A Dutch Ecotope System for Coastal Waters (ZES.1)

To map the potential occurrence of ecological communities in Dutch coastal and transitional waters

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Summary

The Dutch Ecotope System for Coastal Waters (ZES.1) is a tool enabling the potential occurrence of habitats on the bed of brackish and saline national waters to be mapped, to be predicted and to be compared with a previous situation.
Physical environmental factors mainly determine via several processes the occurrence of habitats and with it ecological communities. Based on the main physical environmental factors and processes, we selected a number of abiotic classification characteristics and accompanying variables that may represent these environmental characteristics in a map. Based on the variables and class boundaries we describe the ecotopes and set them up in a hierarchically arranged ecotope system.
The tool may be applied in policy and management preparations, such as future surveys, environmental impact statements (EIS) and the formulation of policy objectives. The approach with ecotopes may be used in the description of the reference conditions of biological quality elements or preservation objectives within the scope of the Water Framework Directive and the Bird and Habitats Directives.

ZES.1 is part of a series of reports made within the project RijksWateren Ecotopen Stelsels (RWES) (Ecotope Systems for National Waters). This series describes ecotope systems for all types of national waters, ZES.1 comprising the brackish and saline national waters.

NB In The Netherlands the term ´ecotope´ is used, which is comparable to the term ´habitat´ as used in Europe, e.g. the European regulations. Although in European context ´habitat´ is the common term, we prefer the term ´ecotope´ as we consider this as more appropriate. ´Ecotope´ refers to the ecosystem as it can be mapped. ´Habitat´ refers, originally, only to the abstract description of the living environment of one single species.

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SUMMARY

Objectives and application

The development of the Dutch Ecotope System for Coastal Waters' objective (below abbreviated as ZES.1 after its Dutch name) is to produce a tool that enables
a. the potential occurrence of ecological communities in and right above the bed of brackish and saline national waters to be mapped (present situation),
b. the prediction of potential changes in the ecosystem if environmental factors change due to organization and management measures,
c. a comparison with a situation in the past, for instance when evaluating effects of organization and management measures.

Scope

ZES.1 is part of a series of reports that have been produced within the project RijksWateren Ecotopen Stelsels (RWES) (Dutch National Waters Ecotope Systems). In this series ecotope systems for all types of national waters (lakes, rivers, canals, etc.) are being worked out and are being described, in which ZES.1 includes the brackish and saline national waters. The water systems that are covered by ZES.1 are North Sea, Wadden Sea, Ems-Dollard, Westerschelde, Oosterschelde, Noordrand (including the New Water Way), Grevelingenmeer and Veerse Meer.

Definitions

Ecotopes are ecological units that can be spatially marked off, the composition and development of which are determined by abiotic, biologic and anthropogenic local conditions. An ecotope is a recognizable, more or less homogeneous natural unit.

An *ecotope system* is a classification system of ecotopes in which the ecotopes of importance in an area (water system) are arranged in an orderly way. It is typical of an ecotope system that its classification characteristics correspond to policy and management measures.

A *habitat* is the environment in which a particular species is living. A species may need different habitats in the course of a year or its lifecycle. These habitats may be side by side (e.g. a low sandbank - a high sandbank; a low sandbank- sublittoral) or in different regions (e.g. the Siberian tundra - Wadden Sea).

A *physiotope* is a unit with homogeneous abiotic circumstances that are important to biologic aspects. In the case of the same management, the same stage of development and without extreme circumstances in the recent past (storm, break-up of ice and the like) a physiotope and an ecotope consist of the same spatial unit.

An *eco-element* indicates a possible stage of (part of) an ecotope, based on the specific information with regard to a species (group).

NB In The Netherlands the term ´ecotope´ is used, which is comparable to the term ´habitat´ as used in Europe, e.g. the European regulations. Although in European context ´habitat´ is the common term, we prefer the term ´ecotope´ as we consider this as more appropriate. ´Ecotope´ refers to the ecosystem as it can be mapped. ´Habitat´ refers, originally, only to the abstract description of the living environment of one single species.

Method

The local physical environmental factors determine primarily the occurrence of ecological communities via various processes. We have chosen a number of abiotic classification characteristics based on the main physical environmental factors and processes.

We have selected exact and abiotic variables that can represent environmental characteristics in a map for all abiotic classification characteristics. An important motivation in the selection of the variables is the availability of data, preferably in the form of maps. An important issue in the selection of the variables is the frequent occurrence of mutual influencing of different variables.

Subsequently, we determined class boundaries for the selected variables that are relevant for the occurrence of ecological communities. In it we have taken into account class boundaries of other, national and international systems.

We describe the ecotopes based on the variables and class boundaries. We have comprised them in an ecotope system built up hierarchically, in which the arrangement is based mainly on both 'the dominance of the physical environmental factors and processes' and the 'logical arrangement of a map' and on 'substantiality of the variables'.

We map the ecotopes by classifying the maps of the variables and combining them afterwards in GIS. Subsequently, the question and the map scale desired, in particular, determine to what level of detail the ecotope classification is depicted
.

Classification characteristics

The abiotic classification we use in ZES.1 are:

1. salinity and its fluctuation
2. substratum 1 (hard substratum, sediment)
3. depth 1 (sublittoral, littoral or supralittoral)
4. hydrodynamics (high energy, low energy)
5. depth 2 (depth, flooding)
6. substratum 2 (sediment composition)

Variables and class boundaries

	variables	classes	Class boundaries	
1	***mean salinity and salinity fluctuation***	little variably brackish little variably saline variably brackish/saline	5.4 - 18 > 18 > 5.4	and fluctuation <= 100% and fluctuation <= 100% and fluctuation > 100%
2	***substratum 1***	hard substratum sediment	stone, wood, peat etc. sediment	

3	***depth 1***	sublittoral littoral supralittoral	< MLWS (underwater) MLWS – MHWN (flooded any tide) > MHWN (not flooded each tide)
4	***Hydrodynamics**** ***(water movement)*** fetch (coasts) linear current velocity (sublittoral and littoral) Orbital velocity (littoral + supralittoral) geomorphology** (littoral)	 high energy (waves) high energy (current) low energy (current) stagnant (no current) high energy (waves) low energy (waves) high energy low energy high energy low energy	 North Sea coast Class boundaries depend on the model used. Theoretically the boundary is at 0.8 m/s being the boundary of the origin of mega-ripples 0 m/s Class boundaries depend on the model used. From result so far it appears that the boundary below works well > 0.2 m/s < 0.2 m/s megaripples, high-energy flat bed, consolidated peat/clay, ridges low-energy flat bed, salt marsh
5	***depth 2*** (depth, flooding) sublittoral littoral (duration of flooding) supralittoral (flooding frequency or vegetation zones)	 Very deep – possible stratification deep - unstratified shallow low littoral middle high littoral high littoral pioneer zone and potential pioneer zone low salt marsh middle high salt marsh high salt marsh	 North Sea: > 30 m Grevelingenmeer: > 15 m Veerse Meer: > 10 m North Sea: 20-30 m Grevelingenmeer: 5-15 m Veerse Meer: 5-10 m Other water systems: > 5 m - MLWS North Sea: 20 m to MLWS Other water systems: 5 m- MLWS to MLWS MLWS - 75 % 75 - 25 % 25 % - MHWN MHWN to > 300 x/year 300 - 150 x/ year 150 - 50 x/ year 50 - 5 x/ year
6	**substratum 2** (sediment composition) median grain size	 Rich in silt fine sands coarse sands gravel	Median — silt (< 63 µm) - — >= 25%# < 250 µm — < 25% 250 - 2000 µm — < 25% > 2000 µm — < 25% (#: North Sea 10% instead of 25%)

Some definitions:

* the variable 'hydrodynamics' consists of three variables that apply to the different water systems or areas.
** geomorphology: this variable may be used as an alternative for linear current velocity and orbital velocity in the emerging parts.

mean salinity = mean salinity at high tide over one year with a mean supply of fresh water (river discharge in particular)
salinity fluctuation = [(4 x standard deviation of salinity) / mean salinity] x 100%, calculated with the same data as used for mean salinity
linear current velocity = the maximum linear current velocity during a mean spring tide irrespective of ebb or flood in average storm circumstances (storm frequency 1x per year)
orbital velocity = the maximum orbital velocity at mean spring tide and average storm circumstances (storm frequency 1x/year)

Ecotope classification hard substrata and sediments

The scheme on the next page shows the ecotope classification.

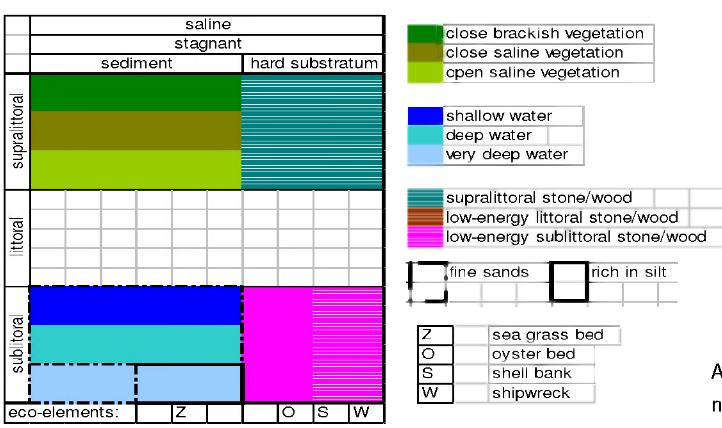
Eco-elements

Within ecotopes smaller areas may occur in which typical, ecological communities with structuring characteristics are present, deviating from the ecological communities that are present elsewhere in the ecotope involved. We call them eco-elements.
The greatest difference between eco-elements and ecotopes is that the (non-)occurrence of these characteristics, structuralizing ecological communities depends partly on coincidental processes and cannot be predicted exactly based on abiotic factors. In ZES.1 we discern the following eco-elements:

-gully
-sea grass bed (*Zostera marina*, Z. noltii*)
-Ruppia-association (*R. maritima, R. cirrhosa*)
-mussel bed (*Mytilus edulis*)
- oyster bed (*Crassostrea gigas*)
-shell bank (a type of hard substratum)
-shipwreck
- shore vegetation along the shores of brackish lakes
(* in UK *Zostera angustifolia* or *Z marina* littoral rsp. sublittoral)

Ecotope-mondriaans

In between classification and mapping of the ecotopes for a certain area it is convenient to make an ecological schedule, the ecotope-mondriaan. It summarizes the ecotope map to be made in an abstract schedule and it indicates the ecological coherence. The ecotope-mondriaan can both serve as help in the making of the map and as a means of communication, to present the arrangement and general working method of the ecotope system. The example below is the ecotope-mondriaan of the Grevelingenmeer.



A blank field means that these ecotopes are not occurring in this area or water system

Ecotope classification ZES.1

WORD OF THANKS

A large group of people has contributed to the realization of this report. People from various fields and disciplines have thought along with us, from experts in the field of benthos, fish and birds to policy makers.

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1. INTRODUCTION

1.1 Objectives

The objectives of the development of the Dutch Ecotope System for Coastal Waters (below abbreviated as ZES.1 after its Dutch name) are the making of a tool that enables
a. the potential occurrence of ecological communities in and just above the bed of brackish and saline national waters to be mapped (present situation).
b. the potential changes in the ecosystem to be predicted if environmental factors change due to organization and management measures.
c. a comparison to be made with a situation in the past, for instance in the evaluation of the effects of those organization and management measures.

In order to achieve these objectives we need to map the ecotopes. The presence of ecological communities and their relations with abiotic environmental factors are the focus of ZES.1. By imitating changes in abiotic environmental factors (for instance in models) we are able to study where and how changes in ecological communities will occur or have occurred. The classification of the system is based on ecological communities living in and right above the bed, such as benthos, algae and angiosperms. The presence of organisms in the water column is not taken into account in this classification. A classification of the ecotopes in water column is formed in the development of the Pelagic Ecotope System.

1.2 SCOPE

ZES.1 is part of a series of reports that have been produced within the project RijksWateren Ecotopen Stelsels (RWES) (Dutch National Waters Ecotope Systems). In this series ecotope systems for all types of Dutch national waters (lakes, rivers, canals, etc.) are being worked out and described.

The ecotope system described in this report applies to the coastal and estuarine Dutch national waters and is called ZES.1; ZES.1, to prevent possible confusion in case of future updates. The water systems that are covered by ZES.1 are North Sea, Wadden Sea, Ems-Dollard, Westerschelde, Oosterschelde, Noordrand (including the New Water Way), Grevelingenmeer and Veerse Meer. ZES.1 does not cover the brackish national canals, but the Canals Ecotope System (KES) does.

The approach of the National Waters Ecotope Systems (RWES) is one of mapping the physical environment and of classification after ecological contents. This way ecotope systems have been set up for the large fresh and (slightly) brackish national waters in the Netherlands, such as the lakes, rivers and canals, followed by the Dutch Ecotope System for Coastal Waters (ZES.1).

RES: Rivers - Ecotope – System (Rademakers & Wolfert, 1994)
MES: Lakes- Ecotope – System (Van der Meulen, 1997)
BES: Ecotope System for the Lower Reaches of Rivers (Maas, 1998)
KES: Canals - Ecotope – System (Peters, 1999)
ZES.1: Ecotope System for Saline Waters (this report)
PES: Pelagic – Ecotope – System (in prep.)
The first four system-oriented systems have been joined and geared to one another into two umbrella systems for the water phase in RWES-aquatic (Van der Molen et al., 2000) and the shores in RWES-shores (Lorenz, 2001) respectively.

The upper boundary in the saline/brackish lakes was set up at the zone that is still affected by the lake water, the more or less halophytic vegetations. ZES.1 does not cover 'man-made' vegetation, e.g. (recreation) meadows, woods, farmland, etc.

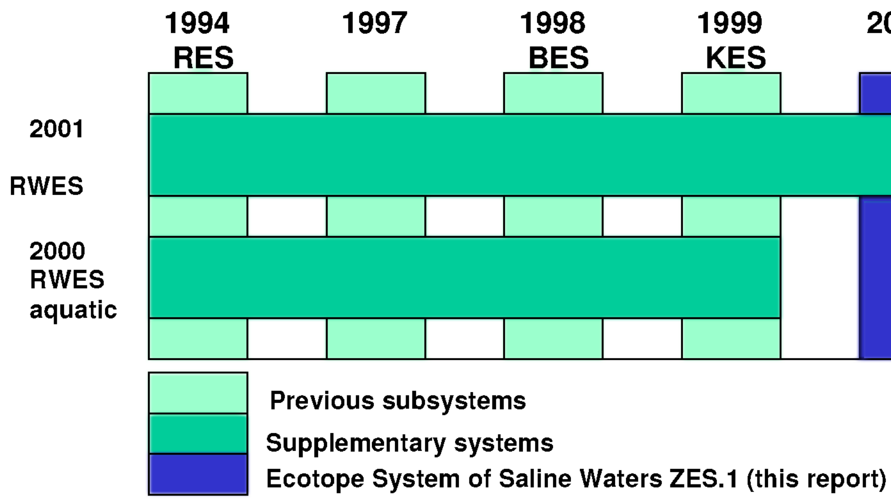

Figure 1.1.1. Position of ZES.1 with regard to systems previously published in the series (RWES) (after Van der Molen et al., 2000)

Figure 1.1.1 depicts the position of ZES.1 with regard to previously published ecotope systems.

Previous to the production of ZES.1 several draft-systems were made (De Jong et al., 1998; Leewis et al., 1998; De Jong, 1999; Dankers et al., 2001). Several draft-systems for specific parts of ZES.1 were set up as well (North Sea: Hartholt, 1998; Van Horssen et al., 1999; brackish tidal waters: Vos & Wolff, 2001; hard substratum: Meijer & Waardenburg, 2002). The (sub-) draft-systems served as a basis for the eventual ZES.1 (see annex 1 for a comparison). We have tried to fit in with the EUNIS (European Nature Information System) marine habitat classification, a European ecotope system that is being developed, meant for application in the European rules (see chapter 7 as well).

1.3 DEFINITIONS

RWES uses the following definitions of ecotope and ecotope system (Wolfert, 1996):

***Ecotopes* are ecological units that can be spatially marked off, the composition and development of which are determined by abiotic, biologic and anthropogenic local conditions. An ecotope is a recognizable, more or less homogeneous natural unit.**

An *ecotope system* is a classification system of ecotopes in which the ecotopes of importance in an area (water system) are arranged in an orderly way. It is typical of an ecotope system that its classification characteristics correspond to policy and management measures.

Internationally the term ‘habitat’ is generally used as well, for example in the EU Habitats Directive. In the Netherlands the terms ecotope and habitat however are having a different meaning. A habitat may comprise several ecotopes and is defined here as (De Jong, 1999):

A *habitat* is the environment in which a particular species is living. A species may need different habitats in the course of a year or its lifecycle. These habitats may be situated side by side (e.g. low sandbank-high sandbank; low sandbank– sublittoral) or in different regions (e.g. Siberian tundra– Wadden Sea).

Within an ecotope a particular community of organisms is occurring potentially. The ecotopes have been defined as seen from the relationship between physics, sediment and benthos-communities. An example of this is a sandbank in which a community of epibenthic animals is present. This community is attracting other organisms. In this case fish and birds to which the benthos is serving as food. The occurrence of a particular ecological community may be linked to a particular set of abiotic environmental factors. The selection of a set of variables for this set of abiotic environmental factors subsequently enables us to map the ecological community (indirectly). This method is suitable to map ecological communities that are present in the bed and are submerged (part of the tide). That is why they cannot be directly observed and mapped.

The only way to get a picture of which and how much organisms are present in and right above the bed is to take samples. Subsequently, we may link their presence in these samples to measured or modelled local variables.

When adequate data on the relations between the abiotic environmental factors and ecological communities is available, the ecological communities can be mapped by using the main physical variables. In fact then it is a matter of depicting physiotopes in which ecological communities are potentially present:

A *physiotope* is a unit with homogeneous abiotic circumstances that are important to biologic aspects. In the case of the same management, the same stage of development and without extreme circumstances in the recent past (storm, break-up of ice and the like) a physiotope and an ecotope consist of the same spatial unit.

As not every factor affecting the presence of organisms can be covered, it is possible that basically within one physiotope several ecological communities (or ecotopes) may exist. In addition, a development cycle (succession) is often taking place within ecological communities (both of plants and animals). An ecological community may be brought back to the starting point of its succession by certain, often sudden and unpredictable events (such as storms, breaking up of ice), after which the community once again passes through the succession. Sometimes several ecological communities can be discerned during the succession. In other cases it is a matter of various manifestations of one ecological community, in particular when these events are occurring frequently and are forming a normal part of the environmental factors within an ecotope. ZES.1 considers various ecological communities/manifestations during a succession to be one ecotope. In benthic communities it is often a matter of mixed patterns. A few dominant species are occurring with a broad range of other species, while this broader group of species, is occurring together with other dominant species as well. Sometimes, it is hardly a matter of different abiotic environmental factors between the different cases. ZES.1 considers these cases as well to be different manifestations of a particular ecological community and to be one ecotope.

Within ecotopes smaller areas may occur in which characteristic ecological communities are present with structural characteristics that differ from the ecological communities within the ecotope concerned. Obvious examples are seagrass beds, mussel beds and oyster beds. RWES discerns them as eco-elements (Van der Molen et al., 2000):

An *eco-element* indicates a possible stage of (part of) an ecotope, based on the specific information with regard to a species (group). It is characterised by operational factors related to the actual chemical and physical processes.

The greatest difference between eco-elements and ecotopes is that the location of these characteristics, structuralizing ecological communities cannot be predicted based on abiotic factors and partly depends on accidental processes. What ecotope is present can be predicted if the physical conditions are known. In addition we can indicate which eco-elements may occur in which ecotope. The mapping of eco-elements should happen by mapping in the field, if necessary supported by the use of aerial photographs.

1.4 GENERAL AND POSSIBLE APPLICATIONS

ZES.1 may be used as a tool enabling the mapping of the occurrence of ecological communities in and right above the bed of brackish and saline national waters.

The mapping of actual, historical, or future situations

With ZES.1 we have a tool at our disposal that enables us to potentially map the actual occurrence of groups of organisms, to make predictions to a certain extent and to review the occurrence of these organisms in the past.

One of the applications of ecotope maps is the mapping of the occurrence of ecological communities in and right above the bed during a particular period of time. With it, ecotope maps form a spatial extension on the usual point measurements. The maps enable us to compose in a more quantitative sense (acreages) a picture of the situation in a water system.

Ecotope maps may be produced for the current situation, but as well for future situations after possible management or organizational measures or for a historical situation when a comparison has to be made with a reference situation. Models are used to calculate what abiotic circumstances will occur or have occurred in that period in order to produce such future or historical ecotope maps. The results of the model calculations are converted into maps of abiotic variables used in the ecotope system, by which subsequently the ecotopes may be pictured.

Scope of application

This method may be applied in the case of management and policy preparations, such as future surveys, environmental impact studies (EIS) and formulating policy objectives. Ecotopes play an important part in the Water Framework Directive and in the Bird- and Habitats Directives, in the description of the reference conditions of biological quality elements or the preservation objectives of the various water systems.

Quantification of changes

Ecotope maps may be used to assign quantitative contents to different parts of a system. With it, it is possible to make comparisons exceeding those of gross acreage between areas. An example: in water system A a littoral (high- and low-energy) area of 1000 ha is present and in system B one of 800 ha. If the quality (i.e. the assessment of certain criteria and the carrying out of a validation of what is available in this field) is included, system A has 500 ha of ecologically valuable area (low energy often is more valuable) and system B has 700 ha. Obviously, within the system different periods may be compared. The results show a completely different picture of the developments than when only the gross acreage is taken into account.

1.5 READING GUIDE

In Chapter 2 we illustrate the method used in the development of the ecotope system. We present as well the classification characteristics, variables, eco-elements and the eventual ecotope system in short and we introduce the concept of the ecotope-mondriaan. We describe the backgrounds and details on these subjects in Chapters 4 and 5.

In Chapter 3 we describe the actual uses of ZES.1. Furthermore, we indicate possible problems and illustrate with examples. In Chapter 4 we discuss the classification characteristics of the ecotope system. We describe for all classification characteristics via which processes they affect the occurrence of benthic flora and benthic fauna. Per classification characteristic we describe the selected variables and class boundaries and underpin them.
In Chapter 5 we give some ecological descriptions of the eco-elements, we show the ecotope-mondriaans for the various water systems and we introduce the ecotopes present.

In chapter 6 we describe the ecological contents of the ecotopes. The ecotopes in the Westerschelde, Ems-Dollard, Wadden Sea, Oosterschelde and Noordrand (including the New Water Way) are dealt with in one section, as mostly the same ecotopes occur. The ecotopes in the North Sea are dealt with in a separate section, as in the North Sea ecotopes are present that do not occur in other water systems. The ecotopes in the Grevelingenmeer and the Veerse Meer as well are dealt with in separate sections, as specific parts (stagnant waters) of the ecotope system apply to these water systems.

In chapter 7 we compare the classification characteristics, variables and class boundaries of ZES.1 with or link them to those of the RWES-aquatic and RWES-shores with the European EUNIS marine habitat classification.

2. THE ECOTOPE SYSTEM

2.1 METHOD

The ZES.1 objective is supplying relevant ecological information for policy, management and research that enables the potential occurrence of ecological communities in the form of maps to be shown, predicted and evaluated. This objective makes the method followed to differ from the international (European) method in the development of habitat (read: ecotope) classifications. RWES focuses on the relations between the abiotic environmental factors and the actual occurrence of organisms. At a European level classifications are rather arranged based on the occurrence of organisms than on abiotic environmental factors. This difference has formed mainly because of the fact that mapping the current situation is prevailing in international habitat mapping. Opportunities to predict and evaluate, an important part of which is the application of physical models, are less focussed upon.

In the method followed in the development of ZES.1, we can discern roughly a number of subsequent steps. We describe and motivate these steps one by one below. Per step we describe first (in bold) the essence of the approach, followed by a more detailed explanation in the subsequent text.

Step 1, abiotic classification characteristics

Local physical environmental factors and processes determine primarily the spatial variation in the occurrence of ecological communities. We have selected a number of abiotic classification characteristics based on the most important physical environmental factors and processes: salinity and its fluctuation, substratum 1 (hard substratum or sediment), depth 1 (sublittoral, littoral, supralittoral), hydrodynamics (high or low energy), depth 2 (depth, flooding) and substratum 2 (sediment composition).

We have studied the available information on the physical environmental factors and their linked processes that affect the presence of living organisms in and on the bed. We have tried to assess as well as possible which of these physical environmental factors and processes mainly determined the occurrence of benthos and which are dominating other factors or processes. We used them to select a series of abiotic classification characteristics (Chapter 4). The distinction between ecotopes is primarily based on differences in physical environmental factors and their linked processes. The variables and class boundaries described in the following steps are a means to discern those ecotopes univocally.

Step 2, variables

We selected exact abiotic variables for all abiotic classification characteristics that may represent those environmental characteristics on a map, or variables that correlate with important characteristics of the system, on which spatial information is less easily to get. An important issue in the selection of the variables is the occurrence of relationships between the various variables.

To enable the application of the abiotic classification characteristics in practice, like enabling mapping them, it is necessary to select 'exact' (i.e. measurable/quantifiable) variables (Chapter 4). An example of such an 'exact' variable that may be used for the classification characteristic 'hydrodynamics' is the maximum linear current velocity during an average spring tide (section 4.4). The variable-maps may originate from direct mapping of measurements (with or without interpolation), and from model calculations as well.
We selected the 'exact' variables primarily based on their ecological relevance. Moreover, we selected them mainly based on the currently available information on abiotic variables and the reliability of the measured and/or modelled data.

In addition, the variables must be mappable. Furthermore, in the actual application of ZES.1 (Chapter 3) it is furthermore important that the variables if possible can be calculated/mapped for situations in the future/past.

We paid attention to the interrelationships between some variables in the selection of the variables. Such as low current velocities that will go hand in hand with a sub soil rich in silt more often, than high current velocities. Then the question arises which variable determines the occurrence of the benthic communities, current velocity, sediment composition or both. Comparison of systems rich in silt and systems poor in silt with the same degree of hydrodynamics may lead to further information on it. If a direct variable is not available in the form of a map, then a derived variable may be used as a substitute. Geomorphology (the appearance of the bed) is such a derived variable that tells us much about the character of hydrodynamics as a whole. Another derived variable is the maximum fetch, which sometimes can serve as substitute for wave action. This way, different methods may lead towards the same goal: the mapping of physical conditions.

Step 3, class boundaries

We have determined class boundaries for the selected variables that are relevant for the occurrence of ecological communities. In it, we have taken into account class boundaries that were selected in other, national and international systems.

After selecting the variables we defined the class boundaries. From an ecological point of view, it is hardly possible to draw hard boundaries as a rule, because in fact it is always a matter of gradual transitions between ecological communities. However, to map an ecotope requires clear and univocal class boundaries. Therefore, we have tried to select class boundaries as well as possible (Figure 2.1.1 and Chapter 4).

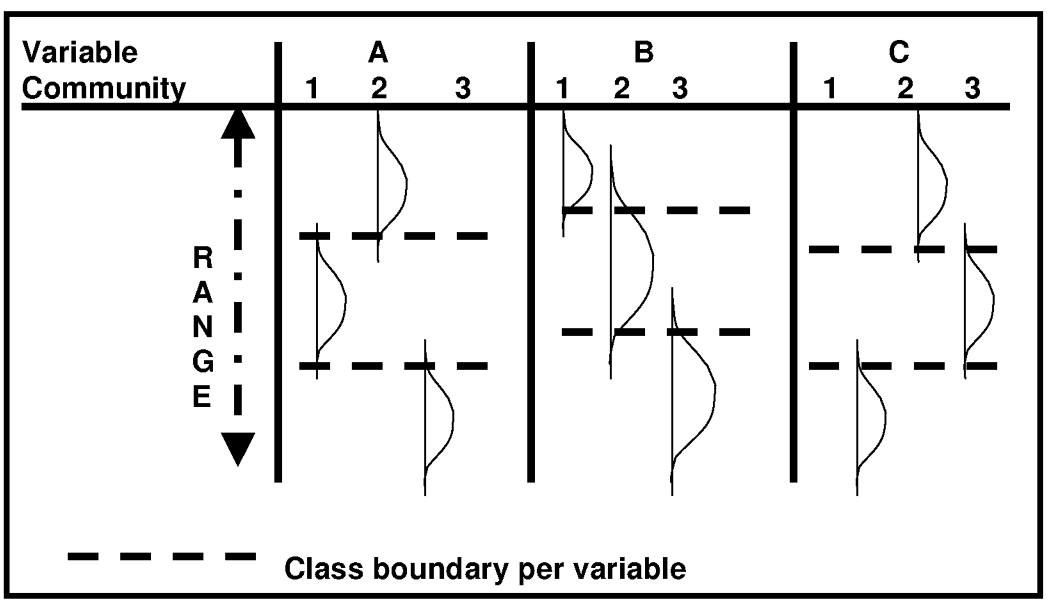

Figure 2.1.1.

Illustration of the selection of class boundaries for different variables (A, B and C) and different ecological communities (1, 2 and 3). The combination of the ranges of the variables, within which a particular ecological community may occur, yields the abiotic description of an ecotope.

The class boundaries are based on ecological differences in the first place. In addition, the feasibility of the system has been taken into account, such as the total number of units and the degree in which details are shown on a map without losing track. In defining the class boundaries, in some cases we have not been able to underpin a further subdivision (up to now) due to a lack of ecological information. In addition, ecological information is on hand sometimes, but a detailed subdivision is not practical or meaningful, for instance because the mapping method or the available model is not adequately reliable. Finally, we looked into the class boundaries that other classification systems are using, like in the other RWES-systems and on a European level the EUNIS-classification.

Step 4, the hierarchic classification

We describe the ecotopes based on the variables and class boundaries. We have comprised them in an ecotope system that is arranged hierarchically. This arrangement is based mainly on 'the dominance of the physical environmental factors and processes', but on the 'logical arrangement of a map' and on 'substantiality of the variables' as well.
Based on steps 1, 2 and 3 we discern ecotopes that are univocally described qua ecological meaning with the aid of the selected variables and class boundaries. For practical use it is convenient to set them up in a coherent system. Such a system can be arranged in many ways, all being good basically and each having its specific pros and cons. In ZES.1 we opted for comprising the ecotopes in a hierarchic classification. We arranged the classification characteristics with their accompanying variables and class boundaries hierarchically (see section 2.3). Different classification characteristics and variables are used on various levels, achieving gradually an increasingly detailed level of description of an ecotope. This hierarchic method makes it possible to produce less detailed maps, like in the case of a lack of detailed information. Moreover, the degree of detail necessary depends on the policy question and on the number of ecotopes that can be presented in a map in a recognizable way. On the other hand, the hierarchic system makes it possible that a smaller area may be zoomed in to. Leading factors in the arrangement of the hierarchic classification as illustrated below are 'the dominance of the physical environmental factors and processes', 'the logic arrangement of a map' and 'the hardness of the variables and/or class boundaries'

'The dominance of the physical environmental factors and processes' means that some physical environmental factors and the associated processes affect the occurrence of (groups of) organisms more than other ones. Salinity as such is a very dominant environmental factor in the occurrence of benthos. Salinity obviously determines which species can live somewhere due to their physiology (physique and functioning), on can think of brackish water species or marine species. The distinction between ecotopes based on salinity is made at the first level of the hierarchic classification in ZES.1 (Chapter 4). Another very dominant environmental factor is the nature of the substratum (hard or sediment). This factor is more important than - or dominates - the sediment composition of the sediment (like rich in silt or coarse sands). For an organism's build and way of life determine in the first place whether it is able to attach to hard substratum or to burrow into sediment. In addition, species-specific preferences for a particular sediment type exist.

The '**logical arrangement of a map**' is taking a logical way of zooming in or out on a map into account, as the degree of detail that is depicted in a map is not always the same. Basically, a map has a finite number of legend units. The number to be depicted is determined by facts such as map scale (1: 50,000, 1:200,000), map size (A4, A3, A...) and the map's function to the user. To keep the map orderly, it will be rather a matter of a minimum number of required legend units than a maximum possible number. It is convenient to comprise legend units as much as possible in the same way, so that the comparability of the maps, possibly on different scale levels, is as best as can be. A logical hierarchic classification can stimulate it.

To achieve a logical hierarchy in the classification we used the ' method of zooming in'. In it, one zooms in further and further on an area as far as map scale, map size and/or demand allow or require. An important question with regard to an overview of a large area for instance, is what the distribution of permanent water, intertidal area and salt marshes is like. Zooming in further, it is important where areas of high and low energy are situated, like with respect to biomass of benthos in the littoral. One level further down, it is a matter of height of the littoral, like in connection with the presence or absence of filter feeders such as mussels or common cockles. A consequence of a system arranged in such a way is that a variable such as height may be used as a criterion at two different levels in the system: first as a rough classification and later on for further subdivision. The big advantage of it is that such a hierarchic system supplies a logical series of ecotopes at all levels.

Contrary to the other Ecotope Systems for the National Waters, no scaling element is linked with the term ecotope in ZES.1. An ecotope may be discerned at different levels, from rough to very fine. The lower limit is determined by the level at which one wants to subdivide still further. In ZES.1 we use the term ecotope for all levels, irrespective of scale. A tidal flat for instance, is an ecotope in itself with typical organisms in a certain composition and the possible broad range within this ecotope does not necessarily have to be relevant at a higher level of abstraction. Some references work with terms such as ´eco-zone´ - ´eco-series´ - ´ecotope´ - ´sub-ecotope´ (Klijn & De Haes, 1990). Such extra terms seem to make the problem of ecotopes at different scale-levels more clearly, but because of the many gradients present in the coastal zone they are not applicable very well.

'The hardness of the variables and/or class boundaries' means that
- some variables may be expressed more reliably in a map than other ones,
- and some class boundaries are more obvious or more reliable to indicate than other ones.

It has its repercussions on the reliability of the map, the contents of a plane and the location of the boundaries. By including less exact variables and/or class boundaries lower in the hierarchy of the system, these will emerge only when we zoom in further. This makes that the reliability of the ecotope map decreases with increasing resolution, like in the silt content, both with contents and with boundaries. In the geomorphologic units 'high-energy plane', 'high-energy megaripples' or 'low-energy plane' the reliability of the boundaries is better than that of the contents.
The actual presence of the ecological community we expect based on the maps is not guaranteed. At the lowest level of ZES.1 we discern in fact physiotopes in which an ecological community máy be present (see section 1.3). In combination with the ecological contents they are ecotopes. Circumstances not included in the system, such as severe winters, pollution, human factors such as grazing of salt marshes, but biological factors as well, such as predation, may cause the biological contents of an ecotope to deviate, either temporary (by severe winters), or semi-permanently (by grazing or frequent fishing). In the case of such matters, ecotopes at the lowest level may be indicated individually by adding an extra code.

Step 5, mapping

We map the ecotopes by making the maps of the variables discrete and combining them afterwards in GIS. The degree of detail of the ecotope classification to be used is, among other things, determined by the map scale desired.

The ecotopes of ZES.1 are mapped with a GIS- application. RIKZ presently has HABIMAP at its disposal for this purpose (Ruiter & De Jong, 1998; De Jong, 1999). Its update, HABITAT, is being worked out by RWS in cooperation with WL|Delft Hydraulics (WL, 2003). HABIMAP is working under Arc/Info-Unix, HABITAT under PC-Raster/WL Delft-tools.
Roughly, the method is as follows (Figure 2.1.2):
1. the required scale and level of the ecotope map is determined;
2. GIS-maps of abiotic variables are selected;
3. class boundaries are selected and combined per variable;
4. the classified maps of variables are combined into an ecotope map.

As the result, apart from a copy of a map, is a GIS-file, all sorts of actions may follow: the calculation of ecotope acreages, comparisons between maps from different years or different organization scenarios, etc. If the exactness and/or reliability of the maps of variables (and possibly class boundaries) are known then the reliability of the ecotope map may be determined (Koeling 1998).

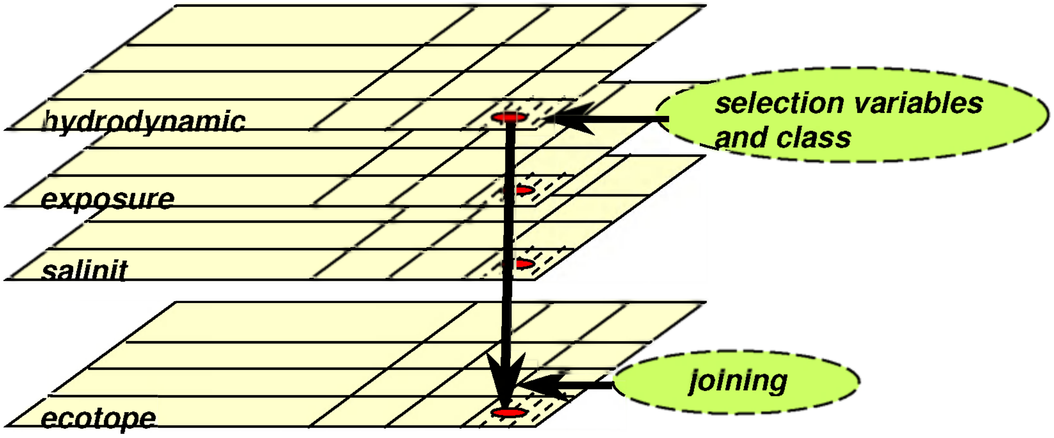

Figure 2.1.2. *Global scheme of the production of an ecotope map.*

2.2 CLASSIFICATION CHARACTERISTICS AND VARIABLES

Table 2.2.1. shows the variables selected in the classification characteristics. It shows as well the classes into which the variables are ordered and their accompanying class boundaries. We elucidate in Chapter 4 why we selected these variables and class boundaries. The selections are based as best as can be on the relations between the physical environmental factors and the occurrence of benthos. In addition, we needed to take the availability of data into account in the form of measuring results and/or models, and the accuracy of the data as well.

	variables	classes	Class boundaries
1	***mean salinity and salinity fluctuation***	little variably brackish little variably saline variably brackish/saline	5.4 - 18 and fluctuation <= 100% > 18 and fluctuation <= 100% > 5.4 and fluctuation > 100%
2	***substratum 1***	hard substratum sediment	stone, wood, peat etc. sediment
3	***depth 1***	sublittoral littoral supralittoral	< MLWS (underwater) MLWS – MHWN (flooded any tide) > MHWN (not flooded each tide)
4	***hydrodynamics****		
	fetch (coasts)	high energy (waves)	North Sea coast
	linear current velocity (sublittoral and littoral)	high energy (current) low energy (current) stagnant (no current)	Class boundaries depend on the model used. Theoretically the boundary is at 0.8 m/s being the boundary of the origin of mega-ripples 0 m/s
	Orbital velocity (littoral + supralittoral)	high energy (waves) low energy (waves) high energy low energy	Class boundaries depend on the model used. From result so far it appears that the boundary below works well > 0.2 m/s < 0.2 m/s
	geomorphology** (littoral)	high energy low energy	megaripples, high-energy flat bed, consolidated peat/clay, ridges low-energy flat bed, salt marsh

* the variable 'hydrodynamics' consists of three variables that apply to the different water systems or areas.
** geomorphology: this variable may be used as an alternative for linear current velocity and orbital velocity in the emerging parts.

5	***depth 2*** (depth, flooding)			
	sublittoral	Very deep – possible stratification	North Sea: > 30 m Grevelingenmeer: > 15 m Veerse Meer: > 10 m	
		deep - unstratified	North Sea: 20-30 m Grevelingenmeer: 5-15 m Veerse Meer: 5-10 m Other water systems: > 5 m - MLWS	
		shallow	North Sea: 20 m to MLWS Other water systems: 5 m- MLWS to MLWS	
	littoral (duration of flooding)	low littoral middle high littoral high littoral	MLWS - 75 % 75 - 25 % 25 % - MHWN	
	supralittoral (flooding frequency or vegetation zones)	pioneer zone and potential pioneer zone low salt marsh middle high salt marsh high salt marsh	MHWN to > 300 x/year 300 - 150 x/ year 150 - 50 x/ year 50 - 5 x/ year	
6	**substratum 2**		Median	silt (< 63 µm)
	(sediment composition) median grain size	Rich in silt fine sands coarse sands gravel	- < 250 µm 250 - 2000 µm > 2000 µm	>= 25%# < 25% < 25% < 25%
			(#: North Sea 10% instead of 25%)	

Table 2.2.1.*An overview of the variables, classes and class boundaries that are used in ZES.1. We describe detailed information and the abbreviations in the section concerned of Chapter 4.*

2.3 HIERARCHIC ARRANGEMENT

ZES.1 has been arranged hierarchically (Figure 2.3.1). Different classification characteristics and variables are used at different levels, making a more detailed description level of an ecotope gradually to be reached. With it, we use the same ecological starting points each time, which makes that the ecotope arrangement may be used in different water types. This makes the similarities of the same ecotope in different water systems to be greater than the differences. Nevertheless, substantial differences between ecotopes on higher levels may exist, such as between those in the Westerschelde and the Oosterschelde due to the fact that silt contents in either water system differ strongly. Such as is shown in great differences in silt content of the bed under similar hydrodynamic conditions. However, it only shows, at a lower level (substratum 2/ sediment composition). The hierarchic method enables to make less detailed maps, for instance in the case of a lack of detailed information. Moreover, the degree of detail necessary depends on the policy question and of the number of ecotopes that can be presented recognizably in a map. On the other hand the hierarchic system makes that we can zoom in on a smaller area as detailed as possible. The hierarchic arrangement of the system controls that choice. On a small map for instance, less detail may be shown than on a large one. A large map is still readable when using all discerning characteristics. In the case of the small map the 'lower' factors have to be discarded: such as differences in sediment composition or in water movement (duration of flooding, current, waves). The hierarchic system is less subdivided for hard substrata than for sediments. The main reason being that in the Netherlands the area of hard substratum is very limited as opposed to the area of sediments, while the former consists mainly of narrow structures, pitchings, groynes, riprap on

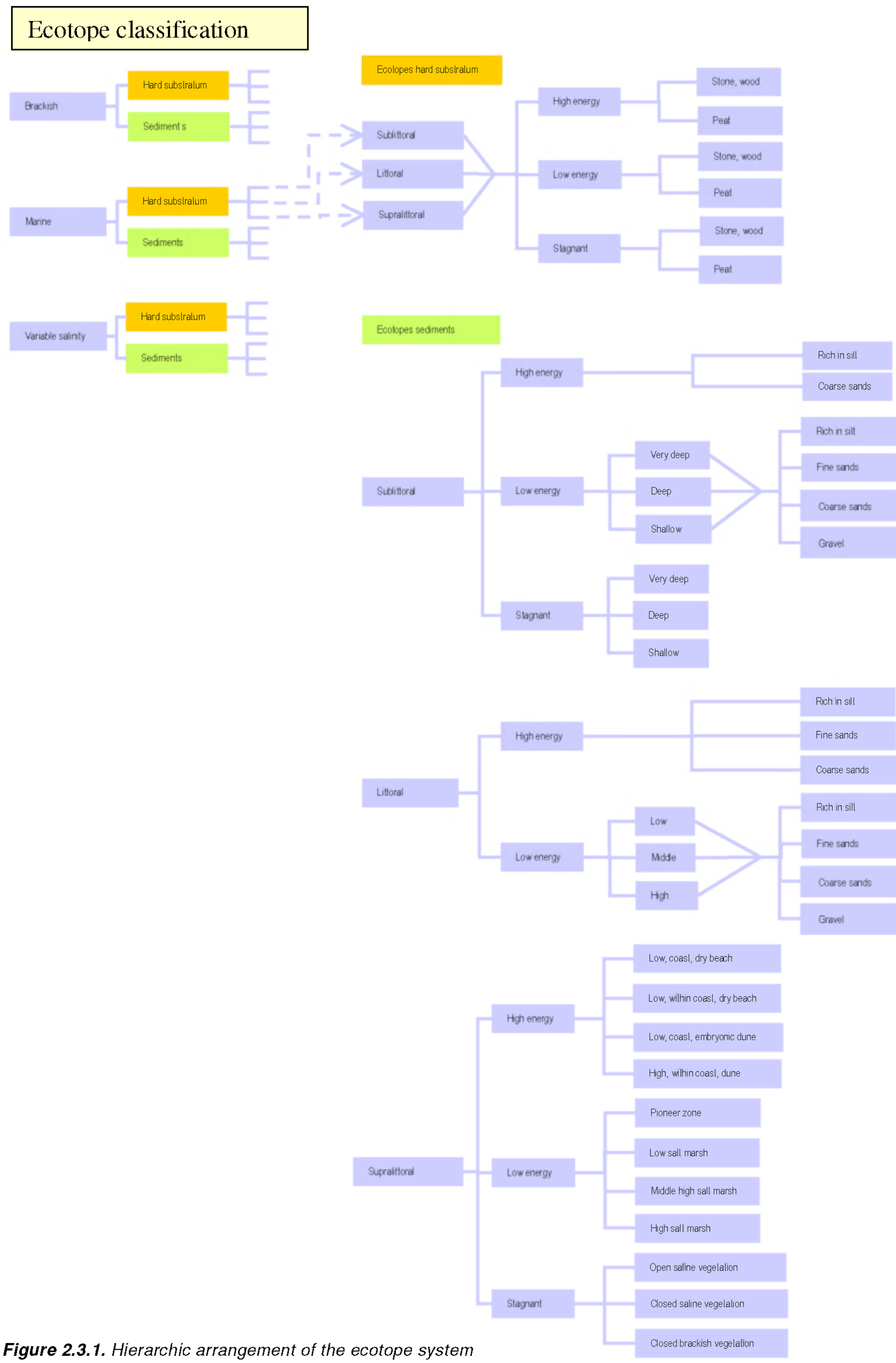

Figure 2.3.1. *Hierarchic arrangement of the ecotope system*

shores etc. The mapping of hard substratum ecotopes in practice will often happen by way of line elements on a map. We have strongly simplified the Meijer & Waardenburg (2002) proposal (see appendix 3 as well) for an ecotope system for the hard substratum in order to fit it in within ZES.1. Their comprehensive proposal should be seen as an extra level of detail within ZES.1 on behalf of hard substrata and fits within ZES.1. If desired for detailed questions it may be applied simply. A summary of their ecotope system has been included in appendix 3.

2.4 ECO-ELEMENTS

Within ecotopes smaller areas may occur in which characteristic ecological communities with structuring characteristics are present, deviating from the ecological communities that are present elsewhere in that particular ecotope (NB: a specific species determines the structure causing an ecological community being dependent on that structure). Sea grass beds, mussel beds and oyster beds are obvious examples and are discerned in RWES as eco-elements (section 1.3).

The greatest difference between eco-elements and the other ecological communities within ecotopes is the fact that the absence or presence of characteristic, structuring ecological communities partly depends on chance processes and cannot be properly predicted based on abiotic factors. We can indicate, however, in which ecotope the elements may occur. The mapping of eco-elements should happen by mapping in the field, supported, if necessary, by aerial photographs.

In ZES.1 we discern the following eco-elements:

- **gully**
- **sea grass bed (*Zostera marina**, *Z. noltii*)**
- **Ruppia-association (*R. maritima, R. cirrhosa*)**
- **mussel bed (*Mytilus edulis*)**
- **oyster bed (*Crassostrea gigas*)**
- **shell bank**
- **shipwreck**
- **shore vegetation along brackish lake shores**

(* in UK *Zostera angustifolia* or *Z marina*, littoral resp. sublittoral)

In section 5.2 we describe the eco-elements and we indicate in which ecotopes the eco-elements may occur.

2.5 ECOTOPE-MONDRIAANS

It is convenient to make an ecologic schedule between classification and production of an ecotope map for a particular area: the ecotope-mondriaan. It is an abstract schedule summarising the making of the ecotope map and indicating the ecological cohesion.

A useful extra step fitting in between the classification and the making of the ecotope map of a particular area is making an ecological schedule in which the ecotope map to be made is summarized abstractly (Figure 2.5.1). The schedule may be considered an abstract form of (part of) the water system concerned, in which the ecotopes in their mutual relationship are made visible. In addition, such a schedule is a convenient way to see how detailed a particular map has to be, which ecotopes may be left out and where they fit into the actually depicted ecotopes. By applying the same colours as those used in the ecotope map something emerges resembling a painting by Mondriaan, hence the term ecotope-mondriaan

An ecotope-mondriaan quickly offers an insight into which ecotopes occur in a system and which variables and class boundaries were used. Ecotope-mondriaans may be used to illustrate the legend of an ecotope map understandingly and efficiently. In section 5.3 we depict the ecotope-mondriaans for the various water systems.

