feeders (such as lug worms and small crustaceans) can occur and in which a lower biomass of the benthic fauna occurs,
⇒ the zone in which no benthic fauna of importance is present and in which possible salt marsh genesis can occur (possibly subdivided into pioneer zone / low salt marsh / middle salt marsh / high salt marsh).
Class boundaries could be here:

> *low littoral   1-50 % emergence*
> *middle littoral   50-75% emergence*
> *high littoral   75-90 % emergence*
> *salt marsh   > 90 % emergence*

Hydrodynamics

Hydrodynamics is a complex parameter which will be elaborated further than the first two parameters.
Hydrodynamics will be defined here as the effect of water movement on the movement of the soil surface and on the possibilities to organisms to live and survive on and in the sediment. Some important aspects of water movement are: 1) water movement determines if and where organisms can live as larvae, 2) water movement determines the extent to which the sediment moves, affecting the chances of living for some organisms, 3) organisms living on the surface can get washed away or be exposed to too much stress, and 4) water movement determines the amount of food supply to e. g. filter feeders. In general, relatively little is known quantitatively about these effects.
In this case the effects of the water movement on the movement of the sediment will primarily be worked out. Here the term hydrodynamics can be

replaced by morphodynamics, but as the boundaries are set by the guiding hydrodynamics the term hydrodynamics will be maintained.

Water movement mainly affects the sediment movement in two ways, via waves and via current. The effect of waves is largely that of turbation without necessarily transporting anything; current may lead to soil turbation, but it does not necessarily have to be the case, and it may lead to transport of soil material etc. Both aspects together can lead to a wide range of dynamics, with on the one side quiet areas, where much silt can settle and on the other side very dynamic areas where the sediment is moving and is being transported continuously, e. g. megaripples, and anything in between.

Although not much material is available to quantify the hypothetical classification, the following classification is used as a first proposal: low dynamic, dynamic, high dynamic. These three classes broadly can be defined as follows:
⇒ low dynamic: the sediment is hardly moved by waves and/or current. If there is a sufficient silt supply via the water then a soft sediment will be present (very) rich in silt. As a result of this high silt content the benthic fauna living in the sediment are not able to keep their burrows open for the oxygen supply that is necessary. This type occurs for example in the more inland parts of estuaries (in The Netherlands e.g. in the Dollard), or in very sheltered areas along dikes. In waters containing very little silt in suspension the soil stays relatively poor in silt and in that case this class resembles strongly the class 'dynamic ' insofar as the communities are concerned (in The Netherlands e.g. the Oosterschelde).
⇒ dynamic: in these areas the top soil regularly moves by waves and/or current, although it only disturbs the top most part of some centimetres. The movement is not so strong that it prevents the benthic fauna from surviving. Temporarily and locally some decline in biomass may occur or the (near) disappearance of a species as a result of e.g. a storm. The sediment is sandy to rich in silt depending on the silt content of the water. Locally seasonal variations may occur in silt content. The largest part of the littoral consists of this type.
⇒ high dynamic: in these areas the sediment is continuously and strongly moving as a result of current and waves, especially around spring tide or in the case of storms. Benthic fauna is not able to survive here, as the burrows are continuously destroyed or the fauna is washed away. The benthic fauna, as a result, is poor and consists mainly of a small number of migrating epibenthic species.
Class boundaries per parameter for the three categories are yet to be determined. An important problem is here which situation is normative: the storm 'events' or the more normal situation around, for example, spring tide. A preliminary proposal is given in figure 5.

Map images of the current velocity and the orbital velocity have to be calculated via hydrodynamic models. However, these often are inadequately tuned to the littoral parts.

