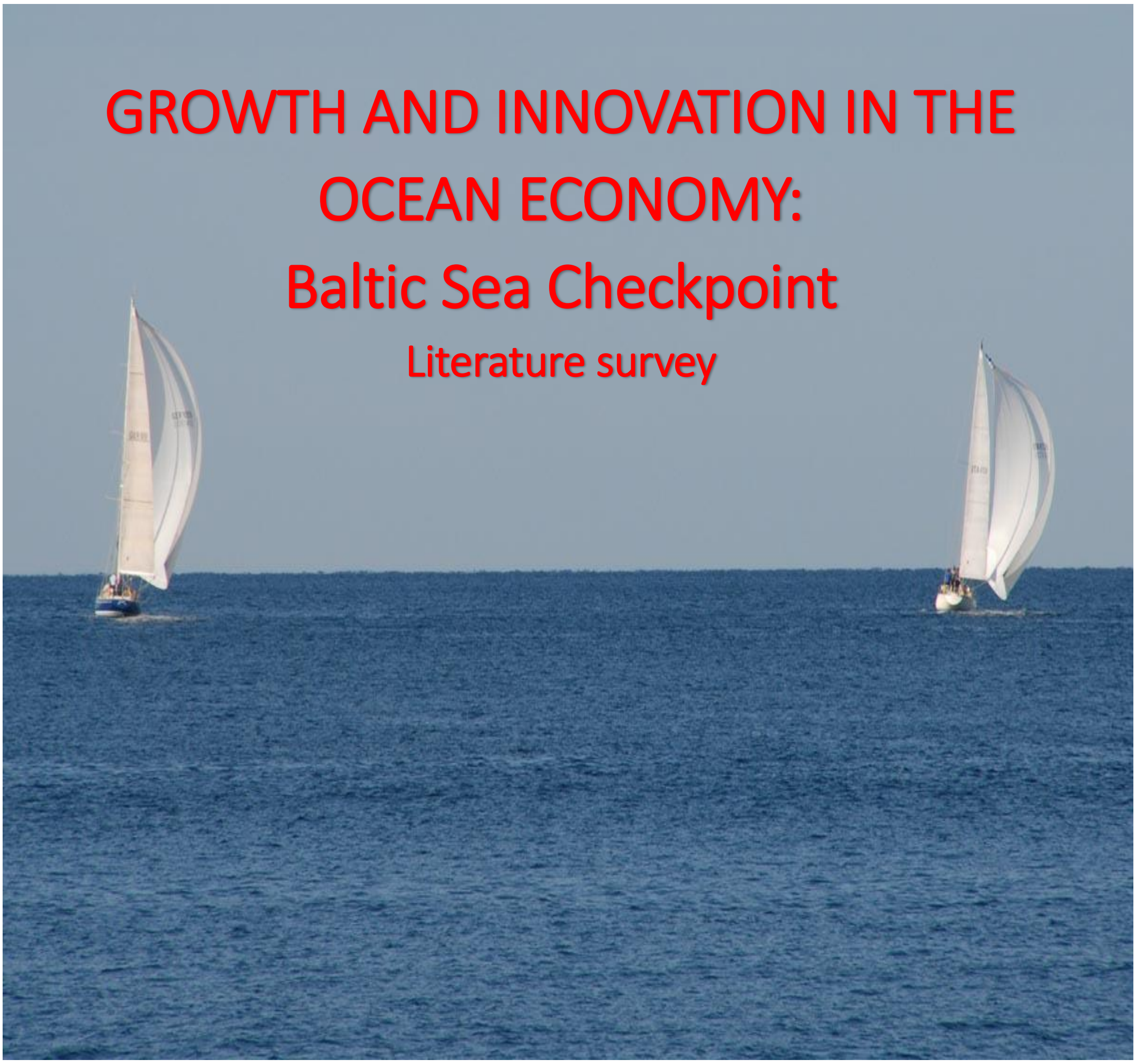
GROWTH AND INNOVATION IN THE OCEAN ECONOMY:

Baltic Sea Checkpoint

Literature survey



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Executive Summary

The Baltic Sea is a unique marine area: the largest body of brackish (low-salinity) body of water in the world, it is also distinguished by its division into a series of basins of varying depths, separated by shallow areas or sills and the link with the North Sea is very narrow and shallow. These special geographical conditions clearly influence the physical, chemical and biological conditions, which are very different from other regional seas of Europe. Historically the Baltic societies have been closely dependant on marine industries and "Blue Growth" is an important part of the strategic development for the Baltic Sea area. For natural reasons utilisation of the marine resources and the threat to the marine environment have always been easily noticeable and it is well known that the maritime industries also put enormous pressure on the vulnerable Baltic marine environment.

This calls for detailed knowledge of the marine environment – physical and biogeochemical processes, interdisciplinary relations and dependencies, changes etc. This must be an essential part in the future planning and decision process, where a rapid access to reliable and accurate information is vital in addressing threats to the marine environment, in the development of policies and legislation to protect vulnerable areas of the coasts and open ocean, in understanding trends and in forecasting future changes. Likewise, better quality and more easily accessible marine data is a prerequisite for further sustainable economic development. Marine research and monitoring however has long traditions in the Baltic Sea and a relatively large and fairly dense (space and time) amount of marine observational data are available from national and research and monitoring programmes.

EMODnet has initiated – Sea Basin Checkpoints - an activity envisaged to determine gaps in data and observation systems and priorities for an observation system that supports the delivery of sustainable growth and innovation. The overarching aim is to support the deployment of a marine observation infrastructure that offers the most effective support to the blue economy. The cost-effectiveness, reliability and utility of the existing monitoring infrastructure are to be assessed by developing products based on these data and determining whether the products are meeting the needs of industry and public authorities.

This report summarizes the findings of a literature survey to identify sources for the required characteristics for the Baltic Sea in order to address the needs in eleven predefined challenges. The identified data sources have as far as possible been evaluated with regard to: availability (accessibility, performance) and appropriateness.

The requirements from the eleven challenges sums up to a total of 140 different characteristics: 10 in Air, 38 in Water, 31 in Biota/biology, 19 in Seabed and 42 in Human Activities.

Based on the available information in the literature used in this survey it has been attempted – when possible – to judge the availability and appropriateness of the required characteristic.

The allocated resources to this literature survey did not allow for a detailed analysis of the collected information on data availability and appropriateness; but a few general observations can be subtracted:

- Important data repositories are: data originator institutions, HELCOM/ICES, ICES, EMODnet and CMEMS.
- Data store at originator institutions are often not very visible, formats requires some efforts to use, the data policy often have some restriction and with some fee involved. This is particularly true for meteorological data.
- Data available at the big international data portals (HELCOM/ICES, ICES, EMODnet, CMEMS) are generally judges to be easy to find, the data format often is a challenge, the data policy is open and free of charge.
- The quality of the data cannot always be judged from the literature; but where information has been subtracted only few has been labelled "high or good" quality while the majority is judged to be of "acceptable or poor" quality.

It must be stressed that the above observations are only general observations based on a limited material that could be subtracted from the literature, and that a more detailed analysis will be available when the individual challenges have completed their work.

The literature survey has demonstrated that we have a good understanding and overview of characteristics need for a variety of stakeholder here represented by the eleven challenges. Based on the survey we also have a good overview of where to find relevant characteristics for the Baltic Sea within the five environmental matrices: air, water, biota/biology, seabed and Human resources.

1. Introduction

Data from the marine environment are a valuable asset. Rapid access to reliable and accurate information is vital in addressing threats to the marine environment, in the development of policies and legislation to protect vulnerable areas of our coasts and oceans, in understanding trends and in forecasting future changes. Likewise, better quality and more easily accessible marine data is a prerequisite for further sustainable economic development, so-called 'blue growth'. Unfortunately, marine data collection, storage and access in Europe have in general been carried out in a fragmented way for many years – less in the Baltic Sea, however, than other regional seas. Most data collection has focused on meeting the needs of a single purpose by a wide range of private and public organisations, often in isolation from each other.

The **European Marine Observation and Data Network (EMODnet)** is a network of organisations supported by the EU's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards and make that information freely available as interoperable data layers and data products. This "collect once and use many times" philosophy benefits all marine data users, including policy makers, scientists, private industry and the public. It has been estimated that such an integrated marine data policy will save at least one billion Euros per year, as well as opening up new opportunities for innovation and growth.
In EMODnet Phase II a new EMODnet type of activity has been introduce with a regional scope:
the EMODnet sea-basin checkpoints along a concept first coined in the EC Marine Knowledge 2020 Communication. These checkpoints are envisaged to determine gaps in data and observation systems and priorities for an observation system that supports the delivery of sustainable growth and innovation. The overarching aim is to support the deployment of a marine observation infrastructure that offers the most effective support to the blue economy. The cost-effectiveness, reliability and utility of the existing monitoring infrastructure are to be assessed by developing products based on these data and determining whether the products are meeting the needs of industry and public authorities.

The Baltic Checkpoint started in June 2015 and the overall aim of this project is to examine the current data collection, observation, surveying, sampling and data assembly programs in the Baltic Sea basin. Additionally it will assess and demonstrate how public available information can fit the purpose in the 11 challenge areas in terms of data uncertainty, availability, accessibility and adequacy, and deliver the findings to stakeholders through an internet portal with dynamic mapping features and a stakeholder workshop. The Baltic Sea region is as defined by the Marine Strategy Framework Directive, i.e., the semi-enclose sea bounded by the parallel of the Skaw in the Skagerrak at 57°44.43'

The first deliverable of the Baltic Checkpoint is a report of a literature survey aim at summarizing previous reported findings on data availability and appropriateness. As an introduction to the literature survey the unique Baltic environment is described and so are the most important components of Blue Growth in the Baltic region.

1.1 The Baltic Environment

The Baltic Sea has quite a unique environment due to the fact that it is an almost totally enclosed sea area which only connection to the open ocean is the narrow and shallow Danish Straits. Moreover, the Baltic Sea is surrounded by a huge drainage area, four times as large as the sea itself, where virtually all terrestrial human activities influence the marine environment. The combination of the large drainage area imposing a massive fresh water input and shallow sill depths between the Baltic and the North Sea - maximum 18 m – makes the Baltic Sea the largest brackish water area in the world with salinities varying from almost zero in the innermost parts of the Baltic to 10-12 psu close to the sills. These physical conditions will naturally also influence conditions for biological life in the Baltic Sea.

1.1.1 Meteorology

1.1.1.1 Importance of weather condition on the Baltic Sea

The Baltic Sea is located between maritime temperate and continental subarctic climate zones, in the latitude-longitude region (54N-66N, 9E-30E). It is a semi-closed Shallow Coastal Sea with an average water depth of slightly over 50m. The Baltic Sea physical and biogeochemical ocean states depend on the positive water balance, weak water exchange with the ocean and strong weather forcing and related river runoff. The Baltic Sea weather is predominantly marine influenced and determined by westerly air flow both at the surface and in the upper air (Feistel et al., 2008). The prevailed westerly winds are essential to keep a mean condition of Baltic-North Sea water level gradient and related two-layer flow. The bottom condition (e.g., habitat, sedimentation and oxygen condition etc.) in shallow waters are largely controlled by the wind and heat conditions in the atmospheric boundary layer. Storms are essential for the ventilation and mixing of the strongly stratified Baltic Sea and inflow events importing salt and oxygen from the North Sea are very dependent on the wind climate and pressure differences between these two seas. Atmospheric and riverine inputs of chemicals and pollutants have great impacts on the water quality and marine ecosystem. With a thermal memory of several months, the Baltic Sea thermal condition is primarily controlled by the atmospheric forcing. The strong seasonal cycle allows the basin to store much heat in the summertime for release in the winter.

In addition to being one of the major controlling factors of the Baltic Sea environment and ecosystem, the atmosphere also plays a significant role in Blue Growth. The wind condition is essential for wind farm siting; the adverse and extreme weather events, such as strong winds, heavy ice and reduced visibility, can have a negative impact on the maritime transport, causing injuries and damages as well as other economic losses. Increasing absorption of CO_2 in the water may cause acidification. Together with global warming and overfishing, this may lead to collapse of the Baltic Sea bio-resources.

The Baltic Sea Basin has large geographical extent and is therefore affected by two large-scale pressure systems over the Northeast Atlantic, the Icelandic Low and the Azores High, and a thermally driven pressure system over Eurasia (high pressure in winter, low pressure in summer).

This makes Baltic Sea lying along the path of the North Atlantic storm track and therefore low-pressure systems frequently bring warm air masses to the Baltic Sea region and reduce the temperature difference between northern and southern latitudes. The climate has large variability due to the opposing effects between the relatively humid and mild marine air flows from the North Atlantic and the cold and dry air mass from Russian continental climate. This variability depends on the exact location of the polar front and the strength of westerlies, and both seasonal and inter-annual variations are considerable. Westerlies are important particularly in winter, when the temperature difference between continental and marine air masses is large.

The location and intensity of the westerlies and storm tracks are closely related to the air pressure difference between the Azores High and Icelandic Low, which is called the NAO (North Atlantic Oscillation, Hurrell 1995) index. The NAO index is positive when there is high pressure in the south and low pressure in the north, at which time relatively mild westerly winds prevail and winters are typically much warmer than on average over most of Europe. When the NAO index is negative there is high pressure in the north and low pressure in the south, at which time the winds blow from northerly and easterly directions and mean winter time temperature is much below normal.
The southern and western parts of the Baltic Sea belong to the central Europe mild climate zone and have a westerly circulation. The northern part locates at polar front where the winter climate is cold and dry due to outbreaks of the cold air masses.

Recent studies suggest that during the past century the increased frequency of both anticyclonic circulation (clockwise circulation around a high pressure, in the Northern Hemisphere) and westerly wind types has resulted in a warmer climate with reduced sea-ice cover and decreased seasonal amplitude of temperature. This indicates multidecadal climate change in the Baltic Sea region is at least partly related to changes in the atmospheric circulation (Omstedt et al., 2004, BACC Author Team, 2015).

Blocking of the atmospheric flow is frequently observed in the Baltic Sea region. Blocking is a large-scale quasi-stationary, quasi-persistent split of the westerly air-flow, which is often responsible for extreme weather events. During warm summers and cold winters, the air pressure field is smooth and winds are weak, and blocking high-pressure situations are a common feature. During such a period the weather can be very stable for several weeks. Certain blocking events in the winter are found to be the driving force of the Major Baltic Inflow events.

1.1.1.2 Large-scale atmospheric circulation over the Baltic Sea

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1.1.1.3 Winds

Surface wind conditions in the Baltic Sea region are determined by the general atmospheric circulation of Northern Europe as well as the vertical structure of the atmospheric boundary layer which has a clear seasonal dependence. In winter and autumn, westerlies prevail in the entire Baltic Sea. In April and May winds are very variable in direction, not particularly strong. In summer, winds are in general weak, more than 98% of the surface winds are lower than Force 8. Winds of Force 5 or more occur on about 15%, 24% and 49% of occasions in the Spring, Summer and Autumn respectively.

Sea breezes are common. They develop around midday. Offshore, land breezes are relatively rare. Through June to August the tendency over the open sea is more towards winds from a westerly point and for some increase in average strength to 12 knots generally and up to 14 in the Kattegat and near Rostock. Near the coast, sea breezes dominate after midday. These will be from a southerly point up the Swedish coast and a northerly point down the Finnish coast.

The winds were unusually calm in 1960 – 1970 when the NAO index was strongly negative and Euro-Atlantic blockings in winter were very frequency, preventing or weakening westerly flow and leading to low wind speeds and fewer storms over Scandinavia. This time period was followed by a strong increase in annual and winter-to-spring storminess with unprecedented high winter storminess in the early 1990s, during which the NAO index reached very high values. In the first decade of the 21st century, wind speeds returned to average values again in the Baltic Sea area.

Comparing data from two time periods, 1970-88 and 1989-2008, shows that the number of deep cyclones, as defined to have core pressure < 980 hPa, has increased and shifted north-eastward in winter and spring and decreased in autumn over the Baltic Sea region, (Lehmann et al., 2011).

The decadal variability in the NAO seems to have impacts on the Baltic-North Sea water exchange (Fig. 1, SUNFISH project). NAO seem to have changed from a negative phase to a positive phase during the mid-70s. Correspondingly, the trend of the surface inflow (from North Sea to Baltic Sea) started to increase while the bottom inflow started to decrease.

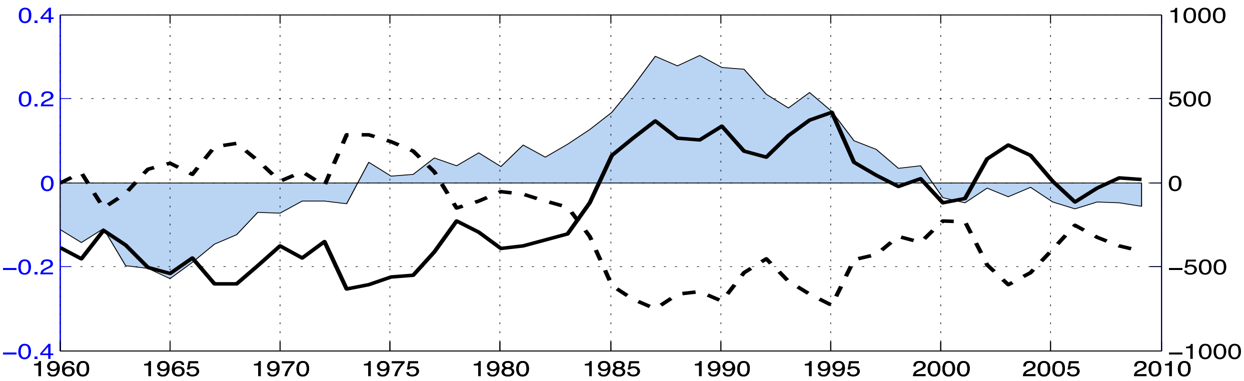


Figure 1. Relationship between 10 year running mean NAO index (shown as the shadow area) and transports acrossing a north-southward section in Skagarrek (surface: solid line; bottom: dashed line) derived from a 50year hindcast study by using 3D ocean circulation model DMI BSHCmod.

Regional climate models have shown that, with strong emission scenario (SRES A1B), the future extreme winds will increase by 5-10% in the southern Baltic Sea (south to 57N) and decrease in the northern Baltic Sea (Fig. 2).

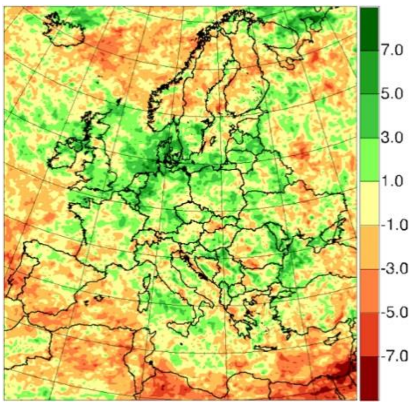


Figure 2. The change in extreme winds (10-year return value of daily maximum wind). Percentage change from the period 1961-1990 to the period 2071-2100, according to a means strong emission scenario (SRES A1B). In any point displays the middle of the 13 model results.

1.1.1.4 Air temperature

The air temperature over the sea is dominated by the sea surface temperature, which in the late spring is dependent on the melting of the ice. By July air temperatures reach 16 or 17^{o}C rising to 22 deg near mainland coasts. Daytime temperatures over land can occasionally be as high as 30^{o}C. During the cold winter, the lowest air temperature in the northern Baltic Sea region can be -40^{o}C.

Because of to the seasonal movement of the polar front, the temperature difference between winter and summer is much larger in the north than in the south. In summer the maximum sea surface temperatures are 15-20°C in the whole Baltic Sea. In winter the northern part of the Baltic Sea is ice-covered and the maximum ice thickness can be more than half a meter whereas the surface temperature is still 2-3°C in the south.

In fall and winter, high latitude seas have characteristically strong sensible and latent heat fluxes to the atmosphere as long as the surface is ice-free and there is transport of warm air from lower latitudes through intense cyclone activities. As a result, the mean air temperature in the Baltic Sea region is much higher than anywhere else at corresponding latitudes.

Earlier studies showed that surface air temperatures have significantly increased in the Baltic Sea region since 1871 (BACC Author Team, 2008). The increase, however, has not been steady. There have been large decadal variations (BACC Author Team, 2015). There has been at least three major phases in the multi-decadal variations. Warming at the beginning of the century 20th century until 1930’s, then cooling until the 1960’s, and another distinct warming during the last decades of the century. Linear trends of the annual mean temperature anomalies from 1871 to 2011 were 0.11 °C per decade north of 60°N and 0.08 °C south of 60°N, which is larger than the trend of the global mean temperature of about 0.05 °C per decade for the period 1861 to 2000 (IPCC, 2001). All seasonal trends are positive and significant except for winter temperature north of 60°N. The largest trends are observed in spring (and winter in the southern part of the area) and the smallest trends in summer. The seasonal trends are stronger in the northern area compared to the southern area. The different reanalysis data sets indicate that in the period 1990 – 2004 only one out of the 15 years had mean temperature less than normal for most of Europe (BACC Author Team 2015). Thus, that period was warmer than normal. It should be kept in mind that in spite of the linear trend there are annual and longer term variability in the temperatures.

An analysis of temperature trends from 1970 to 2008 in the Baltic Sea area showed the strongest increase in the Gulf of Bothnia in autumn and winter (0.5 to 0.6 °C/decade), while significant changes occurred during spring and summer in the central and southern parts of the Baltic Sea area (an increase of 0.2 to 0.3 °C/decade). During the past decade, the warming has continued during spring and summer in the southern parts and during autumn and spring in the northern parts, although the winters of 2009/2010 and 2010/2011 were very cold.

The daily temperature cycle is also changing, with both the mean minimum temperature and the mean maximum temperature in the Baltic Sea area increasing over the past century. The mean maximum temperature has increased more rapidly in the latter part of spring (April and May), while the mean minimum temperature has increased in much of the winter; this has resulted in a decrease in the daily range of temperatures (BACC Author Team, 2008). In addition to an increase in mean temperatures, there has been an increase in temperature extremes. For example, in Poland a statistically significant increase in the annual number of days with daily maximum temperatures above 25 °C and 30 °C was observed for the period 1951 to 2006, while a significant decrease was observed in the length of the frost season and in the annual number of frost days (daily minimum below 0 °C) and ice days (daily maximum below 0 °C) (BACC II, 2015). Furthermore, the duration of extremely mild periods increased significantly in winter and the number of heat waves increased in summer.

The changes in temperature have resulted in changes in the seasons, too. The length of the growing season has increased, whereas the length of the cold season has decreased. The number of days by which autumn and winter are delayed differs from south to north and east to west, but as an example in Tartu, Estonia the number of deep winter days having snow cover has decreased by 29 days over the past century while the growing season has increased by 13 days in this period (BACC II, 2015).

1.1.1.5 Cloudiness, fog, precipitation and hydrology

The mean cloudiness and duration of sunshine have shown large long-term fluctuations over the Baltic Sea Basin during the 20th century. From the 1950s until the 1990s, the total cloud cover decreased over Poland while the amount of low clouds increased over Estonia (BACC Author Team, 2015). These trends were reversed in the 1990s. Increasing cloud cover occurred in parts of the mountainous regions of Scandinavia and in the south-eastern Gulf of Finland, mainly during winter and summer. However, over the water of the Baltic Sea, the cloud cover decreased by 1% per decade from 1970 to 2008, mainly in spring and autumn (Lehmann et al, 2011).

Fog is most frequent over the open sea in April and May while the seas are still cold but the air temperature is rising. In March and April, fog frequencies are around 25% near the South-east of Sweden and near the South of Gotland and 10% elsewhere. During July and August the frequencies are around 10% and 2% respectively.

The amount of precipitation in the Baltic Sea area during the past century has varied between regions and seasons, with both increasing and decreasing precipitation. A tendency of increasing precipitation in winter and spring has been detected during the second half of the 20th century. Comparing the annual mean precipitation during 1994-2008 with that of 1979-1993, less precipitation was observed in the northern and central Baltic Sea region and more precipitation in the southern region (Lehmann et al., 2011). However, patterns for single seasons were rather different. The increase in precipitation in Northern Europe is also associated with an increase in the frequency and intensity of extreme precipitation events; the number of extreme precipitation days per year and the seasons in which they occur vary for the different catchment areas of the Baltic Sea.

The inflow from rivers to the Baltic Sea is an important variable for both the physical and ecological processes of the sea. The form of precipitation, as rain or snow, has a large impact on the annual runoff regime. In winter, much of the precipitation is stored as snow, increasingly so toward the northern part of the basin. Thus, in the north, lake and river water levels and discharges are lowest toward the end of winter before snowmelt. The highest inland water levels and discharges are recorded in spring or early summer owing to snowmelt. Water levels and discharges usually decrease during summer when evaporation is greatest and is normally larger than precipitation. In warm, dry summers, water levels can even drop below the winter minimum. Climate change can be expected to have a clear influence on the seasonal flow regime in response to changes in the type of precipitation and alteration of temperature-evapotranspiration regimes.

An analysis of stream flow in a large number of rivers and streams in the Nordic countries over three periods from 1920 to 2002 generally showed that trends towards increased stream flow dominated annual values as well as the winter and spring seasons, while no trend was found for autumn. An indication of earlier snowmelt floods was also apparent. An example is given in Fig. 3.

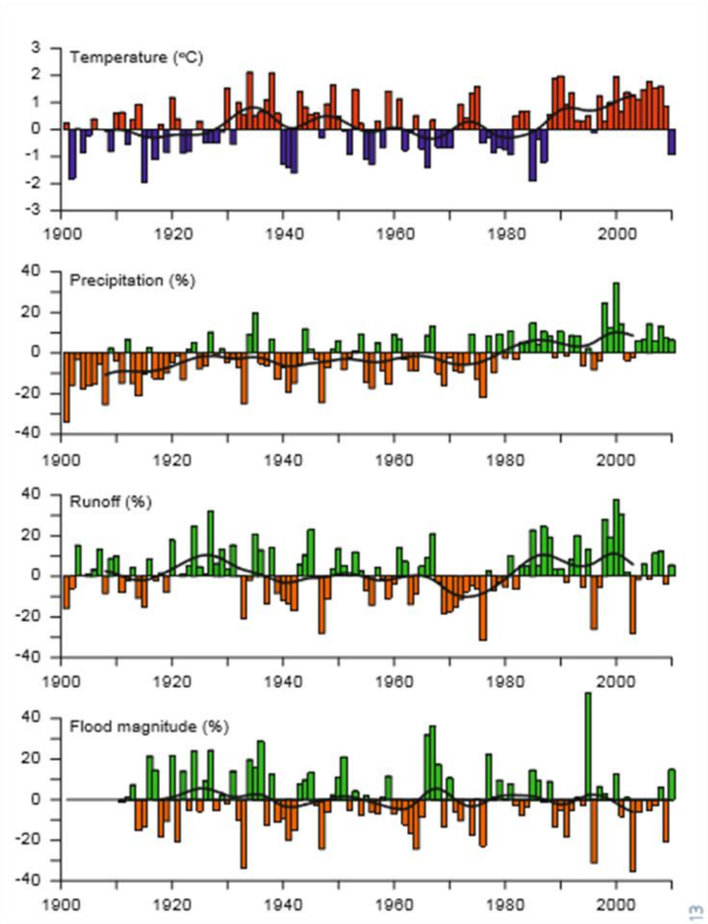


Figure 3 Anomalies and long-term variations in precipitation, temperature, water resources, and flood magnitude in Sweden for the period 1901 to 2010 in relation to the reference period 1961 to 1990.

In contrast, there has been a decrease in annual discharges from southern catchments of the Baltic Sea. A decrease of about 10% in annual discharges from the rivers Nemunas (Lithuania), Vistula and Oder (Poland) has been observed over the past century. Cycles of dry and wet phases lasting about 13 years each were characteristic of these rivers.

The river ice regime is considered to be a sensitive indicator of climate change. A study of ice in the River Daugava (Latvia), which has a data series starting in 1530, showed a pronounced downward trend during the past 150 years with an even clearer trend during the past 30 years. This indicates a reduction of ice-cover duration and a shift to earlier dates of ice break-up. The ice-covered period has been declining by 2.8 to 6.3 days per decade during the past 30 years. Although regional variations exist, similar observations have been made for other rivers flowing into the Baltic Sea. In general, a shift in the river ice break-up toward earlier dates, indicating an earlier start of river flooding, can explain the increase in winter runoff of rivers to the Baltic Sea.

Both the seasonal river discharge and the ice regime are strongly influenced by large-scale atmospheric circulation processes over the North Atlantic that are closely correlated with the NAO index.

The inflows to the Baltic Sea are best quantified by Bergström and Carlsson, 1994; who infilled observed discharge with simulated where observations were not available. This has since been further done by Graham and Bergström 1994 and Donnelly et al. 2014. Graham and Bergström 2001 and Donnelly et al. 2014 show that the impacts of climate change to Baltic Sea inflows are still very uncertain even with respect to the direction of change.

1.1.2 Bathymetry

Bathymetry is the study of underwater depth of oceans and lakes, the underwater equivalent to topography. Within the Baltic Sea bathymetry is to a large degree describing a stable situation where bottom types are predominantly rock and moraine, especially in the northern parts. In areas where bottom soil type is sand and silt the bottom material may move and the water depth is thereby more dynamic and regular resurveys may be necessary to ensure quality bathymetry data.

The depth of the Baltic Sea is described by a few examples that follow. These examples are screen captures from the Baltic Sea Bathymetry Database (http:\\data.bshc.pro). This database is produced in a cooperation project between Hydrographic Offices (National organizations for nautical charting) around the Baltic Sea. It contains a coarse (500 m) and harmonized grid compiled from various sources. Data is available as “open” data with the restriction not to be used for navigation.

The data shows that the landscape beneath the sea surface is very often a direct continuation of the landscape on land.

Figure 4 Bathymetry database

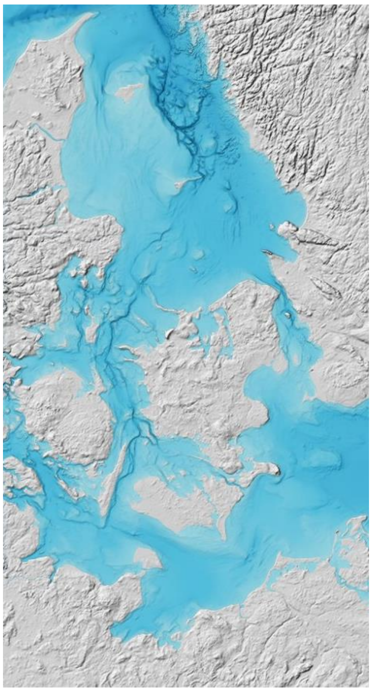


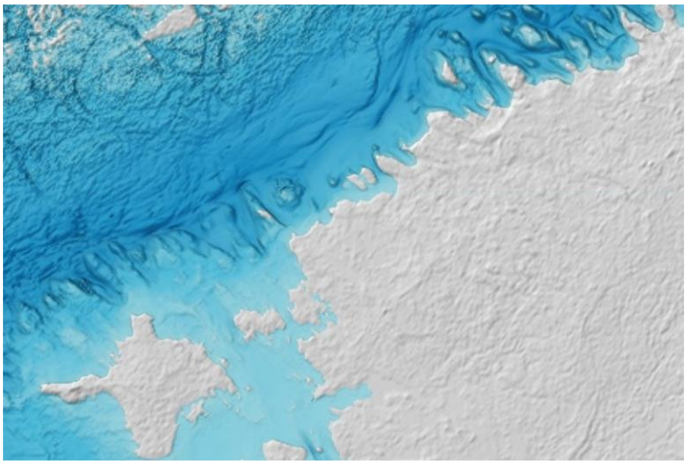
Figure 5. The Danish – Swedish straits

Looking at the bathymetry data makes strikingly clear how important barrier the Danish sounds are for the water exchange between the Baltic Sea and the North Sea. The narrow underwater channels separating Sweden, the Danish Islands and Germany are the routes for the saline water to enter the Baltic Sea. For the natural environment (underwater flora and fauna) of the southern Baltic Sea an influx of salt water is needed with some regularity.

This area is densely populated and there are a lot of human activities that may cause disturbances to the sea environment. These areas are very busy marine traffic entrances to the Baltic Sea that precludes the Baltic Sea from being a landlocked inland lake. The bathymetric conditions in the straits restrict vessels going deeper than approximately 15 meters to enter and exit the Baltic Sea.

Figure 6. South-East Baltic Sea →

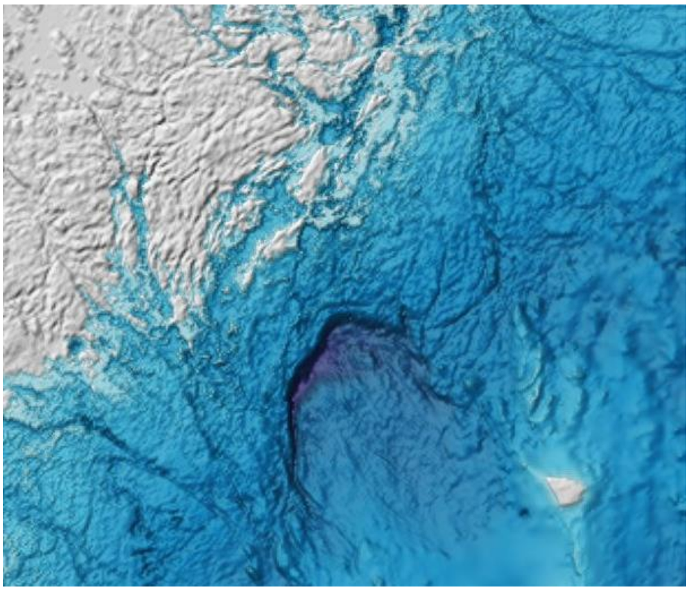
The sandy shores of Germany, Poland, Lithuania and to some extent Latvia are indicators of how the bottom landscape could be described. The Curonian lagoon is an exceptional area that is different to all other areas in the Baltic Sea.



← Figure 7. Estonia towards Gulf of Finland

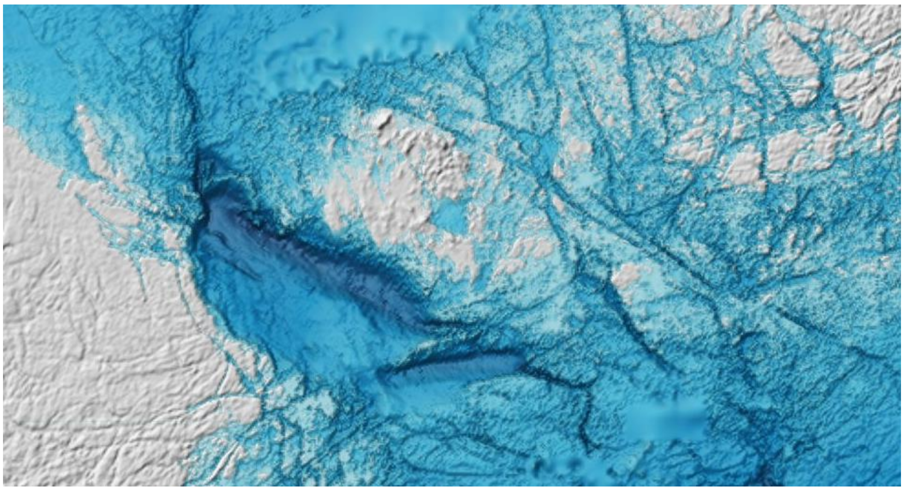
Peninsulas and islands continue as rather odd formations beneath the surface. The deep trench along the Estonian coast favors the Baltic Sea Proper deep waters to enter the Gulf of Finland and makes the gulf a direct continuation of the Baltic Sea proper.

Figure 8. Southern Stockholm archipelago

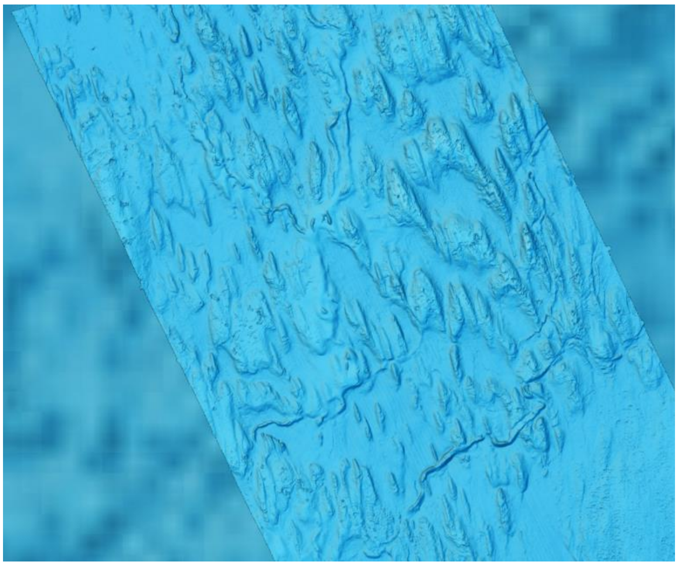


The darker shape is the Landsort deep. The largest depths, 460 m, in the Baltic Sea are in this rather narrow trench. The trench is exceptional because it is almost twice as deep as the next deepest places of the Baltic Sea.

Figure 9. Åland and Archipelago Sea



This picture covers the area from northern Stockholm archipelago to the island of Åland and further east the archipelago sea towards the Finnish mainland. The Åland Sea is a separate sub-basin that is between the Baltic Sea proper and the Gulf of Bothnia to the north. There are sills that separate the main basins from each other.



There is another sill are further north. These dividing areas are sometimes called the Southern and Northern Quarks. The deepest places in the Åland Sea are in the range 200 to 270 meters, but the sill depth between Åland Sea and Bothnian Sea is only some 70 meters. This is of importance for the deep water conditions in the Bothnian Sea because the sills hinder the oxygen poor deep waters of the Baltic Sea proper to penetrate to the Bothnian Sea.

High density bathymetry data

The given examples from the Baltic Sea Bathymetry Database 500 m grid give an overview of the usefulness of that data. Modern hydrographic and oceanographic bathymetry sensors, like multi-beam sonars, produce very high-resolution data. Below is an example of a 5 m resolution grid from the Gulf of Bothnia (the blurry background is the 500 m grid). Width of the sample area west to east is approximately 5-6 km. A geologist sees a postglacial landscape with drumlins and end moraines. Water depth varies in the range 30-50 meters in this area.

1.1.3 The coast

1.1.3.1 Basic types of Baltic Sea shores

The complexity of the dynamics and geological and geometric features of the Baltic Sea extend far beyond the typical features of water bodies of comparable size. Together with the extensive variability in the forcing factors, it results in the formation of highly intermittent regime of various drivers of the coastal environment. While the role of high water levels in the evolution and erosion of the coasts is widely recognised, other features such as the remarkable anisotropy of marine meteorological conditions (Soomere, 2003), abrupt changes in the forcing regime (Soomere et al., 2015), and resulting non-homogenous and rapidly changing wave fields (Soomere and Räämet, 2011) equally or even to a larger extent contribute to the coastal evolution. On top of that the regular presence of sea ice (Kawamura et al., 2001, Granskog et al., 2004) and especially a decrease in the duration of the ice season (Sooäär and Jaagus, 2007) may considerably modify the reaction of the coasts in the nearest future (Orviku et al., 2003; Ryabchuk et al., 2011a).