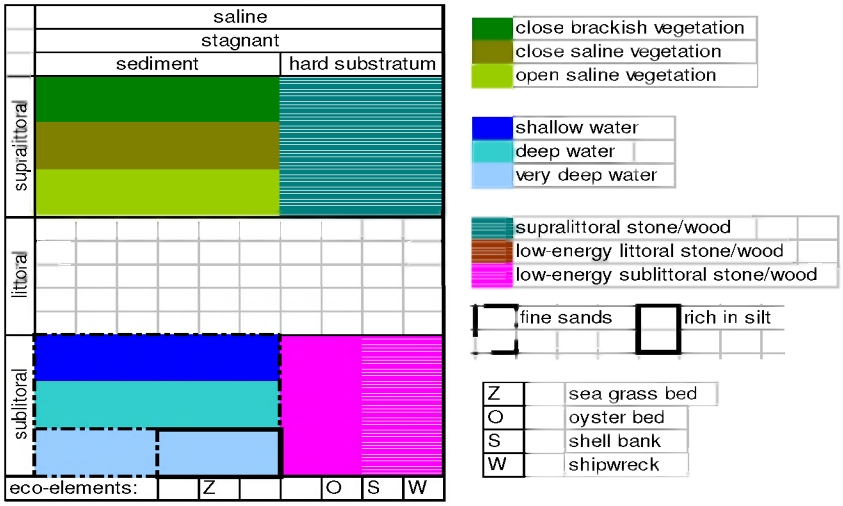

Figure 2.5.1 Example of an ecotope mondriaan: the Grevelingenmeer (white field = ecotope does not occur)

3 PRACTICAL APPLICATIONS, POSSIBLE PROBLEMS AND LIMITATIONS

3.1. PRACTICAL APPLICATIONS

Ecotopes indicate which ecological communities may be expected, basically without taking into account the human use of the area. This use, however, may strongly affect the ecological communities.

Ecotope maps may be applied firstly to describe the present situation of a water system; in appendix 4 we included examples of the North Sea, Oosterschelde, Westerschelde and the Wadden Sea. Ecotope maps may be applied in research as well. One of its examples is the use of ecotopes in a research into the use of tidal flats by waders in the Westerschelde, (project Zeekennis, in prep). Figure 3.1.1. shows the simplified ecotope map of the Westerschelde on behalf of the waders research in the Zeekennis project.

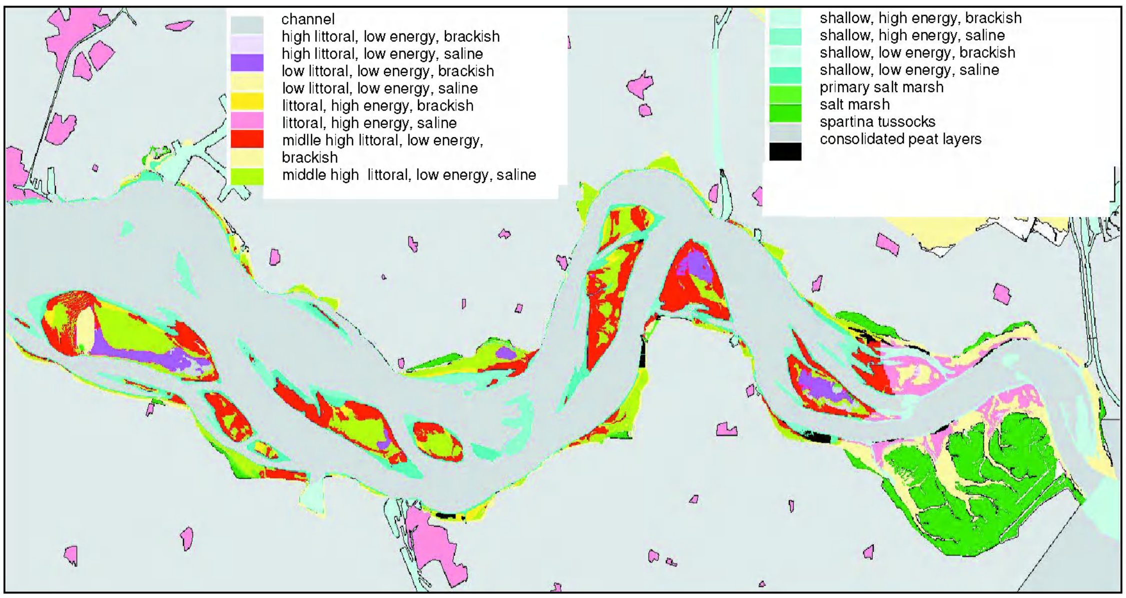

Figure 3.1.1 Ecotope map on behalf of the Westerschelde waders' research

Furthermore, ecotope maps may be produced for a specific goal. To that end certain legend-units may be combined in order to get a simplified picture aimed at a particular policy and management question. An example of such a map is the vulnerability to oil map that was used during the removal of shipwrecks in the Westerschelde. In it we combined ecotopes in groups of similar vulnerability to oil pollution (appendix 4).

Moreover, ZES.1 may contribute to the comparison of the different situations in water systems. Examples of this application can be found 1) in the report 'Verlopend tij' (Changing tide) on changes in the Oosterschelde (Geurts van Kessel.2005.; ecotope maps of before and after the completion of the Oosterschelde storm-surge barrier; see appendix 4), 2) within the scope of the project "MOVE" on the effects in the Westerschelde (Stikvoort et al. 2003; ecotope maps before and after the latest deepening), and 3) within the scope of the project 'ZEEKENNIS" in the global sketch of the historical situation back to 1935 (in prep.).

By using an ecotope map quantitatively (i.e. by quantifying acreages) we can apply it to indicate potential changes in biomass. Table 3.1 shows one of its simple examples in the deepening of the Westerschelde ("MOVE").

	mean biomass MFB ('95-'97 and '99-2001) (g/m2)	*acreage 1996* (ha)	*acreage 2001* (ha)	*biomass 1996* MFB	*biomass 2001* MFB
tidal flats					
high energy	0.2	3,160	3,402	597	643
low energy					
<DOL sands	0.2	484	564	109	128
<DOL silt	0.4	950	1,170	395	486
>DOL sands	0.3	1,249	78	422	26
>DOL silt	0.4	2,057	1,899	858	792
shallow water					
V> 0.5 m/s	0.0	2,780	2,415	94	82
V< 0.5 m/s		233	501		
total		10,913	10,029	2,476	2,157
relative change in biomass T0-T1 (%)			-9		-13

Table 3.1. *An example of an application of ZES.1: quantification of changes. The calculation of the change in biomass of micro-phytobenthos (MFB) in the Westerschelde caused by the deepening (1996 = situation before the deepening; 2001 = situation after deepening).*

If certain species of birds or fish were known to use particular ecotopes specifically, then we could use an ecotope map to map where these mobile species can be expected in particular. Quantifying such species is much more difficult as the presence of a mobile species does not only depend on what is present locally but also on the surrounding ecotopes and on the size of its total population.

3.2. POSSIBLE PROBLEMS

Partial validation of the ecological contents.
After the development of the system it has to be validated in order to check whether the ecotopes are actually present on the location indicated and whether they are actually distinguishing for various ecological communities. A first step that should lead towards the validation of the ecotope system has been set (Wijsman 2003), namely its distinguishing capacity with regard to the benthos communities in the Westerschelde. The research showed little interrelationship between the presence of benthos and the silt contents. This does not mean however that there is no such interrelationship. The data, which originates from the program BIOMON, has not been gathered with the objective to validate ZES.1, causing certain ecotopes to be underrepresented in the samples. To be able to validate the system better the sampling strategy should be rather based on already existing ecotope maps. A further statistic approach or a biological or physical field validation should be done to research whether the physical phenomena are present and whether the ecotopes actually comprise the ecological communities that have been attributed to them.

Prediction of physical condition is poor.
One problem is that models are needed for various variables. In the production of prediction maps or retrospective maps the quality of the underpinning physical models is essential. Ecological prediction will never be better than the physical models that have been used as input.
These models are often not adequately reliable for the intertidal area. The results of the models as well depend strongly on the boundary conditions that have been imposed on a model, such as whether storm conditions should be taken into account or not. Therefore, it should be assessed for each model result again which class boundaries are relevant. In order to compare scenarios it is essential that model calculations be carried out with the same boundary conditions.
We are working on the improvement of these models. In order to make long-term predictions the present models are inadequate to render exact isobath maps that in their turn can be used as e.g. input for current velocity models. These models supply mainly information on relative changes presently. The ecotope approach may use these relative results, however, in a good way. In the case of inadequate quality of models like those of current velocity it might be a better choice to work with geomorphologic data (although this works only for present situations or situations in the recent past).

3.3. LIMITATIONS OF THE ECOTOPE SYSTEM

An ecotope map does not describe exactly what is present at a particular moment, as an ecotope represents a potential niche. Moreover, the maps were made with the intention to give an average picture for a number of years (roughly: 45 years depending on hydrodynamics in the area). This means that ecotope maps are not suitable - and not meant - for use as a monitoring tool in order to follow the developments from year to year. It is more direct and more obvious to carry out biological measurements for monitoring purposes, preferably in combination with abiotic measurements and/or mapping. The ecotope system is probably suitable though to depict developments over longer periods. In addition, we can use it to support the efficient selection of monitoring sites in a water system e.g. to have all ecotopes sampled adequately or to leave out certain (insignificant) ecotopes.
An other limitation is that the effect of human influences on the ecological community in the ecotope has not been included in the system. So, it may be that somewhere an ecotope is indicated, but that actually the ecological content is quite different from what was expected or even that it is a different ecotope altogether. Pollution, water turbidity after the dumping of dredgings or by trawl fishing may cause an ecotope to deteriorate or even to have a different benthos composition altogether. If information is available on the character and extent of human influence and on its effects on the ecosystem, this information may be added to the ecotope map. This has been done for a specific species, the Islandic cyprine (*Arctica islandica*), with respect to the fisheries pressure (AquaSense, 2001), for example.

4 CLASSIFICATION CHARACTERISTICS, VARIABLES AND CLASS BOUNDARIES

In chapter 4 we discuss the classification characteristics of the ecotope system in separate sections. With it, we provide an explanation on the relation with the occurrence of flora and fauna, the selection of the variable(s) and the selection of the class boundaries. In the selection of the classification characteristics, variables and class boundaries, we departed mainly from their relation to benthos and algae. In the description of the ecological contents of the ecotopes (Chapter 6) we pay attention to other organisms that may be present in the ecotopes as well, such as fish and birds. The most important of these descriptions is the ecological relevance, the ecological process that exists between a variable and the biological contents. Many variables are calculated via models and this makes them sensitive to the imposed boundary conditions (see chapter 3.5 as well). Therefore, each model calculation has to be 'calibrated' qua class boundaries with the aid of the ecological processes described.

4.1 SALINTIY AND ITS FLUCTUATION

At the hierarchic system's first dividing level salinity and salinity fluctuation are used as classification characteristics. We selected as variable of salinity:
-average salinity at high tide over a year with an average fresh water supply (river discharge in particular).
We selected for the calculation of the fluctuation in salinity over that same year, at high tide:
-salinity fluctuation = [(4 x standard deviation salinity) / average salinity] x 100%
Table 4.1.1 shows the classes and class boundaries.

But: in order to get a map we will have to use model calculations. To be able to use the 'standard deviation' a large number of salinity calculations is required, which may be (too) time-consuming (and too costly) in practice. In that case a simpler 'approximation' may be chosen, the result of which corresponds roughly with the results of the method described above. In it two salinity situations are calculated, a maximum and a minimum situation. It is assumed that the frequencies of certain salinities during the year follow a more or less normal distribution. This does not have to be the case, in particular where fresh water discharge is controlled strongly. In that case the following formula is used:

salinity fluctuation= [(SituationMax – SituationMin) / Situation Average] x 100%

average salinity = [SituationMax + SituationMin] / 2.

If the difference between maximum and minimum salinity (max-min) is greater than the average, then there is a large fluctuation in salinity. If the average is bigger than the difference between maximum and minimum salinity there is little fluctuation in salinity.

Salinity Salinity fluctuation	5,4 –18: brackish	>18: saline
=< 100 % little fluctuation	Little fluctuation brackish	Little fluctuation saline
> 100 % variable	Variably brackish/saline	

Table 4.1.1. *Salinity and salinity fluctuation (partly after Vos & Wolff, 2001).*
(Salinity divided by 1.81 provides the chloride content in g Cl⁻/l, which is used in the other RWES-classifications)

Ecological meaning of salinity and its fluctuation

Salinity as a classification characteristic is essential for brackish and saline waters, as it strongly affects the occurrence of species (Remane, 1934; Remane & Schlieper, 1971). No benthos exists that can survive both in fresh and saline waters. All species are limited by their physiology to a particular range in salinity, which makes that there are typical fresh water, brackish water and saline water species. The salinity range and its fluctuation that can be tolerated differ per species.

A strong relation exists between salinity and biodiversity, which is described in the classic curve of Remane for invertebrates (Remane, 1934). The curve is formed by a high diversity of species in fresh water, a minimum diversity in brackish water and a high diversity in saline water. Biodiversity in saline water is higher than in fresh water. The so-called fresh water minimum appears in the classic model of Remane at salinity 5-7 (the most used size currently for salinity is without dimensions). Salinity divided by 1.81 gives the chloride content in g Cl^{-}/l, which is used in the other RWESes. Remane's curve was complemented and adjusted by Kinne (1971) (Figure 4.1.1).

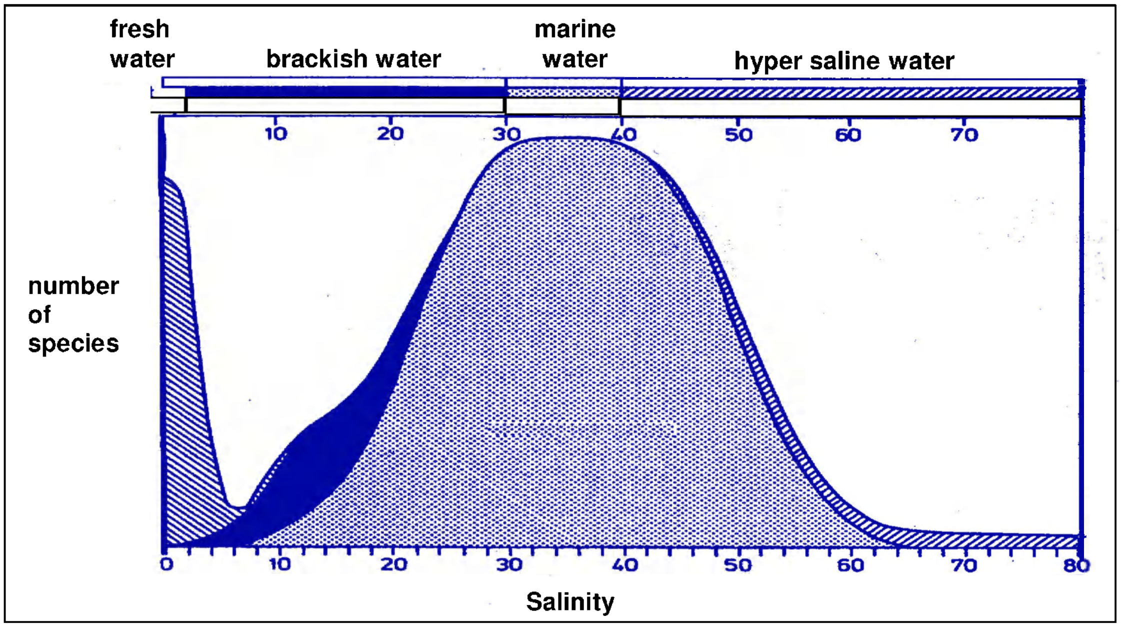

Figure 4.1.1. *The rough, quantitative relation between salinity and the number of invertebrate species (figure from Schmidt-Van Dorp, 1979 after Remane, 1934 and Kinne, 1971). Cross-hatching: fresh water species; black: brackish water species; grey: marine species*

Thirty years ago, Wolff (1973) observed the same pattern for invertebrates in the Zeeland estuaries. Recent observations, however, have shown that an even lower benthos biodiversity is present in the estuary of the river Scheldt (Westerschelde) and in the estuary of the river Ems (Ems-Dollard) in the fresh tidal waters than in the brackish tidal waters. This might be due to pollution, eutrophication or loss of habitat diversity in the upper regions of these estuaries (Ysebaert et al., 1998). In stagnant waters as well biodiversity in brackish water (Veerse Meer) is lower than in saline water (Grevelingenmeer).

In the great stagnant brackish and saline waters fluctuations in salinity are relatively minor. This applies as well to the central North Sea, with no perceivable river effects. In the Wadden Sea and the Oosterschelde bigger fluctuations in salinity may occur due to things like precipitation, draining of polder water and outlet sluices. The spatial and temporal fluctuations in salinity in transitional areas between river and seawater are big, such as in the river Scheldt estuary (Westerschelde), the river Ems estuary (Ems-Dollard), and the canalised estuary of the New Water Way. Tidal movements and river discharges cause these big fluctuations. River discharge is often varying considerably, both within one year and between years. This is caused for the greater part by climatologic factors, such as rainfall and, therefore, cannot be predicted.

Big fluctuations in salinity may cause big variations in species composition, numbers and biomass of benthos. Extremely high river discharges may highly affect the occurrence of benthos. In the brackish transitional region of an estuary benthos communities are frequently changing. This results in communities not developing any further than an early stage in the succession of benthos communities. Short-lived, tolerant pioneer species such as oligochaetes (small worms); clam worms (*Nereis diversicolor*) and mud shrimps (*Corophium volutator*) are dominating. By contrast, benthos communities in the saline part of estuaries, having a less variable salinity, are characterized by bigger, long-lived species such as common cockles (*Cerastoderma edule*) and lugworms (*Arenicola marina*) (Ysebaert, 2000). In addition, less marine species and more brackish water species are to be expected when fluctuations in salinity are big.

Within the water column there may occur fluctuations in salinity as well. In waters that are not mixed well, salinity in deeper water layers is higher than in less deep water layers, due to the differences in relative density. Stagnant waters often are stratified in summer. Differences in salinity cause this in the Veerse Meer, but differences in temperature are the cause in the Grevelingenmeer (temperature stratification occurs when the upper water layer is heated, while in the case of little mixture the deeper water layer remains cooler and therefore heavier).

Selection of variables

We based the selection of the variables for salinity and its fluctuation mainly on Vos & Wolff (2001). They recommend the application of mean salinity and its dispersion over a year with average river discharge, both based on the situation around high tide.

We selected as variable for salinity:

- ***mean salinity at high tide over one year (with average river discharge).***

As variable for the fluctuation in salinity during that same year, at high tide, we selected:

- ***fluctuation in salinity = [(4 x standard deviation salinity) / mean salinity] x 100%***

In order to produce a 'normal' ecotope map, i.e. a map that shows the distribution of ecotopes over a somewhat longer period (several years), it is important that the effect of an incidental, extreme river discharge on the results should be limited. An analysis of river discharges of the river Scheldt (in prep.) shows that this may only be reached by working with mean values over a long period (about five years), or with values from a year with a mean river discharge. If a computer model is used, we prefer calculations for a year with a mean river discharge. Calculation for a period of five years demands much calculation time. Moreover, the results of these calculations approach the results of an average year.

The use of salinity at high tide has as main advantage that a map can be produced that covers the whole surface and that all organisms are in contact with the water column at the moment of high tide. A disadvantage is the part of the penetration of river water in the estuary is lost. At high tide the acreage of the saline area in the ecotope map is larger than at lower water levels, as at lower water levels brackish water can penetrate in part of the area.

We do not take into account vertical differences in salinity (salinity stratification) in the ecotope system. It may be noticed however, that salinity near the bed determines the effects on the benthos and that it may therefore by sensible to use measurements or model calculations of salinity near the bed, if present.

Selection of class boundaries

Currently it is almost normal to use as classification for salinity ' The Venice System' (Symposium on the Classification of Brackish Waters, Venice, 1958. Arch. Oceanogr. Limnol. XI; reference from Vos & Wolff, 2001). The system is starting from the mean salinity and is not taking fluctuations in salinity into account. The class boundaries of most biologic classifications correspond well to this system. Overviews of various salinity classifications are given in Remane & Schlieper (1971), De Leeuw & Backx (2000) and Vos & Wolff (2001). In ZES.1 we selected the class boundaries for salinity based on the Venice-system:

- **brackish: water with a mean salinity between 5.4 and 18 (3-10 g Cl^-/l),**
- **saline: water with a mean salinity > 18 (10 g Cl^-/l) (table 4.1.1).**

The class of brackish corresponds with the mesohaline class of the Venice-system; the class saline comprises the poly- and euhaline. ZES.1 does not comprise the oligohaline, with a salinity of 0.5-5.4 (0.3-3 g Cl^-/l), as oligohaline ecotopes are already included in the RWES-aquatic (sublittoral) and the RWES-shores (littoral and supralittoral).

Little data is at hand on the exact fluctuation of salinity in various areas at the moment. Therefore, we copied the class boundaries for salinity fluctuation for the time being from Vos & Wolff (2001). They selected for the strongly variable class a lower boundary of 100%*. With this boundary they tried to fit in with the field situation as best as can be. Vos & Wolff (2001) discern in addition a little variable class, using it only for stagnant waters. With respect to applicability we opted for a division into two instead of three in salinity fluctuation in ZES.1, in which little variable has a fluctuation in salinity of =<100% and variable has a salinity fluctuation of > 100% (table 4.1.1).

Subsequently, the classes of mean salinity and salinity fluctuation have been combined into three classes: little variably brackish, little variably saline and variably brackish/saline (table 4.1.1). We apply these three classes at the first level of the hierarchic ecotope classification (Chapter 5). Probably variably brackish/saline water only occurs in the present situation in the central and eastern parts of the Westerschelde, in the Ems-Dollard, the New Water Way, locally in the Wadden Sea and possibly in the North Sea (coastal area).

** in Vos & Wolff (2001) 2 x standard deviation /mean salinity is used; however it is meant that 2 x standard deviation on either side of the mean should be used, so 4 x standard deviation in total.*

4.2 SUBSTRATUM 1 (HARD SUBSTRATUM/SEDIMENTS)

The hierarchic system's second level discerns between
- **hard substrata (stone, wood, peat etc.), and**
- **sediments (such as sand and/or silt).**

Both hard substrata and sediments will be subdivided into types lower in the hierarchic order.

Ecological meaning

Rocky shores are a natural hard substratum in brackish and saline waters. No rocky shores are present in the Netherlands and therefore hardly any natural hard substratum is present. Virtually all hard substrata in the Netherlands that are present in the brackish and saline waters are artificial. Some examples are pitchings, jetties, groynes and shipwrecks. Hard substratum consists mainly of natural stones or concrete elements, possibly with an asphalt layer, and wood (think of pile rows on beaches; photo 4.2.1). Some examples of natural hard substratum are consolidated peat and clay layers, shell banks and gravel beds offering settling facilities to typical hard substratum species.

With sediment we mean a bed consisting of sediments. Sediment beds comprise a considerably larger acreage in the Netherlands than hard substratum beds. The grain-size distribution of the sediment grains determines the type of sediment. The sediment may be for example fine sands or coarse sands, and rich or poor in silt. As this affects the occurrence of flora and fauna on the bed, sediments are subdivided at a lower level of the ecotope system based on sediment composition (see section 4.6).

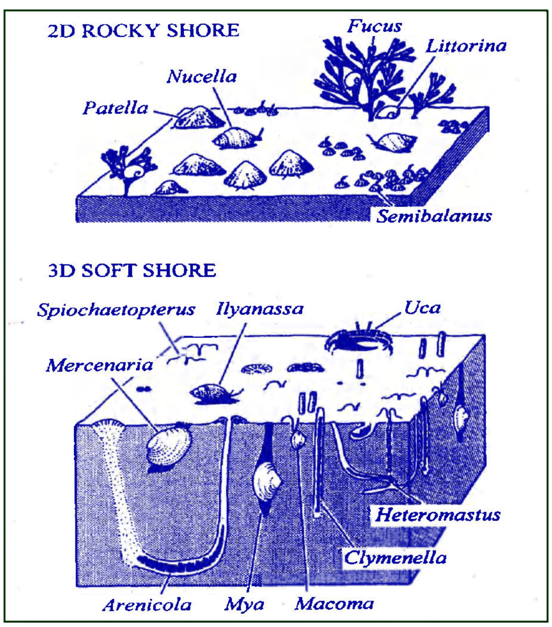

Photo 4.2.1 *Pile row on a beach (and detail)*

Figure 4.2.1. *Illustration from Little (2000) comparing ecological communities on hard substratum and ecological communities in/on sediments. Not all species occur in the Netherlands.*

The greatest difference between hard substrata and sediments to organisms is probably that hard substratum offers mainly a two-dimensional environment, while the environment in sediments is three-dimensional (Little, 2000) (figure 4.2.1). At hard substrata algae and organisms such as anemones and barnacles may attach and a mobile fauna may occur. In a certain sense, a three-dimensional environment is present there as well, but rather in height than in depth. (Salt marsh) plants may root in sediments and benthos such as worms and some bivalves may burrow into it. This makes that an obvious difference exists between flora and fauna on hard substratum and on/in sediments. Only few species can occur both on hard substratum and sediments, such as mussels (*Mytilus edulis*) and Pacific oysters (*Crassostrea gigas*). In ZES.1 we discern between ecotopes of the hard substrata and sediments. It is known for a long time that a distinct zoning in the occurrence of flora and fauna exists on the emerging hard substrata (Den Hartog, 1955; 1959). Differences in duration of exposure, degree of wave action and competition between species are causing this zoning. The degree in which the zoning is 'complete' depends on, among other things, the position of the hard substratum with respect to the low water mark and the characteristics of the hard substratum itself, such as its moisture retention capacity. It is much more difficult to get a grip on the spatial distribution of flora and fauna in and on (emerging) sediments, although much attention is paid to this subject (Peterson, 1991).

Selection of variables and class boundaries

In this case the distinction between the two classes is obvious. We choose to make the distinction between hard substratum and sediments at the second level of the hierarchic system. We subdivide both the hard substratum and sediment at a lower level of the hierarchic system into substratum type (Meijer & Waardenburg, 2002) and sediment composition respectively.

4.3 DEPTH 1 (SUBLITTORAL, LITTORAL OR SUPRALITTORAL ZONES)

At the hierarchic system's third level we discern between

- **the sublittoral zone (permanently under water),**
- **the littoral zone (flooded each tide), and**
- **the supralittoral zone (not flooded each tide).**

The class boundaries are indicated in table 4.3.1.

ecotope classes	class boundaries	description
sub-littoral zone	< MLWS	permanently underwater
littoral zone	MLWS – MHWN	flooded each tide
supra-littoral zone	> MHWN	not flooded each tide

Table 4.3.1. *Class boundaries for the sublittoral zone, the littoral zone and the supralittoral zone. MLWS = mean low water spring tide; MHWN = mean high water neap tide.*

Ecological meaning sublittoral, littoral and supralittoral zones

There are huge differences in the occurrence of species between areas that are permanently under water (the sublittoral zone), areas that emerge part of the tidal cycle (the littoral zone), and areas that are only flooded now and again (the supralittoral zone). These differences are related to the way in which organisms feed. The sublittoral sediments consist of channels and shallow/deep flats, the littoral sediments of sandy or silty tidal flats (possibly covered with pioneer vegetation) and the supralittoral sediments consist of beaches and salt marshes.

Some flora and fauna species are but occurring in one of these subareas. Some of its examples are lichens on the supralittoral hard substratum and salt marsh plants in the high salt marshes. Other flora and fauna species use more than one subarea for different objectives. One of its examples is waders foraging on tidal flats and nesting in the salt marshes. An other example are flat fish that forage at high tide on the tidal flats and retreat to the sublittoral at low tide.

Selection of variables and class boundaries

We chose to discern on the hierarchic system's third level between areas situated in the sublittoral, littoral and supralittoral zones. We selected the mean water level as a variable, in which:

- **the sublittoral zone lies below the mean low water mark at spring tide (MLWS),**
- **the littoral zone between MLWS and the mean high water mark at neap tide (MHWN) and**
- **the supralittoral zone above MHWN (table 4.3.1) and separately**

- **shore zones of stagnant waters**.

This subdivision is actually based on depth and altitude. At a lower level of the hierarchic system we have made a further subdivision after depth and the duration of flooding and flooding frequency that are related to altitude for sediments (section 4.5). The effect of current velocity and wave action is considered to be more important than depth, duration of flooding and flooding frequency, and therefore comes up earlier in the hierarchic system (section 4.4). The distinction between sublittoral, littoral and supralittoral zones remains very useful, in addition to the second subdivision that corresponds with depth and altitude, because of the simplicity in distinction and the, often, strong relation with organizational and management questions. One question often asked is whether due to a certain intervention the acreage of tidal flats and salt marshes will decrease or increase.

4.4 HYDRODYNAMICS

We use hydrodynamics (movement of the water) at the hierarchic system's fourth level as a classification characteristic. It applies to both hard substrata and sediments along the seacoast and hard substrata not along the sea coast that (based on fetch) that:
- **the system of the open North Sea coast is subject to high energy,**
- **the hard substrata 'within the coast', along the shores of the other water systems are subject to low energy.**

We selected as the variable for the sublittoral sediments and hard substrata not present along the shore:
- **the maximum linear current velocity during a mean spring tide, regardless of ebb or flood.**

We selected as variables for the littoral sediments and hard substrata not present along the coast:
- **the maximum linear current velocity during a mean spring tide, regardless of ebb or flood,**
- **orbital velocity= maximum orbital velocity at spring tide and average storm conditions (frequency 1 x per year).**

An alternative is the variable 'geomorphology'. The supralittoral parts within the coast basically are a system of low energy. Table 4.4.1 shows the classes and class boundaries.

variables hydrodynamics	**waves based on fetch (Nienhuis, 1976)**	**maximum linear current velocity (V_{lin})**	**maximum orbital velocity (V_{orb})**	**ecotope class**	**geomorphology[*]**
along the coast	hard substrata and sediments on North Sea coast	---	---	high energy	high energy tidal flat
sublittoral zone	hard substrata	theoretical – physical > 0.8 m/s	---	high energy (current)	---
		theoretical physical =< 0.8 m/s		low energy (current)	
		0 m/s		Stagnant (no current)	

[*] In appendix 5 we have described in short how a geomorphologic map is compiled. In it the complete geomorphologic legend is present and its short explanation

littoral zone	hard substrata	V_{lin} theoretical – physical > 0.8m/s or V_{orb} (in practice) > 0.2m/s		High energy (waves and/or current)	Mega-ripples, ridges, high-energy flat bed (tidal flat), consolidated peat/clay layers
		V_{lin} theoretical –physical =< 0.8m/s ánd V_{orb} (in practice) =< 0.2m/s		low energy (waves and current)	low-energy. tidal flat
supralittoral zone	hard substrata	---	V_{orb} >0.2m/s	High energy	High-energy flat bed (tidal flat)
			V_{orb} =< 0.2m/s	Low energy	Low-energy tidal flat, salt marsh

Table 4.4.1.
Classification of variables for hydrodynamics: the fetch, the maximum linear current velocity, maximum orbital velocity and as an alternative –geomorphology (column below).*

Ecologic meaning of hydrodynamics

In all sorts of ways hydrodynamics affect the occurrence of flora and fauna. Hydrodynamics, either high or low energy, are mainly defined in ZES.1 by current velocity of the water and wave action. In the supralittoral zone a classification can be made based on wave attack during storms: in circumstances of high energy no salt marshes are able to form, (e.g. Razende bol/Noorder Haaks near the island of Texel), in circumstances of low energy salt marshes are able to form.

Flora and fauna of the hard substrata (pitchings, jetties, riprap, channel wall protection, beach groynes, pile rows, consolidated peat layers, shipwrecks but mussel beds and shell banks as well), which are present mainly along the shores of water systems, are affected as far as hydrodynamics are concerned chiefly by wave action. Little is known on the effect of currents on ecological communities on hard substratum. A high degree of wave action limits the settling and chances of survival of algal and animal species on hard substratum. At locations of high energy only a very limited number of algal species may occur such as littoral green seaweeds (*Blidingia minima, Enteromorpha spp.*) (Meijer & Waardenburg, 2002). Development of brown seaweed communities rich in species is mostly impossible at sites of high energy. At places with low energy an extensive zoning of ecological communities rich in species may develop under suitable circumstances in the littoral zone. Sheltered places therefore may be suitable foraging areas for birds eating algae, in ports along the New Water Way for instance large numbers of mute swans (*Cygnus olor*) are foraging. The brown seaweed knotted wrack (*Ascophyllum nodosum*) often occurs in high densities at sheltered locations (Meijer & Waardenburg, 2002). Consolidated clay/peat layers and shell banks occur in the littoral zone at places with high energy due to currents. Consolidated peat/clay layers in the sublittoral zone as well may probably be characterized as places of high energy due to currents. This can be derived from the fact that these areas mostly are bordering parts of high energy so that probably the sandy sediments have permanently been removed. The shore regions in the basin of the Oosterschelde are an exception to this, as the peat here is uncovered by erosion due to the hunger for sand of the Oosterschelde (Geurts van Kessel, 2005).

Regions of high energy on tidal flats can clearly be recognized at low water by the presence of large ripples that may have a height of one to two meters (see photo 4.4.1). The ripples form due to a strong current, approx 0.8m/s at a minimum, causing large parts of the sand to move and to be transported.

Photo 4.4.1 *Aerial photograph of megaripples in the Westerschelde*

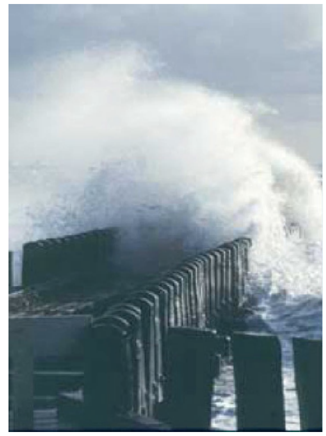

Photo 4.4.2 Breaking waves at a pile row *on the shore*

Current ripples occur as well in the deeper (channel) beds. At such sites of high energy the bed continuously shifts down to a certain depth. This is the case as well when high energy is not caused by high current velocities but by a high degree of wave action. A clear example of this is breaking waves on the coast (photo 4.4.2).

When the current velocity or wave action is so high that the sediment is stirred or suspended frequently, benthos has to take much trouble to keep in place. This can be done by burrowing deeper into the sediment, but when they fail benthos is flushed away. At places where the upper layer of the bed is virtually constant shifting, only a few species occur that are adapted to such high-energy conditions.
Examples of it are *Scolelepis squamata*, the sand digger shrimp (*Bathyporeia sp.*) and *Donax vittatus*. Examples of species that are not well adapted to circumstances of high energy are the mussel (*Mytilus edulis*) and sea grasses (*Zostera angustifola, Z. noltii*) (Wijgergans & de Jong, 1999). It is known from mussel farming that at current velocities higher than 0.6 m/s there is a big chance that mussels are flushed away (Van Stralen & Dijkema, 1994).
Optimum current velocities for sea grasses are up to approx 0.5 m/s, while at (surface) current velocities higher than 1.2 m/s sea grasses cannot exist (Fonseca et al., 1983).

Hydrodynamics not only affect the presence of benthos in extreme cases. It is known that hydrodynamics affect the settlement of benthos. Many benthic animals spend the first weeks of their lives as larvae in the water column. Current velocity and turbulence in the water causing movement of sediment mainly determine the place where post-larval benthos is to settle in the sediment (Bouma et al., 2001a). Various aspects of the effect of hydrodynamics on the settlement of benthos are described extensively in the review by Butman (1987). At a later stage of their lives many benthic animals, such as the common cockle (*Cerastoderma edule*) and Baltic tellin (*Macoma balthica*), end up in the water column once again. This may happen both actively and passively (review Armonies, 1994; Bouma et al., 2001b). These animals that basically live within the sediment are able to move into other areas via the water column. Tidal currents hugely affect this secondary distribution.

Hydrodynamics indirectly affect the food supply of benthos. This applies in particular to benthos that feeds on food particles (phytoplankton) by filtering them from the water (filter feeders). The food supply for these animals is partly determined by the amount of water and with it the amount of food that flows by. At a too low a current velocity and too low a mixing food shortage may occur, mainly in the case of high densities (Fréchette & Bourget, 1985). On the other hand a too high a current velocity and a too high an amount of suspended matter may negatively affect growth (Ducrotoy et al., 1987). In very turbid estuaries few filter feeders are present.

Selection of variables and class boundaries

Hard substratum and sediments along the shores of the water systems (sublittoral and littoral zones)

The hard substrata and sediments of the coasts along the water systems are affected by wave action as far as hydrodynamics are concerned. The degree of wave action at a certain site is related to the space of open water around that place, as the continuous distance across which the wind is able to blow over the water (fetch) determines the size of the waves. The degree of wave action is connected as well with the slope of the shore, but as in the Netherlands dike pitchings and seashores have a rather constant slope, the fetch is decisive.
In ZES.1 we classify the hard substratum of the shores of water systems, as far as hydrodynamics are concerned and recommended by Meijer & Waardenburg (2002), according to the methods and results of Ballantine (1961) and Nienhuis (1976). Nienhuis (1976) determines, partly in agreement with Ballantine (1961), the degree of wave action with the aid of the angle on which the fetch of a certain length applies. It considers sites with a fetch of 80-240 kilometres applying in an angle of at least 20 degrees to be "semi-exposed" and all other locations as "sheltered" (in the situation at high tide) (Figure 4.4.1). This way the results show that

- **the North Sea coast and the mouths of the Westerschelde (up to the line Flushing-Breskens) and the Oosterschelde (up to the storm surge barrier) are in the class of "semi-exposed" (ZES.1: high energy);**
- **hard substratum on the shores of the other water systems is in the class of "sheltered" (ZES.1: low energy).**

In observing Figure 4.4.1 we have to take into account that the storm surge barrier in the Oosterschelde was not yet constructed. After the construction of the storm surge barrier the fetch in a large part of the mouth has become considerably shorter and the Noord-Beveland coast is not one of high energy anymore. The sediments of the coast and the outer regions of the mouths may be approached this way. This makes that the western end of the Hooge Platen in the Westerschelde fall within the class of high energy, and for instance Richel and Simonszand in the Wadden Sea likewise.

Locally, there are sheltered and very sheltered locations both in high energy and low-energy shores of water systems, such as in ports. At such sheltered locations the fetch is only some tens to some hundred metres at a maximum. Because of the incidental character of these locations they are not included as a separate ecotope. Such sites may be considered as other low-energy ecotopes, where in favourable circumstances ecological communities rich in species may occur.

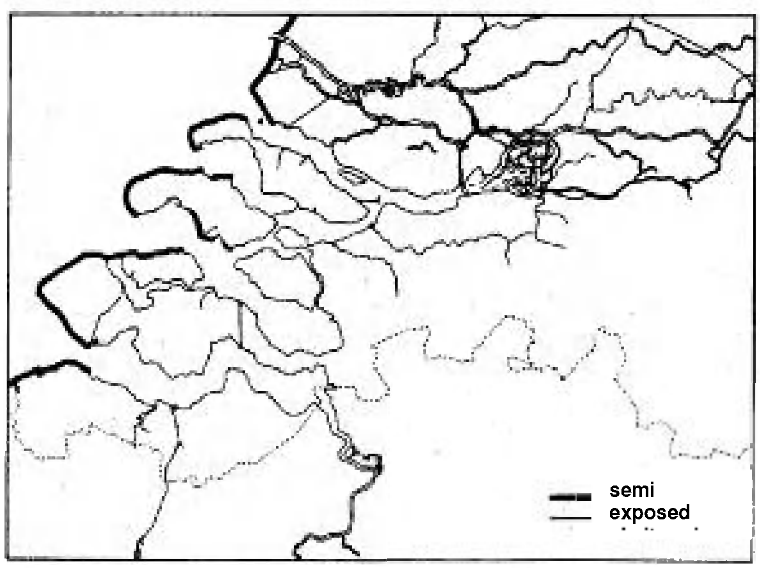

Figure 4.4.1. *The degree of wave action on the shores in the Delta area (figure from Nienhuis, 1976). The North Sea coast, including the mouths of the Westerschelde and the Oosterschelde is "semi-exposed" (ZES.1: high energy) and the shores of the other water systems are "sheltered" (ZES.1: low energy).*

Sublittoral hard substrata and sediments not located on the sea shore[1]

Current affects the ecological communities in the sublittoral sediments as far as hydrodynamics are concerned. An obvious example are tidal channels, with current velocities so high that only few benthic organisms may stand their ground. The flat shallow sublittoral beds that occur for instance in the Wadden Sea and Oosterschelde are too deep to be strongly affected by the generally limited wave action. In the Westerschelde, sublittoral consolidated peat layers (hard substratum) occur that have high-energy conditions due to high current velocities.

- **We selected the linear current velocity as variable for the sublittoral zone**

(i.e. the 'normal' current velocity, in order to avoid confusion with the orbital velocity described below). To be exact: the maximum linear current velocity that occurs during a mean spring tide, irrespective of ebb or flood. This variable is probably most determining for the occurrence of benthic communities during several years. We opted for a subdivision of linear current velocity into two classes. The boundary is at the level on which sand begins to move strongly and the formation of megaripples is possible: theoretical-physical 0.8 m/s.

The benthic communities in the North Sea probably are more related to depth (section 4.5) and to sediment composition (section 4.6) than to hydrodynamics (Holtmann et al., 1996; Hartholt, 1998). Waves play a part in shallow parts (surf) and during severe storms in the deeper parts (to 20m) as well. Since on this topic not many quantitative data is available, it will only show up in the variable depth 2 (see section 4.5.). In tidal channels between/beyond the Wadden Islands and in the Voordelta current velocity plays an important part indeed.

Sediments in the littoral zone

As in the littoral both current and wave action may have an important effect on the occurrence of benthic organisms (De Jonge & Van Beusekom, 1995; Bell et al., 1997), we selected a variable for both elements. The variable and the class boundaries for current are the same as in the sublittoral zone (maximum linear current velocity during a mean spring tide, table 4.4.1). We know little about the effect of breaking waves on the occurrence of benthos in the littoral zone. Within the scope of the ecotope classification a survey has been carried out for the Oosterschelde (Van Helvert, 2001). The studying of the effects is very complicated, for instance due to e.g. the varying water levels. The research has not yielded adequate results so far for the production of ecotope maps. Therefore we selected as variable for the wave action in the littoral zone the maximum orbital velocity during mean spring tide and at average storm conditions. We mean by average storm conditions a storm that affects the lives of benthic organisms, we selected for it a frequency of 1x/year. The orbital velocity is the current velocity in a wave near the bed. A wave in fact, is a circular movement that affects the bed at the bottom. A measure for the amount of energy with which a wave affects the bed is the velocity with which it moves along the bed. The orbital velocity causes, similar to the linear current velocity, bed shear stress and possible resuspension.

To determine the total degree of hydrodynamics in the littoral zone we are using maps of both linear current velocity and orbital velocity.

- **If linear current velocity is larger than the determined maximum velocity at which megaripples start to form <u>and/ór</u> the orbital velocity is larger than 0.2 m/s the littoral location is one of high energy.**
- **A littoral site is only determined to be one of low energy if the linear current velocity is below the determined maximum velocity at which megaripples start to form <u>ánd</u> the orbital velocity is below 0.2 m/s (table 4.4.1).**

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[1] *The areas that are not situated on the North Sea are indicated sometimes as areas located 'within the coast': Wadden Sea, Ems-Dollard, Westerschelde, and Oosterschelde.*
Orbital velocity is a function of wave height and water depth, in which in shallow water the effect on the bed is greatest. The class boundaries for orbital velocity are based on available maps for the Wadden Sea and the Westerschelde, in which we selected a boundary of 0.2 m/s (table 4.4.1). The class boundaries in orbital velocity are much lower than in the linear current velocity as in waves the movement is not constant. Waves have more of a 'plucking' effect and, with it, affect the bed more strongly.

Maps of current velocity and waves are made based on models. In practice, it appeared that these models are performing reasonably well for the channels, but relatively poor in the shallow and emerging parts. In addition, the boundary conditions such as spring tide, storm situation, wind direction(s) at storm situations etc., that are imposed on the model determine the results highly. Every model map should be tested against the situation in the field to determine the velocity boundaries that apply tot that specific map. If subsequently for a scenario calculation, calculations are being carried out with a same set of boundary conditions for different situations then the determined class boundary may be used for different calculated situations. It appeared for the Westerschelde that for the calculation of a spring tide -mean tide- situation, without any wind a boundary of 0.5 m/s is suitable (De Jong, 1999, Ysebaert, 2000). This boundary was used for instance in the project 'MOVE'. For a map of the Wadden Sea, calculated with storm conditions, the boundary of 0.8m/s corresponded well to the field situation. This applies as well to the sublittoral. The comparison of model results with the field situation may happen by direct comparison with data from the field, but may equally be carried out via a comparison with a geomorphologic map of the area (made based on aerial photographs) as well. The latter option makes it possible to apply a more statistic approach by superimposing both maps. An illustration: in the field the formation of megaripples starts roughly at $V_{lin} > 0.8$ m/s. According to a specific model calculation this is possible at a different value already, for instance at 0.6 m/s. Then for that specific calculation (+ model + boundary conditions) the value of 0.6 m/s has got to be used as boundary between high- and low-energy conditions. Each time in scenario calculations the model should be used with the same boundary conditions and each time the same class boundaries should be used.

It appeared from calculations of the orbital velocity in the Oosterschelde and Westerschelde that the boundary of 0.2 m/s is seldom reached, except for the most seaward parts of the Westerschelde. There, the boundary calculated from the fetch already applies. In these systems wave action could possibly be left out.

Hydrodynamics via geomorphology

An alternative way to add hydrodynamics for the littoral parts is indirectly via geomorphology. The geomorphology of a littoral area is the shape of its surface. On tidal flats local hydrodynamics, the current velocity and wave attack, determine to a high extent their shape. If no (adequate) model calculations are available for current velocity and waves, geomorphology is a good alternative. Geomorphology is mapped based on aerial photographs that have been taken at a lowest possible water level. On these photographs all kinds of phenomena can be discerned that correspond to the effect of currents and waves. In low-energy conditions, for instance, the surface on the photo will seem to be (almost) flat, while high current velocities will show (mega) ripple patterns. These phenomena can be mapped and subsequently be applied to the distinction of ecotopes. As the available (Dutch) wave and current models presently are not adequately reliable in the littoral parts, geomorphology can be used well for actual situations and situations in the recent past. An advantage of this parameter is that the mapping is based on the current situation in the field; a disadvantage is that it only works for years from which aerial photographs are available. A geomorphologic map cannot be used, obviously, for a future situation or for scenario calculations. In that case the geomorphologic map may be used to assess the class boundaries of V_{lin} and V_{orb} in the current situation and use these boundaries in the scenario calculations.

As the current velocity models (and wave models) are not reliable either in the shallow areas, the geomorphologic map may be used to assess the distribution in high-energy and low-energy parts in these areas as well. Furthermore, the geomorphologic map may be used when model calculations lack. This happens based on the assumption that if the littoral zone is an area of high or low energy respectively then the bordering shallow area is one of high or low energy respectively as well. Obviously, this is not always the case, but we think that it is roughly the case and errors are not bigger than when current velocity models are used. In appendix 5 we illustrate these matters.

Van Vooren (1997) has set up a standard procedure for the making of geomorphologic maps that describes the entire process in detail. The most essential points for a mapping, and the method to convert the basic map into a map that can be used in GIS are in appendix 5. An essential part of the mapping is the standard legend used. This standard legend is included in appendix 5 as well, including its short description.
The structure of the standard legend is such that it can be used at different levels, depending on the degree of detail desired. A first arrangement is in

- salt marsh
- tidal flat

- large salt marsh creek
- hard substratum
- dune and
- other.

This distinction can be made without many problems. At the second level a subdivision takes place that can be mapped reliably:

- open or close salt marsh
- tidal flat or large salt marsh creek with high or low energy
- natural or artificial hard substratum or dune.