$V_{orbital}$ \ $V_{lineair}$	< 0.5 m/s	0,5 - 1 m/s	> 1.0 m/s
< 0.2 m/s	Low Dynamic	Dynamic	High Dynamic
0.2 - 0.4 m/s	Dynamic	Dynamic	High Dynamic
>0.4 m/s	High Dynamic	High Dynamic	High Dynamic

Alternatively, the resultant of these two parameters may be used: soil composition and/or geomorphology. It should be noted however, that soil composition and especially the parameter silt content, is highly determined by the silt content in the water. This can be illustrated for the Westerschelde and the Oosterschelde (both SW Netherlands). Both systems contain quiet parts; in the Oosterschelde, however, the silt content is so low that hardly any silt is present in the soil nowadays, while in the Westerschelde many tranquil muddy areas are present. In the Oosterschelde the parameter silt content does not reflect the hydrodynamics. Furthermore in many systems a clear seasonal cycle of dynamics is present in the silt content of the topmost soil layer.
The geomorphology of an area might be a better parameter, but practice proves that this parameter is less well mapable for larger areas than it appears at first sight. Besides, field measurements from the Westerschelde prove that not always logic relations exist between the geomorphology of an area and the hydrodynamics that are found there. Probably soil composition affects geomorphology highly.

4.3.2 Proposal for a hierarchic classification of marine coastal tidal waters

Based on the above mentioned parameters and class boundaries, completed with some extra parameters such as Seagrass beds, mussel beds etc. a systematic ecotope classification can be set up. This leads to many dozens of units in 3 salinity classes. It is plausible that in practise many ecotopes either do not exist or can be combined. Therefore a much simplified second classification, based on the above mentioned classification, has been set up hierarchically; see figure 6.
In this classification the parameters are used and mixed up in such a way that on all levels of the classification a workable system remains. This way one level or a combination of more levels can be chosen, depending on the map scale that is worked with, or the availability of (especially more detailed) map data.
The classification that is presented in this report is mainly set up for the polyhaline and marine salinity classes. The ecotopes in these classes almost overlap in these salinity classes. At the most a few will be omitted (e.g. Seagrass beds in the marine part). In the mesohaline class a large number of ecotopes will not occur and individual brackish ecotopes will replace them. However, not much work has been done with field data on this topic in The Netherlands.
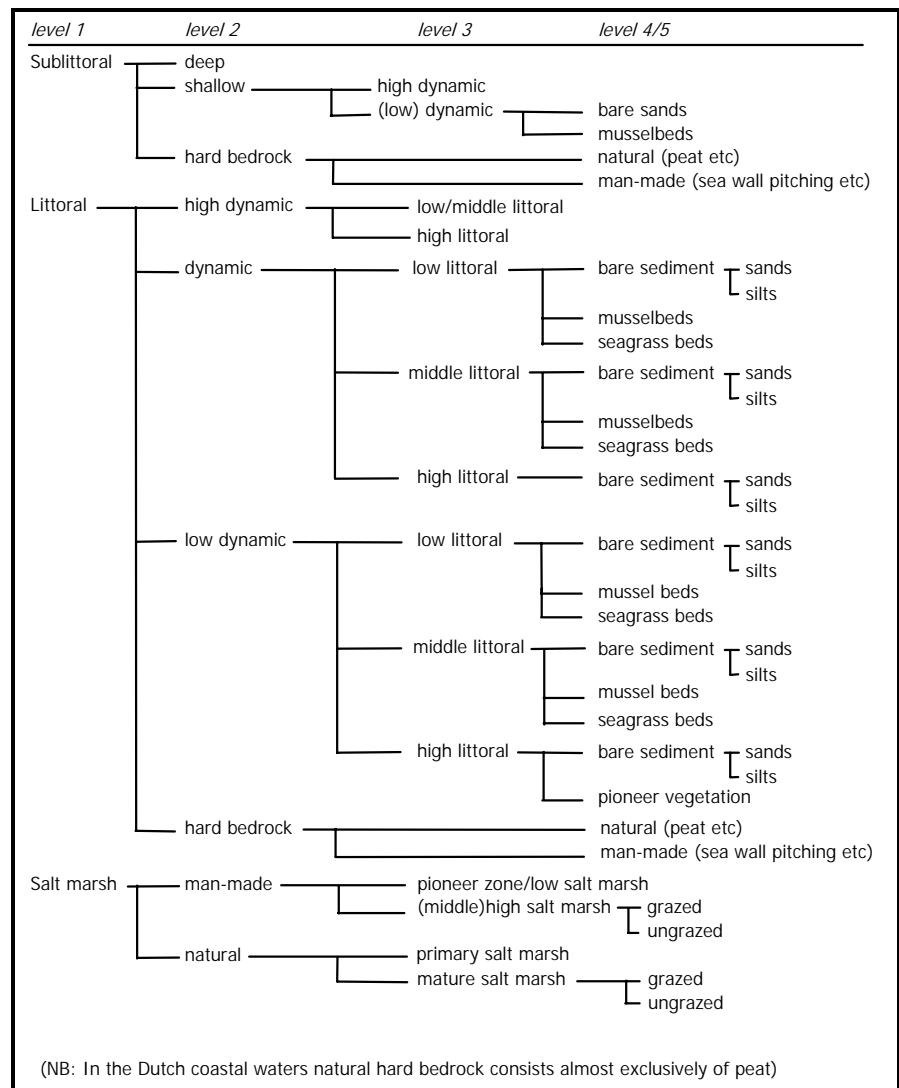
level 1	level 2	level 3	level 4/5

