



## **A Baltic Sea typology according to the EC-Water Framework Directive: Integration of national typologies and the water body concept**

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### **Abstract**

This article is an update and extension of an earlier publication (SCHERNEWSKI & WIELGAT 2004). Intensive public discussions suggested slight modifications in the typology as well as an updating and completion of comparisons between our typology and the national typologies. We further show examples how the water body concept can be applied to subdivide coastal water types as a response to external pressures. The water body concept allows a kind of subdivision of the typology e.g. in river plumes or near emission sources of pollutants.

The Water Framework Directive (WFD) establishes a comprehensive framework for European Community actions in the field of water and introduces new principles of modern water management. New is especially the spatial integration of river basins, coastal and coastal waters as well as the focus on biological ecosystem quality elements. The WFD requires from all EU Member States to protect and enhance the status of water quality of all types of waters, including coastal zone of the sea. For the purpose of the WFD implementation all water bodies must be classified into types of similar characteristics based on the physical factors. This classification scheme is called typology and forms a universal basis for all other activities within the WFD implementation such as: management or monitoring. The implementation of the WFD as well as the development of a national typology are a responsibility of national authorities and are due to be operational in a few years time. As a result, every country develops or has already developed an independent typology. The WFD defines the Baltic Sea as one Ecoregion. The coastal waters have an international character but national typologies will cause interceptions at country borders and different national typologies will complicate large scale comparisons across the Baltic Sea. Further, the definition of coastal waters (1 nm off the baseline) is artificial. The division between coastal waters and open waters is not in agreement with morphological, physical, chemical or biological parameters. Therefore, a joint typology approach, not only for the Baltic coastal waters, but the entire Baltic Sea is needed. Within the EU-project CHARM (Characterization of the Baltic Sea Ecosystem) a joint Baltic Sea typology was developed. The suggestion in the EU-CIS Working Group 2.4 Guidance Document formed the basis.

Salinity was used as the main obligatory factor. For the Baltic Sea typology residence time and depth/mixing conditions were additionally used. The typology is not meant to replace national typologies. It is developed as an umbrella, which allows the integration of the national typologies and a further subdivision according to regional demands. It therefore serves as a link or an integrative element for the national typologies. The Baltic Sea typology covers the entire Baltic Sea and is not limited to the definition area of the Water Framework Directive.

### **1 Introduction**

The Water Framework Directive (WFD) establishes a comprehensive framework for European Community actions in the field of water and introduces new principles of modern water management. New is especially the spatial integration of river basins, coastal and coastal waters as well as the focus on biological ecosystem quality elements (fish, macrozoobenthos, macrophytes and phytoplankton).

The WFD is an important element for the implementation of the new EC Marine Strategy and has indirectly influence on and is interrelated to the EC-Habitat Directive (NATURA 2000), the EC-Nitrate Directive and the EC recommendations on Integrated Coastal Zone Management. One important aspect in this very dominating WFD is the creation of typologies.

To create a typology for the Baltic Sea means to develop a classification scheme, which unifies water bodies with a similar characteristic and separates different water bodies from each other. A typology generalizes the complex and diverse Baltic ecosystem into simplified units and makes it accessible for spacious analyses and comparisons. The underlying parameters used for a classification or typology depend on its objectives and purpose. Several schemes, which are close to a typology, already exist for the Baltic Sea. Against the background of the EC-habitats directive, for example, a mapping and classification of marine habitats was carried out. A habitat classification for the Baltic Sea is supported or independently developed by organizations like ICES, EEA and HELCOM, too. Most important in this respect are the demands arising from the EC-Water Framework Directive (WFD). The WFD asks all European member states to develop a national typology for their coastal and transitional waters. This typology has far reaching implications. It is, for example, the basis for the definition of reference conditions, water quality classification schemes and will cause significant adaptations with respect to monitoring.

The implementation of the WFD as well as the development of a national typology is the responsibility of national authorities. The typology for every country has to be finished by the end of 2004, and monitoring programs should be operational by the end of 2006. As a result, every country develops or has already developed an independent typology. The Baltic Sea is defined as one Ecoregion in the Water Framework Directive, and the coastal waters are of international character. It is expected that some types will be intercepted at country borders and a very similar water body can belong to very different types. Independent national typologies further bear the danger of different national water quality reference states, different water quality classification schemes and finally different definitions of a good ecological state. Many national typologies would complicate large scale comparisons across the Baltic Sea. Therefore, a joint approach towards typology is required for all Baltic coastal waters. As recommended by the CIS Working Group reference points for monitoring purposes should be established in order to allow inter-comparison between types. A general typology should facilitate this task too.

Despite the fact that the Baltic Sea is defined as an Ecoregion, the Water Framework Directive is restricted to a coastal strip of only 1 nautical mile off the baseline. The narrow strip of coastal waters is artificially divided from open waters. This concept violates the suggested ecosystem approach for the Baltic Sea as defined in the EC-Marine Strategy. It further means that types are truncated artificially and a comprehensive Baltic system concerning reference conditions, water quality classification schemes and monitoring is hardly possible. The problems arising from the limitation of coastal waters call for a typology which covers the entire Baltic Sea.

In December 2001, an EU project entitled "Characterization of the Baltic Sea Ecosystem: Dynamics and Function of Coastal Types" (CHARM) was launched aiming, inter alia, at testing and validating a methodology for establishing coastal types in the Baltic Sea Ecoregion. Furthermore, by analyzing coastal ecosystems dynamics and function in relation to anthropogenic pressure, the objectives of the project were to develop recommendations on reference conditions and monitoring strategies for facilitation of the Water Framework Directive implementation for all Baltic Sea coastal waters. All Baltic states (except Russia) participated in the project.

Our work represents the CHARM project approach, formulating a general typology – a classification system – for the Baltic Sea Ecoregion. The aim is to cover the entire Baltic Sea in a flexible manner and to keep the system general enough, that it can serve as an umbrella, linking all national approaches to coastal waters typology for all Baltic countries under one scheme. This article is an update and extension of an earlier publication (SCHERNEWSKI & WIELGAT 2004). Intensive public

discussions suggested slight modifications in the typology as well as an updating and completion of comparisons with national typologies. We further show examples how the water body concept can be applied to subdivide coastal water types according to external pressures. The water body concept allows a kind of subdivision of the typology e.g. in river plumes or near emission sources of pollutants.

## **2 Background: The Water Framework Directive and typology**

In the year 2000, the Water Framework Directive - WFD (DIRECTIVE 2000/60/EC) entered into force. This Directive is a result of a long process of discussions in the field of water policy and replaces as well as unifies water related laws in Europe. It introduces new principles of water management and promotes sustainable water use based on long-term protection of water resources. The goal of the Directive is not only to prevent further deterioration of water bodies but also to protect and enhance the status of water resources to the level of quality defined as “good”. According to the Directive requirements, all water bodies must reach at least “good water status” before year 2015. This means that the water quality must be improved close to the reference or background conditions reflecting natural, undisturbed conditions of the certain water type. The Directive provides a framework for protection of all types of waters: inland surface waters, groundwater and waters of the coastal strip for all seas around Europe.

There are two general types of waters considered in the coastal seas around Europe: coastal and transitional waters. WFD defines coastal waters as bodies of surface sea waters reaching up to one nautical mile on the seaward side from the baseline from which the breadth of territorial waters is measured (Fig. 1). According to the Directive ‘transitional waters’ are bodies of surface sea waters in the vicinity of river mouths ... which are substantially influenced by freshwater flows”. In the present work we consider only coastal waters, since most Baltic States do not intend to identify any transitional waters along their Baltic Sea coast. However, a final decision on defining some areas as transitional waters will be taken on the national level, when all Member States decide on the final classification scheme of the WFD in their coastal zone is a result of a long process of discussions in the field of water policy and replaces as well as unifies water related laws in Europe. It introduces new principles of water management and promotes sustainable water use based on long-term protection of water resources. The goal of the Directive is not only to prevent further deterioration of water bodies but also to protect and enhance the status of water resources to the level of quality defined as “good”. According to the Directive requirements, all water bodies must reach at least “good water status” before year 2015. This means that the water quality must be improved close to the reference or background conditions reflecting natural, undisturbed conditions of the certain water type. The Directive provides a framework for protection of all types of waters: inland surface waters, groundwater and waters of the coastal strip for all seas around Europe.

The Directive requires that all surface waters including waters in the coastal zone of the seas - transitional and coastal waters - shall be divided into types, based on physical factors. The classification system is defined in the Directive as a typology, and factors to be used for classification are specified. Formulating a typology would mean dividing the entire coastal strip around Europe into types of water based on physical factors, such as e.g. depth, water residence time or exposure of the water type. This classification will form a background for all other Directive activities, such as: defining the present status of the water quality as compared to the natural, background status which is specific for each type, managing of waters in order to prevent further pollution and enhance the water status to the “good” level. For the purpose of the WFD implementation each type will have to be monitored and the monitoring program must reflect the need to identify the water status.

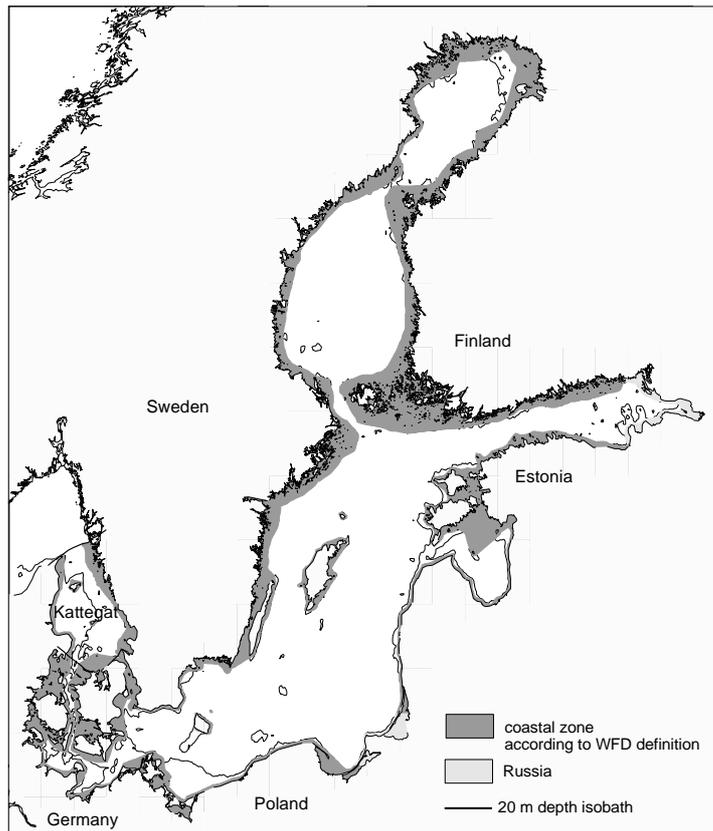


Figure 1: The coastal waters of the Baltic Sea Ecoregion as defined by the Water Framework Directive based on the baseline delimitation. Coastal waters limits as defined by national baselines correspond mostly with the 20 m isobath which is also shown.

