GROWTH AND INNOVATION IN OCEAN ECONOMY – GAPS AND PRIORITIES IN BALTIC SEA BASIN OBSERVATION AND DATA

First Data Adequacy Report
EMODNET Baltic Sea CheckPoint

Total number of pages: 160
Leading partner: Danish Meteorological Institute

Workpackage	15	D15.1 The first Data Adequacy Report
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A project funded by:

EUROPEAN COMMISSION, DIRECTORATE---GENERAL FOR MARITIME AFFAIRS AND FISHERIES, MARITIME POLICY ATLANTIC, OUTERMOST REGIONS AND ARCTIC

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Executive Summary

The value of data can only be realized when they are used. Therefore one major factor to determine the volume of the value of data is their level of "fitness-for-the-use (FFU)". The purpose of the Baltic Sea CheckPoint Data Adequacy Report (DAR) is to assess the FFU levels of the Baltic Sea data in areas of air, water, biota, seabed and human activities for their usages in social-economic benefit areas and marine knowledge generation, which are presented by eleven challenge areas predefined by DG-MARE. The data assessed include in situ observations, satellite observations, model data, human activity data and integrated data by combining models and observations.

The eleven challenge areas include wind farm siting, marine protected areas, oil platform leak, climate change, coastal protection, fishery management, fishery impact, eutrophication, riverine inputs, bathymetry and alien species. The assessment is qualitative with focus on the accessibility, completeness/coverage, resolution and precision when using the data for pre-defined tasks in each challenge areas, e.g., wind farm site suitability design, generate 100 year time series of sea level for entire Baltic coastal stretches etc. The procedure of the assessment is taken in four steps: i) to describe the pre-defined data use cases and objectives; ii) to specify data requirements in performing the data use cases; iii) to investigate the data availability and iv) to assess the "fitness-for-the-use" of data in the selected challenge areas by comparing the data availability with the data requirements.

In this assessment report, all the potential data sources from national, regional and European levels are taken into account. This includes global and European data centres e.g., EMODNET, SeaDataNet, CMEMS, ICES, AquaNIS and GRDC etc., regional data networks such as HELCOM, BOOS and BSHC etc., national data centres of meteorological, oceanographic, hydrological, geological, maritime, environmental and fishery agencies, as well as datasets from research projects. On the other hand, due to the complexity involved in the assessment, in-situ observations, especially those from EMODNET, are given more focus than other datasets. For each challenge area, only key variables are selected and data adequacy assessed. Recommendations for major data gaps, priorities for future observations are given.

Baltic Sea CheckPoint will deliver two Data Adequacy Reports. The first one consists of DARs for each challenge areas, based on the use of data in the challenge areas in the first fifteen project months. The project applications and data adequacy assessment are based on the expert knowledge in each challenge area. It is expected that the report will give a summary of the state-of-the-art usage of data for the specific tasks, as well as the adequacy of the available data in these Baltic Sea applications.

Due to the fact that not all tasks in the challenge areas have been completed, some issues may not be fully resolved in the current version of the DAR. These issues, together with the cross-challenge synergy of data requirements and adequacy will be addressed in the second DAR report. It is also important for readers to be aware of that the adequacy of data is assessed against the data requirements when they are used for specific applications but not for general purposes.

1 The scope of marine data adequacy analysis

The overall aim of Baltic Sea Checkpoint (BSCP) project is to examine the current marine data collection, observation, surveying, sampling and data assembly programs in the Baltic Sea basin, assess and demonstrate how they can fit into 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'N.

The outcome of this practice, such as maps, digital data layers and reports, should be presented through a Checkpoint Portal with dynamic mapping structures, a format compatible with INSPIRE, EMODNET and OGC standards to ensure that they are sustainable and can be readily used as part of the existing EMODNET Portal. The assessment results and recommendations will be summarized into Literature Review and two Data Adequacy Reports (DAR).

The Literature Review report has been published at BSCP web portal http://www.emodnet-baltic.eu/. This report is the first DAR report, containing major assessment findings up to date. Data adequacy is a relative concept regarding to the targeted user needs. Marine data are used in many areas, e.g., serving the blue economic, public security, social challenges such as sustainable marine ecosystems, climate change adaptation and mitigation and new knowledge generation for research etc. The DAR concerns about the adequacy of marine data in the 11 selected challenge areas, i.e.,

- wind farm siting,
- marine protected areas,
- oil spill,
- climate change,
- coastal protection,
- fishery management,
- fishery impact,
- eutrophication,
- river discharge,
- bathymetry,
- alien species.

The data adequacy is normally assessed per key variable and related characteristics e.g., coverage, resolution, quality and completeness. Due to complexity in the data adequacy assessment, following issues should be taken into account:

1. Fit-for-purpose assessment: marine data adequacy will be assessed regarding to specific user needs for the 11 selected challenge areas which are defined in BSCP tender. It should be noted that the data requirements are identified according to specific outputs defined by the EC in the contract.
2. Distinguish data adequacy for “general applications” and an “individual applications”: for a given challenge area, applications can be divided into categories of general applications and individual applications. An individual application, in many cases, needs very high quality and very local

information, which can only be generated by using specific local measurements. This normally cannot be resolved from community data. In this report, data adequacy is only assessed for general applications in the Baltic Sea region rather than individual applications for specific sites.

3. Integrated assessment: marine data can be made available through in-situ, remote sensing, model and integrated use of all of them. The assessment of the marine data adequacy in this report will mainly focus on the adequacy of the marine in-situ observations and human activity information in the 7 EMODNET Themes (Physics, Chemistry, Geology, Biology, Seabed habitat, Bathymetry, Human activity). The data adequacy is, however, referred to the state-of-the-art approach of data production, in many cases an integrated approach of using all data production methods.

2 Methodology used in BSCP DAR

The overall aim of EMODnet CheckPoints is to assess the fitness for use or adequacy of the existing monitoring system at the sea basin level in terms of the Challenge targeted products. This involves the development of CheckPoint Information on upstream data and a CheckPoint Service to perform the assessment and make it available. Mediterranean Sea CheckPoint (MSCP) project has proposed a systematic frame for assessing the data adequacy or "fitness for use", which is closely linked to the ISO stands (The first MSCP DAR report can be accessed at http://www.emodnet-mediterranean.eu/wp-content/uploads/2015/06/D11.2-revised-V11.pdf).

BSCP follows most of the terminologies defined in the MSCP, e.g., data, data adequacy, fitness for use, fitness for purpose etc. However, the BSCP DAR will mainly focus on the assessment of the **fitness** of Baltic marine data **for** the **use**s in the 11 challenge areas, rather than describe the framework of the assessment. For the simplicity, we use the term "data availability" to cover both what and how data are made available to users rather than distinguish "appropriateness" and "availability", as used in MSCP DAR-1.

The methodology for BSCP DAR assessment is mainly a qualitative approach but closely related to the specifications in each BSCP challenge areas. The fitness and gaps identified have to be based on solid application cases. In practice, the assessment of the marine data adequacy for the 11 Baltic Sea challenge areas includes following four steps:

1. To introduce the background of the challenge area, i.e. the purpose of using data, which data are used and how they are used;
2. To identify data requirements for each key variable in the challenge area, including requirements for accessibility, spatial-temporal coverage, resolution, and precision etc.;
3. To identify data availability of each key variable for the challenge area;
4. To assess data adequacy for each key variable in the challenge area.

The key variables for each challenge area and their availability have been mostly identified in the Literature Review report with a general scope for the challenge areas. The BSCP DAR will mainly deal with in-depth fitness for use or data adequacy assessment for dedicated purposes in BSCP challenge areas. Hence the key variables assessed in BSCP DAR are the ones directly used in BSCP project. This may lead to some limits in the scope of the DAR but definitely give sensible recommendations for EMODNET marine data development. For each challenge areas, assessment of using EMODNET data and related recommendations are included in the DAR.

For a given key variable in a challenge area its data adequacy is assessed with its availability against the data requirements. Major assessment criteria used in the BSCP are:

- Data accessibility
  - Delivery types: timeline, cost, style
  - Delivery time: time interval between the time when data are measured and the time when data can be accessed.
- Completeness & coverage
  - Spatial
  - Temporal
- Resolution
  - Spatial
  - Vertical
  - Temporal
- Precision

The assessment of the adequacy is qualitative in this report. For readability and clarity, only three types of data adequacy are used for each assessment criterion and key variable: i) data are adequate for the use (marked with "FFU"); ii) not adequate; iii) recommendations for improving the data adequacy.

For different challenges, the importance of each assessment criterion varies. For example, "Precision" is more important for wind data in wind farm siting than other challenge areas, "real time accessibility" is critical in oil platform leak but not in the other areas. This means that once the assessment methodology has been put in place, the final assessment must be made by challenge experts. For some challenge areas, e.g., alien species and fishery sectors, the data adequacy may not be assessed by the resolution in space and time rather than in categories and types of data.

It should be noted that data may also cover the integrated products, e.g. the outcomes of integrated use of the available data and models. In some cases, although in-situ marine observations are not adequate for the purpose of the challenge areas, data products can be generated by integrating in-situ, satellite data and models in order to fit for the uses.

The rest part of the report is organised according to challenge areas. Each challenge area has a chapter on the data adequacy of key variables used in the area, which describes the purpose and use of data, data requirements, data availability, data adequacy and recommendations for the area.

As mentioned above, BSCP will deliver two DAR reports. At the moment, only part of the application areas has been explored. This also means that our knowledge on the data adequacy is now not complete and will be further developed and updated in the second half of the project period. We do not expect drastic change in the frame of DAR-2 but the new knowledge will be included. The links between the different Challenges will also be investigated.

3 Data adequacy analysis for offshore wind farm siting

3.1 Introduction

The objectives of Offshore Wind Farm (OWF) siting are to identify feasible offshore wind farm sites with balanced economic, environmental and social impacts and consequences. This includes suitability analysis, impact assessment and optimal siting. The suitability analysis is a preliminary analysis that identifies locations which are suitable for offshore wind farms. This consists of wind condition suitability, mete-ocean suitability and environment suitability. The impact assessment is to assess the environmental, ecological and social impacts of a given OWF site, e.g., impacts on the view, aquatic system and habitat etc. The optimal siting is to find an optimal site in terms of cost and benefit. The cost includes not only construction, deployment, transmission and maintenance cost, but also a cost due to negative environment, ecological and social impacts. The benefit also covers the economic (which is mainly through wind power generation) and positive impacts on the ecosystems and society. The state-of-the-art wind farm siting normally applies an integrated approach which uses a large amount of marine data from different sectors as essential inputs.