The complexity and variability of the Baltic Sea coasts is comparable with the variability of their forcing factors. These coasts can be divided into two large categories. Bedrock-based coastal formations (frequently called skären type, see, e.g., Granö and Roto, 1989) predominate in the western, northern and north-eastern parts of the sea. They are characteristic for the eastern (Baltic Proper) coast of Sweden, the entire Gulf of Bothnia, Åland and Archipelago Sea, and the northern coast of Gulf of Finland. All these coasts (except for short sedimentary sections – mostly pocket beaches) are extremely stable. Their evolution is almost not affected by hydrodynamic factors and changes to the location of the waterline and to the geometry of the shore only occur owing to changes in the sea level. The entire area (most strongly the northern Bay of Bothnia but much less the eastern Gulf of Finland or the south-eastern Sweden) is characterised by postglacial uplift that today overrides the global sea-level rise. For the listed reasons the sediment budget of these beaches is not addressed in the current study.

Sedimentary coasts predominate along the southern and eastern margins of the Baltic Sea. Shores of this kind extend from the southern tip of Sweden over Denmark, Germany, Poland and most of the Baltic States up to Cape Kolka in Latvia and further along the southern and eastern coast of the Gulf of Riga to Pärnu Bay. Their rapid evolution has led to the formation of major landforms such as the Curonian Spit after the last ice age and their evolution and erosion is a major concern for the listed countries. Even though coasts mostly experience slow postglacial uplift, the global sea-level rise has led to gradual increase in the local water level and to rapid erosion in recent years and potential loss of land in some coastal segments in the future (Harff and Meyer, 2011).

The two major coastal types are separated by a narrow belt of limestone coasts along the islands of Öland and Gotland, the Western Estonian archipelago and the southern coast of the Gulf of Finland (Šliaupa and Hoth, 2011). These coasts are relatively stable but still experience gradual recession and host appreciable sediment transport in some sections.

1.1.3.2 Local changes and long-range impacts

The properties of sedimentary shores vary substantially along the southern and eastern Baltic Sea coasts. Numerous islands, peninsulas, bays heavily fragment the shores of the western Baltic Sea (the coasts of southern Sweden, Denmark and Germany) and fjords cut into the mainland. Some of these beaches experience crustal down lift and thus relatively rapid relative water level rise (Harff and Meyer, 2011). Even though the wave climate of the south-western Baltic Sea is relatively mild (Soomere et al., 2012) and high waves often occur during low water level events, many beaches in this region not only develop rapidly but also suffer from rapid erosion (e.g. Hanson and Larson, 2008; Pranzini and Williams, 2013). The predominant direction of wave-driven transport is highly variable and the alongshore extent of sediment transport is normally limited to a few tens of kilometres. Thus, sediment relocation along the coasts in question is mostly local and the loss of stability and erosion of long sections is unlikely.

The southern and eastern shores of the Baltic Sea are generally straight and host much longer interconnected sedimentary compartments. These compartments are separated by major landforms (such as the Hel Spit) that extend far into the sea so that deep areas effectively block sediment exchange between neighbouring coastal segments.

A relatively long sedimentary compartment exists along the north-western coast of Poland. The area between Gdansk and Klaipeda hosts several mutually disconnected compartments. The longest (~700 km) more or less continuous sedimentary system of the Baltic Sea stretches from the Sambian (Samland) Peninsula to the eastern coast of the Gulf of Riga (Žaromskis and Gulbinskas, 2010). Even though sediment is mostly transported counter-clockwise along this system (Knaps, 1966; Gudelis et al., 1977), sediment transport here is not necessarily continuous (Knaps, 1982; Soomere and Viška, 2014). It contains an obvious discontinuity and partial discharge at the Kolka Cape (Žaromskis and Gulbinskas, 2010). In addition, only a few parts of the Latvian nearshore host large amounts of fine sediment (Ulsts, 1998).

The appearances of the western and eastern subsections of limestone coasts differ considerably. The shores of the islands Öland and Gotland are relatively straight. Therefore, eroded sediment may be transported to substantial distances. In contrast, most of the coasts of Estonia are heavily fragmented by numerous islands, peninsulas and bays deeply cut into the mainland. This fragmentation confines alongshore sediment transport into relatively small almost disconnected compartments (Soomere and Healy, 2011).

The bay head beaches of the Western Estonian archipelago and in the Gulf of Finland area generally suffer from sediment deficit. They are to some extent stabilised by postglacial uplift (from ~1 mm/year in the eastern part of Estonia up to about ~2.8 mm/year in the north-western Estonia (Vallner et al., 1988) and belong to a rare type of young, relatively rapidly uplifting "almost equilibrium" beaches (Soomere and Healy, 2011). Along with the down lifting shores of the southern Baltic Sea, the described beaches eventually are extremely sensitive to changes in their driving factors. As their slow net development is not specific to the Baltic Sea, it is particularly important to establish parameters of their equilibrium regime, potential sediment supplies, and the main patterns of the natural sediment motions.

Therefore, even though large parts of the Baltic Sea coasts express relatively simple geomorphic and lithodynamic features, understanding of physics and dynamics of lithohydrodynamical processes as well as the actual range of relocation of sediment along these coasts is a major challenge on the way towards establishing an adequate sediment budget of these shores. While the processes on the Swedish, Danish and German coasts are relatively well documented (see, e.g., Deng et al., 2014; Uścinowicz et al., 2014 and references therein), the existing knowledge is scarce and often only qualitative for many coastal segments of the eastern Baltic Sea (Pranzini and Williams, 2013). During the existence of the Baltic Sea in its contemporary shape, this coastal domain has undergone remarkable changes. Perhaps the most impressive landform in the Baltic Sea region, the Curonian Spit, has been created from sediment volume eroded from the Sambian Peninsula Curonian Spit (Žaromskis and Gulbinskas, 2010). The Lithuanian and Latvian coasts further to the north of this spit have been markedly straightened over millennia (Knaps, 1966; Gudelis, 1967; Eberhards, 2003; Eberhards et al., 2006). The changes are less marked in the Gulf of Riga but still substantial even in relatively sheltered areas such as Pärnu Bay (Kartau et al., 2011). Unfortunately, much of the relevant literature has been published only in Russian (Knaps, 1966; Gudelis, 1967) or in small national languages (Ulsts, 1998).

1.1.3.3 Changing forcing factors

Wave activity is the major factor shaping the sedimentary and limestone coasts in the almost tideless Baltic Sea. Although currents do play a role in the transport of fine material from its sources (rivers, cliff erosion) to the offshore, both erosion and sediment transport in the surf and swash zone are governed by wave activity. Major erosion events usually occur when high waves approach unprotected sediment landward the usual swash zone during extremely high tide or storm surge. Synchronisation of these two factors is typical for the eastern and northern Baltic Sea but relatively rare in the western and southwestern parts of the sea.

Although the (annual mean) wave height exhibits extensive interannual and considerable decadal-scale variations at certain locations (Soomere and Räämet, 2011), no long-term changes to the spatially averaged annual mean wave height seems to exist in the entire Baltic Sea (Broman et al., 2006; Zaitseva-Pärnaste et al., 2011; Soomere et al., 2012). However, changes in the nearshore wave direction may also alter the course of coastal processes and in extreme cases even lead to instability of the entire coastal system (Ashton et al., 2001). There is evidence about such effects in the eastern Gulf of Finland (Ryabchuk et al., 2011b).

Owing to a relatively small size of the Baltic Sea, a change in the trajectories of cyclones crossing the sea (Sepp et al., 2005) may become evident as a rotation of wind directions (Jaagus and Kull, 2011) and the associated wave approach direction in some parts of the sea (Räämet et al., 2010). This process change may substantially influence not only the magnitude but even the direction of the wave-driven littoral flow. A more subtle but potentially equal in magnitude change may stem from the presence of a two-peak directional structure of the wind climate of the northern Baltic Proper. The most frequent are south-western winds. North-northwestern winds are less frequent but may be even stronger (Soomere and Keevallik, 2001). The distribution of wave approach directions matches this pattern (Räämet et al., 2010).

The most interesting coastal sections (for which some research results exist) are the Curonian Spit and the Gulf of Finland. Owing to the specific orientation of the Curonian spit with respect to these two predominant wind directions, even a relatively minor change in the proportion of these two peaks may substantially change the resulting net littoral flow (Viška and Soomere, 2012). Predominant winds blow obliquely with respect to the axis of the Gulf of Finland, giving rise to 'slanted-fetch-driven' wave systems with a specific orientation (Pettersson et al., 2010) that frequently differs from the wind direction.

The described features suggest that the beaches in question are sensitive to changes in some properties of their drivers. For example, an increase of the global sea level, increased discharge during more pronounced spring floods in the climate of the future (The BACC Author Team, 2015), construction of a dam to regulate the river flow (Velegrakis et al., 2008), or a new coastal engineering structure blocking the littoral drift (Soomere et al., 2007) may easily distort the balance. Another type of delicate equilibrium exists at the mouths of large rivers. For example, seasonal variations of the river flow and wave intensity give rise to large seasonal changes of the sand bar at the Narva River mouth (Laanearu et al., 2007) and thus may substantially impact the alongshore sediment transport.

An important player in the coastal changes is the ice cover. If present, it protects sediment from erosion during large part of the stormy period. In this light it is natural that rapid erosion events at certain locations in the recent past (Orviku et al., 2003; Eberhards et al., 2006) are associated with a combination of changes to the wave climate and with a decrease in the length of the ice season (Orviku et al., 2003; Ryabchuk et al., 2011a; Tõnisson et al., 2011).

1.1.3.4 The data sets and research challenges

Several national and scientific resources quantify in detail or characterise qualitatively the evolution of the coastal. The most valuable are airborne-laser-scanning-based digital elevation maps of entire countries. These maps involve the coastal zone with an accuracy of a few meters in horizontal and a few centimetres in vertical direction. Combined with simple applications of Bruun Rule and terrestrial laser scanning data they make it possible to adequately quantify changes in sediment volume across the entire coastal zone (Eelsalu et al., 2015). Even though they cover only a few years (generally less than a decade), they are extremely valuable to understand what happens under sea level rise or how large has been sediment loss during major flooding events. These data sets are generally not free.

More conventional national monitoring of coasts has been performed for single cross-sections (profiles) of the coastal zone in each Baltic Sea country (Pranzini and Williams, 2013). The countries with relatively straight coastline usually monitor one profile for each 500–1000 m of the shoreline (Deng et al., 2015; Bagdanavičiūtė et al., 2015). Other countries with complicated geometry of the shoreline and long sections of stable shores have established similar profiles in representative locations (Rodin et al., 2014). In some countries (e.g. Latvia, Soomere et al., 2011) they are only monitored on dry land but still provide valuable information about recession of the coastal scarp. In other countries (e.g., Poland) they extend to about 10 m deep water and thus provide essential knowledge about sediment budget in the wave-driven nearshore.

A major challenge is the identification and quantification of recent and future changes in the coastal evolution of several most vulnerable or rapidly developing segments of the sedimentary coast. However, understanding their evolution in rare hydrometeorological conditions of the Baltic Sea (two-peak directional structure of predominant winds and approaching waves, large aperiodic variations in the nearshore water level, potential impact of the changes in the ice cover) is relevant and important for other parts of the world. A short ‘memory’ of the Baltic Sea wave fields combined with highly intermittent local wave regime makes it frequently possible to identify the impact of single storm or wind event in the coastal landscape. These features suggest that the Baltic Sea may be seen as a natural laboratory that provides insight to what will happen, e.g., at the Arctic coast.

1.1.4 Physical Oceanography[1]

The Baltic Sea is an almost totally enclosed shelf sea whose only connections to the open ocean are the narrow and shallow Danish Straits. It is a brackish sea with both salt and fresh water inflows. The drainage area of the Baltic Sea is four times as large as the sea itself. The population of the drainage are is some 85 million peoples and virtually all terrestrial human activities influence the marine environment. There are nine coastal countries along the Baltic Sea and five more countries have territories in the drainage area. The combination of the huge drainage area with massive fresh water input and shallow sill depths – less or equal than 18 m – makes the Baltic Sea the largest brackish water area in the world. The salinity varies from almost zero in the innermost parts of the Baltic to 10-12 g/kg close to the sills.

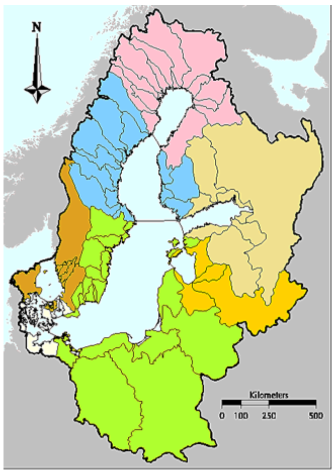


Figure 10 Baltic Sea Drainage area

[1] This chapter is to a large extent based on HELCOM, 2013

The vertical salinity stratification is also from 7 to 12 psu in the Baltic Sea Proper where there is a permanent halocline that isolates the deep waters from the surface. The only natural way to ventilate the deep waters is the occasion of major saline inflows from the North Sea.

1.1.4.1 Water temperature

The thermal regime of the Baltic Sea is controlled mainly by atmospheric heat fluxes, while the contribution of lateral heat advection is quite small. The seasonal cycle of water temperature is superimposed on the more or less permanent two-layer salinity stratification. Cold waters formed during the winter is extending down to the halocline, which has typical depths between 60 and 80 m in the Baltic Proper and somewhat less in the southern basins. During summer, after the development of a seasonal thermocline at depths of about 15 to 20 m, the underlying cold intermediate layer generally keeps a 'memory' of the severity of the previous winter. Thus, the summer (July to August) temperature of the intermediate cold layer is well correlated with the surface (down to the halocline) temperature in March. Below the halocline, deeper waters are formed mainly by lateral advection of saline waters from the North Sea entraining and mixing with ambient waters. Below 100 m depth, the temperature ranges only from 3 °C to 8 °C, while the temperature in surface waters can range up to 25 °C. The vertical overturning of the upper layer resets the thermal memory of the upper layer twice a year.

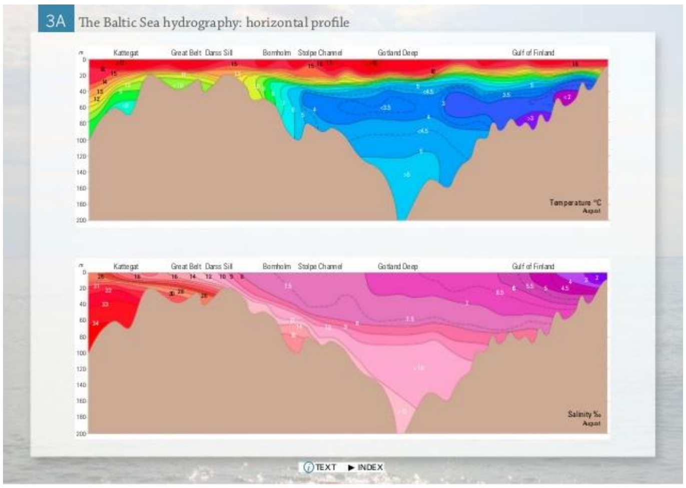


Figure 11 Vertical temperature and salinity distribution in the Baltic Sea

Analyses of a number of data sets of *in situ* measurements of surface temperature, together with more recent remote sensing data, confirm a warming of surface waters in all seasons since 1985. An increase in annual mean sea-surface temperature of up to 1 °C/decade from 1990 to 2008 has been estimated based on remote sensing data, with the greatest increase in the northern Bothnian Bay and large increases also found in the Gulf of Finland, the Gulf of Riga, and the northern Baltic Proper (Figure 12).

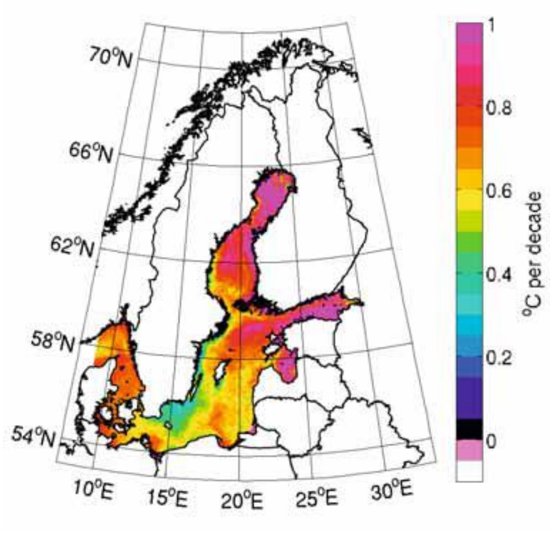


Figure 12. Linear trend of the annual mean sea surface temperature based on infrared satellite data (1990 to 2008) provided by the Federal Maritime and Hydrographic Agency (BSH), Hamburg (Lehmann et al., 2011).

In the northern areas, the recent decrease in the extent and duration of sea-ice cover has strongly influenced the seawater temperatures. The least warming of surface waters (0.3 to 0.5 °C/decade) was found northeast of Bornholm up to and along the Swedish coast, probably owing to an increase in the frequency of coastal upwelling. Among the seasons, the largest increase is in the summer.

1.1.4.2 Salinity

The overall salt content of the Baltic Sea depends to a large extent on the atmospheric net precipitation and riverine discharge, with higher salinity during dry periods and lower salinity during wet periods, and also on the regular water exchange between the North Sea and the Baltic Sea. The salinity and stratification of the deep water are strongly linked to the occurrence of Major Baltic Inflows of North Sea water, which occur sporadically and bring high saline water to the deep layers. In recent decades the major inflows have been followed by a long period of stagnation during which the saline stratification decreases and oxygen deficiency and hydrogen sulphide develops in bottom waters. Major inflows occur normally during winter and spring; they bring relatively cold and oxygen-rich waters to the deep basins. Since 1996, several large inflows have been identified also in the summer. Such baroclinic inflows have transported high-saline, but warm and low oxygen water to the deep layers of the Baltic Sea. The warm water inflows transport less oxygen to the Baltic Sea than cold-water inflows and the higher temperatures increase the rate of oxygen consumption of organic matter in the deep water which ultimately leads to increase the production of hydrogen sulphide. Present mean salinities are estimated to be near the highest values since 1500 AD, but there have been several periods when the mean salinity of the Baltic Sea decreased from the maximum value of about 7.8 g/kg to about 6.5 g/kg.

1.1.4.3 Circulation

The shallow sill depths limit strongly the entrance of saline water to the Baltic Sea. Most of the regular water exchange happens in the upper layer where the Baltic Sea waters flow out from the sea and mix with the North Sea waters and the mixed waters flow back and forth. The more saline waters from the deeper layers of the Skagerrak have to make their way up to the sill against the outflow in order to reach the Baltic Sea. Therefore, the effective water renewals of the Baltic Sea deep waters are infrequent. The deep water anoxia is thus a natural process that is even worsened by human induces nutrient loads from land.

The weather conditions that make the deep saline water inflow to the Baltic Sea are special and therefore the environmental balance of the Baltic Sea is very sensitive to changes. Even small changes in weather conditions may have tremendous impacts on the environment and thereby on the biota existing there - which very often are stressed to the verge of their capacity.

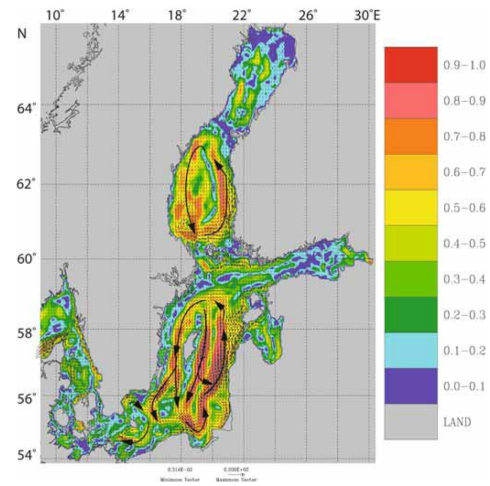
The large-scale circulation in the Baltic depends on several factors: prevailing wind conditions, bottom topography, water exchange with the North Sea, the fresh water supply from land and the Coriolis effect. Schematically, the circulation consists of a surface current with brackish water flows out of the Baltic through Kattegat to the Skagerrak and the North Sea, and a current in deeper layers with more saline water going to the opposite direction. The prevailing south-westerly winds, Coriolis effect and large fresh water input at the end of the gulfs favour counter-clockwise residual circulation in the upper layer of the Baltic Sea.

The fresh water inflow to the Baltic may be described as an engine that drives the large-scale circulation. The inflow generally causes a higher water level in the Baltic than in Kattegat and Skagerrak. This difference in water level forces the brackish surface water out of the Baltic. On its way to the Skagerrak the brackish water becomes increasingly saline since the surface water mixes with the underlying water. In order to replace the water entrained into the surface current an undercurrent of more saline water is formed which runs through the Kattegat and further down into the deeps of the Baltic.

The Sound, the Belt Sea and Kattegat make up the shallow sill area which restricts the exchange of water between the Baltic and the Skagerrak. Here takes place most of the mixing of the Baltic waters and the saltier waters from Skagerrak.

Having passed the shallow sills the saltier, heavier Kattegat water spreads out into the Baltic close to the bottom along a number of channels and at the same time it becomes mixed with surrounding brackish water and increases in volume. Mainly as a result of mixing by the wind, the surface layer has an almost homogeneous salinity. A halocline separates this water from the more continuously stratified deep water. The halocline limits the turbulence and decreases the vertical mixing. Finally, the inflowing water is stratified at the level that corresponds to the density obtained by the bottom current as a result of being mixed with the surrounding water.

When meteorological factors are favourable, which does not happen very often, a large inflow of salty Kattegat water takes place and can displace the water masses present in the deepest basins (Fonselius, 1995). Between these events, salinity slowly decreases in deeper areas as a result of vertical mixing. These stagnation periods have a strong influence on the oxygen and nutrient situation in the Baltic. The rate of turnover of water in the various basins can be estimated by calculating the flows between different sub-basins on the basis of volume and salt balance. The turnover time for the entire water volume of the Baltic is 25 – 35 years. Thus, pollutants entering the Baltic will remain in the system for a long time



Results from model simulations on the mean circulation in the entire Baltic Sea are illustrated in Figure 13. They are in agreement with observational results and show the existence of quite stable, strong cyclonic (counter-clockwise) gyres in the Baltic Proper and the Bothnian Sea, and weaker, less-persistent currents in the Gulf of Riga, Gulf of Finland, and the Bothnian Bay. This regular circulation pattern may be interrupted for short periods when water mass movements may take alternative paths; this may occur, for example, after some Major Baltic Inflows.

Figure 13. Baltic Sea circulation as viewed from modelling results.
(Lehmann and Hinrichsen, 2000)

Interactions between the upper and lower water layers of the Baltic Sea are quite restricted owing to the strong stratification. At the entrance to the Baltic Sea, the deep-water circulation is typically dense bottom current of the inflowing saline water. Processes including convection and mechanical mixing, entrainment and vertical advection of water masses result in interactions between the upper and lower layers in other parts of the Baltic Sea. An analysis of the sensitivity of the Baltic Sea to change indicates that the average salinity of the Baltic Sea depends on and is strongly sensitive to changes in freshwater inflow. The annual maximum ice extent is strongly sensitive to changes in the mean winter (DJF) air temperature over the Baltic Sea: at a mean air temperature of −6 °C the sea will become completely ice covered, whereas the ice cover will not appear at 2 °C. Changes in the annual mean water temperature are closely related to changes in the air temperature above the sea.

The Baltic Sea is almost non-tidal but frequent passages of atmospheric pressure systems cause changes in air pressure and wind forcing that generate rapid sea level fluctuations of up to + 1 m, extremes up to + 2m. Additionally the passage of strong atmospheric pressure systems may cause water level differences between Kattegat and the western Baltic Sea of 0.8 to 1 m that induce very strong barotropic currents through the Danish Straits reaching maximum current velocities of 4-5 m/s . The fetch lengths in the Baltic limit the development of very extreme waves, but rough weathers with high waves and strong winds are believed to have caused several severe accidents. Largest significant wave heights of 8 meters are found in the Northern Baltic Sea Proper where individual waves over 14 meter high have been observed during wintertime. At some locations interfering and topographically focused waves are believed to have caused the accidents, too.

Figure 14. During strong winds the water along the coasts rises leading to flooding at exposed places.

1.1.4.4 Sea ice

The ice season in the Baltic Sea usually begins in November when ice forms in the shallow bays of the Bothnian Bay. On average, the maximum extent of ice on the Baltic Sea occurs in the end of February, when ice covers about 40% of the total Baltic Sea area. The ice edge is typically located in the northern Baltic Proper and the Bothnian Bay, the Gulf of Finland, and the Gulf of Riga are ice covered.

During extremely severe winters, the entire Baltic Sea has been ice covered, while in very mild winters ice is only formed in the Bothnian Bay and the eastern Gulf of Finland. The length of the ice season is 130 to 200 days in the Bothnian Bay, 80 to 100 days in the Gulf of Finland, and 0 to 60 days in the southern Baltic Sea.

Variables such as ice type, ice thickness, and duration of the ice-covered period are very dependent on wind and currents and may reflect changes on a local scale. All of these variables have large inter-annual variability and are very closely related to large-scale atmospheric circulation.

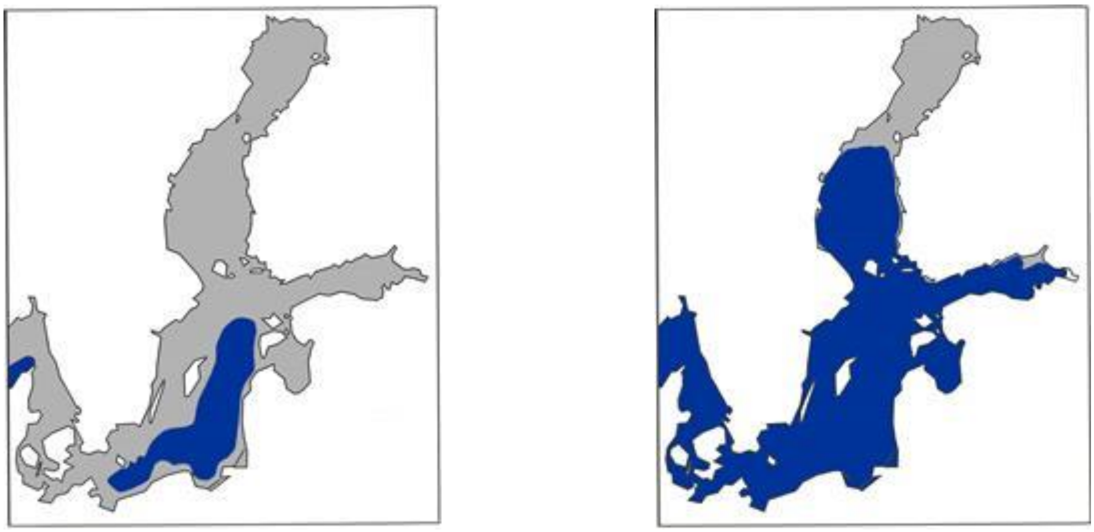


Figure 15. Sea ice distribution in the Baltic Sea in a severe ice winter (1986) and in a mild ice winter (2008), source Finnish Meteorological Institute.

There has been a significant decreasing trend in the Baltic Sea ice cover, which amounted to a decrease of 20% over the past 100 years up to 2011. There has also been a large change in the length of the ice season during the past century. In the Bothnian Bay, which has the longest ice season, the trend is −18 days/century.

1.1.4.5 Oxygen

Oxygen is necessary for all higher organisms in the sea. When there is a lack of oxygen, then hydrogen sulphide occurs, which is poisonous to all higher organisms and its occurrence results in sea-bed mortality. Oxygen enters the surface water through diffusion from the atmosphere and through the photosynthesis of phytoplankton, macro algae and higher plants. During periods with low primary production or high oxygen consumption as a result of respiration and degradation of organic material such as dead algae, decaying faecal matter, etc. the supply from the atmosphere will be of greater importance. In deep water, where no light penetrates, photosynthesis cannot take place, for which reason oxygen is consumed by bacterial degradation of the organic material, which “rains” down from the surface water. Consequently, oxygen concentrations in the deep water are lower than those in the surface layer. The factors decisive for oxygen conditions in deep waters are water turnover, vertical mixing and the amount of organic matter supplied from surface layers.

For many species, survival and reproduction get difficult when oxygen concentrations drop to about 2 ml/l. In Skagerrak and northern Kattegat there is more or less permanent halocline, which prevents vertical mixing between surface and deep layers of water. However, this has only a marginal effect on oxygen concentrations owing to the intensive exchange of water with the North Sea and the large volume of water in relation to the organic material supplied. Nonetheless, the oxygen concentrations may locally decrease during summer and autumn in areas close to the coast where the organic load is generally larger and the water exchange poorer. The oxygen conditions in the southern Kattegat and the Baltic Proper may be compared with those prevailing in fjords i.e. poorer water exchange and smaller volume of deep water combined with a strong halocline and a heavy load cause oxygen deficiency in extensive areas. This mainly concerns deep areas of the Baltic Sea Proper east of Gotland. In these areas, the deep water below depths of 100-130m is rarely replaced and may remain stagnant for 10 years or more, which results in extensive areas with dead bottom and hydrogen sulphide corresponding to 10-15% of the Baltic's area.

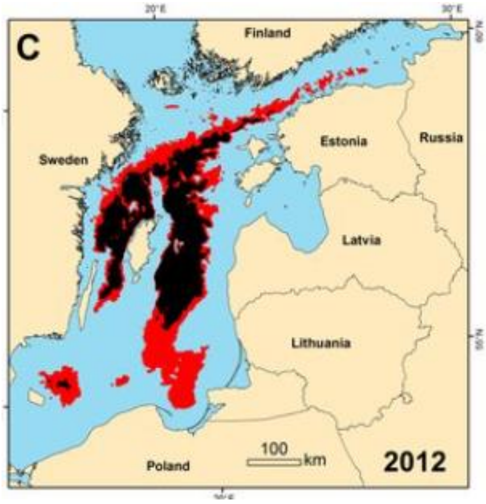


Figure 16. Areas with low oxygen content (red) or no oxygen content (black) in the Baltic Sea, Christensen, 2014

1.1.5 Biology

The brackish Baltic Sea hosts more than 6 thousand species (Ojaveer et al., 2010). According to recent knowledge, approximately half of them are macroscopic (most of benthic invertebrates and macrophytes, fishes, birds), however diverse groups of microscopic organisms (e.g. foraminifera's, meiobenthos) remain poorly investigated. Although, many organisms immigrated to the Baltic after the last glaciation period 10,000 to 15,000 years ago, fraction of those introduced to the system recently is increasing.

1.1.5.1 Marine mammals.

Five species of marine mammals are present in the Baltic Sea: three seals (ringed seal *Phoca hispida*, grey seal *Halichoerus grypus* and harbour seal *Phoca vitulina*), one cetacean and the otter (HELCOM, 2012).

The Baltic Sea is inhabited by three species of seals: ringed seal is an Arctic species and is therefore directly dependent on quality of ice by colonizing mainly the large gulfs in the northeastern Baltic Sea (Gulf of Bothnia, Gulf of Finland, and Gulf of Riga) where ice is annually formed. The main concentrations of grey seal are found in the northern part of the Baltic Proper, while the harbour seal is present only in the southern Baltic. As summarised by Ojaveer et al. (2010), in early 1990s, the population size of all three seal species consisted of tens of thousands individuals, however it decreased drastically before 1970s. By that time, once largest population of ringed seal declined approx. 40 times to about 5,000 individuals. Since then, the populations started to improve, especially the grey seal population, while multiple virus infections since the late 1980s have prevented the harbour seal population in the Kattegat and Skagerrak from fully recovering from the previous deep decline. In the HELCOM Red List assessment (HELCOM, 2013a) the ringed seal and the Kalmarsund population of the harbour seal were categorized as vulnerable, whereas the grey seal and the southern Baltic population of the harbour seal were considered Least Concern.

The only cetacean species reproducing in the Baltic Sea is harbour porpoise comprising two distinct populations: one in the Baltic Proper and the other in the Kattegat and the western Baltic (Ojaveer et al., 2010; HELCOM, 2012). Both subpopulations of harbour porpoise are regarded threatened – the Baltic Sea population even as critically endangered due to the dramatic declines and current low numbers (HELCOM, 2013a). Until the early twentieth century, the harbour porpoise was widely distributed and common, however the population size has decreased by more than 90% during the last century. Much of the decline is presumably due to historically high levels of direct exploitation (Ojaveer et al., 2010).

The Eurasian otter has increased in the Baltic Sea area during the last c. 10–20 years. The populations have expanded from freshwater habitats towards the coast and coastal populations may still be largely supported by freshwater populations. Otters are distributed sparsely along all coasts, often dependent on the distribution in the freshwater habitats on the mainland (HELCOM, 2013b). The Eurasian otter was assessed as near threatened in the HELCOM Red List assessment (HELCOM, 2013a).

1.1.5.2 Breeding and wintering birds.

Baltic Sea is one of the most important areas for seabirds and coastal birds in the Western Palaearctic. Occurring bird species can be grouped into three categories: breeding, wintering and truly marine birds. Breeding birds breed in variety of Baltic coastal habitats, while during the cold period same habitats serve as feeding grounds and shelter for wintering birds that breed outside the Baltic Sea region. Truly marine, pelagic species are only represented by northern fulmars and black-legged kittiwakes (both only in the Kattegat region) and by auks (HELCOM, 2013a).

During the winter period, the total number of seabirds is of 106 magnitude, dominated by benthic feeding diving ducks, such as long-tailed duck, common scoter and velvet scoter (Skov et al., 2007). The results of the Baltic coordinated survey in 2007 to 2009 indicate that the winter population of long-tailed ducks has declined dramatically from 4 272 405 birds in 1988–1993 to 1 486 000 birds. Similar trends for the same period are documented for wintering common and velvet scoters (from 783 310 to 412 000 and from 932 700 to 373 000 birds respectively). The most important wintering areas are the Pomeranian Bay and the Irbe Strait – Gulf of Riga, while the north-western part of the Kattegat comprises the largest number of common scoters in Europe (HELCOM, 2013c).

In total, 56 species and 2 subspecies of breeding birds in the Baltic Sea marine or coastal areas are listed, out of those, 23 are red-listed (HELCOM, 2012; HELCOM, 2013a). The gull-billed tern (*Gelochelidon nilotica*), has been a regular breeding bird in the past but is considered regionally extinct today. The Kentish plover (*Charadrius alexandrinus*) is categorized as critically endangered, which has formerly been a regular breeder in Denmark, Sweden and Germany, but after 2000 has only bred with single pairs in Sweden and Germany (Mecklenburg-Western Pomerania). Four species (the southern dunlin *Calidris alpina schinzii*, the Terek sandpiper *Xenus cinereus*, the Mediterranean gull *Larus melanocephalus* and the black-legged kittiwake *Rissa tridactyla*) are endangered (HELCOM, 2013a).

Out of 58 species, 4 subspecies and 2 different biogeographic populations of wintering birds in the Baltic, 16 are red-listed (HELCOM, 2013a). Two species, the red-throated diver (*Gavia stellata*) and the black-throated diver (*Gavia arctica*), have dramatically decreased as wintering birds in the Baltic Sea and are classified as critically endangered. Seven species, including five sea duck species, are endangered (red-necked grebe, taiga bean goose, common eider, Steller´s eider, long-tailed duck, common scoter, velvet scoter), three taxa are vulnerable (red-breasted merganser, black-legged kittiwake and black guillemot *Cepphus grylle arcticus*) and four – near threatened (Slavonian grebe, light-bellied brent goose, little gull and black guillemot *Cepphus grylle grylle*).

Main threats for seabirds are habitat destruction, bycatch, hazardous substances, plastic waste, oil spills, offshore constructions, disturbance by ship traffic and hunting. For example, gillnet fishery causes the death of tens of thousands of birds every year (mostly long-tailed ducks, black and velvet scoters, red-throated and black-throated divers, eiders, greater scaups, common and black guillemots, cormorants), while oil spills can result in deaths of several tens of thousands of birds a year, mainly sea ducks, auks and divers (HELCOM, 2013a).

1.1.5.3 Fishes.

The diversity of fish species is generally higher in the Kattegat compared to the more northeastern sub-regions of the Baltic Sea (Ojaveer et al., 2010). There are approximately 200 fish species in the entire Baltic Sea (including Kattegat), but the number of species is much less in some of the northerly gulfs (less than 50 species) (HELCOM, 2007, 2009). The fish biomass is dominated by only a few species, i.e. cod, herring and sprat, which are also commercially most important species in the Baltic Sea. These three stocks are interlinked through food-web interactions, i.e. adult cod preys on sprat and herring, which, in return, feed on early life stages of cod (Köster and Schnack, 1994; Köster and Möllmann, 1997). Additionally, cod recruitment is influenced by salinity and oxygen conditions, and food availability for larvae (Köster et al., 2005). Sprat and herring dynamics are also largely influenced by climatic conditions, particularly temperature (MacKenzie et al., 2007), and competition among the species for prey (Casini et al., 2009). The biomasses of cod, sprat and herring have fluctuated substantially the last 40 years (Figure 17). In the 1970s and early 1980s cod was relatively abundant. During the late 1980s, a regime shift was identified in the fish community when cod stock declined and sprat correspondingly increased (Möllmann et al., 2009). The decline in cod was due to a combination of poor hydrographical condition for recruitment and intense fishing pressure (Köster et al., 2003). The sprat stock subsequently increased due to reduced predation pressure from cod, favorable climatic conditions for sprat recruitment and relatively low fishing pressure. Concerning other species, some flatfish species are relatively abundant, e.g., flounder. In addition, several non-commercial fish are present in the Baltic Sea, including gobies, three-spined stickleback, nine-spined stickleback, and pipefish, which are successfully adapted to low-salinity conditions of the Baltic Sea and play several significant roles in the food web (Ojaveer et al., 2010). Also, several migratory species, such as salmon, trout, eel, vimba bream and smelt are of high commercial value locally. The fish communities in coastal areas especially in the northeastern Baltic Sea, including large gulfs and lagoons are dominated by freshwater species, of which the most common are perch, roach, bream, bleak, ruffe, ide, pike, and whitebream. Eutrophication, together with increased temperatures, is considered to have influenced species composition in coastal areas, for example a significant increase in perch and roach abundance has been recorded in the Archipelago Sea (HELCOM, 2006; Adjers et al., 2006).

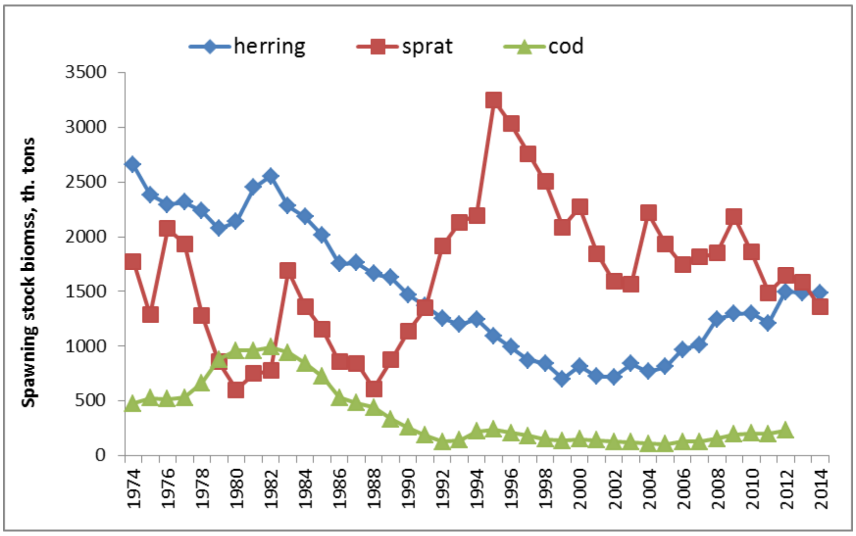


Figure 17. Spawning stock biomass (th. tons) of sprat, central Baltic herring (ICES 2015) and eastern Baltic cod (ICES 2013) in the Baltic Sea.