The EU Member Countries agreed to develop a Common Implementation Strategy (CIS) for the Water Framework Directive to be worked out within the framework of the Commission. Among other working groups established to support this Common Implementation Strategy, the EU-CIS Working Group 2.4 was supposed to produce a practical guidance document on the implementation of the Directive for transitional and coastal waters. The working group included representatives from each Member State as well as experts from other countries. The Document “Guidance on typology, reference conditions and classification systems for transitional and coastal waters” (VINCENT et al. 2002) is non-legally binding. Instead, it aims at providing a practical advice for implementing WFD. The document suggests a unified, Pan-European approach. However, it is not detailed enough to answer all questions, it sets certain direction of work for WFD implementation in coastal and transitional waters and therefore can be considered as a framework for all tasks.

The Water Framework Directive (DIRECTIVE 2000/60/EC) formulated scientific basis to be used for classification of water bodies which are specified in the Annex II of the Directive document. According to the Directive requirements, the classification system – a typology – can be done based on two alternative schemes: System A or System B. System A classifies all coastal regions into Ecoregions and the Baltic Sea is one Ecoregion under System A classification. The next classification factors in system A are: salinity and depth. If the System A is not sufficient, System B can be used alternatively. The obligatory factors in System B are: Latitude/Longitude, tidal range and salinity and then optional factors can be used: current velocity, wave exposure, mean water temperature, mixing characteristic, retention time (of enclosed bays), means substratum composition and water temperature range.

Based on the two Systems the EU-CIS Working Group 2.4 formulated one classification scheme in Guidance Document (VINCENT et al. 2002). It suggested a Pan-European approach in typology to

achieve a generally uniform classification system for all national typologies. A hierarchical approach is recommended and, so called; obligatory factors should be used for main classification in both systems. These are: Latitude/Longitude = Ecoregion; Tidal range; Salinity.

If obligatory factors are not sufficient, they can be followed by optional factors that are most applicable to the ecological situation. Range for each factor is pre-defined in the guidance but it is justified to aggregate or split ranges. All factors and their ranges recommended in the Guidance Document are listed in Table 1.

Table 1: Factors recommended in the EU-CIS Working Group 2.4 Guidance Document to be used for development of typology.

<b>Factor</b>	<b>Range</b>	<b>Range value</b>
Salinity	freshwater oligohaline mesohaline polyhaline euhaline	< 0.5 0.5 to 5 – 6 5 - 6 to 18 - 20 18 – 20 to 30 > higher than 30
Mean Spring Tidal Range	microtidal mesotidal macrotidal	< 30 m 1 m to 5 m > 5 m
Exposure (Wave)	extremely exposed very exposed, exposed moderately exposed sheltered, very sheltered	
Depth	shallow intermediate deep	< 30 m 30 m to 50 m > 50 m
Mixing	permanently fully mixed partially stratified permanently stratified	
Proportion of Intertidal Area	small large	< 50% > 50%
Residence Time	short moderate long	days weeks months to years
Substratum	hard (rock, boulders, cobble) sand-gravel mud mixed sediments	
Current Velocity	weak moderate strong	< 1 knot 1 knot to 3 knots > 3 knots
Duration of Ice Coverage	irregular short medium	< 90 days 90 to 150 days > 150 days

### 3 Methodology

Our work closely followed the suggestions of the WFD Guidance Document on typology. Since most countries will comply with these recommendations we wanted to ensure that our typology generally can be accepted as an umbrella. The Baltic Sea has been defined in the guidance as one Ecoregion – as equivalent to the first classification factor latitude/longitude – and this approach was the basis for our work. Thus, from first obligatory parameters, salinity remained as the main classification factor for the Baltic Sea. The Baltic Sea is a micro-tidal sea and the tidal range is not suitable as a

classification factor. Other parameters related to tides, e.g. proportion of the intertidal area, cannot be used for the Baltic Sea as well.

Exposure is a very suitable parameter for open oceanic shores. In a shelf sea with sub-basins, complex coastal structures and many islands, like in the Baltic Sea, this parameter is of limited use. It would create a very small scale pattern of shelter and exposition. Besides there was also no extensive data available covering this aspect within the entire Baltic Sea. Therefore, exposure along the Baltic Sea coast was not considered. The same is true for current velocity. This parameter is very important in systems with pronounced tidal currents. In the Baltic Sea, currents are mainly wind driven, vary very much in time and space and hardly ever reach a force comparable to the Atlantic coast. Therefore this factor is not very suitable for the Baltic Sea. Instead, other parameters, as discussed below, were chosen to differentiate between the open coastal waters and more sheltered areas in the inner coast: lagoon and inner archipelagos.

Information on the duration of the ice cover for the Baltic Sea was considered as a parameter in our typology as well. Ice cover is of importance for the Baltic Sea, since the sea extends from about 54°N to 66°N ranging from temperate to subarctic climate. If the classification ranges given in Guidance Document on the duration of ice coverage were applied to the Baltic Sea, a zone of long ice cover above 150 days could be distinguished in the northern part of Gulf of Bothnia. The rest of the sea could be classified as one class with respect to the duration of ice cover. The ice cover data were supplied in a form of a map by the Finnish Environment Institute (SYKE) based on data about the ice conditions for the winters 1963/64 - 1979/80 - 17 winters in total (FINNISH INSTITUTE OF MARINE RESEARCH 1988). This parameter is important and allows a subdivision of types on a hierarchical level under our umbrella typology. However, it not used in the umbrella typology because of its regional importance limited to the Gulf of Bothnia.

Finally salinity, depth/mixing and water residence time of enclosed areas (residence time) were used as factors in classification of water types. It was agreed within the CHARM project that results of the typology classification should be displayed on maps and the program used was Surfer. A Baltic Sea basemap with a high resolution coastline (1 x 1 km and 100 x 100 m) for the entire Baltic Sea was obtained from the Baltic Sea Research Institute Warnemünde in Germany (IOW). In the present paper the first, coarser map is used. Most long-term data sets used in the project were for the 1990-2000 period.

### 3.1 Salinity

Salinity was defined as one of the obligatory factors in the WFD and also in the CIS Working Group guidance document, since it is always the first factor defining community composition in every water body and classifications of water bodies into salinity classes have been studied for decades.

The calculation of salinity was done on the basis of data provided by the Department of Systems Ecology, Stockholm University, Sweden (SUSE). It was stored in the Baltic Environmental Database (BED 2002) and the data sets were obtained from institutes from Baltic countries, which participated in the CHARM Project, as well as public data set available in the BED archives.

The calculation was carried out for the period 1990-2000, a period for which the data set is most comprehensive. Only surface data up to the 5 meter depth were considered, in order to achieve comparison between shallow coastal waters and more open, deeper sea areas. The resulting surface salinity for the whole Baltic Sea is shown in Figure 2. Salinity thresholds used to differentiate between types were chosen in line with Water Framework Directive System A and CIS Working Group Guidance ranges and according to the well accepted Venice system:

Freshwater	< 0.5 PSU
Oligohaline waters	0.5 – 6 PSU
Mezohaline waters	> 6 – 18 PSU

Polyhaline waters > 18 – 30 PSU

Thus, there are three salinity classes in the Baltic Sea typology; from oligohaline to polyhaline waters.

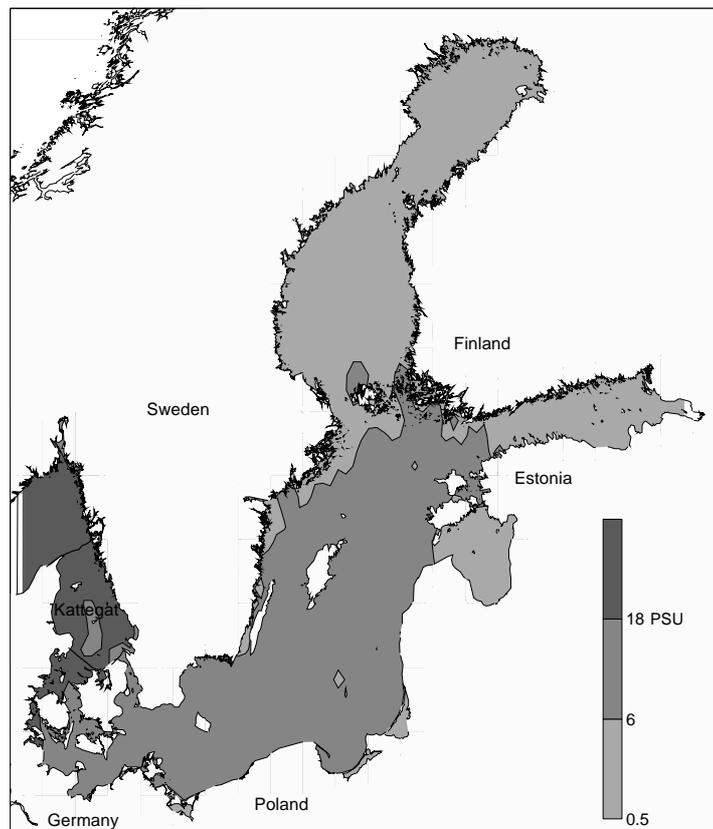


Figure 2: Distribution of salinity in surface Baltic Sea waters up to 5 meters depth. Based on data collected from all institutes participating in the CHARM Project, available via Baltic Environmental Data Base, Stockholm University (BED 2002).

### 3.2 Water depth

An additional factor used in the typology was depth. Depth is regarded as an important factor in the WFD, e.g. according to System A, salinity and depth only can be used as classification factors in typology. Depth affects many other aspects of habitat characteristics such as mixing and stratification of the water column, light penetration and influences sediment characteristic.