Sublittoral — deep
  — shallow —— high dynamic
            —— (low) dynamic —— bare sands
                              —— musselbeds
  — hard bedrock —— natural (peat etc)
                 —— man-made (sea wall pitching etc)

Littoral — high dynamic —— low/middle littoral
                        —— high littoral
  — dynamic —— low littoral —— bare sediment ⌐ sands
                                              └ silts
                            —— musselbeds
                            —— seagrass beds
            —— middle littoral —— bare sediment ⌐ sands
                                                 └ silts
                              —— musselbeds
                              —— seagrass beds
            —— high littoral —— bare sediment ⌐ sands
                                               └ silts
  — low dynamic —— low littoral —— bare sediment ⌐ sands
                                                  └ silts
                               —— mussel beds
                               —— seagrass beds
                —— middle littoral —— bare sediment ⌐ sands
                                                     └ silts
                                  —— mussel beds
                                  —— seagrass beds
                —— high littoral —— bare sediment ⌐ sands
                                                   └ silts
                                 —— pioneer vegetation
  — hard bedrock —— natural (peat etc)
                 —— man-made (sea wall pitching etc)

Salt marsh — man-made —— pioneer zone/low salt marsh
                      —— (middle)high salt marsh ⌐ grazed
                                                 └ ungrazed
           — natural —— primary salt marsh
                     —— mature salt marsh —— ⌐ grazed
                                            └ ungrazed

(NB: In the Dutch coastal waters natural hard bedrock consists almost exclusively of peat)

Figure 6. Proposal for an ecotope classification of marine coastal tidal waters

4.3.3 Ecotope maps

An ecotope map of the Dutch Wadden Sea has been made, based on the in 4.3.1. mentioned parameters and the in 4.3.2 proposed ecotope classification. This is shown in appendix 2. The following parameters and class boundaries have been used:

= maximum current velocity	0 -0.5/ 0.5 -1.0/ > 1.0	in m/s
= maximum orbital velocity	0 -0.2/ 0.2 -0.4/ > 0.4	in m/s
= water depth (only below MLW)	< -5/ -5 - MLW	
		in m with resp. to MSL
= period of emergence (above MLW)	1-50/ 50-75/ 75-90/ > 90	
		in % emergence

Hard bedrock does not or hardly occurs in the Wadden Sea. The salt marshes have not (yet) been taken into account as at the moment of mapping no reliable data files were available; the man-made salt marshes along the coast of the mainland are visible on the map though, as a white zone along the dikes. In the Wadden Sea-SE (= Ems-estuary) no distinction has been made in salinity-classes.

