Towards a Typology for the Baltic Sea

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Abstract

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 based on long-term protection of water resources. It 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

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.

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 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.

2   Background: The Water Framework Directive and Typology

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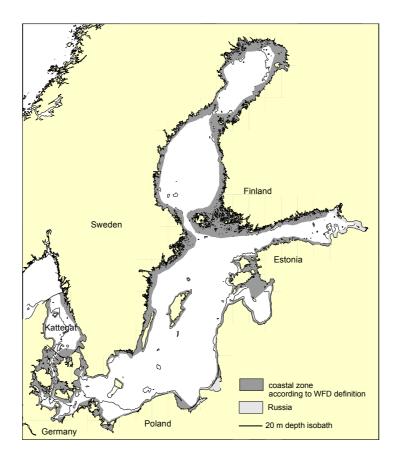
Figure 1: The coastal waters of the Baltic Sea Ecoregion as defined by the Water Framework Directive based on the baseline delimitation. Coastal waters limits as defined by national baselines correspond mostly with the 20 m isobath which is also shown.

The 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 typology, and factors to be used for classification are specified. Formulating 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.

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.

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

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

If obligatory factors are not sufficient, thy 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 the Table 1.

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 tide 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.

Sediment maps were also collected within CHARM project to obtain information on the bottom substrate. Despite many problems in detail (different size fractions, methods and spatial resolution), bottom sediment maps are useful for the southern Baltic, soft bottom regions. In rocky areas, like in Scandinavia sediments show high and small scale variability. Even first approaches to introduce soft and hard bottom as a parameter in the typology did not yield satisfying results, because of the high variability.

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 54oN to 66oN 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.
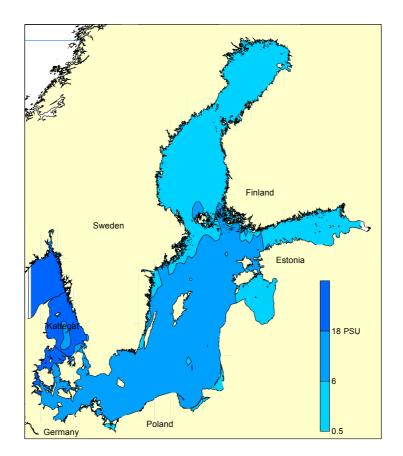

Figure 2: Distribution of salinity in surface Baltic Sea waters up to 5 meters depth. Based on data collected from all institutes participating in the CHARM Project, available via Baltic Environmental Data Base, Stockholm University (BED 2002).

3.2   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 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 (Figure 3). 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, transit time and age.
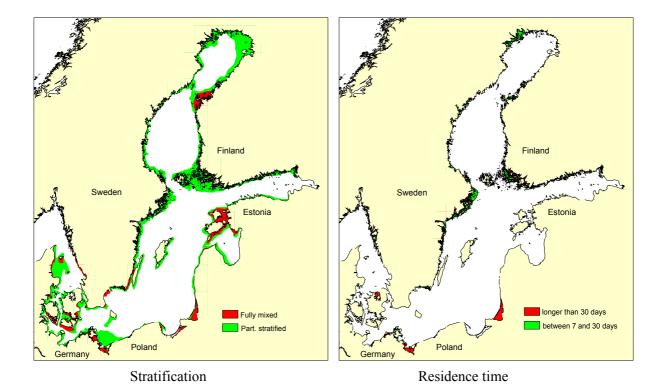

Figure 3: Stratification (left) and water residence time (right) in selected inshore areas of the Baltic Sea calculated for the CHARM project (Björn Sjöberg from the Department of Systems Ecology at Stockholm University, Sweden (SUSE)).

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.

3.3   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.
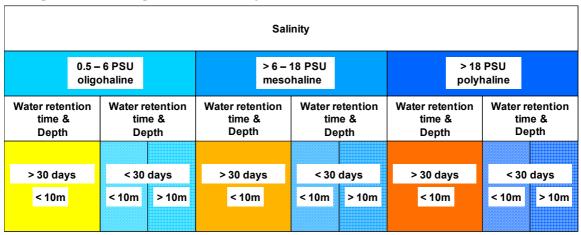
A depth model (with a resolution of 2 x 1 nautical miles) for the entire Baltic Sea was provided by T. Seiffert, Baltic Sea Research Institute Warnemünde, Germany (Seifert T. personal comm.). In the CHARM typology it was assumed that the coastal waters delimited by the WFD rules - 1 mn from the baseline - correspond mostly with the 20 m isobath, as shown in Figure 2. It was therefore assumed in the typology for the Baltic Sea Ecoregion that the 20 m 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 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.