A depth model (with a resolution of 2 x 1 nautical miles) for the entire Baltic Sea was provided by T. Seiffert, Baltic Sea Research Institute Warnemünde, Germany (SEIFERT T. pers. comm.). In the CHARM typology it was assumed that the coastal waters delimited by the WFD rules - 1 mn from the baseline - correspond mostly with the 20 m isobath, as shown in Figure 1. It was therefore assumed in the typology for the Baltic Sea Ecoregion that the 20 m isobath is a depth limit for most of the WFD coastal zone. Only within a few locations coastal waters delimited by baseline are deeper than 20 meters and in such locations this typology leaves areas which, if needed, should be further classified as separate types based on the additional depth classes (e.g. under national typologies).

The 20 m isobath is fairly in agreement with the outer limits of the water framework directive, but are not a suitable boundary within a typology. One biologically important parameter is the depth of the thermocline. In a detailed analysis based on results with the Baltic Sea ecosystem model ERGOM showed that the average depth of the thermocline in summer in the Baltic Sea is in a depth of about 10 m. Therefore, the 10 m isobath was used to distinguish the shallow coastal zone, which is always fully mixed within the entire water column from open waters. Also, the 10 m depth threshold describes the

euphotic zone in coastal areas, where water transparency is lower than in the open sea areas (AARUP 2002), as well. Thus, the typology has two depth classes dividing coastal waters into waters shallower and deeper than 10 m.

### 3.3 Residence time and stratification

Water exchange is regarded as an important factor in the coastal sea zone. The water exchange has a great impact on the concentration of substances in the water column and the sediment/water exchange in the system. It is known, that enclosed systems differ from the open coast waters since many chemical as well as biological parameters depend on the water replacement time, both in freshwater and marine systems (NIXON 1996; SCHEFFER 1998). Water exchange was also one of the major factors used in the Swedish typology (JOHANSSON 2002) for which three water classes according to the water exchange time were used: 0-10 days, 10-40 days and > 40 days. This approach in differentiating open coastal waters from enclosed areas and inner archipelagos was used in the present work. On the basis of morphological data from all CHARM partner countries, 91 prioritized semi-enclosed bays/inshore areas in Baltic Sea were delimited as separate geographical units. For these areas, water residence time and stratification calculation were carried out by the use of numerical models. For open waters residence time is not a suitable parameter, because it depends on the size of the area, which is considered.

For the reconstruction of representative forcing, which are relevant for coastal processes, a 3 dimensional baroclinic model of the Baltic Sea was set up for the 10 year period (1991-2000). It simulated the exchange with the open sea for each of the prioritized semi-enclosed bays. Input parameters were freshwater discharge and wind. The data were collected from all countries participating in CHARM for the 1991-2000 period. In order to calculate the stratification and water exchange in the inshore areas in Baltic Sea, a modified version of the WMM model (GUSTAFSSON 2000A; 2000B) was used. The model uses meteorology, freshwater supply, and offshore stratification as input. The model calculations were carried out by Björn Sjöberg from the Department of Systems Ecology at Stockholm University, Sweden (SUSE) for 31 out of 91 prioritized areas. A first very general partition of the coastal zone was made based on estimates of residence time based on the exchange between the open sea (>30 days, 10-30 days and <10 days) and stratification (fully mixed, partially mixed, stratified) was done (Fig. 4). The results were monthly averages of temperature and salinity stratification. Averages are calculated for the whole integration period, 1991-2000. The output has been compared with observations. A dispersion model was also used to estimate turnover time, transition time and age.

In the present CHARM typology only one threshold of the water residence time calculation was used. Enclosed coastal habitats, such as: lagoons and boddens in the western and southern Baltic Proper, as well as the innermost archipelagos located primarily along the Danish, Swedish and Finnish coast, with water residence time longer than 30 days were separated from the open coast with frequent water exchange based on the model calculation for these areas.

### 3.4 Sediments

Sediment type is a crucial parameter defining bottom habitats. In order to obtain information on the bottom substrate data on surface sediment types were requested from partner institutions, with the aim to establish a database providing information on sediment characteristics with a detailed spatial resolution. However, no raw data sets were made available, mainly due to a lack of data or limited access to existing data. Instead, maps in a digitalized form (at least 1:500000 in scale) were collected for the whole Baltic Sea area. Some regions, namely the coast of Finland, have not yet been surveyed for sediment granulometry in total, therefore, they were not covered. This is why no information is available for the Gulf of Finland, the Bothnian Sea and Gulf of Bothnia. The area covered is presented in Figure 3. This deliverable is available as a series of regional, national and large scale sediment maps, and the general map is split into regional maps - mainly country wide maps - which can be

accessed from one source with metadata information. Despite many problems in detail (different size fractions, methods and spatial resolution), bottom sediment maps are useful for the southern Baltic, soft bottom regions. However, along the rocky areas, like in Scandinavia, sediments show high and small-scale variability. The first approaches to introduce soft and hard bottom as a parameter in the typology did not yield satisfying results, because of the high and small scale variability. Therefore the sediment type was not included as a parameter in the whole Baltic Sea typology.



Figure 3: Coverage of the Baltic Sea sediment with sediment maps collected within the CHARM project.

#### 4 A typology for the entire Baltic Sea

The present classification of types within the Baltic Sea is based on three main factors (Fig. 5):

- Surface salinity;
- Water residence time which separates open coast from semi-enclosed bays/inshore areas which were delimited as separate geographical units;
- Depth, which corresponds to the mixing of the water column;
- Since the Water Framework Directive is restricted to a coastal strip of only 1 nautical mile off the baseline, the narrow strip of coastal waters is artificially divided from open waters.

As mentioned before, the Water Framework Directive defines the entire Baltic Sea as one Ecoregion. On the other hand, the WFD is restricted to a coastal strip of only 1 nautical mile off the baseline. The narrow strip of coastal waters is artificially divided from open waters. This division hardly reflects the spatial distribution of biological parameter, it limits the amount of data available for research in support of the WFD and, most importantly favours a large number of independent and hardly comparable national typology approaches. It means that types are truncated artificially and a comprehensive Baltic system concerning reference conditions, water quality classification schemes and monitoring is hardly possible. All these problems arising from the limitation of coastal waters call for a typology which covers the entire Baltic Sea.

Further, this short-coming violates the suggested ecosystem approach for the Baltic Sea as defined in the EC-Marine Strategy. Against the background of the Marine Strategy the WFD approach will have to be extended into offshore marine waters, as well. This would include the operational monitoring of biological and hydro-morphological quality elements as well as hazardous substances. The reference conditions or Ecological Quality Objectives as well as the typology have to be extended towards the open sea. The present CHARM typology is suitable for coastal waters, because the 20m depth isobath

was, due to ecological reasons, used to separate coastal and open waters. This 20 m isobath is in very many cases well in agreement with the outer boundary of coastal waters as defined by the WFD. However, our approach allows the extension towards the entire Baltic Sea and a further development (further division) of the open sea waters typology as needed for the EU Marine Strategy. An extension allows a more comprehensive view concerning reference conditions, water quality classification schemes and monitoring. Figure 6 presents the type distribution along the coast of the Baltic Sea and types for the whole Baltic Sea. The 20 m depth line representing the outer limit of the WFD coastal waters is also shown.

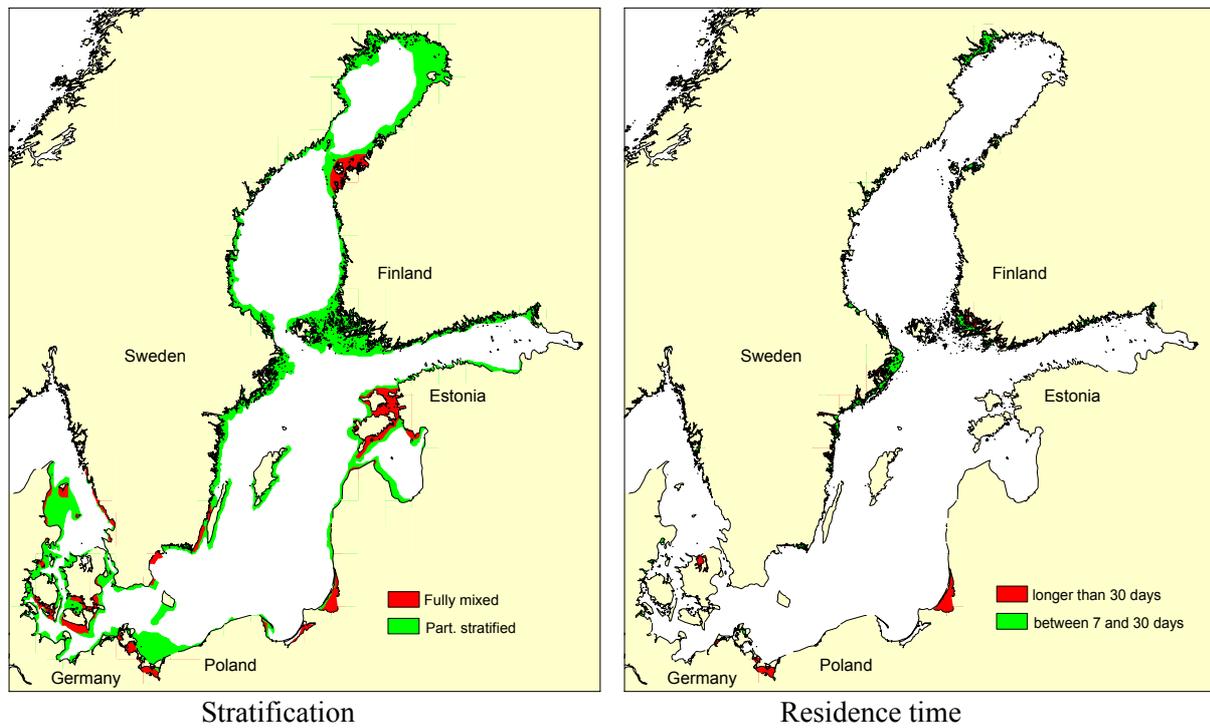


Figure 4: Stratification (left) and water residence time (right) in selected inshore areas of the Baltic Sea calculated for the CHARM project (Björn Sjöberg from the Department of Systems Ecology at Stockholm University, Sweden (SUSE)).

Salinity					
0.5 – 6 PSU oligohaline		> 6 – 18 PSU mesohaline		> 18 PSU polyhaline	
Water retention time & Depth					
> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m

Figure 5: Simple umbrella typology for the Baltic Sea according to the WFD.