As an example of a highly simplified ecotope map a map for the Westerschelde has been made (appendix 3). Here, however, the salinity gradient has been taken into account as well. The parameters and class boundaries that are used here are:

= salinity	<20 / >20	in gNaCl/l
= maximum current velocity	0 - 0.5 / > 0.5	in m/s
= period of emergence	0/ 1 - 40 / 40 - 72 / 72 - 93 / >93	in % emergence (0= < MLW)

Salt marshes are not indicated in this appendix because adequate data are still missing in the application files.

5 Other ecological maps

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5.1 Habitat maps

As indicated in the Introduction and the Method habitat maps can be produced using the same basic information and a similar method. I. e. maps that show the possible presence of one species. In appendix 4 an example of this type of map is given. It is the representation of the possible presence of the Edible cockle (*Cerastoderma edule*) in the littoral of the Westerschelde (so called suitability map). The parameters used here are period of emergence, maximum current velocity and salinity. Comparison with data on the actual presence of the Edible cockle in this estuary (not included in this report) shows that the overall picture of the actual presence and the habitat map match rather well. Tuning of the parameter classes will probably lead to increased improvement of the final product.
A habitat map shows where the cockles basically can be present and to which extent. Whether cockles can actually be found there on a certain time is being determined by other factors as well. For example climatic circumstances (winter mortality, weather circumstances during spawning etc.), fishery activities and possible long-range natural cycles can be thought of. It is much more convenient to call the map a 'potential presence map' of the cockle.
The production of such habitat maps may reveal much information about the state of the art concerning the knowledge about the relations between a species and its (a)biotic environment. In fact the HABIMAP-method is then used as a spatial model to test spatially current sample point data.

5.2 Other ecological maps

Apart from ecotope maps and habitat maps, the HABIMAP-method offers the opportunity to produce other ecological maps.
Maps of future situations, within the framework of conservation measures or as a consequence of other measures, can be thought of. Maps of old situations can be used as a historical reference. They are tools to show the effects of certain policies on a spatial level. This can be done by using basic maps of a new or former situation.
Furthermore maps can be produced oriented at specific problems, such as e. g. the situation of areas that are susceptible to oil pollution and/or that can cause problems when controlling oil pollution.
In conclusion maps can be produced oriented at specific categories of organisms, e.g. the situation of areas that are important to certain groups of birds (e.g. waders).
Management and Policy practice will eventually show in which fields this method is practically applicable.

6 Future

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With the HABIMAP-method a method has been developed to produce ecological maps, including ecotope maps. Using this method two preliminary ecotope classifications for the Dutch marine tidal waters have been set up, one for the DCS of the North Sea and one for the coastal waters. However, this is only the first step. A lot more has to be done before a more definitive classification is ready, based upon reliable ecological data with the right class boundaries for the relevant parameters. Some important aspects are given below:

1) The proposed ecotope classifications are based upon the available biotic information and on correlations between groups and parameters. A lot will have to be done to the causality of these relations. It is especially important that these relations can be generalised, in order to be able to predict things: e.g. when indicating the effects on the present ecotopes of certain measures or when advising on the lay out of new areas with conservation measures. In future this issue will be given full attention as far as the Dutch situation is concerned.

2) In the current classification storm situations have been taken as normative for the wave-action and current maps. Storms that occur 1x/2 years have been chosen to have a frequency that plays a part in the life cycle of most benthic organisms. It seems to become increasingly apparent from research that to a number of organisms the periods with extreme tranquillity (low hydrodynamic) are important as well, for example the settlement of free-swimming larvae in the sediment. Such tranquil periods can also play an important part in the silt balance; in short tranquil periods in spring silt can settle in areas that are normally too dynamic. This effect can locally be intensified by an explosive growth of epibenthic algae in spring. A sequential effect of such a silt settling is the temporary settlement of certain short-lived and/or mobile benthic fauna species. This aspect of the effects of low dynamics in the process of settlement of species and settling of silt and via this way in ecotopes and habitats will be elaborated upon in the near future.