Before discussing the marine data adequacy for wind farm siting in the Baltic Sea, it is necessary to have a brief description of a typical offshore wind farm. As suggested in NREL's paper "Electrical Collection and Transmission Systems for Offshore Wind Power" from 2007, in consideration is a wind farm consists of 100 turbines with 10 turbines in a row. A 3 MW turbine from Vestas (V90) has a rotor diameter of 90 m. The distance between each wind turbine must be at least seven times the rotor diameter, which means 630 m by use of a V90 wind turbine. The cable length between each wind turbine is at least 830 m. All wind turbines in a row could be connected with a 7 Km connection cable to the offshore substation. It should be noted that "90m" of rotor diameter is a bit conservative. Nowadays rotors can be 120-170m and are expected to go beyond 200m. The reason for using 90m is that the cost formulas cited in this report were based on turbines of this size.

There are four different types of foundations for offshore wind farms: Monopile, Gravity base, Tripod and Floating. Each foundation type can be used for a certain water depth. The application of Gravity base foundations is common between 1 m – 20 m. In a water depth range between 1 m – 30 m mostly Monopile foundations are used. Tripod foundations are a transition technology between shallow and deep water (20 m – 50 m). In water depths deeper than 50 m only floating foundations are going to be used.

Since the average depth of the Baltic Sea is only 50 meters, a significant percentage of the waters can be used for cheaper, non-floating foundations. In the BSCP project, the floating foundation will not be a focus. Due to the resource availability, the study will mainly focus on the site suitability study although extreme condition analysis will also carried out during the project period. For the data adequacy report, however, the data needed for impact assessment and cost-benefit analysis are also partly covered.

3.2 Data usage and requirements

Key variables needed for OWF siting covers all 5 data matrix areas: air, water, biota, seabed and human activity. These variables have been identified in BSCP Literature Review Report, which can also be found in Tab. 3.1. Specifications of requirements on these variables are given Tab. 3.2, and described in the following sub-sections.

Table 3.1. Data usage in “Wind farm siting”

Variable	Data type	Usage
Wind profiles (speed, direction)	In-situ	Obs. at site: wind resource estimation, normal/extreme condition assessment, safety and cost assessments i.e. expectable wind load on the wings, wind shear, availability analysis of suitable maintenance and construction windows. General: Model validation and data assimilation.
	Model	Use as defined in “Obs. at site”; boundary forcing for ocean models.
Meteo. data: Air Temperature, Air Pressure, Air density, Specific humidity, Cloudiness, Cloud water	In-situ	Obs. at site: estimation of normal/extreme conditions, safety and cost assessments i.e. architecture of foundations, piles and wings, e.g. cloud water for expectable ice load on the wings. General: Model validation and assimilation.
	Model	Use as defined in “Obs. at site”; boundary forcing for ocean models.
Ocean circulation: Currents (speed, direction), Sea level, Salinity, Temperature	In-situ	Obs. at site: estimating normal/extreme conditions, safety and cost assessments e.g. strength of foundations and weathering of foundations and piles. General: Model validation and assimilation.
	Model	Use as in “Obs. at site”; forcing for atmospheric/wave models
Waves: spectra, significant wave height. dominant period, zero-up-crossing period, Max. wave height	In-situ	Obs. at site: estimating normal/extreme conditions, safety and cost assessments, availability analysis of suitable maintenance and construction windows, max. wave height assessment. General: Model validation and optimisation
Waves: spectra, significant wave height, cross-zero/peak period of wind sea, swell and total sea	Model	As defined in “Obs. at site” except for max. wave height assessment; forcing for atmospheric, ocean circulation and sediment and suspended particulate matter transport models
Sea Ice: thickness, strength, flow size, extend, occurrence	In-situ Satellite	Normal/extreme conditions, safety and cost assessments, availability analysis of maintenance and construction windows. General: Model validation and assimilation.
Ocean nutrients, chlorophyll-A, oxygen	In-situ Model	Environmental status assessment, ecological and economic impact assessment, model validation and assimilation.
Birds/marine mammals/fish: species, red lists, protected status, important areas, migratory patterns; Habitats Abundance, biomass, formations, angiosperm, macro algae, interverbrate and bottom fauna	In-situ	Environmental status assessment, ecological and economic impact assessment
Bathymetry: depth, land rise	In-situ model	For depth dependent foundation design and cost estimations.
Sea bed geology: substrate, sea bed slope, sediments/lithology, coastline evolution, sea bed habitats, energy at the sea bed	In-situ Model	Sea-bed and coastal geology dependent foundation design and cost estimations, sediment dynamic and suspended particulate matter dynamic assessments for impact studies. Identification of sedimentation and resuspension domains.
Human activity: exist. wind farms, maritime traffic, fishing, mari-culture, coastal land use, MPA, dredging and dumping sites, ports, infrastructure aggregate extraction, pipelines and cables, Grid network	Marine Spatial Planning	Identification of avoidable areas for site selection, For construction and maintenance cost estimations, as well as planning of logistic operations: turbine assembly, transport and deployment; Electric transmission costs, downtime and availability for cost-benefit analysis. For assembling and managing logistic operations,
Regulatory constraints	Publications, web sites	Regulatory basis for site selection
Touristic or residential areas ahead of wind turbines		Environmental impact assessment

Table 3.2a. Data requirements for “Wind farm siting”

Variable	Data type	Accessibility		Completeness / coverage		Resolution			Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
Wind profiles	In-situ	open, free	months -years	Baltic Sea	>10-20yr	N/A*	5 heights up to 130m hub-height and surface.	Hourly-Monthly	0.1m/s
	Model	open, free	months -years	Baltic Sea	>10-20yr	Max. 5km			0.5-1 m/s
Meteo.-data: T_{air}, P_{air}, RH, Cloudiness	In-situ	open, free	months -years	Baltic Sea	>10-20yr	N/A			T_{air}: 0.1°C P_{air}: 0.15hPa RH: 3%
	Model	open, free	months -years	Baltic Sea	>10-20yr	Max. 5km			T_{air}: <0.5-1 °C P_{air} :<0.5hPa RH: 3-4%
Currents (speed, direction), Sea level, Salinity, Temperature	In-situ	open, free	months -years	Baltic Sea	>10-20yr	N/A	<3m at surface, <10m at seabed in the in the upper 90m		Current speed: 0.01m/s sea level: 1cm
	Model	open, free	months -years	Baltic Sea	>10-20yr	Max.2km for Baltic 1km for Danish Straits			Current speed: 0.05m/s, Sea level: 5-10cm Salinity: 0.5-1 Temperature: 1°C
Waves	In-situ	open, free	months -years	Baltic Sea	>10-20yr	N/A	N/A		Significant wave height: 0.1m period: 1s
	Model	open, free	months -years	Baltic Sea	>10-20yr	1-10km	N/A		0.2m significant wave height, 10s dominant period, 1s mean period
Sea Ice:	Obs	Delayed, open, free	months -years	Baltic Sea	>10-20yr	1km	N/A		10% ice concentration, <45cm ice thickness, 40% to 80% ice drift.
Nutrients, chlorophyll-A, oxygen	In-situ Model	open, free	months -years	Baltic Sea	>10-20yr	10km	5m in the upper 90m		0.5 psu salinity, 1 °C temperature, 10 cm sea level, 0.1 mmol/m^3 nutrients, 0.1mg/ m^3 chl-a, 0.1ml/l oxygen

*N/A – Not Applied

Table 3.2b. Data requirements for "Wind farm siting"

Variable	Data type	Accessibility		Completeness/ coverage		Resolution			Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
Birds/marine mammals/fish Habitats, abundance, biomass, formations, angiosperm, macro algae, interverbrate, bottom fauna	In-situ	Delayed, open, free	months -years	Baltic Sea	N/A				N/A
Bathymetry	Interpolated		Conti-nuously updated		Most recent data	<50-500m	N/A	N/A	0.01m
Sea bed geology: characteristics and substrate, sediments/lithology, coastline evolution, sea bed slope	Interpolated					50m-1nm	N/A	N/A	0.01m/m sea bed slope
Sea bed habitats, energy at the sea bed	In-situ , Model		Months -years		>10yr	5km	N/A	Monthly	0.001m/s shear stress velocity
Human activity: exist. Wind farms, maritime traffic, fishing, mariculture, coastal land use, MPA dredging and dumping sites	MSP: Maps and digital data	Real time, open, free	Conti-nuously updated		most recent data	N/A	N/A	N/A	N/A
Human activities: ports and infrastructure for assembling and managing logistic operations, aggregate extraction, pipelines and cables						N/A	N/A	N/A	N/A
Human activities: Grid network for electric transmission						N/A	N/A	N/A	N/A
Regulatory constraints	Publications, web sites					N/A	N/A	N/A	N/A
Touristic or residential areas ahead of wind turbines						Not Available	N/A	N/A	N/A

3.2.1 Weather and ocean data

Use of wind data

Major advantages of the offshore wind farms are significant larger wind power outputs than the land-based ones. The roughness of the water surface is very low which leads to stable and relatively strong winds over sea surface comparing with land surface. This gives higher and more stable wind power outputs. Such wind conditions over the sea are affected by the wave-induced roughness, current-induced surface drag and surrounding topography e.g. islands and lighthouses.

The wind shear is also low due to the low roughness which means that the wind speed does not change much with change in the hub height of the wind turbines. This translates into a capital cost advantage in the shorter structural towers. The wind gustiness is also an important parameter as it reflects the stability of the winds. The wind shade effects from land at sea location is important, extending its effect to as far as 20kilometers.

In general, the temperature difference between air and the surface is smaller at sea than at land, which leads to the less wind turbulence at sea. This results in less fatigue loading and therefore longer design lifetimes than land–based turbines.

For the site suitability analysis, historical wind data, including both surface and profile data, in a period longer than 10 years and a sufficiently spatial resolution, are needed. The data should cover entire Baltic Sea.

Use of ocean-ice-waves data

Water observations cover physical and chemical properties in the water environment. The most important variables for the siting are ice, waves and currents which have large impacts on calculating the loads on the foundation. Other variables such as temperature, salinity and chemical properties are needed in estimating the life span of the turbines and assessing environmental impacts of the wind farms.

Use of water observations in wind farm siting can be divided into two categories: the first is that the observations are sparse hence mainly used for model validation; the second is that the observations are measured by satellites with good spatial and temporal coverage, e.g., SST (Sea Surface Temperature) and sea ice, by satellites and therefore can be directly used for all-purposes, e.g., extreme value analysis, environment condition analysis, model validation and assimilation etc.

Data needs specifications

In general, for the site suitability analysis, historical wind data, sea ice, wave and 3D ocean data, in a sufficiently long period and a sufficiently high spatial-temporal resolution, are needed. The length should be minimum 10 years. 20 years' data are needed if a proper estimation of 50 year event should be made. For the temporal resolution, hourly is the minimum. Spatial resolution can vary from 1-3km. The data should cover entire Baltic Sea.

3.2.2 Biota data

One of the important impacts of the OWF is on the marine ecosystems. The Offshore structures will create refuge areas for benthic species, adult and juvenile fish decreasing mortality that may result in positive effects for the high trophic level ecosystems and also economies through revenues from fisheries. They may also decrease or destroy suitable habitat for benthic organisms that are prey for fish populations and reduced habitat may result in population declines of some fish species. This may introduce instability in local food web systems. The detailed ecological impacts will be closely related to the existing ecological status on the site. The ecological impact assessment will need inputs from biota data.