1.1.5.4 Phytoplankton.

The seasonal variation of inorganic nutrient concentrations is observed in the Baltic Sea upper layer: minimum values in summer and maximum in winter. Water pool is mixed down to the bottom or down to the halocline in autumn. In winter (January, February), concentrations of nutrients are high because of deep vertical mixing and low light level preventing phytoplankton growth.

Phytoplankton primary production is highest in spring. Winter level of inorganic nutrients in the surface layer and physical processes, such as prevailing circulation, development of stratification, upward and downward movement of the seasonal thermocline (Kahru and Nõmmann, 1990; Lips et al., 2014) influence the spring bloom species composition, its dynamics, heterogeneity and intensity. In the Baltic Sea, seasonality in phytoplankton growth differs between the east-west and north-south gradient (Gasiunaite et al., 2005). A few decades ago, it was generally accepted that the vernal phytoplankton bloom occurs in the second half of April in the southern and central part of the Baltic Proper, and in early May in the northern part of the Baltic Proper and in the Gulf of Finland (Edler, 1979; Hällfors et al., 1981). Studies in the 1970s demonstrated the dominance of cold-water diatoms in the Baltic Sea during the spring bloom (Hällfors et al., 1981 and references therein). The main diatom species forming the spring bloom are *Achnanthes taeniata*, *Sceletonema marinoi*, *Thalassiosira baltica*, *Thalassiosira levanderi*, *Melosira arctica*, *Chaetoceros* spp. Several recent analyses have shown long-term changes in the spring phytoplankton community composition, abundance, and annual succession. The observed changes in phytoplankton include a higher overall spring bloom biomass throughout the Baltic Sea (Alheit et al., 2005), an increased dinoflagellate contribution to the spring bloom biomass (Wasmund and Uhlig, 2003), and an earlier onset of the spring bloom (Fleming and Kaitala, 2006; Lips et al., 2014). The phytoplankton spring blooms in the Baltic Sea is found to be often dominated by the cold-water dinoflagellates – *Biecheleria baltica*, *Scrippsiella hangoei*, *Gymnodinium corollarium* and *Peridiniella catenata*.

After the spring bloom, in May, inorganic nutrients are almost depleted in the upper mixed layer (some phosphates may still be left) and strong stratification prevents mixing between the nutrient depleted upper layer and the nutrient rich lower layers. That gives competitive advantages for species able to migrate vertically in the water column and exploit inorganic nutrients from the lower layers (Lips et al., 2014). In May-June, the phytoplankton community is often dominated by dinoflagellate *Peridiniella catenata* and photosynthetic ciliate *Mesodinium rubrum*.

In summer, during thermal stratification, when surface layer is depleted of inorganic nutrients, filamentous cyanobacteria able to fix molecular nitrogen and use phosphates left in the upper water layer after spring bloom (Heiskanen, 1998; Lips and Lips, 2008), are favored. The intensity, relative abundance of the major species, and temporal and spatial coverage of the blooms varies considerably from year to year. Main filamentous cyanobacterial species found in the Baltic Sea in summer are *Aphanizomenon flos-aquae*, *Nodularia spumigena* and *Anabaena* spp., and the bloom formation takes place in late June-early July. There is a clear indication that the intensity of *Aphanizomenon* sp. blooms is largely determined by the surplus of phosphorus related mainly to the pre-bloom upwelling events, and the outcome of *N. spumigena* bloom is highly dependent on weather conditions like photosynthetic active radiation and water temperature (Lips and Lips, 2008). The coastal upwelling's plays an important role in replenishing the upper euphotic layer with nutrients and supporting the phytoplankton growth. In the intermediate water layer the N:P ratio is low, and hence, more phosphates in relation to nitrates are brought to the surface layer (Lips et al., 2009). Coastal upwelling's affect strongly both the horizontal and vertical pattern of inorganic nutrients and phytoplankton (Lips and Lips, 2010; Nausch et al., 2009).

Second phytoplankton group able to form summer blooms in the Baltic Sea is dinoflagellates, especially vertically migrating *Heterocapsa triquetra* which is able to perform diurnal and bidiurnal vertical migrations in order to dark assimilate nutrients from lower layers (Lips et al., 2011, Lips and Lips, 2014).

During autumn, the water column is mixed down to the bottom in shallow areas or down to the halocline in deeper areas. If light and nutrient condition are favorable, autumn phytoplankton bloom formed by several diatom species or small flagellates may form.

1.1.5.5 Macrophytes.

Macrophytes account for nearly one fifth of the Baltic macrospecies and cover macroalgae, aquatic vascular plants and mosses. Out of 531 macrophytes (HELCOM, 2012) macroalgae alone comprise 442 species (Ojaveer et al., 2010). Since salinity is the main controlling factor, approx. 75% of species occur in the Kattegat, while diversity in other regions is typically less than 200 species. Although many macrophytes does not play structuring role of the seabed communities, 13 species and 6 large groups (e.g. filamentous algae, kelp, Charales, etc.) are mentioned as dominating taxa in HELCOM underwater biotope and habitat classification (HELCOM, 2013a).

Habitat structuring perennial macroalgae *Fucus vesiculosus* and *Furcellaria lumbricalis* with phanerogams *Zostera marina* and charophytes declined significantly during the second half of the twentieth century. On the other hand, these organisms are still common in their distribution areas and improvements in the status recently have been noticed locally. Other seven macrophyte species were considered threatened and four species classified as near threatened in the current HELCOM Red List assessment (HELCOM, 2013b). All later taxa are characteristic for soft bottoms and sheltered environments confirming the highest pressures in the areas of restricted water exchange. Hence, increased nutrient levels stimulate the phytoplankton growth and subsequently change light conditions within the water column causing both a changes in the vertical distribution of macrophyte species and growth of certain opportunistic groups. These effects remain dominant and common in many Baltic areas, but infrastructure projects associated with modifications of water exchange, shifts in wave regime and changes in water turbidity remain important locally. These frequently limit important ecosystem functions provided by macrophyte belts i.e. provision of food for herbivorous benthic species, forming fish spawning grounds (e.g. Baltic herring) and shelter for juvenile and shallow species.

1.1.5.6 Benthic macroinvertebrates.

This is the most diverse group of macroscopic organisms in the Baltic with the total number of 1476 species recorded after the last inventory (Ojaveer et al., 2010). Similarly to macrophytes, diversity of this group is tightly related to the salinity factor. There are several taxonomic groups such as sea squirts (*Ascidiacea*), echinoderms (*Echinodermata*), sponges (*Porifera*), and sea anemones and corals (*Anthozoa*) that are exclusively restricted to the saline waters of the south-western Baltic. In the northern Baltic Sea, most of the species are of freshwater origin and their overall number is considerably lower. On the other hand, highly heterogeneous freshwater to brackish lagoons typically have higher macroinvertebrate diversity compared to adjacent more saline waters of the Baltic.

Next to salinity, oxygen is another important factor limiting species distribution. Benthic macroinvertebrates are often absent in the deeper basins below the halocline, which tend to increase in area during longer periods without saline water inflows from the North Sea. Although this phenomenon has been natural for the Baltic most likely, several decades of intensive eutrophication have significantly accelerated these processes. On the other, increased organic load to the seabed resulted in 2-6 fold enhancement of the total macroinvertebrate biomass in the shallow areas (e.g. Kube at al., 1997; Andersin et al., 1998, Cederwal et al., 1999).

Benthic invertebrates serve important food spectra for many demersal fishes (juvenile cod, flounder) as well as several wintering bird species (e.g. Long-tailed Ducks, Velvet Scoters), several species play important role in structuring seabed diversity and local benthic communities. Next to

19 benthic macroinvertebrate species classified as threatened during the last Red list assessment (HELCOM, 2013a), tenths of species or higher taxonomic groups are listed as dominant in benthic habitats (HELCOM, 2013b).

1.1.5.7 Alien species.

There are 131 alien (or non-indigenous, NIS) and cryptogenic (CS, i.e. those which origin cannot be reliably demonstrated as being either introduced or native) species recorded in the Baltic Sea (AquaNIS, 2015). Of them at least 27 NIS were introduced since the beginning of 21st century.

At least nine phytoplankton species have been recorded in the Baltic as NIS or CS (Olenina et al., 2010; Kownacka et al., 2013; AquaNIS, 2015), although there is usually a high level of uncertainty when assigning a NIS status to unicellular plankton organisms (Gómez, 2008). However, since phytoplankton species are easily distributed by ships' ballast water, the number of phytoplankton NIS is probably underestimated. The most impacting phytoplankton species is the dinoflagellate *Prorocentrum cordatum*, which forms summer-autumn blooms (with abundance up to 350 cells per litre), changes physical (water transparency) and chemical (nutrient content) properties of sea water (Olenina et al., 2010). *P. cordatum* has the potential to form toxic blooms that can kill crustaceans, fish and other marine organisms, but in the Baltic Sea, toxicity has not been observed for this species. Other potentially toxic cryptogenic phytoplankton species in the Baltic Sea are the dinoflagellates *Alexandrium minutum*, *Alexandrium ostenfeldii*, *Gymnodinium catenatum, Karenia mikimotoi,* silicoflagellates *Pseudochattonella verruculosa* and *Heterosigma akashiwo*. Another type of damage to the ecosystem rather than toxicity can be caused by phytoplankton species that can form dense blooms with copious amounts of mucilage, like *Coscinodiscus wailesii*. Because of its comparatively large size of 175-500 µm in diameter, this species is inedible to most grazing zooplankton and when its bloom decays, the cells aggregate, sink and may cause anoxia at the seafloor. A direct socio-economic impact of mucilage is the clogging of nets and cages used in fisheries and aquaculture.

Thirteen non-native benthic macrophytes, including 11 algae and two vascular plants, have been recorded in the Baltic Sea area, yet none of these NIS has become invasive and caused environmental or economic problems in the area (Olenin et al., in press).

At least eight zooplankton NIS are established in the Baltic Sea: six crustaceans (*Cercopagis pengoi*, *Cornigerius maeoticus*, *Evadne anonyx*, *Penilia avirostris*, *Acartia* (*Acanthacartia*) *tonsa* and *Ameira divagans*) (AquaNIS, 2015) and two gelatinous species (the jellyfish *Maeotias marginata* and the comb jelly *Mnemiopsis leidyi*). The main difference between the two groups is the way they are utilized as a food source by higher trophic levels. Cladocerans and copepods are often valuable additions to the diet of a range of predators, while gelatinous zooplankters are mainly preyed upon by carnivorous gelatinous top-predators, which utilise secondary production that is usually consumed by fish (Olenin et al., in press). Therefore, gelatinous zooplankton organisms are often regarded as "dead ends" in marine food webs (Verity and Smetacek, 1996). The water flea *C. pengoi* is the only NIS in the Baltic Sea that seems to have a strong impact on ecosystem functioning in the pelagic zone (Lehtiniemi and Gorokhova, 2008). Since *C. pengoi* tends to attach to fishing gears, clog nets and trawls it may cause substantial economic losses for fishermen (Leppäkoski and Olenin, 2000).

The largest group of NIS recorded in the Baltic Sea (~80 species) are benthic and nekto-benthic invertebrates, mainly crustaceans (37 species), annelids (18) and molluscs (12). Of these, ~45 species are currently established in the Baltic Sea. No shallow hard- or soft-bottom habitat in the Baltic Sea is entirely free from human-mediated benthic invaders. NIS can even be dominant in these habitats, e.g. *Dreissena polymorpha* on hard bottoms and *Marenzelleria* spp. on soft bottoms in the low-salinity lagoons of the SE Baltic Sea proper (Leppäkoski et al., 2002a). Benthic macrofauna NIS with the largest identified impacts on the Baltic Sea ecosystem are the polychaete *Marenzelleria* spp. and the zebra mussel *Dreissena polymorpha*, the amphipods *Gammarus tigrinus, Obesogammarus crassus* and *Pontogammarus robustoides* and the fish *Neogobius melanostomus* (Zaiko et al., 2011; Ojaveer and Kotta, 2014). Most of these species were introduced to the Baltic Sea in 1975-1992, except for *D. polymorpha* that has been present in the Baltic Sea already for a couple of centuries. Today, the native freshwater amphipods have disappeared from the central freshwater part as well as from the more brackish northern part of the Curonian Lagoon while the Ponto-Caspian amphipods *Obesogammarus crassus* and *Pontogammarus robustoides* proliferate here now, together with the North-American amphipod *Gammarus tigrinus* (Grabowski et al., 2006). High densities of *Pontogammarus robustoides* are associated with a reduced biomass of the filamentous green alga *Cladophora glomerata* (Arbaciauskas and Gumuliauskaite, 2005).

Most of 32 alien fish species were intentionally introduced between the 1950s and the 1970s (Ojaveer, 2010; AquaNIS, 2015). However, the majority of them have not been able to form self-reproducing populations in the Baltic Sea (e.g. the Siberian sturgeon *Acipenser baeri*, the Russian sturgeon *Acipenser gueldenstaedtii*, the sterlet *Acipenser ruthenus*, the spotted silver carp *Aristichthys nobilis*, the longnose sucker *Catostomus catostomus*, the beluga sturgeon *Huso huso*, the silver carp *Hypophthalmichthys molitrix*, the pink salmon *Oncorhynchus gorbusha*, the chum salmon *Oncorhynchus keta*, and the rainbow trout *Oncorhynchus mykiss*). Three of the intentionally introduced NIS that are able to reproduce in the Baltic Sea are the Chinese sleeper *Perccottus glenii*, which occurs in most diluted low-salinity eastern parts of the Gulf of Finland (Orlova et al., 2006), the Prussian carp *Carassius gibelio*, which now has become common in the Wisła Lagoon (Witkowski and Grabowska, 2012) and along the Estonian coast (Vetemaa, 2006) and *Cyprinus carpio*, common in the Curonian Lagoon (Virbickas, 2000). The most notable unintentional fish introduction is that of the Ponto-Caspian round goby *Neogobius melanostomus*. After the first record in the Gdánsk Bay in 1990 its incursion was reported from several other areas in the Baltic Sea. The secondary spread of this species has been facilitated by shipping because in new localities it was first found mainly in or near port areas. The round goby has impact on native biodiversity and ecosystem functioning. For example, in the Gulf of Gdansk, cormorants (*Phalocrocorax carbo*) have shifted their diet from eel (*Anguilla anguilla*) and sprat (*Sprattus sprattus*) to the round goby, resulting in population increases in eel and sprat. The sprat have reduced zooplankton and this reduced grazing pressure has resulted in an increase in phytoplankton biomass (Corkum et al., 2004). The expanding populations of round gobies in the coastal areas have reduced blue mussel *Mytilus* spp. beds by praying on them.

There are one alien bird species (the Canada goose *Branta canadensis*) and two mammals (the mink *Mustela vison* and the muskrat *Ondatra zibethicus*). All three have spread along the Baltic Sea coasts and are causing negative environmental and economic impacts: by hybridisation with native species (the goose), predation on seabirds and causing loss for fish farms (the mink), and disturbing the structure of the littoral vegetation (the muskrat).

1.2 Important Baltic Sea Blue Growth Components

In the Baltic the marine industries fishing, shipping and shipbuilding have been a feature of the history and livelihood of the coastal areas for hundreds of years. For natural reasons, contact with the sea has been, and still is, concentrated in marine areas close to the coast. It is also in such areas that pressure on the utilisation of marine resources and the threat to the marine environment is most noticeable.

Marine resources are usually grouped according to different ways of utilising the sea. Resources that mainly come to mind are fish, the sea as a means of transportation, recreational use of the sea and seabed resources. The international Convention on the Law of the Sea (United Nations Convention on the Law of the Sea) gives a much more detailed account of ways of utilising the marine resources. The main sectors often discussed are:

- Food production
- Extraction of minerals
- Energy exploitation
- Transport
- Military use
- Use of water areas for effluents
- Tourism/Outdoor recreation
- Marine historical preservation
- Marine nature conservancy
- Building activities
- Research and technical development

Interest in the sea and its resources has grown considerably in recent decades. Future development in the marine sector may be expected to lead to increased utilisation of marine resources in different ways depending on the technology developments. In turn, this is linked to economic and social development in different parts of the region. The marine industry has always been an integrated and well-established part of business community in the countries surrounding the Baltic Sea. The most important Blue Growth industries will shortly be described in the following sections.

1.2.1 Marine Transport

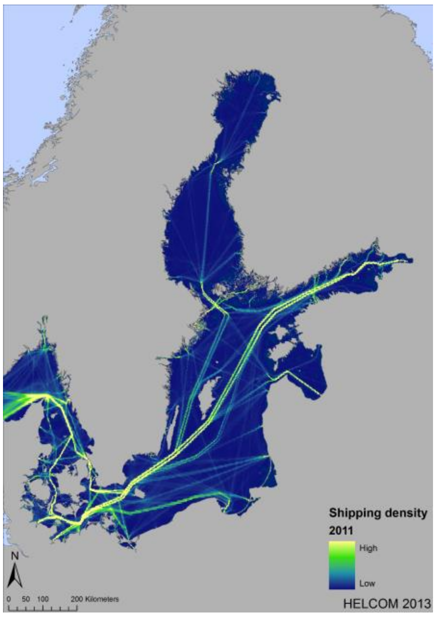
For centuries, marine transport between countries around the Baltic Sea has been important business as well as the transport in and out of the Baltic Sea. As an example, some 80% of the foreign trade of Finland is done by marine transportation. The internal maritime transport is still essential for the exchange of goods and people between the Baltic countries, but the external transport, which has to pass through the narrow and shallow Danish straits, is becoming increasingly important.

Navigation in the Baltic Sea is challenging due to its relative shallowness, narrow navigation routes, and ice cover in wintertime.

Figure 18 Cargo ship in Ice cover waters

The Baltic Sea is today one of the most densely trafficked seas in the world. A detailed picture of the shipping intensity can be obtained via the Automatic Identification System (AIS) required by IMO regulations (International Convention for the Safety of Life at Sea, SOLAS). AIS transponders has to be fitted aboard all ships of 300 tons and upwards engaged on international voyages, cargo ships of 500 tons and upwards not engaged on international voyages, as well as all passenger ships irrespective of size. The AIS enables the identification of the name, position, course, speed, draught and main type of ships, and displays all available data over a common background map.

In the Baltic Sea area AIS registrations are managed by HELCOM. In Figure 19 the intensity of traffic in 2013 is illustrated by the number of ships crossing a number of pre-defined statistical lines (according to the type of vessels).



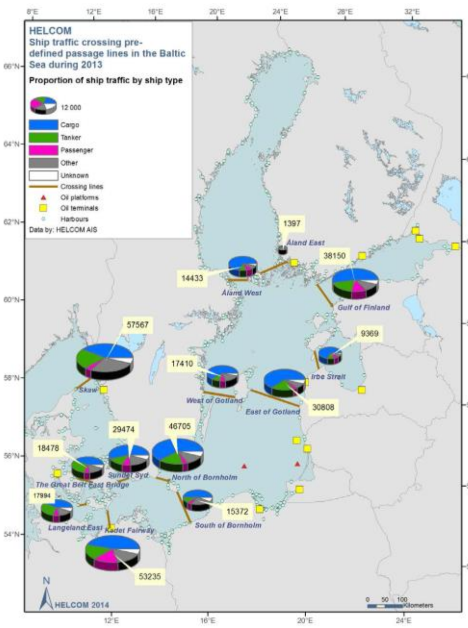


Figure 19. a) Monthly average density of shipping traffic during 2011, with the busiest routes highlighted in yellow. b) Number of ships crossing AIS fixed lines in the Baltic Sea in 2013 according to the type of the vessels, HELCOM 2014.

The HELCOM AIS database opens the possibility to assess annual changes in the ship traffic intensity. Since 2006, HELCOM has been following the trends in vessel traffic crossing the fixed AIS lines which is shown in Figure 20. The overall ship traffic in 2013 decreased compared to the previous year (2012) to roughly 350.000 ship crossings in total. The decrease in 2013 as well as the previous decrease in 2009 and 2010, especially for cargo ships, is likely due to decreased shipping activity resulting from the economic recession (HELCOM, 2014).

Shipping in the Baltic Sea based on AIS data, data on shipping accidents and other relevant data collected under the HELCOM framework has been visualized in a movie to be found on the HELCOM web page (http://helcom.fi/helcom-at-work/press-room/videos/baltic-sea-shipping-visualized*)*

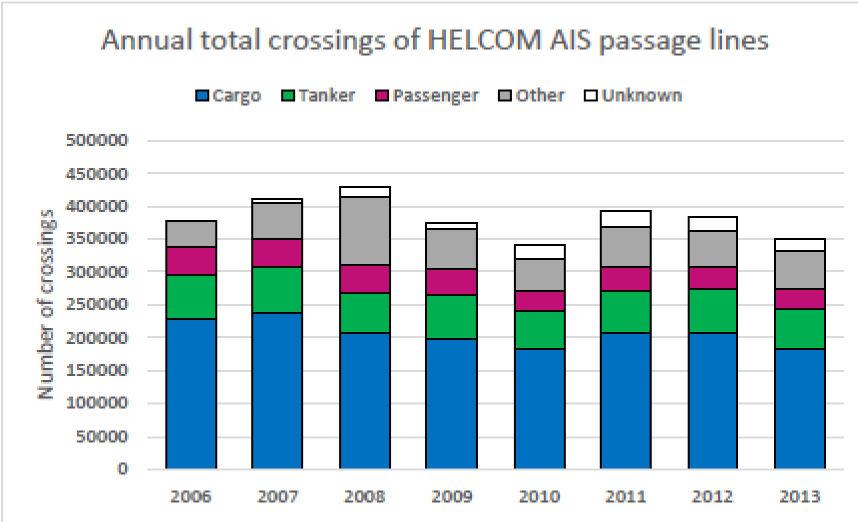


Figure 20 *Number of ships crossing fixed AIS lines in the Baltic Sea during 2006 - 2013, shown here grouped by ship type.*

Looking 10 and 20 years ahead, forecasts predict a huge growth in the sector. The number of ships is expected to double by 2030, (Swedish Environmental Protection Agency, 2008), see Figure 21 and the size of ships is expected to increase substantially as well. Shipping of oil, counted in tonnes, is predicted to grow by 64% by 2030 (Rytkönen et al., 2002. This massive growth in the shipping sector is mainly due to the expansion and construction of oil terminals on the shores of the Gulf of Finland and regional economic growth. In addition, the number of cruise ships in the area is increasing annually with a growing trend for the use of larger ships and more international cruisers.

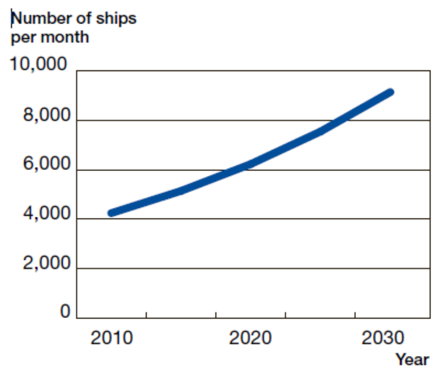


Fig. 21 The increase in number of ships is 2.6% to 5.2% per year until 2030. In the graph the mean value of the increase, 3.9% per year, used when calculating the future growth. (Swedish Environmental Protection Agency, 2008)

The enormous volume of shipping in the Baltic Sea is accompanied by a large risk of accidents. According to HELCOM, there has been an increase in both groundings and collisions during the last years, and the number of accidents is estimated at 150 per year, Figure 22. The number of accidents in the Baltic Sea has shown a slight increase in the last three years and the recorded 150 ship accidents in the Baltic Sea area in 2013, which is the highest recorded number in ten years.

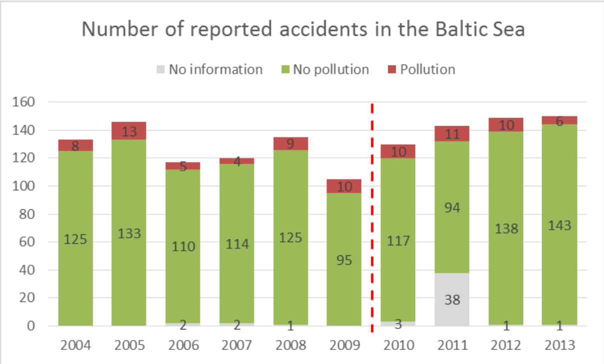


Figure 22. Number of reported ship accidents in the Baltic Sea (The columns right of the vertical dotted red line in this graph include data from the new Danish accident database), (HELCOM, 2014).

The spatial distribution of the reported accidents in 2013 is presented in Figure 23. Most accidents in 2013 occurred close to shore (26% in port and 19% in port approach) and 34% occurred in the open sea However for 21% of the accidents the location of was not specified.

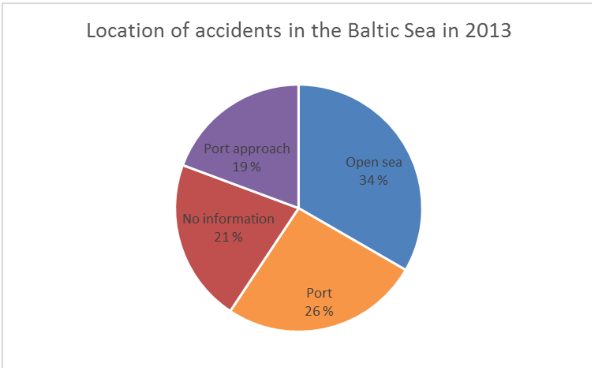


Figure 23 Location of ship accidents in the Baltic Sea in 2013 (HELCOM, 2014).

Many accidents could potentially result in oil spills. A large oil accident in the Baltic Sea would have serious ecological effects. Oil spills can have devastating impacts on vast areas of nature as well as on sectors such as fishing, tourism and recreation. Clean-ups after an oil spill can also cause extensive costs.

1.2.2 Fisheries

Fishing contributes substantially to the economy of the Baltic region and has a central role in the cultural heritage of the Baltic Sea. The main target species in commercial fisheries in the Baltic Sea are cod, herring and sprat. These constitute about 95% of the total catch. The catches of these three main species have shown large variations over time (Figure 24), driven both by fisheries developments and natural factors such as food-web interactions between the predatory (cod) and forage fish (sprat and herring) and environmental and hydrographical conditions influencing stock dynamics of these species. In recent years, sprat and herring dominate the catch biomass in the

Baltic Sea. In the Kattegat, commercially important species include *Nephrops*, cod, flatfishes, herring and sprat.

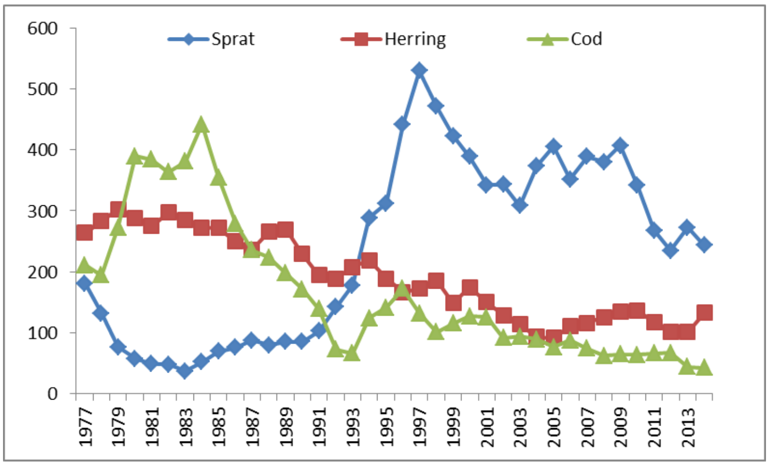


Figure 24 Long term change in landings of the major commercial fish species in the Baltic Sea, i.e. sprat, central Baltic herring and cod (data from ICES, 2015).

The major fisheries in the Baltic Sea can be divided into demersal and pelagic fisheries. Pelagic trawlers catching a mixture of herring and sprat dominate pelagic fisheries. The proportion of the two species in the catches varies according to area and season. To a minor extent, a predominantly herring fishery is carried out with trap-nets/pound-nets and gill nets in coastal areas as well as with bottom trawls. The catches of the pelagic species are used for human consumption, reduction to oil and meal, and to animal fodder. The allocation of the catches into these categories differs not only by country, but also over time. The usage is to a large extent driven by the market conditions. Cod is mainly caught in demersal fisheries using trawls and gill-nets. The demersal fishery in Kattegat is considered to be a mixed fishery catching *Nephrops*, flatfishes (plaice and sole) and cod. Historically, cod has been important species in fish landings from Kattegat, but in later years, cod is only caught as by-catch due to a low stock size. Currently, *Nephrops* has by far been the most economically important species in the demersal fisheries in Kattegat. Industrial fisheries in the Kattegat are targeting mixed clupeids, sandeel and Norway pout. Other target fish species in the Baltic region having local economic importance include salmon, plaice, flounder, dab, brill, turbot, pike-perch, pike, perch, vendace, whitefish, turbot, eel and sea-trout. Many of these species are caught in coastal fisheries with a mixture of gears including fixed gears (e.g. gill, pound and trap nets, and weirs) and Danish seines. Coastal fisheries are conducted along the entire Baltic coastline.

The fishery in Kattegat is almost exclusively Danish and Swedish. In the Baltic Sea, the contribution of different countries to fisheries landings varies by species and stocks. Major part of cod landings in the eastern Baltic Sea are taken by Poland, Sweden and Denmark (Figure 25). The cod in the western Baltic Sea is mainly taken by Denmark and Germany. Herring and sprat fisheries in the central Baltic Sea are dominated by Poland and Sweden, with the other countries taking considerable proportions of either sprat or herring catches as well. The herring catches from sub-populations in large gulfs are generally taken by adjacent countries, i.e. Gulf of Riga herring is caught by Latvia and Estonia and herring catches in Bothnian Bay and Bothnian Sea are taken by Finland

and Sweden. Fishing effort in all major fleet segments in the Baltic Sea has generally substantially declined in recent decade (EU STECF, 2014).

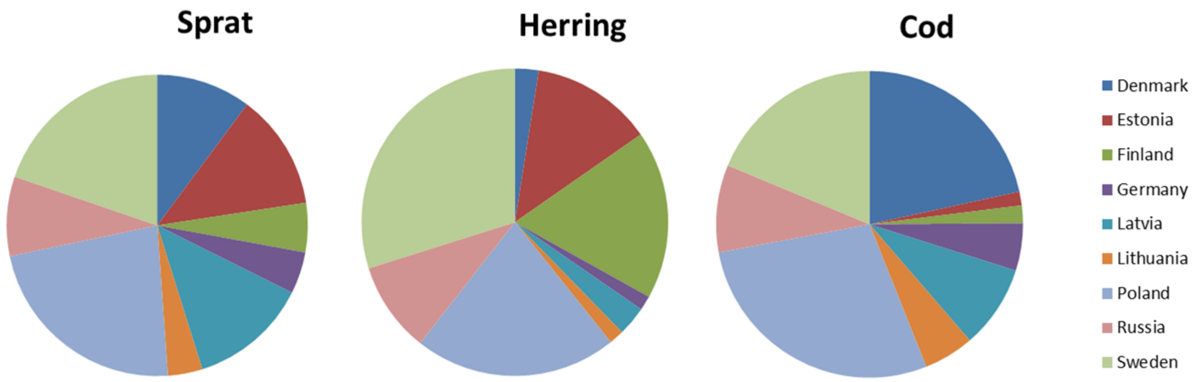


Figure 25. Proportion of different countries in the landings of the three major commercially important fish stocks in the Baltic Sea, i.e. sprat, central Baltic herring and eastern Baltic cod (data from ICES, 2015 based on average for 2010-2014).

Concerning fisheries management, the fisheries for cod, sprat, herring, flatfish and salmon are internationally regulated. The coastal species are subject to national regulations. The major management measure in internationally regulated fisheries is annual total allowable catch (TAC). TACs are set by management areas, which differ by species. Cod is managed in three units, i.e. eastern and western Baltic cod and cod in the Kattegat. Sprat is managed as one unit in the Baltic Sea and the sprat found in Kattegat is managed together with sprat in Skagerrak. Five different units manage herring, i.e. central Baltic Sea, Gulf of Riga, Bothnian Bay, Bothnian Sea and western Baltic herring that includes Kattegat and Skagerrak. Additionally, technical measures such as restrictions for minimum landings size, mesh size of gears, closed areas and seasons and effort regulations are applied. Since 2015, there is a discard ban for cod implemented in the Baltic Sea.

1.2.3 Aqua Culture

Denmark, Finland and Sweden are important countries for marine aquaculture in the Baltic Sea. In the remaining countries in the region, there is extensive freshwater aquaculture but no or very little marine aquaculture.

There is no compiled information about planned future developments of aquaculture in the Baltic Sea. In Estonia, Latvia and Lithuania, the coastline has very few suitable sites for large net cage farms or other types of mariculture. Therefore, development of marine aquaculture in this region is unlikely. Similarly, there are no forecasts indicating a development of marine fish farming in Poland over the next 20 years. In Sweden, the potential to get permission for marine fish aquaculture activities is small due to concerns and worries over the negative impacts fish farming may have on the environment. However, in Denmark and Finland, attitudes to fish farming are more positive which make an expansion of marine aquaculture more likely in these countries. Finland has plans for large off-shore fish farms in the Bothnian Sea. These plans are causing concerns for the newly established national park in the area.

Fish farms release substantial amounts of nutrients to surrounding waters from discarded feed and from fish excrement. The narrow genetic make-up of farmed fish as well as the many diseases and parasites that farmed fish may spread could harm wild fish populations, jeopardizing the sustainability of the fishing industry.

1.2.4 Renewable Baltic Sea Energy

The Baltic Sea joins countries with very different clean energy strategies. There are Denmark and Germany where wind energy is already in the market and future development of offshore capacities is planned. Sweden and Finland use hydropower, but have also started to develop wind energy, mainly onshore, and Finland is relying on nuclear power too. Poland develops onshore wind capacities, but has the potential to become a major offshore wind energy provider as well. Russia, that has limited coastline in the Baltic Sea, has plans to develop wind energy outside the Baltic Sea region. In nearby countries Norway is mainly relying on hydropower to fulfil the National Renewable Energy Action Plan (NREAP). Nordic energy markets work on selling hydropower energy between countries.

As pioneer in the renewable energy production field, wind energy is considered a future strategic resource for more fossil fuel independent economics, a factor for reducing import dependency and a chance for climate change mitigation by carbon emission reduction. Analysis shows that wind energy alone has enough potential to fill the NREAP gap of the Baltic Sea countries (BASREC project). Nevertheless, there are clean alternatives: wave energy and biogas, which could contribute to the national energy mix and could increase the reliability of wind power production as well. The expected use of wind and wave energy is likely to increase in the future as many suitable areas exists (BASREC project, 2012; Heino, 2013), the systems are constantly developed to get more robust and national initiatives exist to expand the electrical grid.

Environmentally friendly, low emission sources for clean energies are supplemented by the conventional alternative of fossil fuels in form of oil and gas and liquefied natural gas (LNG), the newcomer in the field. The potential of LNG, more commonly known as fracking, is developed on land, where offshore installations don't add to the production costs. The situation is different for oil and gas. Resources exist in the southern Baltic Sea, south-east of Gotland, where Poland, Latvia, Lithuania and Russia (Kaliningrad) share the oilfield Kravtsovskoye. Poland operates three platforms: Baltic Beta, Petro Baltic and PG-1, and Russia operates one platform MLSP D-6. Oil leakage has been risen public awareness for the risks of oil exploration in the Baltic (HELCOM, 2010).

Development potential is assessed in three categories: the technical potential (level1), which accesses physical parameter: wind resource and marine meteorology conditions, and does not distinguish between the protective status of individual Baltic Sea areas. The accessible potential (level2), which excludes all environmentally protected areas, and the realistic potential level3, which includes hitherto unconsidered constraints: impacts for marine and benthic (seabed) habitats, bird and marine mammal disturbance, fish migration and recreational areas, sediments and water quality implications. Human activities like shipping and fishing provide constrains for accessible areas that are considered at level1.

1.2.4.1 Wind energy

Offshore wind energy technology is leaving the pioneer stage and is evolving towards larger scale deployments at sites that cover greater depths and a broader range of geographical conditions. Wind energy production is even expected to move into the harsh climate of the northern Baltic Sea. In near future, only resource and cost factors seem to limit the applicability of wind energy. The total capacity of the Baltic Sea has been estimated to be above 180 MW for very high and high productive level1 areas, and is still about 130 MW after removing all sites in protected areas (level2) (BASREC project (2012)).

Figure 26. Offshore windmill

1.2.4.2 Wave energy

Wave energy development is around 20 years behind wind energy. Current trends seem to be focused on improving existing systems in terms of power output and reliability. The power production of a wave point absorber is assumed to be 10kW for waves in the range of 2 m significant wave height, with an expected annual energy production of 25MWh per generator (Heino, 2013). In other words, nine medium size wave parks of 2000 generators have to be installed, to match the 180 MW potential of wind energy.

The accessible potential of wave energy is limited by needs for near coastal areas with long fetches, in already heavily used regions. There are ideas for combining the advantages of wind and wave power generation, at least in the northern Baltic Sea, where sea ice is reducing the season for wave energy harvest. The advantage of wave energy, when compared to wind energy is the lower variability and higher predictability. Wave generators are converting local wind energy in form of wind waves as well as wave energy from long traveling swell, i.e. waves that continue to travel after the wind has changed. A mix of wind and wave energy at considered sites could help to reduce the costs for energy transport and the need for reserve energy.

Offshore installations of wind and wave energy converters have to deal with large installation and operating costs due to limited access to the site and long distances to the shore and to the electrical grid, which add to cable costs. Key barriers to wind and wave energy developments are network availability, transmission costs and processing time. Beside weather and ocean conditions for construction, operation and maintenance cost assessments, it is energy transmission that provides additional cost factors for identified level2 sites.

1.2.4.3 Biogas

Biogas production by fermentation or anaerobic bacterial digestion of organic matter is a well-established technology on land, where it is applied to agricultural by-products, but it has barely entered the test-phase, when it comes to marine environments. Current approaches rely heavily on efficient algae retrieval (harvest) from shores and beaches, and the use of specific energy converters for marine materials. Offshore applications are not planned at the current stage. Projects aim at the recreation of wetlands and the sea areas close to the shore, where riverine waste water inputs, agricultural impacts; i.e. nutrient leakages are high. The development is mainly driven by Southern Baltic communities and municipalities and has reached the stage of feasibility testing and market potential exploration. Successful applications depend on the construction of efficient harvesters, reduction of deployment costs and successful management.