3) The parameter maps used up until now show some shortcomings. In 3.3 this has been mentioned briefly. In the near future everything possible will be done to improve them. Actualisation of outdated files and improved interpolation techniques may be considered. A new interpolation technique of making soil silt content maps starting from sampling point data is developed. This technique uses satellite images to interpolate data above MLW while below MLW the gradients alongside the channels, such are frequently to be found in estuaries, are taken into account (van Essen & Harthold, 1998).

4) There are shortcomings and uncertainties in the basic maps and the relations. A method has already been developed to make it possible to work with this in GIS, so as to take these shortcomings and uncertainties into account. An important issue is consequently to quantify these uncertainties and shortcomings as well as possible.

5) The two ecotope classifications proposed are based on benthic organisms. Pelagic organisms do not play a part of any consequence. It has to be researched whether a pelagic ecotopes classification is realistic, to what extent such a classification is parallel to the benthic classification and whether such a classification is practical. A first survey in the North Sea (where this is an issue) has shown that there are probably possibilities, but that this problem is not easy to solve. Especially the mobility and the migrating behaviour of many of the organisms concerned is a complicating factor.

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(All literature is in Dutch; the essence of the title has been translated by way of illustration.)

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ECOTOPE MAP

based on: water depth, soil composition
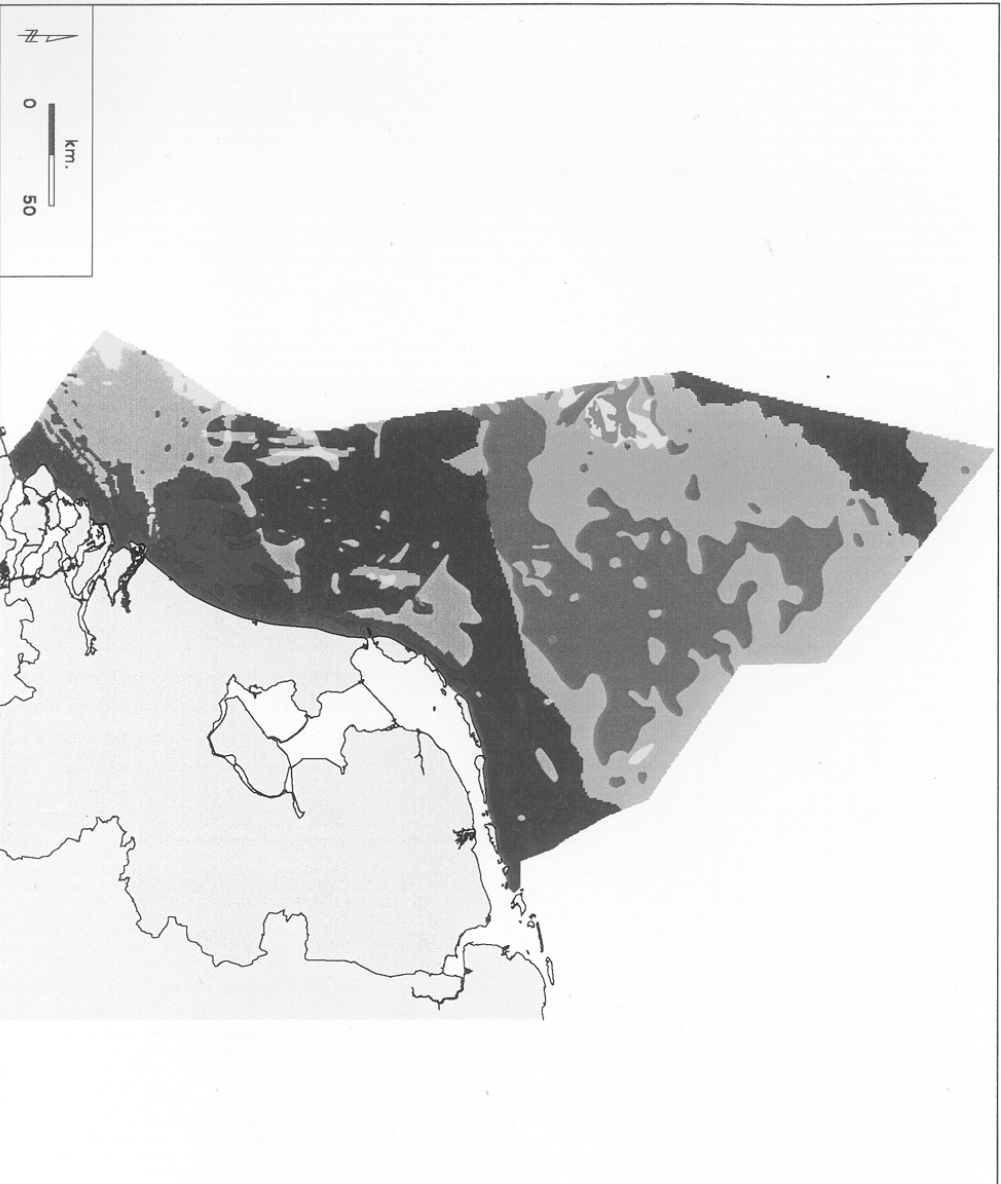
NORTH SEA
Dutch Continental Shelf