Biota data for wind farm siting includes the distribution of the high trophic level species (fish, birds, marine mammals), fauna, macro-algae and habitats. One may use these data to estimate the potential impacts of turbines on the marine ecosystems, which can be either positive or negative. The structures may create new habitats for native fish as protected and nursery areas but may also have negative effects as they will eliminate suitable habitat for benthic organisms, and create new suitable substrate for settlement of potential invasive species. These effects will eventually result in changes to the ecosystem food webs and potentially on fisheries.

Since the integrated assessment of wind farms are still in research and development, the requirements on the biota data for OWF siting are still evolving.

3.2.3 Seabed data

Seabed characteristics are important for design and deploy OWF foundations, not only bathymetry, substrate types but also slopes and seismic structures. Seabed sediment and substrate affect the construction cost of the OWFs. A good site should have a hard seabed. In case of fine grain size sediments, they may be mobilized and redistributed during the construction phase. The habitat data are needed to assess the impacts of the OWFs, as with underwater foundations, the OWFs will create new seabed habitat while the old habitat will be degraded or destroyed.

Bathymetry and seabed slope: topography and distance to the shore/harbor are the most important factors to determine the investment cost of the OWFs. According to existing research (http://css.snre.umich.edu/css_doc/CSS14-27.pdf), the investment cost of four different types of foundations for a "typical" OWF can be roughly estimated by following formulas:

Monopile:	$IC=2242483.33 + 7236*d_{shore} + 986059*exp(0.0182*D)$
Gravity Base:	$IC=3056887.13 + 7514.34*d_{shore}$
Tripod:	$IC=3347254.33 + 7695.72*d_{shore}$
Floating:	$IC=5820907 + 7236*d_{shore}$

Where IC is the total investment cost (in USD), d_{shore} is the distance to the shore (in meter) and D is the water depth (in meter). It should be noted that the above formulas are very much empirical and preliminary, which have not account many other factors. For example, a flat and hard seabed can save quite some cost for the construction.

For wind farm suitability study, the seabed condition is regarded as static and spatial resolution as a size of the typical wind farm (e.g., 7km) will be sufficient. The coverage should be mainly for the water depth less than 50m.

3.2.4 Human activity data

The impact of Offshore Wind Farms on coastal areas varies across a number of thematic dimensions. Positive impacts include their contributions to a diversified and cleaner electricity supply that can reduce GHG emissions and to job opportunities supporting the manufacture of wind turbine components. The feasible waters for OWF development, however, may also already provide a number of current uses, such as for shipping lanes, marine protected areas, cultural resources like shipwrecks, commercial fishing areas, and military operation areas. A database of existing human activities in the Baltic Sea is necessary for the

OWF siting suitability study. It is important that such a database should be updated to reflect most recent and even on-planning activities.

3.3 Data adequacy assessment

The data adequacy is accessed for the fitness of using the data in wind farm siting, mainly for siting suitability but ecological impact assessment and cost-effective siting also touched. Firstly the data availability is assessed and then the adequacy is assessed against data requirement for each key variable and assessment criterion, i.e., accessibility, completeness/coverage, resolution and precision. The assessment of data availability is summarised in Tables 3.3a and 3.3b.

3.3.1 Wind conditions

For a given location, the wind data used for determining the wind conditions consist of observations and modeled data. These data are used to estimate statistics of potential wind power production including stability and amount. The model data include coarser resolution analysis/reanalysis data which assimilated available observations and downscaled high-resolution data. The wind observations are used in both assimilation and model validation. Due to lack of observations, a calibrated, high quality numerical weather model for simulating wind conditions is very important. The wind resource Atlas for the Baltic Sea based on wind observations and model data have been made by some national met. Agencies (e.g. FMI) and research centres (e.g., Risø National Laboratory in Denmark).

3.3.1.1 Wind observation data

The wind observations include Sea Surface Winds (SSW) and wind profiles in 0-150 meters above the sea.

Sea Surface Wind

The SSW (winds at 10m height) is monitored through both satellites and in-situ platforms. The satellite SSW vectors are mainly measured by scatterometers with a spatial resolution in 12.5km and 25km and repeat cycle of 29-days. Altimeters also provide along-track wind speed measurements with a footprint about 7-12km. These data are quality controlled, reprocessed and are freely available through major data portals of CMEMS, CERSAT and JPL etc. The in-situ offshore SSW is measured by VOS (Voluntary Observation Ships), buoys and ferry lines, which are available from meteo-ocean agencies and data portals of BOOS, CMEMS and EMODNET etc. The historical and near real-time SSW data well cover the Baltic Sea coast, which can be obtained from European Climate Assessment Dataset (ECAD - http://www.ecad.eu). The best use of the satellite SSW data is through data assimilation in NWP (Numerical Weather Prediction) models which can generate SSW products with similar quality of satellite winds but much higher resolution and coverage. *Hence for wind farm siting, existing satellite SSW monitoring contributes significantly through data assimilation in NWP models. Future along-track swath altimeters will provide SSW with higher resolution. It is recommended to maintain the current SSW monitoring activities and develop very high-resolution (e.g., 1km) wind reanalysis.*

Wind profiles

The development of offshore wind energy requires accurate information on wind speeds above the surface at least at the levels occupied by turbine blades. Accurate measurement of wind speed profiles aloft in the marine boundary layer is a difficult challenge. Few measured data are available at these heights, and the temporal and spatial behavior of near-surface winds is often unrepresentative of that at the required heights. Offshore wind profile data are measured for existing and potential wind farm sites, but mainly owned by wind farm companies and is limited for open access. As a consequence, numerical model data, another potential source of information, are essentially unverified at these levels of the atmosphere. *It is recommended that the existing wind profile data should be open for research purposes, e.g., calibrate operational NWP models, and more wind profiles should be measured in the Baltic Sea by using existing cost-effective technology, such as ship-born, fixed or floating platform-based Doppler LiDAR (Light Detection and Ranging) devices. Long-term data are also needed for the calibration of operational NWP models.* As an example, the Energy Department (DOE) in the United States recently in 2014 and 2015 deployed two offshore AXYS WindSentinel buoy. One of the key instruments on top of the buoy is a LiDAR device that shoots a series of lasers 650 feet into the sky and measures their reflection to characterize wind speeds at various altitudes. The buoy also uses additional meteorological and oceanographic instruments that record air and sea surface temperature, barometric pressure, relative humidity, wave height, and period, water salinity, and subsurface ocean currents.

3.3.1.2 Wind data from models

Major part of the 3D wind and other meteorological data for wind farm siting is provided by the NWP models, normally needed for a period longer than 10 years. The model data should be able to provide sufficient resolution (finer than 5km for suitability analysis and tens of meters for optimal siting) and quality (root mean square error < 1m/s), and also correct wind-shears and boundary layer stability features. There are currently a wide range of long-term model wind products for the Baltic Sea. The global reanalysis products are available from ERA-Interim (~70km resolution) and NCEP CFSR (~30km resolution). However, both the quality and resolution of these products cannot fulfil the requirements. Several reanalysis products in spatial resolutions ranging from 6-11km exist or are in process of production, e.g., BaltAn65+ by Uni Tartu, Estonia, UERRA reanalysis COSMO-REA6 (by DWD) and SMHI reanalysis HARMONI-3DVAR. DMI has produced a 13 year analysis+6h forecast hourly products in spatial resolution of 3-5km. This product has been successfully used in a few Danish wind farm siting projects, as the forcing to generate high-resolution wave and ocean-ice conditions and higher resolution downscaled wind products for optimal siting. *It should be noted that that the model products should have sufficient horizontal resolution and vertical layers below 200m altitude, which are now not the case in many reanalysis products. Reanalysis with 2.5km resolution is required for Baltic Sea wind-farm siting and the wind profiles in the lower 200m should be calibrated and verified by using observations. Impacts from waves, currents and sea ice should be considered in the regional analysis models.*

3.3.2 Water conditions

Water conditions such as waves, currents, ice, sea level, temperature, salinity etc. affect the winds, turbulence in the marine boundary layer and the loads on the turbines. For the Baltic Sea wind farm siting, the most critical variables are waves, ice and currents. For wind farm siting study, high-resolution and quality data product are needed, which can only be obtained by integrating in-situ and satellite observations with models. In chapter 6 – DAR for Climate change, the availability of T/S, SST and sea ice data (both model and observations) for the Baltic Sea is described in detail. However, the data adequacy is only assessed for their uses in climate change. The information will be used in following sub-sections for assessing the fitness for use in wind farm siting.

3.3.2.1 Water observations

The water observations (sea level, waves, currents and temperature and salinity) in Baltic Sea are produced by agencies of operational monitoring, environmental monitoring, fishery monitoring and research monitoring using buoys, tidal gauge stations and research vessels etc. Most of the data are accessible from the data portals of BOOS, CMEMS, EMODNET, ICES and SeaDataNet. The in-situ water measurements, although sparse, serve for the purpose of wind farm siting, partly due to the fact that the models have a good skill in simulating the surface variables. However, currents and waves in coastal waters are exceptional both due to lack of current measurements and challenges for modelling currents in complex topography. *It is recommended that more current observations should be made available for model validation, e.g., through moored ADCP and HF radars; buoy measurements should be made available in coastal areas with complex topography.*

Surface data with high spatial resolution can be obtained from ferrybox lines for SST and sea surface salinity, and satellites for SST, sea ice and waves. The satellite SST covers entire Baltic Sea for periods of more than 20 years. For SST and sea ice, via merging data from multiple satellites and objective analysis, long-term daily gridded observations are available through CMEMS and national agencies e.g., BSH, DMI, FMI and SMHI. The historical along-track wave height data from multi-satellites have been aggregated by Ifremer and are downloadable from CERSAT website. *These data can be used to serve wind farm siting purpose.*

3.3.2.2 Water data from models

Several state-of-the-art ocean-ice-wave-biogeochemical models have been developed and applied to generate decadal hindcast and reanalysis time series for the Baltic Sea. In the following sub-sections we describe the data adequacy for wind farm siting in the Baltic Sea.