1.2.5 Tourism

For all the riparian countries - except Russia – the coastal areas and the islands of the Baltic Sea have been one of the most important tourism regions since the start of modern tourism. The first sea resorts for medical purposes at the Baltic Sea were opened before 1800, while mass tourism firmly established itself in the 19th and 20th centuries, after the establishment of railway lines and the start of beach holidays. Today the Baltic Sea countries hold a large share of the international tourism. In 2012, the Baltic Sea region accounted for 7% of the world's tourism measured by international arrivals and 13% of the tourism in Europe. That is equivalent to 73 million international arrivals in the Baltic Sea region. In 2012, the total number of overnights was 570 million (DI, 2013). The countries located by the Baltic Sea have generally experienced growth in international arrivals since the 1990s. This follows the global growth trend in the industry with a growth rate of 4% and forecasts predict that the growth in international tourism will continue with an average annual growth of 3.3% until 2030.

Figure 27. Baltic beach.

Moreover, in many Baltic Sea countries, today's seniors are in better health and have a larger disposable income compared to earlier generations. There is a high likelihood that many will choose to retire at an earlier age and/or have a longer period of activity after retirement. As a result, the number of senior tourists is expected to increase substantially, which in turn will create an increased demand for activities, accommodation and transports, including during the low season.

The Baltic Sea has long been a major place for sailing, fishing and other water based sports. Almost all coastal areas and islands offer modern and well-kept marinas and harbours. Large lagoons on the southern coast also offer travelling routes for kayaks and rowing excursions. Recently, there has been a development towards more organised recreational activities. People tend to go fishing on organised trips that include hotel nights, rather than going camping on their own. As this trend increases the need for developed facilities, it will further increase the pressure on coastal ecosystems. The opportunities for sport fishing have been reduced due to the overexploitation of resources by commercial fishery.

There is a general international tendency towards more cultural tourism, which has raised the importance of developing the cultural attractiveness of the destinations. With more than 20 UNESCO World Heritage Sites and many other cultural and natural attractions existing close to the Baltic Sea and on its islands most tourism marketing organisations in the Baltic Sea region are now promoting cultural, wellness and event tourism. Following the trend towards increased city tourism, the cruise industry has experienced a rapid annual growth of 8 % for the last 20 years. This trend has had a positive impact on destinations in Northern Europe, but the Baltic Sea region's popularity as a cruise destination is under pressure. The competition from other growing cruise destinations like Asia and the Pacific foster a continued focus on developing the cruise industry to maintain the market share.

Figure 28. Cruise liner.

Along with the opportunities, follow a number of challenges and possible negative impacts on the environment. Tourism for example has a major environmental impact on coastal areas, which may affect other interests such as nature conservation and fishing. Besides land use, its demand for resources such as water and the need for waste disposal facilities puts pressure on water resources and coastal habitats. However, the pressure caused by the tourism sector is seasonally bound since most of the tourism in the Baltic Sea region takes place during the summer months of June and July. This however is great concern because the future development of Baltic Sea tourism is highly dependent on good environmental quality.

Figure 29. Pleasure boating.

Therefore developing the tourism industry in line with the goals of sustainable tourism has become an area of interest at both national and international level, and the tourism sector has therefore been an important driver for nature conservation in many places, for e.g. in areas where ecotourism takes place. Designing the coasts for touristic purposes, however, has been a source of conflict in many Baltic Sea countries. There is an ongoing debate between tourism interest groups and groups from, for example, the fishing industry, town planning, or the military, on how the coastal areas should be used, (Euroregion Baltic och Östersjön 2004).

1.3 Copernicus

Copernicus, formerly known as Global Monitoring for Environment and Security (GMES), is a European Commissions programme that aims at achieving an autonomous, multi-level operational

Earth observation capacity. Its cost during 1998 to 2020 is estimated to be 8.4 billion euros. European Space Agency has performed much of its design, oversees and co-funds the development of Sentinel satellites (1, 2, 3, 4 and 5) and instruments for MTG and MetOp-SG weather satellites of EUMETSAT.

The objective is to use multi-source data to get timely and quality information, services and knowledge, and to provide autonomous and independent access to information in relation to environment and security on a global level. It will pull together all the information from Copernicus environmental satellites, air and ground stations to provide a comprehensive picture of the "health" of Earth. The geo-spatial information services offered by Copernicus can be grouped into six main interacting themes: land, ocean, emergency response, atmosphere, security and climate change. The first three Copernicus services under the land, ocean and emergency response themes and two additional services addressing the atmosphere and security themes were unveiled at the Copernicus Forum held in Lille in September 2008. These services were intended to into an EU-wide operational phase by 2011 and fully operational by 2014.

Copernicus builds upon three components:

- the space component (observation satellites and associated ground segment with missions observing land, atmospheric and oceanographic parameters) This comprises two types of satellite missions, ESA's five families of dedicated Sentinel (space missions) and missions from other space agencies, called Contributing Missions.
- in-situ measurements (ground-based and airborne data gathering networks providing information on oceans, continental surface and atmosphere)
- services to users.

Copernicus services address six main thematic areas:

- Land Monitoring
- Marine Monitoring
- Atmosphere Monitoring
- Emergency Management
- Security
- Climate Change

The services have reached different degrees of maturity. Some are operational (land monitoring, marine monitoring and emergency management) while others are still in a pre-operational mode (atmosphere monitoring) or in a development phase (climate change monitoring and services for security applications).

1.3.1 Marine Service

The Copernicus marine environment monitoring service provides regular and systematic reference information on the state of the physical oceans and regional seas. The observations and forecasts produced by the service support all marine applications. For instance, the provision of data on currents, winds and sea ice help to improve ship routing services, offshore operations or search and rescue operations, thus contributing to marine safety.

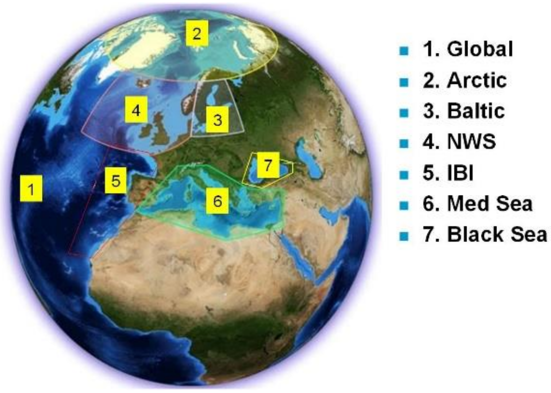


Figure 30.Geographical components of the Copernicus Marine service

The service also contributes to the protection and the sustainable management of living marine resources in particular for aquaculture, fishery research or regional fishery organisations. Physical and marine biogeochemical components are useful for water quality monitoring and pollution control. Sea level rise helps to assess coastal erosion. Sea surface temperature is one of the primary physical impacts of climate change and has direct consequences on marine ecosystems. As a result of this, the service supports a wide range of coastal and marine environment applications.

Many of the data delivered by the service (e.g. temperature, salinity, sea level, currents, wind and sea ice) also play a crucial role in the domain of weather, climate and seasonal forecasting.

In November 2014, the European Commission signed a Delegation Agreement with Mercator Océan for the implementation of the service. The service is delivered in an operational mode since 1st May 2015.

The products delivered by the Copernicus marine environment monitoring service today are provided free of charge to registered users through an Interactive Catalogue available on the marine.copernicus.eu web portal.

Copernicus Marine Service is organised around 5 Thematic Assembly Centres (TAC) for observations: sea level, sea surface temperatures, sea ice, ocean colour and in-situ data; and 7 Monitoring and Forecasting Centres (MFC) - global, Arctic Ocean, Baltic Sea, Atlantic North-western Shelves, Atlantic Irish-Biscay-Iberian Sea, Mediterranean Sea and Black Sea.

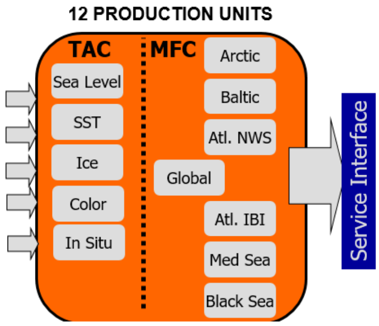


Figure 31 Copernicus Marine Service Production units

1.3.1.1 Baltic MFC

The Baltic Sea component of Copernicus Marine Service (CMEMS) consists mainly the Baltic Monitoring and Forecasting Centre (BAL MFC) which is delivering regular information to describe and forecast and the reanalysis of the physical state and low trophic level ecosystem, and Thematic Assembly Centres (TAC), which deliver near real time satellite, and in-situ observations of physical and biogeochemical parameters. For the Baltic Sea this information has been provided by a group

of Baltic oceanographic institutes, led by DMI, comprising the BAL MFC (Fig. 32). The satellite sea surface temperature and ice parameters are provided by DMI and FMI, sea level by CLS and ocean color by CNR. The Baltic in-situ TAC is led by SMHI.

The current BAL MFC forecasting and reanalysis system has been developed in the past 12 years with support from EC-funded projects MERSEA (2004-2008), MyOcean (2009 – 2012), MyOcean 2 (2012 – 2014) and MyOcean Follow On 2014 – 2015.

Figure 32. Partners of the Baltic Sea Monitoring and Forecasting Centre are Bundesamt für Seeschifffahrt und Hydrographie (BSH), Danish Meteorological Institute (DMI), Finnish Meteorological Institute (FMI), Marine Systems Institute at Tallinn University of Technical (MSI) and Swedish Meteorological and Hydrological Institute (SMHI).

Since 2009, the BAL MFC system has been upgraded and the operational oceanographic products - freely available via the MyOcean (now CMEMS) portal - at least once per year with documented quality improvements each time. Model developers of the BAL MFC group have special focus on both maintaining very high technical standards of the model codes and on improving the model processes describing the physical and biochemical state of the ocean. The forecasting products include two Baltic Sea, 2.5 day long forecast of hourly data, produced twice daily by a coupled ocean-ice-biogeochemical model HBM ERGOM, with a horizontal resolution of 1nm (nautical mile) in the Baltic Sea and 0.5nm in the transition waters. Several reanalysis products, differing in time span, assimilation methods etc. have been provided for the Baltic Sea (Fu *et al.*, 2012). This effort has, for the last couple of years, been led by SMHI. Two new physical and biochemical reanalysis products covering the last 25 and 30 years, respectively, will be released in spring 2015 (Liu *et al.*, 2014).

The focus in the coming years will be the continuation of the development and operationalization of a new sea ice model with improved description of fast ice, particularly important in the Baltic Sea, and data assimilation of sea surface temperature, sea ice, T/S profile and *chl-a* data using ensemble methods and extensive validation of the ecological model. The value-added products will be developed for supporting ecosystem-based management and coastal applications such as the European Union’s Marine Strategy Framework Directive (with indicator-based information products), Integrated Coastal Management and Common Fishery Policy.

Use of observations in BALMFC has been mainly for product quality verification to generate quarterly Quality Information Document (QUID) reports. It is expected that in-situ and satellite observations will be needed in near real time-mode to support the operational data assimilation of SST, sea ice, T/S profiles and *chl-a*.

1.4 EMODnet

The European Marine Observation and Data Network (EMODnet) is a long-term marine data initiative from the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) underpinning its Marine Knowledge 2020 strategy. EMODnet is a consortium of organisations assembling European marine data, data products and metadata from diverse sources in a uniform way. The main purpose of EMODnet is to unlock fragmented and hidden marine data resources and to make these available to individuals and organisations (public and private), and to facilitate investment in sustainable coastal and offshore activities through improved access to quality-assured, standardised and harmonised marine data which are interoperable and free of restrictions on use.

The EMODnet data infrastructure is developed through a stepwise approach in three major phases. Currently EMODnet is in the 2nd phase of development with seven sub-portals in operation that provide access to marine data from the following themes:

1. bathymetry,
2. geology,
3. physics,
4. chemistry,
5. biology,
6. seabed habitats,
7. human activities.

EMODnet development is a dynamic process so new data, products and functionality are added regularly while portals are continuously improved to make the service more fit for purpose and user friendly with the help of users and stakeholders. EMODnet is implemented in three phases:

- Phase I (2009-2013) - developed a prototype (so called ur-EMODnet) with coverage of a limited selection of sea-basins, parameters and data products at low resolution;
- Phase II (2013-2016) - aims to move from a prototype to an operational service with full coverage of all European sea-basins, a wider selection of parameters and medium resolution data products;
- Phase III (2015-2020) - will work towards providing a seamless multi-resolution digital map of the entire seabed of European waters providing highest resolution possible in areas that have been surveyed, including topography, geology, habitats and ecosystems; accompanied by timely information on physical, chemical and biological state of the overlying water column as well as oceanographic forecasts.

1.4.1 EMODnet Checkpoints

EMODnet has initiated an activity – Sea Basin Checkpoints - envisaged to determine gaps in data and observation systems and priorities for an observation system that supports the delivery of sustainable growth and innovation. The overarching aim is to support the deployment of a marine observation infrastructure that offers the most effective support to the blue economy. The cost-effectiveness, reliability and utility of the existing monitoring infrastructure are to be assessed by developing products based on these data and determining whether the products are meeting the needs of industry and public authorities.

EU DG Mare has tendered Sea Basin Checkpoint point projects for the following basins: Atlantic Ocean, Arctic Ocean, Baltic Sea, North Sea, Mediterranean Sea and Black Sea.

1.4.2 Baltic Sea Checkpoint

The Baltic Sea Basin Check Point (BSCP) project is a service contract with the EASME, aiming at providing a fit-for-purpose assessment of existing marine data, especially observations from EMODNET, in the Baltic Sea. The project started in 17 June 2015 and will end in 16 June 2018. Danish Meteorological Institute is the coordinator of the project.

1.4.2.1 Project overview

The project will review the existing assessment and usage of the marine data in eleven challenge areas in terms of data availability, accessibility and adequacy. It will demonstrate integrated usage of marine observations and model data and assess the adequacy of the marine data in the Baltic Sea. Such a practice is the first step to build a sustainable platform for evolving European marine data strategy and usage through an instrument – basin checkpoint.

The BSCP project will investigate the state-of-the-art on the usage of marine data in 11 challenge areas (Figure 33) for the Baltic Sea based on a literature interview. Further systematic demonstration of using marine data to fit the purpose in each challenge area will then be demonstrated. Based on the literature review and project research on fit-for-purpose demonstrations, a more comprehensive evaluation of Baltic marine data adequacy will be given, and the output of the project will be shown in a WMS based web portal.

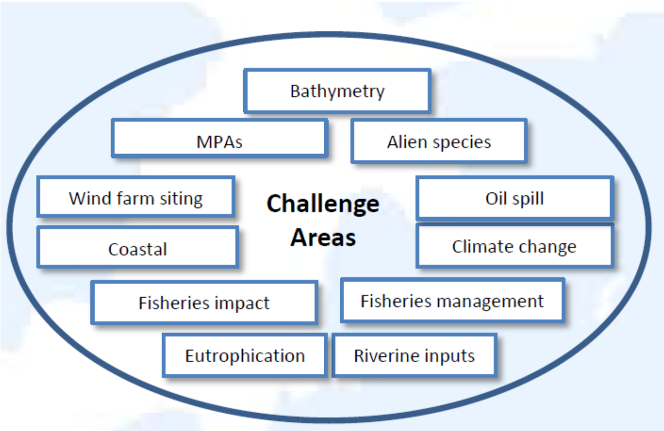


Figure 33 Illustration of the 11 challenge areas in BSCP project

1.4.2.2 Challenge areas

Challenge 1 - Wind farm siting: The objective in this challenge area is to apply existing Baltic Sea monitoring data and identify their adequacy for determining the suitability of sites for development of offshore wind farms, including aspects of wind strength, wave-ice-current conditions, seafloor geology, environmental impact, distance from grid, shipping lanes etc. The sites to be analysed are located in areas of 1). Southeast-middle Baltic Sea where waters of Estonia, Latvia, Lithuania, Poland and Sweden meet; 2) Gulf of Finland where waters of Finland, Estonia and Russia meet and 3) Southwest Baltic Sea where waters of Denmark, Germany and Poland meet. To reach the objectives, following tasks will be carried out:

- wind-strength feasibility check
- met-ocean condition feasibility check
- environmental feasibility check
- human activity feasibility check
- location feasibility check
- extreme condition analysis

Challenge 2 - Marine Protected Areas: The objective in this challenge area is to analyse the existing network of the Baltic Sea Marine Protected Areas (MPA's) in respect to:

- categories of MPA's according to the IUCN classification;
- representativeness and coherence of the network according to Article 13 in the Marine Strategy Framework Directive and
- effects of climate change on the network.

To reach the objectives, following tasks will be carried out:

- classification of MPA's according to IUCN categories for management of protected areas
- assessment layout will be designed and spatial protection measures set by the MSFD programmes of measures will be analysed
- analysis of climate change effects on the MPA network

Challenge 3 - Oil platform leak: The objective is to check the preparedness of operational tools and existing Baltic Sea monitoring data for forecasting oil spill dispersion and estimating the likelihood that sensitive coastal habitats or species or tourist beaches will be affected. SMHI Seatrack Web and DMI operational oil drift model will be used to demonstrate the operational oil drift forecast and on-call service, and to show how a variety of marine data can be used in this forecast and service.

Challenge 4 - Climate change: The objective is to apply existing Baltic Sea monitoring data and identify their adequacy for establishing time series of relevant climate variables. To reach the objectives, following activities will be carried out:

- identify change in average temperature on a grid over past 10/50/100 years
- establish time series of annual temperature at sea surface and bottom
- establish time-series of average annual internal energy of sea (thermal and kinetic energy)
- establish average extent of ice coverage over past 5/10/50/100 yrs., plotted on maps
- estimate total ice cover in sea over past 100 years plotted as time series
- establish phytoplankton abundance time series

Challenge 5 - Coastal protection: The objective is to examine and apply existing Baltic Sea coastal monitoring data and identify the data adequacy for establishing time series of long-term sea level variation and sediment balance per Baltic Sea coastal stretch. To reach the objectives, following activities will be carried out:

- establish long-term sea level change time series in Baltic coast, including both relative change and absolute change
- estimate sediment balance in Baltic Sea coastal stretch based on model and observations

Challenge 6 - Fisheries management: The objective is to apply existing Baltic Sea monitoring data and identify their adequacy for establishing time series of whole sea-basin of i) Mass and number of landings of fish by species and year and ii) Mass and number of discards and bycatch (of fish, mammals, and seabirds) by species and year. To construct a fishery dataset for assessing the quality, extracting the synergies, and identifying the gaps in current datasets in terms of landings, discards and by-catch, data from a variety of sources will be collated, such as ICES databases and expert group reports, possibly supplemented by STECF databases and HELCOM database etc. A quality flag will be attached to the different data sets with respect to time periods and species.

Challenge 7 - Environmental impact of fisheries: The objective is to apply existing Baltic Sea monitoring data and identify their adequacy for establishing time series data and GIS based data layers (gridded) to estimate the extent of fisheries impact on the sea floor, estimated by:

- area where bottom habitat has been disturbed by bottom trawling (number of disturbances per month);
- change in level of disturbance over the past ten years
- damage to the sea floor to both living and non-living components.

Data availability and accessibility of fishing pressure and sea floor components (biological and non-living) at the required spatial and temporal scale will be evaluated using new research results as benchmark (e.g. BENTHIS).

Challenge 8 - Eutrophication assessment: The objectives are to:

- create a digital dataset of seasonal averages and trend of eutrophication in the Baltic Sea for the past ten years;
- assess whether the resolution, availability and consistency of the available data are sufficient for assessment of eutrophication status with certain confidence; and
- evaluate the existing Baltic Sea biogeochemical monitoring network in regard of eutrophication assessment.

To reach the objectives, following tasks will be carried out:

- eutrophication Assessment using HELCOM HEAT3.0
- DIVA analysis of eutrophication indicators in the Baltic Sea
- reanalysis of eutrophication indicators in the Baltic Sea

Challenge 9 - River Inputs Baltic Sea: The objective in this challenge area is to map the extent and quality of publicly available data sources for discharge (Q), nutrient load (TN and TP), sediment and salmon for rivers with discharge to the Baltic Sea, and make this data available in a data service for the blue economy. The objectives are broken down to following tasks:

- map the extent and quality of data sources for river inputs (discharge, sediment, nutrients and fish) to the Baltic Sea
- identify gaps in the currently available data
- explore various methods to fill these gaps including both alternative observation data sources and the use of existing simulated data to interpolate and extrapolate available data in both time and space

<u>Challenge 10 - Bathymetry</u>: The objectives are to investigate and explore existing available sources of bathymetry for the Baltic Sea. Data concerned should be “open data” to high degree i.e. free of charge and with no or limited restrictions. The objectives are broken down to following tasks:

- present bathymetry data in a number of digital maps and will also be available as view services (WMS) through the project portal.
- show maps with various underlying quality and uncertainty will be produced
- investigate the prioritised waterways for commercial shipping and some information on status concerning bathymetry surveys for these areas will be presented

<u>Challenge 11 - Alien species</u>: The objective is to analyse and summarize existing observation data on building up Baltic Sea alien species database and assess their ecosystem and economy impacts. The task includes:

- collate and verify information on the Baltic Sea alien species taxonomy and their introduction history
- compile and analyse data on alien species impacts on ecosystem and economy
- produce a digital map of alien species distribution in the Baltic Sea area
- identify knowledge gaps in relation to alien species and identify most suitable indicators to determine their impacts on marine ecosystem and economy
- review new technologies allowing early detection and more accurate identification of alien species.

2. Major Baltic Sea Monitoring Programmes

There is a long tradition for ocean observations in the Baltic Sea performed via national monitoring programmes and research projects. This means that long time series of selected parameters at predefined positions are available.

In this chapter the most important monitoring programmes and related databases will be shortly described.

2.1 International conventions

2.1.1 HELCOM

HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission) is the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area, known as the Helsinki Convention. The Contracting Parties are Denmark, Estonia, the European Union, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden.

HELCOM was established about four decades ago to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental cooperation. Its permanent secretariat was established to Helsinki, Finland in 1979.

HELCOM's vision for the future is a healthy Baltic Sea environment with diverse biological components functioning in balance, resulting in a good ecological status and supporting a wide range of sustainable economic and social activities.
HELCOM is:

- an **environmental policy maker** for the Baltic Sea area by developing common environmental objectives and actions;
- an **environmental focal point** providing information about the state of and trends in the marine environment, the efficiency of measures to protect it and common initiatives and positions, which can form the basis for decision-making in other international for a;
- a **body for developing**, according to the specific needs of the Baltic Sea, **recommendations** of its own and recommendations supplementary to measures imposed by other international organisations;
- a **supervisory body** dedicated to ensuring that HELCOM environmental standards are fully implemented by all parties throughout the Baltic Sea and its catchment area;
- a **coordinating body**, ascertaining multilateral response in case of major maritime incidents.

HELCOM operate eight main groups to implement policies and strategies and propose issues for discussion at the meetings of the Heads of Delegations, where decisions are made.
The five permanent groups address different aspects of HELCOM's work:

- Group on the Implementation of the Ecosystem Approach (Gear);
- Maritime Working Group (Maritime);
- Working Group on Reduction of Pressures from the Baltic Sea Catchment Area (Pressure);

- Response Working Group (Response);
- Working Group on the State of the Environment and Nature Conservation (State and Conservation);

The following time-limited groups complement the work of the permanent groups:
- Group on Sustainable Agricultural Practices (Agri);
- Group on Ecosystem-based Sustainable Fisheries (Fish);
- Joint HELCOM-VASAB Maritime Spatial Planning Working Group (HELCOM-VASAB MSP WG);

Additionally a number of Expert groups are established:
- AIS EWG - Expert Working Group for Mutual Exchange and Deliveries of AIS data;
- EWG OWR - Expert Working Group on Oiled Wildlife Response ;
- EWG SHORE - Expert Working Group on Response on the Shore;
- HELCOM/OSPAR TG BALLAST - Joint HELCOM/OSPAR Task Group on Ballast Management Convention Exemptions;
- IWGAS - Informal Working Group on Aerial Surveillance;
- MORS EG - Expert group on monitoring of radioactive substances in the Baltic Sea;
- PRF Cooperation Platform - Cooperation Platform on Port Reception Facilities in the Baltic Sea;
- SAFE NAV - Group of Experts on Safety of Navigation;
- SEAL - Ad hoc Seal Expert Group;
- SUBMERGED - Expert Group on Environmental Risks of Hazardous Submerged Objects;

More details on the HELCOM groups and Expert Groups can be found at http://helcom.fi/

2.1.1.1 Monitoring

Monitoring is a well-established function of the Helsinki Convention (HELCOM, 2014). Monitoring of physical, chemical and biological variables of the open sea started in 1979, monitoring of radioactive substances in the Baltic Sea started in 1984. Until 1992, monitoring of coastal waters was considered as a national obligation and only assessment of such data had to be reported to the Commission. However, under the revised Helsinki Convention in 1992, it is also an obligation to conduct monitoring of the coastal waters and to report the data to the Commission. This programme will also cater for the needs of monitoring in the Baltic Sea Protected Areas (BSPA). The Environment Committee of HELCOM decided that, for management reasons, the different programmes should be integrated into a common structure and thus the Cooperative Monitoring in the Baltic Marine Environment - COMBINE - was instituted in 1992. Prior to this date, the programme was referred to as the Baltic Monitoring Programme (BMP). The prefix BMP is still widely used as an identifier of BMP station names.

The aims of COMBINE are to:
- identify and quantify the effects of anthropogenic discharges/activities in the Baltic Sea, in the context of the natural variations in the system;
- identify and quantify the changes in the environment as a result of regulatory actions.

This general statement, which is equally valid for monitoring of inputs as well as monitoring of environmental conditions, is then converted into more specific aims for the different types of monitoring. More specifically the aims of COMBINE mean:

For the open sea and coastal area monitoring:

- hydrographical variations: to set the background for all other measurements related to the identification and quantification of the effects of anthropogenic discharges/activities, the parameters providing an indication of natural fluctuations in the hydrographical regime of the Baltic Sea must be monitored on a continuous basis.

Problems related to eutrophication:

- to determine the extent and the effects of anthropogenic inputs of nutrients on marine biota, the following variables must be measured:
    a) concentrations of nutrients,
    b) the response of the different biological compartments,
    c) integration and evaluation of results

For contaminants to:

- compare the level of contaminants in selected species of biota (including different parts of their tissues) from different geographical regions of the Baltic Sea in order to detect possible contamination patterns, including areas of special concern (or ´hot spots´);
- measure levels of contaminants in selected species of biota at specific locations over time in order to detect whether levels are changing in response to the changes in inputs of contaminants to the Baltic Sea;
- measure levels of contaminants in selected species of biota at different locations within the Baltic Sea, particularly in areas of special concern, in order to assess whether the levels pose a threat to these species and/or to higher trophic levels, including marine mammals and seabirds.

For the effects of contaminants to:

- carry out biological effects measurements at selected locations in the Baltic Sea, particularly at sites of special concern, in order to assess whether the levels of contaminants in sea water and/or suspended particulate matter and/or sediments and/or in the organisms themselves are causing detrimental effects on biota (e.g., changes in community structure)."

In more explicit terms this requires several types of investigations.

For the study of eutrophication and its effects:

- long-term trend studies,
- studies with the budget approach (i.e. budgets or "mass balances" for main nutrients),
- studies of effects on biota,
- studies providing 'online' information on sudden events,
- studies giving background information including baseline studies and joint studies.

For the study of contaminants and their effects:

- studies of temporal trends of contaminants,
- studies of spatial variations in contaminant concentrations and patterns,
- studies providing information on episodic events,
- studies of effects on biota as well as risk evaluations for target species,
- studies of environmental fate of contaminants

2.1.1.2 HELCOM-MORE Project

The main objective of the HELCOM MORE project (revision of HELCOM monitoring programs 2012-2013) was to revise HELCOM's coordinated Monitoring. The first main outcome of this process will be the revised HELCOM Monitoring and Assessment Strategy1 accompanied by an overview of current monitoring of the Baltic Sea marine environment. (http://helcom.fi/Documents/HELCOM%20at%20work/Projects/Completed%20projects/MORE/OverviewMarineMonitoring2013_V3.1.pdf)

Biological monitoring

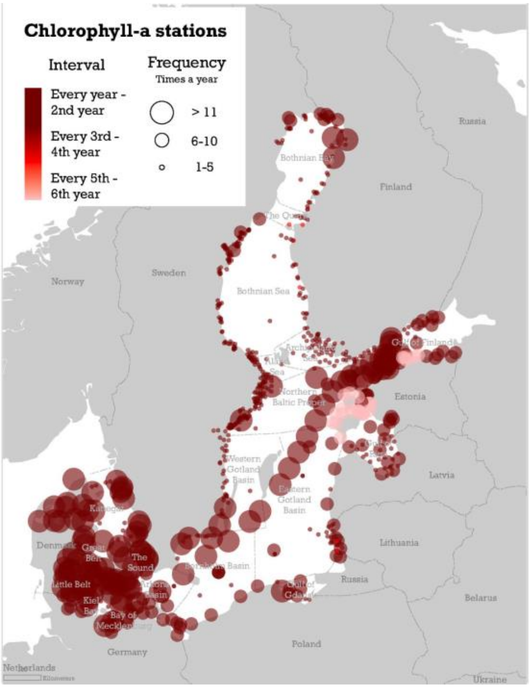
HELCOM Countries have reported the following biological parameters:

- chlorophyll a
- phytoplankton
- zooplankton
- phytobenthos
- primary production
- sea birds
- mammals (found at sea)
- mammals (found dead)
- coastal fish

Table 1. Number of reported biological stations in 2007 and 2013

Parameter	2013	2007	Change	%
Chlorophyll-a	755	440	315	72
Phytobenthos	826	162	664	410
Phytoplankton	257	246	11	4
Zooplankton	141	100	41	41
Zoobenthos	1489	341	1148	337
Primary production	27	19	8	42
Coastal fish	78	n/a	n/a	n/a

In 2007, there were 162 reported coastal stations in total for macrophytobenthos, including 81 high-frequency (monitored once a year, every year) monitoring stations. Regarding macrozoobenthos, there were 341 stations, including 237 high-frequency (once a year, every year) stations. There has been a significant increase in the reported stations in especially two parameters: phytobenthos and zoobenthos. In phytobenthos, there are at present (2015) 664 reported stations more than in 2007 (410%) whereas in zoobenthos there are 1148 stations more (337%). This increase may be due to the fact that some countries, like Denmark, previously reported only a part of the national monitoring at that time.



In general, the number of offshore stations for all relevant parameters is smaller than that of the coastal stations. Whether this kind of a coast-to-off-shore distribution of the monitoring stations is representative and corresponds e.g. with the natural variability of the two environments and management needs should be further discussed when adequacy of monitoring will be analyzed. Some coastal areas also seem to be underrepresented for some parameters like, for example, in phytobenthos. In this parameter, offshore banks are also under-represented.

An example is given for chl-a. Figure 34 shows the frequency of *chl*-a measurements in the Baltic Sea. Details about other parameters can be found in the HELCOM-MORE report.

Figure 34 Sampling frequency distribution of HELCOM chl-a observations

Hydrography monitoring in HELCOM

HELCOM Countries have reported the following hydrographical parameters:

- temperature
- salinity
- secchi depth
- dissolved oxygen
- currents
- hydrogen Sulphide (H_2S)
- pH
- alkalinity

These parameters are essential to determine characteristics of marine environment (e.g. MSFD, WFD) and serve as the background information for other parameters/indicators. Secchi depth is an indicator itself but oxygen indicator requires also information from temperature and salinity *(NOTE: There is no information about frequency or interval of the Russian stations).*

All indicators, except currents, have increased the number of reported monitoring stations. The monitoring of currents has remained the same as in the reporting of 2007. In the rest of parameters there is an increase between 21% of hydrogen sulfide (H2S) and 28% of temperature. In the H2S parameter there are probably more stations since Denmark reports that H2S is monitored “if O2-conc. is about 0 and sample smells”. Both pH and alkalinity where not included in the 2007 overview.

Table 2. Number of reported hydrological stations

Hydrographical	2013	2007	Change	%
Temperature	834	654	180	28
Salinity	797	647	150	23
Secchi depth	702	565	137	24
Currents	20	20	0	0
O_2	792	634	158	25
H_2S	159	131	28	21
Ph	409	n/a	n/a	n/a
Alkalinity	18	n/a	n/a	n/a

Some indicators are mostly well represented geographically, like salinity, temperature, Secchi depth and oxygen though there are some geographical gaps in them south of Gotland and possibly some areas in the Bothnian Sea. Other indicators are very little represented like currents and alkalinity. H2S lack coastal stations in most areas.

An example in Figure 35 shows the frequency of salinity measurements in the Baltic Sea. Details about other parameters can be found in the HELCOM-MORE report

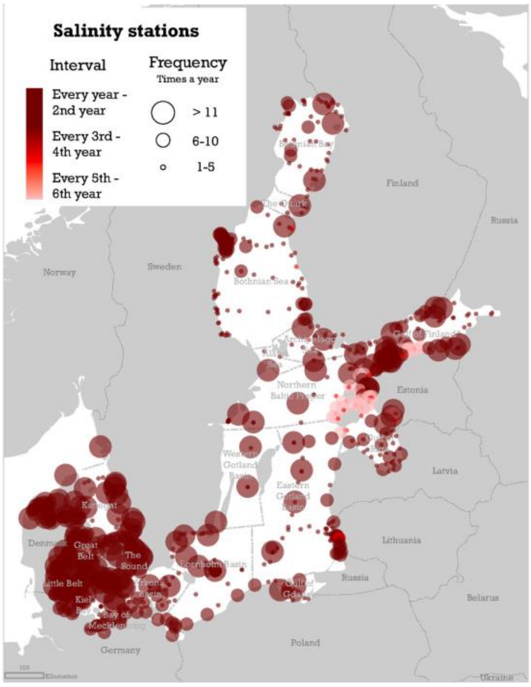


Figure 35. Sampling frequency distribution of HELCOM salinity observations

Nutrient

HELCOM countries have reported the following nutrients parameters:

- phosphate phosphorus (PO_4)
- total Phosphorus (P_{tot})
- silicate (SiO4)
- nitrate and nitrite nitrogen (NO_3+NO_2)
- nitrite nitrogen (NO_2)
- ammonium nitrogen (NH_4)
- total nitrogen (N_{tot})
- particulate organic carbon (POC)
- dissolved organic carbon (DOC)

- humic substances

NOTE: There is no information about frequency or interval of the Russian stations.

Maps in the report show the location of each reported station, the interval between samples (every year, every second year…) and the frequency (how often the monitoring is being done within a year). The interval is represented by color from darker red showing every year to a lighter red for five to six years.

As an example, Figure 36 shows the frequency of PO4 measurements in the Baltic Sea. Details about other nutrient parameters can be found in the HELCOM-MORE report.

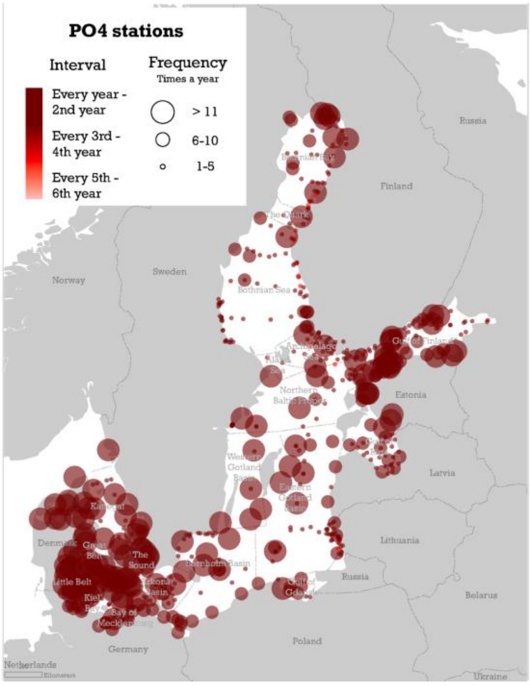


Figure 36. Sampling frequency distribution of HELCOM PO4 observations

Reported stations - comparison with the 2007 monitoring overview

Table 3. Number of reported nutrient stations

Nutrients	2013	2007	Change	%
PO_4	571	475	96	20
DOP	55	n/a	n/a	n/a
Total phosphorus (TP)	549	500	49	10
Silicate (SiO_4)	501	454	47	10
NO_3+NO_2	541	460	81	18
Nitrite nitrogen (NO_2)	307	275	32	12
NH4	281	439	-158	-36
Total nitrogen (N_{tot})	548	501	47	9
POC	12	7	5	71
DOC	32	12	20	167
Humic substances	4	12	-8	-67

The number of reported monitoring stations has increased for all indicators except ammonium nitrogen (NH_4) and humic substances. In absolute terms, the greatest increase in reported monitoring stations has been phosphate phosphorus (PO_4) with 96 reported stations more and nitrate and nitrite nitrogen (NO_3+NO_2) with 81. Ammonium nitrogen (NH_4) presents the greatest decrease in absolute terms with 158 reported stations less. There are only eight stations less for humic substances measurements compared with the 2007 overview.

In relative terms, the greatest increase in reported monitoring stations from 2007 is presented by dissolved organic carbon (DOC) with 167% (increase from 12 to 32 reported stations). Dissolved organic phosphorus was not reported to be monitored in the 2007 overview.

Hazardous Substances

Most of the hazardous substances proposed for the HELCOM core set of indicators have also been documented in the CORESET interim report (BSEP 129 A3):
http://www.helcom.fi/stc/files/Publications/Proceedings/bsep129A.pdf

- PBDE (Polybrominated diphenyl ethers)
- HBCD (Hexabromocyclododecane)
- PCBs (Polychlorinated biphenyls), dioxins and furans
- TBT (Tributyltin)
- PFOS (Perfluorooctane sulphonate)
- PAHs (Polyaromatic hydrocarbons)
- Cadmium (Cd), lead (Pb) and mercury (Hg) in fish and shellfish
- Cesium-137 (Cs_{137})

The following substances are included in HELCOM COMBINE, but not proposed as core indicators:

- DDT and its degradation products
- copper, zinc, nickel
- hexachlorocyclohexanes (e.g. lindane)
- hexachlorobenzene (HCB)
- alpha- and gamma-hexachlorocyclohaxane (HCH)
- pesticides (atrazine, simazine), organotin compounds
- P-nonylphenols (+ethoxylates), phthalates (DEHP), Linear Alkyl Sulphonates (LAS) (detergents), PAH, certain metals (Be, Li, Ag, Sb, Tl) and organotin compounds
- tributyltin, Cu-compounds, irgarol
- Tris(4-chlorophenyl)methanol and tris(4-chloro-phenyl)methane, planar CBs, toxaphene

NOTE: Russia has not reported any data for this parameter.

In HELCOM-MORE report, the distribution of all these hazardous substances are displayed for each sub-basin, reported being monitored and how often (every year, every second year…). The information is presented in maps and tables. The maps present the number of stations per sub-basin. All maps use the same classification and colors to help compare areas.

In general, there is a lack of reported stations in the central part of the Baltic Sea (Åland Sea, Northern Baltic Proper, Archipelago Sea and the Gulf of Finland). The northern and southern parts of the Baltic Sea are better covered but each parameter should be analyzed separately. The parameters with best geographical coverage are probably radionuclide Cs137, metals and PCBs. On the other hand, TBT and PAHs have few reported stations compared to the rest.