Legend
Ecotopes.

- shallow, coarse sands
- shallow, fine sands
- moderate deep, coarse sands
- moderate deep, fine sands
- moderate deep, silts
- deep, coarse sands
- deep, fine sands
- deep, silts
- gravels

details see: chapter 4.2.2
GIS-application: HABIMAP

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Nat. Inst. for Coastal and Marine Managem.

APPENDIX 1

km.

0   50

ECOTOPE MAP WADDEN SEA-west

based on proposed ecotope classification

based on:
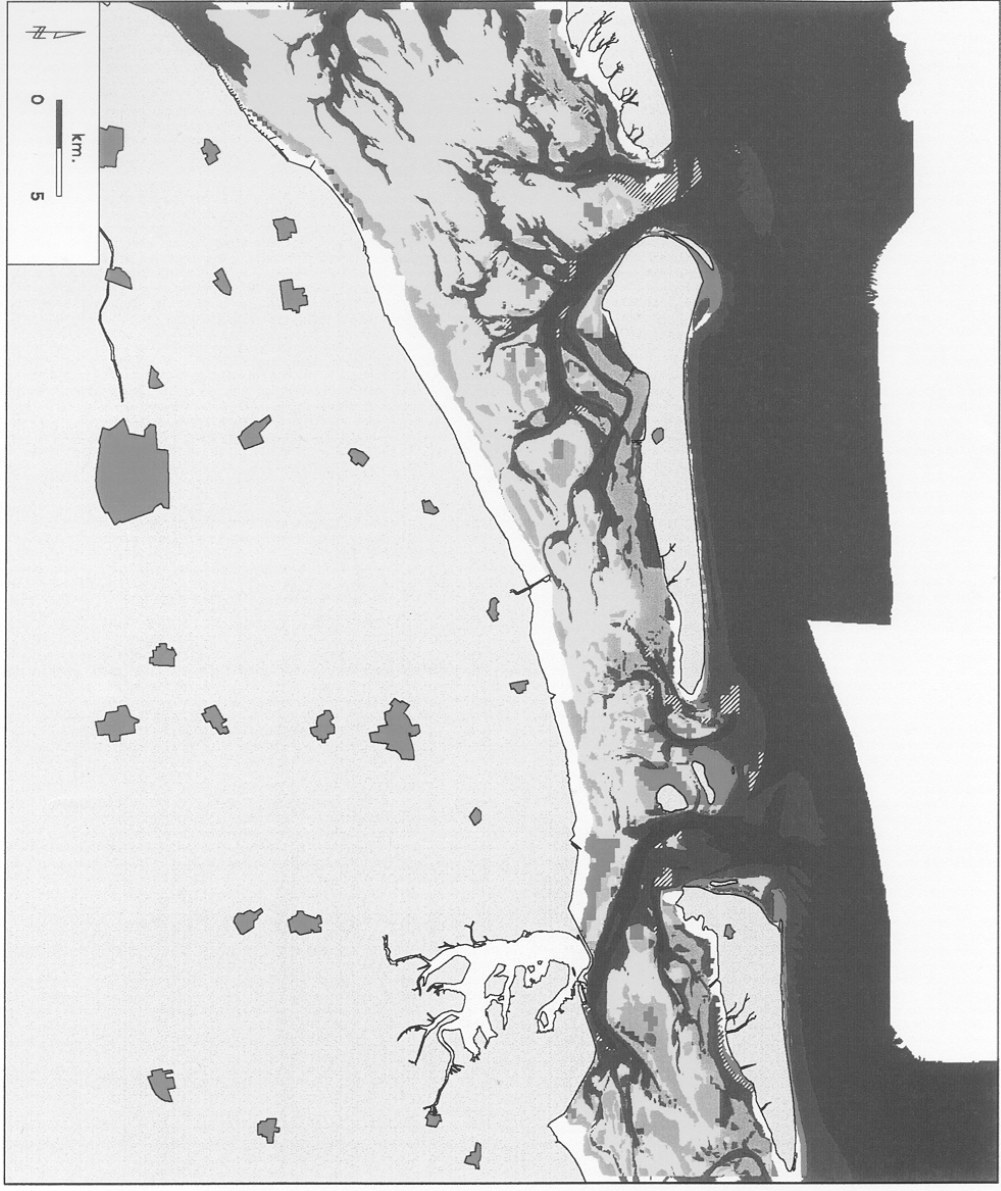- MLW: water depth, current
+ MLW: emergence, waves