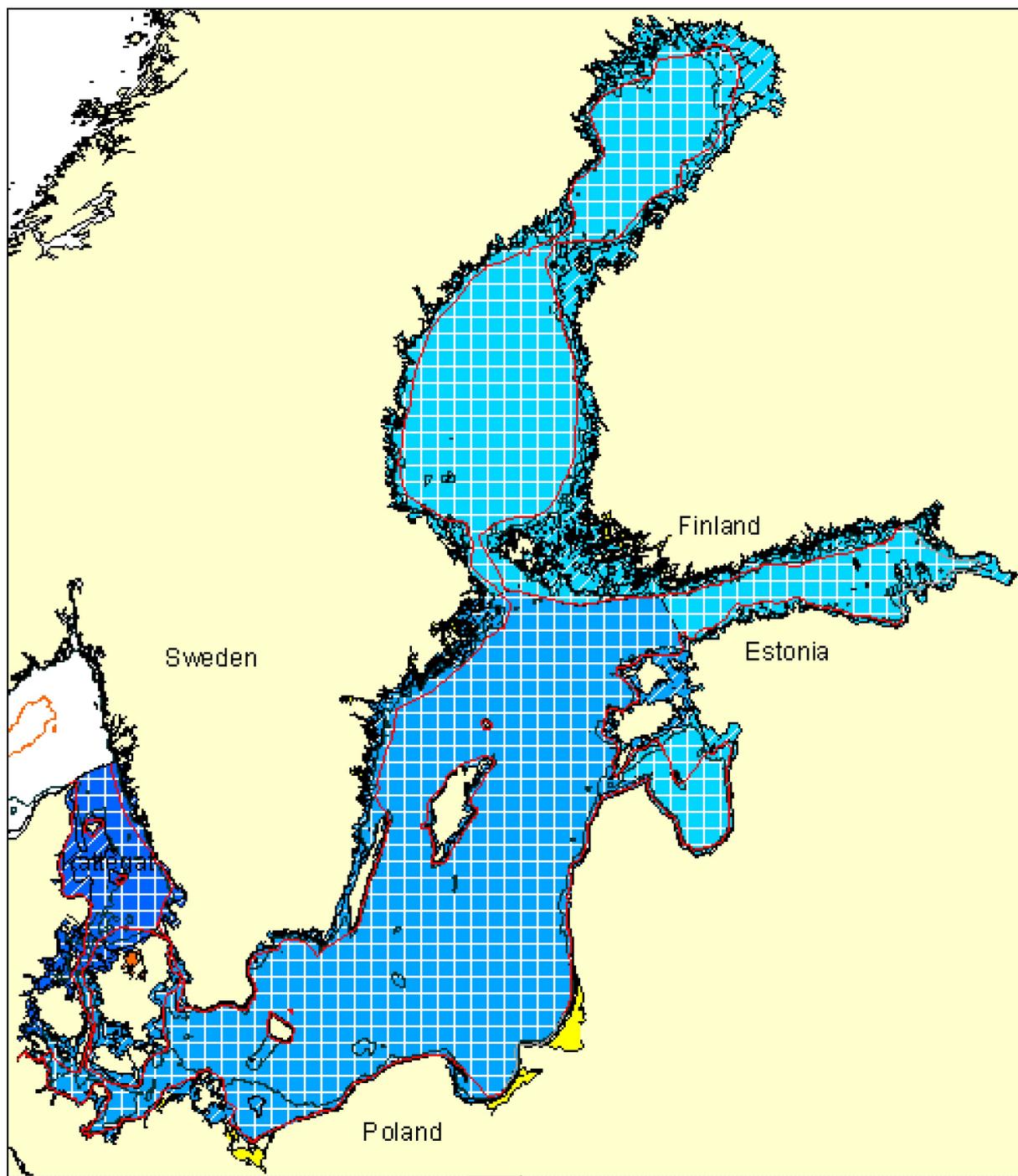


Figure 6: Distribution of types according to the CHARM umbrella Baltic Sea typology.

## 5 The typology as an umbrella for national typologies

In the first CHARM approach to the Baltic typology the entire Baltic Sea was subdivided into nearly 30 types. The large number of types automatically caused significant differences compared to the national typologies. The acceptance of a complex typology for the entire Baltic Sea was poor and specific regional aspects were not reflected. Against this background we changed our strategy and tried to work out the most important parameters for a typology. We tried to simplify our typology as much as possible and to develop it towards an umbrella system. Umbrella system means that the typology allows a further subdivision according to regional demands and allows the integration of the national typologies. It serves as a link between and integrative element for the national typologies.

The salinity boundaries used in our typology was used by most countries since it is based on the well established Venice system. All national typologies accept the main thresholds from 5 to 6 between oligo- and mesohaline waters and from 18 to 20 PSU between mesohaline and polyhaline waters. The strongest surface salinity gradient occurs between the Kattegat and the western Baltic Proper and salinity plays a very important role in national typologies of this region. In the draft German typology e.g. 3 PSU, 5 PSU in oligohaline class and 10 PSU in mesohaline class was used to subdivide basic four types further. Also, in countries, where all waters are oligohaline additional divisions might be suitable. In the draft Finnish national typology according to system B additional salinity threshold - 4 PSU was used and in the draft Swedish typology, there was also an additional threshold subdividing oligohaline waters – 3 PSU.

All Baltic states have chosen System B of the Water Framework Directive. Except for Germany, none of the national typology presented here is a final version and changes in approach and spatial distribution of types can be expected. However, almost all countries have now drafted prepared their own classification systems for the Baltic Sea waters. Available drafts are compared to the umbrella typology and the classification is discussed below.

### 5.1 Danish and German draft national typologies

Danish waters belong to the two Ecoregions: North Sea and the Baltic Sea. There are strong salinity gradients in Danish coastal waters due to the specific strong water stratification in Danish Straits region and extension of the coastal waters strip: from the North Sea to the open mesohaline waters of the central Baltic. Therefore, the first factor used for classification in Danish typology is salinity of the bottom layer with the generally acceptable thresholds. Further, the Danish classification is based on the assumption that open waters require use of different factors for classification than enclosed basins such as fiords. Thus, there are two classification systems used in the Danish typology: for open waters and for classification of fjords. Types in open waters are categorized according to:

- Bottom salinity;
- Exposure;
- Tidal regime.

Types in fjords are categorized according to:

- Bottom salinity;
- Degree of stratification;
- Degree of sensitivity to land-based input of water (CHRISTIANSEN et al. this issue); DANISH EPA 2004).

In a very general sense it can be said that the open waters are separated from enclosed waters in the Danish typology and the classification is based on the geographically defined areas. This first step is comparable to the CHARM umbrella approach; however further classification factors used for Danish waters are specific to this national typology (Fig. 7).

The German coast also faces a quite strong salinity gradient in the western part of the Baltic and salinity is the main classification factor in German typology. All open coast waters are classified as mesohaline with the exception of deeper, stratified areas, where bottom waters are of higher salinity classified as separate type – mixohaline waters. The open coast is divided into two types: open and inner mesohaline coastal waters. The inner lagoons and boddens are classified as oligohaline due to the fresh water inflow. Thus, there are four types in the German typology (INSTITUT FÜR ANGEWANDTE ÖKOLOGIE 2003; WEBER et al. 2002). The German typology can be classified within the CHARM umbrella typology (Fig. 8).

## 5.2 Latvian and Lithuanian draft national typologies

Latvian and Lithuanian coast represents the open sandy or mixed sandy-hard bottom sediment coast of the central Baltic. The Latvian typology considers the following factors: salinity, depth, wave exposure, mixing, residence time, bottom substratum and ice coverage. The governing factors in the Latvian typology are salinity and substratum. Water salinity in the coastal water of Latvia is in general lower than 6 PSU within the Gulf of Riga and along the open Baltic coast exceeds this value (ALBINUS et al. 2004). Thus, there are two salinity classes in Latvian typology. Division into two classes according to salinity reflects also wave exposure, since waters within the Gulf of Riga were classified as moderately exposed and the outer Baltic coast as exposed. Latvian coastal waters as defined by the WFD usually do not exceed 10 - 15 m depth along whole Latvian coast (with one exception when the coastal water stretch has mean depth of about 13 m), and the average depth is 7 m (ALBINUS et al. 2004). Within the salinity classes it is substratum that defines water types along the coast and coastal water stretches have been identified according to the dominant bottom type (ALBINUS et al. 2004). The Latvian typology can therefore be included into the CHARM umbrella classification as shown in Figure 10.

The Lithuanian typology considers similar factors (ANSBÆK & SCHWÆRTER 2004): salinity, depth, wave exposure, mixing, and bottom substratum. The open Lithuanian waters are classified as mesohaline. The other governing factor used for open coast classification is bottom substratum. The Curonian Lagoon is classified in the Lithuanian typology as transitional waters, but the open coast classification – which is not complex in the Lithuanian part of the Baltic coast – can be classified under the CHARM umbrella (Fig. 9).

Both in the Latvian and Lithuanian typologies the large river plumes (the Daugava River and the outlet of the Curonian Lagoon) are classified as transitional waters. This is a different approach to the approaches taken by most other countries and also differs to the CHARM approach, and it calls for additional classification means – such as e.g. defining the river plume border.

## 5.3 Estonian draft national typology

The Estonian typology considers the following factors: salinity, depth, wave exposure, mixing, residence time and bottom substratum (ESTONIAN MINISTRY OF THE ENVIRONMENT 2004). Salinity is the first classification factor, based on the Venice system. The open coast and the western part of Gulf of Finland are considered to be mesohaline up to 5/6 PSU and there are two oligohaline types, along the most inner parts of coast: Parnu Bay (in the Gulf of Riga) and the Narva Bay (in the Gulf of Finland). The mesohaline waters are further divided according to the depth, into two classes: < 30 m and > 30 m. The next governing factor used is wave exposure. All types are also described with respect to mixing conditions, residence time and bottom substratum. This is a classification system similar to CHARM approach (Fig. 11).

## 5.4 Finnish draft national typology

Finnish coastal waters can be classified into two types based on salinity: oligohaline and mesohaline, and most of the coastal strip is shallow. For the Finnish typology the System B was chosen since classification according to System A was found to be too coarse (FINNISH COASTAL EXPERT GROUP

2001; PERUS et al. this issue). This proposal suggested 16 coastal water types (Fig. 12); based on salinity and latitude – longitude, duration of ice coverage, mean bottom substratum type and mixing conditions as well as wave exposure. Finally, some archipelago areas were differentiated after analysis of topographic complexity and zonation patterns (PERUS et al. this issue). This approach can be classified to a certain degree under umbrella typology as presented in Figure 12.