The monitoring is carried out regularly in most stations and most parameters are reported being monitored annually in most sub-basins, except PCBs. In some sub–basins, the monitoring of this substance is carried out only every third or fifth year. Some stations are monitored, however, on a project basis, for example those for PBDEs, HBCD and PFOS.

The HELCOM CORESET expert group for hazardous substances concluded that the monitoring of temporal changes in the Baltic Sea area is rather adequate for most of the core indicator parameters. There are gaps for HBCD, PAHs and PFOS in the eastern parts of the sea area. All the proposed core indicator parameters are selected on the basis of their relevance to policy frameworks (HELCOM, EU, global), PBT-properties (persistence, bioaccumulation, toxicity) and known levels in the Baltic marine environment.

Marine Litter

The GEAR 2/2012 meeting held in Gothenburg in October 2012 requested the MORE project to prepare a short questionnaire about marine litter. The main purpose is to have an overview of the present situation of the monitoring by the Contracting Parties. All countries except Russia have responded to this questionnaire.

The questions sent were:

1. Is there any marine litter monitoring **activity** or are there **plans** to monitor your country? Please mention also project activities.
2. Where is or will the litter monitoring, take place e.g., which sub-basins, coastal or offshore areas?
3. Which fractions of litter, i.e., macro and/or micro litter, is or will the monitoring address?
4. Are the impacts of litter on the ecosystem being considered?
5. Are there reports or studies available in the Baltic, please provide links or references?
6. To which extent are the standards and tools from the MSFD TG Litter are being implemented in your country?

At the moment there is no country carrying out any national monitoring for marine litter. There were, however, several projects like GES-REG, MARLIN and MARLISCO to do some pilot studies in regard of the microlitter in the water column and its potential impact to the zooplankton, and about the macrolitter in the beaches. Some countries are already preparing for the implementation of the directive. There are NGO activities in Lithuania, Estonia and Sweden. Lithuania, Poland and Sweden have already published some reports about marine litter. In Estonia, reports on beach litter are available.No country has yet implemented the TG litter standard. Germany follows the OSPAR guidelines according to MSFD TG and Finland and Estonia follow the UNEP recommendations when monitoring the beach litter.

2.1.1.3 Data

ICES has currently a contract with HELCOM for managing all "at sea" observations collected as part of the HELCOM's COMBINE programme (http://ocean.ices.dk/Helcom). The following map (Figure 37) (http://ocean.ices.dk/Helcom/Helcom.aspx?MinData=1000&DataType=1&Mode=2) shows the HELCOM stations with the selected minimum number of measurements (1000) listed in the ICES station dictionary. Data are available to download by station or as a complete dataset, read the ICES data policy for conditions.

The complete dataset and station datasets are available in comma separated format (.csv) and zipped with WinZip, which can be downloaded at Helcom.zip (1900-2015).

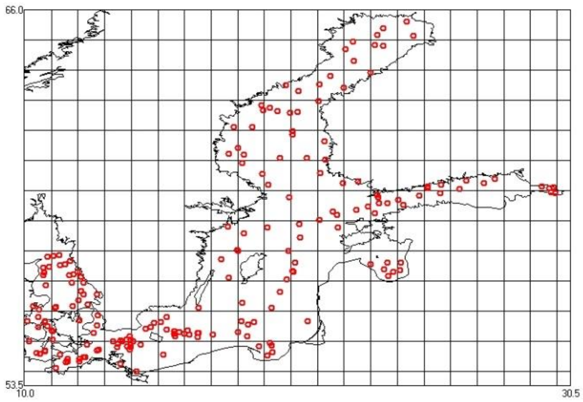


Figure 37 HELCOM stations with min. 1000 observations

2.1.2 International Commission for Exploration of the Sea (ICES)

ICES is an intergovernmental organization whose main objective is to increase the scientific knowledge of the marine environment and its living resources and to use this knowledge to provide unbiased, non-political advice to competent authorities.

ICES science and advice considers both how human activities affect marine ecosystems and how ecosystems affect human activities. In this way, ICES ensures that best available science is accessible for decision-makers to make informed choices on the sustainable use of the marine environment and ecosystems. To achieve this objective ICES prioritizes, organizes, delivers, and disseminates research needed to fill gaps in marine knowledge related to ecological, political, societal, and economic issues.

ICES delivers scientific publications, information and management advice requested by member countries and international organizations and commissions such as the Oslo Paris Commission (OSPAR), the Helsinki Commission - Baltic Marine Environment Protection Commission (HELCOM), the North East Atlantic Fisheries Commission (NEAFC), the North Atlantic Salmon Conservation Organization (NASCO), and the European Commission (EC)

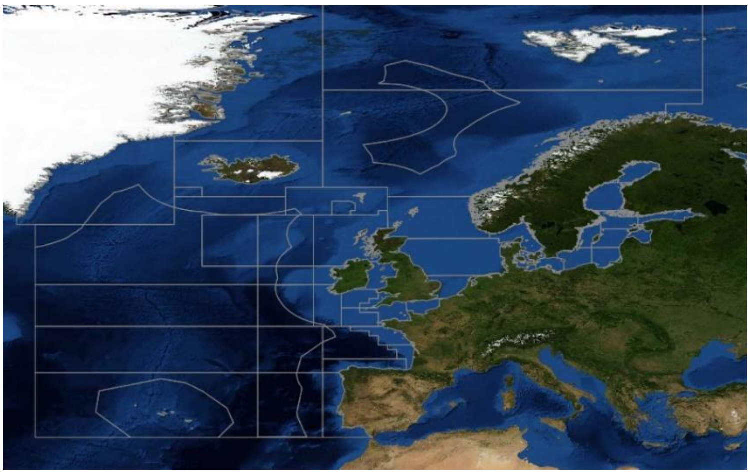


Figure 38 ICES Area Map

2.1.2.1 Expert Groups

ICES has almost 150 expert groups and workshops that address the many diverse issues of the marine ecosystem. The core of ICES work is accomplished through these expert groups and workshops, which tackle a broad spectrum of marine science topics such as:

- ocean dynamics – from hydrology to operational oceanography;
- climate variability and change – including the individual, population and ecosystem responses to change;
- ecology and Ecosystem function– from phytoplankton to mammals;
- survey and Sampling – from bottom trawls to video surveys and new sampling technologies;
- integrated assessment and modelling – linking physics and ecology across regional seas;
- fishery, aquaculture and environmental science – from multispecies assessments to contaminants and their effects, from genetics and their application in management to the sustainability of mariculture.

Expert group members work throughout the year and normally meet with their respective groups annually or bi-annually to work through assigned tasks – Terms of Reference (ToRs). Expert group and workshop participants are nominated by national delegates, or invited by the Chair. Workshops are also open to stakeholder participation.

2.1.2.2 ICES Data Centre

ICES has a well-established Data Centre, which manages a number of large dataset collections related to the marine environment. The majority of data – covering the Northeast Atlantic, Baltic Sea, Greenland Sea, and Norwegian Sea – originate from national institutes that are part of the ICES network.

The ICES Data Centre provides marine data services to ICES member countries, expert groups, world data centers, regional seas conventions (HELCOM and OSPAR), the European Environment Agency (EEA), Eurostat, and various other European projects and biodiversity portals.

Dataset collections are organized around specific thematic data portals as well as an overarching data warehouse. The current dataset portals provided by ICES are:

- biological community;
- contaminants and biological effects;
- eggs and larvae;
- fish predation (stomach contents);
- fish trawl survey;
- historical plankton;
- ocean physics and chemistry.

2.1.2.3 ICES data policy

ICES renewed its data policy in May 2006, and updated it in November 2012. By maximizing the availability of data to the community at large, ICES promotes the use of these data, thereby ensuring that their maximum value can be realized and thus contribute to an increased understanding of the marine environment.

Key points in the policy:

- states the conditions for data use, data contribution and data redistribution.
- is intended to facilitate the production of science based advice and status reports, and serve the scientific community.
- applies to data managed by ICES, and to ICES activities for providing access to data managed elsewhere.
- excludes the commercial catch data from the Regional Fisheries Database (RDB-FishFrame) and InterCatch, which have independent data policies.

Full data policy can be found at:
http://www.ices.dk/marine-data/Documents/ICES_Data_Policy_2012.pdf

2.2 European and Nordic programs and projects

The European and Nordic programs normally support the integration of the observation systems and data management.

2.2.1 EuroGOOS and BOOS

EuroGOOS is an International Non-Profit Association of national governmental agencies and research organisations, committed to European-scale operational oceanography within the context of the intergovernmental Global Ocean Observing System (GOOS).

It was founded in 1994 and has today 40 members from 19 European countries providing operational oceanographic services and carrying out marine research. Since February 2013, EuroGOOS is established as an international non-profit organisation in Belgium (EuroGOOS AISBL). EuroGOOS aims to work in the collective interest of its members to improve the quality and cost effectiveness in the production of operational oceanographic services at national, regional and global levels.

EuroGOOS works to:

- **Identify European priorities for operational oceanography** focusing on defining research priorities and relate to key European initiatives, while linking to the research community, industry, users and EU policies.
- **Promotion of operational oceanography** through publications, conferences, web presence and increased engagement with key actors in the efforts to speak with one voice.
- **Foster Cooperation** through close cooperation at global, European and regional levels.
- **Co-production** allowing reduction in costs and higher specialization, leading to commonly available operational, observation and model-based products and services. Specifically, EuroGOOS aims to better coordinate co-production for the Marine Strategy Framework Directive (MSFD).
- **Sustained Ocean Observations:** EuroGOOS is playing a leading role to ensure coordination of the European contribution to a sustained marine observational system through the promotion of a European Ocean Observing System (EOOS), closely working with all partners.

Five regional sea areas, where operational systems are being developed, have been defined: the Arctic (Arctic ROOS), the Baltic (BOOS), the North West Shelf (NOOS), the Ireland-Biscay-Iberian area (IBI-ROOS) and the Mediterranean (MONGOOS). Strong cooperation within these regions, enabling the involvement of many more regional partners and countries, forms the basis of EuroGOOS work, and is combined with high-level representation at European and Global forums

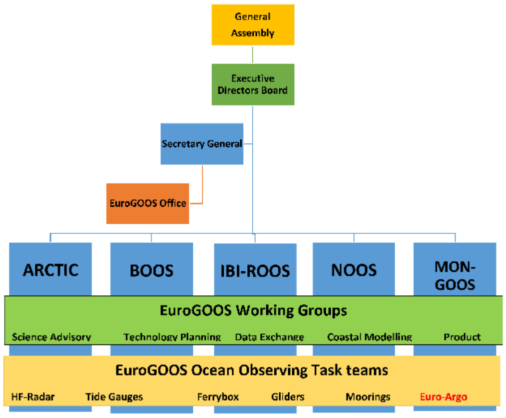


Figure 39 EuroGOOS organization

The Baltic Operational Oceanographic System (BOOS) was formed by the signature of the BOOS Memorandum of Understanding in 2001, with the aim to promote and develop an operational oceanographic infrastructure including routine collection, interpretation and presentation of in situ and satellite data. This information is necessary in order to improve efficiency of marine operations, reduce risks for accidents, optimise monitoring of marine environment and climate, improve assessment of fish stocks and improve foundation of public marine management.

The BOOS Vision 2015 intends to carry on existing concepts and ideas formulated in the BOOS Plan covering the period 1999 up to 2003 and in the BOOS Strategy Plan for 2004 – 2010. In the same time guide and develop the BOOS daily work, taking into account the changes presently going on in Europe and in particular in the Baltic region.

BOOS organized already in 1998 exchange of real-time data between members using a system of ftp-boxes and did - as the first in the world - display real-time sea level data on the web. BOOS has later on formed 3 regional data centres as a contribution to the European data exchange. The institutes that are responsible for data gathering are:

BOOS regional centre for	**Responsible Institution**	**Contact**	**FTP box (password protected)**
Tide gauges, moored buoys	SMHI	Thomas Hammarklint	ftp.smhi.se
Ferryboxes	SYKE	Seppo Kaitala	ftp.ymparisto.fi
Fixed platforms	BSH	Susanne Tamm	ftp.bsh.de/outgoing/rcbono

Table 4 BOOS regional data centres

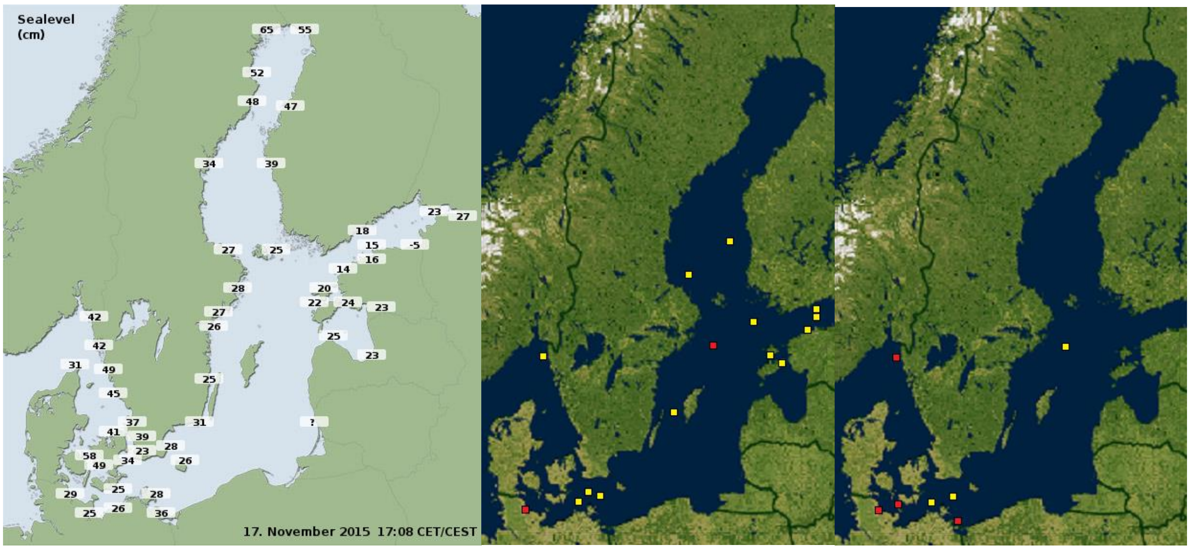


Figure 40. BOOS stations of water level (left), waves (middle) and currents

Status station network

Active tide gauge: data available

Active moored buoy or fixed platform: data available

Maintenance or other: data missing

2.2.2 SEADATANET

SeaDataNet (**http://www.seadatanet.org/)** is a standardized system for managing the large and diverse data sets collected by the oceanographic fleets and the automatic observation systems. The SeaDataNet infrastructure network and enhance the currently existing infrastructures, which are the national oceanographic data centres of 35 countries, active in data collection. The networking of these professional data centres, in a unique virtual data management system provide integrated data sets of standardized quality on-line. As a research infrastructure, SeaDataNet contributes to build research excellence in Europe.

SeaDataNet maintains several metadatabases containing information of institutions, monitoring programmes and research cruises. One important aspect of SeaDataNet is, that it provides a set or common vocabularies that makes possible to deliver metadata in standardized way. SeaDataNet also provides some software products that help in using common vocabularies and producing certain metadata information like cruise summary reports.

For retrieving Baltic Sea marine observations from SEADATANET, go to:
http://sextant.ifremer.fr/en/web/seadatanet/catalogue;jsessionid=7D1D91EBBA6C95A9300E83AA9554B0EB in “Full text search”, searching “Baltic”.

For assessment of T/S profiles in Baltic Sea, please refer to following two documents:
http://www.seadatanet.org/content/download/26556/181357/file/SDN2_D102_WP10_First_aggregated_datasets.pdf page 45-50
http://www.seadatanet.org/content/download/26558/181367/file/SDN2_D104_WP10_Second_aggregated_datasets.pdf page 29-32

2.2.3 Permanent Service for Mean Sea Level (PSMSL)

PSMSL is the global data bank for long term sea level change information from tide gauges and bottom pressure recorders (http://www.psmsl.org/). Established in 1933, the Permanent Service for Mean Sea Level (PSMSL) has been responsible for the collection, publication, analysis and interpretation of sea level data from the global network of tide gauges. It is based in Liverpool at the National Oceanography Centre (NOC), which is a component of the UK Natural Environment Research Council (NERC).

One significant feature of PSMSL data is that the reference level information is well documented.

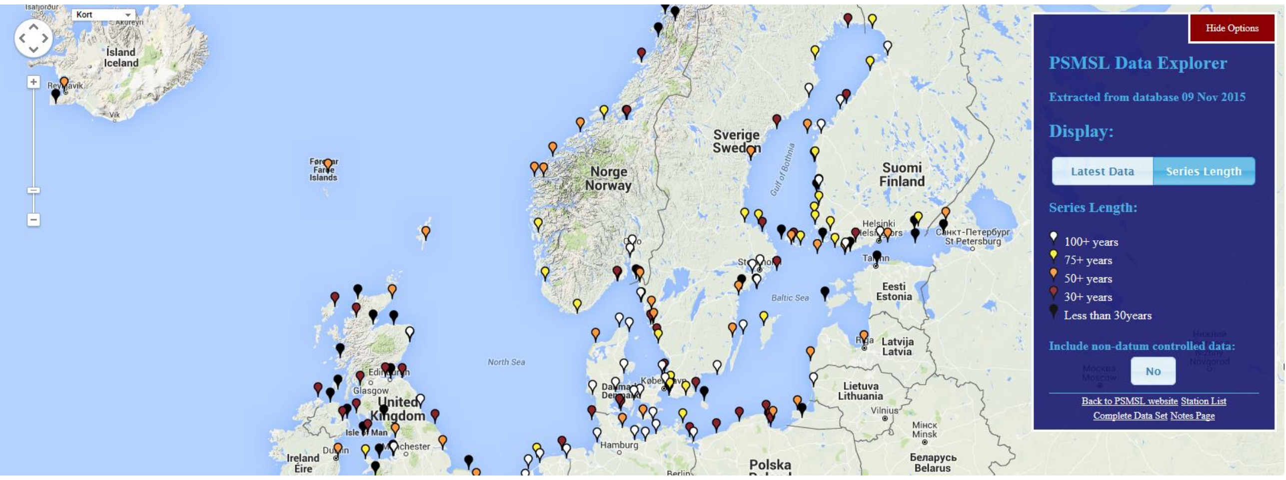


Figure 41 Water levels stations with data store in the PSMSL.

2.3 National systems

Although a large amount of observations from national monitoring programs have been included in the above regional coordinated observation data initiatives (ICES, HELCOM, BOOS, SEADATANET, CMEMS, EMODNET, PSMSL etc.), a significant amount of data is still missing from free and open delivery. This is the case for historical oceanographic data. Most probably many datasets still are only printed on paper. There have been data archaeology projects within e.g. ICES, but it seems that a lot is still to be done. Many project data sets remain out of the national data centres. Some institutions collect oceanographic data as background information for their primary interests, like temperature and sound velocity profiles measured during bathymetric measurements and such datasets may not go to any datacentres. The identification of the missing data will be carried out in the next phase of the project and results to be given in data adequacy report.

It may be noted that during decades the data policies have changed considerably. From early stages of oceanography until 1960's data was published on paper form and collected to international datacentres like ICES and World Data Center A on oceanography. However, there were some restrictions in the use of data. In 1960's data was considered as product that can be sold, and even governmental institutions has to cover the data collection costs by having fees for data delivery.

During recent decade(s) the data policies have returned back to free and open data. This has been enforced e.g. in EUs INSPIRE directive and now data collected by public authorities in EU should be free and accessible, which however, may not always be the case yet.

2.4 Existing research on assessing the Baltic Sea Observation networks

Marine observations are the basis for marine services. Due to the high cost and difficulty of making marine observations as well as the spatial inhomogeneity in the representativeness of observations, research and development on the assessment and design of cost-effective ocean observing networks are needed, to identify the gaps in existing observing systems and to optimise their cost-effectiveness. The assessment study can be divided into different phases: 1) to identify observation data availability and accessibility; 2) ad-hoc assessment of data adequacy for different user areas and 3) quantitative assessment of data adequacy.

Phase 1 – Identification of data availability and accessibility

The goal in this phase is to identify what observations are available and accessible. This study can be quite challenging due to large number of monitoring sources and lack of coordinated data management. Fortunately this situation has been eased due to a strong Baltic Sea regional coordination in the data provision, e.g. HELCOM for environment monitoring data, BOOS for operational (near real time) data and ICES for part of the fishery data. Now EDIOS, SeaDataNet, CMEMS and EMODNET also provide pan-European scale hydrography and biogeochemical data management.

Availability and accessibility of major part of the Baltic Sea marine observations can be assessed by using the meta-database and corresponding data policies from these data-centres. Existing assessment in this phase has been made in a variety of EU and regional projects, e.g., EDIOS, PAPA, ODON, OPEC and HELCOM-MORE, HELCOM FISH-PRO etc.

PAPA (Programme for a BAltic network to assess and upgrade an oPerational observing and forecAsting system, 2003-2005) provided a full metadata set for operational monitoring data in the Baltic Sea and an ad-hoc assessment based on importance of operational oceanography. ODON (Optimal Design of Observation Networks, 2003-2005) provided a metadata set of temperature and salinity observations including both operational and environmental monitoring data. The locations of the data are show in Figure 42.

For the environmental monitoring, the HELCOM Monitoring and Assessment Strategy, was first adopted in 2005, which is a plan laying out a monitoring and assessment system which assists in evaluating whether visions, goals and objectives for the Baltic Sea marine environment are being met. The main idea of the revised strategy HELCOM-MORE (Revision of HELCOM MOnitoring programmes 2012-2013, http://www.helcom.fi/Pages/MORE.aspx) is to make a revision of the joint HELCOM monitoring programme in the Baltic Sea so that it is scientifically sound, well-coordinated, optimised and cost-effective. It aims to provide the necessary data for HELCOM's Baltic-wide indicator-based assessment activities, focusing on the state of the marine environment but also on human-induced pressures impacting the status.

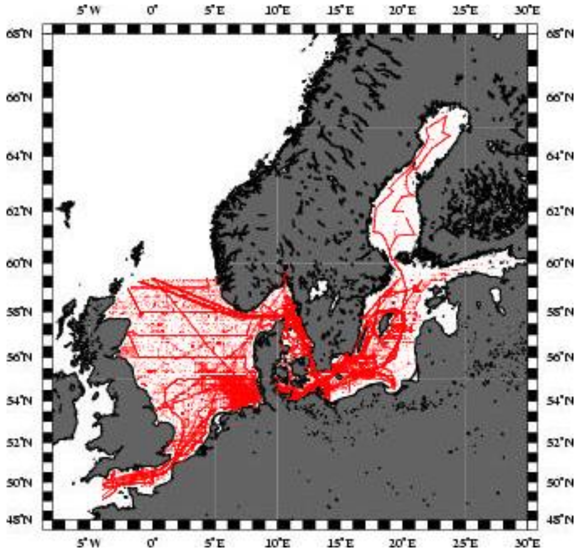


Figure 42. SST measuring stations in 2001 for the Baltic-North Sea.

In HELCOM-MORE report, a detailed illustration of existing sampling parameters, stations and frequencies in the HELCOM monitoring program are described. Most of the parameters for monitoring hydrography, chemical, biota and pollution conditions of the Baltic Sea are covered. The frequency ranges from biweekly to quarterly, depending on parameters and countries. All the sub-basins are covered but with rather large spatial gaps. Some examples are given in Chapter 2.2 HELCOM. Major monitoring platforms are research vessels.

The monitoring of fish and shellfish cover the abundance, distribution, growth, population dynamics and exploitation of fish in the HELCOM area. Much of the programme is carried out under the auspices of ICES. In HELCOM, a few sub-programmes have been established for the monitoring surveys, monitoring of commercial catches and direct assessments of population (stock) dynamics. This includes sub-programmes Coastal Fish, Migratory fish, Offshore fish, Commercial shellfish and Fisheries by catch.

HELCOM FISH-PRO II project is aimed to further develop the assessment and monitoring methodologies and to support ecosystem-based management of coastal fish communities (2013-2018). Coastal fish communities are important components of the Baltic Sea ecosystems, and many species of coastal fish are also of a high socio-economic value for coastal societies, small scale coastal fisheries and recreational fishing. The status of coastal fish communities serves as an indicator of coastal ecosystem health, reflecting pressures like eutrophication, hazardous substances, fishing and degradation of coastal habitats. The structure of coastal fish communities is also dependent on the impact of climate change, and species of coastal fish might also modify other ecosystem components through ecological interactions. Given the dramatic changes in Baltic Sea ecosystems and coastal fish communities during the last decades, attention and focus should be devoted to this component of the ecosystem.

Coastal fish monitoring in the Baltic Sea has a long tradition, dating back to the 1960s in some areas (Olsson and Andersson, 2012). Since 2003, the HELCOM expert network for coastal fish has coordinated monitoring and assessments of coastal fish in the Baltic Sea. Over the years the network has existed on a project basis under the acronyms HELCOM FISH, HELCOM FISH PRO and HELCOM FISH PRO II, with the current project period lasting until mid-2018. A description of the existing monitoring network and sampling strategy can be found in FISH-PRO II publication Guidelines for Coastal Fish Monitoring Sampling Methods of HELCOM (HELCOM, 2015).

It should be noted that a large amount of HELCOM data are not included in the CMEMC, EMODNET and SeaDataNet databases. It is also true that major part of the BOOS operational database is not part of HELCOM database. In addition, there are still significant amount of national data that is not shared within either HELCOM or BOOS and most probably even within the nation itself.

In OPEC (Operational Ecology), the availability and accessibility of the Baltic biochemical data from databases of ICES and SeaDataNet was assessed. It was found that the latent time of accessing most of the data is about 1-2 years, which cannot meet requirement for operational Rapid Environment Assessment in a quarterly or yearly basis.

Phase 2 – Ad-hoc assessment of data adequacy for different areas
In this phase, data adequacy will be examined according to different user needs. This has often been done in the field of operational oceanography and environment assessment. In PAPA project, the operational monitoring groups of BOOS carried out an ad-hoc assessment of data adequacy. The gaps that they identified are shown in Figure 43, which represents ideas from all Baltic Sea member countries.

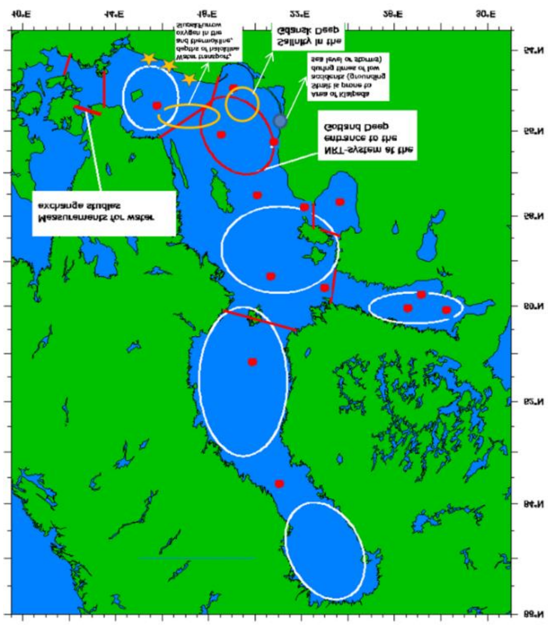


Figure 43. Observation gaps identified by BOOS monitoring groups (stars: sea level stations, sections: SOOP observations; dots: fixed profilers; circles: important areas for monitoring

PAPA also made an assessment based on the modelling groups that are focused on improving operational numerical marine predictions. The results are different from the one in Fig. 43, which was expected.

In HELCOM-MORE and HELCOM FISH-PRO projects, the environmental and costal fishery monitoring strategies were assessed for "indicator-based" assessment. The gaps were also identified in an ad-hoc way. A comprehensive "fit-for-purpose" assessment for a wide range of user challenge areas, similar as BSCP, has not been conducted.

Phase 3 - quantitative assessment of data adequacy
One location may not have in-situ observations but it may not be regarded as a gap for the monitoring purpose. The monitoring gap at a specific spatial-temporal position depends on how much variability at the position can be resolved with the existing monitoring capacities. Integrated monitoring also includes satellite, modelling and objective analysis as capacities for monitoring. Hence, the ocean states at a given location may be partly recovered based on models and observations from other locations. This asks for quantitative assessment of data adequacy.

The quantitative assessment can be divided into three types according to the difference of purpose, i.e.

1) Monitoring for research and development
    - for understanding physical-biogeochemical-ecosystem processes: OS(S)Es
    - for testing new monitoring technology: cost-effective analysis
2) Monitoring for operational purpose
    - for telling current status: concerning quality of reconstructed fields, in terms of effective coverage, explained variance or analysis error.
    - for telling future ocean status: concerning about quality of forecasts, in terms of forecast error or sensitivity of forecasts to sampling schemes.
3) Monitoring for long-term purpose
    - for telling the trend: concerning the length, consistency and accuracy of the data and products
    - for telling long-term variability: concerning representativeness and consistency of the data, in terms of explained variance, signal-noise ratio or analysis error in reconstructing long-term time series.

For different purposes, the gaps of the monitoring network may be defined differently. Existing quantitative assessment of Baltic Sea observational networks are mainly made for improving operational oceanography products.

In general, it is important to define the data adequacy at a given point, which can be quantitatively estimated. Traditionally the data adequacy can be measured by using the reconstruction error that is based on Observing System Experiments (OSEs) or objective analysis. However, the estimated reconstruction error may be limited by the assimilation method (e.g., localisation of the covariance matrix). ODON project developed two indicators, effective coverage and explained variance, based on the covariance structure of the ocean (She et al., 2007). These two indicators are easy to calculate and can effectively represent the data adequacy with a statistical basis (by using model data). The shortcoming is that the model data (normally reanalysis) are also suffered from uncertainties.

In ODON project, Baltic-North Sea temperature and salinity observational network has been assessed quantitatively (use year 2001 as an example). Figure 44 shows the T/S monitoring network in 2001 and its spatial-temporal coverage. The results show large gaps in the mid/north-western Baltic Sea.

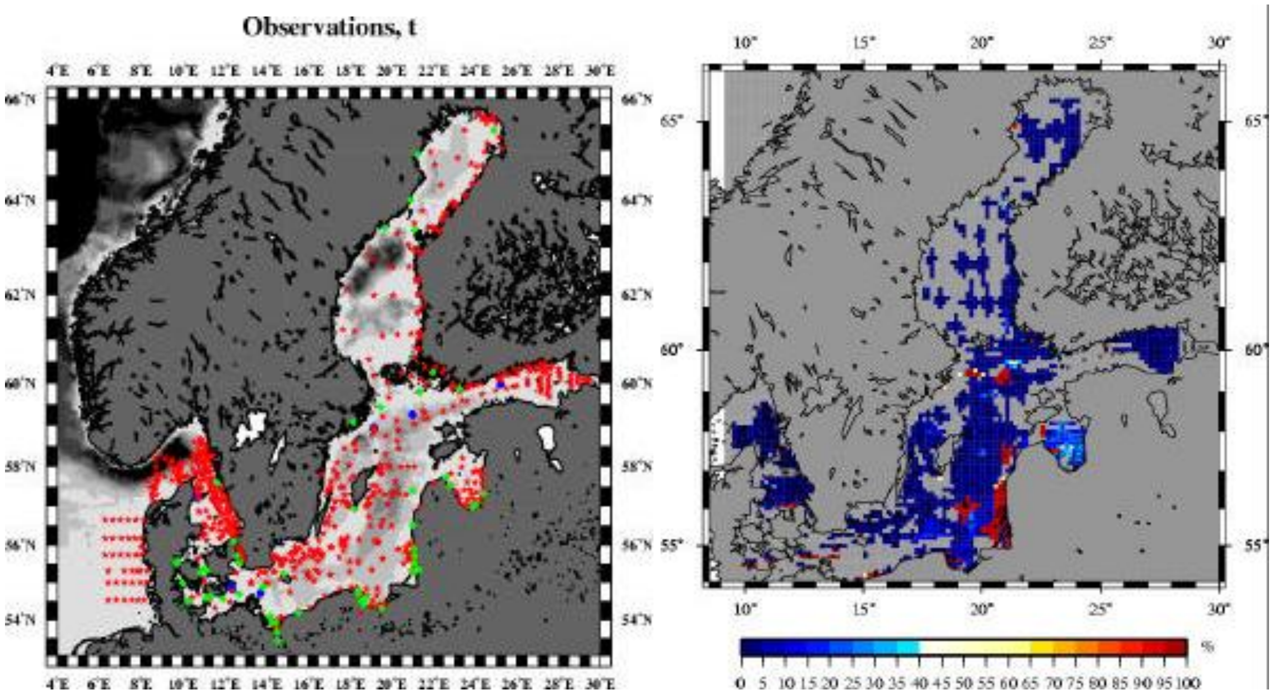


Figure 44. Effective coverage (in percentage) of T/S observational network at 24m water depth. Left: distribution of stations; right: effective coverage.

With a similar method OPEC assessed the gaps in the Baltic biogeochemical monitoring network (combined CMEMS/BOOS and HELCOM monitoring networks). Figure 45 shows the effective coverage of the *chl-a* monitoring at surface (left) and 47m (right), respectively.

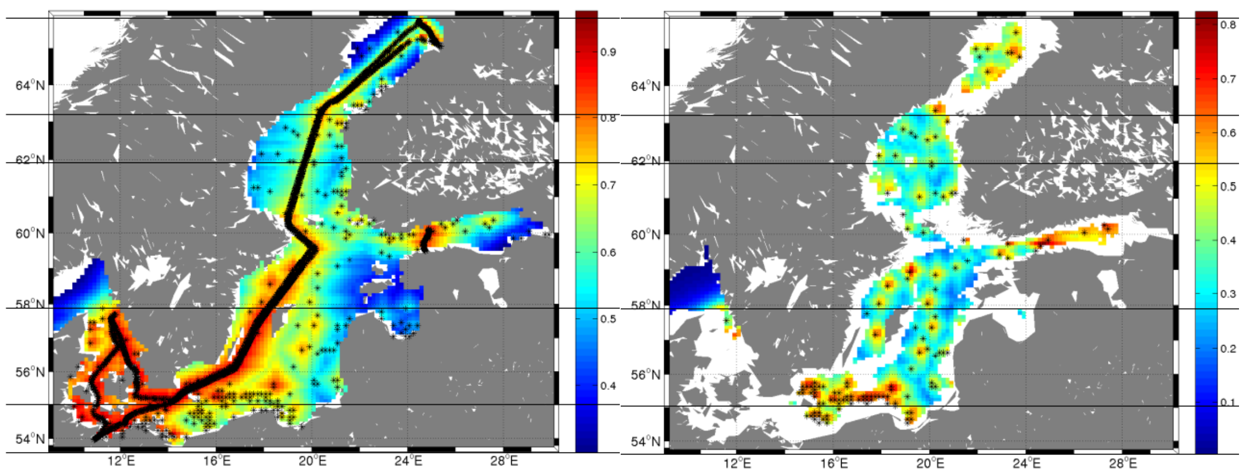


Figure 45. Effective Coverage of Baltic Sea chl-a monitoring network. Left: surface; Right: 47m water depth.

For the Baltic Sea, OSEs have been used to assess the effectiveness of the combined satellite-in situ SST monitoring networks (She et al., 2007) but not extensively in assessing other variables. This should be enhanced in the future research.

3. Literature survey

In planning the literature survey, the EMODnet Baltic Checkpoint consortium decided at the project kick-off meeting to use the same philosophy and approach as used by the EMODnet MedSea Checkpoint (EMODnet MedSea Checkpoint, 2014).

3.1 Concept

The activities in the literature survey have been divided up in the following steps:

1. All 11 challenges identified all the characteristics needed to solve the tasks in their individual challenge. Data was grouped in five environmental matrices as defined in EMODnet MedSea Checkpoint, 2014:
    - Air
    - Water (marine or fresh)
    - Biota/biology
    - Seabed
    - Human activities
2. Relevant literature was surveyed to identify sources for the required characteristics. In the proposal was identified three channels to find relevant literature:
    - Open source library Mendeley,
    - EU/national projects and working groups related to observing network assessment
    - Existing expert knowledge

   The first of these channels turned out not to be manageable due to more than 0.5 mill. hits independent of the search criteria
3. The identified data sources were as far as possible – based on literature information's, personal knowledge and tests – evaluated with regard to:
    - Availability
        - Accessibility
            - Visibility
            - Formats
            - Data policy
            - Pricing
            - Interoperability
        - Performance
            - Responsiveness
            - Reliability
    - Appropriateness'
        - Spatial extent
        - Spatial resolution
        - Time extent
        - Time resolution Quality
        - Usage
        - Completeness
        - Temporal accuracy
        - Delivery time

This evaluation will be carried in more detail in the connection with the work in the individual challenges.

4. Report writing

3.2 Essential characteristics for the individual challenges.

The various characteristics identified in the eleven challenges are presented in the table below.