Data from ocean-ice models

Hydrodynamic models for the Baltic Sea include HBM, NEMO-Nordic and GETM. The model products are used for wind farm siting due to lack of observations. These models have been used for operational forecasting and therefore have been calibrated regularly both for normal conditions and extreme events. Through CMEMS, analysis/forecasts of ocean-ice are available in 1 nautical mile (nm, ca 1,8 km) resolution for the past two years. The ocean-ice reanalysis is available in CMEMS with 5.5km horizontal resolution for the period of 1989-2014. A 13 year hindcast of ocean-ice conditions for the Baltic Sea in horizontal resolution of 1nm for the Baltic Sea and 0.5nm for the Baltic-North Sea transition waters was produced by DMI and used in Danish wind farm siting projects. A more comprehensive summary of the long-term model runs for the Baltic Sea is given in Tab. 6.4 (in Chapter 6). *It is recommended that ocean-ice reanalysis products with high-resolution (e.g., 1nm) should be generated for the Baltic Sea by using well-calibrated operational models. The currents should be calibrated for all the sub-basins and major coastal regions against observations.*

Data from wave models

Several versions of the wave climate of the Baltic Sea are reconstructed based on wave model WAM. For example, a 52-year hindcast (1957-2008) in 3nm horizontal resolution was produced by TUT (Nikolkina etc. 2014) with COSMO wind hindcast. However, the ice was not included. A 6-year wave hindcast in 6nm resolution was produced by FMI with including sea ice conditions (Tuomi et al., 2011. http://www.borenv.net/BER/pdfs/ber16/ber16-451.pdf). The wind forcing used in the hindcast was FMI-HIRLAM analysis/forecast with varying resolutions (9-22km). A 13 year wave hindcast in 6nm resolution was produced by DMI with HIRLAM analysis/forecast in 3-5km resolutions as forcing and sea ice included. It provides boundary condition for a 1nm resolution hindcast covering the Baltic-North Sea transition waters (7-16E, 53-60N). The 1nm resolution wave hindcast have been used in Danish offshore wind farm siting projects.

Waves in Baltic Sea coastal waters are affected by many factors: wind forcing, ice conditions, bottom topography, islands, shallow water and limited fetch effects etc. Current hindcast models are mainly calibrated for open waters. For the near shore waters, it is important to take into account the specific factors in the wave models for the hindcast. For example, the seasonal ice conditions affect the wave climate of the northern Baltic Sea and the formulation of the wave statistics. Due to the irregular shoreline and archipelago, the coastal areas in Northern Baltic Sea are partly sheltered from the more severe wave conditions of the open sea. Modelling of wave conditions in these areas requires high-resolution grids with sufficiently accurate description of bathymetry and land-sea mask. Additional measures are needed to take into account wave refraction and depth-induced wave breaking on a sub-grid scale. Above all, the meteorological forcing plays a key role and production of meteorological datasets with high quality and resolution is essential. In recent years research progresses have been made in these areas (e.g., in Tuomi, 2014, https://helda.helsinki.fi/bitstream/handle/10138/42773/tuomi_dissertation.pdf?sequence=1). In CMEMS, operational wave forecast in 1nm resolution will be freely available in 2017. *It is recommended that recent progresses in wave-current interaction, wave-ice interaction, sub-grid treatment for sheltering effects and limited fetch impacts etc. should be taken into account in new hindcast wave models; the hindcasted products should have high-resolution (e.g., 1nm) and be further calibrated in coastal waters in the Baltic Sea. The wave hindcast products should be forced with reanalysis or analysis/forecast products with horizontal resolution minimum in 5km.The dataset should be freely available via e.g., CMEMS.*

Data from biogeochemical models

Use of water chemical data in wind farm siting is mainly for environmental impact assessment. Currently only a few biogeochemical hindcast and reanalysis data are available. A biogeochemical reanalysis for the period of 1979-1999 with 5.5km resolution was produced by SMHI. The data are available on request. A 25yr (1990-2014) hindcast of biogeochemical variables is available from FP7 project OPEC web portal (http://www.marineopec.eu), with a horizontal resolution of 6nm for the Baltic Sea and 1nm for the Baltic-North Sea transition waters. *For wind farm siting in the Baltic Sea, it is recommended that the biogeochemical model products should be calibrated extensively especially in the coastal waters.*

3.3.3 Biota conditions

Part of the useful biota data products can be found in HELCOM Data and Map Service (DMS, http://maps.helcom.fi). The important bird areas and withering bird areas are shown in Fig. 3.1. The Baltic Sea benthic marine landscape is shown in Fig. 3.2.

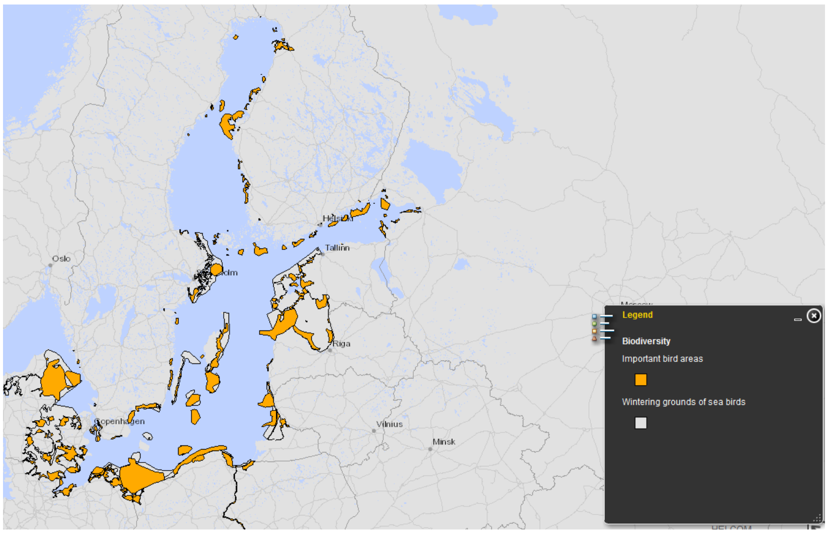

Figure 3.1. Bird areas and withering bird areas in the Baltic Sea (HELCOM DMS)

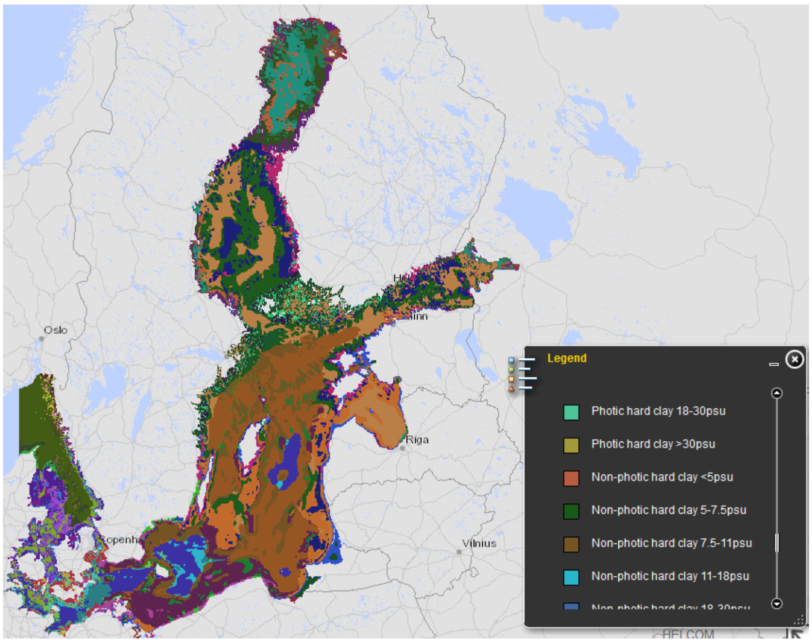

Figure 3.2. Benthic marine landscape in Baltic Sea (HELCOM DMS)

The other useful biota data for wind farm siting may include spatial distribution of endangered species (fish, birds, benthic invertebrates, marine mammals etc). *It is recommended that existing EMODNET Biodiversity may provide a similar viewing service as in* http://maps.helcom.fi/website/mapservice/index.html .

3.3.4 Seabed conditions

General information and data of seabed conditions can be found in EMODNET Habitat and HELCOM-DMS. Figure 3.3 displays the seabed sediment polygon and seabed slope from the HELCOM Service.

Figure 3.4 is the habitat type based on EUNIS-2015. One can also zoom in to see detailed habit features (as shown in Fig. 3.5).

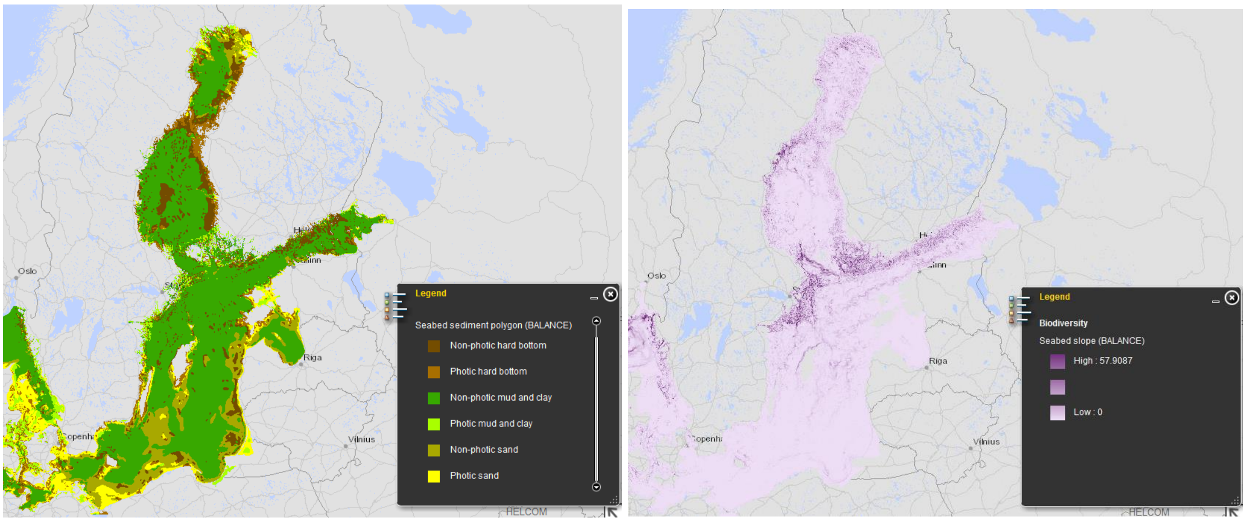

Figure 3.3. Seabed sediment polygon (left) and seabed slope (right) in Baltic Sea

Bathymetry and seabed slope: The best public available bathymetry can be obtained from BSHC (The Baltic Sea Hydrographic Commission) and EMODNET, which are basically the same. The BSHC has produced a Baltic Sea Bathymetry Database (BSBD) based national contribution of gridded bathymetry data from 50m-500m resolution covering their EEZ and territorial waters. For Russian and Lithuanian waters, GEBCO _08 1minute resolution data were used. The newest version is v09.3. The BSBD website provides a dynamic “position – depth” service. EMODNET data is based on BSBD newest version, but also including new data from other resources. For siting suitability study for a typical wind farm in a diameter of a few kilometers, the BSBD data should be sufficient to provide a baseline reference except for Russian and Lithuanian waters. The seabed slope data are a product from BALANCE project. It is suggested that the seabed slope data should be derived from the original bathymetry data.

Existing seabed data and information can only provide a general guidance for the seabed related issues in OWF siting. The detailed data have to be obtained through on-spot measurements for optimal siting.