3.4   Typology and spatial type distribution in coastal waters

The present classification of types within the Baltic Sea is based on three main factors (Figure 4):
  ➢ 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.

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	< 30 days	> 30 days	< 30 days	> 30 days	< 30 days
< 10m	< 10m > 10m	< 10m	< 10m > 10m	< 10m	< 10m > 10m

Figure 4: Simple umbrella typology for the Baltic Sea according to the WFD.

Figure 5a and Figure 5b present the type distribution along the coast of the Baltic Sea showing types within the WFD up to the 20 m depth line and for the whole Baltic Sea area. 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. The present Baltic Sea typology approach allows the extension towards the entire Baltic Sea. It allows a more comprehensive view concerning reference conditions, water quality classification schemes and monitoring (Figure 6).
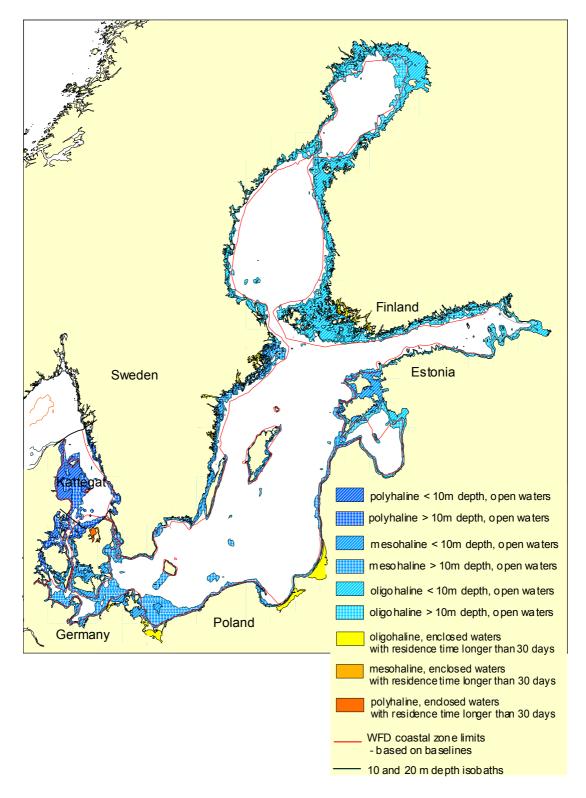