Table 5. List of characteristics by challenge and environmental matrix

General information		
Matrix	**Characteristic**	**Challenge areas**
Challenge 1: Wind Farm Siting		
Air	wind speed (extreme, normal and operational)(directional)	Ch.1: Wind Farm Siting
Air	wind direction	Ch.1: Wind Farm Siting
Air	air pressure	Ch.1: Wind Farm Siting
Air	air density	Ch.1: Wind Farm Siting
Air	specific humidity	Ch.1: Wind Farm Siting
Air	Air temperature	Ch.1: Wind Farm Siting
Air	Precipitation	Ch.1: Wind Farm Siting
Air	Cloudiness	Ch.1: Wind Farm Siting
Water	sea level (HAT, MSL, LAT, Tide, etc.)	Ch.1: Wind Farm Siting
Water	water temperature	Ch.1: Wind Farm Siting
Water	water salinity	Ch.1: Wind Farm Siting
Water	Current velocity	Ch.1: Wind Farm Siting
Water	Current direction	Ch.1: Wind Farm Siting
Water	wave spectra	Ch.1: Wind Farm Siting
Water	significant wave height of total sea Surface, (directional)	Ch.1: Wind Farm Siting
Water	significant wave height of wind sea (wind – wave correlation) - (Directional)	Ch.1: Wind Farm Siting
Water	significant wave height of swell (directional)	Ch.1: Wind Farm Siting
Water	mean wave direction of total sea	Ch.1: Wind Farm Siting
Water	mean wave direction of wind sea	Ch.1: Wind Farm Siting

Water	mean wave direction of swell	Ch.1: Wind Farm Siting
Water	mean wave period, zero-up-crossing period	Ch.1: Wind Farm Siting
Water	peak wave period	Ch.1: Wind Farm Siting
Water	maximum expected wave height*	Ch.1: Wind Farm Siting
Water	Nutrients	Ch.1: Wind Farm Siting
Water	Clorophyl-a	Ch.1: Wind Farm Siting
Water	Oxygen	Ch.1: Wind Farm Siting
Water	Sea Ice (Thickness, strength, Floe sizes, Period)	Ch.1: Wind Farm Siting
Biota/biology	Birds: Species, protected status and migratory patterns	Ch1: Wind farm Siting
Biota/biology	Marine Mammals: Species, protected status and migratory patterns.	Ch1: Wind farm Siting
Biota/biology	Fish: Species, protected status and migratory patterns	Ch1: Wind farm Siting
Biota/biology	habitats	Ch1: Wind farm Siting
Biota/biology	biomass	Ch1: Wind farm Siting
Biota/biology	abundance	Ch1: Wind farm Siting
Biota/biology	formations	Ch1: Wind farm Siting
Biota/biology	angiosperm	Ch1: Wind farm Siting
Biota/biology	macro algae	Ch1: Wind farm Siting
Biota/biology	invertebrate bottom fauna	Ch1: Wind farm Siting
Seabed	bathymetry	ch.1: Wind Farm Siting
Seabed	geology	
Seabed	characteristics and substrate	ch.1: Wind Farm Siting
Seabed	sediments, lithology	ch.1: Wind Farm Siting
Seabed	energy at the seabed	ch.1: Wind Farm Siting
Seabed	seabed slope	ch.1: Wind Farm Siting
Seabed	coastline evolution	ch.1: Wind Farm Siting
Seabed	seismic structure and events	ch.1: Wind Farm Siting
Human activities	Fishing activities	Ch. 1: Wind Farm Siting
Human activities	maritime traffic (shipping routes)	Ch. 1: Wind Farm Siting
Human activities	dredging	Ch. 1: Wind Farm Siting
Human activities	Dredging soil dumping	Ch. 1: Wind Farm Siting
Human activities	port traffic	Ch. 1: Wind Farm Siting
Human activities	Offshore wind farms	Ch. 1: Wind Farm Siting
Human activities	Grid network	Ch. 1: Wind Farm Siting
Human activities	Agregate Extrat.	Ch. 1: Wind Farm Siting
Human activities	MPA	Ch. 1: Wind Farm Siting
Human activities	Natura 2000	Ch. 1: Wind Farm Siting

Human activities	mariculture	Ch. 1: Wind Farm Siting
Human activities	coastal land use	Ch. 1: Wind Farm Siting
Human activities	nautical activities	Ch. 1: Wind Farm Siting
Human activities	coast guards locations	Ch. 1: Wind Farm Siting
Human activities	pipelines, cables	
Human activities	national Grid Network (transmission and electric)	Ch. 1: Wind Farm Siting
Human activities	regulatory constraints	Ch. 1: Wind Farm Siting
Human activities	port facilities	Ch. 1: Wind Farm Siting
Human activities	presence of infrastructure in the area (port with enough depth to assemble the turbines, logistical access for large and heavy items, towing capacity)	Ch. 1: Wind Farm Siting
Human activities	touristic or residential areas ahead of wind turbines	Ch. 1: Wind Farm Siting
Human activities	Archeologic conditions	Ch. 1: Wind Farm Siting
Human activities	Consents, land lease	Ch. 1: Wind Farm Siting
Challenge 2: Marine Protected Areas		
Water	Salinity	Challenge 2: Marine protected areas
Water	Ice-cover	Challenge 2: Marine protected areas
Water	Sea level	Challenge 2: Marine protected areas
Water	Transparency	Challenge 2: Marine protected areas
Water	Temperature	Challenge 2: Marine protected areas
Biota/biology	Red-listed species	Challenge 2: Marine protected areas
Biota/biology	Bird Directive spiecies	Challenge 2: Marine protected areas
Biota/biology	Habitat Directive species	Challenge 2: Marine protected areas
Seabed	Substrate	Challenge 2: Marine protected areas
Seabed	Bathymetry	Challenge 2: Marine protected areas
Seabed	Red-listed habitats	Challenge 2: Marine protected areas

Seabed	EUNIS habitats	Challenge 2: Marine protected areas
Seabed	HUB habitats	Challenge 2: Marine protected areas
Seabed	HD annex I habitat types	Challenge 2: Marine protected areas
Human activities	Boundaries of MPAs	Challenge 2: Marine protected areas
Human activities	National status of MPAs	Challenge 2: Marine protected areas
Human activities	IUCN categories for MPAs	Challenge 2: Marine protected areas
Human activities	Availability of management plan	Challenge 2: Marine protected areas
Human activities	Management measures set by countries in MPA management plans	Challenge 2: Marine protected areas
Human activities	National programs of measures according to MSFD art. 13	Challenge 2: Marine protected areas
Human activities	Ship traffic	Challenge 2: Marine protected areas
Human activities	Benthic trawling	Challenge 2: Marine protected areas
Human activities	Fishing landings	Challenge 2: Marine protected areas
Human activities	Wind farm sites	Challenge 2: Marine protected areas
Human activities	Oil slicks and spills	Challenge 2: Marine protected areas

Challenge 3: Oil platform leak

Air	10 m wind	CH.3: Oil platform leak
Water	Current 3D field	CH.3: Oil platform leak
Water	Temperature 3D field	CH.3: Oil platform leak
Water	Turbulence 3D field	CH.3: Oil platform leak
Water	Salinity	CH.3: Oil platform leak
water	Sea level	CH.3: Oil platform leak
Water	Ice concentration	CH.3: Oil platform leak
Seabed	Coastline	CH.3: Oil platform leak
Seabed	Bathymetry	CH.3: Oil platform leak
Human activities	Oil characteristics	CH.3: Oil platform leak
Human activities	Sensetive areas	CH.3: Oil platform leak
Human activities	Tourist beaches	CH.3: Oil platform leak
Human activities	Oil slicks and spills	CH.3: Oil platform leak

Challenge 4: Climate change

Air	wind speed (extreme, normal and operational)	Challenge 4: climate change
Air	wind direction	Challenge 4: climate change
Water	total ice cover	Challenge 4: climate change
Water	ice concentration	Challenge 4: climate change
Water	ice thickness	Challenge 4: climate change
Water	sea surface temperature	Challenge 4: climate change
Water	sea bottom temperature	Challenge 4: climate change
Water	thermal energy of the sea	Challenge 4: climate change
Water	kinetic energy of the sea	Challenge 4: climate change
Water	water temperature (whole water column/several depths)	Challenge 4: climate change
Water	salinity (whole water column/several depths)	Challenge 4: climate change
Water	currents (whole water column/several depths)	Challenge 4: climate change
Biota/biology	Abundance of *Ahcnanthes (Pauliella) taeniata*	Challenge 4: climate change
Biota/biology	Abundance of *Peridiniella catenata*	Challenge 4: climate change
Biota/biology	Abundance of *Nodularia spumigena*	Challenge 4: climate change
Biota/biology	Abundance of *Heterocapsa triquetra*	Challenge 4: climate change

Challenge 5: Coastal Protection

Water	Sea level	Coastal environment
Water	significant wave height of total sea surface	CH.5: Coastal Protection
Water	mean wave direction of total sea	CH.5: Coastal Protection
Water	peak wave period	CH.5: Coastal Protection
Water	mean wave period	CH.5: Coastal Protection

Seabed	coastline evolution	CH.5: Coastal Protection
Seabed	sediments, lithology	CH.5: Coastal Protection
Seabed	Land rise	CH.5: Coastal Protection
Seabed	Geoid change due to land rise	CH.5: Coastal Protection
Seabed	Digital elevation maps of the coastal zone	CH.5: Coastal Protection
Seabed	Foreshore and backshore evolution	CH.5: Coastal Protection

Challenge 6: Fisheries Management

Biota/biology	Mass of landings of fish by species, country, year	Challenge 6: Fisheries management
Biota/biology	Numbers of landings of fish by species, country, year	Challenge 6: Fisheries management
Biota/biology	Mass of discards of fish by species, country, year	Challenge 6: Fisheries management
Biota/biology	Numbers of discards of fish by species, country, year	Challenge 6: Fisheries management
Biota/biology	Numbers/or mass of bycatch of marine mammals, by species, year	Challenge 6: Fisheries management
Biota/biology	Numbers/or mass of bycatch of seabirds, by species, year	Challenge 6: Fisheries management

Challenge 7: Fisheries impact

Water	Bottom water salinity	Challenge 7: Fisheries Impact
Biota/biology	EUNIS habitats ≥ level 4	Challenge 7: Fisheries impact
Biota/biology	Baltic Sea protected benthic species	Challenge 7: Fisheries impact
Biota/biology	Habitat Directive protected benthic species	Challenge 7: Fisheries impact
Seabed	Bathymetry	Challenge 7: Fisheries Impact
Seabed	Substrate	Challenge 7: Fisheries Impact
Seabed	Near bed light intensity	Challenge 7: Fisheries Impact
Seabed	Baltic Marine Landscapes	Challenge 7: Fisheries Impact
Seabed	EUNIS habitats ≤ level 3	Challenge 7: Fisheries Impact

Seabed	Baltic Sea protected benthic habitats	Challenge 7: Fisheries Impact
Seabed	Habitat Directive Annex I nature types	Challenge 7: Fisheries Impact
Human activities	VMS for vessels ≥15 m (2005-2011)	Challenge 7: Fisheries Impact
Human activities	VMS for vessels ≥12 m (2012-)	Challenge 7: Fisheries Impact
Human activities	Logbook data for vessels ≥8 m	Challenge 7: Fisheries Impact
Human activities	National sales slip data of landings for vessels <8 m	Challenge 7: Fisheries Impact

Challenge 8: Eutrophication

Water	DIN	Challenge 8: Eutrophication
Water	DIP	Challenge 8: Eutrophication
Water	Chlorophyll-a	Challenge 8: Eutrophication
Water	Secchi depth	Challenge 8: Eutrophication
Water	Dissolved oxygen	Challenge 8: Eutrophication
Water	Temperature	Challenge 8: Eutrophication
Water	Salinity	Challenge 8: Eutrophication
Water	Secchi depth	Challenge 8: Eutrophication

Challenge 9: River input to Baltic Sea

Air	Precipitation	Challenge 9: riverine input
Air	Temperature	Challenge 9: riverine input
Air	Evaporation	Challenge 9: riverine input
Water	Discharge	Challenge 9: riverine input
Water	Nutrient Load (TN and TP)	Challenge 9: riverine input
Biota/biology	Salmon	Challenge 9: riverine input
Biota/biology	Type of crop, demand of water	Challenge 9: riverine input
seabed	Sediment	Challenge 9: riverine input
seabed	Topography	Challenge 9: riverine input
seabed	Soil characteristics	Challenge 9: riverine input

seabed	Land use characteristics	Challenge 9: riverine input
seabed	Lake and wetland	Challenge 9: riverine input
Human activities	Type of crop, demand of water	Challenge 9: riverine input
Human activities	Dams	Challenge 9: riverine input
Human activities	Irrigation	Challenge 9: riverine input

Challenge 10: Bathymetry

Water	Sound velocity	Bathymetry
Water	Temperature	Bathymetry
Water	Water level	Bathymetry
Seabed	Depth	Bathymetry
Seabed	Reliability	Bathymetry
Seabed	Depth data quality	Bathymetry
Seabed	Substrate (soil, hardness)	Bathymetry
Seabed	Bottom objects	Bathymetry
Human activities	Harbor,fairway and other constructions	Bathymetry
Human activities	Pipes	Bathymetry

Challenge 11: Alien species

Water	Salinity	Challenge 11: Alien species
Water	Ice-cover	Challenge 11: Alien species
Water	Near bottom oxygen content	Challenge 11: Alien species
Water	Near bottom presence of H2S	Challenge 11: Alien species
Water	Temperature	Challenge 11: Alien species
Biota/biology	Red-listed species	Challenge 11: Alien species
Biota/biology	Habitat Directive species	Challenge 11: Alien species
Biota/biology	Alien species	Challenge 11: Alien species
Biota/biology	Cryptogenic species	Challenge 11: Alien species
Biota/biology	Zooplankton	Challenge 11: Alien species
Biota/biology	Phytoplankton	Challenge 11: Alien species
Biota/biology	Zoobenthos	Challenge 11: Alien species
Biota/biology	Phytobenthos	Challenge 11: Alien species
Biota/biology	Parasites	Challenge 11: Alien species
Seabed	Substrate	Challenge 11: Alien species
Seabed	Bathymetry	Challenge 11: Alien species
Seabed	Red-listed habitats	Challenge 11: Alien species
Human activities	Aquaculture sites	Challenge 11: Alien species
Human activities	Ports	Challenge 11: Alien species
Human activities	Life food trade	Challenge 11: Alien species
Human activities	Ship traffic	Challenge 11: Alien species
Human activities	Wind farm sites	Challenge 11: Alien species

Each of the eleven challenges has its own requirements of data in the five environmental matrices. In the figure 46 the number of characteristics for each challenge subdivided into the 5 environmental matrices are shown. Only challenge 1 and 9 require data from all 5 environmental matrices, and challenge 2, 3. 7 and 11 require data in four matrices; while challenge 6 only require data within 1 environmental matrix (Human activities). Challenge 1 is by far the most data requiring challenge (67 characteristics), while challenge 6 only has a need for 6 characteristics.

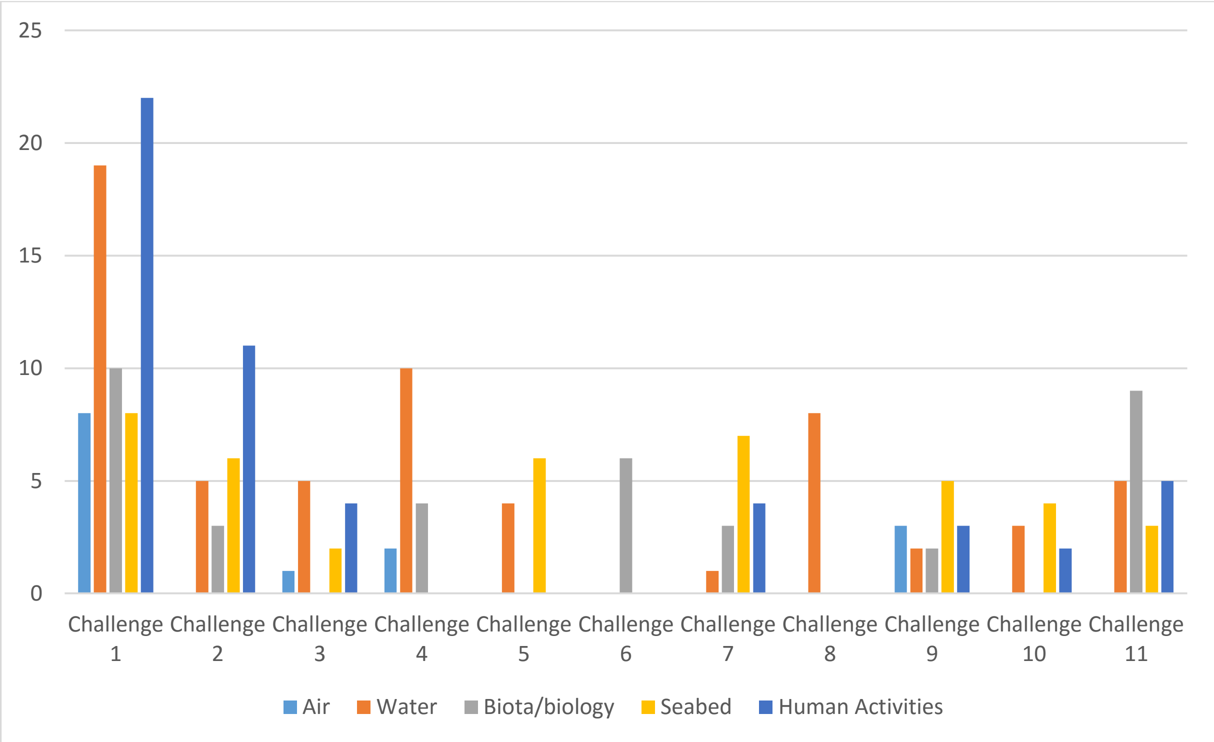


Figure 46. Number of characteristics by challenge and environmental matrix.

Comparing the requirements for characteristics from the eleven challenges there naturally are large numbers of overlaps, so filtering the characteristic list in table 5 for duplicates the list is reduced to a total of 140 characteristics: 10 in Air, 38 in Water, 31 in Biota/biology, 19 in Seabed and 42 in Human Activities. The list of characteristic is given in Table 6 and displayed in figure 47.

Table 6. Filtered list of characteristics required by the eleven challenges order by environmental matrices

Air	wind speed
	Wind speed extremes
Air	wind direction
Air	air pressure
Air	air density
Air	specific humidity
Air	air temperature

Air	Cloudiness
Air	Precipitation
Air	Temperature
Air	Evaporation

Water	Temperature 3D field
Water	Sea surface temperature -SST
Water	Bottom temperature
Water	Salinity 3D field
Water	sea level
	Tide
Water	Current 3D field - directional
Water	wave spectra* (surface)
Water	significant wave height of total sea Surface, (directional)
Water	significant wave height of wind sea (wind – wave correlation) - (Directional)
Water	significant wave height of swell (directional)
Water	mean wave direction of total sea
Water	mean wave direction of wind sea
Water	mean wave direction of swell
Water	mean wave period, zero-up-crossing period
Water	peak wave period
Water	mean wave period
Water	maximum expected wave height*
Water	Sea Ice extent
Water	Sea Ice concentration
Water	Sea Ice thickness
Water	Sea ice strenght
Water	Sea ice floe size
Water	Sea Ice period
Water	Transparency
Water	Turbulence 3D field
Water	thermal energy of the sea
Water	kinetic energy of the sea
Water	DIN

Water	DIP
Water	Chlorophyll-a
Water	Secchi depth
Water	Dissolved oxygen - 3D
Water	Discharge
Water	Nutrient Load (TN and TP) -3D
Water	Sound velocity
Water	Near bottom presence of H2S
Water	Near bed light intensity

Biota/biology	Birds: Species, protected status and migratory patterns
Biota/biology	Marine Mammals: Species, protected status and migratory patterns.
Biota/biology	Fish: Species, protected status and migratory patterns
Biota/biology	habitats
Biota/biology	biomass
Biota/biology	abundance
Biota/biology	formations
Biota/biology	angiosperm
Biota/biology	macro algae
Biota/biology	invertebrate bottom fauna
Biota/biology	EUNIS habitats ≥ level 4
Biota/biology	Baltic Sea protected benthic species
Biota/biology	Salmon
Biota/biology	Red-listed species
Biota/biology	Alien species
Biota/biology	Cryptogenic species
Biota/biology	Zooplankton
Biota/biology	Phytoplankton
Biota/biology	Zoobenthos
Biota/biology	Phytobenthos
Biota/biology	Parasites
Biota/biology	Abundance of *Ahcnanthes (Pauliella) taeniata*
Biota/biology	Abundance of *Peridiniella catenata*

Biota/biology	Abundance of *Nodularia spumigena*
Biota/biology	Abundance of *Heterocapsa triquetra*
Biota/biology	Numbers of landings of fish by species, country, year
Biota/biology	Mass of discards of fish by species, country, year
Biota/biology	Numbers of discards of fish by species, country, year
Biota/biology	Numbers/or mass of bycatch of marine mammals, by species, year
Biota/biology	Numbers/or mass of bycatch of seabirds, by species, year
Biota/biology	Type of crop, demand of water

Seabed	bathymetry
Seabed	geology
Seabed	characteristics and substrate
Seabed	sediments, lithology
Seabed	energy at the seabed
Seabed	seabed slope
Seabed	coastline evolution
Seabed	seismic structure and events
Seabed	Coastline
Seabed	coastline evolution
Seabed	sediments, lithology
Seabed	Digital elevation maps of the coastal zone
Seabed	Foreshore and backshore evolution
Seabed	Land rise
Seabed	Baltic Marine Landscapes
Seabed	Reliability
Seabed	Depth data quality
Seabed	Substrate (soil, hardness)
Seabed	Bottom objects

Human activities	Fishing activities

Human activities	maritime traffic (shipping routes)
Human activities	dredging
Human activities	Dredging soil dumping
Human activities	port traffic
Human activities	aggregate extrat.
Human activities	MPA
Human activities	Natura 2000
Human activities	mariculture
Human activities	coastal land use
Human activities	coast guards locations
Human activities	Offshore windfarms
Human activities	pipelines, cables
Human activities	national Grid Network (transmission and electric)
Human activities	regulatory constraints
Human activities	port facilities
Human activities	touristic or residential areas ahead of wind turbines
Human activities	Archeologic conditions
Human activities	Consents, land lease
Human activities	Boundaries of MPAs
Human activities	National status of MPAs
Human activities	IUCN categories for MPAs
Human activities	Availability of management plan
Human activities	Management measures set by countries in MPA management plans
Human activities	National programs of measures according to MSFD art. 13
Human activities	Benthic trawling
Human activities	Wind farm sites
Human activities	Oil slicks and spills
Human activities	Oil characteristics
Human activities	Sensetive areas
Human activities	Tourist beaches
Human activities	VMS for vessels ≥15 m (2005-2011)
Human activities	VMS for vessels ≥12 m (2012-)
Human activities	Logbook data for vessels ≥8 m

Human activities	National sales slip data of landings for vessels <8 m
Human activities	Pipes
Human activities	Dams
Human activities	Aquaculture sites
Human activities	Life food trade
Human activities	Land use characteristics
Human activities	Lake and wetland
Human activities	Irrigation

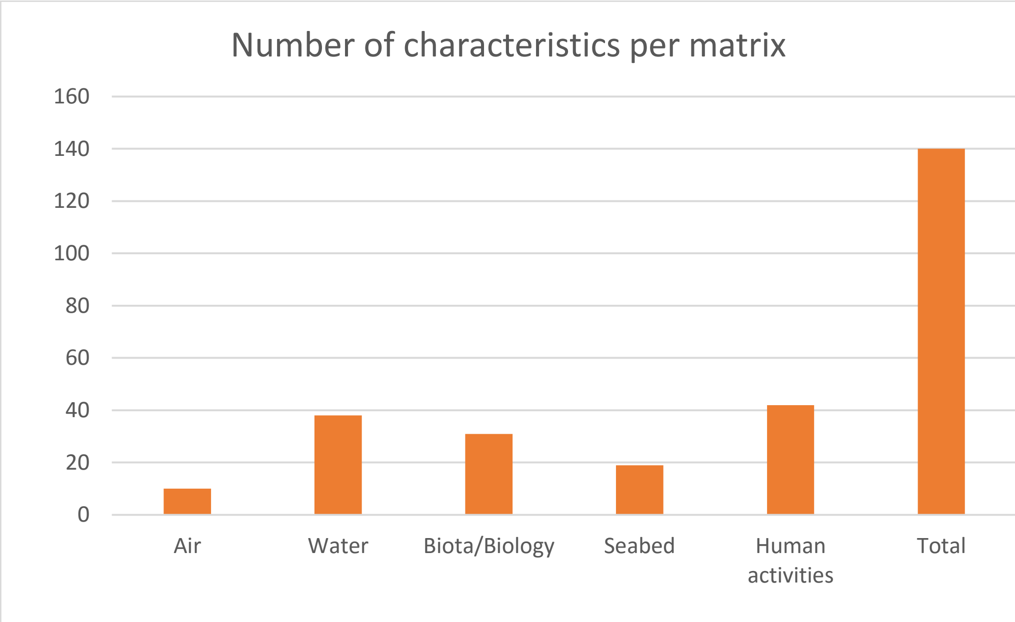


Figure 47. Number characteristics per environmental matrix.

3.3 Data sources and providers; evaluation of appropriateness and availability

3.3.1 Air

Atmospheric motions provide the raw source of energy that is driving most of the hydro-dynamics of the Baltic Sea and in combination with the ocean, atmospheric climate change is likely to influence all aspects of the physical, ecological and social system of the Baltic Sea. This makes it a primary aspect of all maritime activities in the Baltic Sea and will have - directly or indirectly - an impact on all the challenges in the Baltic Sea Checkpoint Project.

The number of the in-situ observations of the atmosphere over the open Baltic Sea is limited. That can be overcome by well-validated numerical models both in interpreting the past and drawing conclusions on the possible future changes in the marine environment. Therefore identifying good reanalysed atmospheric forcing data for the Baltic Sea is important.

Maritime wind observations at greater heights (above 100m) are only available from fixed platforms, like Fino2 (www.fino2.de). Most wind observations are from sea surface stations, monitored by wave buoys. These observations are suitable for model evaluation of the 10m wind product used by ocean model, but are of limited use for data analysis and weather model skill assessments at hub height. Synoptic weather observations have been considered an alternative, but their limited availability at relevant locations has largely reduced their applicability. Synoptic weather stations are mostly positioned at locations on land and on island, with greater surface roughness than at sea.

National weather services have operational data flows of many types of weather observations like surface weather observations from ships, drifters and land based synoptic stations, profile data from airplanes, radio probes, wind profilers and satellite cloud tracking wind measurements, as well as satellite, weather radar, lightning, ozone and precipitation observations. The data are archived at each institute independently and is usually not available to users outside the data network. Clients have to request the data from national weather services to get access to it. Following EU INSPIRE directive, some national weather services, like FMI and SMHI, have opened their weather station and numerical forecasting data for public access via their open data interfaces as catalogue services (CSW), view services (VMS) and download services (WFS). Other national services, like DMI, are planning to establish a free data policy in the near future.

The number of such coastal weather stations in Finland is some 36, Sweden 37, Denmark 28, Germany??, Poland ??, Lituania ??, Latvia ???, Estonia 23.

The Swedish coastal weather stations from the Sound to the Bay of Bothnia are 37. All of them measure air temperature, relative humidity and wind speed, but only 25 measure air pressure and visibility, 24 measure cloud cover and 7 measure radiation and sunshine.

Danish Weather Stations are not often located far from the sea, but only half of the available 61 stations, i.e. 28 stations is located in the immediate vicinity of the coast between Skagen and Bornholm (Kenan et al, 2013). Except for Skagen and Anholt, the main part of the coastal weather stations is located south of the Kattegat and around Bornholm. All of them measure air temperature, but only 26 measure relative humidity and wind speed, 25 measure air pressure, 18 measure visibility, 12 measure cloud cover and 11 measure radiation and sunshine, which are the main parameter to mention. Most of the data is provided to the world meteorological community and available via the Global Telecommunication System GTS.

For the specific Baltic Sea Checkpoint challenges shall be noted:

- Wind Farming - Atmospheric data in wind farm sighting are used for estimating resource and construction factors, i.e. energy output under normal conditions as well as downtime estimates for weather that is either too calm or too stormy. Most useful for wind farm sighting are surface observations. Airborne wind profile measurements and satellite derived wind products focus on the upper layers of the atmosphere, at heights far beyond the range of wind turbines. There is, however, a requirement for long-time series of wind data at hub-heights of more than 100m, used for offshore wind farm constructions. Only models can provide long enough time series suitable for wind farm sighting. Wind atlases have been produced to aid wind energy planning and construction. As an example there is a freely available interactive wind atlas for land and sea areas of Finland (http://www.tuuliatlas.fi/en/). This atlas was mainly done in Finnish Meteorological Institute by using numerical mesoscale model AROME with 2.5 km horizontal resolution and diagnostic downscaling method Wind Atlas Analysis and Application Programme (WAsP) with 250 m resolution (Tammelin et. al 2011). Additionally, Denmark's Technical University's (DTU) wind energy department has produced a European Wind Atlas, based on DTU WAsP wind resource and energy yield assessment software package.

- Climate change - for studies of climate change effects on the Baltic Sea, atmospheric data is needed both for driving ocean climate simulation and for analysing climate impacts. In that sense in-situ data from above mentioned weather stations is important for interpretations of the in-situ oceanographic data. Numerical ocean models are intensively used for analysis of potential changes in the marine environment and the models need as input gridded data of atmospheric parameters. Such reanalysed dataset is available from SMHI/Rossby Center.
- Oil spill - to forecast the dispersion of an oil spill the SMHI Seatrack Web model will be used. The only air parameter in Seatrack Web is 10 m wind which is model data and can be downloaded from SMHI open data, http://www.smhi.se/en/services/open-data. The wind data from SMHI open data is always available with quick online access, free to download in grib format. The data is covering the Baltic Sea area with the horizontal resolution 2,5 km, time resolution 1h. It is near real time data generally used for operational forecasting updated at least every sixth hour.
- River input - Meteorological data on precipitation and temperature are needed running the hydrological model for calculating riverine inputs in challenge 9. These data has been produced for regional and global studies of climate and water within the European WATCH project and can be found at http://www.eu-watch.org/data_availability.

3.3.2 Water

Oceanographic observations in the Baltic has very long traditions and therefore century long time series can be established for selected parameters and locations e.g. water level at a large number of coastal stations. In-situ observations are used – in real time and delayed mode - for description and understanding of the ocean state and processes as well as for model product improvement by model validation and data assimilation, but are also for quality assessments and best fit for purpose selection of available models and set-ups. In the Baltic Sea several oceanographic products are available via MyOcean/Copernicus, BOOS and a number of national institutes, with each product having its strength and weakness. Observations near the site are used for skill assessments of operational model. There is also a small number of parameter that can't be derived from model simulations directly, like maximum wave height, surface elevation, which is not forecasted by wave model. Another example, Ice conditions in the Baltic Sea are described by many models, but are normally evaluated using ice charts, because of the higher quality of the satellite derived product.

For climate change studies long in-situ time series of water temperature and salinity are essential. There are a limited number of fixed oceanographic stations from where there are regular depth profiles covering many decades. Unfortunately, many of such stations have been stopped because of lack of observers in the distant coastal sites. Open sea observations are usually done with research ships and they visit the stations seldom and with irregular time steps. More regularly coastal station data sets are in some cases long, but the observational procedures and availability of observers have caused the time series to stop in many cases.

Ocean data in wind farm sighting are used for estimating cost factors, i.e. construction costs of site-specific wind farm designs, that withstand the present day climate and costs of operating and maintaining wind farms at the site. This requires long-term, high-resolution data sets that cover the entire domain. Offshore in-situ observations are too sparse to be used directly for wind farm sighting and satellite derived products are to infrequent and unavailable for some of the most critical parameters: winds, currents. Models deliver long time series (decades) of high quality data to estimate average and extreme conditions for construction and maintenance cost estimates.

Baltic Sea in-situ observations are today primarily available via ICES, HELCOM, BOOS, SeaDataNet, EMODnet, MyO/CMEMS, Baltic Nest institute and many national data providers. The system is rather well integrated, so that the data is provided to the community via several platforms. It should be noted that the data from the above mentioned sources is mostly from the same origin and thus overlapping. These Databases will shortly be described in the following.

3.3.2.1. ICES database

The International Council for the Exploration of the Sea (ICES) was founded in series of occasions in 1902 – 1904 to cover the North Atlantic Ocean and the Baltic Sea (www.ices.dk). One of ICES's tasks has from the very beginning been the collection of oceanographic, environmental and fisheries data from the member countries to a common database. This makes the ICES database the longest existing international oceanographic database. ICES is a regional data centre in World Data System. Thus it has also delivered data to former World Data Center for Oceanography A, Silver Springs, which now is called World Data Service (WDS) for Oceanography (https://www.nodc.noaa.gov/worlddatacenter/).

ICES data policy is to encourage the use of publicly available data and to guarantee that quality controlled data is available to the users as soon as possible. Thus, the data in ICES water databases is open unless the originator has given restrictions to the use of its data. It should be noted that there are some justifiable reasons for restrictions, like the exact locations of endangered species.

ICES maintains several databases and applications to access the data. For our purposes, the most relevant are CTD and bottle data, IROC data and HELCOM data (see below). ICES oceanographic database contains data from 1877 onwards. The core parameters are: temperature, salinity, oxygen, phosphate, total phosphorus, silicate, nitrate, nitrite, ammonium, total nitrogen, hydrogen sulphide, pH, alkalinity, chlorophyll *a* and Secchi depth. These data are available from http://ocean.ices.dk/HydChem/HydChem.aspx?plot=yes. At the writing of this, the most recent update of ICES oceanographic database was from 2015-11-16 containing 12.947.564 stations from which 296.424 are high-resolution CTD stations. Of all these stations from the Baltic Sea, including Skagerrak and Kattegat, are 385.931 bottle stations and 16.750 CTD stations. The number of Skagerrak stations is 55.444 bottle stations and 2.387 CTD stations.

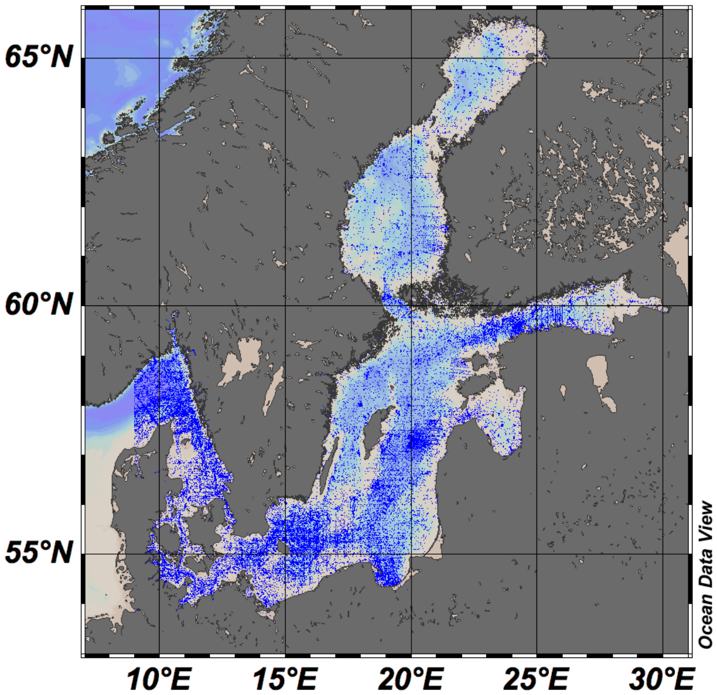


Figure 48. Positions of hydrographic observations stored in the ICES database.

3.3.2.2. HELCOM database

The Baltic Sea marine environment protection commission, HELCOM, has had permanent secretariat since 1979. It has had monitoring programmes at least since then. At present ICES serves HELCOM as data consultant and the water data collected in HELCOM monitoring program, COMBINE, is available from ICES Internet-pages, http://ocean.ices.dk/Helcom/Helcom.aspx?Mode=1. The present HELCOM dataset contains data from years 1900 – 2015. It is more or less a subset of ICES oceanographic data and contains at present data from 102.524 stations (Skagerrak is not included).

HELCOM produces a set of core indicators – dissolved inorganic nitrogen and phosphorus, chlorophyll-*a,* water clarity and oxygen. These indicators represent nutrient status and its direct and indirect effects which are all essential when assessing the eutrophication status of the Baltic Sea.

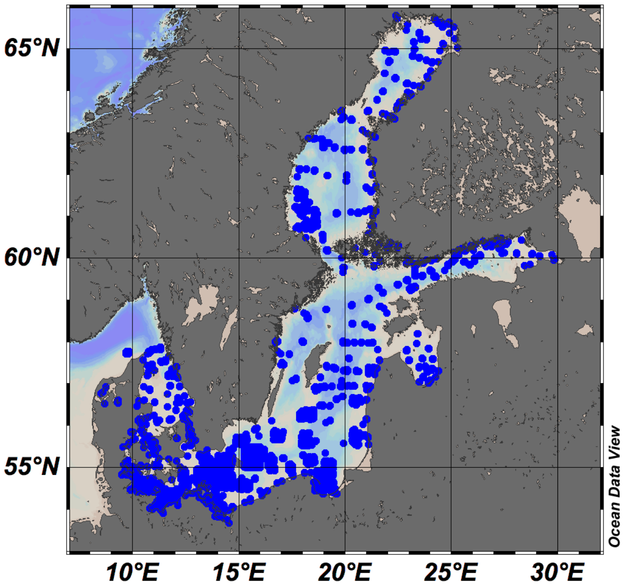


Figure 49 Stations in the HELCOM monitoring programme.

3.3.2.3 BOOS

The development of the BOOS Data Portal started already in the late 1990'es and has undergone large improvements during the MyOcean projects, which lasted over the years 2009-2015, and later also via the EMODnet project. The system is the Baltic contribution of in-situ observations to EMODnet and Copernicus Marine Service.

Baltic Sea organization

The data distribution in the Baltic region is built on a well-established exchange of in-situ data between the partners and organizations in the region. SMHI coordinates the work and is responsible for acquisition, quality control and distribution of the data in the Baltic region. SYKE has the quality assessment responsibility for ferrybox data. Through a close cooperation together with SeaDataNet, large amount of temperature- and salinity data is available via the portal. Data distributed from the system are made available for internal BOOS users, the public society and for other projects and programs, such as EMODnet (Figure 50). All data are freely available.

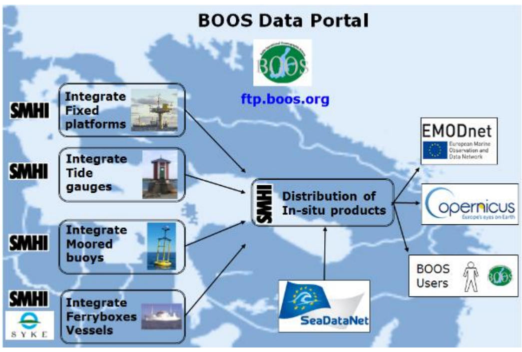


Figure 50. The Baltic organization to make oceanographic data available from the region.

Harmonized routines for quality control and assessment
The data handling in the region is harmonized and the same quality control and routines are applied in all regions (Figure 51). Quality control flags are applied to the data, which is the same conventions used in SeaDataNet.

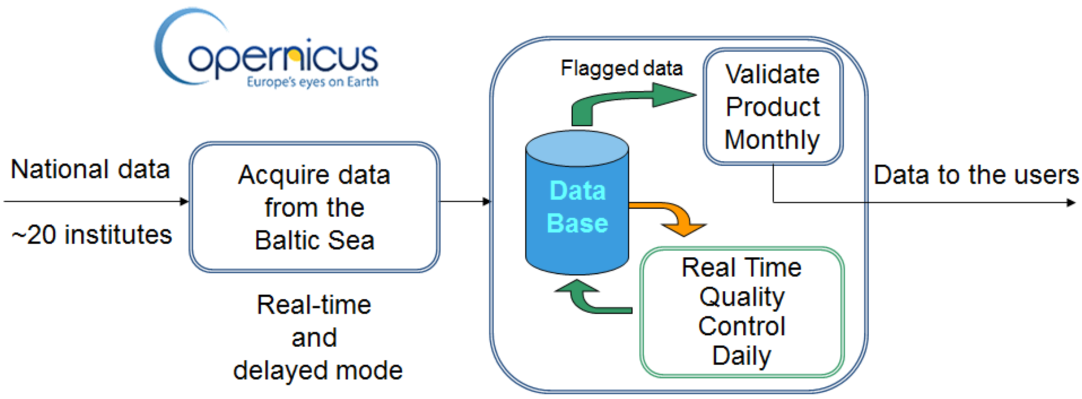


Figure 51. Schematic data flow for data coming from the Baltic Sea.

Same data structure in all regions
The portal consists of a FTP-box structure and data are organized in three main directories (Figure 52):

- Latest: Providing access to a sliding window on the latest 30 days of observations for real-time applications.
- Monthly: Accumulating the best copy of a dataset, organized by platform and by month.
- History: Providing historical aggregated datasets (data since 1978, if available).