The subdivision at the third level is mappable less exactly and that at the fourth level is least reliable as a rule. In this case a subdivision is made like in sandy tidal flats, tidal flats rich in silt and tidal flats very rich in silt (mud flats). At the important level for ecotopes of high/low energy, the boundaries are adequately reliable to be mapped as a rule.

4.5 DEPTH 2 (DEPTH, FLOODING)

At the hierarchic system's fifth level the sublittoral, littoral and supralittoral zones are subdivided even more detailed based on depth/height. We selected as variables for the sublittoral, the littoral and the supralittoral zones:
- the number of metres below the mean low water mark at spring tide (m below MLWS)
- the duration of flooding (%)
- the flooding frequency (number of times per year)

Table 4.5.1 shows the classes and class boundaries.

Table 4.5.1. *Classification of the variables depth (metres below MLWS), duration of flooding (%) and flooding frequency (number of times per year). MLWS = mean low water spring tide; MHWN = mean high water neap tide.*

variables	**class boundaries**	**ecotope classes**
sublittoral zone (depth below MLWS)	North Sea: > 30 m Grevelingenmeer: > 15 m Veerse Meer: > 10 m	very deep – possible stratification
	North Sea: 20-30 m Grevelingenmeer: 5-15 m Veerse Meer: 5-10 m other water systems: > 5 m –MLWS	deep - unstratified
	North Sea: 20 m to MLWS other water systems: 5 m –MLWS to MLWS	shallow
littoral zone (duration of flooding)	MLWS to 75% 75% - 25% 25% - MHWN	low littoral middle high littoral high littoral
supralittoral zone (flooding frequency or vegetation zoning)	MHWN to > 300x/year 300 – 150 x/year 150 – 50x/year 50 – 5x/year	pioneer zone and potential pioneer zone low salt marsh middle high salt marsh high salt marsh

Sublittoral zone: ecological meaning of depth

We can make a distinction between ecological characteristics after depth for the sublittoral areas. In the Oosterschelde and in the Grevelingenmeer algae have been found up to a depth of about five metres below the low water mark (Van Geldere & Vanalderweireldt, 1995). Not enough light is penetrating at greater depths to enable the algal growth. Visibility in the Oosterschelde and in the Grevelingenmeer in general is considerably better than in the other Dutch brackish and saline waters, where no algae occur for certain below this depth. Visibility in the central North Sea may be very good, but there the bed is at a great depth.

Shallow plane beds in the Wadden Sea, Ems-Dollard and Westerschelde play an important part during the growing up of young flat fish, crabs and shrimps (Zijlstra et al., 1982; Jager, 1999). These areas have the function of nursery grounds. Many juvenile, but adult fish and crustaceans as well, are using, in addition to the shallow sublittoral zone, the littoral zone to forage. These animals commute with the rising and ebbing tide between the shallow sublittoral zone and the littoral zone and are therefore called tidal migrants (Kuipers, 1973; Janssen & Kuipers, 1980) (Figure 4.5.1). Van Damme & Van der Veer (2001) conclude based on literature search that the sublittoral part that is important for the nursery function and for tidal migrants, extends from the mean low water mark (MLW) to five metres below MLW.

In stagnant waters, such as the Grevelingenmeer and the Veerse Meer, the water column is often stratified in spring and summer due to poor mixing. This may cause that in due time a lack of oxygen occurs in the lower water layer causing massive mortality of benthos (Peperzak et al., 2002). Therefore the depth of the thermocline, the boundary between the lower (cooler) and upper (warmer) water mass, is important for the presence of benthos as well. In the Grevelingenmeer the thermocline is at approximately 15 metres (Hoeksema, 2002), in the Veerse Meer at approximately 10 metres (Figure 4.5.2). In 2004, a culvert between the Veerse Meer and the Oosterschelde (Holland et al., 2004) was completed. It is expected that this will improve water quality and it will reduce stratification or even will make it to disappear.

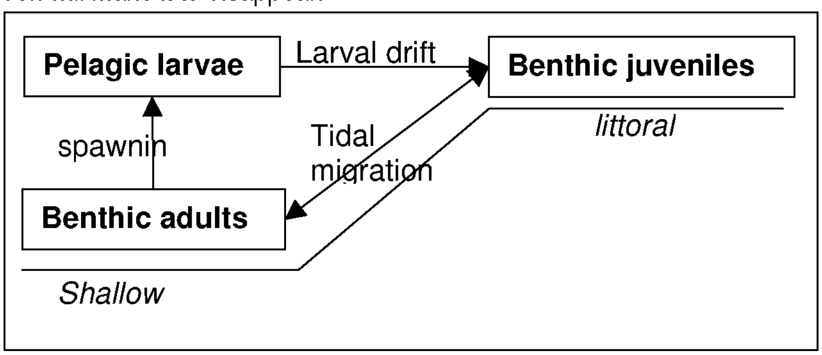

Figure 4.5.1. *The function of nursery grounds of the shallow sublittoral zone and the littoral zone for various species of flat fish, shrimps and crabs. The pelagic (= living in the water column) larvae develop in the shallow sublittoral zone, float towards the littoral zone and change into benthic (= living in or, in this case, right above the bed) juveniles. Both juveniles and adults commute with the tide (figure after Reise, 1985).*

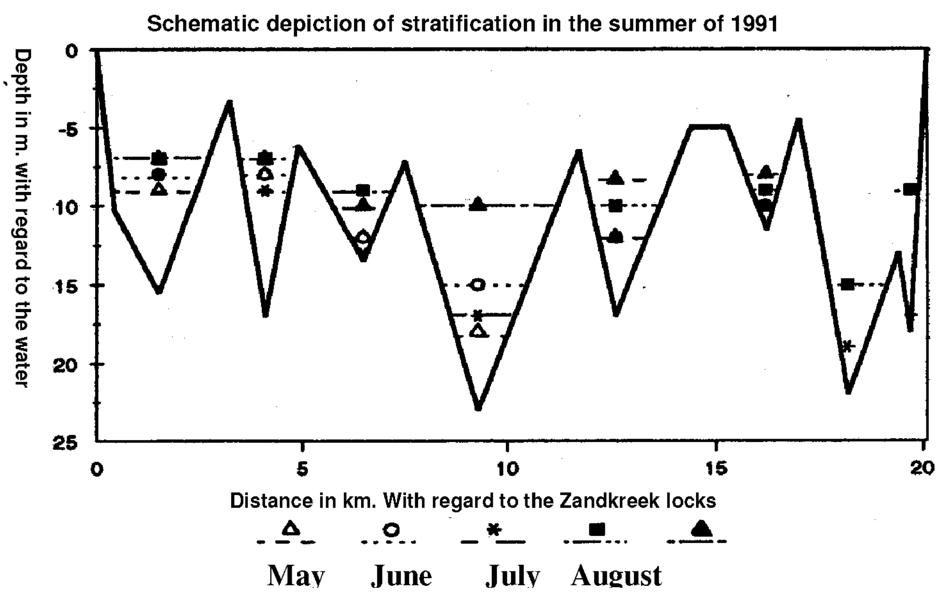

Figure 4.5.2. *Stratification in the Veerse Meer (figure from Wattel, 1994). The lines depict the level of stratification per month.*

Sublittoral zone: selection of variables and class boundaries

We selected as variable for depth in the sublittoral the number of metres below the low water mark at spring tide (MLWS). We selected MLWS instead of MLW with respect to the practical link with the distinction between the sublittoral and littoral zones (section 4.3). There we selected MLWS as upper boundary for the sublittoral zone. As the ecotope system is used for different water systems, it is more consistent to work with a low water mark than with the number of metres below DOL. This way the water layer concerned covers an equal number of metres in all cases. We opted for two depth classes in most water systems (table 4.5.1), namely

• the shallow class, this comprises beds that are situated between the mean low water mark at spring tide (MLWS) and five metres below MLWS, and

• the deep class, this comprises beds that are situated more than five metres below MLWS.

By using the boundary of five metres, (shallow) flat beds of the different water systems are all included in the shallow class. These areas are important to nursery ground species and tidal migrants, as described above. Apart from the flat shallow parts, the upper part of the channel wall will fit into this class frequently. Channel walls are of little ecological value, unlike shallow plane beds. The relative acreage of channel walls in the ecotope, however, is very small.

We selected different class boundaries for depth for the North Sea (table 4.5.1). In the North Sea the acreage of the zone of five metres below MLWS to MLWS is very limited, seen on the scale of the Dutch Continental Shelf in particular; therefore this boundary has been left out. In stead we opted for the seaward boundary of the shallow zone at twenty metres below MLWS, making the coastal area with its specific benthos communities (and birds!) to be considered as a separate ecotope (Holtmann et al., 1996; Van Horssen et al., 1999). In addition, we set up an extra boundary at thirty meters, as the presence of benthic communities in the North Sea corresponds with depth and this depth seems to make sense (Holtmann et al., 1996).

For stagnant waters we selected likewise three depth classes (table 4.5.1). Both in the Grevelingenmeer and in the Veerse Meer beds occur in the shallow class that are situated at less than five metres below the water level. The deep class comprises in the Grevelingenmeer beds between five and fifteen metres below the water level, in the Veerse Meer beds between five and ten metres below the water level (boundaries with respect to stratification and location of the thermocline). In the case of very deep beds (Grevelingenmeer deeper than fifteen metres, Veerse Meer deeper than ten metres) there is in spring and summer frequently a chance of lack of oxygen exists, and the benthic fauna is very poor.

Littoral zone: ecological meaning of duration of flooding

In the littoral parts situated within the coast the height in the littoral zone together with the local tidal curve determine the duration of flooding. The duration of flooding directly affects the occurrence and the growth of benthos in the sediment. There is a distinct boundary above which benthos cannot occur because the time they are submerged is too short to be able to survive (Reise, 1985). In addition, the duration of flooding determines directly the foraging time of most benthos. It is longer as the bed is longer submerged (Buschbaum & Saier, 2001). The duration of flooding indirectly affects the occurrence of benthos via predation pressure. During periods of emergence of the intertidal area, waders can forage on benthos (Hulscher, 1981; Zwarts, 1997), while during periods of submergence crabs, shrimps and flat fish may eat the smallest benthos (Sanchez-Salazar et al., 1987; Hiddink et al., 2002). Different stages of life of benthos may sometimes use different zones in the littoral, such as is the case with the Baltic tellin (*Macoma balthica*) (Beukema, 1993; Bouma et al., 2001b).

High-energy parts of littoral areas, both within the coast and on the North Sea, are poor in benthos. Height here plays a less important part. In this zone no further distinction is made qua height, as it is less relevant.

Littoral zone: selection of variables and class boundaries

As height with respect to DOL as such does not correspond directly to the occurrence of benthic flora and fauna, we chose to subdivide the littoral sediments further by flooding frequency (%). With it, different areas such as the Wadden Sea and the Zeeland waters may be compared. The duration of flooding affects the occurrence of ecological communities on littoral hard substratum likewise (see Meijer & Waardenburg, 2002). The littoral hard substratum however is not subdivided in order to keep the ecotope system practical and well organized. The high-energy littoral zone is not subdivided any further either as hydrodynamics in these areas are clearly dominating. The high-energy littoral zone is subdivided, though, based on sediment composition (section 4.6).

We chose to subdivide flooding frequency into three classes. One of its reasons is that the density and biomass of benthos in the middle high littoral zone often is higher than in the low and high littoral zones (Beukema, 1976; Wolff & De Wolf, 1977). Sometimes a high biomass and a high biodiversity of benthos will occur in the low littoral zone possibly as there are no other environmental factors that are limiting, such as hydrodynamics. The biomass is high as well when in the low littoral zone mussel beds or oyster beds (eco-elements, see section 4.7) are present.

Based on for instance BIOMON (BIOlogical MONitoring program) biomass data of the Westerschelde (unpublished) we selected the class boundaries of 25% and 75% (table 4.5.1).

- **the low littoral zone is the area between the mean low water mark at spring tide and the line of 75% duration of flooding,**
- **the middle high littoral zone is the zone between 75% and 25% duration of flooding, and**
- **the high littoral zone is the zone from 25% duration of flooding to the mean high water mark at neap tide (table 4.5.1).**

Mussel and oyster beds may occur in the low and middle high littoral zone. Sea grass beds may occur in the middle high and high littoral zones. In the high littoral zone hardly any or no filter feeders occur and the benthic fauna consists mainly of sediment feeders such as worms and small crustaceans. The total benthic biomass in the high littoral zone is low and a pioneer vegetation like rice grass (*Spartina anglica*) may be present in the highest parts.

Supralittoral zone: ecological meaning of flooding frequency

We can divide the supralittoral zone, the area above the mean high water mark at neap tide, roughly into parts within the coast and along the North Sea coast.
Flooding frequency is an important factor for the vegetation of salt marshes in the low-energy parts of the areas within the coast. The specific physiology of each species of plants determines how often and how long it can be flooded (with respect to salt tolerance and duration of flooding). A gradient in the vegetation on salt marshes is present from low to high, in which the succession of vegetation has progressed increasingly. In low parts pioneer plants are present, in high parts the vegetation is higher and 'rougher'. Biodiversity of plants is highest in the middle high area. When salt marshes are managed, for instance by grazing or mowing, the vegetation has a far more different look than in the natural situation. The vegetation is kept short and succession to the end stage of the vegetation development will be hampered (making high parts of salt marshes less high and rough). Management of salt marshes has only been included in ZES.1 in the description of the ecological contents of the ecotopes (chapter 6). This factor can be included, if desired, in the ecotope concerned by adding a code.

We can divide the supralittoral zone of the North Sea coast and the higher parts of the water systems situated 'within the coast' roughly into two zones:

- **a low zone in which no formation of embryonic dunes takes place and beach drift plants may occur, and**
- **a high zone in which embryonic dune formation takes place including accompanying plants (such as sand twitch (*Agropyron junceiforme*))**;

respectively the dry beach and the embryonic dunes.
In the low supralittoral zone along the coast very high tidal flats such as the Richel and Noorderhaaks are included as well.

Supralittoral zone: selection of variables and class boundaries

We decided, therefore, to use the variable flooding frequency only for the salt marshes in the supralittoral zone. The supralittoral hard substratum (with lichens), such as it occurs on pitchings is not subdivided any further. The beaches (and shores of stagnant waters) are subdivided based on the presence of embryonic dunes or a particular vegetation (see Chapter 6). Apart from that, the vegetation in salt marshes is separately mapped and in those cases one can obtain directly the information desired from the vegetation map.

We decided to use as an exact variable for the subdivision of salt marshes the flooding frequency per year. We discern between the pioneer zone, low, middle high, high and very high parts. In it we combined the different subdivisions that are used for salt marshes in the Wadden Sea and salt marshes in Zeeland. The class boundaries were derived from Dankers et al. (2001), who based their classification on a standard vegetation classification (De Jong et al., 1991):

- **the pioneer zone and potential pioneer zone are flooded virtually each tide (MHWN - > 300 times per year),**
- **the low salt marshes frequently (300-150 times per year),**
- **the middle high salt marshes now and again (150-50 times per year),**
- **the high salt marshes rarely (50-5 times per year) (table 4.5.1).**

4.6 SUBSTRATUM 2 (SEDIMENT COMPOSITION)

At the hierarchic system's sixth level sediment composition is used for classification. We selected as variables:
- the median grain size of the sand fraction (µm)
- the silt content (% < 63 µm).
Table 4.6.1 shows the classes and class boundaries 4.6.1

Method

It is of the utmost importance that sampling data are used that has been sampled in the same way (sampling depth, treatment) for classification of ecotopes with the variable 'sediment composition'. The sampling method and determination of the grain size composition and silt content are therefore very important and it may affect the classification of ecotopes. In ZES.1 we work with samples of the upper ten cm of sediment. We propose to maintain the McLaren method (McLaren et al., 1993; McLaren, 1994) in the determination of the grain size of the samples. In this method samples are not prepared with acid to remove organic matter and calcium particles and to split up aggregates into mineral particles. In the fine fraction preparation may cause highly differing results with regard to the sieve and pipette method. The grain size distribution is determined with the Malvern 2600L Laser Particle Sizer. If another method is used then a series of samples should be analysed with either method in order to enable a good adjustment of data.

ecotope-indication	median grain size	silt content (< 63 µm)
rich in silt	-	≥ 25%#
fine sands	=< 250 µm	< 25%
coarse sands	250 – 2000 µm	< 25%
gravels	> 2000 µm	< 25%
		#: North Sea < 10%

Table 4.6.1. *Classification of the variables median grain size and silt content (< 63 µm).*

Ecological meaning sediment composition

In addition to salinity, the sediment composition is the main factor determining the occurrence and distribution of benthos in estuaries (Ysebaert 2000). With sediment composition we mean the grain size composition. The sediment composition affects the efficiency of the take-in of food (Huz et al., 2002) and the opportunities for burrowing. Foraging opportunities and efficiency of some waders depend on the sediment composition as well.

Sediment composition often reflects the hydrodynamic conditions, making it indirectly connected with the occurrence of benthos (see section 4.4). As flowing water is stagnant just above the bed, a transition zone is present above the bed in which the horizontal velocity of the water increases sharply. This difference in current velocities exerts a shear stress on the bed, the bed shear stress. The bed shear stress may cause the sediment to erode or resuspend and prevent suspended sediment in the water from reaching the bed (sedimentation). The critical bed shear stress for resuspension and sedimentation differs between fine and coarse particles. Sediment consists mostly of coarse sand at places with high current velocities. An obvious example is the tidal channels in which current velocities are very high and the bed is unstable (Ysebaert et al., 2000; Ysebaert & Herman, 2001). In places with low current velocities the sediment mostly consists of fine sands and silt (sediment particles < 63 µm). The silt content of the bed, however, not only depends on current velocity, but likewise on the silt content in the water column (silt supply), the presence of benthos enabling silt to be trapped (think of mussel beds), and diatoms

on the bed that are able to retain silt. The silt content often shows seasonal dynamics, with silt contents being highest in summer and autumn.
Even if adequate silt is present in the water column, the silt contents of the bed do not always correspond to the current velocity. Sediment particles in beds that are rich in silt become attached making the bed cohesive. Moreover, a layer of diatoms (micro-algae) at the sediment surface often keeps beds that are rich in silt together. This consolidated structure enables silt to get less easily stirred by currents, which makes it possible that places occur with at the same time high current velocities and beds rich in silt. Clay (sediment particles < 2 µm) plays an even bigger part in cohesiveness of beds than silt, but as no data on clay are generally available it is not included in the ecotope system.

Each benthic species has its own range of sediment composition in which it can occur. Facts such as the animal's foraging strategy and its way of life in the sediment determine this range. Probably many species may occur in a broad range of sediment composition, the boundaries of which are species specific as the sediment is too rich in silt or too sandy. Some examples of species that are present in sediments rich in silt are the clam worm (*Nereis diversicolor*) and the mud shrimp (*Corophium volutator*). Examples of species that occur in coarser sands are the white catworm (*Nephtys spp.*) and the sand digger shrimp (*Bathyporeia sp.*), while the lugworm (*Arenicola marina*) and the common cockle (*Cerastoderma edule*) for instance show an intermediate optimum in finer sands (Ysebaert & Herman, 2001) (Figure 4.6.1).

Selection of variables and class boundaries

We decided to subdivide the hierarchic system's lowest level for the sublittoral and littoral sediments based on sediment composition. The exact variables chosen are median grain size of the sand fraction and silt content (< 63 µm). We selected silt content, as in practice data on clay are not available in general. It appeared though, that within a water system silt content and clay content correlate well. When silt data of several points in time within one year are available, preference should be given to summer or autumn data. Its reasons are the accumulation of silt, in summer in particular, and highest numbers of benthos in these seasons.

Based on the occurrence of particular benthic species in the sediment with a specific grain size (Ysebaert 2000), we decided to make a subdivision in the classes:

- **rich in silt (silt content => 25% irrespective of median grain size),**
- **fine sand (median grain size =< 250 µm and silt content < 25%),**
- **coarse sand (median grain size 250-2000 µm and silt content < 25%) and**
- **gravel (median grain size > 2000 µm) (table 4.6.1).**

Only for the North Sea we apply a boundary for silt content of 10% (see Holtmann et al., 1996). The class boundaries were selected based on the occurrence of various types of sediment in the field (see Van Eck, 1999 and www.waddenzee.nl), and based on knowledge that exists on individual benthic species (see Ysebaert, 2000). On gravel beds in particular, only occurring in the North Sea (Cleaverbank) in the Netherlands, specific fauna species occur and some species of hard substrata may settle there likewise.

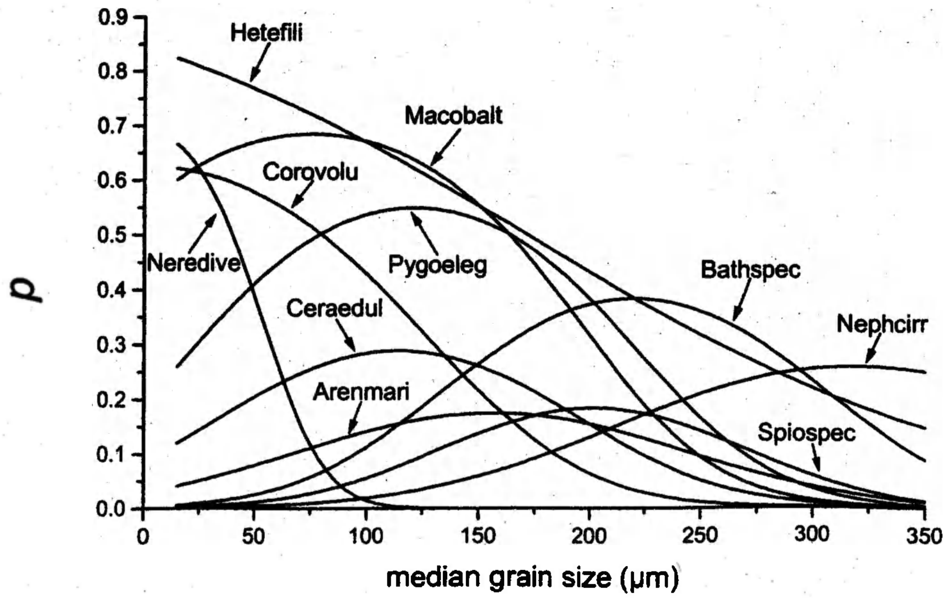

Figure 4.6.1. *The chance of a species being present as function of the median grain size (based on the Westerschelde) (figure from Ysebaert, 2000).*
Corovolu: Corophium volutator, Neredive: Nereis diversicolor, Macobalt: Macoma balthica, Bathspec: Bathyporeia sp., Pygoeleg: Pygospio elegans, Arenmari: Arenicola marina, Ceraedul: Cerastoderma edule, Hetefili: Heteromasus filiformis, Nephcirr: Nephtys cirrosa.

5 ECOTOPES PER WATER SYSTEM

5.1. OCCURRENCE OF ECOTOPES IN THE DUTCH SALINE AND BRACKISH WATERS

In this chapter we deal with the occurrence of ecotopes in the Dutch brackish and saline water systems. Not all possible combinations of ecotopes (with their assigned codes, see Tables 5.1.1. up to and including 5.1.3) are actually occurring in the Dutch water systems. Not all ecotopes are occurring, for instance, both in brackish, variable and saline waters. At the most detailed level we discern a total of 31 brackish ecotopes (table 5.1.1), 29 variably brackish/saline ecotopes (table 5.1.2) and 49 saline ecotopes (table 5.1.3). In table 5.1.4 all ecotopes occurring in the Dutch water systems are listed. Therefore, we indicated as well which combinations of abiotic environmental factors (ecotopes) are not occurring (codes in italics). We elaborated further upon the occurrence of ecotopes in the different water systems in section 5.3, where this is illustrated schematically by the so-called ecotope-mondriaans.

THE BRACKISH ECOTOPES		salinity	substratum	position	hydrodynamics	depth/height	composition of substratum
			hard substratum in the sublittoral zone				
B1.112	high energy consolidated peat layer	b	h	sb	he		p
B1.121	low energy stone/wood	b	h	sb	le		sw
B1.131	stone/wood in stagnant water	b	h	sb	st		sw
			hard substratum in the littoral zone				
B1.212	high energy consolidated peat layer	b	h	l	he		p
B1.221	low energy stone/wood	b	h	l	le		sw
			hard substratum in the supralittoral zone				
B1.3	hard substratum in the supralittoral zone	b	h	sp			sw
			sediments in the sublittoral zone				
B2.11	high energy bed sands	b	s	sb	he		f/cs
B2.11s	high energy bed rich in silt	b	s	sb	he		rs
B2.122s	low energy deep bed rich in silt	b	s	sb	le	d	rs
B2.122f	low energy deep bed fine sands	b	s	sb	le	d	f
B2.123s	low energy shallow bed rich in silt	b	s	sb	le	sh	rs
B2.123f	low energy shallow bed fine sands	b	s	sb	le	sh	f
B2.131	very deep bed in stagnant water	b	s	sb	st	s	
B2.132	deep bed in stagnant water	b	s	sb	st	d	
B2.133	shallow bed in stagnant water	b	s	sb	st	sh	
			sediments in the littoral zone				
B2.21	high energy littoral zone sands	b	s	l	he		f/cs
B2.21s	high energy littoral zone rich in silt	b	s	l	he		rs
B2.221s	low energy low littoral zone rich in silt	b	s	l	le	ll	rs
B2.221f	low energy low littoral zone fine sands	b	s	l	le	ll	f
B2.222s	low energy middle high littoral zone rich in silt	b	s	l	le	ml	rs
B2.222f	low energy middle high littoral zone fine sands	b	s	l	le	ml	f
B2.223s	low energy high littoral zone rich in silt	b	s	l	le	hl	rs
B2.223f	low energy high littoral zone fine sands	b	s	l	le	hl	f
			sediments in the supralittoral zone				
B2.311	dry beach	b	s	sp	hd		f /cs
B2.321	pioneer zone + potential pioneer zone	b	s	sp	le	pz	
B2.322	low salt marsh	b	s	sp	le	ls	
B2.323	middle high salt marsh	b	s	sp	le	ms	
B2.324	high salt marsh	b	s	sp	le	hs	
B2.331	shore stagnant open brackish vegetation	b	s	sp	st	sv	
B2.332	shore stagnant closed saline vegetation	b	s	sp	st	sv	
B2.333	shore stagnant: closed brackish vegetation	b	s	sp	st	sv	

Table 5.1.1. *Brackish ecotopes with their accompanying abiotic characteristics.*
b=brackish;
h=hard substratum; sw=stone/wood; p=peat; s=sediment; rs=rich in silt; f=fine sand; cs=coarse sands
sb=sublittoral; l=littoral; sp=supralittoral;
he= high energy; le=low energy; st=stagnant;
v=very deep; d=deep; sh=shallow; ll=low littoral; ml=middle high littoral; hl=high littoral;
pz=pioneer zone; ls=low salt marsh; ms=middle high salt marsh; hs=high salt marsh; sv=shore vegetation;

			hard substratum in the littoral zone				
V1.211	high energy stone/wood	v	h	l	he		sw
V1.212	high energy consolidated peat layer	v	h	l	he		p
V1.221	low energy stone/wood	v	h	l	le		sw
			hard substratum in the supralittoral zone				
V1.3	hard substratum in the supralittoral zone	v	h	sp			sw
			sediment in the sublittoral zone				
V2.11	high energy bed sands	v	s	sb	he		f/cs
V2.11s	high energy bed rich in silt	v	s	sb	he		rs
V2.122s	low energy deep bed rich in silt	v	s	sb	le	d	rs
V2.122f	low energy deep fine sands	v	s	sb	le	d	f
V2.123s	low energy shallow bed rich in silt	v	s	sb	le	sh	rs
V2.123f	low energy shallow fine sands	v	s	sb	le	sh	f
			sediment in the littoral zone				
V2.21	high energy littoral zone sands	v	s	l	he		f/cs
V2.21s	high energy littoral zone rich in silt	v	s	l	he		rs
V2.221s	low energy low littoral zone rich in silt	v	s	l	le	ll	rs
V2.221f	low energy low littoral zone fine sands	v	z	l	le	ll	f
V2.221z	low energy low littoral zone coarse sands	v	s	l	le	ll	cs
V2.222s	low energy middle high littoral zone rich in silt	v	s	l	le	ml	rs
V2.222f	low energy middle high littoral zone fine sands	v	s	l	le	ml	f
V2.222z	low energy middle high littoral zone coarse sands	v	s	l	le	ml	cs
V2.223s	low energy high littoral zone rich in silt	v	s	l	le	hl	rs
V2.223f	low energy high littoral zone fine sands	v	s	l	le	hl	f
V2.223z	low energy high littoral zone coarse sands	v	s	l	le	hl	cs
			sediment in the supralittoral zone				
V2.31	high energy supralittoral zone	v	s	sp	he		cs/f
V2.321	pioneer zone + potential pioneer zone	v	s	sp	le	pz	
V2.322	low salt marsh	v	s	sp	le	ls	
V2.323	middle high salt marsh	v	s	sp	le	ms	
V2.324	high salt marsh	v	s	sp	le	hs	

Table 5.1.2. *Variably brackish/saline ecotopes with their accompanying abiotic characteristics.*
v=variably brackish/saline;
h=hard substratum; sw=stone/wood; p=peat; s=sediment; rs=rich in silt; f=fine sands; cs= coarse sands
sb=sublittoral; l=littoral; sp=supralittoral; he= high energy; le=low energy;
d=deep; sh=shallow; ll=low littoral; ml=middle high littoral; hl=high littoral;
pz=pioneer zone; ls=low salt marsh; ms=middle high salt marsh; hs=high salt marsh; vs= very high salt marsh

THE SALINE ECOTOPES		salinity	substratum	position	hydrodynamics	depth/heigth	composition of susbstratum
				hard substratum in the sublittoral zone			
Z1.111	high energy stone/wood	sa	h	sb	he		sw
Z1.112	high energy consolidated peat layer	sa	h	sb	he		p
Z1.121	low energy stone/wood	sa	h	sb	le		sw
Z1.122	low energy consolidated peat layer	sa	h	sb	le		p
Z1.131	stone/wood in stagnant water	sa	h	sb	st		sw
Z1.132	consolidated peat layer in stagnant water	sa	h	sb	st		p
				hard substratum in the littoral zone			
Z1.211	high energy stone/wood	sa	h	l	he		sw
Z1.212	high energy consolidated peat layer	sa	h	l	he		p
Z1.221	low energy stone/wood	sa	h	l	le		sw
Z1.222	low energy consolidated peat layer	sa	h	l	le		p
				hard substratum in the supralittoral zone			
Z1.3	hard substratum in the supralittoral zone	sa	h	sp			sw
				sediment in the sublittoral zone			
Z2.11	high energy bed sands	sa	s	sb	he		f/cs
Z2.11s	high energy bed rich in silt	sa	s	sb	he		rs
Z2.121s	low energy very deep bed rich in silt	sa	s	sb	le	v	rs
Z2.121f	low energy very deep bed fine sands	sa	s	sb	le	v	f
Z2.121z	low energy very deep bed coarse sands	sa	s	sb	le	v	cs
Z2.121g	low energy very deep bed gravel	sa	s	sb	le	v	g
Z2.122s	low energy deep bed rich in silt	sa	s	sb	le	d	rs
Z2.122f	low energy deep bed fine sands	sa	s	sb	le	d	f
Z2.122z	low energy deep bed subsoil coarse sands	sa	s	sb	le	d	cs
Z2.123s	low energy shallow bed rich in silt	sa	s	sb	le	sh	rs
Z2.123f	low energy shallow bed fine sands	sa	s	sb	le	sh	f
Z2.123z	low energy shallow bed coarse sands	sa	s	sb	le	sh	cs
Z2.131	very deep bed in stagnant water	sa	s	sb	st	v	
Z2.132	deep bed in stagnant water	sa	s	sb	st	d	
Z2.133	shallow bed in stagnant water	sa	s	sb	st	sh	
				sediment in the littoral zone			
Z2.21z	high energy littoral zone coarse sands (wet beach)	sa	s	l	he		cs
Z2.21f	high energy littoral zone fine sands within the coast	sa	s	l	he		f
Z2.21s	high energy littoral zone rich in silt	sa	s	l	he		rs
Z2.221s	low energy low littoral zone rich in silt	sa	s	l	le	ll	rs
Z2.221f	low energy low littoral zone fine sands	sa	s	l	le	ll	f
Z2.221z	low energy low littoral zone coarse sands	sa	s	l	le	ll	cs
Z2.222s	low energy middle high littoral zone rich in silt	sa	s	l	le	ml	rs
Z2.222f	low energy middle high littoral zone fine sands	sa	s	l	le	ml	f
Z2.222z	low energy middle high littoral zone coarse sands	sa	s	l	le	ml	cs
Z2.223s	low energy high littoral zone rich in silt	sa	s	l	le	hl	rs
Z2.223f	low energy high littoral zone fine sands	sa	s	l	le	hl	f
Z2.223z	low energy high littoral zone coarse sands	sa	s	l	le	hl	cs
				sediment in the supra-littoral zone			
Z2.311	high energy supralitt. coarse sands (dry beach)	sa	s	sp	he	db	cs
Z2.312	high energy supralitt. high coarse sands (embryonic dune)	sa	s	sp	he	ed	cs
Z2.313	high energy supralitt fine sands low inner coast	sa	s	sp	he	h	f
Z2.314	high energy supralitt fine sand low inner coast (embryonic dune)	sa	s	sp	he	l	f
Z2.321	pioneer zone	sa	s	sp	le	ps	
Z2.322	low salt marsh	sa	s	sp	le	ls	
Z2.323	middle high salt marsh	sa	s	sp	le	ms	
Z2.324	high salt marsh	sa	s	sp	le	hs	
Z2.331	shore stagnant open saline vegetation	sa	s	sp	st	sv	
Z2.332	shore stagnant: close saline vegetation	sa	s	sp	st	sv	
Z2.333	shore stagnant: close brackish vegetation	sa	s	sp	st	sv	

Table 5.1.3. *Saline ecotopes with their accompanying abiotic characteristics.*
S=saline; h=hard substratum; sw=stone/wood; p=peat; s=sediment; rs=rich in silt; f=fine sands; cs= coarse sands; g=gravel
sb=sublittoral; l=littoral; sp=supralittoral;
he= high energy; le=low energy; st=stagnant;
v=very deep; d=deep; sh=shallow; ll=low littoral; ml=middle high littoral; hl=high littoral;
wb=wet beach; db=dry beach; ed=embryonic dunes;
pz=pioneer zone; ls=low salt marsh; ms=middle high salt marsh; hs=high salt marsh; sv=shore vegetation

THE OCCURENCE OFTHE ECOTOPES IN THE WATER SYSTEMS																							
	brackish	ws	ed	nr	wz	os	nz	vm	**variable**	ws	ed	nr	wz	os	nz	**saline**	ws	ed	nr	wz	os	nz	gm
hard substratum in the sublittoral zone																							
high energy stone/wood	*B1.111*								**V1.111**						nz	**Z1.111**						nz	
high energy consolidated peat layer	**B1.112**	ws							**V1.112**	ws						**Z1.112**	ws				os		
low energy stone/wood	**B1.121**	ws	ed	nr					**V1.121**	ws	ed	nr	wz		nz	**Z1.121**	ws			wz	os	nz	
low energy consolidated peat layer	*B1.122*								*V1.122*							**Z1.122**					os		
stone/wood in stagnant water	**B1.131**							vm	**V1.131**							**Z1.131**							gm
consolidated peat layer in stagnant water	*B1.132*								*V1.132*							**Z1.132**							gm
hard substratum in the littoral zone																							
high energy stone/wood	*B1.211*								**V1.211**						nz	**Z1.211**						nz	
high energy consolidated peat layer	**B1.212**	ws							**V1.212**	ws						**Z1.212**	ws						
low energy stone/wood	**B1.221**	ws	ed	nr					**V1.221**	ws	ed	nr	wz		nz	**Z1.221**	ws			wz	os	nz	
low energy consolidated peat layer	*B1.222*								*V1.222*							*Z1.222*							
hard substratum in the supralittoral zone		**B/V/Z1.3**			ws ed nr wz os nz gm vm																		
sediment in the sublittoral zone																							
high energy bed sands	**B2.11**	ws	ed	nr					**V2.11**	ws	ed	nr	wz	os	nz	**Z2.11**	ws			wz	os	nz	
high energy bed rich in silt	**B2.11s**	ws	ed						**V2.11s**	ws	ed					**Z2.11s**	ws						
low energy very deep bed rich in silt	*B2.121s*								*V2.121s*							**Z2.121s**						nz	
low energy very deep bed fine sands	*B2.121f*								*V2.121f*							**Z2.121f**						nz	
low energy very deep bed coarse sands	*B2.121z*								*V2.121z*							**Z2.121z**						nz	
low energy very deep bed gravel bed	*B2.121g*								*V2.121g*							**Z2.121g**						nz	
low energy deep bed rich in silt	**B2.122s**	ws	ed	nr					**V2.122s**	ws	ed	nr	wz			**Z2.122s**	ws			wz	os	nz	
low energy deep bed fine sands	**B2.122f**	ws	ed	nr					**V2.122f**	ws	ed	nr	wz			**Z2.122f**	ws			wz	os	nz	
low energy deep bed coarse sands	*B2.122z*								*V2.122z*							**Z2.122z**						nz	
low energy shallow bed rich in silt	**B2.123s**	ws	ed	nr					**V2.123s**	ws	ed	nr	wz		nz	**Z2.123s**	ws			wz	os	nz	
low energy shallow bed fine sands	**B2.123f**	ws	ed	nr					**V2.123f**	ws	ed	nr	wz		nz	**Z2.123f**	ws			wz	os	nz	
low energy shallow bed coarse sands	*B2.123z*								**V2.123z**						nz	**Z2.123z**						nz	
very deep bed in stagnant water	**B2.131**							vm	*V2.131*							**Z2.131**							gm
deep bed in stagnant water	**B2.132**							vm	*V2.132*							**Z2.132**							gm
shallow bed in stagnant water	**B2.133**							vm	*V2.133*							**Z2.133**							gm
shallow bed in stagnant water with shore vegetation	B2.133ov							vm	*V2.133OV*							***Z2.133ov***							gm
sediment in the littoral zone																							
high energy littoral zone	**B2.21**	ws	ed						**V2.21**	ws	ed		wz		nz	**Z2.21**	ws			wz	os	nz	
high energy littoral zone rich in silt	**B2.21s**	ws	ed						**V2.21s**	ws	ed					**Z2.21s**	ws						
low energy low littoral zone rich in silt	**B2.221s**	ws	ed						**V2.221s**	ws	ed		wz		nz	**Z2.221s**	ws			wz		nz	
low energy low littorral zone fine sands	**B2.221f**	ws	ed	nr					**V2.221f**	ws	ed	nr	wz		nz	**Z2.221f**	ws			wz	os	nz	
low energy low littoral zone coarse sands	*B2.221z*								**V2.221z**						nz	**Z2.221z**						nz	
low energy middle high littoral zone rich in silt	**B2.222s**	ws	ed						**V2.222s**	ws	ed		wz		nz	**Z2.222s**	ws			wz		nz	
low energy middle high littoral zone fine sands	**B2.222f**	ws	ed	nr					**V2.222f**	ws	ed	nr	wz		nz	**Z2.222f**	ws			wz	os	nz	
low energy middle high littoral zone coarse sands	*B2.222z*								**V2.222z**						nz	**Z2.222z**						nz	
low energy high littoral zone rich in silt	**B2.223s**	ws	ed						**V2.223s**	ws	ed		wz		nz	**Z2.223s**	ws			wz		nz	
low energy high littoral zone fine sands	**B2.223f**	ws	ed	nr					**V2.223f**	ws	ed	nr	wz		nz	**Z2.223f**	ws			wz	os	nz	
low energy high littoral zone coarse sands	*B2.223z*								**V2.223z**						nz	**Z2.223z**						nz	
sediment in the supralittoral zone																							
dry beach	**B2.311**								**V2.311**							**Z2.311**	ws			wz	os	nz	
embryonic dunes	**B2.312**								**V2.312**							**Z2.312**	ws			wz	os	nz	
supralittoral high energy sands	**B2.313**	ws							**V2.313**	ws			wz			**Z2.313**				wz	os	nz	
supralittoral high energy silt	**B2.314**	ws							**V2.314**	ws			wz			**Z2.314**				wz			
pioneer zone	**B2.321**	ws	ed	nr					**V2.321**	ws	ed	nr	wz		nz	**Z2.321**	ws			wz	os	nz	
low salt marsh	**B2.322**	ws	ed	nr					**V2.322**	ws	ed	nr	wz		nz	**Z2.322**	ws			wz	os	nz	
middle high salt marsh	**B2.323**	ws	ed	nr					**V2.323**	ws	ed	nr	wz		nz	**Z2.323**	ws			wz	os	nz	
high salt marsh	**B2.324**	ws	ed	nr					**V2.324**	ws	ed	nr	wz		nz	**Z2.324**	ws			wz	os	nz	
open saline vegetation	*B2.331*								*V2.331*							**Z2.331**							gm
close saline vegetation	**B2.332**							vm	*V2.332*							**Z2.332**							gm
close brackish vegetation	**B2.333**							vm	*V2.333*							**Z2.333**							gm

Table 5.1.4. *The occurrence of the ecotopes in the Dutch water systems*
ws=Westerschelde; ed= Ems-Dollard; nr= Noordrand (= ca area west of Rotterdam); wz-Wadden Sea; os=Oosterschelde; nz= North Sea; gm- Grevelingenmeer; vm= Veerse Meer.
The codes (ecotopes) in italics do not occur in the Netherlands.

5.2 ECO-ELEMENTS

We illustrated the term eco-elements in section 2.4. Table 5.2.1 indicates which eco-elements we discern in ZES.1, and in which ecotopes they may occur. Subsequently we present a short ecological description of the eco-elements, and illustrate them with photos.

eco-element	the potential occurrence in ecotopes			
	description	brackish	saline	variably brackish/saline
gullies	low-energy low littoral zone low-energy middle high littoral zone low-energy high littoral zone	X X X	X X X	X X X
sea grass fields	low-energy shallow bed shallow bed in stagnant water low-energy middle high littoral zone low-energy high littoral zone	X X X X	X X X X	X X X
Ruppia-associations	low-energy shallow bed in stagnant water low-energy middle high and high littoral zone	X X		
mussel beds	low-energy shallow bed low-energy low littoral zone low-energy middle high littoral zone		X X X	
oyster beds	low-energy shallow bed low-energy low littoral zone low-energy middle high littoral zone		X X X	
shell banks	sublittoral zone littoral zone	X X	X X	X X
shipwrecks	sublittoral zone	X	X	X
shore vegetation along shores of brackish lakes	low-energy shallow bed and sublittoral zone in stagnant brackish water	X		

Table 5.2.1 *The potential occurrence of eco-elements in the ecotopes.*

Photo 5.2.1 *Gullies*

Gullies are small and shallow channels occurring in tidal flats and salt marshes (photo 5.2.1). The eco-element gullies only comprises gullies in tidal flats. We consider the gullies (creeks) in salt marshes to be standard in the ecotope concerned. We consider the creeks in salt marshes that are wider than 100 metres to belong to the littoral. Although gullies are often situated above the low water mark, they hold water for a long time or even permanently, which discharges from the surrounding area during ebb until the tide turns. During ebb many benthic animals that live on or right above the sediment are retreating in the gullies (Berghahn, 1983). Examples of animals that occur generally in gullies are shrimps, crabs and flat fish. Gullies and creeks play an important part as nursery grounds for the brown shrimp (*Crangon crangon*) (Cattrijsse, 1997). Birds foraging frequently in gullies on shrimps and other crustaceans are gulls, spoonbills (*Platalea leucorodia*), green shanks (*Tringa nebularia*), spotted redshanks (*Tringa erythropus*) and avocets (*Recurvirostra avosetta*) (from Dankers et al., 2001).

Photo 5.2.2 *Sea grass beds; Zosera marina right, Z noltii left*

Both species of sea grasses, dwarf grass-wrack (*Zostera noltii*) and eel grass (*Zostera marina*) that occur in the Netherlands are target species of the ANF nature policy (Bal et al., 2001). The criterion for a sea grass bed (photo 5.2.2.) is a cover percentage of 5%. The two species of sea grass may occur next to one another, but also separately. Although the associated flora and fauna are similar for the greater part, we generally discern between the associations of either species. Both species occur in brackish and saline waters as well. In the intertidal area, sea grass beds occur in the low-energy littoral zone, in stagnant waters in the shallow sublittoral zone. The dwarf grass-wrack-association currently occurs in the Wadden Sea, Oosterschelde and Westerschelde. The eel grass-association occurs in the eastern Wadden Sea, the Ems-estuary, the Oosterschelde and the Veerse Meer. Sea grass beds play an important ecological part within a water system. Various species of red and brown algae live epiphytically on the sea grass leaves, on which in lakes often polypites occur as well. Shellfish such as *Hydrobia ulva* and the (juvenile) periwinkle (*Littorina littorea*) are occurring abundantly in sea grass beds. The sea grass beds offer shelter to animals such as crabs (Wilson et al., 1990). Sublittoral sea grass beds offer a suitable environment to cephalopods (*Sepia officinalis*) and fish (such as the deep-snouted pipefish *Syngnathus typhle* and fifteen-spined stickleback *Spinachia spinachia*) (Van Goor, 1919). Wigeons (*Anas penelope*), brent geese (*Branta bernicla*) and swans(*Cygnus sp.*) forage on sea grass beds. More information on sea grass beds and their occurrence in the Netherlands can be found in De Jong & De Jonge (1989), Wijgergangs & De Jong (1999) and on www.zeegras.nl.

Ruppia-associations (plant-associations) mainly occur in brackish waters within embankments (to which ZES.1 does not apply), but they are found likewise in creeks and supralittoral pools in salt marshes (Schaminée et al., 1995). The strongly fluctuating salinity in supralittoral pools prevents that other species of plants oust beaked tassel pondweed or spiral tassel pondweed. Currently much beaked tassel pondweed occurs on the western part of the Balgzand (Western Wadden Sea). This annual mainly occurs in low-energy shallow waters. Spiral tassel pondweed is a perennial, occurring in deeper water and it tolerates higher energy than beaked tassel pondweed. In the beaked tassel pondweed-association the most common plants next to beaked tassel pondweed are fennel pondweed (*Potamogeton pectinatus*), horned pondweed (*Zannichellia palustris*) and spiral tassel pondweed. The spiral tassel pondweed-association is poorer in species, only fennel pondweed (*Potamogeton pectinatus*) occurs frequently alongside spiral tassel pondweed.
The species beaked tassel pondweed (*Ruppia maritima*) and spiral tassel pondweed (*Ruppia cirrhosa*) are occurring in the Netherlands, and are both target species of the ANF nature policy (Bal et al., 2001).

Photo 5.2.3. *Mussel beds*

Mussel beds (photo 5.2.3.) are benthic communities in which mussels (*Mytilus edulis*) set the scene, and that consist of a spatially well-defined quilt-like pattern of large and small groups of mussels, that may protrude above their surroundings and that are bisected by open spaces. The boundary with (loose lying) sown mussels is set up on 1 kg per m^2. Mussel beds occur in saline water, in the low and middle high littoral and shallow sublittoral zones. The beds are able to develop when suitable substratum is present on which seed mussels can settle, such as (empty) shells, tubes of annelid worms (Lanice conchilega) and sea grasses as well. A silt layer forms between and under the mussels due to deposition of (pseudo-)faeces and the settling of suspended silt. Mussel beds are a suitable settling place for a number of hard substratum species, such as sea lettuce (*Ulva* sp.), barnacles (*Cirripedia*) and polypites. In addition, a large number of worms, molluscs and crustaceans are associated with mussel beds. In the pools between the littoral mussel humps anemones grow and during ebb shrimps stay behind. Various species of fish, for instance the common eel (*Anguila anguila*) and butterfish (*Pholis gunnellus*) find shelter between the mussel humps. Species such as oystercatchers (*Haematopus ostralegus*) (during low tide) and eiders (*Somateria mollissima*) (during high tide) eat mussels. In addition, the curlew (*Numenius arquata*), the common redshank (*Tringa totanus*), the green shank (*Tringa nebularia*), turnstones (*Arenaria interpres*) and Black-headed gull (*Larus ridibundus*) forage for crabs, shrimps, small fish and worms in the mussel beds. Extensive information on mussel beds can be found in the ecoprofile of wild littoral mussel beds (Tydeman, 1996). In the Wadden Sea and the Oosterschelde mussels are cultivated in shallow permanently submerged plots. These man-made and managed cultivation plots are considered to be (a separate) eco-element, as here mussels often are present for a long time (over a year). Since 1965 the Pacific oyster (*Crassostrea gigas*) has been cultivated in the Oosterschelde. Since the 1990s the species has been spreading explosively in the wild. The species currently is present, apart from in the Oosterschelde, very commonly in the western part of the Westerschelde and in the Grevelingenmeer, and is spreading considerably in the Wadden Sea and the Ems (Source: www.waddenzee.nl). Generally, an oyster plot is a considerable monoculture, but in principle algae may attach to oysters, such as *Polysiphonia nigra*, Irish moss (*Chondrus crispus*), wireweed (*Sargassum muticum*), *Ceramium rubrum*, *Hypoglossum hypoglossoides*, *Bryopsis plumosa*, *Codium fragile* and sea lettuce (*Ulva* sp.). Sponges may be present on the layer of oysters as well, such as *Cliona celata* and Mermaid's glove (*Haliclona oculata*), and anemones (e.g. *Diadumene cincta*, *Sagartia troglodytes*, Plumose anemone, *Metridium senile*) and sea squirts (e.g.. leathery sea squirt *Styela clava*, sea squirt *Ciona intestinalis*, *Ascidiella aspersa*).