Figure 5a: Distribution of types in coastal waters up to 20 m depth according to the Baltic Sea typology (whole Baltic Sea area).
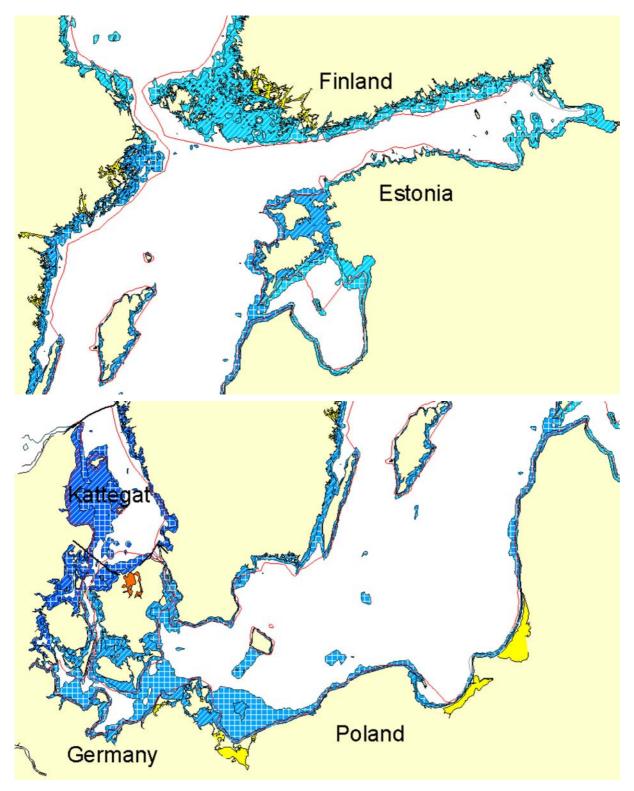
Figure 5b: Distribution of types in coastal waters up to 20 m depth according to the Baltic Sea typology (western and central Baltic Sea).
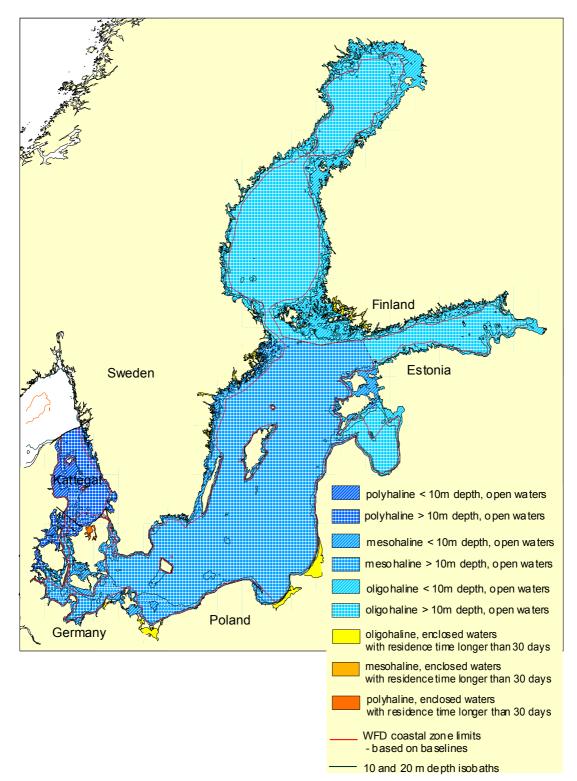
Figure 6: Distribution of types for the entire Baltic Sea typology.

4 Umbrella approach 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 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 Finnish national typology according to system B additional salinity threshold - 4 PSU is used and in the Swedish typology, there is also an additional threshold subdividing oligohaline waters – 3PSU.

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 (Figure 7).

4.1   Southern coast of central part of the Baltic - 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 then 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 cost 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 show in Figure 7.

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 Lituanian part of the Baltic coast can be classified under the CHARM umbrella (Figure 7).

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.

4.2   From Kattegat to western Baltic coast 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 then 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 range.

Types in fjords are categorized according to:
 ➢ Bottom salinity,
 ➢ Degree of stratification
 ➢ Degree of sensitivity to land-based input of water (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 (Figure 7).
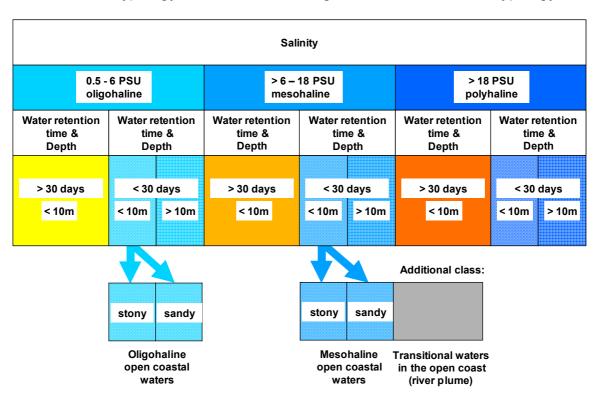
German coast also faces a quite strong salinity gradient in the western part of the Baltic and salinity is the main classification factor in German typology. All open coast waters are classified as mesohaline with the exception of deeper, stratified areas, where bottom waters are of higher salinity classified 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 and the entire). 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 (Figure 7).