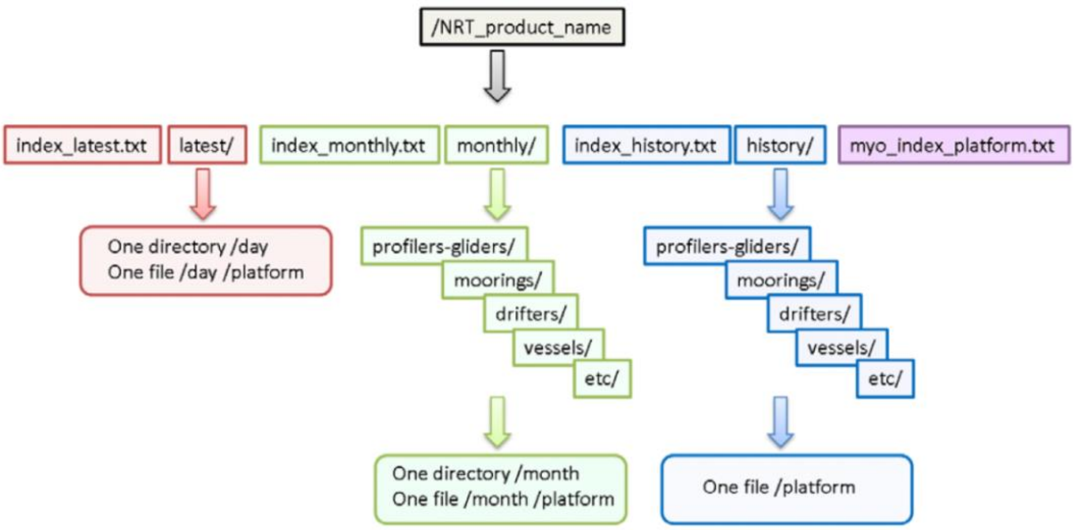


Figure 52. Scheme of the FTP structure in the portal.

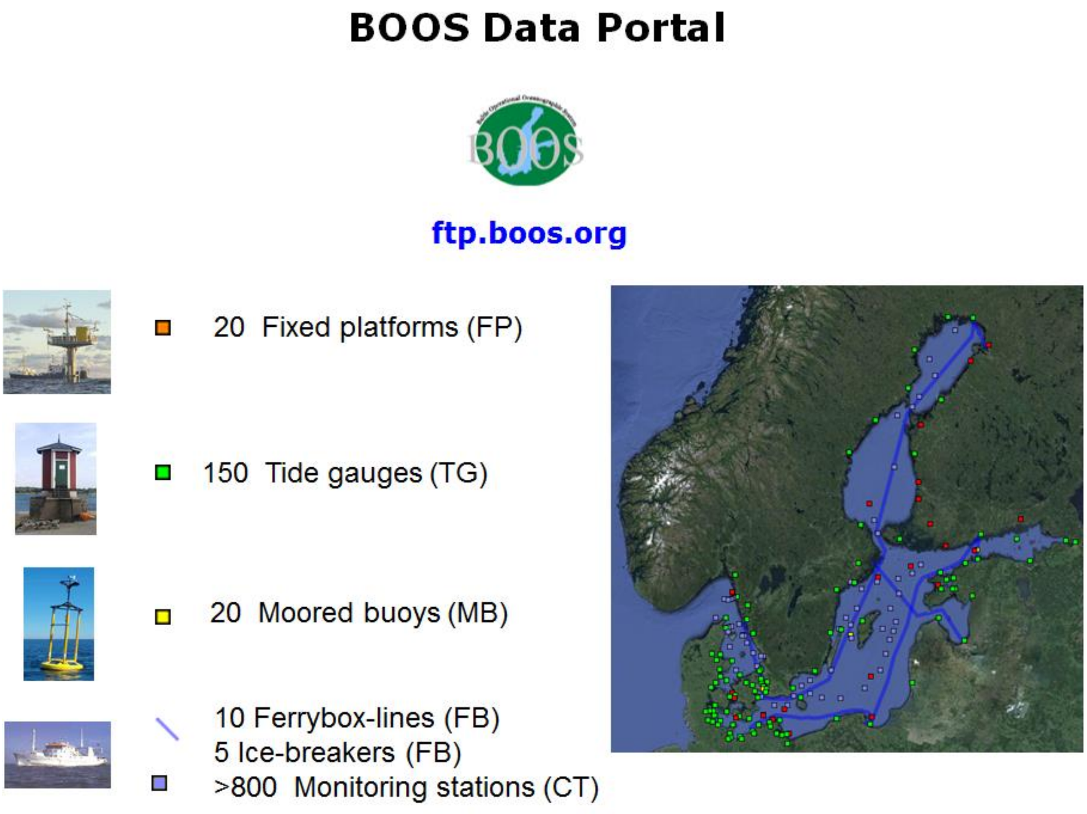


Figure 53. Observations available in the BOOS Data Portal.

3.3.2.4. EMODnet Physics database

The EMODnet Physics is being developed through a stepwise approach in three major stages and is currently in its second phase of development (2013 - 2016). It is a one-stop portal to access to near real time and historical achieved data sets. It provides a combined array of services and functionalities (such as dynamic map facility for viewing and downloading, dashboard reporting and machine-to-machine communication services) to users for obtaining free of charge data, meta-data and data products on the physical conditions of European sea basins and oceans.

EMODnet Physics is built on and it is working in coordination and cooperation EuroGOOS-ROOSs, CMEMS and the SeaDataNet network of NODCs.

As Pan-European marine data collector, EMODnet Physics is providing access to near real-time in-situ observations from operational data provider BOOS and CMEMS In-situ TAC, as well as having access to the archived data from SeaDataNet.

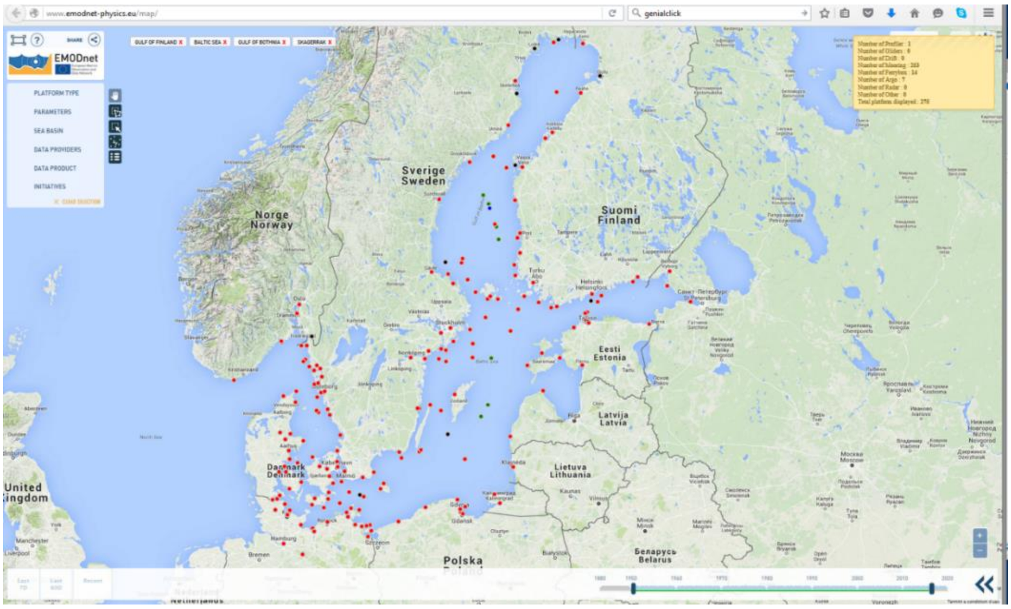


Figure 54. Platforms in EMODnet Physics (operational and historical validated data)
(http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932016417066268*)*

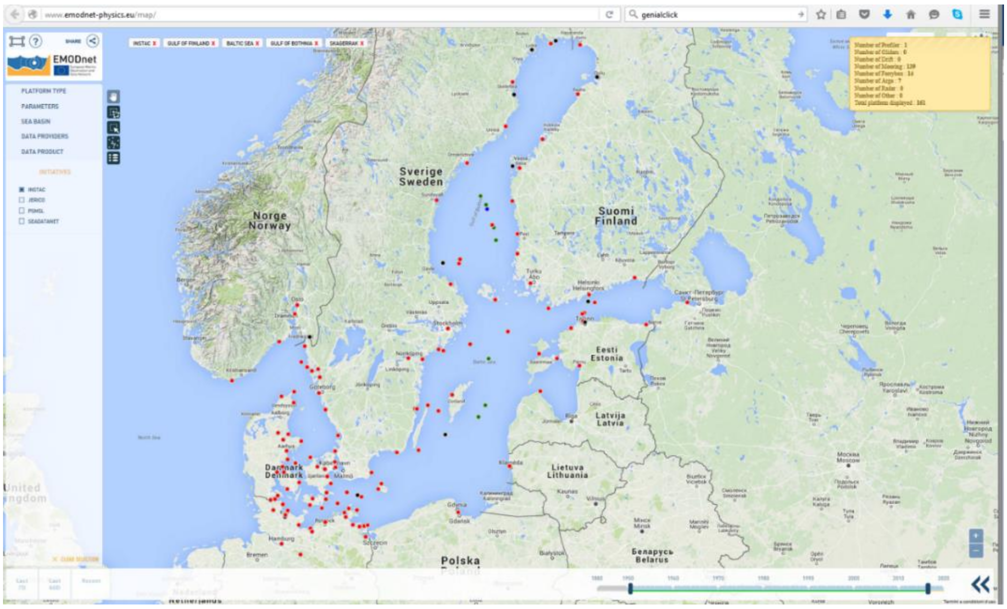


Figure 55. Platforms coming from the BOOS and CMEMS. For these platforms, all available data are downloadable from EMODnet Physics directly.
(http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932018153435582*)*

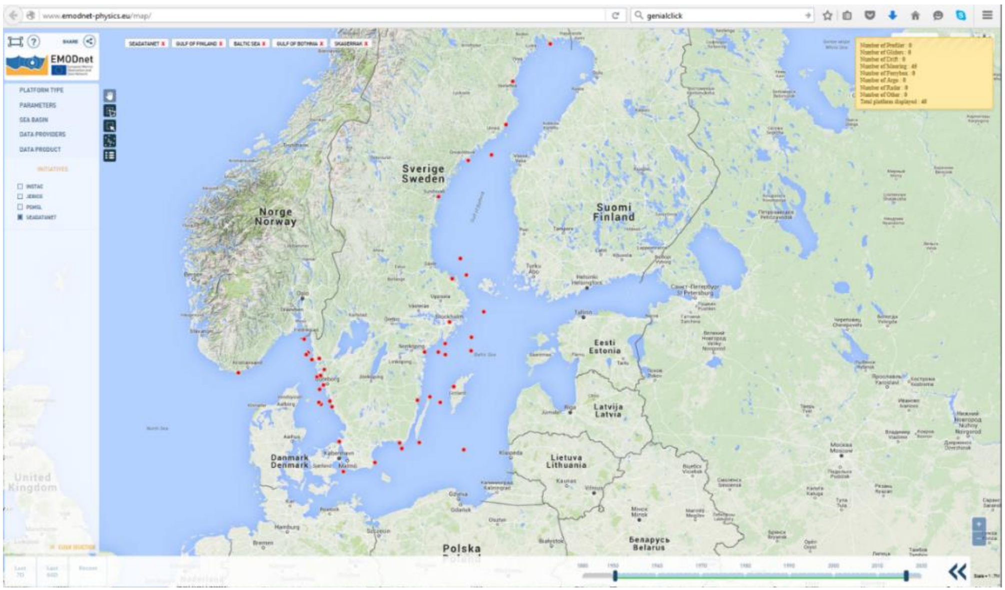


Figure 56. Platforms with CDIs in EMODnet Physics – if a platform has a CDI, it has a SeaDataNet historical validated data. EMODnet Physics can support the user to select CDIs but the user can only download these datasets via SeaDataNet.
(**[**http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932018807973020**](http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932018807973020)**)

Data for long term assessments, model trend analysis and for model skill analysis, which are based on scenario studies haves to be taken from SeaDataNet climatologies or from ICES databases. The number of available storm scenarios with low probability depends on the length of the time series. Model skill in predicting extreme conditions is of interest for wind farm construction companies, but operators are more interested in typical conditions at the site. Ocean models are therefore evaluated for a broad range of weather situations.

Historical time series of sea level data are available via the permanent service for Mean Sea Level (PSMSL). The same data are also available in EMODnet Physics (http://www.emodnet-physics.eu/Map/Products/PRPSMSL.aspx).

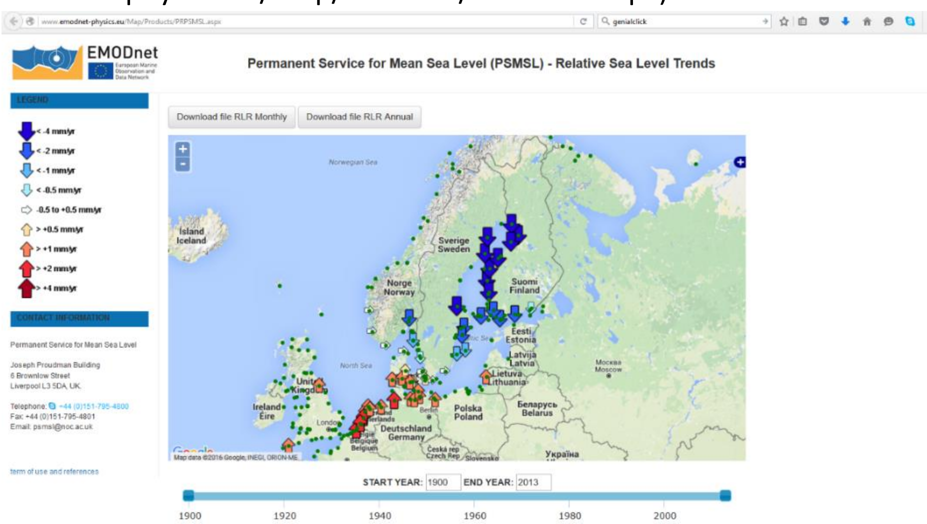


Figure 57. PSMSL via EMODnet Physics

EMODnet data coverage in the Baltic Sea is supposed to match the coverage of the regional and operational data provider BOOS and MyO/CMEMS. This does not seem to be the case, as a comparison of the list of stations shows.

In EMODnet there are at least 3 platforms that are not in the BOOS/CMEMS (Table 7).

Table 7. EMODnet platforms not included in the BOOS/CMEMS.

platform name	parameters	Provider/owner
6902020	PRES,TEMP,PSAL,TEMP_DOXY,DOX2,CHLT,SCATTERING	FMI
6902021	PRES,TEMP	FMI
KielTG	DEPH,SLEV	WSAL

There is some ambiguity in the search results as BOOS lists some of the stations twice, as fixed moorings and as tide gauge stations, when sea level additional parameter are recorded.

BOOS and MyO/CMEMS as regional, operational data provider are collecting observations from national data providers, i.e. tide gauge stations, buoys, fixed moorings, ship cruise data and ferry box data, as well as operational wave and circulation model forecasts of basin scale models. In terms of in-situ observations the two platforms are mirroring each other.

Sea level: BOOS lists 127 tide gauge stations of which 16 stations in the south-eastern Baltic Sea are not available at the moment, whereas EMODnet lists 121 stations including 2 extra stations in the Skagerrak that are not included in the BOOS list. There are 4 BOOS stations missing: 127-16=111 to 109-2=107.

Temperature: BOOS lists 178 results of which 17 are not available, 4 are ferry box lines and 107 are ship cruise stations, so that 50 stations remain. EMODnet lists 57 stations and 12 ferry box lines, with one station in the Skagerrak being outside the BOOS domain.

Salinity: BOOS lists 130 results of which 12 are not available, 4 are ferry box lines and 107 are ship cruise stations, so that only 7 currently active stations remain. EMODnet lists 20.

Currents: BOOS lists 17 results (Drogden is counted twice) of which only 7 refer to available buoys and only 2 seem to be currently active. EMODnet lists 11 moorings and 1 radar station.

HELCOM, ICES databases seem to be less relevant for ocean data related wind farm sighting activities. HELCOM is focusing mainly on water quality and biological parameter and ICES is including cruise data, sparse in time and space.

EMODnet Physics BOOS/CMEMS platforms:
Sea level (146)

http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932025275992969
operational (with data in last 60 days) 117
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932026102050217

Temperature (72)
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932027145109877
operational 52
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932027438656666

Salinity (22)
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932018153435582
Operational 9
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932018153435582

Currents (9)
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932028712889548
operational 6
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932029114292507

Wave (18)
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932035764232862
operational 11
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932036275162086

Biochemical data (20)
http://www.emodnet-physics.eu/map/DefaultMap.aspx?sessionid=635932030325701796
http://www.emodnet-physics.eu/map/platinfo/piroosplot.aspx?platformid=8427

3.3.2.5. SeaDataNet database

SeaDataNet is operating a Pan-European infrastructure for ocean and maritime data collection since it was established in 2006, financed by the EU 6-th framework program. The data portal is continuously developed. It is a distributed datacentre that is based on so called common data index (CDI) database, which makes possible that the data itself is located and maintained in national data centres or originator institutes and the system collects the data from these to the user “behind the scenes”. Thus, the data includes research cruise data and other observations from National Oceanographic Data Centres, maritime information services and research institutes from 35 European states. SeaDataNet provides also aggregated products and climatology’s, by collecting data from as many as 62 providers, including data centres that may not be part of BOOS and MyOcean/Copernicus. The quality of the available data is controlled and managed at data providing centres, monitored by SeaDataNet. The quality requirements are generally high, which prevents real time data provision. Data access to the aggregated product is therewith delayed by usually one year. Available data products for the Baltic Sea include temperature and salinity observations of version

V1.1 and V2, which differ in data extend. Provisions for additional parameters have been made by defining quality control guidelines for current meter measurements, wave data and sea level data. The Baltic Sea catalogue of aggregated data starts at 1900 and includes historical data, which seems to be unavailable via EMODnet.

Within SeaDataNet, the data from the Baltic Sea, among others, has been quality controlled again for producing climatology's. These climatology datasets are available from SeaDataNet (http://www.seadatanet.org/Products/Aggregated-datasets) and at present, they contain data between and including 1900 and 2014. The number of stations is 358.419 from which 34.465 are from Skagerrak. The SeaDataNet data is also more or less the same as in ICES oceanographic database because ICES and the Baltic Sea countries are partners in SeaDataNet.

3.3.2.6. Baltic Nest Institute database

Baltic Nest Institute (http://www.balticnest.org/) has Baltic Environment Database, BED (http://nest.su.se/bed/) that is available in Internet. The data can be visualized with Data Assimilation System, DAS (Sokolov et el., 1997), or with Nest –system. The data comes from different institutes around the Baltic Sea.

3.3.2.7 EMSA

Oil spill at sea is a great threat on the marine environment and marine ecosystem health. In this section we describe the usage of marine data in identify and forecast the position, type and amount of oil spill in the Baltic Sea.

Identification of oil spill

EMSA has developed an "Integrated European satellite-based aerial oil spill surveillance and vessel detection service" through CleanSeaNet project. The service provides users with satellite images (with oil spill identification) within 30 minutes (Figure 58)

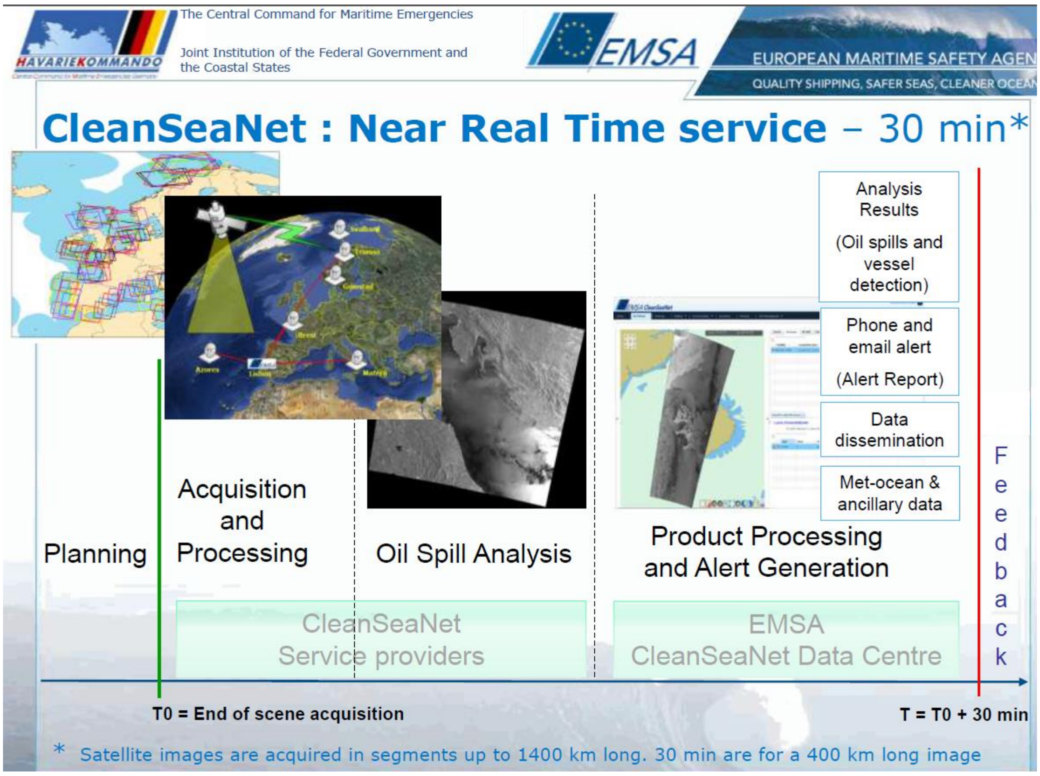


Figure 58. Illustration of CleanSeaNet near real time service.

EMSA also provides large amount of oil-spill combatting related marine data through its ordering system, which includes:

- Long Range Identification and Tracking (LRIT) data
- CleanSeaNet image data
- Satellite AIS data
- SafeSeaNet Data

LRIT is a global ship identification and tracking system based on satellite communication. Under IMO regulations, certain categories of vessels send mandatory position reports once every six hours. The LRIT data available at EMSA includes the position data of ships flying an EU Member State flag. Data dating back as far as June 2009, when the EU LRIT Data Centre was established, is available. Each position includes the latitude and longitude of the ship, as well as the ship particulars and time stamp indicating when the information was received by the Data Centre. Information includes Automatic Identification System (AIS) data as well as additional ship and voyage information.

The CleanSeaNet provide following image data:

a) satellite radar images;
b) oil spill statistics;
c) vessel detection data;
d) additional Member State data, e.g. on confirmation of spills.

Satellite AIS data available at EMSA consists of AIS position data transmitted from ships fitted with AIS equipment and which is made available to EMSA by satellite AIS data providers. Data is available from mid-2010 to the present day. A global feed of Satellite AIS data is currently available through an arrangement that EMSA has with the European Space Agency (ESA) as part of the ESA-EMSA SAT-AIS initiative and by means of an agreement reached with the Norwegian Coastal Administration that enables EMSA to receive SAT-AIS data from the Norwegian satellite AISSat-1.

SafeSeaNet information includes Automatic Identification System (AIS) data as well as additional ship and voyage information, including: port notifications (e.g. pre-arrival, arrival and departure times), Hazmat notifications (carriage of dangerous and polluting goods), ship notifications (additional information sent in mandatory reporting areas), and incident reports (e.g. pollution reports).

For more details on how to order the data, go to http://emsa.europa.eu/emsa-documents/data-request-procedure/download/2822/2076/23.html .

In-situ observations are needed for identifying the time, location, types and amount of the spilled oil. These data are essential for making oil drift forecast.

Oil drift forecast and backtracking

After the oil spill information is identified and sent to the operational forecasting agency, an oil drift forecast can be made by using an oil drift model. The model in general is able to predict the 3D oil trajectory in the coming days and also back-tracking the origin of the oil or objects. Most of these *3D Drift Models* predict drift and dispersion processes at sea applying the Lagrangian dispersion formulation (Christiansen, 2003).

Four types of drifts may be considered and simulated by such a model:

- floating object
- dissolved substance
- oil spill
- backtracking

The drift of a *floating object* can for example be a “man-over-board”, a container or a ship without a steering ability. The objects are drifting under influence of winds and currents. The drift and dispersion of “*Dissolved substance”* and *“oil spill”* are represented by a particle cloud drifting with the current. The particle cloud can either be released instantaneously or continuously. For substances and oil floating on the surface 3% of the wind speed is added to the drift. Turbulence induced motion is taken into account and described by the Monte Carlo method.

In the simulation of *oil drift and dispersion*, the model includes the so-called; “weathering processes”, which is the collectively term for: oil spreading, evaporation, dispersion (vertical and horizontal), emulsification and dissolution. As the weathering processes depend on the oil types (oil’s chemical compounds and physical properties as: density, viscosity, maximum evaporation and pour point) – the model also takes into account different oil types. In the model the oil types are defined by 7-14 groups of hydrocarbon compounds and by a residuum. The so-called *"backtracking"* is a simulation back in time to trace the source of pollution or where an object came from.

In addition to the meteorological and hydrodynamic data input, a set of information's concerning the spill conditions and oil properties must be given:

- spill location (latitude, longitude)
- oil type/oil density [kg/m3]
- spill rate [m3/hour] – or instantaneous volume spill
- spill duration [hours]
- spill situation (surface or seabed release)
- water temperature

In case of a seabed release the water depth at the spill is needed.

Major input data for the model include forecast fields of winds at 10m height, water level and 3D current field simulated by an Ocean Circulation Model. The applied current field includes both wind-induced motion, contribution from density-driven motion, tidal current and turbulences motion. Wave-induced Stocks drift is also important. Currently this term is parameterised by the wind.

Among the input data, the winds are one of the main driving forces of oil at the surface. In the case of our oil drift model, the wind related drift amounts to 3% of the wind speed in the direction of the wind. Experiences in BalticWay project showed that during the windy seasons the average wind drift might exceed the current drift by far (depending on the season).

Below the surface, currents are the main driving force. The oil is transported much slower than at the surface and it usually does not remerge at the surface, but sinks down to the sea floor.

As to oil drift simulations, high-resolution topography can also be one of the important factors, beside oil type and winds, especially in the near-coastal zone. Oil type defines the chemistry and therewith the weathering of oil, wind describes the main forcing factor, topography defines the drift pattern and currents might actually steer the drift in the near coastal zone.

In the near-coastal zone, long-shore currents might actually act as a kind of protector to some coastal stretches. In the BalticWay project, some partners used current driven lagrangian transport model and the oil rarely hit the coast (Murawski and Nielsen, 2013). Wind in the direction of the coast acts as an onshore driving force. In their lagrangian transport simulation (no wind drift was involved), they had to define a near coastal zone that would act as a kind of stretched out coast. When oil was hitting this zone, it was counted as stranded.

3.3.2.8. Other international databases

EIONET Central Data Repository: This database holds among others data on transitional, coastal and marine waters, reported for EU obligations.

PSMSL: For the assessment of long-term sea level variations in the Baltic Sea coasts, the main data need is quality-controlled observations of long-term variations in sea level, and for this, the main source is monthly mean data from PSMSL (Holgate et al., 2013; PSMSL, 2015). However, in the PSMSL database, there is a lack of stations with long term observations reaching present day in the south eastern Baltic Sea (Hünicke et al., 2015) which need to be solved by use of national databases. Addressing river runoff there are many databases to consider:

- the Global Runoff Center (GRDS) has a global runoff database with discharge data collected at daily or monthly intervals from more than 9000 stations in 160 countries;
- the BALTEX Hydrological Data Center (BHDC) hosted by SMHI store hydrological data from the countries draining into the Baltic Sea. Daily and monthly discharge data is available for some years;
- the European Water Archive (EWA) contains daily discharge data and catchment information for more than 4000 stations in 30 countries;
- other providers of databases for nutrient loads include HELCOM (PLC data) and EEA;
- sediment loads are needed. A database was built within the EUROSION program and it can be downloaded as vector and point data from EEA;
- topography for worldwide catchment systems has been developed by WWF in the HydroSHED database including stream networks, watershed boundaries, drainage directions, and other data layers such as flow accumulations, distances, and river topology information. HYDRO1k is another geographic database developed by USGS;
- soil characteristics needed is available in the Digital Soil Map of the World (DSMW) developed by FAO/UNESCO. In Europe there is also the European Soil Databases (ESDB). This database is published by DG JRC and its scale 1:1 000 000;
- land use characteristics are available in CORIN land cover developed within the Corine programme initiated in the European Union and now available through EEA. Scale is 1:100 000 and land cover is divided in 44 classes. Areas not covered by Corine can find dataset in the Global Land Cover 2000 Project (GLC 2000) a global product developed by JRC;
- urban areas with impervious surfaces are in a database, produced by GeoVille, Planetek, Infoterra, Euroland Soil Sealing for urban area. It tells to what degree the soil is impervious;
- lakes and wetlands can be found in the Global Lakes and Wetland Database (GLWD) developed by Lehner and Döll in 2004. The database focuses on large lakes and reservoirs, smaller water bodies and wetlands at a global scale based on the best available information. The database is free to download;
- irrigated areas can be found in the European Irrigation Map (EIM) developed by Wriedt et al 2009. It covers Europe and is a combination on statistical information and the Global map of irrigation;
- information on crops grown and crops water demand is available in the MIRCA2000 data set. MIRCA2000 is the global monthly irrigated and rain fed crop areas around the year 2000 and the data set has been developed for agricultural and hydrological modeling by Portmann et al in 2010;
- FAO Irrigation and Drainage Paper No. 56 is useful for calculating crop water requirements.

3.3.2.9. National databases

Some National Data Centres in the Baltic Sea and North Sea are unique in the sense that they are not only collecting points of national monitoring programmes, but act also as responsible focal data centres for international cooperation initiatives like BOOS, NOOS and MyOcean/Copernicus, that are dealing with operational monitoring data. In the Baltic, SMHI is responsible for tide gauges and moored buoys, SYKE and MSI is providing ferrybox data (Alg@line) and BSH is delivering data from fixed platforms (MARNET stations)), and MSI is delivering data from autonomous profiling buoy station in the Gulf of Finland.

DMI is Denmark's national responsible centre for operational oceanographic forecasts and storm surge prediction, with strong focus on monitoring the physical processes in the seas around Denmark and Greenland. Sea level is in the main focus of DMI's monitoring strategy, but current and temperature profilers in the Danish straits are operated as well. DMI is collecting data from its own stations and is receiving oceanographic data from the Danish network of monitoring stations, operated by the Coastal Authorities (KDI), municipalities and local providers. DMI owns 34 sea level stations, mostly situated in transition zone between North Sea and Baltic Sea, of which 27 measure temperature as well. It has also access to 30 KDI sea level stations along the Westcoast of Denmark, of which 6 stations measure temperature. On top of these more permanent stations, from which data is provided to BOOS, NOOS and MyOcean/Copernicus, there are currently 23 sea level stations from harbours and local municipalities, which are not provided further to any user outside DMI. From these stations, 6 are measuring temperature as well. Historical sea level data has been made available to MyOcean/Copernicus with the purpose to model reanalysis validation. This data is not available via EMODnet and SeaDataNet. DMI has also become responsible for 3 mooring stations in the Danish Straits: W26 (Österrenden), Vengence Ground and Drogden, which measure water temperature and currents, and in case of Drogden also sea level. Temperature and current data has not been made available to BOOS, but is stored at DMI for further analysis. Wave monitoring in Denmark is carried out by the coastal authorities KDI, who operate 5 wave riders along the Westcoast of Denmark, outside the focus area of this study.

Denmark's Centre for Environment and Energy (DCE) is organising regular research cruises to a network of monitoring stations in the seas around Denmark. Environmental and ecological parameters are in the focus of the research program, but physical reference data: temperature, salinity, etc. for data analysis are measured as well. These data sets are provided to HELCOM and ICES.

SMHI, the Swedish Meteorological and Hydrological Institute is operating an extensive monitoring programme in the Baltic, using buoys, fixed moorings and research vessels. The ocean data can be accessed via BOOS and MyOcean/Copernicus and SMHI's own database. The ocean data from SMHI open database (http://www.smhi.se/en/services/open-data) is always available with quick online access, free to download in grib format. The data is covering the Baltic Sea area with the horizontal resolution 1 nm, time resolution 1 h. It is near real time data generally used for operational forecasting updated at least every sixth hour. SMHI has developed the hydrological model: Hydrological Predictions for the Environment (E-HYPE). The model is open source and through a web interface simulated discharge time-series can be downloaded for the drainage area of the Baltic Sea. Nutrient load for phosphorus and nitrogen is also available.

FMI, the Finish Meteorological Institute, is responsible of physical oceanography monitoring of the open sea areas in Finland. This is done by research ship, some fixed oceanographic stations and now since a couple of years with Argo-buoys. The Argo-buoys are in the middle of the Bothnian Sea and in the Gotland deep area in the Baltic Sea Proper. FMI runs the Finnish sea level network that has 14 sea level stations along the coast of Finland, the longest time series being from Hanko since autumn 1887. Sea level data is complemented by sea level forecasts, too. FMI has four operational moored wave buoys and gives wave forecast in addition to the data for the entire Baltic Sea and for the Archipelago Sea, too. The ice service of Finland is part of FMI, too. This includes regular monitoring of ice situation, production of ice charts and delivering other types of ice related products that are based on remote sensing and ice modelling. One development is the use of coastal radars in following the real-time ice movements.

Many of FMI's historical and real-time datasets are available via FMI's open data (https://en.ilmatieteenlaitos.fi/open-data).

The Finnish Environment Institute (SYKE) is responsible of bio-chemical monitoring of the sea in Finland. It conducts regular monitoring cruises with its research ship Aranda. Monitoring data has so far been collected to a common monitoring database with FMI, but the situation is changing. SYKE maintains Finnish environment administrations databases where monitoring data from coastal stations are stored. Environmental authorities along the coasts of Finland do the observations. The databases have open access (http://www.syke.fi/en-US/Open_information).

Natural Resources Institute Finland (LUKE) is responsible for fisheries research and statistics in Finland. The fisheries statistics since 1980 can be found and downloaded from (http://stat.luke.fi/en/commercial-marine-fishery). There are several parameter groups, like aquaculture, commercial fishing, recreational fishing and fish production. Aquaculture data includes information on number of fish farms since 1993, food fish production, food fish production by species, food fish production by area, production of fish juveniles and the value of fry production. Commercial marine fishery statistics include number of commercial fishermen, number of registered vessels, amount of catches and value of catches and fishing effort in commercial marine fishery. Available are also statistic on recreational fishing and fish processing.

Metsähallitus (Finnish forest administration) is a state-run enterprise whose tasks are divided into business activities and primarily budget-funded public administration duties (http://www.metsa.fi/web/en/organisation#sthash.qXGT05hU.dpuf). It collect data from the coastal waters of Finland and manages e.g. national parks.

SYKE and other organisations, including Metsähallitus, LUKE, Geological survey of Finland and others, published in 2016 a map portal/service VELMU (The Finnish Inventory Programme for the Underwater Marine Environment) (http://paikkatieto.ymparisto.fi/velmuviewers/Html5Viewer_2_5_2/Index.html?configBase=http://paikkatieto.ymparisto.fi/Geocortex/Essentials/REST/sites/VELMU_karttapalvelu/viewers/HTML5/virtualdirectory/Resources/Config/Default) where there is data on species observations, biotopes and habitats and environmental variables. The portal also displays human activities and pressures and general information on the underwater marine environment and its protection.

Marine Systems Institute at Tallinn University of Technology (MSI, Estonia) conducts open sea monitoring as part of national environmental monitoring program in Estonia. MSI runs ferryboxes, autonomous profiling buoys and sea level stations (11 coastal stations, where also meteorological parameters are recorded). MSI has established operational near real time data delivery via the BOOS consortium (available also via Copernicus marine service and EMODnet physics portals), and developed operational sea level forecast system for Estonian sea area. MSI operates an operational wave buoy in the Northern Baltic Sea and has built a cabled profiling station in the Gulf of Finland.

BSH, the German Federal Agency for Sea-Shipping and Hydrography operates a system of fixed monitoring platforms: MARNET in the North and Baltic Sea. The 6 stations in the southern Baltic Sea, between Denmark and Germany are measuring profiles of temperature, salinity, currents and density at all stations, as well as oxygen, turbidity and chlorophyll at some stations.

National ice services collect the data of the ice cover in the Baltic Sea. They operate in close co-operation with operative services. There exists operational ice data that is available, but long-term, high-quality data that is needed for marine spatial planning and climate studies is not as easily available. Daily ice charts are only available for the recent years, but twice weekly products covering the entire Baltic Sea have been provided by FMI, SMHI and BSH for at least 30 years. Problematic are the early years, which do not include as many observations. For maritime planning, these data sets are just long enough to provide significance to the statistical results. Alternatively, climatological ice atlases use statistical methods to compile long-term data sets of ice parameters, covering recent and historic periods alike.

For climate change studies the time series of maximum annual ice extent of the Baltic Sea is a lot used. It consists of data from winter 1719/1720. The old part of the time series was constructed by R. Jurva (see Palosuo, 1953).

SMHI and FMI produced in 1982 in co-operation and ice atlas for the Baltic Sea (A climatological ice atlas for the Baltic Sea, Kattegat, Skagerrak and Lake Vänern (1963-1979)). The data of the atlas is available in gridded form. Another atlas "Phases of the ice season in the Baltic Sea North of latitude 57°N" was published in 1988. It gives the ice winter phases as numbers, too, for the winters 1963/64 – 1979/80.

BSH Climatological Ice Atlas for the western and southern Baltic Sea (1961-2010), a statistical evaluation of 50 years ice observation south of 56°N.

From the user's point of view the data is available from one point though it comes from several data centres because of the distributed structure. Some national data centres, like SMHI and FMI, have implemented their own open data services for their national monitoring data following the INSPIRE directives requirements.

3.3.3 Biology/Biota

The main database for biota/biology data for the Baltic Sea is the ICES/HELCOM databases, while others such as EMODnet plays a minor role at present.

3.3.3.1 ICES/HELCOM

Fishery:

Landings in weight:

ICES (International Council for Exploration of the Sea) has been gathering and publishing fisheries landings statistics since 1904. Due to historical reasons, the landings data available from ICES website are split into three datasets:

- ICES Historical Landings 1903-1949
- Historical Nominal Catches 1950-2010
- Official Nominal Catches 2006-present

The current data is collected and coordinated in collaboration with Statistical Office of the European Communities (EUROSTAT). The data sources are the national statistical offices, in some countries the collection and compilation of fisheries statistics are handled by specialized organizations. The geographical breakdown is according to the ICES system of subareas, divisions and subdivisions.

All landings statistics gathered since 1903 are freely downloadable electronically from ICES website in form of archived data files in .xls and .csv format. The data in other formats can be supplied per request. The data are arranged as nominal catches in tonnes live weight per country per species per area and year. The landings of both internationally regulated fish and the more coastal species that are regulated nationally are included in the database. ICES Catch Statistics dataset is updated every year. ICES Working Group members can view the last year's preliminary catch data from March next year. Other users can get access to these preliminary last years' data per request. Data presented in the datasets have not been corrected for non-reported landings, where these may have occurred. Therefore, in some cases, the data differ from those presented in ICES fish stock assessment working group reports. The landings data are constantly updated with corrections and amendments that the countries provide after the submission deadlines.