In addition oyster beds accommodate and supply shelter to mobile fauna such as the common lobster (*Homarus gammarus*), *Macropodia rostrata* and common shore crab (*Carcinus maenas*). Locally, it may be a matter of a highly developed ecological community. although this was only observed in few places (Meijer & Waardenburg, 2002).

We consider shell banks to be an eco-element, as the presence of a shell bank affects largely the occurrence of benthos and as its location is not to be predicted based on environmental factors. Shell banks may occur both in the littoral and the sublittoral zones. We use 80% cover of the sediment with shells as a criterion.
The surface of a shell bank may be flat, but there may also be humps and holes. The shell banks are a form of hard substratum, on which green algae may occur (e.g. *Enteromorpha spp.*, sea lettuce *Ulva spp.*). Between the shells virtually no benthic life is possible. Sessile organisms that are fast-growing

and fast-reproducing (such as ciliates) may occur though on the (empty) shells. The occurrence of a characteristic bryozoans *Electra melolontha* is known of shell banks (pers comm Gerhard Cadee).

Shipwrecks (and other artefacts) such as drilling rigs and production platforms) as they occur on the North Sea bed in particular, are comparable to oases in a desert. Both biodiversity and biomass are considerably higher on and around the wrecks than in and above the bare sands around them. We consider shipwrecks and other artefacts to be eco-elements, because of their structuring characteristics and as their location cannot be predicted based on environmental factors. Shipwrecks are a kind of hard substratum on which all sorts of organisms may settle, such as sponges (e.g. breadcrumb sponge *Halichondria panicea*), anemones (e.g. *Diadumene cincta, Sagartiogeton undatus*, Plumose anemone *Metridium senile*), hydroids (*Tubularia spp.*) and barnacles (*Cirripedia*). In addition, shipwrecks offer accommodation and shelter to mobile organisms such as crustaceans (e.g. edible crab *Cancer pagurus*, velvet swimmer crab *Necora puber*) and fish (e.g. cod *Gadus morhua*, bib *Trisopterus luscus*). Algal growth is impossible due to the great depth of the wrecks in the North Sea (Meijer & Waardenburg, 2002).

Photo 5.2.4 *Shoreline vegetation along brackish lakeshores (Grevelingenmeer)*

Shoreline vegetation along brackish lakeshores. This involves the vegetation in the shallow parts of brackish and variably brackish lakes (photo 5.2.4.) They occur in sheltered parts, for example along old creeks and gullies. Especially sea club-rush (*Scirpus maritimus*) and common reed (*Phragmites australis*) are involved in a zone several metres wide along the shore.
It is unclear to what extent water level regime and/or fresh water seepage from the higher shore plays a part in the occurrence of these vegetations. Other higher plants do not occur in this zone. The vegetation zone may offer space to birds to nest, for example coot and typical reedbirds.

5.3 ECOTOPE-MONDRIAANS

Westerschelde

The Westerschelde is an estuary (Scheldt-estuary), where the river water of the river Scheldt (Belgium) discharges into the North Sea. It causes a gradient in salinity from brackish in the eastern part to saline in the western part of the Westerschelde.

Typical of the Westerschelde are the large tidal differences to Dutch standards, the high current velocities and high water turbidity. Primary production and system mean benthos biomass are low in the Westerschelde with respect to water bodies like the Oosterschelde, the Grevelingenmeer and the Veerse Meer (Herman et al, 1999). Detailed information on physical and chemical characteristics of the Westerschelde can be found in the ScheldeAtlas (Van Eck, 1999. http://www.scheldenet.nl/?url=/nl/natuur2/atlas/).

Figure 5.3.1 shows the ecotope-mondriaan for the Westerschelde. From east to west brackish, variably brackish/saline and saline ecotopes occur respectively in the Westerschelde. In all three saline classes 'the same' ecotopes are present. Hard substrata are present sublittoral, littoral and supralittoral zones, in which the sublittoral and littoral stone/wood are subdivided into high-energy and low-energy parts. Both in the sublittoral and the littoral zones consolidated peat layers are present in the Westerschelde, which are high-energy ecotopes by definition.

We only discern beds rich in silt or fine sands for the high-energy sublittoral and littoral sediments. The low-energy sublittoral and littoral sediments are primarily subdivided after depth/height (shallow or deep; low, middle high or high), and subsequently after sediment composition as well (rich in silt or fine sands). Sediment ecotopes in the supralittoral zone are beaches and salt marshes, in which salt marshes are further subdivided into pioneer zone, low salt marsh, middle high salt marsh, high salt marsh and very high salt marsh. The eco-elements gully (littoral zone), sea grass beds (middle high and high littoral zones), shell bank (sublittoral and littoral zones) and shipwreck (sublittoral zones) may occur here.

Ems-Dollard

The Ems-Dollard is the estuary (Ems-estuary), in which the river water of the river Ems (Germany) discharges in the Wadden Sea. The Dollard is the (brackish) southeastern part, the Ems the (variably brackish/saline) northwestern part. The tidal difference is smaller than in the Westerschelde, but the Ems-Dollard likewise has high water turbidity. Primary production and system mean benthic biomass in the Ems-Dollard are comparable with the Westerschelde (Herman et al., 1999).

Figure 5.3.1 shows the ecotope-mondriaan for the Ems-Dollard. Only the salinity classes 'brackish' and 'variably brackish/saline' occur in the Ems-Dollard. The part in which the salinity class 'saline' is present is included in the Wadden Sea. In either salinity class hard substrata (stone/wood) are present in both the sublittoral and the littoral zones, subdivided into high-energy and low energy. Hard substratum in the supralittoral zone is probably only present in the brackish part. We do not know of any consolidated peat layers being present in the Ems-Dollard.

We do not subdivide any further after sediment composition for the high-energy sublittoral and littoral sediments, as high-energy beds that are rich in silt do not occur in the Ems-Dollard. All high-energy sublittoral and littoral sediments consist of fine sands (median grain size < 250 μm). The low-energy sublittoral and littoral sediments are subdivided primarily after depth/height (shallow or deep; low, middle high or high), and subsequently after sediment composition (rich in silt or fine sands). Sediment ecotopes in the supralittoral zones are salt marshes, which are further subdivided into pioneer zone, low salt marsh, middle high salt marsh and high salt marsh. No beaches occur in the Ems-Dollard. The eco-elements gully (littoral zone), sea grass beds (middle high and high littoral zones), Ruppia-association (littoral zone), mussel bed (variably brackish/saline, low and middle high littoral zones) and shell banks (sublittoral and littoral zones) may occur here.

Noordrand

The area of the Noordrand comprises the New Water Way, the Calandkanaal, Beerkanaal and Hartelkanaal (canals); the Nieuwe and Oude Maas are borderline cases. The Noordrand forms an open connection between the river area of the rivers Rhine and Meuse and the North Sea. Therefore, from east to west a salinity gradient is present from fresh to saline. The watercourses in the area of the Noordrand consist mainly of high-energy shipping channels. Hardly any emerging intertidal areas are present, except for some sheltered locations along the edges.

Figure 5.3.1 shows the ecotope-mondriaan for the Noordrand. Only the salinity classes brackish and variably brackish/saline occur in the area. In both saline classes 'the same' ecotopes are present. Hard substrata (stone/wood) are present in both sublittoral, littoral and supralittoral zones, in which the sublittoral and littoral stone/wood are subdivided into high energy and low energy. We do not know of any consolidated peat layers being present In the Noordrand.

We do not subdivide the high-energy sublittoral sediments any further as the sediment composition in the Noordrand is fine sands (median grain size < 250 μm) everywhere. The low-energy sublittoral sediments are primarily subdivided after depth (shallow or deep), and subsequently after sediment composition as well (rich in silt or fine sands). The low-energy (everywhere) littoral zone is subdivided after height (low, middle high, high). No areas that are rich in silt are known in the littoral of the Noordrand. Sediment ecotopes in the supralittoral zone are salt marshes, which are further subdivided into pioneer zone, low salt marsh, middle high salt marsh and high salt marsh. Beaches are not present in the Noordrand and neither are eco-elements.

Wadden Sea

The Wadden Sea is a mainly saline intertidal area, although locally very variably brackish/saline sites occur near for instance outlet sluices. De Boer and Wolff (1996) mapped such sites in the Wadden Sea. A considerable acreage of emerging tidal flats is present in the Wadden Sea. Submerged beds in the Wadden Sea are shallow (< 5 m), except for the deeper tidal channels. The Wadden Sea is one of the most important foraging areas for (migrating) birds in the northwest of Europe.

Figure 5.3.2 shows the ecotope-mondriaan for the Wadden Sea. The salinity classes saline and variably brackish/saline are present in the Wadden Sea. Low-energy hard substrata (stone/wood) are present in sublittoral, littoral and supralittoral zones. As far as we know there are no consolidated peat layers in the Wadden Sea.

We do not subdivide the high-energy sublittoral and littoral sediments any further as these consist of fine sands (median grain size < 250 μm) all over the Wadden Sea. The low-energy sublittoral and littoral sediments are primarily subdivided after depth/height (shallow or deep; low, middle high or high) and subsequently after sediment composition (rich in silt or fine sands). Sediment ecotopes in the supralittoral zone are beaches and salt marshes, in which salt marshes are further subdivided into pioneer zone, low salt marsh, middle high salt marsh and high salt marsh. The eco-elements gully (littoral zone), sea grass beds (middle high and high littoral zones), Ruppia-association (littoral zone) mussel bed (low and middle high littoral zones) oyster bed (low and middle high littoral zones) and shell banks (sublittoral and littoral zones) may occur here.

Oosterschelde

On the eastside the Oesterdam, the Philipsdam and the Grevelingendam close off the Oosterschelde from other waters. On the westside the Oosterschelde storm surge barrier was constructed on behalf of safety. The construction of these dams and the barrier made current velocities lower than before. A reasonably large acreage of emerging tidal flats is present. The clarity of the water for the larger part of the year is considerably better than in other Dutch water systems. It causes more extensive algal communities and more hard-substratum species to occur.

Figure 5.3.2 shows the ecotope-mondriaan for the Oosterschelde. Only the salinity class saline is present. Low-energy hard substrata (stone/wood) are present in sublittoral, littoral and supralittoral zones. Consolidated peat layers (both high and low energy) occur in the littoral and sublittoral zones.

We do not subdivide the high-energy sublittoral and littoral sediments any further after sediment composition as these are fine sands (median grain size < 250 μm) all over the Oosterschelde. The low-energy sublittoral sediments are primarily subdivided after depth (shallow or deep), and subsequently after sediment composition as well (rich in silt or fine sands). The low-energy littoral sediments are subdivided after height (low, middle high, high). There is no littoral zone rich in silt present in the Oosterschelde, the sediment consists of fine sands everywhere. Sediment ecotopes in the supralittoral zone are beaches and salt marshes, in which salt marshes are further subdivided into pioneer zone, low salt marsh, middle high salt marsh, and high salt marsh. The eco-elements gully (littoral zone), sea grass beds (middle high and high littoral zones), mussel bed (low and middle high littoral zones), oyster bed (low and middle high littoral zones), shell banks (sublittoral and littoral zones) and shipwreck may occur here.

North Sea

A number of specific areas based on depth and sediment composition may be indicated in the North Sea (Dutch Continental Shelf). Examples are the shallow coastal zone (with the 20 m-isobath as a boundary), the Dogger bank in the north part of the DCS (20-30 metres deep, fine sands), the Oyster grounds and the Frisian Front in the central part of the DCS (beds rich in silt and deeper than 30 metres), and the Cleaver banks (gravel bed deeper than 30 metres).

Figure 5.3.2 shows the ecotope-mondriaan for the North Sea. In addition to saline ecotopes, variably brackish/saline ecotopes occur at places where rivers are discharging into the sea. Hard substratum ecotopes (stone/wood) occur in the sublittoral, littoral and supralittoral zones, in which for the sublittoral and littoral hard substrata we discern high and low energy.

We do not subdivide the high-energy sublittoral and littoral sediments (surf zone and parts of the beaches that are daily flooded) any further after depth (secondary to hydrodynamics) or after sediment composition (fine sands, median grain size < 250 µm). The low-energy sublittoral sediments are primarily subdivided after depth (shallow MLW -20 m, deep 20-30m or very deep > 30 m). In de North Sea the class boundaries for depth differ from those in the other water systems. In addition, we discern based on sediment composition (rich in silt, fine sand, coarse sand or gravel), in which gravel beds do not occur in variably brackish/saline areas and not in saline (shallow and) deep areas. The low-energy littoral sediments (emerging tidal flats, for instance in the Voordelta) are subdivided after height (low, middle high, high). In addition, the sediment may consist of fine sands, coarse sands or be rich in silt. The sediment ecotopes in the supralittoral zone are beaches and salt marshes that are present on the North Sea-sides of the Wadden Islands. We subdivide salt marshes further into pioneer zone, low salt marsh, middle high salt marsh, high salt marsh and very high salt marsh. The eco-elements gully (littoral zone), shell bank (sublittoral and littoral zones) and shipwreck (sublittoral zone) may occur here.

Grevelingenmeer

The Grevelingenmeer was until about thirty years ago an estuary. To protect the surrounding area against flooding the Grevelingendam was constructed at the eastside of the area in 1965 and at the westside the Brouwersdam in 1971. This formed a tideless saline lake, slowly getting fresher.

Due to the closing off of the tide a large part of the tidal flats and salt marshes and a number of sand flats permanently emerged (Nienhuis, 1975). The Slikken van Flakkee and the Slikken van Bommenede are examples.

As the lake getting fresher had negative consequences for the marine flora and fauna, the Brouwerssluis was constructed in 1978. This restored the connection with the North Sea. Currently the sluice is open virtually all year round. The water has become more saline again and many marine animals have returned gradually causing an underwater world with a high biodiversity.

Figure 5.3.3 shows the ecotope-mondriaan for the Grevelingenmeer. The part of ZES.1 comprising stagnant saline waters applies to the Grevelingenmeer. The ecotopes are specific to the Grevelingenmeer, as this is the only stagnant saline water, which ZES.1 includes. As no tidal difference is present, no littoral ecotopes are present. We discern in the sublittoral zone very deep, deep and shallow beds. The hard substrata consist of stone/wood or peat. In the supralittoral zone a subdivision is made between shores with close brackish vegetation, close saline vegetation or open saline vegetation. In addition, the supralittoral hard substratum is a separate ecotope (lichens). In the sublittoral sediment ecotopes the eco-elements sea grass beds (shallow), oyster bed, shell bank and shipwreck may be present.

Veerse Meer

The Veerse Meer is a lake formed by dams with stagnant, meanwhile brackish water. To the eastside of the Veerse Meer the Zandkreekdam is present, to the westside the Veerse Dam. The water level is controlled via the Zandkreeksluis and is kept lower in winter than in summer, with respect to the drainage of the surrounding lands. In spring the water column is often stratified (salinity stratification) due to poor mixing. In combination with the settling of organic material (for instance mortality of algal blooms), anoxic conditions near the bed may occur, causing massive mortality of benthos.

Figure 5.3.3 shows the ecotope-mondriaan for the Veerse Meer. The part of ZES.1 comprising stagnant brackish waters applies to the Veerse Meer. The ecotopes are specific to the Veerse Meer, as this is the only stagnant brackish water that ZES.1 includes. As no tidal difference is present, no littoral ecotopes are present. We discern in the sublittoral very deep, deep and shallow beds. The hard substrata consist of stone/wood, to our knowledge no consolidated peat layers are present. In the supralittoral zone a subdivision is made between shores with close brackish vegetation and close saline vegetation and the supralittoral hard substratum is a separate ecotope (lichens). In the sublittoral sediment ecotopes the eco-elements sea grass beds (shallow), Ruppia-association (shallow) and shipwreck may be present.

Kanaal door Zuid-Beveland

Figure 5.3.3 shows the ecotope-mondriaan for the Kanaal door Zuid-Beveland (canal). Only variably brackish/saline ecotopes occur here. Tidal movement is present in the canal. Hard substrata in the form of stone and wood are present in the sublittoral, littoral and supralittoral zones. Al hard substrata are low energy. No consolidated peat layers are present. The low-energy sublittoral sediments are subdivided after depth (shallow or deep), and subsequently after sediment composition (rich in silt or fine sands). We do not discern sediment ecotopes in the littoral and supralittoral zones.

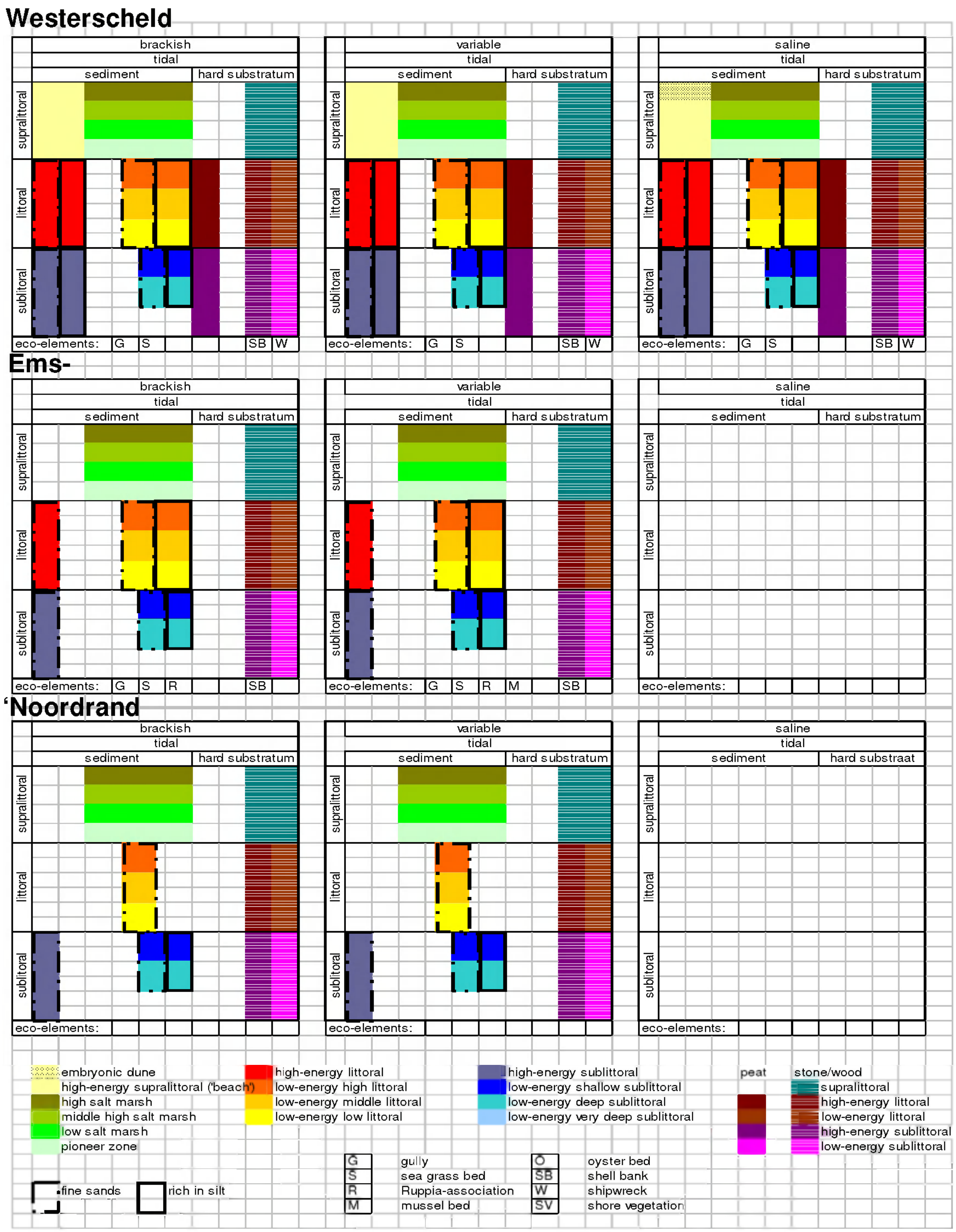

Figure 5.3.1 *The ecotope-mondriaans for the Westerschelde, Ems-Dollard and the Noordrand (New Water way, Caland-, Beer- and Hartelkanalen and the Nieuwe and Oude Maas). Empty field: ecotopes not present in this area.*

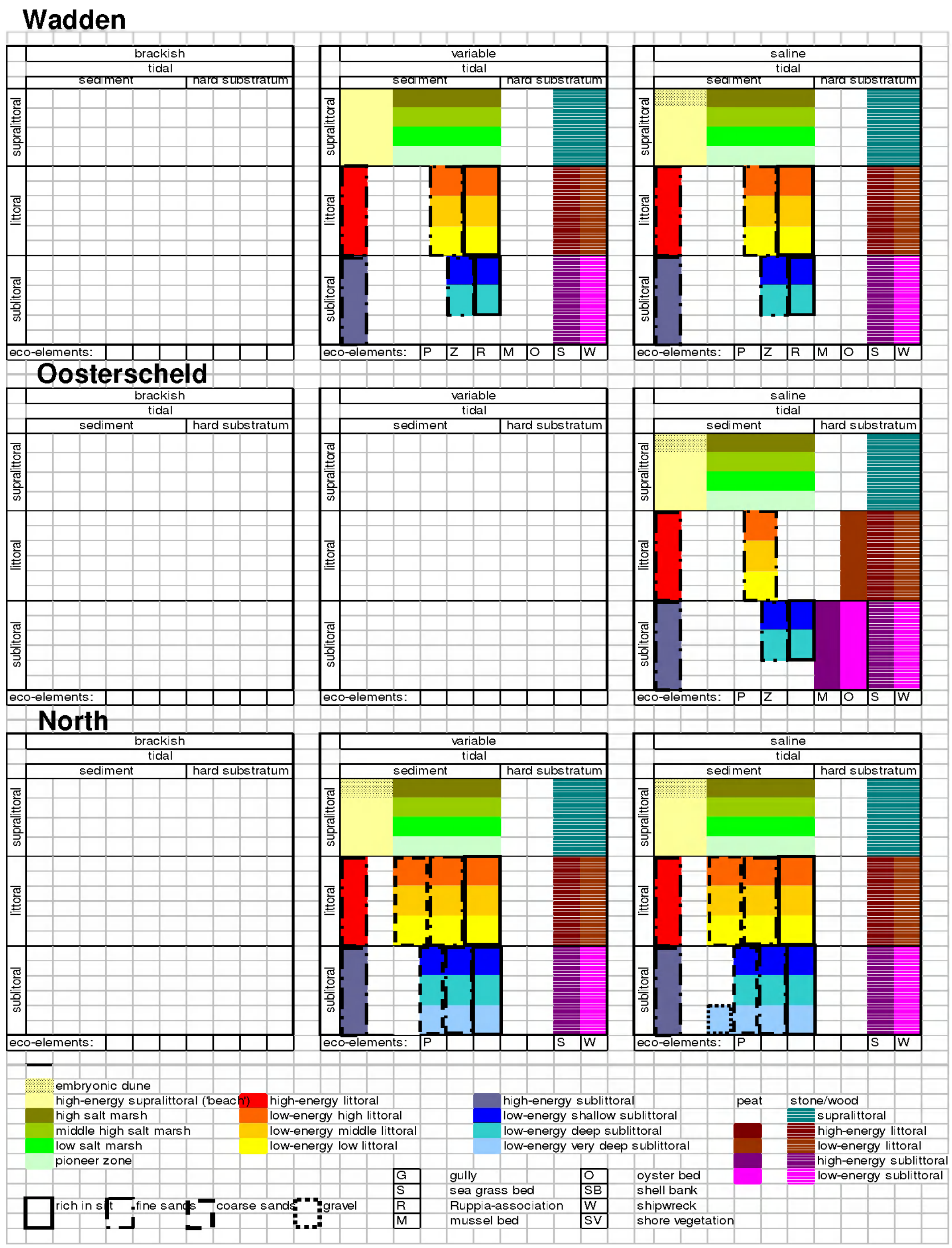

Figure 5.3.2 *The ecotope-mondriaans for the Wadden Sea and the Oosterschelde and the North Sea .*

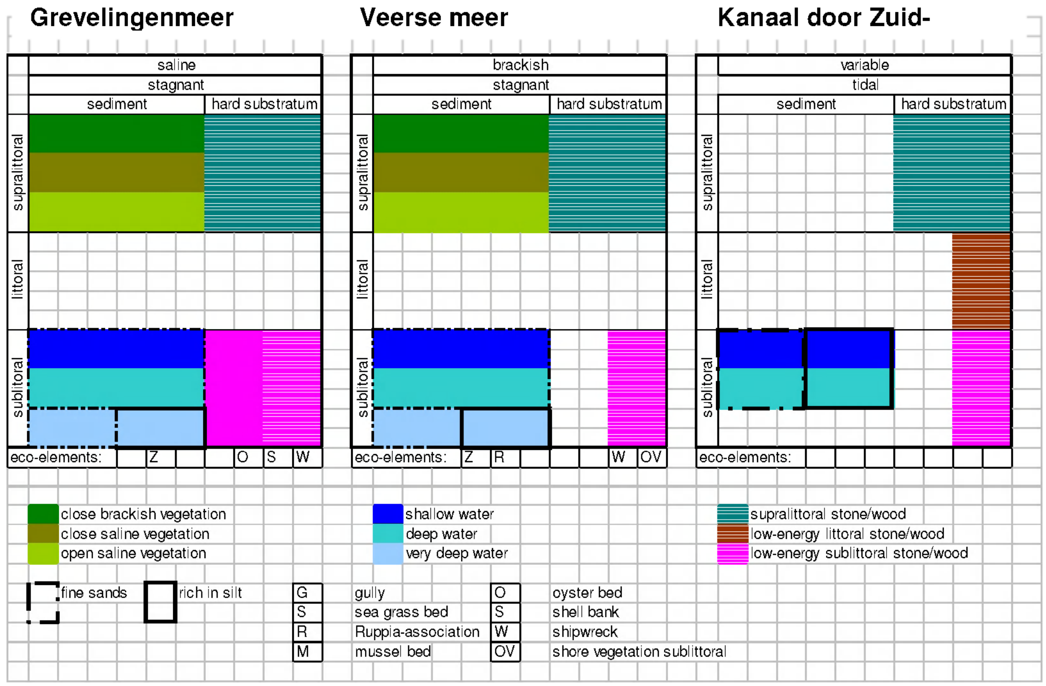

Figure 5.3.3. *The ecotope-mondriaans for the Grevelingenmeer, the Veerse Meer and the Kanaal door Zuid-Beveland.*

6 THE ECOTOPES' ECOLOGICAL CONTENTS

6.1 GENERAL

In sections 6.2 up to and including 6.5 we describe the ecotopes' ecological contents. In section 6.2 we deal with the ecotopes occurring in the Westerschelde, Ems-Dollard, Wadden Sea, Oosterschelde and New Water Way. The description of the ecotopes in these water systems is combined into one section, as the water systems show many overlaps in the occurrence of ecotopes (see their ecotope-mondriaans as well in section 5.4). The ecotopes in the North Sea are dealt with in a separate section (section 6.3), as in the North Sea ecotopes are present that do not occur in other water systems. The ecotopes in the Grevelingenmeer and the Veerse Meer as well are dealt with in separate sections (6.4 and 6.5 respectively), as specific parts (saline and brackish stagnant waters respectively) of the ecotope system apply to these water systems.

We describe the ecotopes' potential ecological contents by first giving a general description and subsequently listing the generally occurring species per group (algae, sponges, worms etc.) in tables. We indicate in them which species are target species in the ANF nature policy (Min. of Agriculture, Nature Management and Food security), which species are on the national Red List and which species apply to the EU Habitats and Bird Directives. We indicate in the tables as well the potential occurrence of the various eco-elements. In appendix 3 we supply a description of the ecological communities that may occur on hard substrata in the littoral zone (after Meijer & Waardenburg, 2002). Ecotopes with a very variable salinity are included for the time being in the brackish ecotopes with regard to the description of their ecological contents.

The sources we used mainly in describing the species per ecotope are (per subject and in alphabetical order):

hard substratum	Meijer & Waardenburg (2002)
sediment	Craeymeersch (1999) (Westerschelde, North Sea)
	Dankers et al. (2001) (saline)
	De Boer & Wolff (1996; brackish)
	Dekker & De Bruin (2000; Wadden Sea, Ems-Dollard)
	Essink et al. (1998)
	Gittenberger & Janssen (1998; fresh water molluscs)
	Holtmann et al. (1996; North Sea)
	Kranenbarg & Backx (2001)
	Meire et al. (1991) (Westerschelde, Oosterschelde)
	Paalvast (1999) (estuarine organisms)
	Vos & Wolff (2001) (brackish)
	Ysebaert (2000) (Westerschelde, Oosterschelde, Ems-Dollard)
fish and shrimps	Elliott & Hemingway (2002)
	Hostens et al. (1996)
	Nijssen & De Groot (1987)
birds	Berrevoets et al. (2002)
marine mammals	Dankers et al. (2001)
general	Campbell (1994)
species information	Hayward et al. (1999)

6.2 WESTERSCHELDE, EMS-DOLLARD, NEW WATER WAY, WADDEN SEA AND OOSTERSCHELDE

6.2.1 Ecotopes of the hard substratum in the sublittoral zone

High-energy sublittoral consolidated peat layer in brackish or variably brackish/saline water
The ecotope occurs in the eastern part of the Westerschelde at least. Here, permanently submerged consolidated peat layers are present in a high-energy environment. Energy is high because of high current velocities. This makes algal growth (virtually) impossible. We hardly know anything about the occurrence of organisms on the permanently submerged consolidated peat layers in the eastern part of the Westerschelde. Most probably, the flora and fauna will be poor in species due to both high

energy and the brackish or variably brackish/saline water. Typical species of consolidated peat layers are piddocks (*Petricola pholadiformis*, *Barnea candida*, *Zirfaea crispata*) that may burrow into the peat. It is not clear, however, to what extent these species are able to tolerate low salinities (table 6.2.1).

Low-energy sublittoral stone/wood in brackish or variably brackish/saline water
This low-energy brackish or variably brackish/saline ecotope comprises the permanently submerged substratum on the shores/edges like those in the eastern part of the Westerschelde, the Ems-Dollard and the New Water Way and locally as well in the Wadden Sea. The hard substratum mainly consists of (permanently submerged parts of) pitchings, jetties and groynes. The number of species is lower than in its saline version. As visibility in the Dutch brackish (parts of) water systems is poor, algal growth is only possible in the upper tens of centimetres of the sublittoral zone. Organisms that may be present in the ecotope are purple laver (*Porphyra umbilicalis*), hydroids, anemones, common shore crabs, barnacles and sea squirts (e.g. *Molgula manhattensis*). The presence or absence of organisms such as anemones and sea squirts however, depends strongly on local conditions, such as water turbidity. Sites with even lower energy still may occur in the ecotope, like in little ports and along the lee sides of the groynes. Because of the incidental character of such sheltered sites, we do not consider them to be a separate ecotope.

High-energy sublittoral consolidated peat layer in saline water
The ecotope occurs in the western part of the Westerschelde and in the basin (southeast part) of the Oosterschelde. Energy is high because of high current velocities. This makes algal growth (virtually) impossible. We know little about the presence of organisms in these permanently submerged consolidated peat layers. Most probably its flora and fauna will be poor in species because of high-energy conditions. Species that are typical have consolidated peat layers and will probably hold their own in high-energy conditions are the American piddock (*Petricola pholadiformis*), white piddock (*Barnea candida*) and the great piddock (*Zirfaea crispata*) that have burrowed in the peat.

Low-energy sublittoral stone/wood in saline water
This low-energy saline ecotope comprises the permanently submerged hard substrata along the shores/edges of the Wadden Sea, Oosterschelde and the western part of the Westerschelde, and locally as well along the North Sea coast (sheltered locations, see section 6.3). The hard substratum mainly consists of (permanently submerged parts of) pitchings, jetties and groynes. The number of species is higher than in its brackish and variably brackish/saline version. As visibility in most Dutch water systems is poor, algal growth in general is only possible in the upper tens of centimetres of the sublittoral zone. The presence of organisms such as anemones and sea squirts strongly depends on water turbidity likewise. In the Oosterschelde the water is generally considerably clearer and algae have been found to a depth of about five metres below the low water mark (Van Geldere & Vanalderweireldt, 1995). In addition to algae, sponges, hydroids, anemones, crustaceans (e.g. common lobster *Homarus gammarus*, common shore crab *Carcinus maenas*, barnacles *Cirripedia*), sea squirt, star fish and fish (e.g. butterfish *Pholis gunnellus*, tadpole fish *Raniceps raninus*) are living in the ecotope. The Pacific oyster-community (*Crassostrea gigas*) may occur in the ecotope as well (see appendix 4). Sites with even lower energy still may occur in the ecotope, like in little ports and along the lee sides of the groynes. Because of the very local character of such sheltered sites, we do not consider them to be a separate ecotope.

Low-energy sublittoral consolidated peat layer in saline water
The ecotope occurs in the basin of the Oosterschelde. The peat offers adequate grip to most algae and sessile benthos that occur on other hard substrata as well.
Algae that are present on the consolidated peat layers are e.g. *Bryopsis plumosa* and sea lettuce (*Ulva lactuca*). Sponges and anemones are present on the peat as well. The overhanging grotto-like structures offer accommodation and shelter to animals such as crustaceans and fish (e.g. tadpole fish *Raniceps raninus*, sea bass *Dicentrarchus labrax*) (Meijer & Waardenburg, 2002). Typical species of consolidated peat layers are piddocks (*Petricola pholadiformis*).

The ecotopes **high-energy sublittoral stone/wood** are poor forms of the loe-energy types.

ECOTOPES OF THE SUB-LITTORAL HARD SUBSTRATUM		High-energy consolidated peat layer (brackish or variably brackish/saline)	Low-energy stone/wood (brackish or variably brackish/saline)	High-energy consolidated peat layer (saline)	Low-energy stone/wood (saline)	Low-energy consolidated peat layer (saline)	
GROUPS	SPECIES						
algae	*Polysiphonia nigra*				x	x	
	Irish moss *(Chondrus crispus)*				x	x	
	Ceramium rubrum				x	x	
	Purple laver *(Porphyra umbilicalis)*		x		x	x	
	Hypoglossum hypoglossoides				x	x	
	Bryopsis plumose				x	x	
	Sea lettuce *(Ulva lactuca)*				x	x	
sponges	Breadcrumb sponge *(Halichondria panicea)*				x	x	
	Mermaid's glove *(Haliclona oculata)*				x	x	
hydroids	*Campanulariidae*		x		x	x	
	Common flowerhead *(Tubularia larynx)*				x	x	
	Herringbone hydroid *(Halecium halecium)*				x	x	
	Hydractinea echinata				x	x	
	Sertulariidae				x	x	
	Tubularia spp.		x		x	x	
anemones	*Diadumene cincta*		x		x	x	
	Red sea anemone *(Actinea equina)*		x		x	x	
	Sagartia troglodytes		x		x	x	
	Sagartiogeton undatus				x	x	
	Plumose anemone *(Metridium senile)*				x	x	
	Dahlia anemone *(Urticina felina)*		x		x	x	
molluscs	American piddock *(Petricola pholadiformis)*	x		x		x	
	Pacific oyster *(Crassostrea gigas)*				x		
	Slipper limpet *(Crepidula fornicata)*		x		x		
	Great piddock *(Zirfaea crispata)*	x		x		x	
	White piddock *(Barnea candida)*	x		x		x	
crustaceans	Common lobster *(Homarus gammarus)*				x	x	
	Caprella linearis				x	x	
	Common shore crab *(Carcinus maenas)*		x		x	x	
	Gammaridae	x					
	Barnacles *(Cirripedia)*		x		x	x	
bryozoans	*Electra pilosa*				x	x	
echinodermata	Common star fish *(Asterias rubens)*				x	x	
ascidiacea	*Molgula manhattensis*		x		x	x	
fish	Butterfish *(Pholis gunnellus)*				x	x	TS, RL
	Common eel *(Anguilla anguilla)*		x		x	x	
	Tadpole fish *(Raniceps raninus)*				x	x	TS, RL
	Sea bass *(Dicentrarchus labrax)*				x	x	
	Bull rout *(Myoxocephalus scorpius)*				x	x	

Table 6.2.1. *List of species of the ecotopes of the hard substratum in the sublittoral zone.*
TS = target species Min. ANF; RL = species listed in national Red List (both from Bal et al., 2001).

6.2.2 Ecotopes of the hard substratum in the littoral and supralittoral zones

High-energy littoral consolidated peat layer in brackish or variably brackish/saline water
The ecotope comprises emerging consolidated peat layers in brackish or variably brackish/saline water. Emerging consolidated peat layers are known to occur but in the Westerschelde. We know little about the flora and fauna that occurs on consolidated peat layers. Typical species of consolidated peat layers are piddocks (*Petricola pholadiformis*, *Barnea candida*, *Zirfaea crispata*)

that may burrow into the peat it is not clear however, to what extent these species are able to tolerate low salinities. Little algal growth is possible in high-energy conditions. Pioneer species such as *Enteromorpha spp.* may possibly occur.

Low-energy littoral stone/wood in brackish or variably brackish/saline water
The ecotope comprises the emerging hard substratum like along the shores/edges of the eastern part of the Westerschelde, the Ems-Dollard and the New Water Way. Wave dynamics are considerably lower than along the North Sea coast due to the shorter fetch. The variably brackish/saline version of the ecotope locally occurs in the Wadden Sea and in the North Sea (see section 6.3). The hard substratum consists mainly of pitchings (photo 6.2.1), jetties and groynes. Its ecological content resembles the saline version of the ecotope, but the number of ecological communities and the number of species in particular is more limited. In addition to salinity, the characteristics of the hard substratum (such as water retaining capacity) and other local environmental factors (visibility, sedimentation) strongly affect the number of communities and species. The ecological communities that are often observed in this ecotope are those of the barnacles-periwinkles (*Cirripedia-Littorinidae*), *Blidingia minima, Enteromorpha sp.* and bladder wrack (*Fucus vesiculosus*) (see appendix 3). When a channel or shallow is present in front of the hard substratum, the substratum lies between the mean low water mark and the mean low water mark at spring tide (see appendix 3). We call this zone the infralittoral margin. In brackish water only a limited number of small algal species occur on the infralittoral margin with respect to saline water. When in front of the pitching a tidal flat or salt marsh is present, then the infralittoral margin is not present (see appendix 3) and these small algal species neither. The bladder wrack (*Fucus vesiculosus*) -community is at the most marginally present and is mostly completely absent. Emerging hard substratum at very sheltered sites, such as ports, are included in this ecotope as well.

Photo 6.2.1 *Low-energy littoral hard substratum. An emerged pitching with a zone of green algae and below it a zone of brown algae.*

High-energy littoral consolidated peat layer in saline water
Emerging consolidated peat layers in saline water are comprised in this ecotope (photo 6.2.2). As far as we know they only occur in the Westerschelde. We know little about the flora and fauna present on these consolidated peat layers. Species that are typical of consolidated peat layers and that will probably hold their own in high-energy conditions are the American piddock (*Petricola pholadiformis*), white piddock (*Barnea candida*) and the great piddock (*Zirfaea crispata*) that have burrowed in the peat. Little algal growth is possible in high-energy conditions. Pioneer species such as *Enteromorpha spp.* may possibly occur.

Photo 6.2.2 *.A littoral consolidated peat layer in the Westerschelde.*

Low-energy littoral stone/wood in saline water
The ecotope occurs along the shores/edges like those of the Wadden Sea and the Oosterschelde. Wave dynamics are considerably lower than along the North Sea coast due to a shorter fetch. The hard substratum consists mainly of pitchings, jetties and groynes. The number of ecological communities and the number of species in particular is considerably higher than in brackish water. In addition to salinity, the characteristics of the hard substratum (such as water retaining capacity) and other local environmental factors (visibility, sedimentation) strongly affect the number of communities and species. In the current situation, conditions in the Oosterschelde are such that here communities of high biodiversity may develop. The ecological communities that may occur in the ecotope are those of the barnacles-periwinkles (*Cirripedia-Littorinidae*), *Blidingia minima*, *Enteromorpha sp., Fucus spiralis,* bladder wrack (*Fucus vesiculosus*) and *Fucus serratus*. The Pacific oyster-community (*Crassostrea gigas*) may occur in the ecotope as well. In the high part of the tidal zone in the Oosterschelde sometimes the channelled wrack community (*Pelvetia canaliculata*) is found (see appendix 3). When a channel or shallow is present in front of the hard substratum, the substratum lies between the mean low water mark and the mean low water mark at spring tide (see appendix 3). We call this zone the infralittoral margin. Various small green, brown and red algae may occur on the infralittoral margin. When in front of the pitching a tidal flat or salt marsh is present, then the infralittoral margin is not present (see appendix 3) these small algal species will not be present and the bladder wrack-community (*Fucus vesiculosus*) mostly is completely absent. The hard substratum that is situated very sheltered, like in little ports, is included in this ecotope. In such sheltered sites often a broad zone with the knotted wrack-community (*Ascophyllum nodosum*) is present.

Stone above the high water mark
Both along brackish and saline waters a typical yellow-coloured lichens-community is present on hard substratum above the high water mark (photo 6.2.3). This community may be grey or black as well. The lichen-community can usually be found on all hard substrata that are present above the watermark. The greater part of the lichens belongs to the genera *Caloplaca* and *Xanthoria*, which are yellow. In addition, species of the genera *Verrucaria* and *Lecanora* occur that are black and grey respectively. Next to lichens hardly any other species is present in the community. Sometimes we find on the lower edge of the zone *Blidingia minima*, the barnacle *Elminius modestus*; rough periwinkle (*Littorina saxatilis*), *Ligia oceanica* and the springtail *Lipura maritima*. Below the lichen-community, a community of cyanobacteria *Entophysalis deusta* may be present as a black band-like zone, which consists mainly of this single cyanobacterium (Nienhuis, 1976). In spring the green-algae community of *Prasiola stipitata* may occur at virtually the same height (Den Hartog, 1959).

Photo 6.2.3 *Hard substratum (stone) above the high water mark with typical lichens.*

Low-energy littoral consolidated peat layer in saline water
Emerging consolidated peat layers in the Oosterschelde are comprised in this ecotope. It concerns an ecotope that has been increasing in the past few years, due to the hunger for sand in the Oosterschelde, causing the sediment on top of the consolidated peat layers to be slowly transported to the channels. Little is known yet about the ecological community on it. Important species will be most probably mainly piddocks and green algae and perhaps periwinkles on the algae.

The ecotopes **high-energy (supra)littoral stone/wood** are poor forms of the low-energy types.

ECOTOPES OF THE LITTORAL AND SUPRALITTORAL HARD SUBSTRATUM COMMUNITIES (roughly from high to low in the tidal zone)	High-energy consolidated peat layer of the littoral zone (brackish or variable	Low-energy stone/wood of the littoral zone (brackish or variable brackish/saline)	High-energy consolidated peat layer of the littoral zone (saline)	Low-energy stone/wood of the littoral zone (saline)	Stone above the high water mark	Low-energy consolidated peat layer (saline)	
Lichens-community *(Lichenes)*					x		
Cyanobacteria-community *(Entophysalis deusta)*					x		
Channelled wrack-community *(Pelvetia canaliculata)*				x			Oosterschelde
Blidingia minima-community	x	x	x	x		x	
Barnacle-periwinkle-community *(Cirripedia-Littorinidae)*		x		x			
Enteromorpha- community *(Enteromorpha compressa, E. intestinalis)*	x	x	x	x		x	
Spiral wrack –community *(Fucus spiralis)*				x			
Bladder wrack-community *(Fucus vesiculosus)*		x		x			
Toothed wrack-community *(Fucus serratus)*				x			
Knotted wrack-community *(Ascophyllum nodosum)*				x			
Mussel-community poor in species *(Mytilus edulis)*							
Barnacle-periwinkle-Pacific oyster-community						x	
Pacific oyster –community (*Crassostrea gigas)*				x		x	
American piddock *(Petricola pholadiformis)*	x		x			x	
Great piddock *(Zirfaea crispata)*	x		x			x	
White piddock *(Barnea candida)*	x		x			x	

Table 6.2.2. *The ecological communities of the littoral hard substratum (after Meijer & Waardenburg, 2002).*

6.2.3 Ecotopes of sediments in the brackish and variably brackish/saline sublittoral zone

High-energy sublittoral fine sands in brackish or variably brackish/saline water
This ecotope comprises the tidal channels in the eastern part of the Westerschelde and in the Dollard and the shipping channel in the New Water Way. Energy is high in this sublittoral ecotope because of high linear current velocities. The ecotope is not subdivided any further after depth, as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms. We distinguish between this ecotope and its version that is rich in silt, because of the cohesive characteristics of a bed rich in silt. A strong current will stir a sandy bed more quickly. The bed of the tidal channels is moving constantly up to a certain depth due to high current velocities. There are but few benthic animals that can hold their own in such conditions. Benthic density, biomass and biodiversity all are very low (table 6.2.3). Typical species are the speckled sea louse (*Eurydice pulchra*), the sand digger shrimp (*Bathyporeia sp.*) and the amphipod *Haustorius arenarius* (Ysebaert, 2000). The sublittoral zone in the eastern part of the Westerschelde is important for the growing up of various juvenile (flat) fish (Hostens et al., 1996).

High-energy sublittoral bed rich in silt in brackish or variably brackish/saline water
This ecotope occurs in the Westerschelde at least and probably in the Ems-Dollard as well. Energy is high in this sublittoral ecotope because of high linear current velocities. The ecotope is not subdivided any further after depth, as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms. We distinguish between this ecotope and its sandy version, because of the cohesive characteristics of a bed rich in silt, due to which it starts to move less quickly. Benthic density, biomass and biodiversity all are relatively low due to the high-energy conditions, but are higher than in the sandy version of this ecotope. Benthic species that are able to hold their own in this ecotope are the worm *Polydora ligerica*, the capetellid thread worm (*Heteromastus filiformis*), the clam worm (*Nereis sp.*) and the mud shrimp (*Corophium volutator*). The sublittoral zone in the eastern part of the Westerschelde is important for the growing up of various juvenile (flat) fish (Hostens et al., 1996).

Low-energy deep beds rich in silt in brackish or variably brackish/saline water
The ecotope occurs in the eastern parts of the Westerschelde and in the Ems-Dollard. The bed is below five metres below the low water mark. Energy is low in this sublittoral ecotope because of low current velocities. At very low current velocities and strong consolidation of the silt it is possible that just below the sediment surface anoxic sediments form. Biodiversity is lower than in its saline version. Examples of benthic species that prefer sediments rich in silt are the mud shrimp (*Corophium volutator*) and the clam worm (*Nereis sp.*). Oligochaetes may form an important group qua densities in this ecotope. Typical species of the brackish waters are the worm *Polydora ligerica* and the Atlantic ditch shrimp (*Palaemonetes varians*). The bivalve Baltic tellin (*Macoma balthica*) is able to hold its own in brackish water as well (Ysebaert, 2000).