4.3   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 tree 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 (Figure 7).
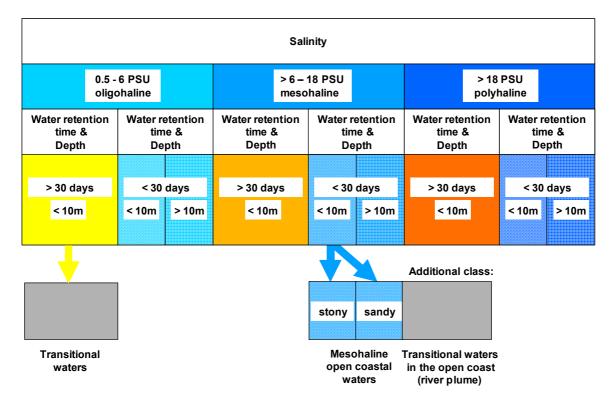
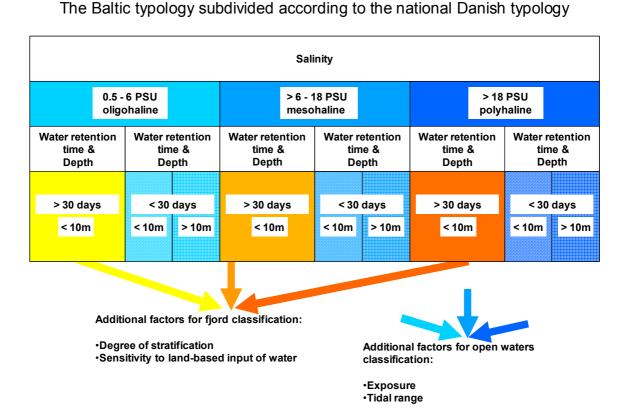## 4.4   Finnish draft national typology

In the Finnish typology according to system B the coastal areas are oligohaline and are subdivided based on additional salinity thresholds 4 PSU and 1 PSU. Further subdivision of archipelago waters identifies most inner archipelago waters, intermediate type and open water type – with deep most exposed coast (Finnish Coastal Expert Group 2001). This approach can be classified under umbrella typology. At the moment, the Finnish typology is under revision and some changes in the types and their distribution can be expected.

The Baltic typology subdivided according to the national Latvian typology

The Baltic typology subdivided according to the national Lithuanian typology

The Baltic typology subdivided according to the national Danish typology

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	< 30 days	> 30 days	< 30 days	> 30 days	< 30 days
< 10m	< 10m / > 10m	< 10m	< 10m / > 10m	< 10m	< 10m / > 10m

Additional factors for fjord classification:

- Degree of stratification
- Sensitivity to land-based input of water

Additional factors for open waters classification:

- Exposure
- Tidal range

The Baltic typology subdivided according to the national German typology

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	< 30 days	> 30 days	< 30 days	> 30 days	< 30 days
< 10m	< 10m / > 10m	< 10m	< 10m / > 10m	< 10m	< 10m / > 10m

0.5-3 PSU	3-5 PSU	5-10 PSU	10-18 PSU	5-10 PSU	10-18 PSU		10-30 PSU

Oligohaline inner coastal waters

Mesohaline inner coastal waters

Mesohaline open coastal waters (fully mixed)

Mixohaline open coastal waters (part. stratified)

The Baltic typology subdivided according to the national Swedish typology

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

Swedish typology uses non hierarchical approach with following factors:

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

The Baltic typology subdivided according to the national Finish typology

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

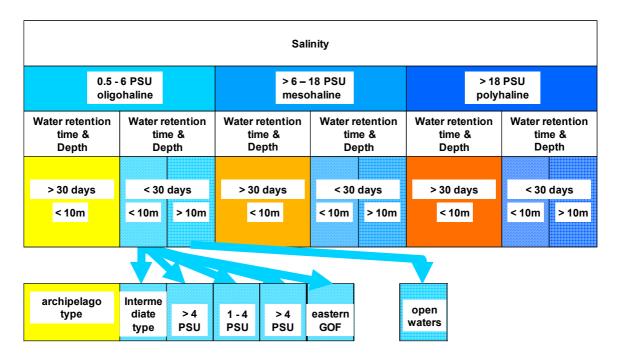| archipelago type	Interme diate type	> 4 PSU	1 - 4 PSU	> 4 PSU	eastern GOF		open waters

Figure 7: The Baltic typology subdivided according to the available national typology.

5   Data sources/Acknowledgements:

This article is available in color under: http://www.eucc-d.de/baltcoast2004/papers.html.

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