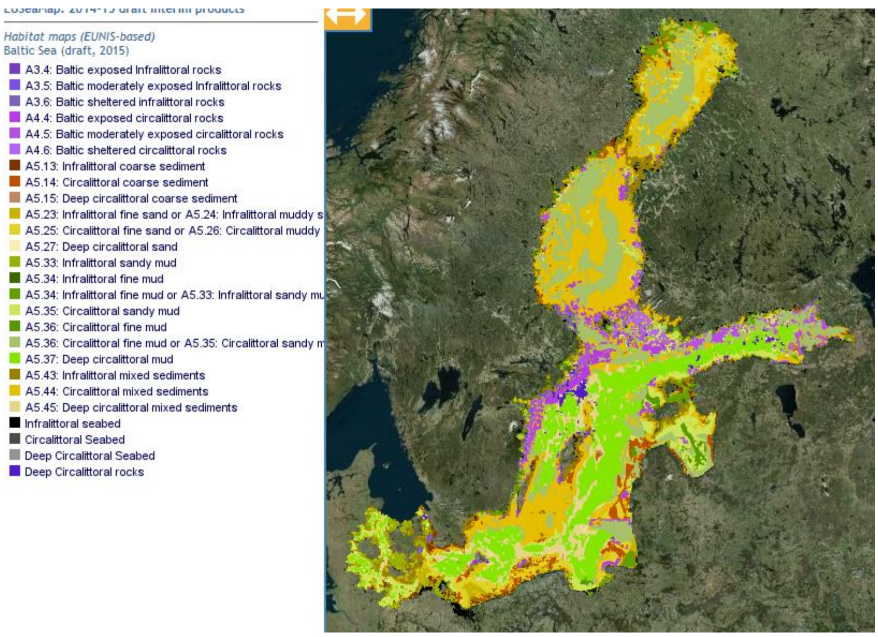

Figure 3.4. Baltic Sea habitat map from EMODNET Habitat

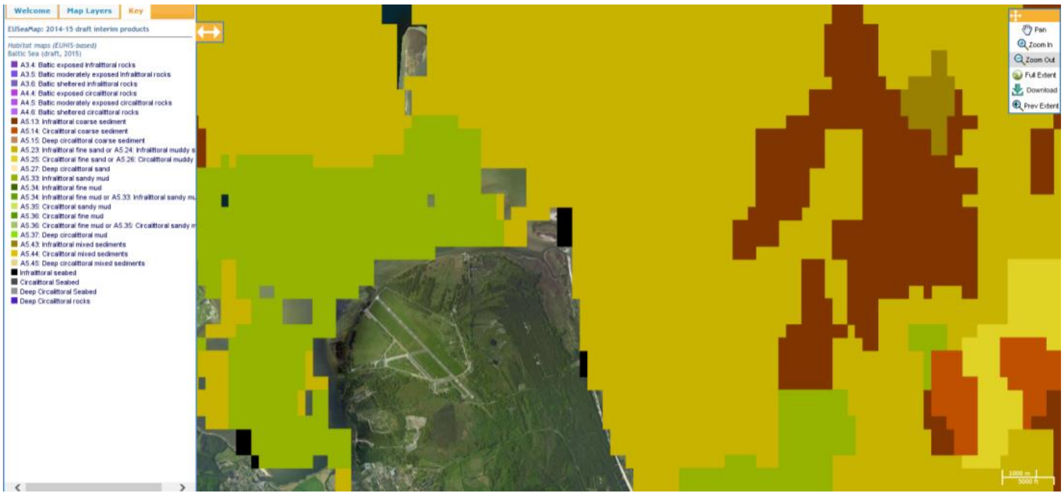

Figure 3.5. Enlarged habitat maps in western Baltic Sea reveals more details

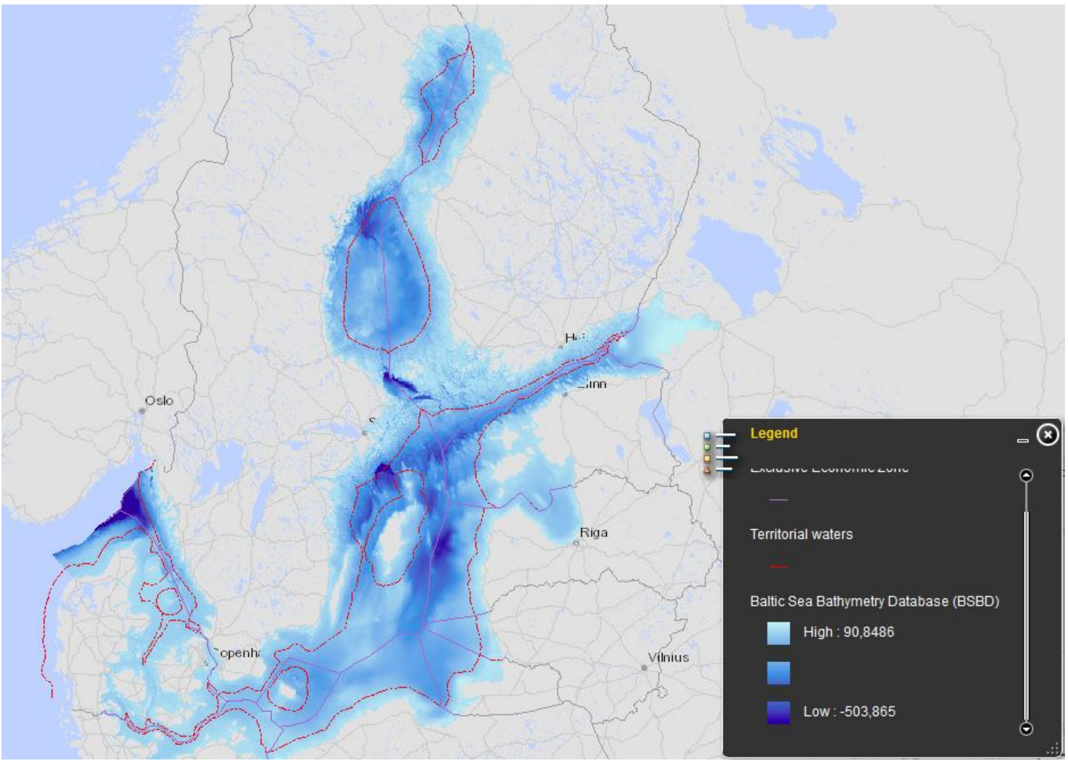

Figure 3.6. Baltic Sea bathymetry based on BSBD, boundaries of EEZ and territorial waters

For Baltic Sea wind farm siting, it is recommended to enrich existing bathymetry database with new data, especially in eastern Baltic Sea, and to develop new seabed slope products, in a similar way of generating the bathymetry database. The current resolution of the bathymetry data (500m) should be increased to 100-200m.

3.3.5 Human activities

The human activity data in the Baltic Sea can be obtained from web portals of HELCOM-DMS and EMODNET Human activity theme. The two databases are mostly overlapped but some differences should be noted. For example, Fig. 3.7 displays part of the human activity data from HELCOM-DMS. The cables and pipelines are not from the same dataset as in EMODNET (Fig. 3.8). HELCOM has more detailed fish catch maps than EMODNET, which is important for assessing the economic impacts of the OWFs. The spatial distribution of commercial fish catch was given in Fig. 1.9. HELCOM also has more data for MPAs by adding UNESCO heritage sites and fish closure sites, ship lane statistics are also available from the HELCOM-DMS (figures not shown here).