Low-energy deep fine sands in brackish or variably brackish/saline water
The ecotope occurs in the eastern part of the Westerschelde, in the Ems-Dollard and in the New Water Way. The bed is over five metres below the low water mark. Energy is low in this sublittoral ecotope because of low current velocities. Biodiversity is lower in this ecotope than in its saline version. Examples of benthic species preferring sandy sediments are the sand digger shrimp (*Bathyporeia sp.*) and the brown shrimp (*Crangon crangon*). Typical species of the brackish waters are the worm *Polydora ligerica* and the Atlantic ditch shrimp *Palaemonetes varians*. The bivalve Baltic tellin (*Macoma balthica*) is able to hold its own in brackish waters as well.

Low-energy shallow bed rich in silt in brackish or variably brackish/saline water
The ecotope occurs in the eastern part of the Westerschelde and in the Ems-Dollard. The bed is less than five metres below the low water mark. Energy is low in this sublittoral ecotope because of low current velocities. At very low current velocities and strong consolidation of the silt it is possible that just below the sediment surface anoxic sediments form. Biodiversity in this ecotope is lower than in its saline version.
Examples of benthic species preferring sediments rich in silt are the mud shrimp (*Corophium volutator*) and the clam worm (*Nereis sp.*). Oligochaetes may form an important group in this ecotope qua densities (Ysebaert, 2000). Typical species of brackish water are the worm *Polydora ligerica* and the Atlantic ditch shrimp (*Palaemonetes varians*).

BRACKISH AND VARIABLY BRACKISH/SALINE ECOTOPES OF THE SUBLITTORAL SEDIMENTS		High-energy bed fine sands	High-energy bed rich in silt	Low-energy deep bed rich in silt	Low-energy deep fine sands	Low-energy shallow bed rich in silt	Low-energy shallow fine sands	
GROUPS	SPECIES							
oligochaetes	*Limnodrilus claparedianus*			x		x		
	Limnodrilus hoffmeisteri			x		x		
	Limnodrilus udekemianus			x		x		
	Tubifex costatus			x		x		
	Tubifex tubifex			x		x		
worms	*Paranais litoralis*			x	x	x	x	
	Polydora ligerica	x	x	x	x	x	x	
	Capetellid thread worm *(Heteromastus filiformis)*		x	x	x	x	x	
	Clam worm *(Nereis spp.)*	x	x	x	x	x	x	
molluscs	Baltic tellin *(Macoma balthica)*			x	x	x	x	
crustaceans	Mysid *(Mesopodopsis slabberi)*				x		x	
	Mysid *(Neomysis integer)*	x						
	Speckled sea louse *(Eurydice pulchra)*	x						
	Amphipod *(Haustorius arenarius)*	x						
	Atlantic ditch shrimp *(Palaemonetes varians)*			x	x	x	x	
	Brown shrimp *(Crangon crangon)*	x			x		x	
	Hog louse *(Idotea chelipes)*			x	x	x	x	
	Sand digger shrimp *(Bathyporeia sp.)*	x			x		x	
	Mud shrimp *(Corophium volutator)*		x	x		x		
	Sea slater *(Idotea granulosa)*			x	x	x	x	
fish	Flounder *(Platichthys flesus)*	x	x	x	x	x	x	
	Common goby *(Pomatoschistus microps)*	x			x		x	
	Gobies *(Gobiidae)*	x	x	x	x	x	x	
	Herring *(Clupea harengus)*	x	x	x	x	x	x	
	Lesser pipefish *(Syngnathus rostellatus)*	x	x	x	x	x	x	
	Dab *(Limanda limanda)*	x	x	x	x	x	x	
	Plaice *(Pleuronectes platessa)*	x	x	x	x	x	x	TS
	Striped sea snail (*Liparis liparis)*	x	x	x	x	x	x	TS
	Smelt *(Osmerus eperlanus)*	x	x	x	x	x	x	TS
	Sprat *(Sprattus sprattus)*	x	x	x	x	x	x	
	Bib *(Trisopterus luscus)*	x	x	x	x	x	x	
birds	Cormorant *(Phalacrocorax carbo)*	x	x	x	x	x	x	TS
	Grebe *(Podiceps cristatus)*	x	x	x	x	x	x	
	Red-breasted merganser *(Mergus serrator)*			x	x	x	x	
	Greater scaup *(Aythya marila)*			x	x	x	x	TS
	Common tern *(Sterna hirundo)*	x	x	x	x	x	x	TS, BD, RL
eco-elements	Sea grass bed *(Zostera marina, Z. noltii)*					x	x	TS, RL

Table 6.2.3. *List of species of the ecotopes of sediments in the brackish and the variably brackish/saline sublittoral zone. TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); RL = species listed in national Red List (both from Bal et al., 2001).*

The bivalve Baltic tellin (*Macoma balthica*) is able to hold its own in brackish waters as well. Differences with the deep version of the ecotope are its function as nursery grounds and its function for tidal migrants (see section 4.5) and the potential presence of sea grass beds (*Zostera marina*) (eco-element).

Low-energy shallow fine sands in brackish or variably brackish/saline water
The ecotope occurs in the eastern part of the Westerschelde, in the Ems-Dollard and in the New Water Way. The bed is less than five metres below the low water mark. Energy is low in this sublittoral

ecotope because of low current velocities. Biodiversity is lower than in the saline version of this ecotope. Examples of benthic species preferring sandy sediments are the sand digger shrimp (*Bathyporeia sp.*) and the brown shrimp (*Crangon crangon*). Typical species of the brackish waters are the worm *Polydora ligerica* and the Atlantic ditch shrimp (*Palaemonetes varians*). The bivalve Baltic tellin (*Macoma balthica*) is able to hold its own in brackish waters as well. Differences with the deep version of the ecotope are its function as nursery grounds and its function for tidal migrants (see section 4.5) and the potential presence of sea grass beds (*Zostera marina*) (eco-element).

6.2.4 Ecotopes of sediments in the saline sublittoral zone

High-energy fine sands in saline water
Energy is high in this sublittoral ecotope because of high linear current velocities. The ecotope comprises deep and less deep saline tidal channels in the Wadden Sea, Oosterschelde and in the western part of the Westerschelde. The surf zone along the North Sea coast is also part of this ecotope, but in that case the strong degree of wave action causes high energy (see section 6.3). The ecotope is not subdivided any further after depth, as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms. We distinguish between this ecotope and its version rich in silt because of the cohesive characteristics of a bed rich in silt. A strong current will stir a sandy bed more quickly. The sediment of the tidal channels mainly consists of coarse sands. As the bed is constantly moving up to a certain depth, little benthic life is possible. Benthic density, biomass and biodiversity are low. Sometimes biomass is high due to the presence of molluscs of genera such as *Ensis* (razor clams) and *Spisula* (surf clams). Typical species of this high-energy ecotope are the speckled sea louse (*Eurydice pulchra*) and *Scolelepis squamata* (table 6.2.4). The water in the channels is an important means of transport for both adult benthic animals and fish and their larvae (Creutzberg, 1978; Dankers & Binsbergen, 1984; Hostens et al., 1996).

High-energy beds rich in silt in saline water
Energy is high in this sublittoral ecotope because of high linear current velocities. The ecotope is not subdivided any further after depth, as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms. A distinction is made with this ecotope and its sandy version, because of the cohesive characteristics of a bed rich in silt, due to which it starts to move less quickly. The ecotope occurs in the western part of the Westerschelde. Benthic density, biomass and biodiversity are relatively low due to the high-energy conditions, but are higher than in its sandy version. Benthic species that are able to hold their own in this ecotope are the capetellid thread worm (*Heteromastus filiformis*), the clam worm (*Nereis sp.*) and the mud shrimp (*Corophium volutator*).

Low-energy deep beds rich in silt in saline water
The ecotope occurs in the Wadden Sea, Oosterschelde and the western part of the Westerschelde. The bed is over five metres below the low water mark. Energy is low in this sublittoral ecotope because of low current velocities. At very low current velocities and strong consolidation of the silt it is possible that just below the sediment surface anoxic sediments form. Biodiversity is higher than in its brackish version. Examples of benthic species preferring sediments rich in silt are the mud shrimp (*Corophium volutator*) and the clam worm (*Nereis sp.*).

Low-energy deep fine sands in saline water
The ecotope occurs in the Wadden Sea, Oosterschelde and the western part of the Westerschelde. The bed is over five metres below the low water mark. Energy is low in this sublittoral ecotope because of low current velocities. Biodiversity is higher than in its brackish version. Examples of benthic species preferring sandy sediments are the sand digger shrimp (*Bathyporeia sp.*) and the brown shrimp (*Crangon crangon*).

Low-energy shallow beds rich in silt in saline water
The ecotope occurs in the Wadden Sea, Oosterschelde and the western part of the Westerschelde. The bed is less than five metres below the low water mark. Energy is low in this sublittoral ecotope because of low current velocities. At very low current velocities and strong consolidation of the silt it is possible that just below the sediment surface anoxic sediments form. Biodiversity is higher than in its brackish version. Examples of benthic species preferring sediments rich in silt are the mud shrimp (*Corophium volutator*) and the clam worm (*Nereis sp.*). The benthic species in the shallow sublittoral parts show in most places a rather high likeness to the benthic species in the nearby littoral zone. Benthic densities, biomass and biodiversity are rather high, but generally lower than in the littoral zone (Beukema, 1976; Ysebaert, 2000). The ecotope is important to certain species of fish and crustaceans of which both juveniles and adults migrate at high tide towards the tidal flats and stay at low tide in the

shallow littoral zone (tidal migrants). Examples of such species are plaice (*Pleuronectes platessa*) (Kuipers, 1973) and the brown shrimp (*Crangon crangon*) (Janssen & Kuipers, 1980). In the ecotope mussel beds (*Mytilus edulis*), oyster beds (*Crassostrea gigas*) and sea grass beds (*Zostera marina, Z. noltii*) may occur (eco-elements).

Low-energy shallow fine sands in saline water
The ecotope occurs in the Wadden Sea, Oosterschelde and the western part of the Westerschelde. The bed is less than five metres below the low water mark. Energy is low in this sublittoral ecotope because of low current velocities. Biodiversity is higher than in its brackish version. Examples of benthic species preferring sandy sediments are the sand digger shrimp (*Bathyporeia sp.*) and the brown shrimp (*Crangon crangon*). The benthic species in the shallow sublittoral parts show in most places a rather high likeness to the benthic species in the nearby littoral. Benthic densities, biomass and biodiversity are rather high, but generally lower than in the littoral zone (Beukema, 1976; Ysebaert, 2000). The ecotope is important to certain species of fish and crustaceans of which both juveniles and adults migrate at high tide towards the tidal flats and stay at low tide in the shallow littoral zone (tidal migrants). Examples of such species are plaice (*Pleuronectes platessa*) (Kuipers, 1973) and the brown shrimp (*Crangon crangon*) (Janssen & Kuipers, 1980). In the ecotope mussel beds (*Mytilus edulis*), oyster beds (*Crassostrea gigas*) and sea grass beds (*Zostera marina, Z. noltii*) may occur (eco-elements). Part of the shallow sandy sublittoral in the Wadden Sea and the Oosterschelde is used as cultivation area for mussels. Mussels are cultivated in permanently submerged cultivation plots. The seed mussels required are fished from the wild sublittoral mussel beds in the Wadden Sea. Parts of the sandy shallow sublittoral zone in the Oosterschelde are being used for the cultivation of oysters as well.

SALINE ECOTOPES OF SUBLITTORAL SEDIMENTS		High-energy fine sands	High-energy bed rich in silt	Low-energy deep bed rich in silt	Low-energy deep fine sands	Low-energy shallow bed rich in silt	Low-energy shallow fine sands
GROUPS	SPECIES						
worms	*Anaitides groenlandica*	x					
	Anaitides maculata		x	x		x	
	Aricidea minuta		x	x	x	x	x
	Scolelepis squamata	x					
	Eteone longa		x	x	x	x	x
	Harmothoe sp.		x	x	x	x	x
	Ophelia spp.	x					
	Pygospio elegans		x	x	x	x	x
	Capetellid thread worm *(Heteromastus filiformis)*		x	x	x	x	x
	Spio spp.	x					
	Tharyx marioni		x	x		x	
	Lugworm *(Arenicola marina)*						x
	Catworms *(Nephtys cirrosa, N. longoseta)*	x			x		x
	Catworms *(Nephtys hombergii, N. caeca)*		x	x		x	
	Clam worm *(Nereis spp.)*		x	x		x	
molluscs	*Abra spp*	x					
	Common cockle *(Cerastoderma edule)*			x	x	x	x
	Baltic tellin *(Macoma balthica)*			x	x	x	x
	Surf clams *(Spisula spp.)*	x					
	Pullet carpet shell *(Venerupis pullastra)*	x					
	Mysella bidentata				x		x
	Razor clams *(Ensis spp.)*	x					
crustaceans	Mysid *(Gastrosaccus spinifer)*	x					
	Mysid *(Schistomysis spiritus)*	x					
	Mysid *(Schistomysis kervillei)*	x					
	Speckled sea louse *(Eurydice pulchra)*	x					

	Amphipod *(Haustorius arenarius)*	x						
	Brown shrimp *(Crangon crangon)*				x		x	
	Sand digger shrimp *(Bathyporeia sp.)*	x			x		x	
	Mud shrimp *(Corophium volutator)*		x	x		x		
	Common shore crab *(Carcinus maenas)*			x	x	x	x	
fish	Flounder *(Platichthys flesus)*	x	x	x	x	x	x	
	Butterfish *(Pholis gunnellus)*		x	x	x	x	x	TS, RL
	Thick-lipped grey mullet *(Chelon labrosus)*	x	x	x	x	x	x	
	Garfish *(Belone belone)*	x						TS
	Gobies *(Gobiidae)*	x	x	x	x	x	x	
	Lesser pipefish *(Syngnathus rostellatus)*			x	x	x	x	
	Eelpout *(Zoarces viviparus)*			x	x	x	x	TS
	Plaice *(Pleuronectes platessa)*	x	x	x	x	x	x	TS
	Dab *(Limanda limanda)*	x	x	x	x	x	x	
	Striped sea snail (*Liparis liparis*)	x	x	x	x	x	x	TS
	Sprat *(Sprattus sprattus)*	x	x	x	x	x	x	
	Sole *(Solea solea)*	x	x	x	x	x	x	TS
	5-bearded rockling *(Ciliata mustela)*			x	x	x	x	TS
	Whiting *(Merlangius merlangus)*	x	x					
	Sand lances *(Ammodytes sp.)*	x	x					
birds	Cormorant *(Phalacrocorax carbo)*	x	x	x	x	x	x	TS
	Little tern *(Sterna albifrons)*	x	x	x	x	x	x	TS, BD, RL
	Eider *(Somateria mollissima)*			x	x	x	x	TS, RL
	Grebe *(Podiceps cristatus)*	x	x	x	x	x	x	
	Sandwich tern *(Sterna sandvicensis)*	x	x	x	x	x	x	TS, BD, RL
	Red-breasted merganser *(Mergus serrator)*			x	x	x	x	
	Greater scaup *(Aythya marila)*			x	x	x	x	TS
	Common tern *(Sterna hirundo)*	x	x	x	x	x	x	TS, BD, RL
mammals	Common seal *(Phoca vitulina)*	x	x	x	x	x	x	TS, HD2, RL
	Grey seal *(Halichoerus grypus)*	x	x	x	x	x	x	TS, HB2, RL
eco-elements	Mussel bed *(Mytilus edulis)*					x	x	
	Oyster bed *(Crassostrea gigas)*					x	x	
	Sea grass bed *(Zostera marina, Z. noltii)*					x	x	TS, RL

Table 6.2.4. *List of species of the saline ecotopes of the sublittoral sediments.*
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); HD2 = species of the EU Habitats Directive (appendix 2); RL = species listed in national Red List (both from Bal et al., 2001).

6.2.5 Ecotopes of sediments in the brackish littoral zone

High-energy littoral fine sands in brackish or variably brackish/saline water
The ecotope comprises the emerging high-energy sands like those in the eastern part of the Westerschelde and in the Ems-Dollard. A high degree of wave action (high orbital velocity) or high linear current velocities cause high-energy conditions in this littoral ecotope. The ecotope is not subdivided any further after flooding frequency (related to height), as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms. A sandy bed is moved to a much stronger degree than a bed rich in silt, due to the consolidation of silt and the possible presence of a layer of diatoms on top of the sediment. High current velocities mainly cause high-energy conditions in the littoral zone of the Westerschelde. The ecotope here is often characterized by the so-called megaripples on the tidal flats (Photo 4.4.1). As the sediment in this ecotope constantly is stirred up to a relatively large depth, the benthic fauna is very poor. The benthic fauna is virtually dominated by the sand digger shrimp (*Bathyporeia sp.*). Typical species are the amphipod *Haustorius arenarius* and the speckled sea louse (*Eurydice pulchra*) (Ysebaert, 2000) (table 6.2.5). Shellfish are virtually absent due to high-energy conditions in this ecotope.

High-energy littoral bed rich in silt in brackish or variably brackish/saline water
The ecotope comprises emerging high-energy beds rich in silt that occur in the eastern part of the Westerschelde and probably in the Ems-Dollard as well. A high degree of wave action (high orbital velocity) or high linear current velocities cause high-energy conditions in this littoral ecotope. The ecotope is not subdivided any further after flooding frequency (related to height), as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms.

Due to consolidation of the silt and the possible presence of a layer of diatoms on top of the sediment the bed will be less disturbed than in the high-energy sandy littoral zone. Benthic diversity, density and biomass are low, but higher than in its sandy version.

Low-energy low littoral bed rich in silt in brackish or variably brackish/saline water
The ecotope comprises low-energy beds rich in silt in the littoral that are submerged over 75% of the tide. This brackish or variably brackish/saline ecotope occurs in the eastern part of the Westerschelde and in the Ems-Dollard. In the case of very low energy and strong consolidation of the silt, little oxygen will penetrate into the sediment and just below the surface anoxic sediments form. Very poor benthic and bird fauna characterize beds very rich in silt. In particular in eutrophic conditions many oligochaetes and few other species occur. Species in the ecotope preferring sediments rich in silt include the worms *Manayunkia aestuarina* and *Marenzelleria viridis*. Typical species of the brackish waters include *Hydrobia ventrosa* and *Cyathura carinata*. Gullies may occur in the ecotope (eco-element).

Low-energy low littoral fine sands in brackish or variably brackish/saline water
The ecotope comprises the low-energy emerging sands that are submerged over 75% of the tide. This brackish or variably brackish/saline ecotope occurs in the eastern part of the Westerschelde, the Ems-Dollard and the New Water Way. Compared to its saline version ecotope few species are present and their densities and biomass are low. Some examples of species that occur in this ecotope and prefer sandy sediments are the mysids *Mesopodopsis slabberi* and *Neomysis integer*. Waders (such as avocets *Recurvirostra avosetta*) and ducks (such as shelducks *Tadorna tadorna*) forage in this ecotope. Gullies may occur in the ecotope (eco-element).

Low-energy middle high littoral bed rich in silt in brackish or variably brackish/saline water
The ecotope comprises emerging low-energy beds rich in silt that are submerged between 75% and 25% of the tide. This brackish or variably brackish/saline ecotope occurs in the eastern part of the Westerschelde and in the Ems-Dollard. Benthic biomass is often higher than in the low littoral zone. Compared to its saline version only few species occur and densities and biomass are low. In the case of very low-energy and strong consolidation of the silt, little oxygen will penetrate into the sediment and just below the surface anoxic sediments form. Very poor benthic and bird fauna characterize beds very rich in silt. In particular in eutrophic conditions many oligochaetes and few other species occur. Species in the ecotope preferring sediments rich in silt include the worms *Manayunkia aestuarina* and *Marenzelleria viridis*. Typical species of the brackish waters include *Hydrobia ventrosa* and *Cyathura carinata*. Gullies and sea grass beds (*Zostera marina, Z. noltii*) may occur in the ecotope (eco-elements).

Low-energy middle high littoral fine sands in brackish or variably brackish/saline water
The ecotope comprises emerging low-energy fine sands that are submerged between 75% and 25% of the tide. This brackish or variably brackish/saline ecotope occurs in the eastern part of the Westerschelde, the Ems-Dollard and the New Water Way. Biomass is often higher than in the low littoral zone. Compared to its saline version only few species occur and densities and biomass are low. The brackish water species *Mesopodopsis slabberi* and *Neomysis integer* (mysids) prefer sandy sediments. Waders (such as avocets *Recurvirostra avosetta*) and ducks (such as shelducks *Tadorna tadorna*) forage in this ecotope. Gullies and sea grass beds (*Zostera marina, Z. noltii*) may occur in the ecotope (eco-elements).

Low-energy high littoral bed rich in silt in brackish or variably brackish/saline water
The ecotope comprises emerging low-energy beds rich in silt that are submerged less than 25% of the tide. This brackish or variably brackish/saline ecotope occurs in the eastern part of the Westerschelde and in the Ems-Dollard. No filter feeders are present because of the short period of submergence. Benthos consists mainly of crustaceans and worms (such as *Leptocheirus pilosus* and *Polydora ligni* respectively). The total benthic biomass is low. Worms in this ecotope preferring sediment rich in silt are *Manayunkia aestuarina* and *Marenzelleria viridis*. Pioneer plants may occur in the ecotope such as glaucous club-rush (*Scirpus tabernaemontani*) and sea club-rush (*Scirpus maritimus*). Gullies and sea grass beds (*Zostera marina, Z. noltii*) may occur in the ecotope as well (eco-elements).

Low-energy high littoral fine sands in brackish or variably brackish/saline water
The ecotope comprises low-energy fine sands that are submerged less than 25% of the tide. This brackish or variably brackish/saline ecotope occurs in the eastern part of the Westerschelde, the Ems-Dollard and the New Water Way. No filter feeders are present because of the short period of submergence. Benthos consists mainly of crustaceans and worms. The total benthic biomass is low.

The amphipod *Orchestia cavimana* is typical of this ecotope. Pioneer plants such as glaucous club-rush (*Scirpus tabernaemontani*) and sea club-rush (*Scirpus maritimus*) may occur in the ecotope. Gullies and sea grass beds (*Zostera marina, Z. noltii*) may occur in the ecotope as well (eco-elements).

BRACKISH AND VARIABLY BRACKISH/SALINE ECOTOPES OF LITTORAL SEDIMENTS

GROUPS	SPECIES	High-energy littoral fine sands	High-energy littoral beds rich in silt	Low-energy low littoral beds rich in silt	Low-energy low littoral fine sands	Low-energy middle high littoral beds rich in silt	Low-energy middle high littoral fine sands	Low-energy high littoral beds rich in silt	Low-energy high littoral fine sands	
plants	Rice grass *(Spartina anglica)*							x	x	
	Reed *(Phragmites australis)*							x	x	
	Bulrush *(Scirpus tabernaemontani)*							x	x	
	Arrow grass *(Triglochin maritima)*							x	x	
	Sea aster *(Aster tripolium)*							x	x	
	Bulrush *(Scirpus maritimus)*							x	x	
	Lesser sea spurrey *(Spergularia salina)*							x	x	
oligochaetes	*Limnodrilus claparedianus*			x		x		x		
	Limnodrilus hoffmeisteri			x		x		x		
	Limnodrilus udekemianus			x		x		x		
	Tubifex tubifex			x		x		x		
worms	*Scolelepis squamata*	x								WS
	Manayunkia aestuarina			x		x		x		
	Marenzelleria wireni			x		x		x		ED
	Polydora ligni			x	x	x	x	x	x	
	Pygospio elegans			x	x	x	x	x	x	
	Capetellid thread worm *(Heteromastus filiformis)*		x	x	x	x	x	x	x	
	Spio filicornis	x	x							
	Catworms *(Nephtys hombergii, N. caeca)*		x	x		x				
	Clamworm *(Nereis spp.)*			x	x	x	x	x	x	
molluscs	Baltic tellin *(Macoma balthica)*			x	x	x	x			
	Mud snail *(Hydrobia ventrosa)*			x		x		x		
	Peppery furrow shell *(Scrobicularia*			x		x				
	Sand gaper *(Mya arenaria)*			x		x				
crustaceans	Mysid *(Mesopodopsis slabberi)*				x		x			
	Mysid *(Neomysis integer)*				x		x			
	Speckled sea louse *(Eurydice pulchra)*	x	x							
	Amphipod *(Haustorius arenarius)*	x								
	Amphipod *(Orchestia cavimana)*								x	
	Cyathura carinata			x	x	x	x			
	Palaemonet. Varians			x	x	x	x			
	Leptocheirus pilosus			x		x		x		
	Brown shrimp *(Crangon crangon)*				x		x			
	Sea slater *(Idotea balthica)*				x		x			
	Sand digger shrimp *(Bathyporeia sp.)*	x			x		x			
	L. rugicauda			x	x	x	x	x	x	
	Hog louse *(Idotea chelipes)*			x		x		x		
	Mud shrimp *(Corophium volutator)*			x		x		x		
	Sea slater *(Idotea granulosa)*				x		x		x	
	Sea slater *(Jaera praehirsuta)*							x		

fish	Flounder *(Platichthys flesus)*	x	x	x	x	x	x			
	Common goby *(Pomatoschistus microps)*	x			x		x			
	Gobies *(Gobiidae)*	x	x	x	x	x	x			
	Lesser pipefish *(Syngnathus rostellatus)*			x	x	x	x			
	Dab *(Limanda limanda)*	x	x	x	x	x	x			
	Plaice *(Pleuronectes platessa)*	x	x	x	x	x	x			TS
	Sprat *(Sprattus sprattus)*	x	x	x	x	x	x			
	Sea bass *(Dicentrarchus labrax)*	x	x	x	x	x	x			
birds	Shelduck *(Tadorna tadorna)*			x	x	x	x			TS
	Dunlin *(Calidris alpina)*			x	x	x	x			TS
	Eider *(Somateria mollissima)*			x	x	x	x			TS, RL
	Greylag goose *(Anser anser)*							x	x	TS, WS
	Knot *(Calidris canutus)*			x	x	x	x			
	Avocet *(Recurvirostra avosetta)*			x	x	x	x			TS, VR
	Black-headed gull *(Larus ridibundus)*			x	x	x	x			
	Bar-tailed godwit *(Limosa lapponica)*			x	x	x	x			TS, VR
	Oystercatcher *(Haematopus ostralegus)*			x	x	x	x	x	x	TS
	Common redshank *(Tringa totanus)*			x	x	x	x			TS, RL
	Teal *(Anas crecca)*							x	x	
	Curlew *(Numenius arquata)*			x	x	x	x			TS
	Herring gull *(Larus argentatus)*			x	x	x	x			
	Black-bellied plover *(Pluvialis squatarola)*			x	x	x	x			TS
eco-elements	Gully			x	x	x	x	x	x	
	Sea grass field *(Zostera marina, Z. noltii)*					x	x	x	x	TS, RL

Table 6.2.5. *List of species of the ecotopes of sediments in the brackish and the variably brackish/saline littoral zone. WS= Westerschelde, ED= Ems-Dollard, TS = target species Min. ANF; RL = species listed in national Red List (both from Bal et al., 2001).*

6.2.6 Ecotopes of sediments in the saline littoral zone

High-energy littoral coarse sands in saline water, the 'wet beach'
The ecotope comprises the emerging high-energy beds as they occur along the North Sea coast, the so-called 'wet beach'. It comprises the zone that is frequently flooded in the normal tide cycles. The ecotope is poor in benthos due to the high energy of the wave attacks, in winter in particular, while plants are lacking completely. Some species that may occur are lugworms (*Arenicola marina*), *Scololepus squamata* and *Chamarus spec.* (Waders forage on them such as oystercatchers (*Ostralegus haematopus*) and sanderlings (*Calidris alba*).

High-energy littoral fine sands in saline water
The ecotope comprises emerging high-energy sands and occurs in the Wadden Sea, the Oosterschelde and in the western part of the Westerschelde. A high degree of wave action (high orbital velocity) or high linear current velocities cause high-energy conditions in this littoral ecotope. The ecotope is not subdivided any further after flooding frequency (related to height), as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms. A sandy bed is disturbed to a higher degree than a bed rich in silt, due to consolidation of the silt and a possible presence of a layer of diatoms on top of the sediment rich in silt. In the Westerschelde high current velocities mainly cause high-energy conditions in the littoral. The ecotope here is often characterized by the so-called megaripples on the tidal flats (Photo 4.4.1). As the sediment in this ecotope constantly is stirred up to a relatively large depth, benthos is very poor. Species that may occur in the ecotope are speckled sea louse (*Eurydice pulchra*), *Scolelepis squamata*, white catworm (*Nephtys cirrhosa*) and the worm *Spio sp.* Shellfish do not occur in this ecotope due to high energy.

High-energy littoral bed rich in silt in saline water
The ecotope comprises emerging high-energy sediments rich in silt in the western part of the Westerschelde. High linear current velocities cause high-energy conditions. The ecotope is not subdivided any further after flooding frequency (related to height), as we assume hydrodynamics and sediment composition to be more determining in the occurrence of organisms. Due to consolidation of the silt and the possible presence of a layer of diatoms on top of the sediment the

bed will be less disturbed than in the sandy versions of this ecotope. The benthos diversity, densities and biomass are low.

Low-energy low littoral bed rich in silt in saline water
The ecotope comprises emerging low-energy beds rich in silt that are submerged over 75% of the tide, occurring in the Wadden Sea and in the western part of the Westerschelde. At very low energy and strong consolidation of the silt little oxygen is able to penetrate the sediment. This causes just below the sediment surface anoxic conditions. Benthic biomass often is lower than in the middle high littoral zone, (Beukema, 1976; Wolff & De Wolf, 1977). Benthic biomass and biodiversity may be high in this ecotope like when eco-elements are present. The ecotope may therefore be an important foraging area to waders such as avocet (*Recurvirostra avosetta*) and knot (*Calidris canutus*). Beds very rich in silt are characterized though by a very poor benthic and bird fauna. Gullies, mussel beds (*Mytilus edulis*) and oyster beds (*Crassostrea gigas*) may occur in this ecotope.

Low-energy low littoral fine sands in saline water
The ecotope comprises emerging low-energy fine sands that are submerged over 75% of the tide and occurring in the Oosterschelde, Wadden Sea and the western part of the Westerschelde. Benthic biomass often is lower than in the middle high littoral zone, (Beukema, 1976; Wolff & De Wolf, 1977). Benthic biomass and biodiversity may be high in this ecotope, like when eco-elements are present. The ecotope is often characterized by the typical little worm heaps of the lugworm (*Arenicola marina*) (photo 6.2.4). On low tidal flats waders, gulls and ducks are foraging. The trample holes by shelducks (*Tadorna tadorna*) and eiders (*Somateria mollissima*) are easily spotted. Gullies, mussel beds (*Mytilus edulis*) and oyster beds (*Crassostrea gigas*) may occur in this ecotope.

Photo 6.2.4. *Characteristic little heaps of lugworms (Arenicola marina) on a tidal flat in saline water.*

Low-energy middle high littoral bed rich in silt in saline water
The ecotope comprises emerging low-energy beds rich in silt that are submerged between 75% and 25% of the tide, occurring for instance in the Wadden Sea and the western part of the Westerschelde. At very low energy and strong consolidation of the silt little oxygen is able to penetrate the sediment. This causes just below the sediment surface anoxic conditions. A very poor benthic and bird fauna often characterize beds very rich in silt. In sediments that are a little less rich in silt biomass often is higher than in the low littoral zone.
Densities of juvenile benthic animals may be high (Farke et al., 1979; Günther, 1992). Opportunities to survive are better here than in its lower version, due to a lower predation pressure by fish, crabs and shrimps. Adult animals often migrate to the lower parts. The organic matter content and the occurrence of microphytobenthos on the sediment surface (food for many benthic animals) are higher than in its version with fine sands. The ecotope may be an important foraging area for waders such as avocet (*Recurvirostra avosetta*) and knot (*Calidris canutus*). In the ecotope gullies, mussel beds (*Mytilus edulis*), oyster beds (*Crassostrea gigas*) and sea grass beds (*Zostera marina, Z. noltii*) may occur.

Low-energy middle high littoral fine sands in saline water

The ecotope comprises emerging low-energy fine sands that are submerged between 75% and 25% of the tide, occurring in the Oosterschelde, Wadden Sea and the western part of the Westerschelde. Biomass in the middle high littoral zone often is higher than in the low littoral zone. Densities of juvenile benthic animals may be high (Farke et al., 1979; Günther, 1992). Opportunities to survive are better here than in its lower version, due to a lower predation pressure by fish, crabs and shrimps. Adult animals often migrate to the lower parts. Middle high tidal flats are important foraging areas to waders, gulls and ducks (such as avocet (*Recurvirostra avosetta*), black-headed gull (*Larus ridibundus*) and shelducks (*Tadorna tadorna*) respectively). In the ecotope gullies, mussel beds (*Mytilus edulis*), oyster beds (*Crassostrea gigas*) and sea grass beds (*Zostera marina, Z. noltii*) may occur.

Low-energy high littoral bed rich in silt in saline water

The ecotope comprises emerging low-energy sediments rich in silt that are flooded less than 25% of the tide (photo 6.2.5), occurring in the Wadden Sea and in the western part of the Westerschelde. At very low energy and strong consolidation of the silt little oxygen is able to penetrate the sediment. This causes anoxic conditions just below the sediment surface. No filter feeders are present because of the short period of submergence. The benthic fauna consists mainly of small crustaceans and worms. Total benthic biomass is low. A pioneer vegetation like rice grass (*Spartina anglica*) may be present (photo 6.2.6). Gullies and sea grass beds (*Zostera marina, Z. noltii*) may occur in the ecotope (eco-elements).

Photo 6.2.5. *High littoral rich in silt*

Photo 6.2.6. *A pioneer vegetation of rice grass (Spartina anglica) in the high littoral zone.*

Low-energy high littoral fine sands in saline water

The ecotope comprises emerging low-energy fine sands that are flooded less than 25% of the tide, occurring in the Oosterschelde, Wadden Sea and western part of the Westerschelde. No filter feeders are present because of the short period of submergence. The benthic fauna consists mainly of small crustaceans and worms. The ecotope may be characterized by typical little lugworm heaps (*Arenicola marina*), but densities are lower than on the lower tidal flats. A pioneer vegetation like rice grass (*Spartina anglica*) may be present. Gullies and sea grass beds (*Zostera marina, Z. noltii*) may occur in the ecotope as well.

					Low-energy low littoral fine sands	Low-energy middle high littoral beds rich in silt	Low-energy middle littoral fine sands	Low-energy high littoral beds rich in silt	Low-energy high littoral fine sands	
plants	Rice grass *(Spartina anglica)*							x	x	
	Glasswort *(Salicornia spp)*							x	x	
worms	*Anaitides maculata*			x		x				
	Aricidea minuta			x	x	x	x			
	Scolelepis squamata	x								
	Bristle worm *(Pectinaria koreni)*				x		x			
	Eteone longa				x		x		x	
	Harmothoe sp.				x		x			
	Marenzelleria wireni			x		x		x		
	Pygospio elegans			x	x	x	x	x	x	
	Capetellid thread worm *(Heteromastus filiformis)*		x	x	x	x	x	x	x	
	Annelid worm *(Lanice conchilega)*			x	x	x	x			
	Gallery worm *(Capitella capitata)*			x		x		x		
	Spio filicornis	x								
	Tharyx marioni			x		x				
	Lugworm *(Arenicola marina)*				x		x		x	
	Scoloplos armiger				x		x		x	
	Catworms *(Nephtys hombergii, N. caeca)*		x	x		x		x		
	Catworms *(Nephtys cirrhosa, N.*	x			x		x		x	
	Clamworm *(Nereis spp.)*			x	x	x	x	x	x	
molluscs	Dun sentinel *(Assiminea grayana)*							x	x	
	Common cockle *(Cerastoderma edule)*			x	x	x	x			
	Baltic tellin *(Macoma balthica)*			x	x	x	x			
	Retusa obtusata							x	x	
	Peppery furrow shell *(Scrobicularia*			x		x				
	Sand gaper *(Mya arenaria)*			x	x	x	x			
	Abra tenuis			x	x	x	x			
	Mysella bidentata			x	x	x	x			
	Mud snail *(Hydrobia ulva)*			x		x		x		
crustaceans	Speckled sea louse *(Eurydice pulchra)*	x	x							
	Brown shrimp *(Crangon crangon)*				x		x		x	
	Sand digger shrimp *(Bathyporeia sp.)*	x			x		x		x	
	Mud shrimp *(Corophium volutator)*					x		x		
	Common shore crab *(Carcinus maenas)*			x	x	x	x	x	x	
fish	Flounder *(Platichthys flesus)*			x	x	x	x			
	Thick-lipped grey mullet *(Chelon*			x	x	x	x			
	Gobies *(Gobiidae)*			x	x	x	x			
	Lesser pipefish *(Syngnathus rostellatus)*			x	x	x	x			
	Plaice *(Pleuronectes platessa)*			x	x	x	x			TS
	Dab *(Limanda limanda)*			x	x	x	x			
	Sprat *(Sprattus sprattus)*			x	x	x	x			
	Sole *(Solea solea)*			x	x	x	x			TS
	Sea bass *(Dicentrarchus labrax)*			x	x	x	x			
birds	Shelduck *(Tadorna tadorna)*			x	x	x	x			TS
	dunlin *(Calidris alpine)*			x	x	x	x			TS
	Sanderling (*Calidris alba*)	x								
	Eider *(Somateria mollissima)*			x	x	x	x			TS, RL
	Grey-leg goose *(Anser anser)*							x	x	TS, WS
	Knot *(Calidris canutus)*			x	x	x	x			
	Avocet *(Recurvirostra avosetta)*			x	x	x	x			TS, BD
	Black-headed gull *(Larus ridibundus)*			x	x	x	x			
	Bar-tailed godwit *(Limosa lapponica)*			x	x	x	x			TS, BD

	Oystercatcher *(Haematopus ostralegus)*	x		x	x	x	x	x	x	TS
	Common redshank *(Tringa totanus)*			x	x	x	x			TS, RL
	Teal *(Anas crecca)*							x	x	
	Curlew *(Numenius arquata)*			x	x	x	x			TS
	Herring gull *(Larus argentatus)*			x	x	x	x			
	Black-bellied plover *(Pluvialis squatarola)*			x	x	x	x			TS
eco-elements	Gullies			x	x	x	x	x	x	
	Sea grass beds *(Zostera marina, Z. noltii)*					x	x	x	x	TS, RL
	Mussel beds *(Mytilus edulis)*			x	x	x	x			
	Oyster beds *(Crassostrea gigas)*			x	x	x	x			

Table 6.2.6*.* *List of species of the ecotopes of sediments in saline littoral.*
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); RL = species listed in national Red List (both from Bal et al., 2001).

6.2.7 Ecotopes of sediments in the saline supralittoral zone

High-energy 'low' supralittoral coarse sands, the so-called 'dry beach'. Beach drift plants, such as sea rocket (*Cakile maritima*) and sea purslane (*Honkenya peploides*), but also sea kale (*Crambe maritima*) and samphire (*Crithmum maritimum*) may grow on the lower, infrequently flooded parts of the 'dry beach' (table 6.2.7). The ecotope is suitable as nesting grounds for snowy plovers (*Charadrius alexandrinus*), ringed plovers (*Charadrius hiaticula*) and little terns (*Sterna albifrons*). This ecotope occurs locally in the waters 'within the coast', in particular on the more seaward sides of the area.

High-energy 'high' supralittoral coarse sands, the 'embryonic dunes'
In the highest parts of the 'dry beach' the first dune-forming plants may start to grow, sand twitch (*Elytrigia junceiformis*) and sea rocket (*Cakile maritima*). These may cause the formation of embryonic dunes. The ecotope is suitable as nesting grounds for shelducks (*Tadorna tadorna*), common gulls (*Larus canus*), herring gulls (*Larus argentatus*) and lesser black-backed gulls (*Larus fuscus*) due to the presence of embryonic dunes. This ecotope occurs locally in the waters 'within the coast', in particular on the more seaward sides of the area.

(Potential) pioneer zone brackish salt marsh
The pioneer zone of a salt marsh comprises the area between the mean high water mark at neap tide and a minimum flooding frequency of 300 times per year. The ecotope occurs in the eastern part of the Westerschelde and the Ems-Dollard. The pioneer zone is characterized by open vegetation, but does not have to be covered; this means that much bare sediment is present. The bare zone in which the formation of salt marshes is potentially present should be considered to be a 'potential pioneer zone'. This zone is essential to enable the salt marsh cycle of accretion and erosion. In general it is only discerned as such in reclamation works. As it is not yet possible to indicate exactly what boundary conditions exist in order to enable potentially salt marsh development, we will not distinguish here between 'potential pioneer zone', 'bare zone non-potential pioneer zone' and 'pioneer zone' itself. As soon as we know more about the exact boundary conditions the boundaries of the potential pioneer zone may be indicated separately with regard to the real bare zone. For the time being the entire bare zone between MHWN – 300 x/year is included in this ecotope.
Its vegetation only exists of a few species of plants that have adapted to high flooding frequencies (pioneer species). These are in particular sea club-rush (*Scirpus maritimus*) and glasswort (*Salicornia spp.*). Typical snails are the mouse-eared snail (*Ovatella myosotis*) and *Assiminea grayana* (table 6.2.7). Virtually always gullies are present in this ecotope, they are included in the ecotope and we do not consider them to be an eco-element.

Low brackish salt marsh
The low part of a salt marsh comprises the area between a maximum flooding frequency of 300 times per year and a minimum flooding frequency of 150 times per year.
The ecotope occurs in the eastern part of the Westerschelde and in the Ems-Dollard. In the eastern part of the Westerschelde lies the Verdronken Land van Saeftinge, one of the biggest salt marshes in Europe. In contrast with the pioneer zone vegetation in this ecotope is close, this means that little bare sediment is present. Typical plant species for this ecotope are sea club-rush (*Scirpus maritimus*), sea aster (*Aster tripolium*), common salt-marsh grass (*Puccinellia maritima*) and reed (*Phragmites australis*) (see photo 6.2.7). Typical snails are the mouse-eared snail (*Ovatella myosotis*) and *Assiminea grayana*. Many species of waders and gulls use the ecotope as a high tide refuge. Virtually always creeks are present in this ecotope, they are included in the ecotope and we do not consider

them to be an eco-element. Creeks play an important part as nursery grounds for the brown shrimp (*Crangon crangon*) (Cattrijsse. 1997), and are very important for drainage and sediment supply. Pools may develop in the ecotope, for instance by silting up of parts of creeks or by scouring holes during storm surges. The pools are filled with seawater during spring tides or storms. In the intermediate periods dry spells cause an increase in salinity and precipitation causes a decrease in salinity (De Boer & Wolff, 1996). In such pools Ruppia-associations (*Ruppia cirrhosa, Ruppia maritima*) may occur.

Photo 6.2.7. *Reed (Phragmites australis) in a low brackish salt marsh.*

Middle high brackish salt marsh

The middle high part of a salt marsh comprises the area between a maximum flooding frequency of 150 times per year and a minimum flooding frequency of 50 times per year. The ecotope occurs in the eastern part of the Westerschelde and the Ems-Dollard. In the eastern part of the Westerschelde lies the Verdronken Land van Saeftinge, one of the biggest salt marshes in Europe. The vegetation in the ecotope is close; this means that virtually no bare sediment is present. Typical plant species for this ecotope are common salt-marsh grass (*Puccinellia maritima*), arrow grass (*Triglochin maritima*), sea club-rush (*Scirpus maritimus*) and reed (*Phragmites australis*). Typical snails are the mouse-eared snail (*Ovatella myosotis*) and *Assiminea grayana*. The ecotope is used as high tide refuge by many species of waders and gulls, and is important as foraging area for greylag geese (*Anser anser*; WS), brent geese (*Branta bernicla*; ED), barnacle geese (*Branta leucopsis*; ED) and wigeons (*Anas penelope*). Virtually always creeks are present in this ecotope, they are included in the ecotope and we do not consider them to be an eco-element. Creeks play an important part as nursery grounds for the brown shrimp (*Crangon crangon*) (Cattrijsse, 1997), and are very important for drainage and sediment supply. Pools may develop in the ecotope, e.g. by silting up of parts of creeks or by scouring holes during storm surges. The pools are filled with seawater during spring tides or storms. In the intermediate periods dry spells cause an increase in salinity and precipitation causes a decrease in salinity (De Boer & Wolff, 1996). In such pools Ruppia-associations (*Ruppia cirrhosa, R. maritima*) may occur.

High brackish salt marsh

The high part of a salt marsh comprises the area between a maximum flooding frequency of 50 times per year and a minimum flooding frequency of 5 times per year. The ecotope occurs in the eastern part of the Westerschelde and the Ems-Dollard. In the eastern part of the Westerschelde lies the Verdronken Land van Saeftinge, one of the biggest salt marshes in Europe. The vegetation in the ecotope is close; this means that virtually no bare sediment is present. Typical plant species for this ecotope are sea twitch (*Elymus athericus*), red fescue (*Festuca rubra*) and reed (*Phragmites australis*) and in the highest parts creeping bent (*Agrostis stolonifera*). The ecotope is important as a foraging area for greylag geese (*Anser anser*; WS), brent geese (*Branta bernicla*; ED), barnacle geese (*Branta leucopsis*; ED) and wigeons (*Anas penelope*). The reed offers nesting opportunities for reed warblers (*Acrocephalus scirpaceus*) and reed buntings (*Emberiza schoeniclus*). Virtually always creeks are present in this ecotope, they are included in the ecotope and we do not consider them to be an eco-element. Creeks play an important part as nursery grounds for the brown shrimp (*Crangon crangon*) (Cattrijsse., 1997), and are very important for drainage and sediment supply. Pools may develop in the ecotope, e.g. by silting up of parts of creeks or by scouring holes during storm surges. The pools are filled with seawater during spring tides or storms. In the intermediate periods dry spells cause an increase in salinity and precipitation causes a decrease in salinity (De Boer & Wolff, 1996). In such pools Ruppia-associations (*Ruppia cirrhosa, R. maritima*) may occur.

In the highest parts without grazing the ecological meaning for vegetation and birds decreases sharply by the monotonous, rough nature of the vegetation. Waders and the like prefer mostly more open terrains as high tide refuge. Locally, the ecotope may be important as nesting and foraging area for e.g. marsh harriers (*Circus aeruginosus*), black-headed gulls (*Larus ridibundus*) and spoonbills (*Platalea leucorodia*). In addition the ecotope is important for winter visitors such as snow buntings (*Plectrophenax nivalis*), shore larks (*Eremophila alpestris*) and twites (*Carduelis flavirostris*). The reed offers nesting opportunities for reed warblers (*Acrocephalus scirpaceus*) and reed buntings (*Emberiza schoeniclus*). In the ecotope less creeks and supralittoral pools occur than in the lower parts of salt marshes.
In the possibly present pools Ruppia-associations (*Ruppia cirrhosa, R. maritima*) may occur.

(Potential) pioneer zone saline salt marsh
The pioneer zone of a salt marsh comprises the area between the mean high water mark at neap tide and an minimum flooding frequency of 300 times per year. The ecotope has its greatest extension in the Wadden Sea, but occurs as well in the western part of the Westerschelde and in the Oosterschelde. The pioneer zone is characterized by open vegetation; this means that much bare sediment is present. The bare zone in which the formation of salt marshes is potentially present should be considered to be a 'potential pioneer zone'. This zone is essential to enable the salt marsh cycle of accretion and erosion. In general it is only discerned as such in reclamation works. As it is not yet possible to indicate exactly what boundary conditions exist in order to enable potentially salt marsh development, we will not distinguish here between 'potential pioneer zone', 'bare zone non-potential pioneer zone' and 'pioneer zone' itself. As soon as we know more about the exact boundary conditions the boundaries of the potential pioneer zone may be indicated separately with regard to the real bare zone. For the time being the entire bare zone between MHWN – 300 x/year is included in this ecotope. Its vegetation only exists of a few species of plants that have adapted to high flooding frequencies (pioneer species). In the Westerschelde this rice grass (*Spartina anglica*) (see photo 6.2.6) in particular and in the Wadden Sea glasswort (*Salicornia spp.*) (photo 6.2.8). A typical snail in the Westerschelde is the mouse-eared snail (*Ovatella myosotis*).