### **5.5 Swedish draft national typology**

Sweden has the longest coast line amongst all Baltic countries stretching in the all three salinity classes from polyhaline waters in Kattegat to oligohaline waters in the Gulf of Bothnia with a complex coast structure. In the Swedish national typology non-hierarchical approach is used and types are classified on the basis of two or three governing factors out of the following list: salinity, water exchange of bottom waters, substratum, stratification, wave exposure, ice days. Depth is also considered for the type description. Salinity is considered for most regions as a main governing factor. To differentiate between open coast areas and inner, more enclosed cost types, wave exposure and water exchange are considered as factors defining types, but in some other regions bottom substratum and stratification are taken into account. In the Gulf of Bothnia one of the main governing factors is ice cover (SWEDISH EPA 2004). This is a different strategy than hierarchical approach used in other countries, and also differs from the CHARM approach (Fig. 13 and Fig. 14).

## **6 Water bodies as management units of the WDF**

A detailed look at the suggested typology reveals that the present ecological state of coastal waters varies significantly within a type. Types reflect coastal waters with similar framework conditions and a similar potential ecological state. Recent anthropogenic pressures, like point sources or rivers, cause very different ecological situations within one type. These anthropogenic pressures are variable in time and space and therefore not suitable to be directly included in a typology. For example, many rivers show an ongoing serious reduction of their nutrient loads. The size of river plumes, measured in form of elevated nutrient levels are decreasing and the same is true for their general impact on coastal waters. Therefore, the water body concept allows a subdivision of coastal water types according to the existing external pressures and the visible modifications of the ecological state. Different to the typology, water bodies are not fixed in time and space. Their boundaries require an adaptation from time to time, according to the changes that took place in a coastal region. Water bodies can be regarded as a flexible subdivision of types suitable for management purposes. The following cases show how water bodies can create a refined subdivision of coastal types (Fig. 15 and Fig. 16).

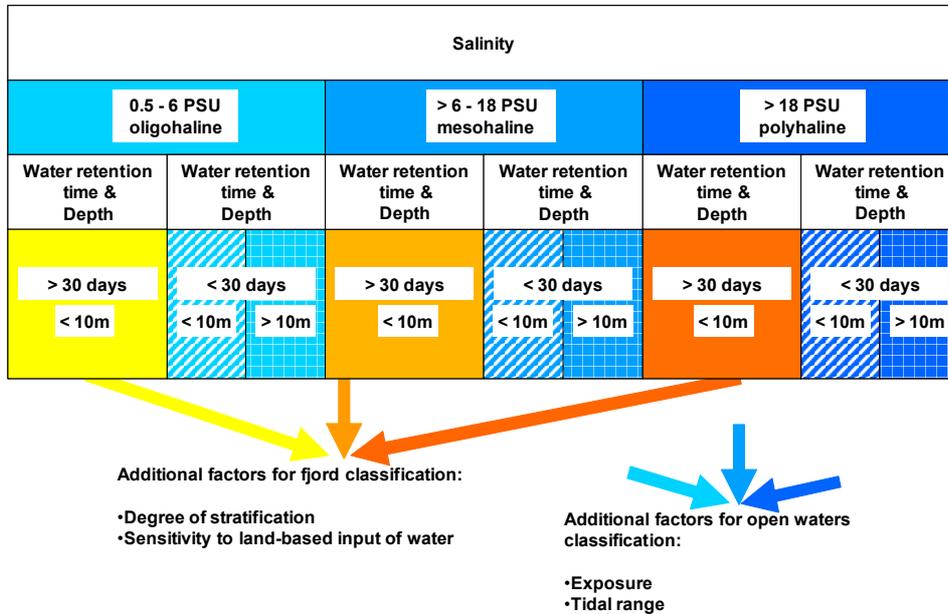
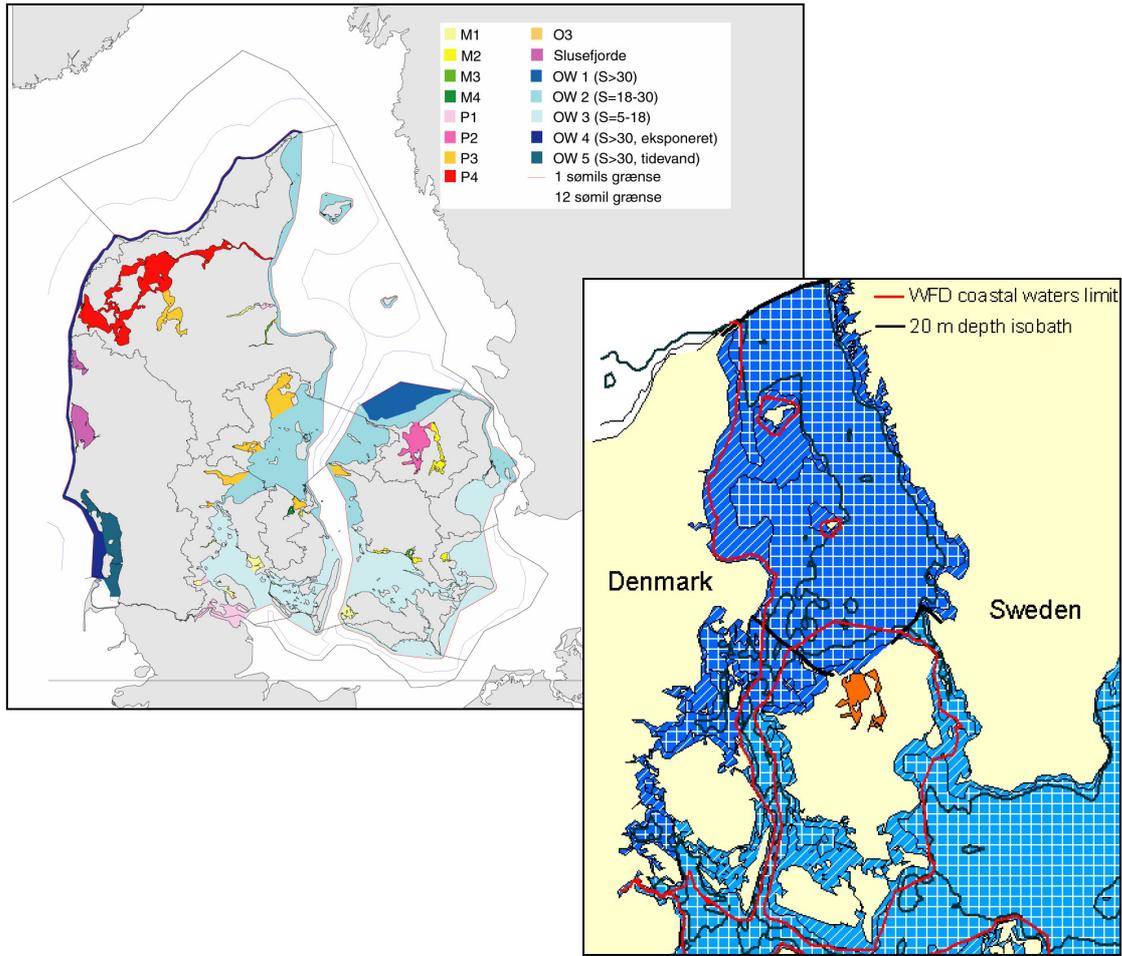


Figure 7: National Danish typology (after DANISH EPA 2004) as compared to the CHARM umbrella typology for the Baltic Sea.