Landings in numbers:

The landings in numbers of individuals can be obtained by combining landings in weight with biological sampling for size/age compositions of landings and body weight of individual fish. This information is presently collected under of the data collection regulation (EC, 2000) and framework (EC, 2008). Information on landings in numbers for assessed species (cod, herring, sprat, flatfish) are compiled by ICES. For these purposes, a web-based system Intercatch and Regonal Database FishFrame are available. In InterCatch national institutes can upload national data. Fish stock coordinators can compile international catch in numbers for a stock that are subsequently used as input to fish stock assessment models. InterCatch is developed to ease data handling, standardize procedures and calculations, remove errors and document the national data and process done at ICES level. The Regional DataBase Fishframe is a regionally coordinated database platform for fisheries assessments. The Regional DataBase FishFrame is an important tool to assist in a regional approach to survey design and data collection, it supports the Regional Coordination Meetings, including Baltic Sea. The Regional DataBase FishFrame platform was developed by the National Institute of Aquatic Resources at the Technical University of Denmark (DTU-Aqua), now hosted and maintained by ICES for the preparation and analysis of commercial catch and landing data received from the cooperating countries. Both InterCatch and FishFrame are tools that can be used within ICES (i.e. require login) while the outputs, including annual landings in numbers of different fish stocks are publicly available through annual reports of the Baltic Fisheries Stock Assessment Working Group (WGBFAS). The reports are downloadable from ICES website.

In the Baltic Fisheries Stock Assessment Working Group (WGBFAS) reports, the data are compiled by Subdivisions and quarters of the years. The longest time series are available for cod extending back to the 1960s, for herring and sprat the time series start in the mid-1970s while for some flatfishes the ICES time series of landings in numbers only starts in the 2000s.

Discards:

Data on discards are collected through internationally coordinated sampling at sea using observers. The longest data series start in the mid-1990s. The data for internationally regulated species are compiled in ICES, similarly to landings in numbers described above. The outputs in terms of discards in weight and in numbers for cod and flatfish are available from the WGBFAS annual reports, downloadable from ICES website.

The quality of discard information has improved over time. Uncertainties in discard estimates are mainly related to in some cases low sampling levels, high variability in observed discard rates and variable calculation procedures applied to raise the sampled discards to the level of fisheries.

*By-catch of marine mammals and seabirds**:***

ICES collates information on bycatch under the Working Group on Bycatch of Protected Species (WGBYC). Since the commencement of WGBYC in 2009, the WG has been collating, storing and summarizing annual data reported by European member states. This has resulted in the development of WGBYC database that currently stores data on dedicated monitoring effort and bycatch of cetaceans as reported to the European Commission by member states under the Regulation 812/2004. The data reported by member states start from 2006 and are stratified by species, broad gear type (i.e. gillnets and pelagic trawls), year, and RCM region and include records collected by traditional fisheries observers and remote electronic monitoring (REM) methods. Bycatch rates are calculated by dividing the total observed number of specimens by the annual total observer effort defined as days at sea (ICES, 2015).

WGBYC cooperates with the ICES Data Centre to make advances toward a more comprehensive database design. Presently, overviews of the information available in WGBYC are presented in the annual reports of the WG; the reports are freely available for download from ICES website (e.g. ICES, 2015).

A significant limitation in evaluating the magnitude of bycatch mortality since the implementation of Council Regulation No 812/2004 is not having an accurate estimate or census of total fishing effort. With the cooperation of the ICES Data Centre, WGBYC long-term goal is to obtain a census of total fishing effort through more appropriate databases. Potential significant sources of uncertainty in bycatch rates include missing data and different monitoring duties among regions. Measures of uncertainty are generally not reported in the Reg. 812 MS reports. As a result it is not possible to properly assess if apparent “trends” in the bycatch rate data are significant, as it is unknown how much variability is associated with each of the point estimates (ICES, 2015).

Information on by-catch on other species, such as seals and waterbirds is sporadic and scares and there is currently no coordinated monitoring of by-catch. WGBYC database does include bycatch data for some other species than cetaceans but is provided in a non-systematic fashion (e.g. voluntarily submitted by MS that may have additional bycatch data via the DCF or other monitoring sources).

Phytoplankton

Under challenge 4 (Climate change) the trend analysis of Baltic Sea phytoplankton abundance will be done using 4 species – 2 spring species (*Achnanthes taeniata* – diatom; *Peridiniella catenata* – dinoflagellate) and 2 summer species (*Nodularia spumigena* – cyanobacteria; *Heterocapsa triquetra* – dinoflagellate). These species were chosen as they form an important part in the spring and summer bloom, respectively, and their systematics has not changed much over the years. Baltic Sea Checkpoint has identified several international and national databases, which may be used for such analysis.

The ICES/HELCOM database is containing phytoplankton time series for a period of 1979-2014, which makes it the main source of data for the initial trend analysis of phytoplankton abundance. The spatial coverage of data is whole Baltic Sea, data are collected either monthly or yearly from HELCOM coastal and open sea stations from the surface layer (mostly integrated water samples from depth of 1-10 or 1-20 m).

The data are free with quick on-line access and data source always available. The data are easy to locate – either direct download from the online database or through direct contact with data managers. The latter is more useful if also data about the data provider/country and division by HELCOM sub-basins is needed, as this information is not available when one is downloading data from the on-line database. The origin of data is necessary in order to analyse the completeness of the dataset. By now, the project has identified that there are lot of missing data in the ICES/HELCOM phytoplankton database and we there is a need to complement these data series by turning directly to the national data holders of different Baltic Sea member states. The reason for missing data is not always due to data providers not submitting the data. Very often, there have been an error in provided datasets and ICES data managers have asked the data provider to make corrections and resubmit the data. Unfortunately, often data providers have not responded and so there are many datasets in status “pending submitter”, some already for several years. It was surprising to find many datasets in status “pending ICES” for five or more years. Meaning, that the delay is from ICES side. The high percentage of data in pending status lowers the reliability of analysis completed using the ICES/HELCOM database only.

Eutrophication

The eutrophication assessment for the Baltic Sea should be made using HELCOM core indicators – dissolved inorganic nitrogen and phosphorus, chlorophyll-*a,* water clarity and oxygen. These indicators represent nutrient status and its direct and indirect effects which are all essential when assessing the eutrophication status of the Baltic Sea for the years 2005-2014. For nutrient indicators the wintertime (Dec-Feb) data from surface layer (1-10 m) is used. Summer (June-Sept) data is used for chlorophyll-*a* (surface layer – 1-10m) and Secchi depth. For oxygen data from the entire year is used. Now the project has been focusing on three major international databases from where the data could be used for the eutrophication assessment.

The ICES/HELCOM database contains in-situ data from 1900 to 2015. Spatial coverage is the whole Baltic Sea. At this moment it is unknown if all the sub basins are covered with sufficient data. The database provides a freely downloadable Excel file (all data from 1900 to 2015) which can be easily opened and manipulated. A big problem is that stations are not associated with assessment areas. After contacting ICES an Excel file was provided where stations were associated with assessment areas. The temporal and spatial sufficiency of the database is not yet determined.

Marine protected areas

HELCOM provides main data sources for this challenge. It consists of checklists for Baltic Sea dwelling species, lists and description of red-listed species, HELCOM Baltic Sea Data and Map service (http://maps.helcom.fi/website/mapservice/index.html) provides georeferenced information on some pressures and maritime activities such as offshore wind farms, dredging and dredge spoil dumping areas, maritime traffic, oil discharges, bird hunting areas, also spatial information on the distribution of red-listed species, boundaries of marine protected areas and important bird areas. HELCOM MPAs database (http://mpas.helcom.fi/apex/f?p=103:1) provide description of Baltic Sea MPAs, their protection status with links to management plans and IUCN categories.

The detailed information on the distribution of waterbirds in the Baltic Sea is provided in the report "Waterbird Populations and Pressures in the Baltic Sea" (Skov et al., 2011), done under the SOWBAS project (Status of wintering Waterbird populations in the Baltic Sea).

ICES marine dataset collections (http://www.ices.dk/marine-data/Pages/default.aspx) can be used as a supplementary sources, especially for the spatial distribution of zoobenthos and phytobenthos species.

Wind Farming

In the HELCOM database the data for fish, birds, marine mammals are easy to locate and freely accessibly from online database. The data can be downloaded as digital shape file format and can be used in plotting as layers e.g. in Ocean Data Viewer (ODV). The datasets have the detailed metadata included with the data updates and contacts information for future inquiries.

ICES receive the data from national programmes and marine institute, therefore it only holds the data provided to them by the institutes. However, it contains a lot of information about different parameters in question. It is possible to search datasets available for certain areas while selecting the search area straight from the map. This makes it easier to look for all the datasets available for particular area instead of looking for particular dataset, e.g. biological community data, oceanographic data, etc.

3.3.3.2 EMODnet database

Phytoplankton

Phytoplankton data in the EMODNET Biology database cover years 1983-2013. The data available at the present are mostly provided by Sweden or ICES. Hence, even the coverage on a map might look promising, after closer examination of the data, these are not suitable data for the Baltic Sea wide trend analysis and therefore the project will not use this database. The data, which are in the database, are free with on-line access and data source always available. The data can be downloaded by species under interest.

Eutrophication

The EMODNET Chemistry database covers the necessary years for the assessment with in-situ data for the entire Baltic Sea. At this moment it is unknown if all the sub-basins are covered with sufficient data. The EMODNET Chemistry database provides data access to registered users through an extensive query interface. After selecting the desired data the datasets have to be added to a basket maximum 1000 at a time and maximum 10 000 per request. This makes data requesting inconvenient considering the amount of data needed for the eutrophication assessment (~ 50 000 datasets). After requesting the data the datasets wait the approval of data holders. When requesting the data for most of it access was granted except for Institute of Meteorology and Water Management, Maritime Branch in Gdynia (IMWM MB) Poland.

Wind Farming

EMODnet Biology database contains data for biomass, abundance, formations, angiosperm, macro-algae, invertebrate bottom fauna, birds, fish mammals - the portal is freely accessible with the data source always available. It is possible to search the data by species names and/or by datasets or by selecting from available species lists that are already inserted to the data portal. However, if one is looking for species information for certain sea area, e.g. the Baltic Sea, then it is not possible to limit the search into the areas. Also the data about mammals e.g. is available only on harbour porpoise which is based on HELCOM data.

3.3.3.3 Copernicus

Eutrophication

The COPERNICUS database covers the necessary years for the assessment with in-situ data for the entire Baltic Sea. The database provides Baltic Sea wide in-situ near real time observations, which can be downloaded as .nc files via ftp access.

3.3.3.4 STECF

Fisheries landings and discards:

Expert Working Group on Fisheries Dependent Information in EU STECF (Scientific, Technical and Economic Committee for Fisheries) provides estimates of fisheries related information, including landings and discards of different species in the Baltic Sea and Kattegat. The information is based on data submitted by Member States. All the annexed tables of the reports of this Expert Group are made available on the STECF website https://datacollection.jrc.ec.europa.eu/dd/effort . Landings and discards are provided by weight and by numbers at age.

The data on annual landings and discards in EU STECF database cover the period from mid2000s onwards. The data are publicly available and free to use. Only data for EU countries are included. Concerning the areas relevant for the Baltic region, the data are available separately for Kattegat and three sub-areas in the Baltic Sea as defined by R (EC) No 1098/2007 (Baltic Sea):

- ICES division 22 to 24,
- ICES divisions 25 to 28, by distinguishing areas 27 and 28.2
- ICES divisions 29 to 32

Reported data by country are aggregated by fisheries properties and raised to the officially reported landings or discards in the format stipulated in the annual DCF fishing effort data calls. The estimation of fisheries specific international landings and discards is based on linking the information about fisheries specific discards and catch and discards at age among countries and replacing poor or lacking values with aggregated information from other countries. Consequently, great care should be used in the interpretation of the discard and resulting catch data owing to the incomplete nature of information on discarded fish. Several procedures are in place to assure quality of data transmitted. Checks are carried out both during the uploading procedure (Syntactic checks) and after the uploading procedure. An important part of the quality assurance is scrutiny by fisheries experts during analyses of processed data at the WG. However, the reliability of the data is highly dependent on the quality of the submissions by the national authorities (STECF, 2015).

Due to the nature of the data tables, there is no release calendar. Release date depends on the calendar of the relevant STECF working groups and the endorsement of the working group outcomes by STECF plenary.

3.3.3.5 National databases

Phytoplankton

Project has collected additional phytoplankton data from Estonia, Latvia, Finland and Sweden. Database from Estonian Environmental Agency contains phytoplankton data from national marine monitoring stations in the Estonian EEZ for a period of 1993-2014. These data are completely missing in the ICES/HELCOM database. Data from SMHI database Sharkweb were compared with the data available in the ICES/HELCOM database in order to identify the need to complement the latter. After personal communication with Latvian data holder LHEI, project has identified that data from only few stations have been submitted to the ICES/HELCOM database. Hence, for the more reliable trend analysis, project requested additional phytoplankton monitoring data for better spatial coverage in the Gulf of Riga and Baltic Proper areas. Requested data were provided and included to the database used for trend analysis. Additional data were also received from Finland after a request. These data will be included to the trend analysis. Project have also requested the additional phytoplankton data from Poland but unfortunately the response have not been positive.

3.3.3.6 Other databases

Fisheries

Bycatch of marine mammals and seabirds:

Number of drowned mammals and waterbirds in fishing gear is one of HELCOM Core Indicators for Biodiversity (Korpinen and Braeger, 2013). In this context, an HELCOM report by Korpinen and Braeger (2013) has gathered information on bycatch from different case studies available for the Baltic Sea. The report includes references to the individual studies in different countries, mainly focusing on bycatch of seabirds. These include studies in Germany, Lithuania (Dagys and Zydelis, 2002; Zydelis et al., 2006), Denmark (Bregnballe and Frederiksen, 2006), Sweden (Olden et al., 1988; Lunneryd et al., 2004; Lunneryd et al., 2005; Larsson and Tyden, 2005; Bardtrum et al., 2009), Poland (Stempniewicz, 1994; Meissner et al., 2001), and Latvia (Urtans and Priednieks, 2000). A review paper on bycatch of seabirds has been produced by Zydelis et al. (2009) and information on harbor porpoise by-catch can be found in Berggren et al. (2002). A recent Danish project on gillnet fisheries in Denmark includes information on bycatch of marine mammals (Olesen et al, 2015).

Phytoplankton

Two major databases compiled during EU funded past projects have been identified:

- Characterization of the Baltic Sea Ecosystem: Dynamics and Function of Coastal Types (CHATM-EVK3-CT-2001-00065)

- Thresholds of Environmental Sustainability (THRESHOLDS) (Global Change and Ecosystems ‘‘GOCE-003900’’).

These databases contain Baltic Sea wide (mainly coastal stations) phytoplankton data series for periods of 1973-2001 and 1966-2008, respectively. Unfortunately, it is not easy to get access to these databases. There are no publicly available on-line databases. Through several personal communications, the project succeeded to get the access for the CHARM phytoplankton database. At the same time, the THRESHOLDS phytoplankton database was announced as restricted by communication with project THRESHOLDS partners.

Eutrophication

EIONET Central Data Repository database holds among others data on transitional, coastal and marine waters, reported for EU obligations. The database holds data gathered by national monitoring programmes. Data can be searched by EU obligation, country or year. Files are provided as .xls files. The temporal and spatial sufficiency of the database is not yet determined.

Alien species

The main data source for this challenge is an online information system on aquatic non-indigenous (NIS) and cryptogenic species introduced to marine, brackish and coastal freshwater environments of Europe and neighboring regions – AquaNIS (www.corpi.ku.lt/databases/aquanis). AquaNIS contains information on 131 species introduced to 10 recipient regions in the Baltic Sea (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia / Kaliningrad area, Russia / St. Petersburg area and Sweden). AquaNIS inherited and incorporated multiple NIS data collections from the earlier projects where the developers of this information system have participated, such as:

- EU Concerted Action "Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters" (1997-1999)
- EU FP6 Integrated Project ALARM "Assessing Large-scale environmental risks with tested methods" (2004-2009)
- EU FP6 project DAISIE "Delivering Alien Species Inventory for Europe" (2005-2008)
- EU FP6 project IMPASSE "Environmental impacts of invasive alien species in aquaculture" (2006-2008)
- EU FP7 project MEECE "Marine Ecosystem Evolution in a Changing Environment" (2008-2012)
- European Census of Marine Life (2009-2010)
- Baltic Sea Alien Species Database (1997-2012)

The system also provides general information for each NIS, including its taxonomy, biological traits (such as reproductive type, characteristic feeding method, mobility, etc.), native origin and availability of molecular information. Taxonomy is based on the updated accounts in major global organism-specific databases such as FishBase (www.fishbase.org) and WoRMS (www.marinespecies.org). Native origin refers to a region where a species originates. It can be indicated according to its biogeographical range at different levels of scale from ocean to a Large Marine Ecosystem or a particular country.

3.3.4 Seabed/Bathymetry

When searching the web for existing literature references to bathymetry for the Baltic Sea created during the last two decades there are a number of sources that appear high on the search results.

3.3.4.1 IOWTOPO 1 and 2

The Leibniz Institut für Ostseeforschung, Warnemünde (IOW) has produced two datasets and published and made them available for download in 2001. These datasets are referenced as IOWTOPO1 and IOWTOPO2 respectively. Earlier datasets have been available, but the objective with these new IOW datasets was to update and make corrections to the earlier versions. The IOWTOPO1 dataset covers only the southwest part (Denmark, Germany, Sweden) of the Baltic Sea and has an approximate resolution of 1 kilometer. The IOWTOPO2 covers the whole Baltic Sea area with an approximate resolution of 2 kilometers. According to the available descriptions, the datasets were created mostly using depth figures and contours from existing nautical charts.

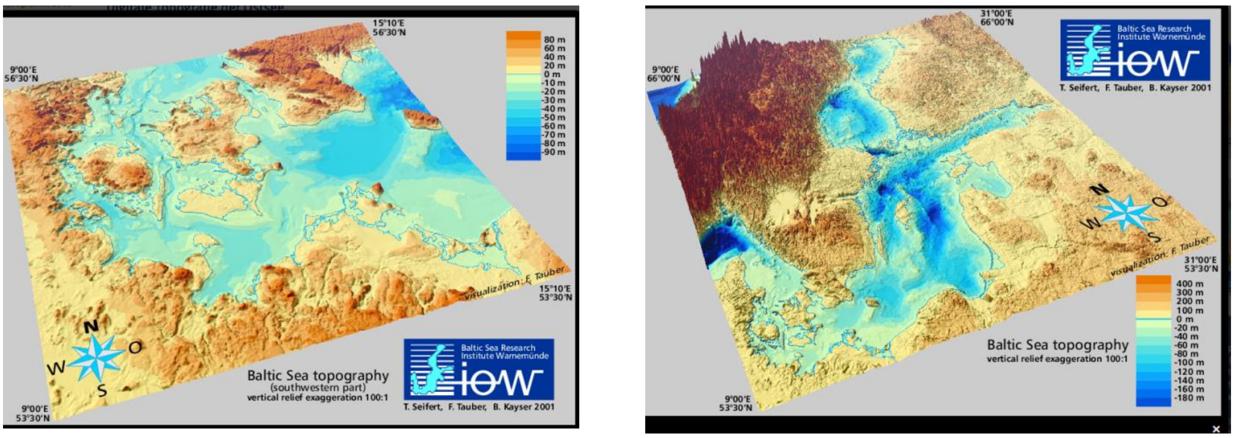


Figure 59 IOWTOPO1 and IOWTOPO2

3.3.4.2 The Baltic Sea Bathymetry Database

From September 2013 the Baltic Sea Bathymetry Database (BSBD) Portal (http://data.bshc.pro) has been in operation and is likely to be found high on the lists for a search using keywords "Baltic Sea Bathymetry". The website offers bathymetry data (harmonised 500 m grid) for the Baltic Sea for download and provides geodata view services (WMS). It has a simple map viewer and also a tool for displaying bottom profiles. The site provides information on how data has been gathered, standardised metadata is published and there is an alternative view displaying source data density.

This website is the result of a Swedish government directive (with funding) to the Swedish Maritime Administration. The Baltic Sea Hydrographic Commission (www.bshc.pro), one of the regional commissions within the International Hydrographic Organization (IHO), was used as platform for the cooperation between national hydrographic offices (national nautical chart producers) around the

Baltic Sea. A dedicated Baltic Sea Bathymetry Database Working Group is working with maintenance and future improvements of data and functionality for the website.

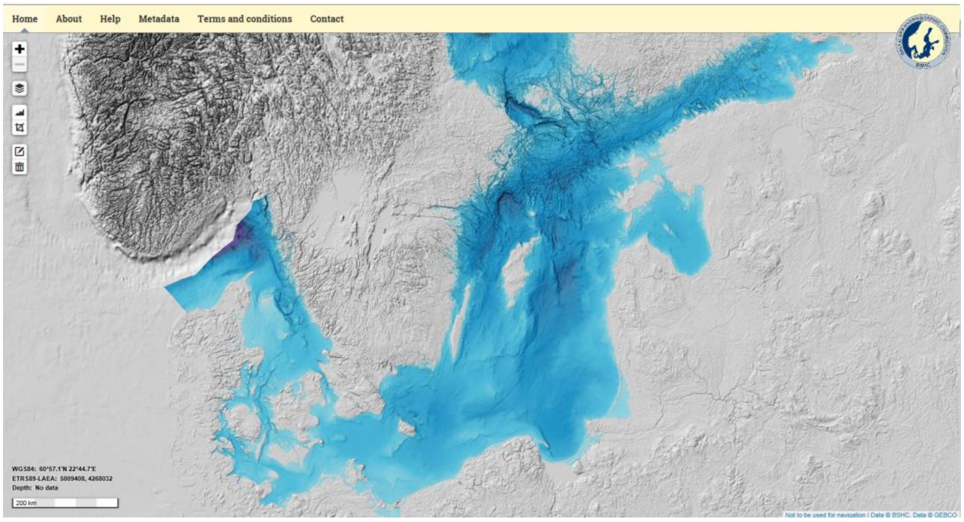


Figure 60 Baltic Sea Bathymetry Portal (http://data.bshc.pro)

3.3.4.3 GEBCO (General Bathymetric Chart of the Oceans)

GEBCO (www.gebco.net) is a cooperation between IHO and the Intergovernmental Oceanographic Commission (IOC). The Baltic Sea Bathymetry Database provides the data for the Baltic Sea area.

3.3.4.4 EMODNET Bathymetry

EMODNET Bathymetry (www.emodnet-hydrography.eu) is one of several EMODNET themes and organized through an EU initiative. The Baltic Sea Bathymetry Database provides the data for the Baltic Sea area.

EMODnet Bathymetry aims to provide a single access point to bathymetric products, Digital Terrain Models (DTM) and data (survey data sets and composite DTM) collected and managed by an increasing number of organisations from government and research scattered over Europe.

EMODnet Bathymetry portal gives access to bathymetric data by using the download product button where the user can download in different file formats (i.e. EMO, ASCII, NetCDF, CD and XYZ). However, it requires for the user to have a special program to open any of the particular file formats. In the case where users does not have the program, it is necessary to download the program first The bathymetric view and download service does not have the option of downloading data about any specific area, rather the map is divided into sections. It the area of interested is separated between many sections, the user needs to download more than one section. This makes it inconvenient for the user to get information about specific area. For the Baltic Sea region, there is not much information available.

EMODnet Geology portal is free to use and accessible at any time. For the Baltic Sea region there is basically only two things available, sediment accumulation rates and seabed substrate maps, in two different scales 1:1 000 000 (1M) and 1:250 000 (250k). These datasets are available for download as Google Earth data layers and as .cml format.

3.3.4.5 HELCOM Map and Data Service

The Helsinki Commission (HELCOM) is the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea. The Web map viewer on their web site enables display of a number of data themes for the Baltic Sea (http://maps.helcom.fi/website/mapservice/index.html). For bathymetry the view service (WMS) from the Baltic Sea Bathymetry Database is being used.

The data retrieval from the HELCOM Baltic Sea data and maps service is relatively simple. The seabed dataset is always accessible and easy to download as digital shape files. The dataset consist data about seabed slope, seabed sediments and seabed sediments polygon. The dataset was produced by the BSR INTERREG IIIB project BALANCE. For the project, seabed sediment data was derived using different field techniques during the past decades. The seabed sediment maps from offshore and coastal areas exist in a wide range of scales from local (1:20.000) to regional (up to 1:1.000.000). The datasets about seabed habitats consist of modelled data.

The datasets have the detailed metadata included with the data updates and contacts information for future inquiries.

3.3.4.6 Higher density bathymetry data

There are a lot of high density good quality bathymetry that have been gathered for charting purposes by the Hydrographic Offices around the Baltic Sea but it is not as obvious from web search results how to find it. The respective national hydrographic office should be contacted and it is also possible to explore national geodata portals for high resolution data. The conditions for access to such data vary greatly among Baltic Sea nations with regard to for example open data policies and rules for military classified data.

The Baltic Sea nations have committed to the Helsinki Commission to establish a survey scheme for bathymetry and to continuously report progress. A classification is established to describe the order of significance for maritime shipping in three categories The Baltic Sea Hydrographic Commission has set up a dedicated working group to monitor progress with the survey scheme and a database with a web site to present results (http://helcomresurvey.sjofartsverket.se/helcomresurveysite). For areas marked as finished in this presentation high-resolution bathymetry data is present and could be made available for use.

3.3.4.7 Other sources of bathymetry data

Certain commonly used software packages include bathymetry data. Such is e.g. OceanDataView (https://odv.awi.de/) that is recommended by SeaDataNet. There are several alternative bathymetries that can be used in ODV, one is specifically for the Baltic Sea. The bathymetries are from ETOPO and GEBCO.

Some software use GSHHG-data (A Global Self-consistent, Hierarchical, High-resolution Geography Database) that is freely available from https://www.soest.hawaii.edu/pwessel/gshhg/. Such software is e.g. Generic Mapping Tools (GMT).

3.3.5 Human Activities

Databases containing information's on human activities are limited and scattered, for this reason the few identified sources of information are presented as linked to the relevant challenges.

3.3.5.1 Fisheries management

Key fishery impact data sources identified from the literature survey include Vessel Monitoring Data (VMS) and logbook data. These data are collated by ICES, and can be directly applied to the Baltic Sea region. VMS collects real time catch and effort data for commercial fishing vessels via satellite, and is mandatory in the region for use on all vessels > 12m, having recently been only mandatory on vessels >15 m prior to 2012. Information such as the location, direction, speed of vessel, and gear is collected (typically) on an hourly basis, and this information, coupled with logbook data on gear type and landings data, can provide a useful tool in estimating fishing impact or pressure in a given area.

Unfortunately, there is restricted access to VMS and logbook data, and the raw data is not publically available. This presents significant challenges to data analysis. Data available from ICES is provided in the form of advice documents, produced on a regular basis by ICES, or as a result of special requests. The exception is the provision of national VMS data, which is afforded to National Fishery Institutions. However, this data cannot be shared (publically or between institutions) and is subject to strict restrictions of usage. As a result, potential discrepancies in the outcome of data analysis may occur, and in the type of information produced by individual national institutions and ICES documents.

The type and format of data provided by ICES advice documents, such as ICES (ICES, 2015a), include data from 2009 – 2013 (data is also provided quarterly for 2013), and presented in the form of VMS-based fishing effort maps, compatible across all regions (OSPAR, HELCOM, etc.). These maps are based on a 0.05 x 0.05 c-square degrees, and are also available in ESRI shapefile format (ICES, 2015b).

All data provided is aggregated, and mapped under the following categories (all fishing effort is provided in hours):

- fishing effort from 2009 to 2013, by each fishing gear (longlines, midwater trawls, and mobile contacting gear);
- fishing effort Q1 – 4 2013, by each fishing gear;
- total fishing effort from 2009 to 2013;
- total fishing effort Q1 – 4 2013;

- fishing abrasion pressure from 2009 to 2013 (subsurface or surface - only relevant to bottom contact fisheries);
- fishing abrasion pressure Q1 – 4 2013 (subsurface and surface).

Data is also provided in terms of fishing effort within official Marine Protected Areas, for each type of fishing gear. Values (in hours) were calculated by overlaying information on fishing effort and MPA boundaries, and adding the number of hours for each fishery (ICES, 2015a) .

Potential for inconsistencies exist in the recording of VMS and logbook data, in that VMS accounts for different gear type and gear configuration, and this information is not always recorded in logbook data. This problem is being now being investigated by authors such as Eigaard *et al.* (2015), and there is scope to model data on gear type and gear footprints (e.g. door spread or beam width) to meet this data gap, which can also then be combined with standard logbook data on catch and effort.

3.3.5.2 Fishing pressure – Data sources and providers

Fishing pressure data (logbook and sales slip data) from EU-STECF

Another source of Fishing pressure data for the Baltic Sea is the EU-STECF (Scientific, Technical and Economic Committee for Fisheries), which releases a data call to member states on a regular basis for the provision of fishing effort data (Logbooks and Sales slip information). These data are used for an annual Evaluation of Fishing Effort Regimes in European Waters (https://stecf.jrc.ec.europa.eu/reports/effort) – including an assessment of all effort in the Baltic Sea - he data behind the reports are freely available as electronic Excel files from: https://stecf.jrc.ec.europa.eu/data-reports. The logbook data of catch and effort for the Baltic Sea (vessels ≥ 8 m) are available by ICES rectangles. For a part of the vessels below 8 meters, the same spatial scale applies (ICES rectangle), bot for other group sales slips provide basis for information of effort and landings only at a cruder level: area A (ICES Subdivision 22 to 24); area B (ICES Subdivision 25 to 28); area C (ICES Subdivision 29 to 32). The following variables are available as yearly values from 2003 to 2013:

- gear (*beam trawl, demersal seine, dredge, gillnet, longline, otter trawl, pelagic seine, pelagic trawl, pots, trammel nets*)
- fishing effort (*kWdays and GT days*)
- fishing activity (*days absent from port*)
- fishing capacity (*kW, GT and number of vessels*)
- catches (landings and discards provided separately) by species, by weight and by numbers at age
- vessel length Baltic Sea (under 8m, 10-12m, 12-18m, 18-24m, 24-40m and above 40m)
- vessel length Kattegat (under 10m, 10-15 m, above 15m)
- member state (DEU, DNK, EST, FIN, LTU, LVA, POL, SWE)

3.3.5.3 Wind Farming

HELCOM database

The HELCOM database is freely accessible with the database always available. The user can download data layers as shape files and make use of them in available programs. The data layers available include: MPAs; Natura2000 sites; Baltic Sea fisheries closure sites; Ramsar sites; cables and pipelines; offshore wind farms, with color-coded label it is possible to identify whether the wind farm is cancelled, in early planning, under construction; onshore nuclear facilities; oil terminals bigger than 3 million tonnes; oil platforms; etc.

The Baltic Sea dredged spoil dumping data was created for the HELCOM HOLAS project. Most of the dump sites have information on the quantity of dumped material. Some sites include information about the quality of material. All information (available) about the contamination is in the national reports in HELCOM Secretariat. No Russian data is included due to missing information.

The Baltic Sea dredging data set includes spatial information on all kinds of dredging (harbour maintenance, harbour capital, sea lanes, sand/gravel/boulder/maerl extraction). The aim of the dataset is to describe extent and spatial distribution of the sea bed disturbance caused by human activities.

Information and data on fishing intensity at surface and subsurface level; and information on fishing effort, depending on the gear type, is available for 2009-2013. All datasets are available for download as digital shape files.

Total commercial fishery in the Baltic Sea dataset contains information on commercial fishery in Baltic Sea in 2007 (Lithuanian data from 2008). Catches/landings are given per ICES rectangle, both as total values and per species.

All the datasets have detailed metadata included which is very useful for future references and inquiries.

EMODnet Human Activities database

The EMODnet Human Activities portal has information available on the geographical position, spatial extent and attributes of a wide array of marine and maritime human activities throughout Europe. Particular attention is given to providing, when possible, historical time series to indicate the temporal variation of activities such as fishing and port traffic. Time when data was provided together with attributes to indicate the intensity of each activity is also be included.

The portal allows users to view, query and download data and metadata from public and private sources – from throughout Europe - via a single entry portal. It provides access to data that has been harmonised into interoperable formats and that includes agreed standards, common baselines or reference conditions and assessments of their accuracy and precision. Users can view, query, and download datasets or subsets of them, via web GIS. Metadata are also available for download. The portal is based on free, open-source technology, using both MapServer and OpenLayers. Data feeding into the portal comes from a multitude of public and private data sources at EU, international, national, and local level.

Every time when downloading dataset the user is requested by the portal to fill in the form with organisation name, country and sector. This makes downloading the data little inconvenient, this however does not perturb the use of the portal.

ICES
The information about fishing activities in the Baltic Sea coincides with the HELCOM data.

3.3.5.4 Oil platforms

Oil characteristics are in-situ measurements and can be collected from the SINTEF website, http://www.sintef.no/, in ASCII format, but the data is hidden. Oil slicks and spill is remote sensing from CleanSeaNet, portal.emsa.europa.eu/web/csn, also hidden data. No data source can be found regarding sensitive areas and tourist beaches.

3.3.5.5 River runoff

Information on human activities such as dam cites in rivers is available at the World Register of Dams (WRD) created by the International Commission of Large Dams (ICOLD). The register has been updated since its creation in 1958. Data is available for more than 37500 dams with heights over 15 m.

Another database is the Global Reservoir and Dam Database (GRanD), which has been developed for the scientific community in order to make a complete register on dams.

3.3.5.6 Bathymetry

Human activities do not influence or change bathymetry on the larger scale. However, near coastal areas, especially harbours and shallow shipping lanes, the seabed is both modified (dredging's, other constructions) and could be affected by the intense shipping movements. In these areas, hydrographic offices normally perform re-surveys for bathymetry data with given intervals.

4. Discussion and conclusions

The Baltic Sea is unique: the largest body of brackish (low-salinity) body of water in the world, it is also distinguished by its division into a series of basins of varying depths, separated by shallow areas or sills. The many rivers flowing into the Sea are the reason for its brackish character. Furthermore, the link with the North Sea is very narrow, the shallowest sill being only 18 m deep. Thus inflows of salt water must be extremely forceful to penetrate and renew the deepest waters of the Baltic Proper.

Nine countries share the Baltic Sea coastline; Sweden and Finland to the north, Russia, Estonia, Latvia and Lithuania to the east, followed by Poland in the south, and Germany and Denmark in the west. About 16 million people live on the coast, and around 80 million in the entire catchment area of the Baltic Sea. The catchment area includes part of Belarus, the Czech Republic, Norway, the Slovak Republic and Ukraine, as some of the rivers find their sources here

These special geographical conditions clearly influences the physical, chemical and biological conditions, which are very different from other regional seas of Europe. This report is therefore started with an overview of the meteorology, bathymetry, coasts, oceanography and biology of the Baltic Sea.

Historically the Baltic societies have been closely dependant on marine industries such as fishery, transport – for a long time the Baltic Sea has been one of the most densely trafficked seas in the world and the maritime transport is expected increase intensively the coming decade. In recent years also energy, aqua culture and recreation for tourists from all Europe has become an increasingly important businesses. The conditions for maritime industries and their growth naturally are influenced by the special physical environment governing the Baltic Sea. For natural reasons utilisation of the marine resources and the threat to the marine environment have always been easily noticeable and it is well known that the maritime industries also puts enormous pressure on the vulnerable Baltic marine environment. This calls for detailed knowledge of the marine environment – physical and biogeochemical processes, interdisciplinary relations and dependencies, changes etc. This must be an essential part in the future planning and decision process, where a rapid access to reliable and accurate information is vital in addressing threats to the marine environment, in the development of policies and legislation to protect vulnerable areas of the coasts and open ocean, in understanding trends and in forecasting future changes. Likewise, better quality and more easily accessible marine data is a prerequisite for further sustainable economic development, so-called ‘blue growth’

Marine research and monitoring however has long traditions in the Baltic Sea and a relatively large and fairly dense (space and time) amount of marine observational data are available from national and research and monitoring programmes. It is therefore possible to establish very long time series of selected parameters at a few selected stations contributing to gaining a good picture of changes in the Baltic environment over the last one –two centuries. The work with this report has however also displayed the need for many different characteristics to meet the needs of the predefined 11 challenges.

In planning the literature survey the EMODnet Baltic Checkpoint consortium to use the same philosophy and approach as used by the EMODnet MedSea Checkpoint (EMODnet MedSea Checkpoint, 2014). Therefore, the 11 challenges identified all the characteristics they need to solve the tasks in their individual challenge. Data was grouped in five environmental matrices as defined in EMODnet MedSea Checkpoint, 2014: air, water (marine or fresh), biota/biology, seabed and human activities. Relevant literature was surveyed to identify sources for the required characteristics (in the proposal it was planned to use the open source library Mendeley, but it turned out not to be manageable due to more than 0.5 mill. hits independent of the search criteria). The identified data sources have as far as possible been evaluated with regard to: availability (accessibility, performance) and appropriateness.

The requirements from the eleven challenges sums up to a total of 140 different characteristics: 10 in Air, 38 in Water, 31 in Biota/biology, 19 in Seabed and 42 in Human Activities. Each of the eleven challenges has its own requirements of characteristics in the five environmental matrices.

	Air	**Water**	**Biota/biology**	**Seabed**	**Human Activities**
Challenge 1: Wind Farm sites	8	19	10	8	22
Challenge 2: Marine protected areas	0	5	3	6	11
Challenge 3: Oil platform leaks	1	5	0	2	4
Challenge 4: Climate change	2	10	4	0	0
Challenge 5: coastal protection	0	4	0	6	0
Challenge 6: Fisheries Management	0	0	6	0	0
Challenge 7: Environmental impact of fisheries	0	1	3	7	4
Challenge 8: Eutrophication assessment	0	8	0	0	0
Challenge 9: River inputs to Baltic Sea	3	2	2	5	3
Challenge 10: Bathymetri	0	3	0	4	2
Challenge 11: Alien Species	0	5	9	3	5

Only challenge 1 and 9 require data from all 5 environmental matrices, and challenge 2, 3. 7 and 11 require data in four matrices; while challenge 6 only require data within 1 environmental matrix (Human activities). Challenge 1 is by far the most data requiring challenge (67 characteristics), while challenge 6 only has a need for 6 characteristics.

Based on the available information in the literature used in this survey it has been attempted – when possible – to judge the availability and appropriateness of the required characteristic. All this information is stored in an excel-file, which is available to the eleven challenges for their more details studies and the writing of the “Data Adequacy Report” later in the project.

The allocated resources to this literature survey did not allow for a detailed analysis the collected information on data availability and appropriateness; but a few general observations can be subtracted:

- Important data repositories are: data originator institutions, HELCOM/ICES, ICES, EMODnet and CMEMS.
- Data store at originator institutions are often not very visible, formats requires some efforts to use, the data policy often have some restriction and with some fee involved. This is particularly true for meteorological data.
- Data available at the big international data portals (HELCOM/ICES, ICES, EMODnet, CMEMS) are generally judges to be easy to find, the data format often is a challenge, the data policy is open and free of change.
- The quality of the data cannot always be judged from the literature; but where information has been subtracted only few has been labelled “high or good” quality while the majority is judged to be of “acceptable or poor” quality.

It must be stressed that the above observations only are general observations based on a limited material that could be subtracted from the literature, and that a more detailed analysis will be available when the individual challenges have completed their work.

In conclusion, the literature survey has demonstrated that we have a good understanding and overview of characteristics need for a variety of stakeholder here represented by the eleven challenges. Based on the survey we also have a good overview of where to find relevant characteristics for the Baltic Sea within the five environmental matrices: air, water, biota/biology, seabed and Human resources.

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