Photo 6.2.8 *Glasswort (Salicornia sp.) in the pioneer zone of a saline salt marsh*

Low saline salt marsh
The low part of a salt marsh comprises the area between a maximum flooding frequency of 300 times per year and a minimum flooding frequency of 150 times per year. The ecotope has its greatest extension in the Wadden Sea, but occurs as well in the western part of the Westerschelde and in the Oosterschelde. In contrast with the pioneer zone vegetation in this ecotope is close, this means that little bare sediment is present. Typical plant species of this ecotope are rice grass (*Spartina anglica*) (table 6.2.8), sea aster (*Aster tripolium*) and common salt-marsh grass (*Puccinellia maritima*). A typical snail is the mouse-eared snail (*Ovatella myosotis*). The ecotope is used as high tide refuge by many species of waders and gulls. Gullies and creeks play an important part as nursery grounds for the brown shrimp (*Crangon crangon*) (Cattrijsse, 1997), and are very important for drainage and sediment supply. Pools may develop in the ecotope, for instance by silting up of parts of creeks or by scouring holes during storm surges. The pools are filled with seawater during spring tides or storms. In the intermediate periods dry spells cause an increase in salinity and precipitation causes a decrease in salinity (De Boer & Wolff, 1996). In such pools Ruppia-associations (*Ruppia cirrhosa, R. maritima*) may occur. In the creeks sea grasses (*Zostera marina* in particular) may occur.

Middle high saline salt marsh
The middle high part of a salt marsh comprises the area between a maximum flooding frequency of 150 times per year and a minimum flooding frequency of 50 times per year. The ecotope has its greatest extension in the Wadden Sea, but occurs as well in the western part of the Westerschelde and in the Oosterschelde. The vegetation in the ecotope is close; this means that virtually no bare sediment is present. Typical plant species for this ecotope are sea purslane (*Halimione portulacoides*), common salt-marsh grass (*Puccinellia maritima*) and sea lavender (*Limonium vulgare*) (see photo 6.2.9). A typical snail is the mouse-eared snail (*Ovatella myosotis*). The ecotope is used as high tide refuge by many species of waders and gulls, and is important as foraging grounds for greylag geese (*Anser anser*; WS), brent geese (*Branta bernicla*; WZ), barnacle geese (*Branta leucopsis*; WZ) and wigeons (*Anas penelope*). Virtually always creeks are present in this ecotope, they are included in the ecotope and we do not consider them to be an eco-element. Creeks play an important part as nursery grounds for the brown shrimp (*Crangon crangon*) (Cattrijsse, 1997), and are very important for drainage and sediment supply. Pools may develop in the ecotope, e.g. by silting up of parts of creeks or by scouring holes during storm surges. The pools are filled with seawater during spring tides or storms. In the intermediate periods dry spells cause an increase in salinity and precipitation causes a decrease in salinity (De Boer & Wolff, 1996). In such pools Ruppia-associations (*Ruppia cirrhosa, R. maritima*) may occur. In the creeks sea grasses (*Zostera marina* in particular) may occur.

Photo 6.2.9. *Sea lavender (Limonium vulgare) in a middle high saline salt marsh*

High saline salt marsh
The high part of a salt marsh comprises the area between a maximum flooding frequency of 50 times per year and a minimum flooding frequency of 5 times per year. The ecotope has its greatest extension in the Wadden Sea, but occurs as well in the western part of the Westerschelde and in the Oosterschelde. The vegetation in the ecotope is close; this means that virtually no bare sediment is present. Typical plant species for this ecotope are sea twitch (*Elymus athericus*), and red fescue (*Festuca rubra*)) and in the highest parts creeping bent (*Agrostis stolonifera*). In well-drained places mostly sea twitch (*Elymus athericus*) is dominating, in some years together with hastate orache (*Atriplex hastata*). When the high salt marsh is being mowed or grazed, sea twitch (*Elymus athericus*) is less dominant and other species are more prominent. The ecological meaning of unmanaged high salt marshes is relatively minor to birds by the monotonous, rough nature of the vegetation. Waders and the like prefer mostly more open terrains as high tide refuge.
Locally the ecotope may be of importance as nesting and foraging grounds for instance to the marsh harrier (*Circus aeruginosus*), black-headed gull (*Larus ridibundus*), spoonbill (*Platalea leucorodia*) and herring gull (*Larus argentatus*). In addition the ecotope is important for winter visitors such as snow buntings (*Plectrophenax nivalis*), shore larks (*Eremophila alpestris*) and twites (*Carduelis flavirostris*). Virtually always creeks are present in this ecotope, they are included in the ecotope and we do not consider them to be an eco-element. Creeks play an important part as nursery grounds for the brown shrimp (*Crangon crangon*) (Cattrijsse, 1997), and are of great importance for drainage and sediment supply. Pools may develop in the ecotope, for instance by silting up of parts of creeks or by scouring holes during storm surges. The pools are filled with seawater during spring tides or storms. In the intermediate periods dry spells cause an increase in salinity and precipitation causes a decrease in salinity (De Boer & Wolff, 1996). In such pools Ruppia-associations (*Ruppia cirrhosa, R. maritima*) may occur. In the creeks sea grasses (*Zostera marina* in particular) may occur.

BRACKISH OR VARIABLE BRACKISH/SALINE ECOTOPES OF THE SUPRALITTORAL SEDIMENTS	(Potential) pioneer zone brackish salt marsh

GROUPS	SPECIES		Low brackish salt marsh	Middle high brackish salt marsh	High brackish salt marsh	
plants	Creeping Thistle *(Cirsium arvense)*				x	
	Common Scurvy Grass *(Cochlearia*		x	x		TS, RL
	Rice grass *(Spartina anglica)*		x			
	Creeping Bent (*Agrostis stolonifera*)			x	x	
	Common Salt-marsh Grass *(Puccinellia maritima)*		x	x		
	Eel Grass (*Zostera marina*)		x	x	x	TS; RL
	Marsh Mallow *(Althaea officinalis)*				x	TS, RL
	Fen Sowthistle *(Sonchus palustris)*				x	
	Reed *(Phragmites australis)*		x	x	x	
	Red fescue *(Festuca rubra)*				x	
	Glaucous Club-rush *(Scirpus*	x	x			
	Sea Arrow-grass *(Triglochin maritima)*		x			
	Beaked Tassel Pondweed *(Ruppia*		x	x	x	TS, RL, pools
	Spiral Tassel Pondweed *(Ruppia cirrhosa)*		x	x	x	TS, RL, pools
	Sea twitch *(Elymus athericus)*				x	
	Sea aster *(Aster tripolium)*		x			
	Sea Club-rush *(Scirpus maritimus)*	x	x			
	Glasswort *(Salicornia spp.)*	x				
	Sea Spurrey *(Spergularia salina)*		x			
molluscs	Mouse-eared snail *(Ovatella myosotis)*	x	x	x		Typical
	Dun sentinel *(Assiminea grayana)*	x	x	x		Typical
crustaceans	Brown shrimp *(Crangon crangon)*	x	x	x	x	In gullies/creeks
birds	Barnacle goose *(Branta leucopsis)*			x	x	TS, BD, Ems-Dollard
	Marsh harrier *(Circus aeruginosus)*				x	TS, BD
	Twite *(Carduelis flavirostris)*				x	
	Grey-legged goose *(Anser anser)*			x	x	TS, WS
	Reed warbler *(Acrocephalus scirpaceus)*			x	x	Summer bird (reed)
	Black-headed gull *(Larus ridibundus)*	x	x	x	x	Creeks
	Spoonbill *(Platalea leucorodia)*					TS, BD, RL
	Pintail *(Anas acuta)*	x	x	x	x	TS, RL, creeks
	Reed bunting *(Emberiza schoeniclus)*			x	x	Summer bird (reed)
	Brent goose *(Branta bernicla)*			x	x	TS, Ems-Dollard
	Shoveler *(Anas clypeata)*	x	x	x	x	Creeks
	Wigeon *(Anas penelope)*			x	x	
	Snow bunting *(Plectrophenax nivalis)*				x	
	Shore lark *(Eremophila alpestris)*				x	
	Common tern *(Sterna hirundo)*		x	x		TS, BD, RL, summer bird

Table 6.2.7. *List of species of the ecotopes of sediments in the brackish littoral zone.*
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); RL = species listed in national Red List (both from Bal et al., 2001).

SALINE ECOTOPES OF SUPRALITTORAL SEDIMENTS		Low dry shore	High dry shore with embryonic dunes	Potential pioneer zone saline salt marsh	Low saline salt marsh	Middle high saline salt marsh	High saline salt marsh	
GROUPS	SPECIES							
plants	Sand Twitch *(Elytrigia junceiformis)*	x	x					
	Sea Pink *(Armeria maritima)*						x	TS, RL
	Rice grass *(Spartina anglica)*			x	x			
	Creeping bent *(Agrostis stolonifera)*						x	
	Eel grass (*Zostera marina*)				x	x	x	TS; RL
	Common Salt-marsh Grass *(Puccinellia maritima)*				x	x		
	Sea Lavender *(Limonium vulgare)*				x	x		TS
	Red Bartsia *(Odontites verna)*					x	x	TS, RL
	Red fescue *(Festuca rubra)*						x	
	Annual Sea-blite *(Suaeda maritima)*				x			
	Sea Arrow-grass *(Triglochin maritima)*				x	x		
	Beaked Tassel Pondweed *(Ruppia maritima)*				x	x	x	TS, RL, pools
	Hastate Orache *(Atriplex hastata)*				x	x	x	
	Spiral Tassel Pondweed *(Ruppia*				x	x	x	TS, RL, pools
	Sea twitch *(Elymus athericus)*						x	
	Sea Wormwood *(Artemisia maritima)*				x	x		TS, RL
	Sea aster *(Aster tripolium)*	x			x	x		
	Sea Kale (*Crambe maritime*)							
	Glasswort *(Salicornia spp.)*	x		x				
	Sea Rocket *(Cakile maritima)*	x	x					
	Samphire (*Crithmum maritimum*)							TS; RL
	Sea Plantain *(Plantago maritima)*					x		TS, RL
	Salt Mud Rush *(Juncus gerardii)*					x	x	
	Sea Purslane *(Halimione portulacoides)*				x	x		
worms	*Scolelepis squamata*							
molluscs	Mouse-eared snail *(Ovatella myosotis)*			x	x	x		
crustaceans	Brown shrimp *(Crangon crangon)*			x	x	x	x	Creeks
birds	Shelduck *(Tadorna tadorna)*	x	x					Summer bird
	Ringed plover *(Charadrius hiaticula)*		x					Summer bird
	Barnacle goose *(Branta leucopsis)*					x		TS, BD
	Marsh harrier *(Circus aeruginosus)*						x	TS, BD
	Sanderling *(Calidris alba)*	x						
	Little tern *(Sterna albifrons)*		x					TS, BD, RL
	Twite *(Carduelis flavirostris)*						x	
	Black-headed gull *(Larus ridibundus)*			x	x	x	x	Creeks
	Spoonbill *(Platalea leucorodia)*						x	TS, BD, RL
	Brent goose *(Branta bernicla)*					x		TS
	Pintail *(Anas acuta)*			x	x	x	x	TS, RL, creeks
	Oystercatcher *(Haematopus*					x		TS
	Shoveler *(Anas clypeata)*			x	x	x	x	Creeks
	Wigeon *(Anas penelope)*					x		
	Snow bunting *(Plectrophenax nivalis)*						x	
	Common gull *(Larus canus)*		x					Summer bird
	Shore lark *(Eremophila alpestris)*	x					x	
	Snowy plover *(Charadrius*		x					TS, RL
	Common tern *(Sterna hirundo)*				x	x		TS BD, RL, summer
	Herring gull *(Larus argentatus)*							

Table 6.2.8.
List of species of the ecotopes of sediments in saline supralittoral zone.
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); RL = species listed in national Red List (both from Bal et al., 2001).

6.3 NORTH SEA

6.3.1 Ecotopes of hard substrata

High-energy sublittoral stone/wood in saline or variable brackish/saline water
Due to the high degree of wave action (large fetch), virtually all permanently submerged hard substrata along the North Sea coast are included in this ecotope. The mouths of the Westerschelde (pragmatically as far as the line Flushing-Breskens) and the Oosterschelde (up to the storm surge barrier) (see section 4.4: Figure 4.4.1) are included as well. The hard substratum mainly consists of the permanently submerged parts of pitchings and heavily exposed sides of jetties and groynes. Algae only develop poorly because of high-energy conditions. Moreover, possible algal growth is limited to the upper tens of centimetres of the sublittoral due to high water turbidity caused by high energy. In addition to limited algal growth, anemones, *Gammaridau*, common shore crabs, barnacles (*Cirripedia*) and starfish may occur in this ecotope (table 6.3.1). In locations on the North Sea coast where river effects or other discharge points of brackish (fresh) water are present, salinity shows great fluctuations. In such locations the number of species will be less than in its saline version.

Low-energy sublittoral stone/wood in saline or variably brackish/saline water
This low-energy ecotope includes permanently submerged hard substratum in sheltered locations on the North Sea coast, such as in ports and on the lee sides of jetties. The ecotope occurs only locally along the North Sea coast, as the entire North Sea coast is a high-energy ecotope due to the large fetch except for these sheltered areas. Due to low energy, algae mainly are well developed. In addition to algae, sponges, hydroids, anemones, crustaceans (e.g. common shore crabs *Carcinus maenas*, barnacles *Cirripedia*), sea squirts, star fish and fish (e.g. sea bass *Dicentrarchus labrax*) are living in the ecotope. The Pacific oyster-community (*Crassostrea gigas*) may occur in the ecotope as well (see appendix 4). In locations on the North Sea coast where river effects or other discharge points of brackish (fresh) water are present, salinity shows great fluctuations. In such locations the number of species will be less than in its saline version.

High-energy littoral stone/wood in saline or variably brackish/saline water
Due to the large fetch over the North Sea, there is a high degree of wave action (breaking waves) on the North Sea coast. Virtually all emerging hard substrata on the North Sea coast, therefore, are included in this high-energy ecotope. The mouths of the Westerschelde (pragmatically as far as the line Flushing-Breskens) and the Oosterschelde (up to the storm surge barrier) (see section 4.4: Figure 4.4.1) are included as well. The hard substratum consists for instance of pitchings, jetties, groynes and pile rows (see appendix 3). Algae develop poorly due to the strong wave action and the number of ecological communities is limited. Biodiversity within the ecological communities is low due to this high energy. In addition to the barnacle-periwinkle (*Cirripedia-Littorinidae*)-community, *Blindigia minima* and *Enteromorpha sp.*-communities may occur (see appendix 4). Sometimes small mussels (*Mytilus edulis*) are found. In locations on the North Sea coast where river effects or other discharge points of brackish (fresh) water are present, salinity shows great fluctuations. In such locations the number of species will be less than in its saline version.

Low-energy littoral stone/wood in saline or variably brackish/saline water
The ecotope occurs only locally along the North Sea coast, as the entire North Sea coast is a high-energy ecotope due to the large fetch except for these sheltered areas. In such locations only limited wave action is present (short fetch). Ecological communities that are to be expected are the barnacle-periwinkle (*Cirripedia-Littorinidae*), *Blidingia minima*, *Enteromorpha sp.*, *Fucus spiralis*, bladder wrack (*Fucus vesiculosus*) and *Fucus serratus* communities (see appendix 4). Frequently a broad zone with the knotted wrack-community (*Ascophyllum nodosum*) is present instead of the latter two. In ports, hard substratum is present between the mean low water mark and the mean low water mark at spring tide. We call this zone the infralittoral margin (see appendix 3). Various small green, brown and red algae may occur on the infralittoral margin. In locations on the North Sea coast where river effects or other discharge points of brackish (fresh) water are present, salinity shows great fluctuations. In such locations the number of species will be less than in its saline version.

Stone above the high water mark
A typical yellow-coloured lichens-community is present on hard substratum above the high water mark. This community may be grey or black as well. The lichen-community is mostly observed on all hard substrata that are present above the watermark. The greater part of the lichens belongs to the genera *Caloplaca* and *Xanthoria*, which are yellow. In addition species from the genera *Verrucaria* and *Lecanora* occur that are black and grey respectively. Next to lichens hardly any other species is

present in the community. Sometimes *Blidingia minima*, acorn barnacle (*Elminius modestus)*, the rough periwinkle (*Littorina saxatilis*), the common sea slater (*Ligia oceanica*) and the springtail *Lipura maritima* are seen at the zone's lower margin. Below the lichen-community, a community of cyanobacteria *Entophysalis deusta* may be present as a black band-like zone, which consists mainly of only this single cyanobacterium (Nienhuis, 1976). In spring the green-algae community of *Prasiola stipitata* may occur at virtually the same height (Den Hartog, 1959) (table 6.3.1.).

ECOTOPES OF THE HARD SUBSTRATUM IN THE NORTH SEA		High-energy sublittoral stone/wood	Low-energy sublittoral stone/wood	High-energy littoral stone/wood	Low-energy littoral stone/wood	Stone above the high water	
GROUPS	SPECIES						
cyanobacteria	*Entophysalis deusta*					x	
lichens	*Lichenes*					x	
algae	Bladder wrack (*Fucus vesiculosus*)				x		
	Enteromorpha spp.			x	x		
	Polysiphonia nigra	x	x				
	Irish moss *(Chondrus crispus)*		x				
	Toothed wrack (*Fucus serratus*)				x		
	Blidingia minima			x	x		
	Spiral wrack (*Fucus spiralis*)				x		
	Knotted wrack (*Ascophyllum nodosum*)				x		
	Ceramium rubrum	x	x				
	Purple laver *(Porphyra umbilicalis)*	x	x				
	Hypoglossum hypoglossoides		x				
	Bryopsis plumosa		x				
	Sea lettuce *(Ulva spp.)*	x	x				
sponges	Breadcrumb sponge *(Halichondria panicea)*	x	x				
	Mermaid's glove *(Haliclona oculata)*		x				
hydroids	Common flowerhead *(Tubularia larynx)*		x				
	Herringbone hydroid *(Halecium halecium)*		x				
	Hydractinea echinata	x	x				
	Sertulariidae		x				
	Tubularia spp.	x	x				
anemones	*Diadumene cincta*	x	x				
	Red sea anemone *(Actinea equina)*	x	x				
	Sagartia troglodytes	x	x				
	Sagartiogeton undatus	x	x				
	Plumose anemone *(Metridium senile)*	x	x				
molluscs	Periwinkles *(Littorinidae)*			x	x		
crustaceans	Velvet swimmer crab *(Necora puber)*		x				
	Edible crab *(Cancer pagurus)*		x				
	Caprella linearis	x	x				
	Common shore crab *(Carcinus maenas)*	x	x	x	x		
	Gammaridae	x					
	Barnacles *(Cirripedia)*	x	x	x	x		
bryozoans	*Electra pilosa*	x					
echinoderms	Common star fish *(Asterias rubens)*	x	x				
fish	Butter fish *(Pholis gunnellus)*		x		x		TS, RL
	Cod *(Gadus morhua)*		x		x		
	Bib *(Trisopterus luscus)*		x		x		
	Tadpole fish *(Raniceps raninus)*		x		x		TS, RL
	Sea bass *(Dicentrarchus labrax)*		x		x		
	Bull rout *(Myoxocephalus scorpius)*		x		x		

Table 6.3.1. *List of species of the ecotopes of the hard substrata in the North Sea.*
TS = target species Min. ANF; RL = species listed in national Red List (both from Bal et al., 2001)

6.3.2 ECOTOPES OF THE SUBLITTORAL SEDIMENT

High-energy beds in saline water
The ecotope is not subdivided any further after depth, as we assume hydrodynamics to be more determining in the occurrence of benthos. The ecotope includes e.g. the tidal channels north/west off the Wadden islands and in the Voordelta. High linear current velocities cause high-energy conditions in the tidal channels. The surf zone on the North Sea coast (the non-emerging part) is included in this ecotope as well. Along the coast, a high degree of wave action (large fetch)causes high-energy conditions. As the bed is constantly moving up to a certain depth, little benthic life is possible. The numbers of benthos, their biomass and biodiversity are low. A typical species of benthos in the surf zone is *Scolelepis squamata*. The water in the channels is an important means of transport for both adult benthic animals and fish and their larvae (Creutzberg, 1978; Dankers & Binsbergen, 1984; Hostens et al, 1978; Dankers & Binsbergen, 1984) (table 6.3.2). Sandwich terns (*Sterna sandvicensis*), Arctic terns (*Sterna paradisaea*), common tern (*Sterna hirundo*) and red-throated divers (*Gavia stellata*) and the like are foraging in the tidal channels. Grebes (*Podiceps cristatus*) and gulls (*Larus spp.*) are foraging in the surf zone.

Low-energy very deep beds rich in silt in saline water
In this ecotope, in the Netherlands only occurring in the North Sea, the bed is deeper than 30 metres and the sediment is rich in silt (> 10% silt). The ecotope occurs in the areas of the Oyster grounds and the Frisian Front. As water masses from the southern and central North Sea are meeting here, many nutrients can reach the bed in these areas. This causes high biodiversity, density and biomass of benthos to be present. Indicative species for the benthic communities of the Oyster grounds and the Frisian Front are for instance the worms *Glycera rouxi, Lumbrineris latreilli* and *Pholoe minuta*, the sand digger shrimp (*Callianassa subterranean*) and *Mysella bidentata*. Qua densities important species are *Amphiura filiformis* (a brittle star) and the bivalve *Mysella bidentata*. Typical species of the northern and central part of the DCS, in which the Oyster grounds and Frisian Front are situated, are e.g. parchment worms (*Chaetopterus variopedatus*) and the amphipod *Harpinia antennaria* (Holtmann et al., 1996). Due to the food present (in particular pelagic fish, not included in ZES.1) the Oyster grounds and the Frisian Front are important areas for sea birds such as razorbills (*Alca torda*), guillemots (*Uria aalge*) and kittiwakes (*Rissa tridactyla*), and for marine mammals such as the porpoise (*Phocoena phocoena*) as well.

Low-energy very deep fine sands in saline water
In this ecotope, in the Netherlands only occurring in the North Sea, the bed is deeper than 30 metres and the sediment consists of fine sands. The ecotope occurs in large parts of the central DCS, such as in and around the areas of the Oyster grounds and the Frisian Front. Benthic biodiversity, density and biomass in general are lower than in the beds rich in silt in these areas. Indicative species of this ecotope are *Scoloplos armiger* (a bristle worm), the small crustaceans *Eudorellopsis deformis* and *Harpinia antennaria*, and the bean-like tellin (*Tellina fabula*). A typical species of the northern and central part of the DCS is for instance the parchment worm (*Chaetopterus variopedatus*). Important species qua densities are the worms *Spiophanes bombyx* and *Magelona papillicornis, Amphiura filiformis* (a brittle star) and the bivalve *Mysella bidentata* (Holtmann et al., 1996). Due to the food present (in particular pelagic fish, not included in ZES.1) the Oyster grounds and the Frisian Front are important areas for sea birds such as razorbills (*Alca torda*), guillemots (*Uria aalge*) and kittiwakes (*Rissa tridactyla*), and for marine mammals such as the porpoise (*Phocoena phocoena*) as well.

Low-energy very deep coarse sands in saline water
In this ecotope, in the Netherlands only occurring in the North Sea, the bed is deeper than 30 metres and the sediment consists of coarse sands (median grain size > 250 µm). The acreage of this ecotope is limited, it is present at least near the Cleaver banks (northwestern DCS). Indicative species of benthic communities in this ecotope are a catworm (*Nephtys cirrosa*) and the small crustacean *Bathyporeia guilliamsoniana* (Holtmann et al., 1996). Qua densities the worms *Spiophanes bombyx* and *Magelona papillicornis* may be important, qua biomass the sea potato (*Echinocardium cordatum*). A typical species of sandy sediments in the central North Sea is Alder's necklace shell (*Lunatia alderi*).

Low-energy very deep gravel beds in saline water
In this ecotope, in the Netherlands only occurring in the North Sea, the bed is deeper than 30 metres and the sediment consists of gravel. The ecotope occurs in the northwestern part of the

DCS, the Cleaver banks. The benthic community present on and in gravel is clearly different from communities in sandy sediment and those rich in silt. Many species occur that are typical of hard substrata, such as sea anemones and polypites. Cold-water corals are present as well. Shellfish are numerous and have a high biomass individually. The Cleaver bank is important to long-lived species such as the Icelandic cyprine (*Arctica islandica*) and the common whelk (*Buccinum undatum*). Many starfish (e.g. sand star *Astropecten irregularis*), sea cucumbers and sea urchins (sea potato *Echinocardium cordatum*) are present as well.

Low-energy deep beds rich in silt in saline water
In this ecotope the bed is between 20 and 30 metres and the sediment is rich in silt. The ecotope is only occurring very locally. The benthic fauna may be similar to the fauna in the surrounding fine sands. Qua densities the worms *Spiophanes bombyx* and *Magelona papillicornis* may be important, qua biomass the sea potato (*Echinocardium cordatum*) (Holtmann et al., 1996) (table 6.3.3).

Low-energy deep fine sands in saline water
In this ecotope the bed is between 20 and 30 metres and the sediment consists of fine sands. This ecotope includes large parts of the Southern Bight, but the Dogger Bank in the northern part of the DCS as well. Indicative species for benthic communities in the depth zone of 20 to 30 metres in the North Sea (including the Dogger Bank) are a catworm (*Nephtys cirrosa*) and the small crustacean *Bathyporeia guilliamsoniana* (Holtmann et al., 1996). Qua densities the worms *Spiophanes bombyx* and *Magelona papillicornis* may be important, qua biomass the sea potato (*Echinocardium cordatum*). Due to the food present (in particular pelagic fish, not included in ZES.1) the Oyster grounds and the Frisian Front are important areas for sea birds such as razorbills (*Alca torda*), guillemots (*Uria aalge*) and kittiwakes (*Rissa tridactyla*), and for marine mammals such as the porpoise (*Phocoena phocoena*) as well.

Low-energy deep coarse sands in saline water
In this ecotope the bed is between 20 and 30 metres and the sediment consists of coarse sands (median grain size > 250 µm). The southern part of the Southern Bight in particular is included in the ecotope. Indicative species for benthic communities in the depth zone of 20 to 30 metres in the North Sea (including the Dogger Bank) are a catworm (Nephtys cirrosa) and the small crustacean *Bathyporeia guilliamsoniana* (Holtmann et al., 1996). Species occurring exclusively in sandy beds in the southern part of the North Sea are *Donax vittatus* and the worm *Aricidea minuta*. The worms *Spiophanes bombyx* and *Magelona papillicornis* may be important qua densities, and qua biomass the sea potato (*Echinocardium cordatum*).

Low-energy shallow beds rich in silt in saline water
In this ecotope the bed is at less than 20 metres and the sediment is rich in silt. The ecotope occurs in the coastal area, however, beds rich in silt occur but very locally. The benthic fauna is probably similar to that of the surrounding fine sands in the coastal area. Indicative species for benthic communities in the coastal area are a catworm (*Nephtys hombergii*), the cut trough clam (*Spisula subtruncata*) and the Baltic tellin (*Macoma balthica*) (Holtmann et al., 1996). In locations on the North Sea coast where river effects or other discharge points of brackish (fresh) water are present, salinity shows great fluctuations. In such locations the number of species will be less than in its saline version.

Low-energy shallow fine sands in saline water
In this ecotope the bed is at less than 20 metres and the sediment consists of fine sands. The ecotope includes the greater part of the coastal area. Indicative species for benthic communities in the coastal area are a catworm (*Nephtys hombergii*), the cut trough clam (*Spisula subtruncata*) and the Baltic tellin (*Macoma balthica*) (Holtmann et al., 1996). Locally in the coastal area benthic biodiversity and biomass may be high. Large stocks of shellfish may occur, such as cut trough clam banks (*Spisula subtruncata*) and American razor clam banks (*Ensis directus*). The presence of these beds and the densities present vary strongly annually. Such shell banks are an important source of food for eiders (*Somateria mollissima*) and common scoters (*Melanitta nigra*). The coastal area of the North Sea is important as nursery grounds to many species of fish. Species of fish living near the bed in the coastal area are e.g. flounder (*Platichthys flesus*), plaice (*Pleuronectes platessa*), dab (*Limanda limanda*) and sole (*Solea solea*). In locations on the North Sea coast where river effects or other discharge points of brackish (fresh) water are present, salinity shows great fluctuations. In such locations the number of species will be less than in its saline version.

Low-energy shallow coarse sands in saline water
In this ecotope the bed is at less than 20 metres and the sediment consists of coarse sands (median grain size > 250 µm). The ecotope includes parts of the coastal area. Indicative species for benthic communities in the coastal area are a catworm (*Nephtys hombergii*), the cut trough clam (*Spisula subtruncata*) and the Baltic tellin (*Macoma balthica*) (Holtmann et al., 1996). Locally in the coastal area benthic biodiversity and biomass may be high. Large stocks of shellfish may occur, such as cut trough clam banks (*Spisula subtruncata*) and American razor clam banks (*Ensis directus*). The presence of these beds and the densities present vary strongly annually. Such shell banks are an important source of food for eiders (*Somateria mollissima*) and common scoters (*Melanitta nigra*). The coastal area of the North Sea is important as nursery grounds to many species of fish. Species of fish living near the bed in the coastal area are e.g. flounder (*Platichthys flesus*), plaice (*Pleuronectes platessa*), dab (*Limanda limanda*) and sole (*Solea solea*). In locations on the North Sea coast where river effects or other discharge points of brackish (fresh) water are present, salinity shows great fluctuations. In such locations the number of species will be less than in its saline version.

6.3.3 Ecotopes of the littoral and sublittoral sediments

As the ecological content of the littoral and supralittoral ecotopes in the North Sea does not deviate from the other tidal waters, we refer to the description and lists of species in section 6.2. The littoral and supralittoral ecotopes occurring in the North Sea are listed in table 6.2.5 to 6.2.8, and in table 6.3.4.

ECOTOPES OF HIGH ENERGY, LOW ENERGY VERY DEEP SEDIMENTS IN THE NORTH SEA		High-energy beds	Low-energy very deep beds rich in silt	Low-energy very deep fine sands	Low-energy very deep coarse sands	Low-energy very deep gravels
GROUPS	SPECIES					
worms	*Anaitides groenlandica*			x	x	
	Scolelepis squamata	x				
	Glycera rouxi		x	x		
	Harmothoe spp.		x	x		
	Lumbrineris latreilli		x	x		
	Magelona papillicornis		x	x	x	x
	Ophelia borealis			x	x	
	Parchment worm *(Chaetopterus variopedatus)*		x	x		
	Pholoe minuta		x			
	Spio filicornis		x	x	x	x
	Spiophanes bombyx		x	x	x	x
	Scoloplos armiger			x	x	x
	White catworm (*Nephtys cirrosa*)			x	x	x
molluscs	Alder's necklace shell *(Lunatia alderi)*			x	x	
	Red whelk *(Neptunea antiqua)*					x
	Icelandic cyprine (*Arctica islandica*)		x	x	x	x
	Bean-like tellin (*Tellina fabula*)			x		
	Nucula nitidosa		x	x		
	Mysella bidentata		x	x		
	Chamelea striatula			x	x	
	Abra alba		x	x		
	Common whelk (*Buccinum undatum*)		x	x	x	x
crustaceans	*Bathyporeia guilliamsoniana*			x	x	
	Callianassa subterranea		x			
	Eudorellopsis deformis			x		
	Harpinia antennaria (amphipod)		x	x		
	Macropipus holsatus		x	x	x	x

	Common hermit crab *(Eupagurus bernhardus)*		x	x	x	x	
	Pandalus montagui					x	
echinoderms	Brittle star *(Amphiura filiformis)*		x	x	x	x	
	Echinocyamus pusillus				x	x	
	Brittle star *(Ophiura texturata)*			x	x		
	Sea potato *(Echinocardium cordatum)*		x	x	x	x	
	Sand star *(Astropecten irregularis)*		x	x	x	x	
	Brittle star *(Ophiura albida)*			x	x		
fish	Herring *(Clupea harengus)*		x	x	x	x	
	Small spotted catshark *(Scyliorhinus canicula)*		x	x	x	x	
	Cod *(Gadus morhua)*		x	x	x	x	
	Nursehound *(Scyliorhinus stellaris)*		x	x	x	x	
	Thornback ray *(Raja clavata)*		x	x	x	x	
	Common skate *(Raja batis)*		x	x	x	x	
birds	Razorbill *(Alca torda)*		x	x			
	Kittiwake *(Rissa tridactyla)*		x	x	x	x	
	Little gull *(Larus minutus)*	x					TS
	Grebe (*Podiceps cristatus)*	x					
	Sandwich tern (*Sterna sandvicensis*)	x					TS, BD, RL
	Gannet *(Morus bassanus)*		x	x	x	x	
	Lesser black-backed gull *(Larus fuscus)*	x					TS
	Black-headed gull (*Larus ridibundus)*	x					
	Arctic tern (*Sterna paradisaea*)	x					TS, BD, RL
	Fulmar *(Fulmarus glacialis)*		x	x	x	x	
	Red-throated diver (*Gavia stellata)*	x					TS, BD
	Common tern *(Sterna hirundo)*	x					TS, BD, RL
	Guillemot *(Uria aalge)*		x	x			
	Herring gull *(Larus argentatus)*	x					
Marine mammals	Porpoise *(Phocoena phocoena)*	x	x	x	x	x	TS, HD2/4, RL
	Common seal *(Phoca vitulina)*	x	x	x	x	x	TS, HD2, RL
	Grey seal *(Halichoerus grypus)*	x	x	x	x	x	TS, HD2, RL
eco-elements	Shipwrecks	x	x	x	x	x	

Table 6.3.2. *The list of species of ecotopes of the sublittoral sediments in the North Sea (high energy and low energy very deep).*
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); HD2 = species of the EU Habitats Directive (appendix 2); HD2/4 = species of the EU Habitats directive, (appendices 2 and 4); RL = species listed in national Red List (both from Bal et al., 2001).

ECOTOPES OF LOW-ENERGY DEEP AND SHALLOW SEDTMENTS IN THE NORTH SEA		Low-energy deep beds rich in silt	Low-energy deep fine sands	Low-energy deep coarse sands	Low-energy shallow beds rich in	Low-energy shallow fine sands	Low-energy shallow coarse sands	
GROUPS	SPECIES							
worms	*Anaitides groenlandica*		x	x		x	x	
	Aricidea minuta		x	x		x	x	
	Harmothoe spp.	x	x	x	x	x	x	
	Magelona papillicornis	x	x	x	x	x	x	
	Ophelia borealis		x	x		x	x	
	Spio filicornis	x	x	x	x	x	x	
	Spiophanes bombyx	x	x	x	x	x	x	
	Scoloplos armiger	x	x	x	x	x	x	
	Clamworm (*Nephtys cirrosa*)		x	x		x	x	
	Clamworm (*Nephtys hombergii*)				x	x	x	
molluscs	Razor clam *(Ensis directus)*		x	x		x	x	
	Alder's necklace shell *(Lunatia alderi*)		x	x		x	x	
	Cut trough shell *(Spisula subtruncata.)*				x	x	x	
	Baltic tellin *(Macoma balthica)*				x	x	x	

	Tellina fabula	x	x		x	x		
	Tellina tenui		x			x		
	Abra alba	x	x		x	x		
	Donax vittatus		x	x		x	x	
crustaceans	*Bathyporeia guilliamsoniana*		x	x		x	x	
	Macropipus holsatus	x	x	x	x	x	x	
	Common hermit crab *(Eupagurus bernhardus)*	x	x	x	x	x	x	
Echinoderms	*Echinocyamus pusillus*		x	x				
	Brittle star *(Ophiura texturata)*	x	x	x	x	x	x	
	Sea potato *(Echinocardium cordatum)*	x	x	x	x	x	x	
fish	Flounder *(Platichthys flesus)*	x	x	x	x	x	x	
	Herring *(Clupea harengus)*	x	x	x	x	x	x	
	Cod *(Gadus morhua)*	x	x	x	x	x	x	
	Dab *(Limanda limanda)*	x	x	x	x	x	x	
	Plaice *(Pleuronectes platessa)*	x	x	x	x	x	x	TS
	Sole *(Solea solea)*	x	x	x	x	x	x	TS
birds	Cormorant *(Phalacrocorax carbo)*				x	x	x	TS
	Razorbill *(Alca torda)*		x					Dogger bank
	Common goldeneye *(Bucephala clangula)*				x	x	x	
	Kittiwake *(Rissa tridactyla)*	x	x	x				
	Little gull *(Larus minutus)*				x	x	x	TS
	Eider *(Somateria mollissima)*				x	x	x	TS, RL
	Grebe (*Podiceps cristatus)*				x	x	x	
	Sandwich tern (*Sterna sandvicensis*)				x	x	x	TS, BD, RL
	Velvet scoter *(Melanitta fusca)*				x	x	x	
	Gannet *(Morus bassanus)*	x	x	x				
	Lesser black-backed gull *(Larus fuscus)*				x	x	x	TS
	Black-headed gull (*Larus ridibundus)*				x	x	x	
	Arctic tern (*Sterna paradisaea*)				x	x	x	TS, BD, RL
	Fulmar *(Fulmarus glacialis)*	x	x	x				
	Red-throated diver (*Gavia stellata)*				x	x	x	TS, BD
	Common tern *(Sterna hirundo)*				x	x	x	TS, BD, RL
	Guillemot *(Uria aalge)*		x					Dogger bank
	Herring gull *(Larus argentatus)*				x	x	x	
	Common scoter *(Melanitta nigra)*				x	x	x	
marine mammals	Porpoise *(Phocoena phocoena)*	x	x	x	x	x	x	TS, HD2/4, RL
	Common seal *(Phoca vitulina)*	x	x	x	x	x	x	TS, HD2, RL
	Grey seal *(Halichoerus grypus)*	x	x	x	x	x	x	TS, HD2, RL
eco-elements	Shipwrecks	x	x	x	x	x	x	

Table 6.3.3.
The list of species of ecotopes of the sublittoral sediments in the North Sea (low energy deep and shallow).
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); HD2 = species of the EU Habitats Directive (appendix 2); HR2/4 = species of the EU Habitats Directive(appendices 2 and 4); RL = species listed in national Red List (both from Bal et al., 2001).

ECOTOPES OF HIGH-ENERGY LITTORAL AND SHORE SEDIMENTS IN THE NORTH SEA (remaining littoral in table 6.2.6; salt marshes in table 6.2.8)		Low high-energy littoral zone, the 'wet shore'	Low high-energy supralittoral zone, the 'dry shore'	High, high-energy supralittoral zone, 'embryonic dunes'	
GROUPS	SPECIES				
plants	Sand twitch *(Elytrigia junceiformis)*		x	x	TS
	Marram Grass *(Ammophila arenaria)*			x	
	Sea kale (*Crambe maritime*)		x	x	

	Sea Rocket *(Cakile maritima)*		x	x	
	Samphire (*Crithmum maritimum)*		x	x	TS; RL
crustaceans	Sand hopper (*Gammarus* spec.)	x	x		
worms	*Scolelepis squamata*	x	x		
birds	Shelduck *(Tadorna tadorna)*			x	TS, summer bird
	Common ringed plover *(Charadrius hiaticula)*			x	summer bird
	Dunlin *(Calidris alpina)*	x	x		TS
	Sanderling *(Calidris alba)*	x	x		
	Little tern *(Sterna albifrons)*			x	TS, BD, RL, summer bird
	Lesser black-backed gull *(Larus fuscus)*			x	TS, summer bird
	Black-headed gull *(Larus ridibundus)*	x	x		
	Oystercatcher *(Haematopus ostralegus)*	x	x		TS
	Common gull *(Larus canus)*			x	TS, summer bird
	Snowy plover *(Charadrius alexandrinus)*			x	TS, RL, summer bird
	Herring gull *(Larus argentatus)*			x	summer bird

Table 6.3.4.
The list of species of the high-energy littoral sediments and beaches of the North Sea. We refer to table 6.2.6 (section 6.2) for the species lists of the low-energy sediments, for that of the salt marshes to table 6.2.8 (section 6.2).
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); RL = species listed in national Red List (both from Bal et al., 2001).

6.4 ECOTOPES IN THE GREVELINGENMEER

Low-energy sublittoral stone/wood in saline water
The hard substrata along the shores of the Grevelingenmeer are of low energy because of the limited fetch and wave action with respect to the North Sea coast (see section 4.4: Figure 4.4.1). The hard substrata consist mainly of pitchings, jetties and groynes. Only recently artificial reefs (concrete spheres with holes in them) have been placed in the Grevelingenmeer in various locations. Due to poor mixing of the water temperature stratification occurs frequently in summer. This may cause that in due time a lack of oxygen occurs in the lower water layer causing massive mortality of benthos. The water in the Grevelingenmeer is usually rather clear and algae are found to a depth of five metres below the water level. The hard substratum is covered with algae (e.g. wireweed *Sargassum muticum*), sponges, anemones (e.g. *Sagartiogeton undatus*) and sea squirts (e.g. *Ascidiella aspersa*), between which crustaceans; echinoderms and small fish (such as butterfish (*Pholis gunnellus)*, Black goby (*Gobius niger*)) find shelter (Van Geldere & Vanalderweireldt, 1995). The Pacific oyster-community (*Crassostrea gigas*) may occur in the ecotope as well (see table 6.4.1.).

Low-energy sublittoral consolidated peat layer in saline water
At least one consolidated peat layer occurs near Scharendijke in the Grevelingenmeer. This consolidated peat layer offers grip to similar algae and sessile animals that are found on the artificial hard substratum in the Grevelingenmeer (Meijer & Waardenburg, 2002). Algae that are present on the consolidated peat layers are species like *Bryopsis plumosa* and sea lettuce (*Ulva lactuca*). In addition, sponges and anemones occur on the peat and it offers suitable conditions for *Petricola pholadiformis*. The overhanging grotto-like structures offer accommodation and shelter to for instance crustaceans and fish (e.g. tadpole fish *Raniceps raninus*, sea bass *Dicentrarchus labrax*) (Meijer & Waardenburg, 2002).

Stone above the watermark in saline water
A typical yellow-coloured lichens-community is present on hard substratum above the high water mark. This community may be grey or black as well. The lichen-community is mostly found on all hard substrata that are present above the watermark. The greater part of the lichens belongs to the genera Caloplaca and *Xanthoria*, which are yellow. In addition species from the genera *Verrucaria* and *Lecanora* occur that are black and grey respectively. Next to lichens hardly any other species is present in the community. Sometimes *Blidingia minima*, an acorn barnacle *Elminius modestus*, the rough periwinkle (*Littorina saxatilis*), the common sea slater (*Ligia oceanica*) and the springtail *Lipura maritima* are seen at the zone's lower margin. Below the lichen-community, a community of cyanobacteria *Entophysalis deusta* may be present as a black band-like zone, which consists mainly of only that single cyanobacterium (Nienhuis, 1976). In spring the green-algae community of Prasiola *stipitata* may occur at virtually the same height (Den Hartog, 1959).

Very deep beds in stagnant saline water

Because of the stagnant saline water this ecotope is specific for the Grevelingenmeer. The bed in this ecotope is deeper than fifteen metres. Due to poor mixing of the water a temperature stratification occurs in the Grevelingenmeer in spring and summer. The upper water layer is warmer and with it lighter than the lower and colder water layer. Due to poor mixing of the water layers anoxic conditions may occur in the lower water layer in due time. This may cause massive mortality of organisms. During or shortly after these anoxic conditions hardly any benthic fauna is present in this ecotope. An obvious example of this ecotope is the deep pits in the Grevelingenmeer that become anoxic in summer (for instance near Scharendijke and Den Osse) (from Hoeksema, 2002).

Deep beds in stagnant saline water
Because of the stagnant saline water this ecotope is specific for the Grevelingenmeer. The bed is between fifteen and five metres below the water level. Worms are most important qua densities and molluscs qua biomass in the sediments in the Grevelingenmeer as a whole. Worms occurring much are oligochaetes, the gallery worm (*Capitella capitata*) and the clam worm (*Nereis virens*). The most important mollusc is the slipper limpet (*Crepidula fornicata*) both qua numbers and qua biomass. In addition, the Pacific oyster (*Crassostrea gigas*) (eco-element) is currently booming and is competing with the native oyster (*Ostrea edulis*) (from Hoeksema, 2002). Fish-eating birds occurring mostly in the Grevelingenmeer are the merganser (*Mergus serrator*), grebe (*Podiceps cristatus*) and eared grebe (*Podiceps nigricollis*) (Berrevoets et al., 2002) (table 6.4.2.).

Shallow beds in stagnant saline water
Because of the stagnant saline water this ecotope is specific for the Grevelingenmeer. The bed is at less than five meters below the water level, due to which anoxic conditions will not appear quickly. Worms are most important qua densities and molluscs qua biomass in the sediment in the Grevelingenmeer as a whole. Worms occurring much are oligochaetes, the gallery worm (*Capitella capitata*) and the clam worm (*Nereis virens*). The most important mollusc is the slipper limpet (*Crepidula fornicata*) both qua numbers and qua biomass. In addition the Pacific oyster (*Crassostrea gigas*) (eco-element) is currently booming and is competing with the native oyster (*Ostrea edulis*) (from Hoeksema, 2002). In the ecotope eel grass beds (Zostera marina) may occur (eco-element), offering opportunities to all kinds of small fish and plant-eaters. Currently, no sea grass beds are present anymore in the Grevelingenmeer (from Hoeksema, 2002). Fish-eating birds occurring mostly in the Grevelingenmeer are the merganser (*Mergus serrator*), grebe (*Podiceps cristatus*) and eared grebe (*Podiceps nigricollis*) (Berrevoets et al., 2002).

Open saline vegetation on the shores of stagnant saline water
The part of the shores of the Grevelingenmeer that is frequently affected by saline water is bare, or sparsely covered with glasswort (*Salicornia spp.*) and/or annual sea-blite (*Suaeda maritima*). Ringed plovers (*Charadrius hiaticula*) and avocets (*Recurvirostra avosetta*) are nesting on the shores of the lake that are rich in silt. Vast, bare planes, like those occurring on the Slikken van Flakkee are important nesting sites for snowy plovers (*Charadrius alexandrinus*) and ringed plovers (*Charadrius hiaticula*).

Close saline vegetation on the shores of stagnant saline water
The effect of the saline water in this ecotope is less than in the ecotope with an open saline vegetation. It causes opportunities for a further succession of the plant communities. Little bare sediment is present in this ecotope. Generally occurring plant species are common salt-marsh grass (*Puccinellia maritima*), sea spurrey (*Spergularia salina*) and sea aster (*Aster tripolium*). On the covered shores of the Grevelingenmeer barnacle geese (*Branta leucopsis*), white-fronted geese (*Anser albifrons*), brent geese (*Branta bernicla*) and wigeons (*Anas penelope*) overwinter. The Hompelvoet is an important nesting site for the Sandwich tern (*Sterna sandvicensis*).

Close brackish vegetation on the shores of stagnant saline water
On nearly all desalinated parts of the shores of the Grevelingenmeer creeping bent (*Agrostis stolonifera*) and red fescue (*Festuca rubra*) are present. As desalination progresses, the vegetation becomes more diverse. Also species such as sea pearlwort (*Sagina maritima*), buck's-horn plantain (*Plantago coronopus*), lesser centaury (*Centaurium pulchellum*), sea milkwort (*Glaux maritima*) and salt mud rush (*Juncus gerardii*) may occur. The upper boundary of the ecotope is at the level at which the contribution of halophytes in the vegetation cover is less than 5%. The grazed areas are suitable as nesting grounds for meadow birds such as lapwings (*Vanellus vanellus*) and common redshank (*Tringa totanus*).