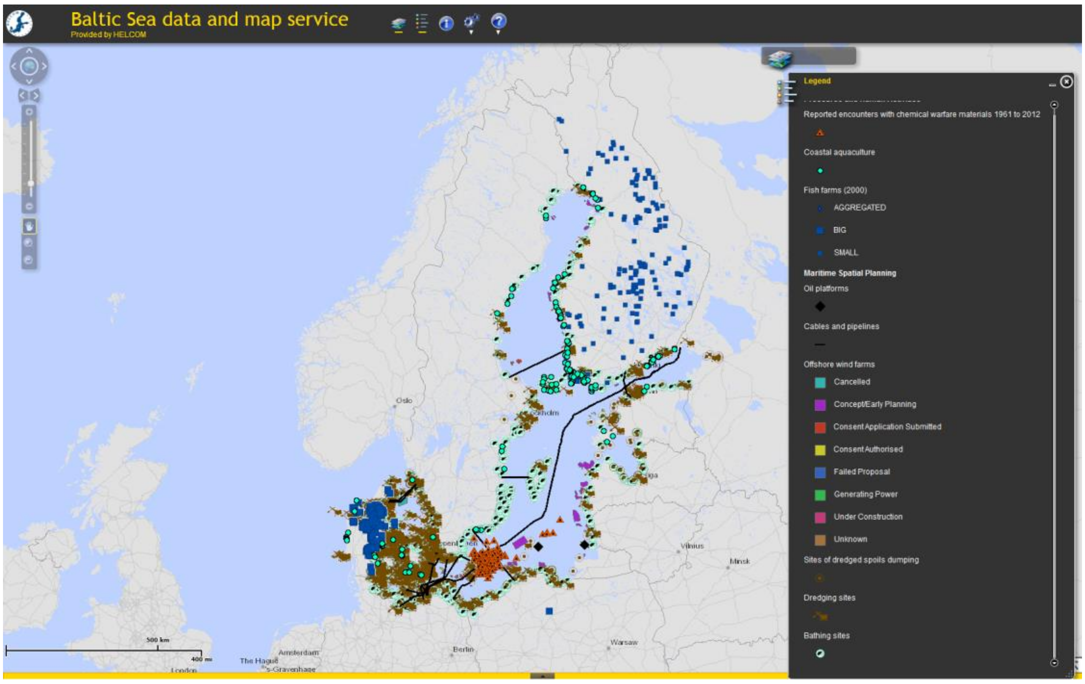

Figure 3.7. Part of the human activities shown in HELCOM-DMS

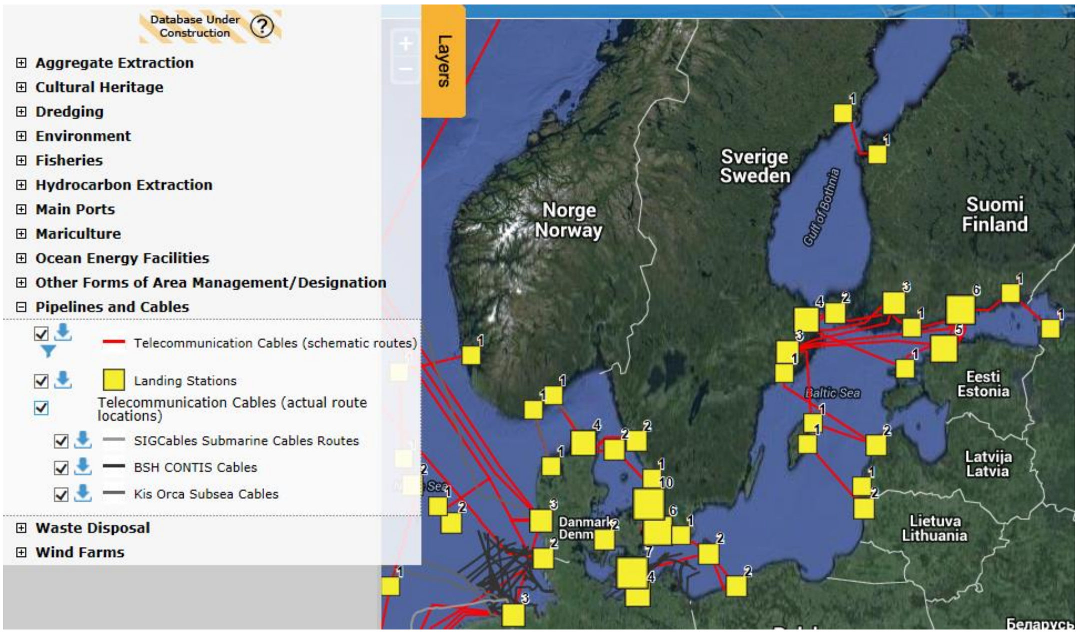

Figure 3.8. Pipelines and cables shown in EMONET Human activity

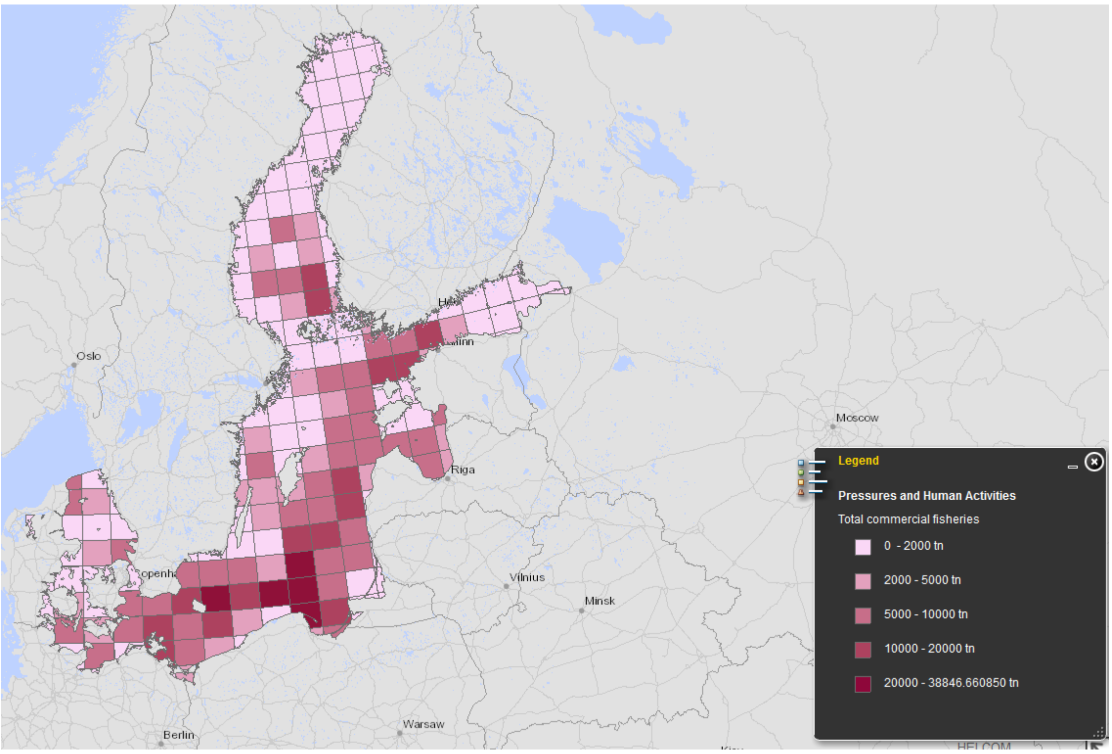

Figure. 3.9. Spatial distribution of commercial fish catch in the Baltic Sea.

Some human activity data needed are not available from HELCOM or EMODNET, e.g., electricity grid network in the Baltic Sea, regulatory documents and cost of different type of foundations which are in general hold by national agencies or wind farm companies. A Baltic Sea grid network map was made by Nordregio in Sweden but for 2007 (Fig. 3.10).

Figure 3.10. A Baltic Sea grid network map (Nordregio, 2007)

Table 3.3a. Data availability for “Wind farm siting”

Variable	Data type	Accessibility	Completeness / coverage		Resolution			Precision
		Delivery type/time	Spatial	Temporal	Hor.	Ver.	Temp.	
Wind profiles	In-situ (private/ institutional data)	Restricted, on request, in months-years	Baltic Sea	1960-now	Sparse points	A few heights up to 130m	Hourly	0.1m/s
	Model (DMI)	On request or open, free, in months-years		2003-now	3-5km	User specified		1 -1.5m/s
Winds at 10m	In-situ (ECAD, GTS)			1900-	Sparse points	N/A		0.1m/s
	Satellite			1993-	7-25km			1m/s
	RAN/ HC*			1980-now	3-5km			1-2m/s
T_{air}, P_{air}, RH, Cloudiness	In-situ		Baltic Sea	1960-now	Sparse points	User specified		T_{air}: 0.1^{o}C P_{air}: 0.15hPa RH: 3%
	RAN/HC		Baltic Sea	1980-now	3.5km			T_{air}: <1-2 ^{o}C P_{air} :<0.5hPa RH: <30%
Currents	In-situ (BOOS, MARNET, EMODNET)		Baltic Sea	1990-now	<10 stations	1-2m	Hourly	<0.1m/s
T/S				1960-now	10^{2-3} stations		Hourly-daily	T: <0.1C S: <0.1psu
Sea level				1900-now	15-100 stations	N/A	10-60 min.	<1cm
Currents, T/S, sea level	DMI HC	On request	Baltic Sea	2003-now	0.5-1nm	1-3m in upper 50m	Hourly-monthly	Current speed: 0.1-0.3m/s, Sea level: 5-10cm Salinity: 0.5-1 Temperature: 1^{o}C
	CMEMS RAN	open, free		1989-2014	5.5km			
Waves	In-situ	On request, in months-years	Baltic Sea	1990-now	<10 stations	N/A	Hourly	Hs: 0.01m Period: 0.1s
	Satellite	open, free, in months-years		1993-now	7km along track		Instant	Hs: <0.1m
	Model HC	On request	Baltic Sea	6-40y	1-10km		Hourly	Hs:0.3-0.5m Tp: 1-3s Tm: 1-2s
Sea Ice:	Satellite	open, free	Baltic Sea	1979-	1-3km	N/A	Daily	Concentration: 10% Thickness: <45cm Drift: 40% to 80%
	Model			1989-	2-6km		hourly	
Nutrients (N&P), Chl-a Dissolved oxygen (DO)	In-situ (ICES)	Internet access, delayed by 1-1.5y		1980-	>100 stations		4-24 times/y	N&P: 0.1mmol/m^3 Chl-a: 0.1mg/m^3 DO: 0.1 ml/l
	CMEMS RAN	Internet access, delayed by 1.5y		1979-1999	5.5km	Multiple	Hourly-monthly	N&P: 2 mmol/m^3 Chl-a: 1mg/ m^3 DO: 0.2ml/l
	OPEC HC	Internet access		1990-2013	6nm	Multiple		

*RAN: reanalysis; HC: hindcast

Table 3.3b. Data availability for “Wind farm siting”

Variable	Data type	Accessibility		Completeness / coverage		Resolution			Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
Birds/marine mammals/fish Habitats, abundance, biomass, formations, angiosperm, macro algae, interverbrate, bottom fauna	In-situ (ICES/ HELCOM, EMODNET)	On request or open, free, delayed in months-years		Baltic Sea	N/A				N/A
Bathymetry	BSBD	Internet			N/A	500m	N/A	N/A	10^0m
	National data	Restricted				<50-100m	N/A	N/A	1m
Substrate, sediments lithology, coastline evolution, sea bed slope	EMODNET,	Internet				Unavailable	N/A	N/A	0.01m/m sea bed slope
Sea bed habitats	In-situ HELCOM	Internet			N/A	N/A	N/A	N/A	Unknown
Energy at sea bed	Model	On request, delayed in months-years			>10yr	5km	N/A	Monthly	0.001m/s shear stress velocity
Human activity: exist. Wind farms, maritime traffic, fishing, mariculture, coastal land use, MPA dredging and dumping sites	EMODNET, HELCOM	Open, free, Continuously updated			most recent data	N/A	N/A	N/A	N/A
Human activities: ports and infrastructure for assembling and managing logistic operations, aggregate extraction, pipelines and cables						N/A	N/A	N/A	N/A
Human activities: Grid network for electric transmission						N/A	N/A	N/A	N/A
Regulatory constraints	Publications, web sites					N/A	N/A	N/A	N/A
Touristic or residential areas ahead of wind turbines						Not Available	N/A	N/A	N/A

3.4 Conclusions

In this chapter, marine data usage, requirement and adequacy are investigated for the fitness for use in wind farm siting. Major focus is on the application in site suitability assessment, which is part of the BSCP demonstration. The application of environmental and ecological assessment and optimal (cost-efficient) siting design are of the wind farm siting but out of the scope of the project. Therefore they are touched mainly in the level of data availability rather than the adequacy assessment.

Table 3.4a. Data adequacy for “Wind farm siting”

Variable	Data type	Accessibility	Completeness/ coverage	Resolution	Precision
		Delivery type/time	Spatial/ Temporal	Hor./Ver./Temp.	
Wind profiles	In-situ	Existing data should be more open to research	More new data are needed. Time series over sea are sparse and too short on hub height (100m-130m)	Lack of offshore wind profile measurements	FFU* Observed and modelled winds are roughly of the same quality. .
	Model	Post processing should make wind profile data available	Current data are adequate for extreme estimation up to 50yr return period. Longer time series are needed for 100yr return periods.	Reanalysis needs higher spatial resolution	
Air Temperature, Air Pressure, humidity, Cloudiness	In-situ (ECAD, GTS)	FFU	More data are needed. Time series are sparse over sea .	FFU	FFU
	Model data	FFU	FFU	FFU	FFU
Currents	In-situ EMODNET, Natl. data centres	Data should be more open. Faster QC and data provision is recommendable	Point observations are rather sparse. Most of the offshore data is available from cruises (delay time for quality control). Faster data provision is recommendable		FFU
T/S	EMODNET, BOOS	FFU	FFU	FFU	FFU
Sea level		FFU	More stations needed in Poland and Lithuanian cost	FFU	FFU
Currents, T/S, sea level	Model data	FFU	FFU. Hindcast and operational products with adequate spatial and temporal resolution are available; reanalysis products feature a lower resolution, which makes them less suitable for wind farm sighting		FFU but more validation/assimilation needed for coastal waters
Waves:spectra, Hs/periods, Max. Wave height	In-situ , satellite, model	FFU	Some long time series exist; point observations are sparse in space and time. More observations needed in shallow waters. Satellite data have good spatial/temporal coverage		FFU
Sea Ice: thickness, strength, flow size, extend, occurrence	Model, satellite	FFU for ice concentration. Reprocessed sea ice thickness is needed. No floe size data.	Digital maps from CMEMS are available from 2010 onwards. Ice charts go back a longer time, but are often not digitalized. Model data have coverage and resolution that are adequate for normal statistics and extreme statistics.		FFU, but model data needs more validation and quality improvement.
Nutrients, chlorophyll-A, oxygen	In-situ Model	The required time for making observations available is with 1yr to 1.5yr to long. Recent data should be available in months.	Time series of adequate length are available at some buoy positions and ship cruise stations. Model data from reanalysis, hindcast and operational products are freely accessible. Observations need more coverage in space and time. The resolution of model data products is adequate. Observations of ecosystem variables are still point data and can only be used for local assessments.		Model quality is inadequate for assessment, but still useful for long term and large scale studies.