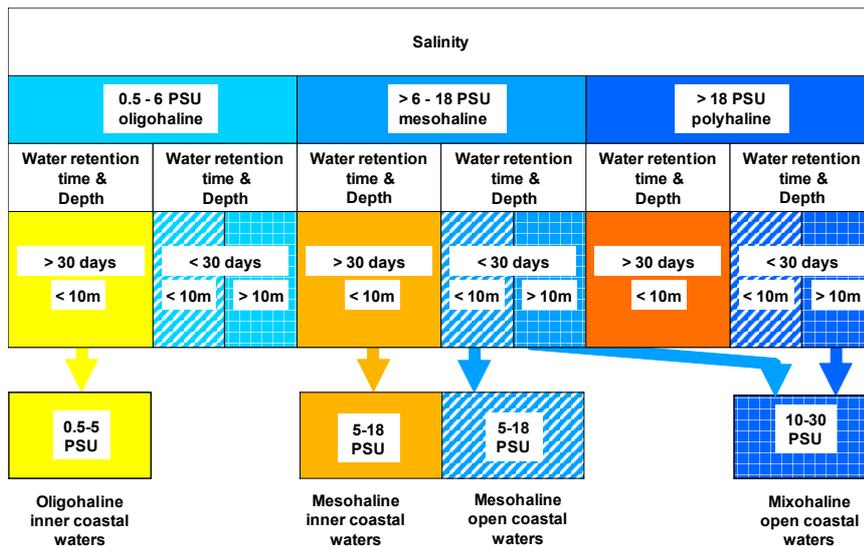
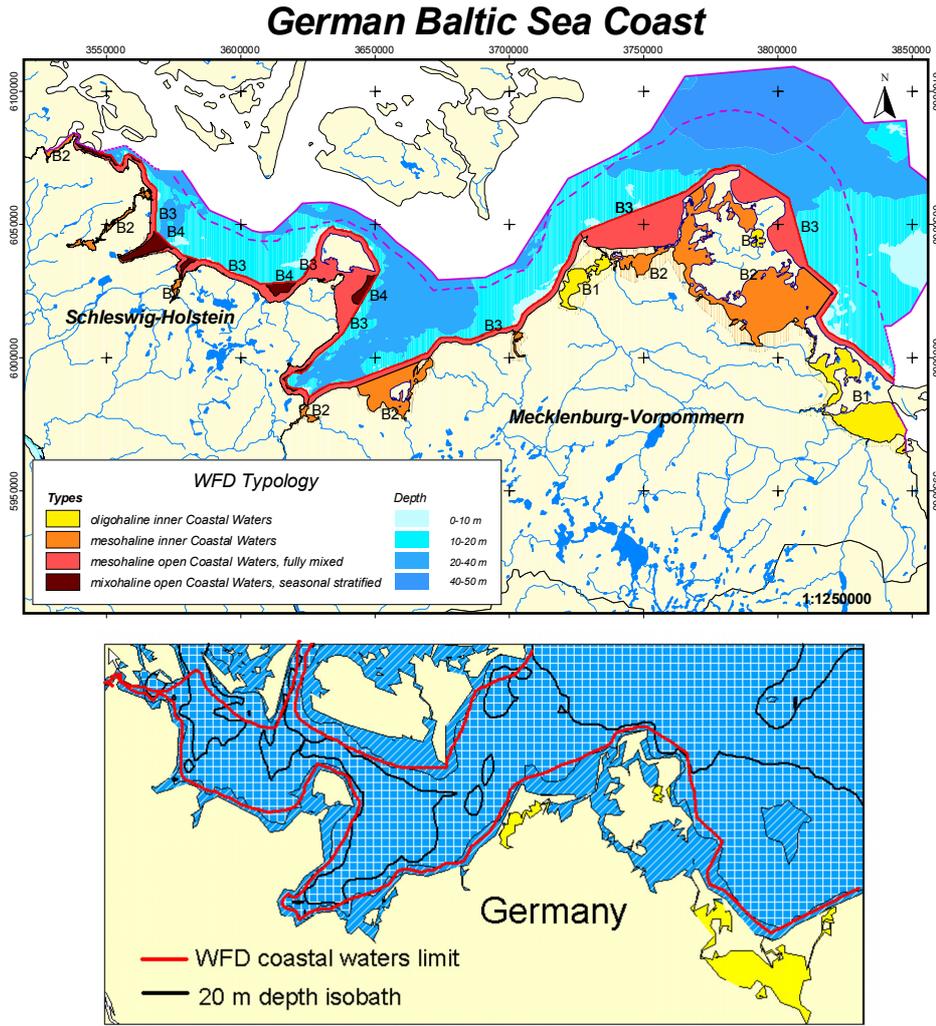
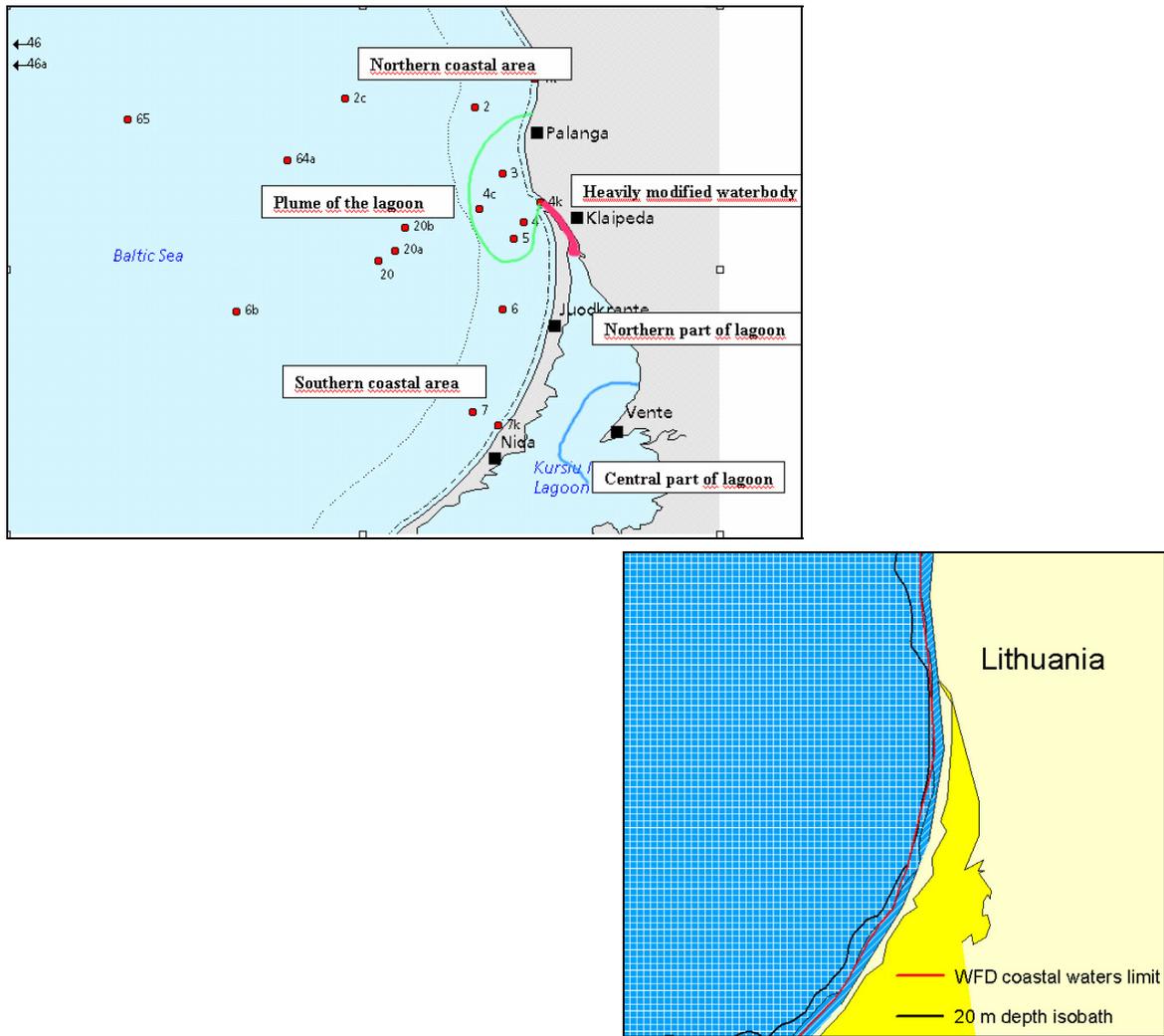
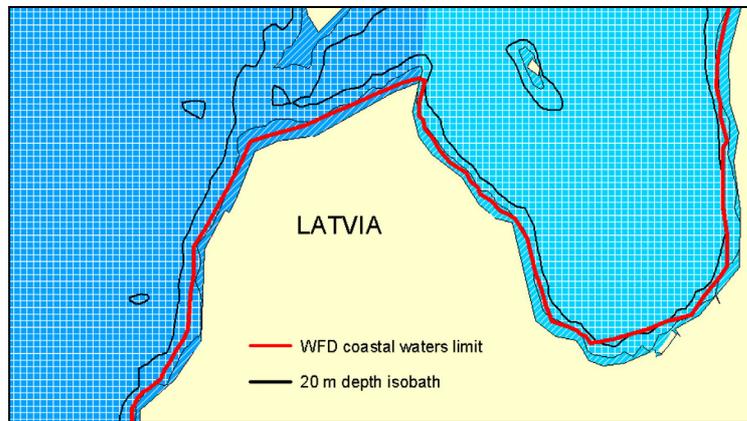
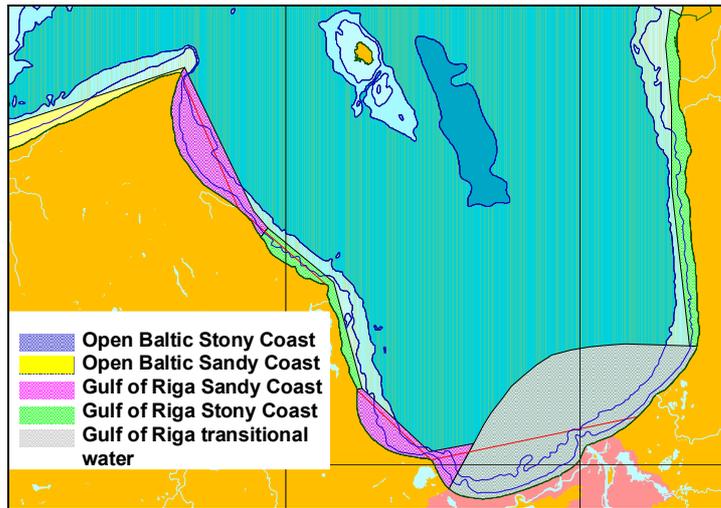


Figure 8: National German typology (after INSTITUT FÜR ANGEWANDTE ÖKOLOGIE, 2003; WEBER et al., 2002) as compared to the CHARM umbrella typology for the Baltic Sea.



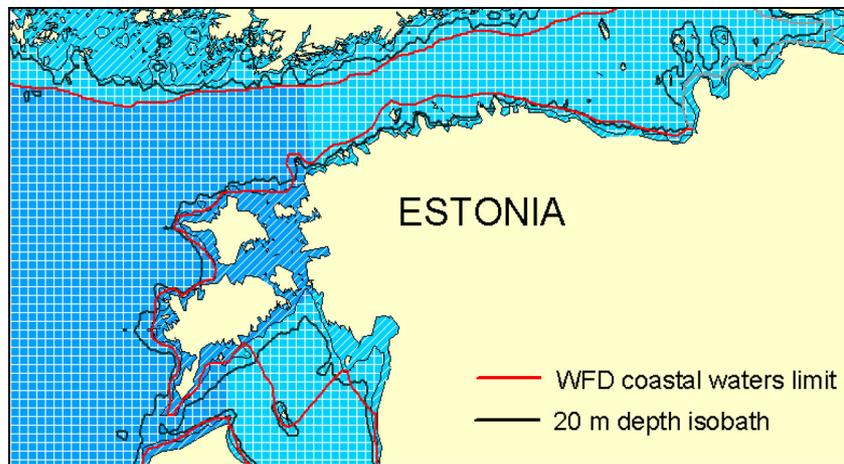
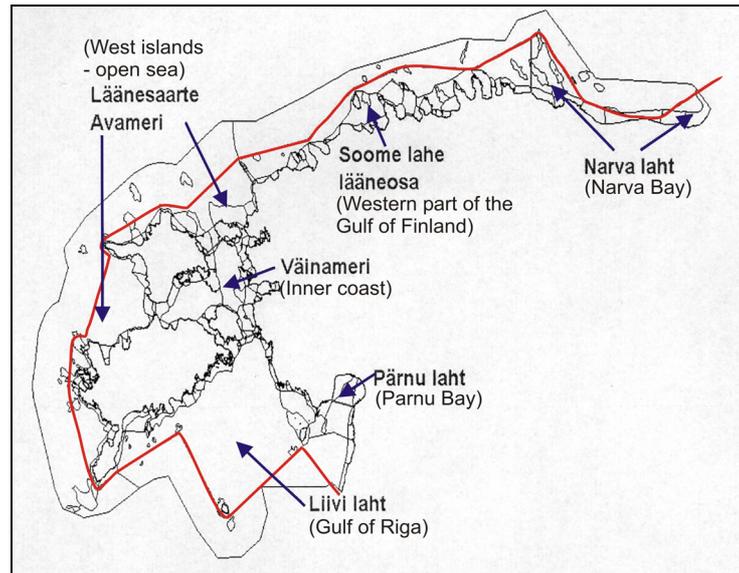
Salinity					
0.5 - 6 PSU oligohaline		> 6 - 18 PSU mesohaline		> 18 PSU polyhaline	
Water retention time & Depth	Water retention time & Depth	Water retention time & Depth	Water retention time & Depth	Water retention time & Depth	Water retention time & Depth
> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m
↓		↓			
Transitional waters		Additional class: stony sandy		Additional class: stony sandy	
		Mesohaline open coastal waters		Transitional waters in the open coast (river plume)	

Figure 9: National Lithuanian typology (after ANSBÆK & SCHWÆRTER, 2004) as compared to the CHARM umbrella typology for the Baltic Sea.