ECOTOPES OF THE HARD SUBSTRATUM IN THE GREVELINGENMEER		Low-energy sublittoral stone/wood	Low-energy sublittoral consolidated peat layers	Stones above the water mark	
GROUPS	SPECIES				
cyanobacteria	*Entophysalis deusta*			X	
lichens	*Caloplaca spp.*			X	
	Xanthoria spp.			x	
	Verrucaria spp.			x	
	Lecanora spp.			x	
algae	Japweed or wireweed *(Sargassum muticum)*	x			
	Bryopsis plumosa	x	x		
	Codium fragile	x			
	Sea lettuce *(Ulva lactuca)*	x	x		
sponges	*Cliona celata*	x	x		
	Mermaid's gloves *(Haliclona oculata)*	x	x		
	Halichondria bowerbanki)	x	x		
anemones	*Diadumene cincta*	x	x		
	Sagartiogeton undatus	x	x		
molluscs	American piddock *(Petricola pholadiformis)*		x		
	Pacific Oyster *(Crassostrea gigas)*	x			
	Mussel *(Mytilus edulis)*	x			
	Flat periwinkle *(Littorina littoralis)*	x			
crustaceans	Acorn barnacle *(Elminius modestus)*	x			
	Common shore crab *(Carcinus maenas)*	x	x		
echinoderms	Common star fish *(Asterias rubens)*	x	x		
tunicates	Sea squirt *(Ciona intestinalis)*	x	x		
	Leathery sea squirt *(Styela clava)*	x	x		
	Sea squirt *(Ascidiella aspersa)*	x	x		
fish	Butterfish *(Pholis gunnellus)*	x	x		TS, RL
	Great pipefish *(Syngnathus acus)*	x	x		
	Lesser pipefish *(Syngnathus rostellatus)*	x	x		
	Common eel *(Anguilla anguilla)*	x	x		
	Eelpout *(Zoarces viviparus)*	x	x		TS
	Tadpole fish *(Raniceps raninus)*	x	x		TS, RL
	Bull rout *(Myoxocephalus scorpius)*	x	x		
	Sea bass *(Dicentrarchus labrax)*	x	x		
	Black goby *(Gobius niger)*	x	x		TS, RL

Table 6.4.1.
List of species of the ecotopes of the hard substratum in the Grevelingenmeer.
TS = target species Min. ANF; RL = species listed in national Red List (both from Bal et al., 2001)

ECOTOPES OF SEDIMENTS IN THE GREVELINGENMEER

GROUPS	SPECIES	Very deep water	Deep water	Shallow water	Open saline vegetation	Close saline vegetation	Close brackish vegetation	
plants	Creeping Bent *(Agrostis stolonifera)*						x	
	Lesser Centaury *(Centaurium pulchellum)*						x	
	Common Salt-marsh Grass *(Pucinellia maritima)*					x		
	Buck's-horn Plantain *(Plantago coronopus)*						x	
	Sea Milkwort *(Glaux maritima)*						x	
	Red Fescue *(Festuca rubra)*						x	
	Annual Sea-blite *(Suaeda maritima)*				x			
	Sea aster *(Aster tripolium)*					x		
	Glasswort *(Salicornia spp.)*				x			
	Sea Pearlwort *(Sagina maritima)*						x	
	Salt Mud Rush *(Juncus gerardii)*						x	
	Sea Spurrey *(Spergularia salina)*					x		
oligochaetes	*Oligochaeta*	x	x	x				
worms	*Anaitides maculata*	x	x	x				
	(Eteone longa)	x	x	x				
	Magelona papillicornis			x				
	Pholoe minuta			x				
	Pygospio elegans			x				
	Gallery worm *(Capitella capitata)*	x	x	x				
	Tharyx marioni			x				
	(Scoloplos armiger)			x				
	Catworm *(Nephtys hombergii, N. caeca)*			x				
	Clam worm *(Nereis virens)*	x	x	x				
molluscs	Netted dog whelk *(Nassarius reticulatus)*			x				
	Pacific Oyster *(Crassostrea gigas)*		x	x				
	Common cockle *(Cerastoderma edule)*			x				
	Mussel *(Mytilus edulis)*			x				
	Slipper limpet *(Crepidula fornicata)*		x	x				
	Native oyster *(Ostrea edulis)*		x	x				
	Sand gaper *(Mya arenaria)*		x	x				
	Abra tenuis			x				
	Mysella bidentata			x				
	Abra alba			x				
crustaceans	Brown shrimp *(Crangon crangon)*			x				
	Hog louse *(Idotea chelipes)*			x				
	Mud shrimp *(Corophium volutator)*			x				
	Sea slater *(Idotea granulosa)*			x				
fish	Flounder *(Platichthys flesus)*		x	x				
	Great pipefish *(Syngnathus acus)*		x	x				
	Lesser pipefish *(Syngnathus rostellatus)*		x	x				
	Common eel *(Anguilla anguilla)*		x	x				
	Plaice *(Pleuronectes platessa)*		x	x				TS
	Sole *(Solea solea)*		x	x				TS
birds	Common ringed plover *(Charadrius hiaticula)*				x			summer bird
	Lesser whitethroat *(Sylvia curruca)*						x	densely vegetated grounds
	Barnacle goose *(Branta leucopsis)*					x		TS, BD, overwinter
	Common goldeneye *(Bucephala clangula)*		x	x				
	Willow warbler*(Phylloscopus trochilus)*						x	densely vegetated grounds

	Grebe *(Podiceps cristatus)*		x	x				
	Eared grebe *(Podiceps nigricollis)*		x	x				TS, RL
	Golden plover *(Pluvialis apricaria)*						x	grazed areas
	Sandwich tern *(Sterna sandvicensis)*					x		TS, BD, RL, summer bird
	Common whitethroat *(Sylvia communis)*						x	densely vegetated grounds
	Lapwing *(Vanellus vanellus)*						x	grazed areas
	Avocet *(Recurvirostra avosetta)*				x			TS, BD, summer bird
	White-fronted goose *(Anser albifrons)*					x		overwinter
	Gadwall *(Anas strepera)*			x				overwinter
	Red-breasted merganser *(Mergus serrator)*		x	x				overwinter
	Pintail *(Anas acuta)*			x		x		TS, RL
	Brent goose *(Branta bernicla)*					x		TS, overwinter
	Wigeon *(Anas penelope)*			x		x		overwinter
	Snowy plover*(Charadrius alexandrinus)*				x			TS, RL, summer bird
	Common redshank *(Tringa totanus)*						x	TS, RL, grazed
eco-elements	Sea grass bed *(Zostera marina)*			x				TS, RL
	Oyster bed *(Crassostrea gigas)*		x	x				

Table 6.4.2.
List of species of the ecotopes of sediments in the Grevelingenmeer.
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); RL = species listed in national Red List (both from Bal et al., 2001).

6.5 VEERSE MEER

Low-energy sublittoral stone/wood in brackish water
The hard substratum along the shores of the Veerse Meer is that of low energy because of the limited fetch and wave action with respect to the North Sea coast (see section 4.4: Figure 4.4.1). The hard substratum consists mainly of pitchings, jetties and groynes. Due to poor mixing in the water column (salinity-)stratification may occur. This causes possibly a lack of oxygen in the lower parts of the ecotope, causing massive mortality of benthos. Algae (such as sea lettuce *Ulva spp.*) are occurring down to a limited depth. In addition hydroids (*Campanulariidae*), anemones and sea squirts (e.g. *Molgula manhattensis*) are present on the hard substratum. Biodiversity is lower than in the Grevelingenmeer partly due to the brackish water. Typical crustaceans of brackish water are the mysid *Praunus flexuosa* and *Rhithropanopeus harrisii*.

Stone above the watermark in brackish water
A typical yellow-coloured lichens-community is present on hard substratum above the high water mark (table 6.5.1). This community may be grey or black as well. The lichen-community is mostly observed on all hard substrata that are present above the watermark. The greater part of the lichens belongs to the genera *Caloplaca* and *Xanthoria*, which are yellow. In addition, species from the genera *Verrucaria* and *Lecanora* occur that are black and grey respectively. Next to lichens hardly any other specie are present in the community. Sometimes *Blidingia minima*, an acorn barnacle *Elminius modestus*, the rough periwinkle (*Littorina saxatilis*), the common sea slater (*Ligia oceanica*) and the springtail *Lipura maritima* are seen at the zone's lower margin. Below the lichen-community, a community of cyanobacteria *Entophysalis deusta* may be present as a black band-like zone, which consists mainly of only this single cyanobacterium (Nienhuis, 1976).

Very deep beds in stagnant brackish water
This ecotope occurs but in the Veerse Meer because of the stagnant brackish water. The bed is deeper than ten metres below water level in this ecotope. Due to poor mixing of the water, in particular in times of little wind, (salinity-) stratification frequently occurs in the Veerse Meer (Wattel, 1994). This may cause that in due time a lack of oxygen occurs in the lower water layer causing massive mortality of benthos. Densities, biomass and biodiversity of benthos are low in this ecotope. During or shortly after these anoxic conditions hardly any benthic fauna is present in this ecotope.

Deep beds in stagnant brackish water

This ecotope occurs but in the Veerse Meer because of the stagnant brackish water. The bed is between ten and five metres below the water level. Benthic biodiversity is low, partly because of the brackish water. Benthic density and biomass are considerably lower than in its shallow version. Oligochaetes form an important group qua densities in this ecotope. The worm *Pygospio elegans* occurs in large densities as well. The mussel (*Mytilus edulis*) is qua biomass, but not qua density an important species in this ecotope (Brummelhuis et al., 1996).

Shallow beds in stagnant brackish water
This ecotope occurs but in the Veerse Meer because of the stagnant brackish water. The bed in this ecotope is less than five metres. The benthic biodiversity is low. The benthic densities and the biomass are higher than in its deeper version. Oligochaetes form an important group qua densities in this ecotope. The worm *Pygospio elegans* occurs in large densities as well. The lugworm (*Arenicola marina*) is an important species qua biomass in this ecotope (Brummelhuis, 1996). In the ecotope Ruppia-associations (*Ruppia maritima, R. cirrhosa*) and eel grass beds (Zostera marina) (eco-elements) may occur.

Open saline vegetation on the shores of stagnant brackish water
The part of the shores of the Veerse Meer that is frequently affected by the saline water is bare, or sparsely covered with glasswort (*Salicornia spp.*), sea-blite (*Suaeda maritima*) and/or sea spurrey (*Spergularia salina*). Ringed plovers (*Charadrius hiaticula*) and avocets (*Recurvirostra avosetta*) are nesting on the shores of the lake that are rich in silt.

Close saline vegetation on the shores of stagnant brackish water
In the ecotope little desalination has taken place, making the vegetation typical of saline soils. Little bare sediment is present in this ecotope. Generally occurring plant species are common salt-marsh grass (*Puccinellia maritima*), sea spurrey (*Spergularia salina*) and sea aster (*Aster tripolium*). On the covered shores of the Veerse Meer barnacle geese (*Branta leucopsis*), white-fronted geese (*Anser albifrons*), brent geese (*Branta bernicla*) and wigeons (*Anas penelope*) overwinter.

Close brackish vegetation on the shores of stagnant brackish water
On nearly all desalinated parts of the shores of the Veerse Meer creeping bent (*Agrostis stolonifera*) and red fescue (*Festuca rubra*) are present. As desalination has progressed, the vegetation becomes more diverse. Also species such as sea pearlwort (*Sagina maritima*), buck's-horn plantain (*Plantago coronopus*), lesser centaury (*Centaurium pulchellum*), sea milkwort (*Glaux maritima*) and salt mud rush (*Juncus gerardii*) may occur. In some places, like on islands, a dense cover has formed. In such densely covered places many species of songbirds occur, such as the lesser whitethroat (*Sylvia curruca*) and the willow warbler (*Phylloscopus trochilus*). The grazed areas are suitable as nesting grounds for waders such as lapwings (*Vanellus vanellus*) and common redshank (*Tringa totanus*). The shores of the Veerse Meer serve as high tide refuge to birds that forage in the Oosterschelde, such as dunlins (*Calidris alpina*), bar-tailed godwits (*Limosa lapponica*) and black-bellied plovers (*Pluvialis squatarola*).

VEERSE MEER ECOTOPES GROUPS	SPECIES	Low-energy sublittoral stone/wood in brackish	Stone above the water mark in brackish water	Very deep water	Deep water	Shallow water	Open vegetation on the shore	Close saline vegetation on the shore	Close brackish vegetation on the shore
cyanobacteria	*Entophysalis deusta*		x						
lichens	*Caloplaca spp.*		x						
	Xanthoria spp.		x						
	Verrucaria spp.		x						
	Lecanora spp.		x						
plants	Creeping Bent *(Agrostis stolonifera)*								x
	Lesser Centaury *(Cent. pulchellum)*								x
	Common Salt-marsh Grass *(Puccinellia maritima)*						x	x	
	Buck's-horn Plantain *(Plantago*								x
	Sea Milkwort *(Glaux maritima)*						x		x
	Red Fescue *(Festuca rubra)*								x
	Sea aster *(Aster tripolium)*						x	x	
	Sea Pearlwort *(Sagina maritima)*								x
	Salt Mud Rush *(Juncus gerardii)*								x
	Sea Spurrey *(Spergularia salina)*						x	x	
algae	*Callithamnion roseum*	x							
	Chaetomorpha linum	x							
	Ceramium diaphanum	x							
	Dasya baillouviana	x							
	Pterothamnion plumula	x							
	Ceramium rubrum	x							
	Bryopsis plumosa	x							
	Sea lettuce *(Ulva sp.)*	x							
hydroids	*Campanulariidae*	x							
anemones	*Diadumene cincta*	x							
oligochaeta	Oligochaeta			x	x	x			
worms	*Alkmaria romijni*					x			
	Tharyx marioni			x	x	x			
	Polydora ligni			x	x	x			
	Pygospio elegans				x	x			
	Capetellid thread worm *(Heteromastus filiformis)*					x			
	Gallery worm *(Capitella capitata)*					x			
	Ficop. Enigmatica					x			
	Lugworm *(Arenicola marina)*					x			
	Clam worm *(Nereis sp.)*			x	x	x			
molluscs	Lagoon cockle *(Cerastoderma glaucum)*				x	x			
	Netted dog whelk *(Nassarius reticulatus)*					x			
	Mussel *(Mytilus edulis)*	x			x	x			
	Sand gaper *(Mya arenaria)*				x	x			
	Mysella bidentata					x			
crustaceans	Palaemonid shrimp *(Palaemon. varians)*					x			
	Praunus flexuosa	x							
	Brown shrimp *(Crangon crangon)*				x	x			

	Melita palmata (amphipod)					x				
	Microdeutopus gryllotalpa (amphipod)					x				
	L. rugicauda					x				
	Hog louse *(Idotea chelipes)*					x				
	Mud shrimp *(Corophium insidosium)*				x	x				
	Common shore crab *(Carcinus maenas)*	x				x				
	Jaera spp.					x				
	Barnacles *(Cirripedia)*	x								
	Estuarine mud crab *(Rhithropanopeus harrisii)*	x				x				
tunicates	Golden Star Tunicate *(Botryllus*	x								
	Molgula manhattensis	x								
fish	Common goby *(Pomatoschistus microps)*	x								
	Sand goby *(Pomatoschistus minutus)*	x				x				
	Three-spined stickleback *(Gaster.*	x								
	Common eel *(Anguilla anguilla)*	x			x	x				
	Black goby *(Gobius niger)*	x								TS, RL
birds	Dunlin *(Calidris alpina)*						x	x	x	TS, htr
	Lesser whitethroat *(Sylvia curruca)*								x	densely vegetated
	Barnacle goose *(Branta leucopsis)*							x	x	TS, BD,
	Common goldeneye *(Bucephala*				x	x				
	Willow warbler *(Phylloscopus trochilus)*								x	densely vegetated
	Grebe *(Podiceps cristatus)*				x	x				
	Lapwing *(Vanellus vanellus)*								x	grazed grounds
	Avocet *(Recurvirostra avosetta)*						x	x	x	TS, BD
	Tufted duck *(Aythya fuligula)*				x	x				
	Coot *(Fulica atra)*				x	x				
	Red-breasted merganser *(Mergus*				x	x				
	Bar-tailed goldwit *(Limosa lapponica)*							x	x	TS, BD, htr
	Brent goose *(Branta bernicla)*							x	x	TS, overwinter
	Oystercatcher *(Haematopus ostralegus)*							x	x	TS
	Wigeon *(Anas penelope)*				x	x		x	x	overwinter
	Common redshank *(Tringa totanus)*								x	TS, RL, grazed
	Black-bellied plover *(Pluvialis squatarola)*							x	x	TS, htr
	Spotted redshank *(Tringa erythropus)*							x	x	
eco-elements	Ruppia-association *(R. maritima, R.*					x				TS, RL
	Sea grass bed *(Zostera marina)*					x				TS, RL

Table 6.5.1. *List of species of the ecotopes in the Veerse Meer.*
TS = target species Min. ANF; BD = species of the EU Bird Directive (appendix 1); RL = species listed in national Red List (both from Bal et al., 2001); htr = high tide refuge to birds from the Oosterschelde

7 FITTING IN OF ZES.1 WITH OTHER (INTER)NATIONAL CLASSIFICATIONS

7.1 NATURE TARGET TYPES

The system of nature target types, as set up by Ministry of Agriculture Nature management and Food quality (Min. ANF (Bal et al., 2001) is a system having a different objective than ZES.1, viz. nature management. The elaboration on nature target types for saline waters was rather roughly, resulting in their being an umbrella to ZES.1. That is to say that many ecotopes of ZES.1 at their lowest level are within a nature target type. The 'ecotopes' of a higher level in ZES.1, correspond more or less with the nature target types (table 7.1.).

ANF nature target types (Bal et al., 2001)	Present in:
type 1.4 virtually natural estuary	Westerschelde (except for the channels) and Ems-Dollard
type 1.5 virtually natural saline tidal landscape	Wadden Sea (except for the reclamation works)
type 1.6 open sea	North Sea
type 2.13 shore landscape of a dammed inlets	Veerse Meer and Grevelingenmeer, above the water mark
type 2.15 saline dammed inlet	Veerse Meer and Grevelingenmeer, below the water mark
type 2.16 controlled natural estuary	Noordrand (New Water Way etc.)
type 2.17 controlled natural saline tidal landscape	Oosterschelde
type 3.12 brackish tidal water	eastern part of the Westerschelde, Dollard and New Waterway
type 3.13 brackish stagnant water	in salt marshes
type 3.14 buffered pool	in salt marshes
type 3.40 semi-natural tidal landscape	reclamation works, slufters and the like.

Table 7.1. *The Min. ANF nature target types (Bal et al., 2001) with respect to ZES.1. Bal et al. (2001) subdivide the nature target types further into subtypes, which are not included in the table below.*

7.2 RWES-AQUATIC AND SHORES

Within the scope of RWES various classifications have been set up aimed at types of water systems, lakes, canals, rivers and the area of the lower regions of the rivers. ZES.1 fits in that series as well. These regionally aimed systems have been 'combined' in two umbrella classifications criss-crossing the regionally aimed systems, RWES-aquatic and RWES-shores (see Figure 1.1.1 as well). Here we compare ZES.1 to both latter classifications. Comparison with the separate regionally aimed systems would make less sense as they are region specific. In this comparison we compare the class boundaries as they are described in both umbrella-RWES-classifications to those in ZES.1.

The classification characteristics applied in RWES-aquatic (V.d. Molen et al., 2000) are current direction, salinity, mechanic dynamics, water depth and soil type (table 7.2.1). In RWES-aquatic only sublittoral ecotopes are included. The mesohaline (brackish) part of RWES-aquatic overlaps with the sublittoral brackish ecotopes of ZES.1. The classification characteristic of mechanic dynamics in RWES-aquatic largely overlaps with the characteristic of hydrodynamics in ZES.1 (and with the morpho-dynamics in BES). In RWES-aquatic a number of eco-elements are discerned as are in ZES.1. The classification characteristics of the shore-system are salinity, mechanic dynamics and management/use and it is applied in rivers, tidal waters, lakes and canals.

	Classification characteristics RWES-aquatic/ *shores*	classes RWES-aquatic / *shore*	Class boundaries RWES-aquatic / *shores*
1	current direction /-	unilateral current bilateral current no current	rivers tidal waters lakes and canals
2	salinity	Fresh / *fresh* oligohaline (slightly brackish) */slightly brackish* mesohaline (brackish) */ brackish-saline (poly-and euhaline)*	< 0.3 g Cl-/l */ < 0.3 g Cl-/l* 0.3-3 g Cl-/l */ 0.3-3 g Cl-/l* 3-10 g Cl-/l */ 3-10 g Cl-/l* > 10 g Cl-/l
3	mechanical dynamics	Very high energy */ high energy* High energy */ moderate energy* energy */ low energy* low energy	V_{lin} > 1 m/s; bed sand or shells */ >1 m/s* V_{lin} 0.35 - 1 m/s, bed sand or shells */ 0.5 – 1 m/s* V_{lin} < 0,35m/s, bed rich in silt */ <0.5 m/s* The bed is hardly moved by current or waves
4	water depth (tidal waters)/-	very deep water deep water moderately deep water shallow water	> 10 m below MLW 10 - 3 m below MLW 3 - 1 m below MLW 1 m below MLW to MLW
	Water depth (lakes)	very deep water deep water moderately deep water shallow water	> 5 m below summer level 5 - 3 m below summer level 3 - 1 m below summer level 1 m below summer level – summer level
5	Soil type/-	clay silt sand consolidate	D50 < 2 µm D50 0 or 2 – 63 µm D50 63 – 2000 µm D50 > 2000 µm
6	- /*management/use*	- */ hardly any to no management* - */ extensively managed* - */ intensively managed* - */ artificial*	- - - -

Table 7.2.1. *Overview of the classification characteristics applied in RWES-aquatic and -shores (V.d. Molen et al., 2000, Lorenz 2001).*
g Cl-/l = chloride content; MLW = mean low water mark; MHWS = mean high water mark spring tide; Vlin = linear current velocity; D50 = median grain size.

Comparison of variables and class boundaries

In the Tables 7.2.2 up to and including 7.2.6 we compare the variables and class boundaries RWES-shores and RWES-aquatic to those of ZES.1 Some differences between the three systems are that
- in ZES.1 salinity fluctuation is taken into account in addition to salinity (table 7.2.2)
- in ZES.1 wave action is taken into account in addition to current velocity (table 7.2.3).
- the class boundaries of depth, duration of flooding and flooding frequency are not the same (table 7.2.4).
- in RWES-shores sediment composition is not a classification characteristic, but it is described as the result of morphodynamics (table 7.2.5).
- in RWES-shores no eco-elements are discerned, and in RWES-aquatic different ones from those in ZES.1 (table 7.2.6).
- geomorphology is more or less similar to vegetation in RWES-shores and RWES- aquatic.

Salinity		
RWES-shores g Cl^-/l	RWES-aquatic g Cl^-/l	ZES.1 PSU (g Cl^-/) fluctuation
< 0.3	< 0.3	
0.3-3	0.3-3	
3-10	3-10	5.4-18 3-10 < 100%
> 10		> 18 > 10 < 100%
		> 5.4 > 3 >100%

Table 7.2.2. *Comparison of the classification characteristic salinity of RWES-shores(Lorenz, 2001), RWES-aquatic (V.d. Molen et al., 2000) and ZES.1. In RWES-shores and RWES-aquatic g Cl^-/l is used, in ZES.1 salinity (no unit). Salinity divided by 1.8 gives g Cl^-/l. Only in ZES.1 the fluctuation in salinity is included as a classification characteristic.*

hydrodynamics (as defined in ZES.1)		
RWES-shores V_{lin} (m/s)	RWES-aquatic V_{lin} (m/s)	ZES.1 V_{lin} (m/s) V_{orb} (m/s) L (km)
> 1	> 1	> 0.8 or > 0.2 or > 80-240
0.5-1	0.35/0.5 - 1	
< 0.5	< 0.35/0.5	< 0.8 and < 0.2 and < 80

Table 7.2.3. *Comparison of the classification characteristic hydrodynamics of RWES-shores (Lorenz, 2001), RWES-aquatic (V.d. Molen et al., 2000) and ZES.1. In RWES-shores and RWES-aquatic only the linear current velocity (Vlin) is used. In ZES.1 we use wave action (orbital velocity Vorb) and fetch L) as well*

depth, duration of flooding and flooding frequency		
RWES-shores	RWES-aquatic	ZES.1
	> 10 m below MLW	> 5 m below MLWS
	10 to 3 m below MLW	
	3 to 1 m below MLW	5 m below MLW to MLWS
	1 m below MLW to MLW	
>90% duration of flooding		MLWS to > 75% duration of flooding
–70 – 90% duration of flooding		75% - 25% duration of flooding
50 – 70 % duration of flooding		< 25% duration of flooding - MHWN
flooded 363-150 days/year		MHWN to > flooded 300 times/year
flooded 150 – 100 days/year		flooded 300-150 times/year
flooded 100 – 50 days/year		flooded 150-50 times/year
-		flooded 50-5 times/year

Table 7.2.4. *Comparison of the classification characteristics depth, duration of flooding and flooding frequency between RWES-shores (Lorenz, 2001), RWES-aquatic (V.d. Molen et al., 2000) and ZES.1*

Sediment composition		
RWES-shores	RWES-aquatic D50 (µm)	ZES.1 D50 silt (< 63 µm)
	< 2	
	0/2-63 63-250	- > 25%# =< 250 < 25%
-	250-2000	250-2000 < 25%
-	> 2000	> 2000 < 25%
		#: North Sea 10%

Table 7.2.5. *Comparison of the classification characteristic sediment composition of the shores (Lorenz, 2001), RWES-aquatic (V.d. Molen et al., 2000) and ZES.1. In shores and RWES sediment composition are not used as a classification characteristic, it is described in RWES as a resultant of morphodynamics. In ZES.1 we include in addition to median grain size (D50) the silt content as well.*

RWES-aquatic	ZES.1
water plants	sea grass bed
algae	Ruppia-association
helophytes	gully (in tidal flats)
zebra mussels	mussel bed
other benthos	oyster bed
	shell bank shipwreck
	shore vegetation in shallow brackish/variable

Table 7.2.6. *Comparison of eco-elements of RWES-shores (Lorenz, 2001), RWES-aquatic (V.d. Molen et al., 2000) and ZES.1. In RWES-shores no eco-elements are discerned.*

7.3 EUNIS MARINE HABITAT CLASSIFICATION

The EUNIS marine habitat classification can be found at the Internet site *http://mrw.wallonie.be/dgrne/sibw/EUNIS/home.html*. The EUNIS classification (autumn 2004) discerns eight marine habitats (read, and from this point: ecotopes). Not all its ecotopes occur in the Netherlands, as there are e.g. no deep-sea beds in the Netherlands. At the first level within the marine ecotopes it distinguishes between on the one hand hard substrata and sediments and on the other hand sublittoral and littoral zones (table 7.3.1). Salt marshes are included in the littoral zone within EUNIS (in ZES.1 in the supralittoral zone). The subdivision of the marine 'principal' ecotopes A1 up to and including A4 in more detailed ecotopes can be found in appendix 2. Tables 7.3.2 up to and including 7.3.5 below, depict the comparison per 'principal' ecotope between the ecotopes of EUNIS and those of ZES.1. In some cases an ecotope from the EUNIS classification is an eco-element in ZES.1 (such as mussel beds and sea grass beds). A striking difference between the EUNIS classification and ZES.1 is, that ZES.1 subdivides already at the first level already after salinity, while salinity in EUNIS comes up not until a much lower level and less extensively. In the EUNIS marine habitat classification few brackish and variably brackish/saline ecotopes are present (see for example table 7.3.2, ecotope A4.32). Another striking difference is that in EUNIS considerably more hard substratum ecotopes are discerned (see appendix 2). This distinction is caused by the fact that in comparison with other European coastal countries, there is little hard substratum present in the Netherlands. Moreover, the Netherlands lack high-energy classes that are present on locations with swell (see table 7.3.6 as well).

code	description	code	description
A	marine habitats	A1	littoral rock and other hard substrata
		A2	littoral sediments
		A3	sublittoral rock and other hard substrata
		A4	sublittoral sediments

Table 7.3.1. *A first subdivision of 'marine habitats' in the EUNIS classification. EUNIS distinguishes both between hard substratum and sediments and between sublittoral and littoral (including supralittoral) zones.*

ZES.1	EUNIS
X1.1 sublittoral hard substratum Z1.111 high-energy stone/wood	A3 sublittoral rock and other hard substrata A3.2 infralittoral rock moderately exposed to wave action and/or currents and tidal streams A3.6 circalittoral rock moderately exposed to wave action or currents and tidal streams
Z1.121 low-energy stone/wood	A3.3 infralittoral rock sheltered from wave action and currents and tidal streams A3.7 circalittoral rock sheltered from wave action and currents including tidal streams
Z1.131 stone/wood in stagnant water	A1.42 hydrolittoral solid rock (bedrock)
Z1.112 high-energy consolidated peat layer Z1.122 low-energy consolidated peat layer Z1.132 consolidated peat layer in stagnant water	A1.45 hydrolittoral peat
eco-element shipwreck	---
eco-element mussel bed	A1.44 hydrolittoral Mytilus edulis beds

Table 7.3.2. *Comparison ZES.1 – EUNIS: Ecotopes of the hard substratum in the sublittoral zone.*

ZES.1	EUNIS
X1.2 littoral hard substratum	A1 littoral rock and other hard substrata
Z1.211 high-energy stone/wood	A1.2 littoral rock moderately exposed to wave action
Z1.221 low-energy stone/wood	A1.3 littoral rock sheltered from wave action
Z1.212 high-energy consolidated peat layer Z1.222 low-energy consolidated peat layer	A1.45 hydrolittoral peat
X1.3 supralittoral hard substratum	---

Table 7.3.3. *Comparison ZES.1 – EUNIS: Ecotopes of the hard substratum in the littoral and supralittoral zones.*

ZES.1	EUNIS
X2.1 sublittoral sediments	A4 sublittoral sediments
Z2.11s high-energy rich in silt	---
Z2.11f high-energy fine sands	A4.23 communities of well sorted fine sands
Z2.121s low-energy very deep beds rich in silt Z2.122s low-energy deep beds rich in silt Z2.121f low-energy very deep fine sands Z2.122f low-energy deep fine sands	A4.36 animal communities of circalittoral muds A4.23 communities of well sorted fine sands
Z2.121z low-energy very deep coarse sands Z2.122z low-energy deep coarse sands	A4.14 animal communities in deeper coarse sands
Z2.121g low-energy very deep gravels	A4.13 animal communities of circalittoral mobile cobbles, gravels and sands
Z2.123s low-energy shallow beds rich in silt	A4.31 shallow fully marine mud communities
V2.123s low-energy shallow beds rich in silt B2.123s low-energy shallow beds rich in silt Z2.123f low-energy shallow fine sands	A4.32 variable or reduced salinity sublittoral muds A4.42 animal communities in shallow-water mixed sediments
V2.123f low-energy shallow fine sands B2.123f low-energy shallow fine sands	A4.43 variable or reduced salinity sublittoral mixed sediments
Z2.131 very deep stagnant water	A4.35 periodically and permanently anoxic sublittoral muds
Z2.132 deep stagnant water	---
Z2.133 shallow stagnant water	---
eco-element seagrass bed	A4.53 Zostera beds in infralittoral sediments
eco-element Ruppia-association	A4.54 Ruppia and Zannichellia communities
eco-element oyster bed	A4.63 Oyster beds
eco-element mussel bed	A4.64 structures formed by mussels over sublittoral sediment

Table 7.3.4. *Comparison ZES.1 – EUNIS: Ecotopes of sublittoral sediments.*

ZES.1	EUNIS

X2.2 littoral sediments	A2 littoral sediments
Z2.21s high-energy beds rich in silt	---
Z2.21f high-energy fine sands	A2.24 sand shores
Z2.221s low littoral low-energy beds rich in silt Z2.221f low littoral low-energy fine sands	A2.33 muddy shores with < 70% air exposure A2.23 sandy and muddy sand shores with < 70% air exposure
Z2.222s middle high littoral low-energy beds rich in silt	A2.32 muddy shores with 70-90% air exposure
Z2.222f middle high littoral low-energy fine sands	A2.22 sandy and muddy sand shores with 70-90% air exposure
Z2.223s high littoral low-energy beds rich in silt	A2.31 muddy shores with 90-100% air exposure
Z2.223f high littoral low-energy fine sands	A2.21 sandy and muddy sand shores with 90-100% air exposure
eco-element seagrass bed	A2.71 Zostera beds on littoral sediments
eco-element Ruppia-association	A2.73 Ruppia beds on littoral sediments
eco-element mussel bed eco-element oyster bed	A2.8 biogenic structures on littoral sediments
X2.3 supralittoral sediments	
Z2.311 low beach	
Z2.312 middle high beach	---
Z2.313 high beach	---
B2.321 pioneer zone B2.322 low brackish salt marsh B2.323 middle high brackish salt marsh B2.324 high brackish salt marsh	A2.56 geolittoral wetlands and meadows: reed, rush and sedge stands
Z2.321 pioneer zone	A2.65 pioneer salt marshes A2.34 salt marsh creeks A2.35 salt marsh pools
Z2.322 low saline salt marsh	A2.64 low-mid salt marshes A2.34 salt marsh creeks A2.35 salt marsh pools
Z2.323 middle high saline salt marsh	A2.63 mid-upper salt marshes and saline reed beds A2.34 salt marsh creeks A2.35 salt marsh pools
Z2.324 high saline salt marsh	A2.62 species-rich upper salt marshes A2.34 salt marsh creeks A2.35 salt marsh pools
Z2.331 shore stagnant: open saline vegetation	A2.65 pioneer salt marshes?
Z2.332 shore stagnant: close saline vegetation	A2.62 species-rich upper salt marshes?
Z2.333 shore stagnant: close brackish vegetation	A2.56 geolittoral wetlands and meadows: reed, rush and sedge stands

Table 7.3.5. *Comparison ZES.1 – EUNIS: Ecotopes of the littoral and supralittoral sediments.*

In addition to the classification characteristics sublittoral/littoral and hard substrata/sediments the EUNIS classification applies as well hydrodynamics, sediment composition and duration of air exposure as classification characteristics. The descriptions of the various classes for hydrodynamics are given in table 7.3.6. The class exposed corresponds with the class high energy in ZES.1, the class sheltered with the class low energy. In table 7.3.7 the class boundaries applied in EUNIS for sediment composition and duration of air exposure are given.

classes of hydrodynamics in EUNIS	Description
extremely exposed	Applied to the few open coastlines which face into prevailing wind and receive ocean swell without any offshore breaks (such as islands or shallows) for several thousand km and where deep water is close to the shore (50 m depth contour within about 300 m).
very exposed	Applied to open coastlines which face into prevailing wind and receive ocean swell without any offshore breaks (such as islands or shallows) for several thousand km but where deep water is not close (> 300 m) to the shore. They can be adjacent to extremely exposed sites but face away from prevailing winds (here swell and wave action will refract towards these shores) or where, although facing away from prevailing winds, strong winds and swell often occur.
exposed (= high energy ZES.1)	Prevailing wind is onshore although there is a degree of shelter because of extensive shallow areas offshore, offshore obstructions, a restricted window (>900) to open water. Not generally exposed to strong or regular swell. Also refers to open coasts facing away from prevailing winds but where strong winds with a long fetch are frequent.
moderately exposed	Open coasts facing away from prevailing winds and without a long fetch, but where strong winds can be frequent
sheltered (= low energy ZES.1)	Restricted fetch and/or open water window. Coasts can face prevailing wind but with a short fetch (say < 20 km) or extensive shallow areas offshore or may face away from prevailing winds.
very sheltered	Unlikely to have a fetch greater than 20 km, the exception being through a narrow (<300) open water window. They face away from prevailing wind or have obstructions, such as reefs, offshore.
extremely sheltered	Fully enclosed with a fetch no greater than about 3 km.
ultra sheltered	With a fetch of a few tens or at most hundreds of meters.

Table 7.3.6. *The hydrodynamics classes that are used in the EUNIS classification.*

classes of sediment composition in EUNIS	classes of duration of exposure in EUNIS
gravel or coarse sand > 1 mm grain size	< 70 % air exposure (ZES.1: low/ middle littoral)
fine sand or muddy sand =< 1 mm grain size with =< 30% silt (< 63 µm)	70-90 % air exposure (ZES.1: high littoral)
mud > 30% silt (< 63 µm)	90-100 % air exposure (ZES.1: supralittoral)
combination sediments (intimate mixtures of the above, and mosaics and veneers)	
biogenic structures	

Table 7.3.7. *The classes of sediment composition and duration of air exposure that are used in the EUNIS classification.*

7.4. THE EUROPEAN HABITATS DIRECTIVE

European Habitats Directive (HD) designates a number of habitats that have to be protected. The term ‘habitat’ that is used here is derived from the English term habitat, which in the mean time means both ‘habitat’ and ‘ecotope’ in European usage. The Habitats Directive uses the sense of ‘ecotope’. A number of habitats from the directive are situated in the coastal zone and with it they are relevant to ZES.1. Table 7.4.1 shows the habitats concerned.

number	Name
11	**Marine waters and tidal areas**
1110	Sandbanks permanently submerged by seawater
1130	Estuaries
1140	Mudflats and sand flats not covered by seawater at low tide
1160	Large shallow inlets and bays
13	**Atlantic and continental salt marshes**
1310	Salicornia and other annuals colonising mud and sand
1320	Spartina swards (Spartinion maritimae)
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
21	**Coastal dunes of the Atlantic Ocean, the North Sea and the Baltic**
2110	Embryonic shifting dunes

Table 7.4.1. Overview of habitats in the European Habitats Directive, being relevant to ZES.1. (after Janssen & Schaminée, 2003)

These habitats as a rule have an ample definition, making most ecotopes of ZES.1 fit within these habitats. In fact they are a subdivision of the global habitats. Some categories of habitats in ZES.1 do not fit or it is not clear whether they fit within a HD-habitat. Table 7.4.2 shows a global overview of the link between the ZES.1-ecotopes and the habitats in the Habitats Directive.

Not fitting within HD	Possibly fitting within HD	Fitting within HD	Considered fitting within HD
All ecotopes of hard substrata	Deep channels in estuaries	Saline salt marshes	Brackish salt marshes
Sublittoral deep North Sea, Wadden Sea		All supralittoral ecotopes	
		All littoral ecotopes	
		Embryonic dunes	

Table 7.4.2. *Global overview of the link between the habitats in the Habitats Directive and the ecotopes in ZES.1*

LIST OF ABBREVIATIONS AND CONCEPTS

Alterra	Research Institute for the green living environment
CBS	Statistics Netherlands
Fetch	continuous distance over which the wind can blow over the water
Linear current velocity	'normal' current velocity
Littoral	area that is flooded each tide
MHW	mean high water
MHWN	mean high water neap tide
MLW	mean low water
MLWS	mean low water spring tide
Neap tide	weak ebb and flood
NIOO-CEME	Centre for Estuarine and marine ecology
NIOZ	Netherlands Institute for Sea Research
Orbital velocity	the current velocity near the bed in a wave
Rijkswaterstaat	Directorate-General of Public Works and Water Management of the Ministry of Transport, Public works and Water management
RIKZ	National Institute of Coastal and Marine Management
RIZA	National Institute for Inland Water Management and Waste Water Treatment
Salt marsh	areas covered with vegetation between the high water mark and the high water mark at spring tide
Sandy tidal flat	area emerging during ebb, not bordering to land often with sandy sediments
Sublittoral	area permanently under water
Supralittoral	area, not flooded each tide
Tidal flat	area emerging during ebb bordering to land often with sediment that is more rich in silt than a sandy tidal flat

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APPENDIX 1. COMPARISON ZES.1 TO PREVIOUS DRAFT-SYSTEMS FOR SALINE TIDAL WATERS

Previous to the completion of the version of the Saline Ecotope System at hand, various stages were completed during the development, previous versions were made and worked out increasingly further. The tables below compare the variables and class boundaries that were proposed in previous draft-systems for the brackish and saline waters to those in the eventual ZES.1. We refer to the draft-systems concerned for backgrounds De Jong (1999); Dankers et al. (2001); Vos & Wolff (2001) and Meijer & Waardenburg (2002).

De Jong, 1999 g NaCl-/l	Dankers et al., 2001 g Cl-/l	Vos & Wolff, 2001 g Cl-/l	fluctuation	Meijer & Waardenburg, 2002 g Cl-/l	ZES.1 (no unit)	fluctuation
		0,3-3				
5.4 - 18	< 18	3-10	</> 100%	3-10	5.4-18	</> 100%
18 - 31	> 18	10-17	</> 100%	> 10	> 18	</> 100%
> 31						

Table 1. *Comparison of the draft-systems with ZES.1: variables and class boundaries for the classification characteristic salinity. (NaCl = 1.8* Cl)*

De Jong, 1999 V_{lin} (m/s)	V_{orb}	Dankers et al., 2001 V_{lin} (m/s)	V_{orb}	Vos & Wolff, 2001 V_{lin} (m/s)	V_{orb}	Meijer & Waardenburg, 2002	ZES.1 V_{lin}	V_{orb} (m/s)	fetch
> 1	> 0.4	> 1	> 0.4	> 0.8	> 0.4	fetch 80-240 km	> 0.8 or	> 0.2 or	> 80-240km
0.5-1	0.2-0.4	0.5-1	0.2-0.4	0.4-0.8	0.2-0.4	fetch < 80 km			
< 0.5	< 0.2	< 0.5	< 0.2	< 0.4	< 0.2	Very short fetch	< 0.8 ánd	< 0.2 ánd	< 80 km

Table 2. *Comparison of the draft-systems with ZES.1: variables and class boundaries for the classification characteristic hydrodynamics. V_{lin} = linear current velocity; V_{orb} = orbital velocity (wave action).*

De Jong, 1999	Dankers et al., 2001	Vos & Wolff, 2001	Meijer & Waardenburg, 2002	ZES.1 Tidal waters North Sea (Inland) *lakes*
Sublittoral				
50 to 30 m below DOL	> 30 m below MLW	> 0,5/1m below MLW or > 3/5 m below water level	below MLWS	> 5m – MLWS > 30m 30 – 20m *Gm: > 15m* *15 to 5m* *Vm: > 10m* *10 to 5m*
30 to 20 m below DOL	30 to 5 m below MLW			
20 to 5 m below MLW				
5 m below DOL -MLW	5 m below MLW - MLW	0,5/1 below MLW to MLW or 3/5 m below water level to water level		5 m - MLWS <20m –MLWS - MLWS *5m to lake level*
Littoral				*(no lakes)*
1-50 % duration of emergence	1-50 % duration of emergence	1-75 % duration of emergence	above MLWS	MLWS to 75% duration of flooding
50-75 % duration of emergence	50-75 % duration of emergence			75-25% duration of flooding
75-90 % duration of emergence	75-90 % duration of emergence	75 duration of emergence –MHW		25% duration of flooding to MHWN
> 90 % duration of emergence	> 90 % duration of emergence			
Supralittoral				
	Flooded > 300 / 150-300 x per year	MHW-MHWS		Flooded MHWN to > 300 x per year
	Flooded 50-300 / 70-100 x per year			Flooded 300-150 x per year
				Flooded 150-50 x per year
	Flooded 5-50 / 20-30 x per year	MHWS-EHWS		
	Flooded < 5 / < 20 x per year			Flooded 50-5 x per year

Table 3. *Comparison of the draft-systems with ZES.1: variable and class boundaries for the classification characteristics depth, flooding time and flooding frequency. (Lakes: GM: Grevelingenmeer, Vm: Veerse meer)*

De Jong, 1999 D50	 silt	Dankers et al., 2001 D50	 silt + clay	Vos & Wolff, 2001 D50	 silt	Meijer & Waardenburg, 2002	ZES.1 D50	 silt
	> 10%	< 2 µm	> 10%	< 75 µm	> 25%	Pitching on sea walls, breakwater, pier, channel wall protection, sub-aquatic slopes, shipwreck, pole row, jetty, consolidated peat layer	variable	> 25%*
< 250 µm	< 10%	2-63 µm	> 10%	75-200 µm	variable		=< 200 µm	< 25%
							200-2000 µm	< 25%
> 250 µm	< 10%	63-212 µm	< 10%	> 200 µm	< 25%		>2000 µm	< 25%
gravel > 30%		> 212 µm	< 10%					

* in North Sea 10% silt

Table 4. *Comparison of the draft-systems with ZES.1: variable and class boundaries for the classification characteristic sediment composition. In addition some examples of hard substrata. Median grain size; silt = < 63 µm.*

De Jong, 1999	Dankers et al., 2001	Vos & Wolff, 2001	Meijer & Waardenburg, 2002	ZES.1
-----	-----	gully seagrass bed (*Zostera marina*, Z. noltii*) Ruppia-association (*R. maritima, R. cirrhosa*) mussel bed (*Mytilus edulis*) sand mason community (*Lanice conchilega*)	-----	Gully seagrass bed (*Zostera marina*, Z. noltii*) Ruppia-association (*R. maritima, R. cirrhosa*) mussel bed (*Mytilus edulis*) oyster bed (*Crassostrea gigas*) shell bank shipwreck shore vegetation on shallow brackish shores

** In UK Zostera angustifolia*

Table 5. *Comparison of the draft-systems with ZES.1: the eco-elements described. In De Jong (1999), Dankers et al. (2001) and Meijer & Waardenburg (2002) no eco-elements are described. A biological variable was added in the two former draft-systems, which includes mussel beds and sea grass beds.*

APPENDIX 2. EUNIS marine habitat classification

EUNIS marine habitat classification (regular updated ; version of December 2004; see: http://eunis.eea.eu.int/habitats.jsp)

A 1	**Littoral rock and other hard substrata**
A 1 .1	Littoral rock very exposed to wave action
A 1 .1 1	Mussels and/or barnacles on very exposed littoral rock
A 1 .1 2	Robust fucoids or red seaweeds on very exposed littoral rock
A 1 .1 3	Communities of the upper mediolittoral rock
A 1 .1 4	Communities of the lower mediolittoral rock very exposed to wave action
A 1 .2	Littoral rock moderately exposed to wave action
A 1 .2 1	Mussels and/or barnacles on littoral rock moderately exposed to wave action
A 1 .2 2	Fucoids and barnacles on moderately exposed littoral rock
A 1 .2 3	Red seaweeds on moderately exposed littoral rock
A 1 .2 4	Ephemeral green or red seaweeds (freshwater- or sand-influenced) on moderately exposed littoral rock
A 1 .2 5	Mussels and fucoids on moderately exposed littoral rock
A 1 .2 6	Sabellaria reefs on littoral rock
A 1 .2 7	Communities of the lower mediolittoral rock moderately exposed to wave action
A 1 .3	Littoral rock sheltered from wave action
A 1 .3 1	Dense fucoids on sheltered littoral rock
A 1 .3 2	Fucoids , barnacles or ephemeral seaweeds on sheltered littoral mixed substrata
A 1 .3 3	Mussel beds on sheltered littoral mixed substrata
A 1 .3 4	Red algal turf in lower eulittoral, sheltered from wave-action
A 1 .3 5	Communities of the lower mediolittoral rock sheltered from wave action
A 1 .4	Rock habitats exposed by action of wind (e.g. hydrolittoral)
A 1 .4 1	Hydrolittoral soft rock
A 1 .4 2	Hydrolittoral solid rock (bedrock)
A 1 .4 3	Hydrolittoral hard clay
A 1 .4 4	Hydrolittoral Mytilus edulis beds
A 1 .4 5	Hydrolittoral peat
A 1 .5	Rockpools
A 1 .5 1	Communities of littoral rockpools
A 1 .5 2	Communities of rockpools in the supralittoral zone
A 1 .5 3	Brackish permanent pools in the geolittoral zone
A 1 .6	Littoral caves and overhangs
A 1 .6 1	Communities of littoral caves and overhangs
A 2	**Littoral sediments**
A 2 .1	Littoral gravels and coarse sands
A 2 .1 1	Shingle and gravel shores
A 2 .1 2	Estuarine coarse sediment shores
A 2 .1 3	Communities of the mediolittoral coarse detritic bottoms
A 2 .2	Littoral sands and muddy sands
A 2 .2 1	Sandy and muddy sand shores with 90-100% air exposure
A 2 .2 2	Sandy and muddy sand shores with 70-90% air exposure
A 2 .2 3	Sandy and muddy sand shores with <70% air exposure
A 2 .2 4	Sand shores
A 2 .2 5	Muddy sand shores
A 2 .3	Littoral muds
A 2 .3 1	Muddy shores with 90-100% air exposure