Legend
Ecotopes.

- subtittoral deep
- subtittoral shallow, high dynamic
- subtittoral shallow, (low)dynamic
- total littoral, high dynamic
- low littoral, dynamic
- high littoral, dynamic
- middle littoral, dynamic
- low littoral, low dynamic
- middle littoral, low dynamic
- high littoral, low dynamic
- supralittoral

details see: chapter 4.3.3
GIS-application: HABIMAP

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APPENDIX 2-A

km.

0   5

ECOTOPE MAP WADDEN SEA-middle

based on proposed ecotope classification

based on:

- MLW: water depth, current
+ MLW: emergence, waves

Legend

Ecotopes.

- sublittoral deep
- sublittoral shallow, high dynamic
- sublittoral shallow, (low)dynamic
- total littoral, high dynamic
- low littoral, dynamic
- middle littoral, dynamic
- high littoral, dynamic
- low littoral, low dynamic
- middle littoral, low dynamic
- high littoral, low dynamic
- supralittoral

details see: chapter 4.3.3
GIS-application: HABIMAP

km.

0   5

ECOTOPE MAP WADDEN SEA-east

based on proposed ecotope classification

based on:
- MLW: water depth, current
+ MLW: emergence, waves

Legend
Ecotopes.

- sublittoral deep
- sublittoral shallow, high dynamic
- sublittoral shallow, (f)low)dynamic
- total littoral, high dynamic
- low littoral, dynamic
- middle littoral, dynamic
- high littoral, dynamic
- low littoral, low dynamic
- middle littoral, low dynamic
- high littoral, low dynamic
- supralittoral

details see: chapter 4.3.3
GIS-application: HABIMAP

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km.

0   5

SIMPLIFIED ECOTOPE MAP

based on: *period of emergence, current velocity, salinity-winter*

WESTERSCHELDE
(SW Netherlands)

Legend

km.

0   5

Ecotopes.