*FFU – Fit-for-the-use

Table 3.4b. Data adequacy for "Wind farm siting"

Variable	Data type	Accessibility	Completeness/ coverage	Resolution	Precision
		Delivery type/time	Spatial/ Temporal	Hor./Ver./Temp.	
Birds/marine/ ma-mmals/fish, habitats, abundance, biomass, formations, angiosperm, macro algae, interverbrate and bottom fauna	In-situ	FFU	Not Assessable for this report		FFU for site suitability but not for ecological impact assessment
Bathymetry	Interpolated	FFU. Openly available for BSHC/EMODNET but restricted access for national data	The coverage with high-resolution data is adequate, except for Russian and Lithuanian waters, where an update with original data is needed.	The spatial resolution is adequate for Baltic Sea wide large scale studies. Local studies need higher resolution data that is often not freely available from national data centers.	FFU for site suitability except for Russian and Lithuanian waters
Substrate, sediments/lithology, coastline evolution, sea bed slope	Interpolated data	FFU. Openly available	Not Assessable for this report	Not Assessable for this report	Improved Seabed slope needed
Energy at the sea bed	In-situ model	FFU.	Not Assessable for this report	Not Assessable for this report	Not Assessable
Exist. Wind farms, maritime traffic, , fishing, mariculture, coastal land use, MPA, dredging and dumping sites	MSP, Maps, digital data from web sites	Open data access	More cables/pipeline /land station data in EMODNET; more fish maps, ship lane, coastal land data in HELCOM	N/A	Need updated information, e.g., for fish catch spatial distribution.
Ports, infrastructure for assembling and managing logistic operations, aggregate extraction, pipelines and cables		Open data access EMODNET http://www.worldportsource.com/	Completeness of the data set is restricted by the access to new and local data. More port information needed: e.g., port depth for assembling the turbines, logistical access for large and heavy items, towing capacity		Not Assessable for this report
Human activities: Grid network for electric transmission		Nordregio web site; EMODNET portal	The Baltic Sea grid map was made for 2007. An updated map is needed.	Not Assessable for this report	
Regulatory constraints	Publications, web sides	Not available	This information is lacked	This information is lacked	This information is lacked
Touristic or residential areas ahead of wind turbines	EMODNET, Publications, web sides	Partly adequate	EMODNET provides bathing water quality; HELCOM has land information.	N/A	N/A

Major findings are summarised in Tables 3.4a and 3.4b. Major data gaps are identified as follows:

1. Offshore wind profile measurements in the boundary layer up to the hub height (150m) are not sufficiently monitored and shared.
2. Coastal currents are not sufficiently monitored and shared.
3. Quality of modelled wind and current in the shallow coastal region needs to be improved
4. Human activity data e.g., navigation (AIS), grid network and national regulations in related to wind farm siting should be made available and shared

Recommendations for filling the above data gaps:

1. A detailed optimal design of offshore winds (profile) and currents monitoring array is needed, to select minimum number of optimal locations as validation stations for weather and ocean models.
2. Develop high-resolution weather and ocean-ice assimilation and reanalysis (>30years) to improve the quality of coastal wind and current product.
3. To extend EMODNET Human activity to cover necessary data for wind farm siting.
4. Centralised data management and provision.

Following notifications are made when using the above results and recommendations:

1. There are two levels of data use in wind farm siting: one is for site suitability study and the other for detailed site design and impact assessment. The former is an area where community data can largely benefit. For the latter, specific local monitoring and modelling are required, which are services performed by private companies. Use of data in this report is mainly limited in the first level.
2. Data adequacy also depends on the state-of-the-art of modelling and data assimilation. Products based on in-situ -satellite-model integration are frequently used. When the integration methods reach sufficient quality, major use of the in-situ observations becomes validation and assimilation rather than generating final products. This will significantly reduce the number of in-situ stations required.
3. Climate change may alter local wind resources significantly. Wind resource data with reliable statistics and error bar estimates for the future climate (in 20years) should be considered as necessary for the wind farm siting

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4 Data adequacy for marine protected areas

4.1 Introduction

The objectives of MPA (Marine Protected Areas) Challenge in BSCP are to analyse the existing network of the Baltic Sea MPA's in respect to 1) categories of MPA's according to the IUCN classification; 2) representativeness and coherence of the network according to Article 13 in the Marine Strategy Framework Directive; and 3) effects of climate change on the network.

Task 1. Classification of MPA's according to IUCN (International Union for Conservation of Nature) categories. The IUCN protected area categories are a global framework for classifying protected areas according to management types and conservation targets. This framework defines 7 classes of protection: IA Strict Nature Reserve; IB Wilderness Area; II. National Park; III. Natural Monument; IV. Habitat/Species Management; V. Protected Landscape / Seascape; VI. Protected Area with Sustainable Use of Natural Resource (Dudley, 2008). IUCN categories to MPA areas into categories were used for classification of the Baltic MPAs by HELCOM (2013) using newly published guidelines (Day et al., 2012).

Task 2. Coherence of the network according to Article 13 in the Marine Strategy Framework Directive. Article 13 of the Marine Strategy Framework Directive (MSFD) is related to the Programs of Measures (PoM's), which Member States should identify in order to achieve Good Environmental Status (GES) in relevant marine waters. According to MSFD, PoM of Member States shall include spatial protection measures, contributing to coherent and representative MPA network, adequately covering the diversity of the constituent ecosystems considered by Habitats Directive, Birds Directive and other regional and international agreements. Coherence of the network has been typically assessed by four measures: representativity, replication and connectivity of sites/features, as well as adequacy. Although replication and adequacy were assessed applying simple numerical thresholds for the area or number of similar sites, representativity and connectivity aspects are more complex. Information on environmental heterogeneity (diversity of habitats set by bathymetry, salinity and substrate) serve background information in assessment of physical features covered by MPA network (i.e. representativity). In the Challenge these layers will be primarily used to assess the distribution of planned management measures across ecologically relevant depth ranges, substrate types and salinity classes, and by this estimate their contribution to increased coverage of protected features. If programs of measures will target concrete species and habitats, then coherence parameters should be explored in a context of their distribution patterns.

Task 3. Assessment of climate change effects on the MPA network. Analysis of climate change effects in the Baltic Sea typically addresses changes in temperature, water level and salinity. In the MPA Challenge this task will be based on comparison of current background environmental conditions (salinity, ice cover, transparency) with available data on their historical records and/or future projections. Only those environmental layers, which have tight relation to distribution of protected species and habitats will be utilized. Such comparison should provide insights on spatial changes of conservation features, which have been observed or should be expected in connection to the climate change effects.

Mechanisms of climate change effects acting on biodiversity through salinity, temperature and sea level rise have been described in Dahl et al. (2012) addressing well known, functionally important and/or commercially important species (see example in Fig. 4.1). Although many of these species are not targeted by MPA network directly, the approach itself illustrates well the algorithm for the testing climate change effects on spatial distribution of nature conservation features addressed by the Challenge

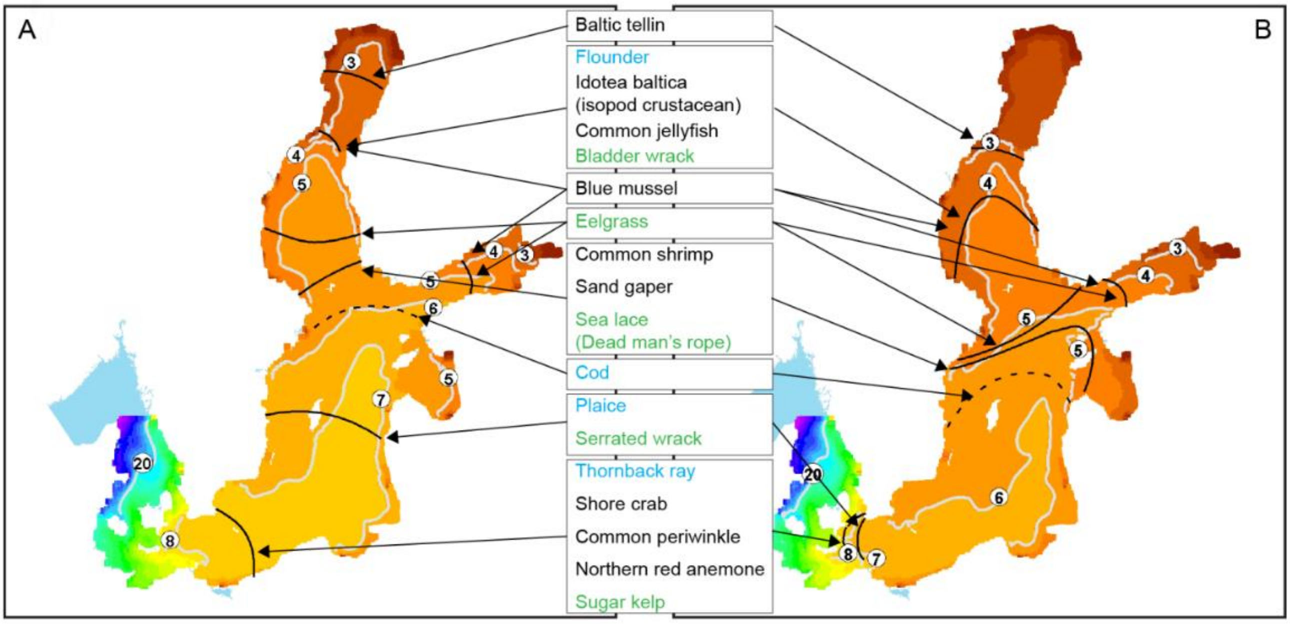

Figure 4.1. Example of the long-term surface salinity change (according to Meier et al., 2011) effects on distribution of selected marine species (boundaries redrawn from Bonsdorff, 2006).

Use of data for the above three tasks are summarized in Table 4.1.