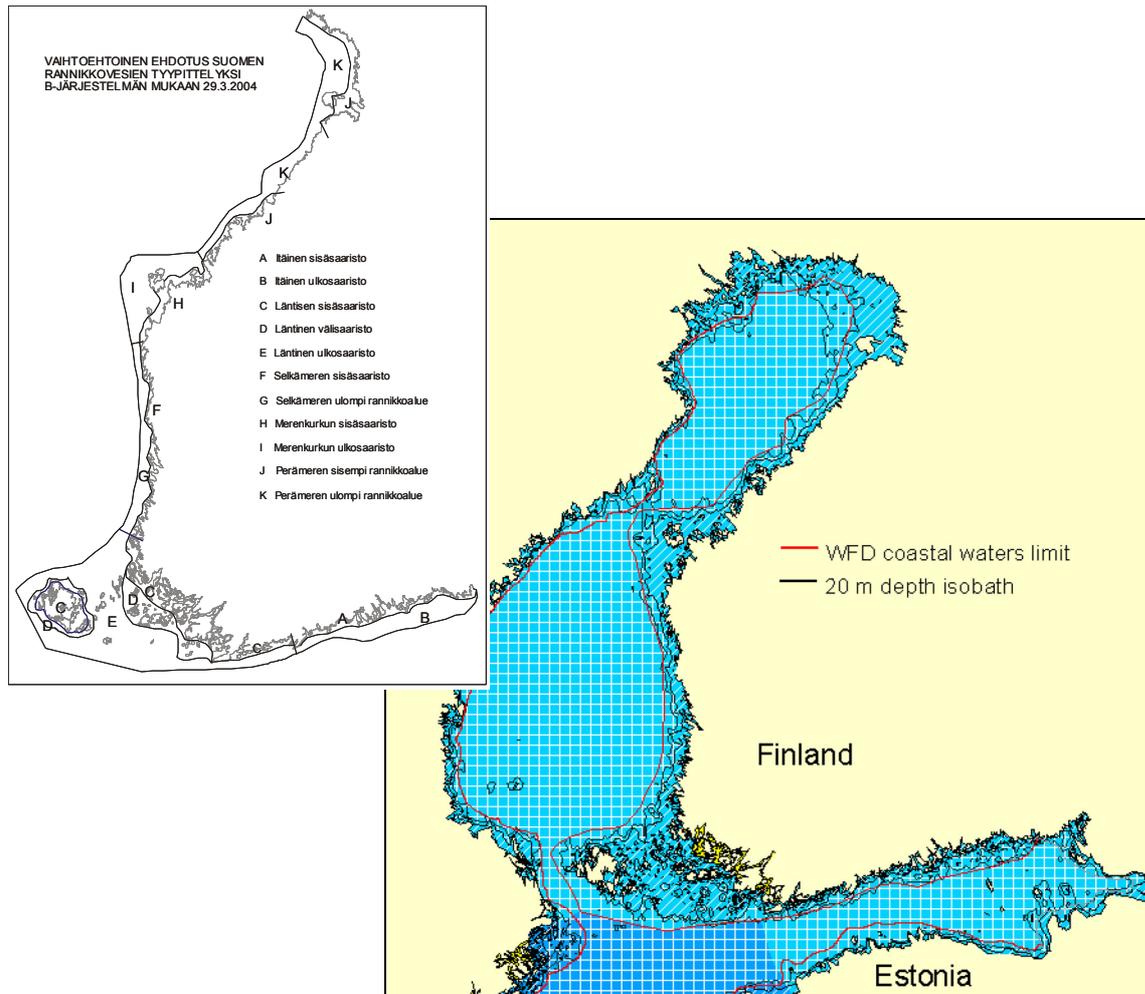
Salinity					
0.5 - 6 PSU oligohaline		> 6 - 18 PSU mesohaline		> 18 PSU polyhaline	
Water retention time & Depth	Water retention time & Depth	Water retention time & Depth	Water retention time & Depth	Water retention time & Depth	Water retention time & Depth
> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m
<p>stony sandy</p> <p>Oligohaline open coastal waters</p>		<p>stony sandy</p> <p>Mesohaline Transitional waters in the open coast (river plume) open coastal waters</p>			

Figure 10: National Latvian typology (after ALBINUS et al. 2004) as compared to the CHARM umbrella typology for the Baltic Sea.



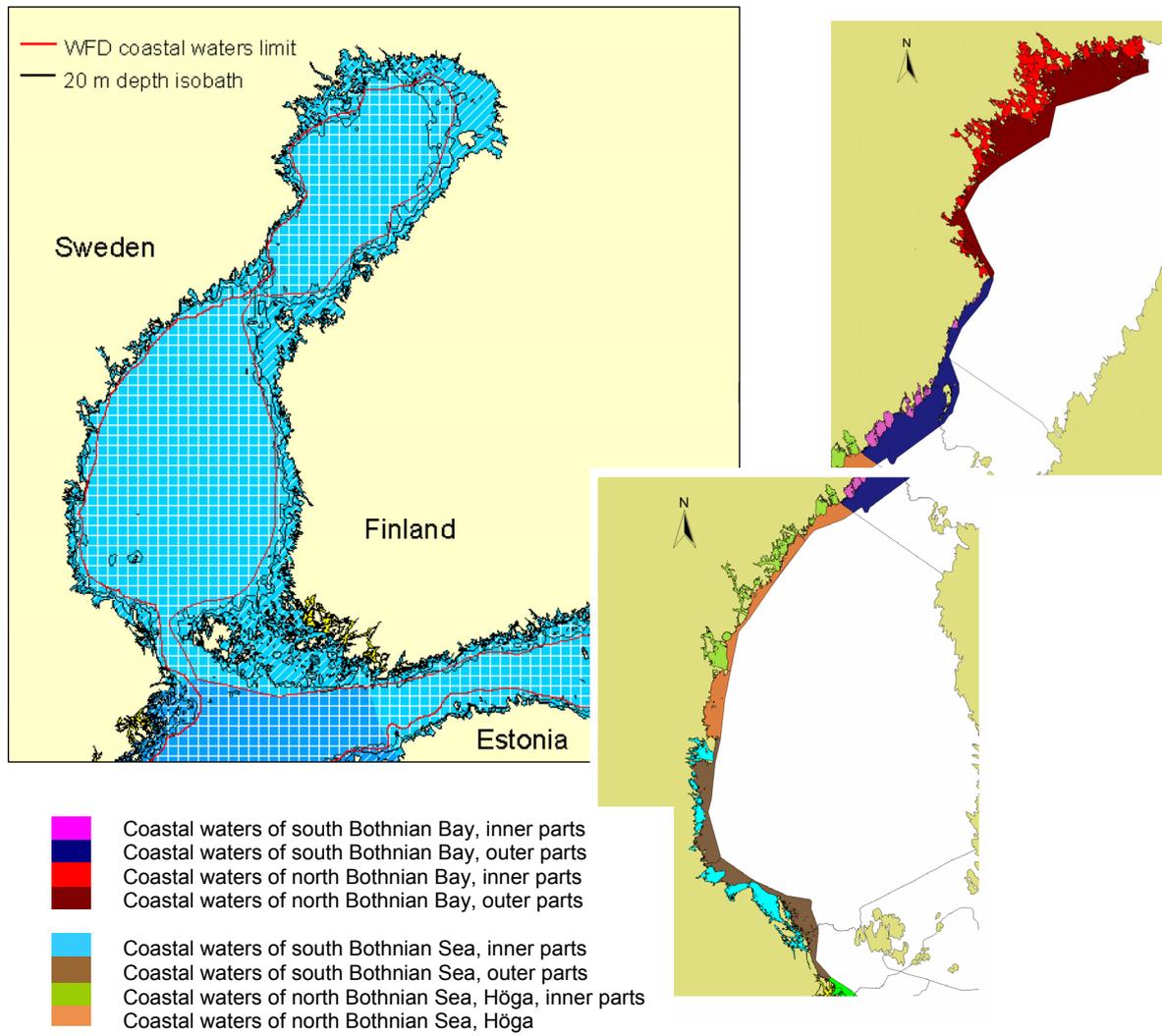
Salinity					
0.5 - 6 PSU oligohaline		> 6 - 18 PSU mesohaline		> 18 PSU polyhaline	
Water retention time & Depth					
> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m

Figure 11: National Estonian typology (after ESTONIAN MINISTRY OF THE ENVIRONMENT, 2004) as compared to the CHARM umbrella typology for the Baltic Sea.



Salinity					
0.5 - 6 PSU oligohaline		> 6 - 18 PSU mesohaline			> 18 PSU polyhaline
Water retention time & Depth					
> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m
archipelago type	intermediate type	> 4 PSU	1 - 4 PSU	> 4 PSU	eastern GOF
					open waters

Figure 12: National Finnish typology (after FINNISH COASTAL EXPERT GROUP 2001; PERUS et al. this issue) as compared to the CHARM umbrella typology for the Baltic Sea.



Salinity					
0.5 - 6 PSU oligohaline		> 6 - 18 PSU mesohaline		> 18 PSU polyhaline	
Water retention time & Depth					
> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m	> 30 days < 10m	< 30 days < 10m > 10m

Swedish typology uses non hierarchical approach with following factors:

- |                                |               |
|--------------------------------|---------------|
| Salinity                       | Wave exposure |
| Water exchange - bottom waters | Substratum    |
| Stratification                 | Ice days      |

Figure 13: National Swedish typology (after SWEDISH EPA 2004) as compared to the CHARM umbrella typology for the Baltic Sea – oligohaline waters.