A 2 .3 2	Muddy shores with 70-90% air exposure
A 2 .3 3	Muddy shores with <70% air exposure
A 2 .3 4	Saltmarsh creeks
A 2 .3 5	Saltmarsh pools
A 2 .3 6	Sandy mud shores
A 2 .3 7	Soft mud shores
A 2 .4	Littoral combination sediments
A 2 .4 1	Sheltered combination sediment shores
A 2 .5	Habitats with sediments exposed by action of wind (e.g. hydrolittoral)
A 2 .5 1	Hydrolittoral stony substrates
A 2 .5 2	Hydrolittoral gravel substrates
A 2 .5 3	Hydrolittoral sandy substrates
A 2 .5 4	Hydrolittoral muddy substrates
A 2 .5 5	Hydrolittoral mixed sediment substrates
A 2 .5 6	Geolittoral wetlands and meadows: reed, rush and sedge stands
A 2 .6	Coastal saltmarshes and saline reedbeds
A 2 .6 1	Saltmarsh driftlines
A 2 .6 2	Species-rich upper saltmarshes
A 2 .6 3	Mid-upper saltmarshes and saline reedbeds
A 2 .6 4	Low-mid saltmarshes
A 2 .6 5	Pioneer saltmarshes
A 2 .7	Littoral sediments dominated by aquatic angiosperms
A 2 .7 1	Zostera beds on littoral sediments
A 2 .7 2	Eleocharis beds
A 2 .7 3	Ruppia beds on littoral sediments
A 2 .7 4	Methane seeps in littoral sediments
A 2 .8	Biogenic structures on littoral sediments
A 2 .8 1	Biogenic features (scars) on littoral mixed sediments
A 3	**Sublittoral rock and other hard substrata**
A 3 .1	Infralittoral rock very exposed to wave action and/or currents and tidal streams
A 3 .1 1	Kelp with cushion fauna, foliose red seaweeds or coralline crusts (exposed rock)
A 3 .1 2	Fauna and seaweeds on vertical exposed infralittoral rock
A 3 .1 3	Communities of infralittoral algae very exposed to wave action
A 3 .1 4	Areas dominated by encrusting algae
A 3 .1 5	Areas dominated by frondose algae, other than kelp
A 3 .2	Infralittoral rock moderately exposed to wave action and/or currents and tidal streams
A 3 .2 1	Kelp and red seaweeds on moderately exposed infralittoral rock
A 3 .2 2	Grazed kelp with algal crusts on moderately exposed infralittoral rock
A 3 .2 3	Sand-tolerant or disturbed kelp and seaweed on moderately exposed infralittoral rock
A 3 .2 4	Fauna and seaweeds on vertical moderately exposed infralittoral rock
A 3 .2 5	Communities of infralittoral algae moderately exposed to wave action
A 3 .2 6	Baltic brackish water sublittoral biocenoses of hard substrata influenced by varying salinity
A 3 .2 7	Animal-dominated communities of moderately exposed infralittoral rock
A 3 .3	Infralittoral rock sheltered from wave action and currents and tidal streams
A 3 .3 1	Silted kelp communities on sheltered infralittoral rock
A 3 .3 2	Estuarine faunal communities on shallow rock or mixed substrata
A 3 .3 3	Submerged fucoids, green and red seaweeds on reduced/low salinity infralittoral rock
A 3 .3 4	Communities of infralittoral algae sheltered from wave action
A 3 .3 5	Animal-dominated communities of sheltered infralittoral rock in full salinity
A 3 .4	Caves, overhangs and surge gullies in the infralittoral zone
A 3 .4 1	Robust fauna on infralittoral surge gullies and cave walls
A 3 .5	Circalittoral rock very exposed to wave action or currents and tidal streams

A 3 .5 1	Faunal crusts or short turfs on exposed circalittoral rock
A 3 .5 2	Alcyonium-dominated communities on tide-swept circalittoral rock
A 3 .5 3	Barnacle, cushion sponge and Tubularia communities on very tide-swept circalittoral rock
A 3 .6	Circalittoral rock moderately exposed to wave action or currents and tidal streams
A 3 .6 1	Mixed faunal turf communities on moderately exposed circalittoral rock
A 3 .6 2	Sand-influenced bryozoan and hydroid turfs on moderately exposed circalittoral rock
A 3 .6 3	Sabellaria spinulosa communities on circalittoral rock
A 3 .6 4	Mussel beds on moderately exposed circalittoral rock
A 3 .6 5	Brittlestar beds on circalittoral rock or mixed substrata
A 3 .6 6	Grazed faunal communities on moderately exposed or sheltered circalittoral rock
A 3 .6 7	Silt-influenced ascidian communities on moderately exposed circalittoral rock
A 3 .6 8	Communities on soft moderately exposed circalittoral rock
A 3 .6 9	Faunal turfs on vertical circalittoral rock
A 3 .6 A	Coralligenous communities moderately exposed to hydrodynamic action
A 3 .7	Circalittoral rock sheltered from wave action and currents including tidal streams
A 3 .7 1	Brachiopods and solitary ascidian communities on sheltered circalittoral rock
A 3 .7 2	Sheltered Modiolus beds
A 3 .7 3	Coralligenous communities sheltered from hydrodynamic action
A 3 .8	Deep circalittoral rock habitats exposed to strong currents
A 3 .8 1	Animal communities of deep circalittoral rock habitats exposed to strong currents
A 3 .9	Deep circalittoral rock habitats exposed to moderately strong currents
A 3 .9 1	Animal communities of deep circalittoral rock habitats exposed to moderately strong currents
A 3 .A	Deep circalittoral rock habitats exposed to weak or no currents
A 3 .A 1	Animal communities of deep circalittoral rock habitats exposed to weak or no currents
A 3 .B	Caves and overhangs below the infralittoral zone
A 3 .B 1	Communities of circalittoral caves and overhangs
A 3 .B 2	Caves in total darkness, including deep-sea caves
A 3 .C	Vents and seeps in sublittoral rock
A 3 .C 1	Bubbling reefs in the sublittoral euphotic zone
A 3 .C 2	Bubbling reefs in the aphotic zone
A 3 .C 3	Freshwater seeps in sublittoral rock
A 3 .C 4	Oil seeps in sublittoral rock
A 3 .C 5	Vents in sublittoral rock
A 4	**Sublittoral sediments**
A 4 .1	Sublittoral mobile cobbles, gravels and coarse
A 4 .1 1	Animal communities in shallow-water gravels
A 4 .1 2	Animal communities in shallow-water coarse sands
A 4 .1 3	Animal communities of circalittoral mobile cobbles, gravels and sands
A 4 .1 4	Animal communities in deeper coarse sands
A 4 .1 5	Animal communities in variable or reduced salinity gravels and coarse sands
A 4 .2	Sublittoral sands and muddy sands
A 4 .2 1	Animal communities in fully marine shallow clean sands
A 4 .2 2	Communities of fine sands in very shallow waters
A 4 .2 3	Communities of well sorted fine sands
A 4 .2 4	Animal communities in variable or reduced salinity shallow clean sands
A 4 .2 5	Animal communities in fully marine shallow-water muddy sands
A 4 .2 6	Animal communities in variable or reduced salinity muddy sands
A 4 .2 7	Animal communities of circalittoral muddy sands
A 4 .2 8	Communities of the muddy detritic bottom
A 4 .3	Sublittoral muds
A 4 .3 1	Shallow fully marine mud communities
A 4 .3 2	Variable or reduced salinity sublittoral muds

A 4 .3 3	Communities of superficial muddy sands in sheltered waters
A 4 .3 4	Communities of coastal terrigenous muds
A 4 .3 5	Periodically and permanently anoxic sublittoral muds
A 4 .3 6	Animal communities of circalittoral muds
A 4 .4	Sublittoral combination sediments
A 4 .4 1	Kelp and seaweeds on shallow-water mixed sediments
A 4 .4 2	Animal communities in shallow-water mixed sediments
A 4 .4 3	Variable or reduced salinity sublittoral mixed sediments
A 4 .4 4	Animal communities of circalittoral mixed sediments
A 4 .4 5	Communities of the coastal detritic bottom
A 4 .5	Shallow sublittoral sediments dominated by angiosperms
A 4 .5 1	Cymodocea beds
A 4 .5 2	Halophila beds
A 4 .5 3	Zostera beds in infralittoral sediments
A 4 .5 4	Ruppia and Zannichellia communities
A 4 .5 5	Sublittoral macrophyte beds of coastal brackish waters
A 4 .5 6	Posidonia beds
A 4 .6	Biogenic structures over sublittoral sediments
A 4 .6 1	Seaweeds and maerl on coarse shallow-water sediments
A 4 .6 2	Maerl beds on shallow-water muddy mixed sediments
A 4 .6 3	Oyster beds
A 4 .6 4	Structures formed by mussels over sublittoral sediment
A 4 .6 5	Maerl beds on deep-water muddy sediments
A 4 .7	Deep shelf sediment habitats
A 4 .7 1	Animal communities of deep circalittoral gravel bottoms
A 4 .7 2	Animal communities of deep circalittoral sandy bottoms
A 4 .7 3	Animal communities of deep circalittoral shell gravel bottoms
A 4 .7 4	Animal communities of deep circalittoral muddy bottoms
A 4 .7 5	Animal communities of deep circalittoral mixed sediment bottoms
A 4 .7 6	Communities of shelf-edge detritic bottom
A 4 .8	Seeps and vents in sublittoral sediments
A 4 .8 1	Freshwater seeps in sublittoral sediments
A 4 .8 2	Methane seeps in sublittoral sediments
A 4 .8 3	Oil seeps in sublittoral sediments
A 4 .8 4	Vents in sublittoral sediments

APPENDIX 3. VARIOUS SHORE TYPES OF HARD SUBSTRATUM

In the appended tables the ecotopes of the hard substrata are depicted as proposed by Meijer & Waardenburg (2002). These ecotopes were strongly summarized in ZES.1, but can be used in cases when a more detailed ecotope classification for hard substrata is advisable. We refer for more information on their ecotope system to their report..

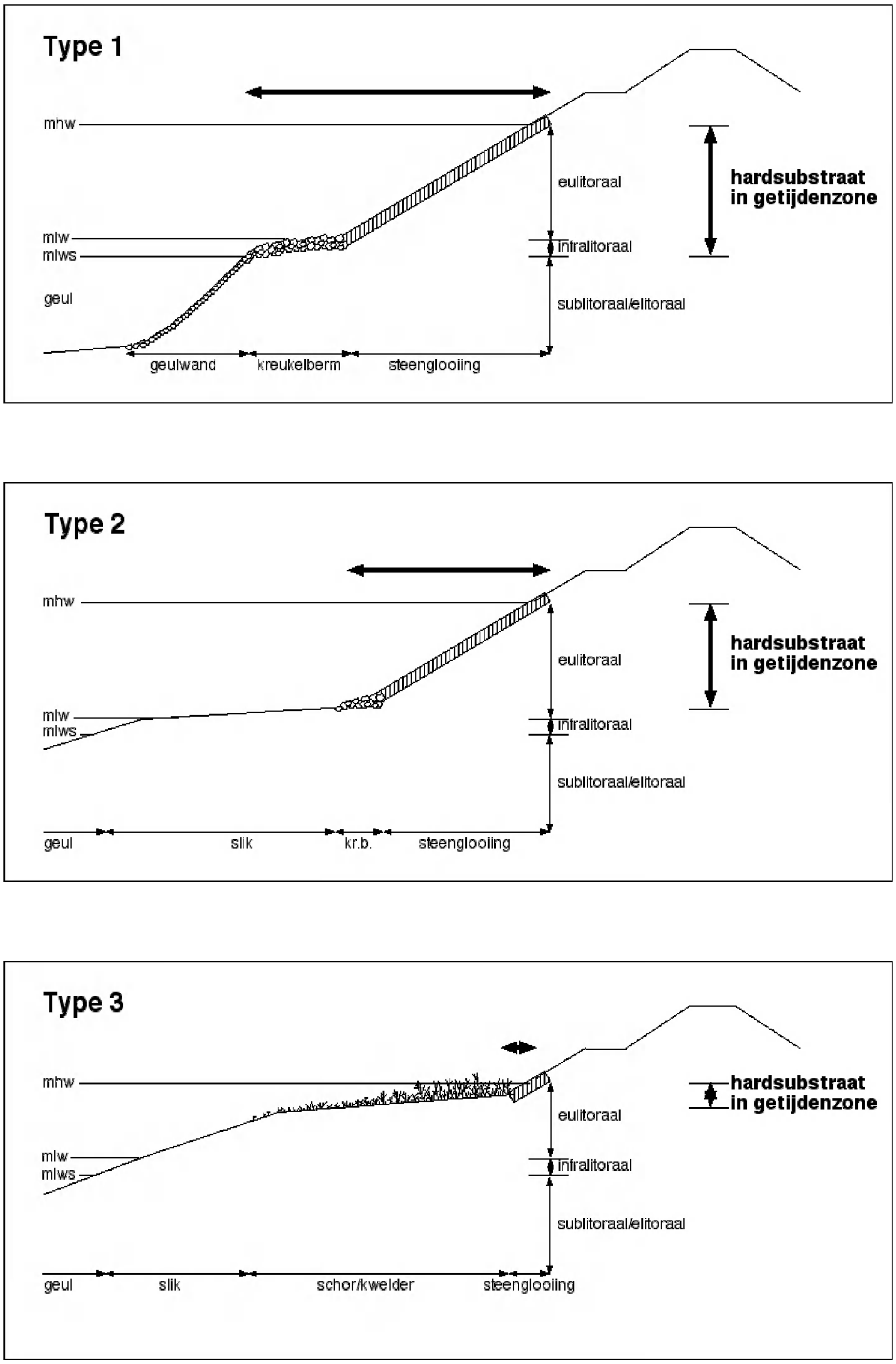
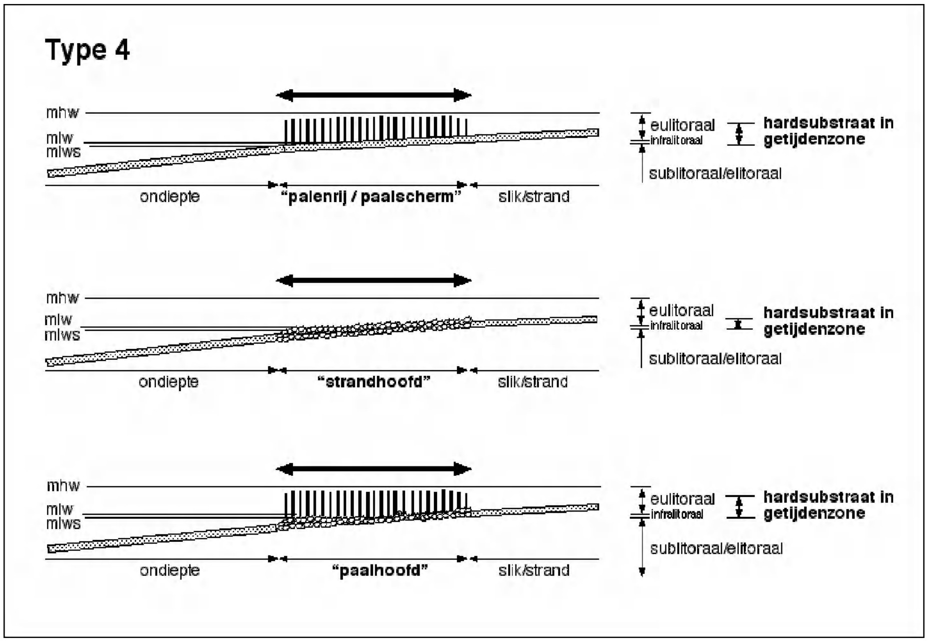
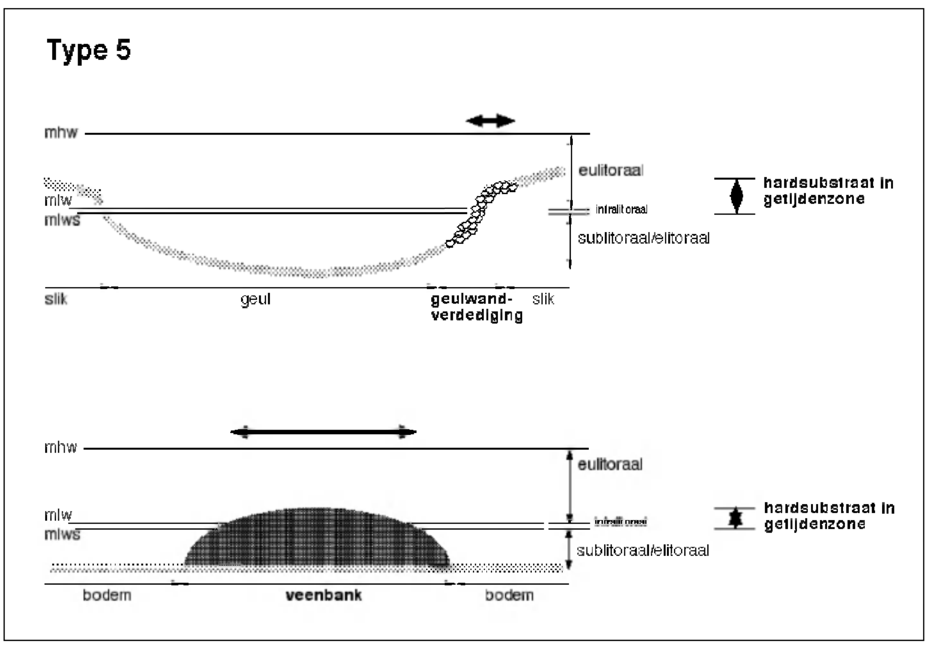


Figure 1.
Shore types of the tidal zone (schematically) (from Meijer & Waardenburg 2002) Legend see below)

Figure 1 continued





Legend
Mhw = mhw; *mlw* = mlw; *mlws* = mlws; *ondiepte* = shallow
Eulitoraal = eulittoral; *infralitoraal* = infralittoral; *sublitoraal/elitoraal* = sublittoral/elittoral
slik/strand = tidal flat/beach; *hardsubstraat in getijdenzone* = hard substratum in the tidal zone;
veenbank = consolidated peat layer; *bodem* = sea bed; *slik* = tidal flat; *geul* = channel
palenrij/paalscherm = row of piles/cut-off piling; *strandhoofd* = beach groyne; *paalhoofd* = groyne;
geulwandverdediging = channel wall protection

Table 1. *Proposal of an ecotope system for hard substrata in the tidal zone. after Meijer & Waardenburg, 2002*

number	salinity	wave dynamics	type positioning in the tidal zo (see figures appendix 3)	infralittoral margin	main type of substratum and construction		foreshore	distribution
1	saline	strong	type 1: the total eulittoral	present	stone	pitchings. breakwaters. piers	channel	mouth of Westerschelde. Neeltje Jans. various
2	saline	strong	type 4: part of eulittoral	absent/marginal	stone	groynes	at the beach	North Sea
3	saline	strong	type 4: part of eulittoral	absent/marginal	wood	pile rows	at the beach	Westerschelde. North Sea
4	saline	light - moderate	type 1: the total eulittoral	present	stone	pitchings. breakwaters. piers	channel	W'schelde. O'schelde. Wadden Sea. Ems
5	saline	light - moderate	type 2: (the high) part of eulittoral	absent	stone	pitchings. breakwaters. piers	tidal flat	W'schelde. O'schelde. Wadden Sea. Ems
6	saline	light - moderate	type 2: (the high) part of eulittoral	absent	stone	pitchings. breakwaters. piers	salt marsh/tidal flat	W'schelde. O'schelde. Wadden Sea
7	saline	light - moderate	type 5: (the low) part of eulittoral	present	stone	channel wall protections	channel	W'schelde
8	saline	light - moderate	type 5: (the low) part of eulittoral	present	peat	consolidated peat layers	channel/shallows	O'schelde. W'schelde
9	saline	sheltered	type 1: the total eulittoral	present	stone	pitchings. breakwaters. piers	channel	W'schelde. O'schelde. Wadden Sea. Ems
10	saline	sheltered	type 2: large part of eulittoral	absent	stone	pitchings. breakwaters. piers	tidal flat	W'schelde. O'schelde. Wadden Sea. Ems
11	saline	sheltered	type 2: (the high) part of eulittoral	absent	stone	pitchings. breakwaters. piers	salt marsh/tidal flat	W'schelde. O'schelde. Wadden Sea. Ems
12	brackish	light - moderate	type 1: the total eulittoral	present	stone	pitchings. breakwaters. piers	channel	W'schelde. Noordland. Dollard
13	brackish	light - moderate	type 2: large part of eulittoral	absent	stone	pitchings. breakwaters. piers	tidal flat	W'schelde. Noordland. Dollard
14	brackish	light - moderate	type 2: (the high) part of eulittoral	absent	stone	pitchings. breakwaters. piers	salt marsh/tidal flat	W'schelde. Noordland. Dollard
15	brackish	light - moderate	type 5(the low) part of eulittoral	present	stone	channel wall protections	channel	W'schelde
16	brackish	light - moderate	type 5: (the low) part of eulittoral	present	peat	consolidated peat layers	channel/shallows	W'schelde
17	brackish	sheltered	type 1: the total eulittoral	present	stone	pitchings. breakwaters. piers	channel	W'schelde. Noordland. Dollard
18	brackish	sheltered	type 2: large part of eulittoral	absent	stone	pitchings. breakwaters. piers	tidal flat	W'schelde. Noordland. Dollard
19	brackish	sheltered	type 2: (the high) part of eulittoral	absent	stone	pitchings. breakwaters. piers	salt marsh/tidal flat	W'schelde. Noordland. Dollard

Table 2. *Proposal of an ecotope system for hard substrata in the sublittoral and elittroal zone. after Meijer & Waardenburg, 2002*

number	salinity	hydro-dynamics & current	wave-dynamics	depth	dominance of Pacific Oyster yes/no	T-stratification yes/no	O2-stratification yes/no	main type of substratum	distribution
A	saline	yes	strong	> 10m - MLW	no	no	no	shipwrecks, artefacts	DCS
B	saline	yes	strong	MLWS-at a max.	no	no	no	breakwaters, piers, coast protections	North Sea coast
C	saline	yes	moderate	MLWS-at a max.	no	no	no	stones	Marsdiep, Wadden Sea
D	saline	yes	moderate	MLWS-at a max.	yes	no	no	underwater slopes, channel wall protections	western part of Westersch., Oostersch.
E	saline	yes	slight-moderate	MLWS-at a max.	no	no	no	consolidated peat layers	Oosterschelde, Zijpe, Slaak
F	saline	minor	slight-moderate	MLWS-at a max.	ja	no	no	underwater slopes, channel wall protections	Krammer, Zijpe, Mastgat
G	saline	no	moderate	0 m - at a max.	no	yes	yes	underwater slopes, channel wall protections	Grevelingenmeer
H	saline	no	slight-moderate	0 m to 2,5 m	no	not up to a depth of 2.5 m	not up to a depth of 2.5 m	consolidated peat layers	Grevelingenmeer
I	brackish	yes	moderate	MLWS-at a max.	yes	no	no	underwater slopes, channel wall protections	Westersch., eastern part of ; New Waterway, Dollard
J	brackish	nee	slight-moderate	0 m - at a max.	no	yes	yes	underwater slopes, channel wall protections	Veerse Meer

APPENDIX 4. EXAMPLES OF ECOTOPE MAPS

Figure 1.
Ecotope map North Sea

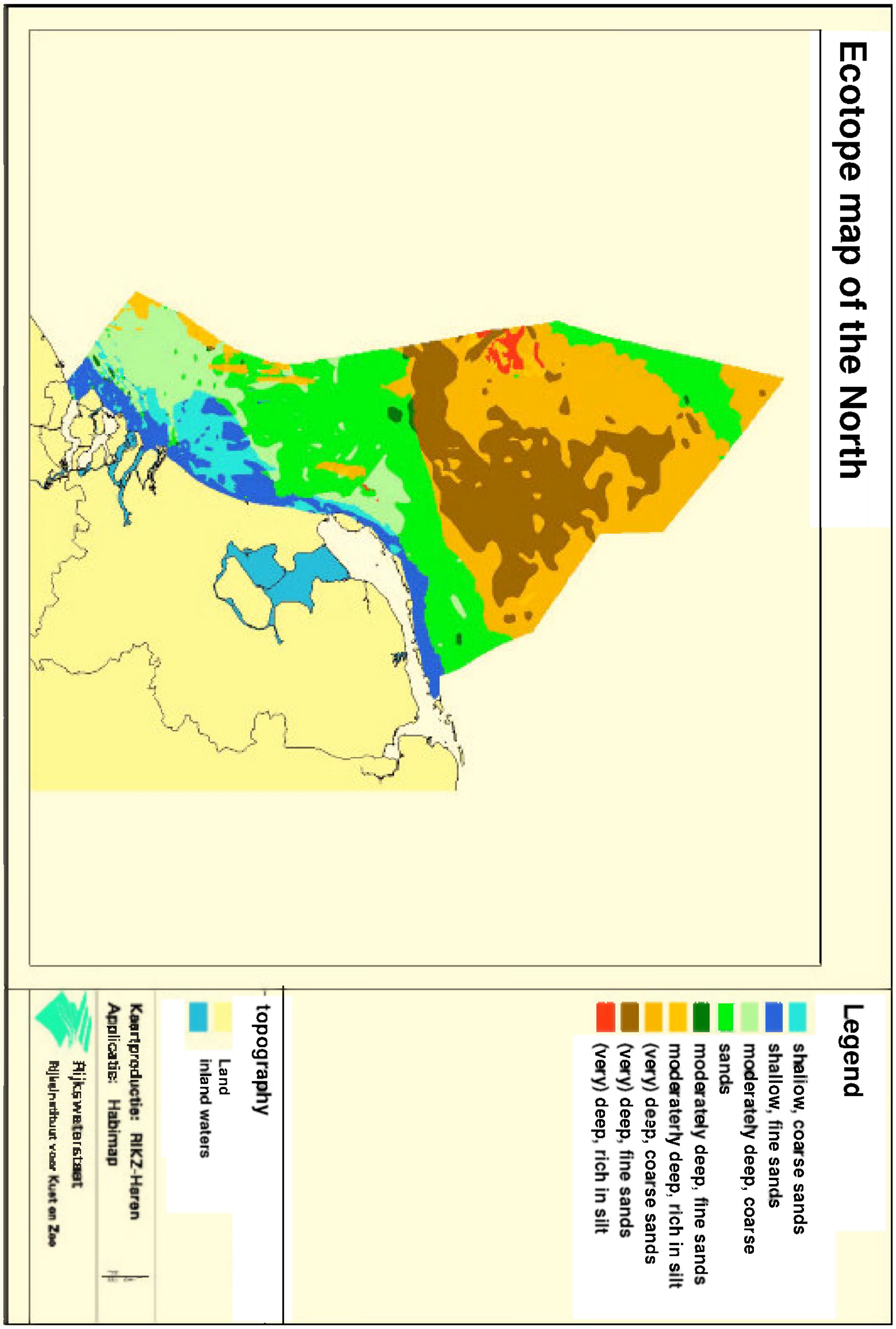


***Figure 2**. Ecotope map Oosterschelde before the completion of the storm surge barrier; situation about 1983*

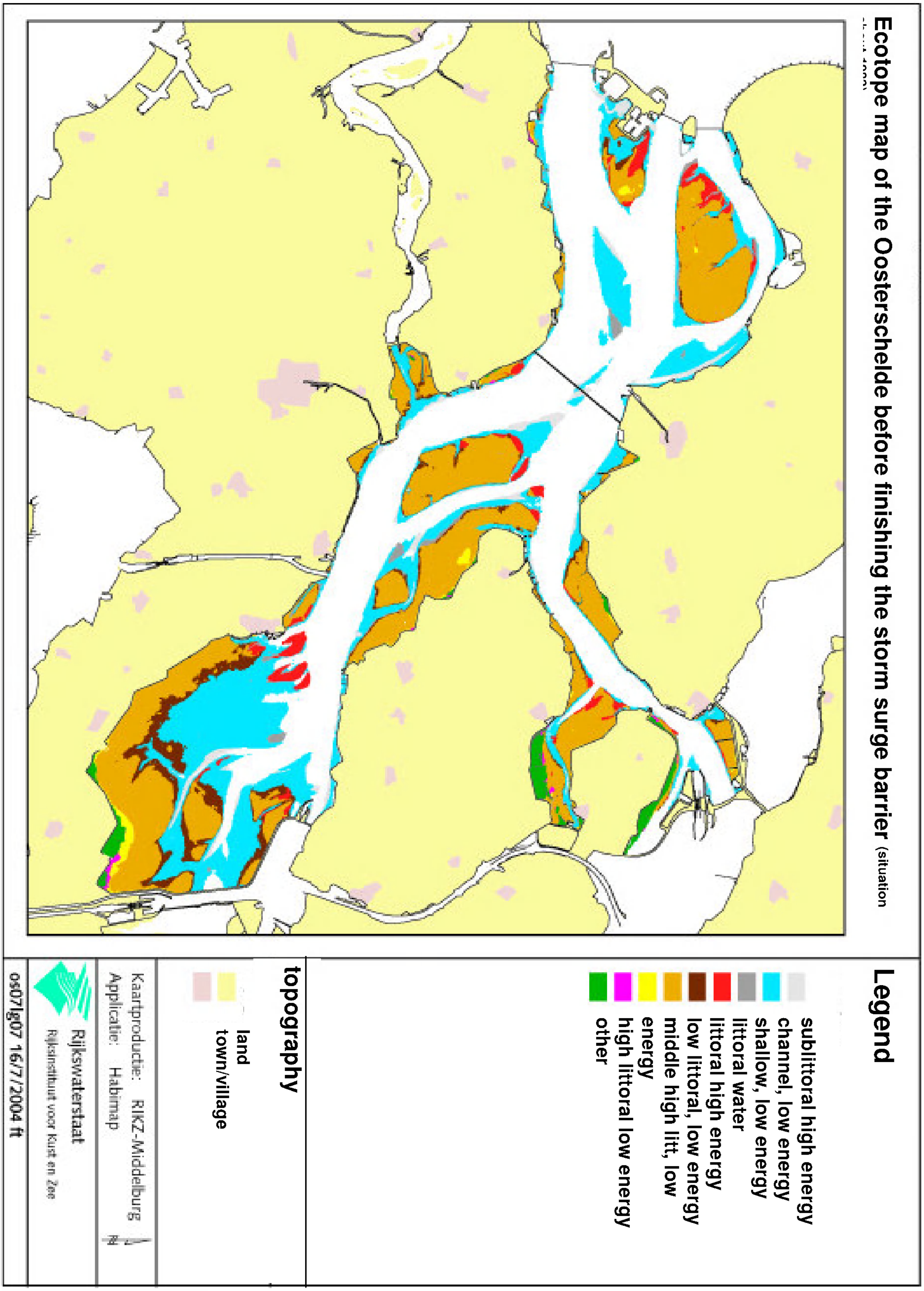
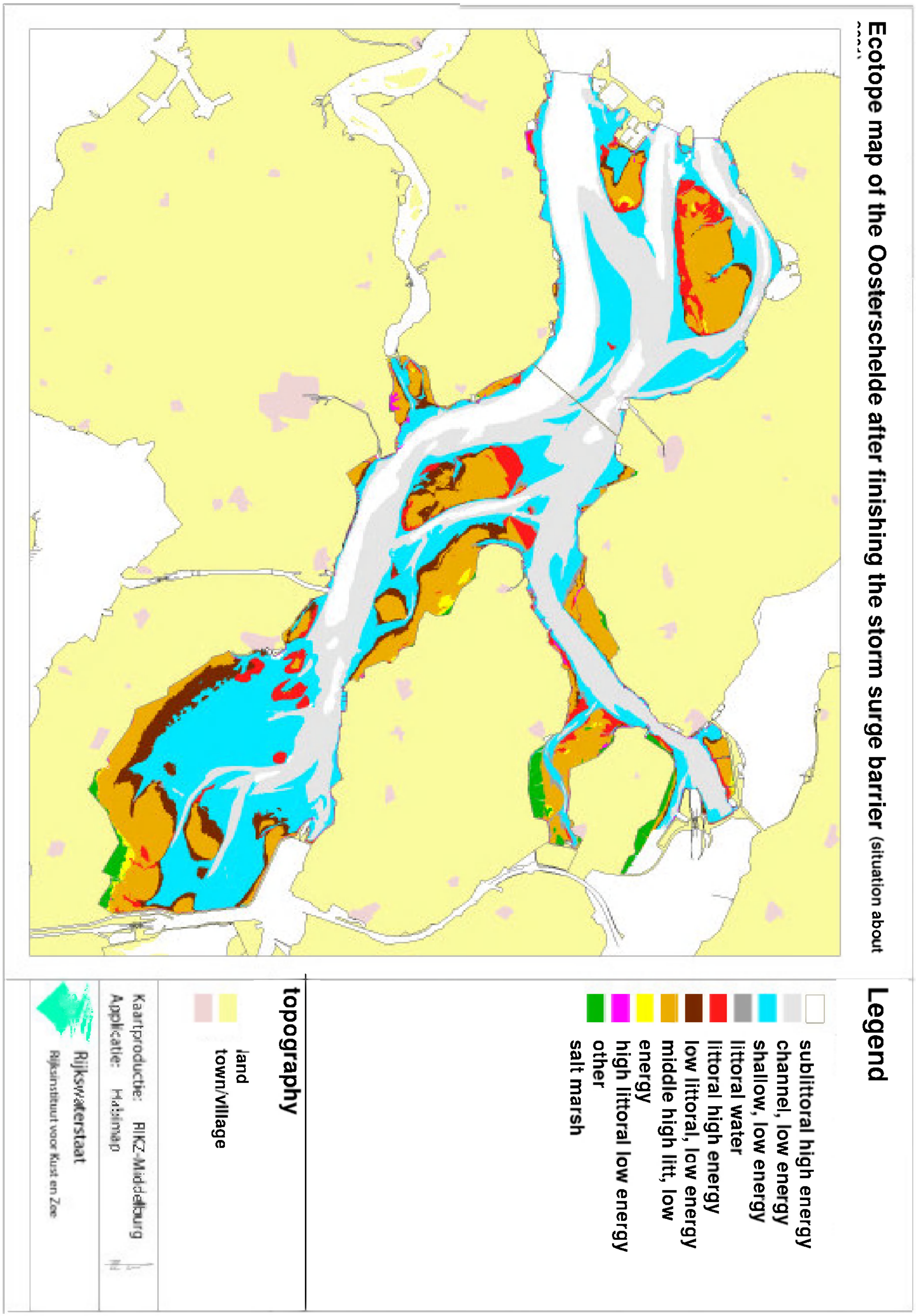


Figure3. *Ecotope map Oosterschelde after completion of the storm surge barrier; situation about 2001*



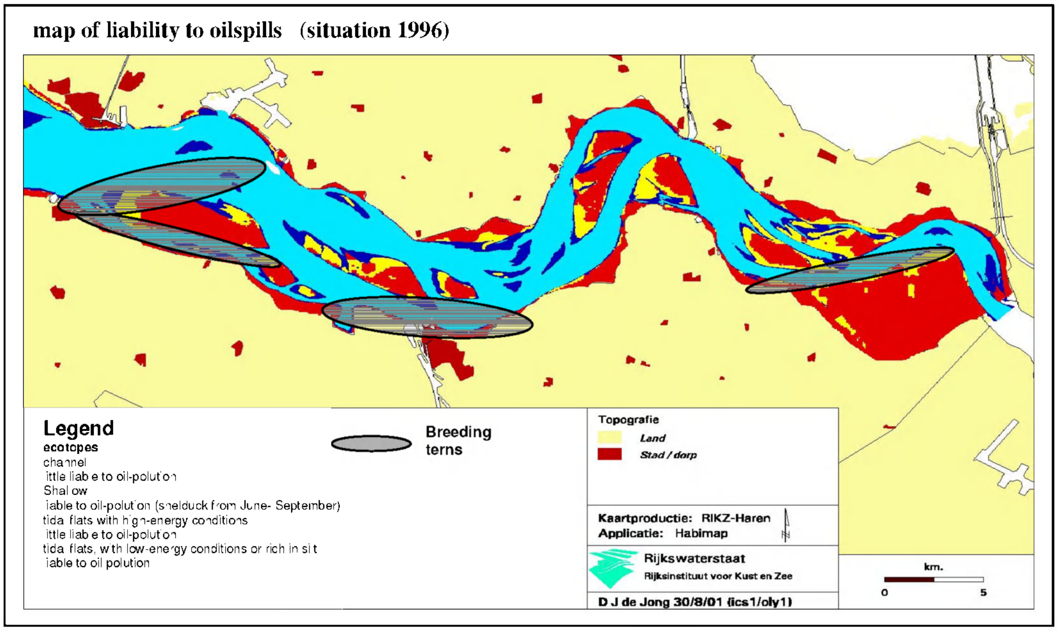
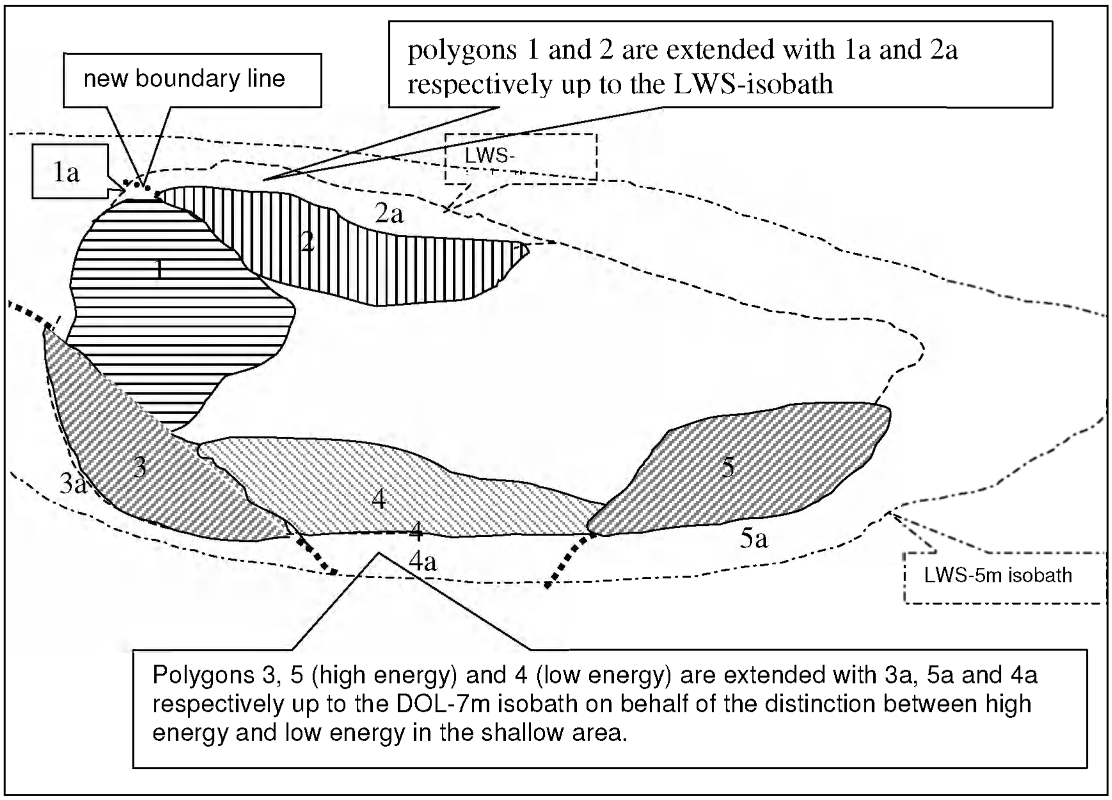


***Figure 4**. Liability to oil pollution in the Westerschelde*

APPENDIX 5. STANDARD LEGEND GEOMORPHOLOGY

The geomorphologic map is based on aerial photographs 1:10,000. Simultaneously a photo-series 1:30,000 is made to enable the right geographical fitting in of shoals. Some perspective corrections are made to the latter series of photographs2, after which the photographs 1:10,000 can be fitted in. On the aerial photographs areas are discerned conform the standard legend. In difficult situations a field survey will be required to find a more definitive determination of the legend unit, such as in plane areas that may have both high or low-energy conditions or in low-energy areas where it is not immediately obvious whether the sediment is rich in silt or just wet. For more details we refer to the standard manual for geomorphologic mapping (AGI/RIKZ in prep.). After the map is made and is available as a GIS-file, an expert makes some last checks in the area. As the photographs are made when the water level is as low as possible, but not at the level of low water spring tide, the map will be adjusted to that level. In order to do so, the map is fitted on a map with the low-water-spring-tide-isobath (LWS). Where the mapped area is larger than the area outside the low-water-spring-tide-isobath it remains the same, but where the mapped area lies within this line, the area is extended to that line. In doing so the adjoining polygon is extended towards the low water isobath. The boundary between two adjoining polygons is extended to that line according to a logical line qua water movement (upper part of the Figure). In a similar way we can even work this out towards the LW\S - 5m-isobath in order to divide the shallow areas into parts with high and low-energy conditions (lower part of the figure).



[2] Making perspective corrections: The procedure in which an aerial photograph is depicted in such a way that it completely corresponds qua orientation with a topographical map. This is required, as an aeroplane is never flying at exactly the right height and exactly horizontally.

Standard legend of geomorphology 2003

Level	1		2		3		4
S	Salt marsh	1	Close vegetation (≥ 50% cover B)	a	Natural salt marshes		
				b	Reclamation works		
				c	Open areas (Cover % < 25 within S1a/b)		
		2	Open vegetation (pioneer zone) (< 50% cover)	a	Primary salt marsh (10 < Cover % < 50)		
				b	Tussocks Cover % <10 and >10 tussocks		
		3	Medium sized creek				
P		1	Low-energy conditions	a	Plane bed	1	Sands
						2	Sands rich in silt
				b	Slightly undulating relief (h<0.25 m, L> 10 m)		
				c	Mussel bed	1	Natural
						2	Anthropogenic
				d	Reclamation works		
		2	High-energy conditions	a	Undulating relief (h<0.25 m, L> 10m		
				b	Megaripples (h> 0.25 m)	1	2-dimensional
						2	3-dimensional
				c	Plane bed		
				d	Ridges	1	Sand ridges
						2	Shell ridges
						3	Shell ridges along dike
		3	Water (bed invisible)				
K	Large creek in salt marsh (e.g. Saeftinge)	1	Low-energy conditions	a	Plane bed	1	Sands
						2	Sands rich in silt
						3	Very silty sands
				b	Slightly undulating relief (h< 0.25 m, L>10 m)		
		2	High-energy conditions	a	Undulating (h< 0.25 m, L>10m		
				b	Megaripples (h> 0.25 m)	1	2-dimensional
						2	3-dimensional
				c	Plane bed		
				d	Ridges	1	Sand ridges
						2	Shell ridges
		3	Water (bed invisible)				
H	Hard substratum	1	Natural (consolidated peat layers)	a	< 25% covered by sand	*	Anthropogenic traces
				b	> 25% covered by sand	*	Anthropogenic traces
D	Dunes	1	Natural				
		2	Artificial				
O	Other	1	Sand dam				
		2	Platform				
		3	Roads/platform				
		4	Tidal harbour				
		5	Water storage				

ILLUSTRATION OF THE STANDARD LEGEND

General
We distinguish four levels. A first classification is made into salt marsh, tidal flats, large salt marsh creek, hard substratum, dunes and other. We subdivide salt marsh further into natural salt marsh, reclamation works and larger creek and the open parts we divide into primary salt marsh and areas with tussocks. We discern very large creeks in Saeftinge (salt marsh in the Westerschelde) separately as K, as they look more like a tidal flat than a salt marsh creek. These large salt marsh creeks are subdivided in a similar way as tidal flats. We subdivide the tidal flats into high-energy and low-energy parts (dynamically).

<u>Main legend units</u>

S: salt marsh
Here there is always (some) vegetation; bare parts in reclamation works are included in P1. Open parts are only mapped when they are substantial.

S1: salt marsh, close vegetation
The vegetation cover is >50%. Reclamation works with vegetation are indicated separately because of their artificial nature.

S2: salt marsh, open vegetation
This includes both the primary salt marsh with a vegetation cover of less than 50% (= pioneer zone) and the open areas with tussocks, that are sometimes present in front of the salt marsh edge or on a tidal flat (e.g. Westerschelde).

The definition salt marsh concerns the categories under S1, i.e. those parts with a vegetation cover of over 50%. A simple classification of salt marshes is: S1 = salt marsh and S2a =primary salt marsh. S2b may be included as a separate unit 'tussocks' or may be joined with e.g. P1b (sandy tidal flats rich in silt). Less than 10 tussocks per ha is included in P1a- or K1a-

K: large salt marsh creeks
These are the large creeks as they occur for instance in Saeftinge (large salt marsh in the Westerschelde) in particular. These creeks are looking more like a tidal flat qua size and function than to a small salt marsh creek in the smaller salt marshes in e.g. the Westerschelde or Oosterschelde.
As it may be convenient in some options to call these creeks salt marsh creek and for other options tidal flat, they have been indicated separately at the first level. At lower levels the classification is virtually identical to that of P (tidal flats) except for the units that cannot occur in K.

P: tidal flats
It concerns the bare tidal flats P1a: low-energy intertidal area, plane (idem K1a). These are the areas of low energy with a more or less plane bed. Relief that is possibly present consists small wave ripples, lugworm heaps and gullies. In some areas the surface may have craterlike structures, probably because in spring silt settles and is retained by diatoms, after which shallow 'holes' develop induced by grazing of benthos and birds (for example the higher parts of the Hooge Platen). Based on the grey tone in the photograph (differences in moisture contents) two classes are distinguished after degree of silt; in rich in silt; and poor in silt. Field surveys are required in this, as drainage plays a part as well.

P1b: Low-energy intertidal area with a low undulating relief (idem K1b)
These are low-energy areas in which due to a long-lasting wave action a relief develops of low broad ridges with in between wet 'valleys'. The bed is only slightly disturbed per tide, so that there are no limitations for benthos; green algae may cover shells. On aerial photographs they look like low megaripples. But no megaripples would be expected here, because of the distance of the tidal channel and their situation along the dikes. In the field this can be recognized by the undulations with a normal benthic fauna and green algae growing on shells.
E.g.: Oosterschelde: Rattekaai-west., Slikken van de Dortsman to the southeast of Stavenisse.(see article L M J U van Straten, Megaripples in the Dutch Wadden Sea and the Basin of Arcachon (France); Geologie en mijnbouw, 1953, nr 1 p 1-11.)

P2a: High-energy intertidal area with a low undulating relief (idem K2a)
These are low sand ripples with large wavelengths. They can form at places where:
I. short-lasting high current velocities occur causing a short period of megaripple formation, but these ripples do not get high; the depth to which the surface is disturbed is limited, so that species that burrow deeply into the bed may survive, but species that burrow shallowly will not.
Example: southwest edge of tidal flat south of St. Philipsland/ Oosterschelde.
II. in the storm-season during storms much wave action and currents occur, but these 'traces' are not levelled out during quiet periods in summer (a kind of fossil large wave ripples); the surface is stirred temporarily (in winter in particular), so that during the summer a kind of pioneer community of short-lived, well-migrating species such as *Corophium* may live there.
Example: west tip of the Hooge Platen (entrance of the Westerschelde).

P2b: High-energy intertidal area with megaripples (idem K2b)
These are high-energy areas, where real megaripples have formed. These megaripples may vary considerably in height and length depending on the maximum current velocity and its duration, roughly from some tens of cm to 1.5-2 m high. In lower current velocities the ripples have a more or less regular pattern (2-d ripples), in very high currents velocities they have a more irregular pattern (3-d ripples). Often the lopsided shape of the ripples may discern the direction of the dominant current.

P2c: high-energy, plane bed (idem K2c)
These are mainly areas along the edges of the tidal flat where high current velocities may occur parallel to the tidal flat. They occur as well on the highest part of the tips of the tidal flats. Sometimes they are confused with P1a, as both types are sandy and plane bed. Then a survey is required.

P2d1: sand ridges (idem K2d1)
Local phenomena. Probably the result of sand accumulations due to the joining of currents.

P2d2: shell ridges (idem K2d2)
These are accumulations of shells, often at places where 2 currents meet or as the result of a residual current across the tidal flat.
They may get up to 0.5 m high (at the Roggenplaat, Oosterschelde, a ridge used to tower about 3 m above DOL {= 1m + MHW}).

P2d3: shell ridges against dikes
Accumulation of shells mixed with more or less sand in corners of dikes. Important as (potential) nesting grounds for e.g. plovers. These cannot be mapped exhaustively as there are a great many small ridges.

P3: water on the tidal flat(idem K3)
This is a water layer on top of the surface, making the underlying bed structure invisible. If possible these are included as much as possible in one of the units that can be mapped, for instance if this unit is (virtually) completely lying in one of the units defined; incidentally this may not be possible.

H: hard substratum
This includes on the one hand the artificial substrata such as pitchings and groynes and on the other hand consolidated peat layers such as they crop out locally in the Westerschelde and Oosterschelde. In the Westerschelde these outcrops of consolidated peat layers are always an indication of high energy, due to which hardly any sediment remains on the peat. Often anthropogenic traces can be found on the consolidated peat layers due to previous habitation.

D: dunes
Here as well a distinction is made between artificial and natural dunes.

O: other
This includes all sorts of non-natural phenomena that may occur in a basin. More figures may be present than the 5 mentioned here. They may be added if required per map.

Colophon

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