sub littoral

total littoral, high dynamic

Bathyporeia community

total littoral, low dynamic, polyhaline

Heteromastus and Macoma community

middle littoral, low dynamic, polyhaline

Cerastoderma community

total littoral, low dynamic, mesohaline

Corophium and Nereis community

supra littoral

salt marshes not indicated!
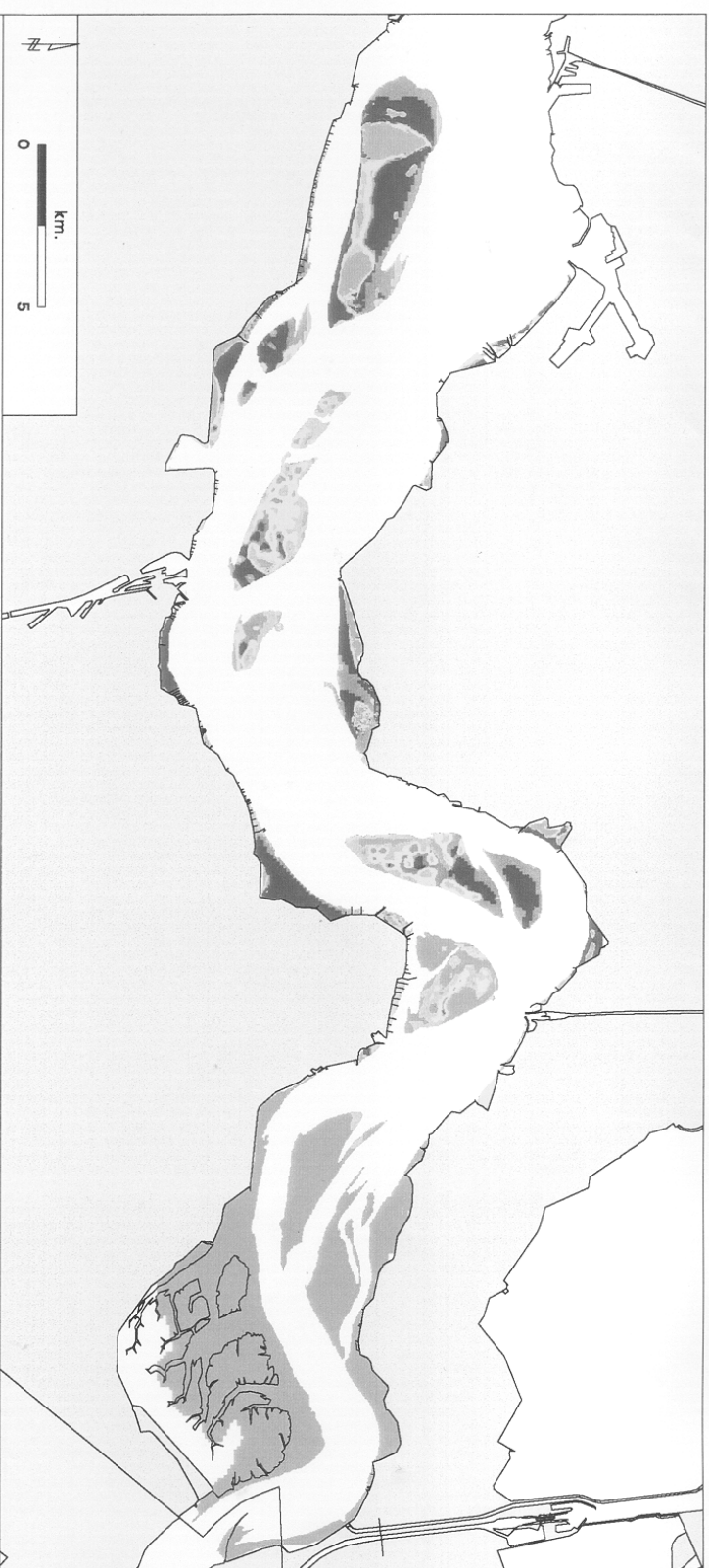
details see: chapter 4.3.3

GIS-application: HABIMAP

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APPENDIX 3

HABITAT MAP: Cerastoderma edule

based on: emergence, current velocity, salinity-winter, silt

WESTERSCHELDE
(SW Netherlands)

Legend

Suitability
- 0 - 20%
- 20 - 40%
- 40 - 60%
- 60 - 80%
- 80 - 100%

km.

0   5

only littoral zone indicated

details see: chapter 5.1

GIS-application: HABIMAP

Dir. Gen. for P.W. and Water Managem.
Nat. Inst. for Coastal and Marine Managem.

APPENDIX 4