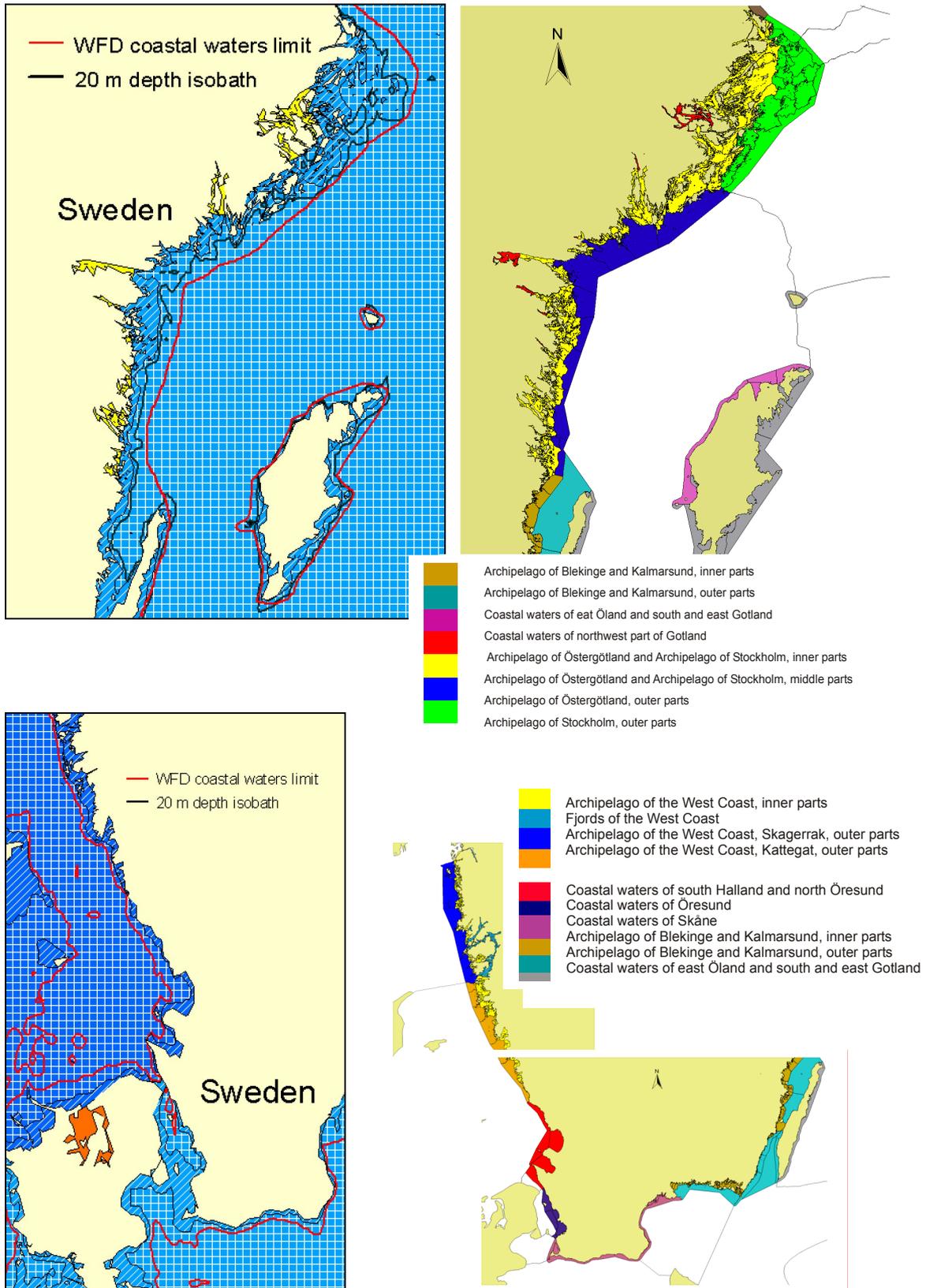


Figure 14: National Swedish typology (after SWEDISH EPA 2004) as compared to the CHARM umbrella typology for the Baltic Sea – mesohaline and polyhaline waters.

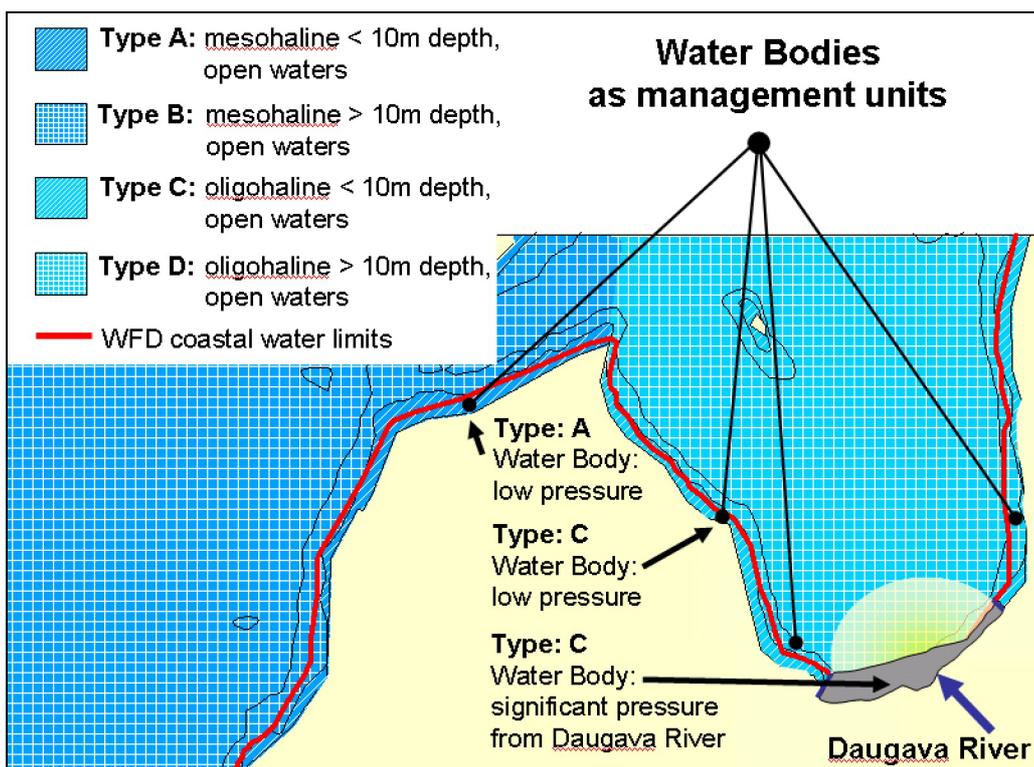


Figure 15: Designation of water bodies as management units of the WDF based on environmental pressure; example of Latvian coastal waters.

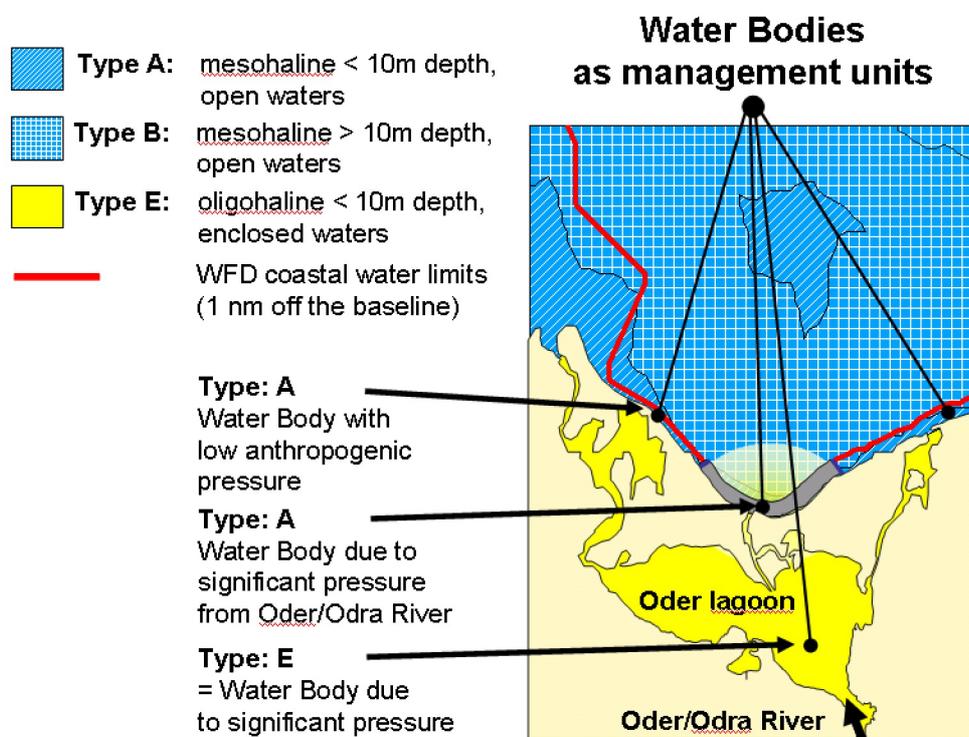


Figure 16: Designation of water bodies as management units of the WDF based on environmental pressure; example of the Oder estuary.

## Acknowledgement and data sources

This work was supported by the EU-project CHARM (Contract no.: EVK3-CT-2001-00065). The CHARM work is based on contributions from the institutes participating in the CHARM project:

- National Environmental Research Institute (NERI)
- Finish Environmental Institute (FEI)
- Aabo Akademi University (AAU)
- Environmental Institute, Joint Research Centre (JRC/EI)
- Klaipeda University, Coastal Research & Planning Institute (CORPI)
- Baltic Sea Research Institute, Warnemünde (IOW)
- Estonian Marine Institute (EMI)
- University of Latvia, Institute of Aquatic Ecology (IAE)
- Stockholm University, Department of System Ecology (SUSE)
- Sea Fisheries Institute (MIR)
- University of Greifswald (EMAUG)

The data used for salinity calculation was supplied by the Department of Systems Ecology, Stockholm University, Sweden. It was stored in the Baltic Environmental Database (BED). Different research institutes contributed to BED by providing data from several monitoring programs.

The project “IKZM-Oder” funded by the Federal Ministry of Education and Research (No. 03F0403A) supported the continuation and publication of the updated work.

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