Table 4.1 Data usage in "Marine Protected Areas"

Variable	Data type	Usage
MPA boundaries	Coordinates of legal boundaries	Classification of MPA's according to IUCN categories, distribution and intensity of management measures contributing to ecological coherence criteria of MPA network, extent of climate change effects in the existing MPA network
IUCN categories for MPA	Derived from conservation targets and management measures	Classification of MPA's according to IUCN categories
Member States MSFD reports on Programs of measures	Documents	Distribution and intensity of management measures contributing to ecological coherence criteria of MPA network
Substrate	In-situ	Distribution and intensity of management measures contributing to ecological coherence criteria of MPA network
Bathymetry-1	Interpolated	Distribution and intensity of management measures contributing to ecological coherence criteria of MPA network
Bathymetry-2	Interpolated	Effects of long-term changes in Secchi depth on distribution of vegetation and selected

		phytobenthos species in existing MPA network
Distribution of threatened HELCOM Red List species	In-situ Obs., Model	Distribution and intensity of management measures contributing to ecological coherence criteria of MPA network, extent of climate change effects in the existing MPA network
Distribution of Bird Directive and Habitat Directive species	In-situ Obs. Model	Distribution and intensity of management measures contributing to ecological coherence criteria of MPA network, extent of climate change effects in the existing MPA network
Distribution of Habitat Directive Annex I Habitats	In-situ Obs. Model	
Salinity	In-situ , Model	Extent of long-term salinity effects in distribution of threatened species
Salinity trend/forecast	In-situ , Model	
Average/maximum/minimum ice cover OR Duration of ice cover OR Average end date of the ice cover season	In-situ Obs.	Effects of long-term changes in ice cover on distribution of selected Bird Directive and Habitat Directive species
Historic/future average / maximum / minimum ice cover OR Duration of ice cover OR End date of the ice cover season	Model	
Secchi depth	In-situ , Model	Effects of long-term changes in Secchi depth on distribution of vegetation and selected phytobenthos species in existing MPA network
Secchi depth trend/forecast	In-situ , Model	

4.2 Data requirement assessment

Data requirements according to the three MPA Challenge tasks are listed in the Table 4.2. Datasets on MPA boundaries, bathymetry and salinity will be needed as background layers for more than one Challenge task. Since physical layers are either modelled or merge various datasets of different origin and resolutions, in many cases there are no specific requirements for spatial resolution of environmental datasets (bathymetry, water transparency, ice cover, salinity). As long as these layers are technically compatible, e.g. resolution of the modelled photic depth is meaningful in the areas of complex coastlines with relatively steep slopes (e.g. Archipelagos), their use can provide useful results.

In contrast to physical and administrative layers, resolution of protected features (species and habitat types) is directly linked to the interpretation of results. Since the size of the smallest MPA is 0.6 km^2, and there is a number of sites smaller than 10 km^2, it is obvious that existing data layers of protected features will not be compatible with size of conservation zones at the whole Baltic scale. On the other hand, minimum resolution may highly vary among features being high for rare/small scale features and relatively low for large and widespread features. Although numerical information on the amount of feature (abundance, density, etc.) would be preferable for the species, presence/absence data within MPA and Baltic wide distribution will fulfil a minimum requirement for coherence assessment. For analysis of the habitat types, their Baltic wide distribution would ideally fit for analysis of the Challenge tasks. Distribution of the habitat type within individual MPA is minimum information needed to proceed with analysis on contribution of management measures to the MPA network coherence.

Table 4.2 Data requirements for “Marine Protected Areas”

Variable	Data type	Accessibility		Completeness/ coverage		Resolution			Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
MPA boundaries	Legal boundaries	Open	Online	Entire Baltic	Designated till 2016	Varying	N/A	N/A	N/A
IUCN categories	Derived			Entire Baltic	Current	N/A	N/A	N/A	N/A
MSFD Programs of measures	Legal document			All Member States	Till 2020	N/A	N/A	N/A	N/A
Bottom sediment	Model		Online, ready for delivery	Entire Baltic	N/A	N/A	N/A	N/A	.N/A
Bathymetry-1	Model			Entire Baltic	N/A	500m	N/A	N/A	1 m
Bathymetry-2	Model			Entire Baltic	N/A	250m	N/A	N/A	0.1 m
Distribution of threatened HELCOM Red List species	Model		Ready for delivery	Entire Baltic	2003 onwards	N/A	N/A	N/A	N/A
Distribution of Bird Directive and Habitat Directive species	Model			Entire Baltic	2003 onwards		N/A	N/A	N/A
Distribution of Habitat Directive Annex I Habitats	Model			Entire Baltic	2003 onwards		N/A	N/A	N/A
Salinity	Model			Entire Baltic	>10 years average		N/A	N/A	1 psu
Salinity trend/forecast	Model			Entire Baltic	50-100 years		N/A	N/A	1 psu
Ice cover	Model			Entire Baltic	>10 years (average, min. max.)		N/A	N/A	1 km^2
Ice cover/forecast	Model			Entire Baltic	50-100 years		N/A	N/A	1 km^2
Secchi depth	Model			Entire Baltic	>10 years (average, min, max.)		N/A	N/A	0.1 m
Secchi depth trend/forecast	Model			Entire Baltic	50-100 years		N/A	N/A	0.1 m

4.3 Data adequacy assessment

The data adequacy in the MPA Challenge is assessed considering the most relevant data sources for implementation of the tasks. All variables are grouped into three classes:

i) physical variables (salinity, bathymetry, sea level, sediment, water transparency, including impact of climate change on these variables);
ii) conservation features (Red-List threatened species, Habitat Directive species and habitat types, Bird Directive species);
iii) administrative data (MPA boundaries, conservation measures of countries according to Marine Strategy Framework Directive, Article 13)

For each variable group data availability is investigated first and the adequacy to fit for the use in implementation of Challenge tasks is then assessed against the data requirements in Tab. 4.2. Major findings are summarised in Tabs. 4.3 and 4.4, respectively.

4.3.1 Administrative data

The administrative data includes MPA boundaries, conservation measures of countries according to Art. 13, MSFD. HELCOM database MPA data layer contains boundary information on 173 sites (Fig. 4.2). Out of them, 61 sites are purely marine and 112 sites occupy both marine and terrestrial parts. Most of the sites (163) are assigned to NATURA 2000 network, therefore primarily linked to the species and habitat types specified by Habitat and Bird Directives. Species and habitat types considered for protection by MPA (classified as "species/habitat type justifying designation") or present within MPA are provided. However data on species absence are not available (dataset considered as providing presence only and not presence/absence data).

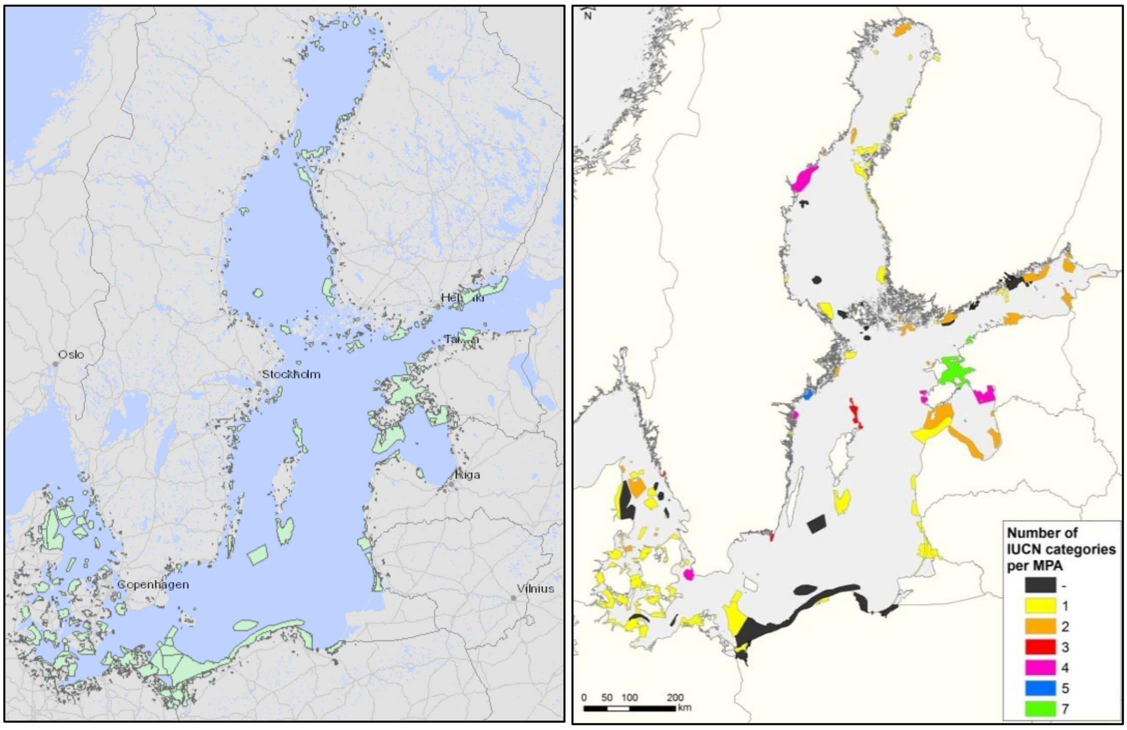

Figure 4.2. MPA boundary layer (left) and number of IUCN categories assigned to the individual sites (right) (source: HELCOM MPA map service, 2016).

Table 4.3 Data availability for "Marine Protected Areas"

Variable	Data type	Accessibility	Completeness/ coverage		Resolution	Precision	Data provider
		Delivery type/time	Spatial	Temporal	Hor./Ver./Temp.		
MPA boundaries	Legal boundaries	Open, online	Entire Baltic	-2015	N/A	N/A	HELCOM MPA-DB
				-2016	N/A	N/A	Natura 2000 database
IUCN categories	Derived			2013	N/A	Category	HELCOM MPA-DB
MSFD Programs of measures	Legal document		All member states	Till 2020	N/A	N/A	Websites of MS MoE
Substrate	Model	Open, online, ready for delivery	Entire Baltic	N/A	bottom sediment, five classes		HELCOM DMS
Bathymetry	Gridded			N/A	H: 0.5 km	1 m	HELCOM DSM, BSBD
Bathymetry	Gridded			N/A	H: 1/8 min	1 m	EMODNET
Distribution of threatened HELCOM Red List species	Model	Open, ready for delivery		2003 onwards	N/A	presence	HELCOM MPA-DB HELCOM DMS
Distribution of Bird Dir. and Habitat Dir. Species	In-situ Obs.			2003 onwards	N/A	presence	HELCOM MPA database
Distribution of Bird Directive species	Model	On request		2007-2009	H: 1.235 km	Birds/km^2	Skov et al., 2011
Distribution of Habitat Dir. Annex I Habitats	Model	Open, ready for delivery	Entire Baltic	2003 onwards	H: Per MPA	Presence in MPA	HELCOM MPA-DB
Salinity	In-situ			N/A	A few hundred stations; 4-24 profiles/yr	0.1 psu	EMODNET
Salinity*, ice cover* (RAN/ HC, scenario runs)	Model	Open or On request		1960-2100	H: 1-6nm V: multi-levels T: hourly	Varying	CMEMS, SMHI, DMI, FMI
Ice cover, historical	In-situ Obs.	Open		1719-now	Annual	N/A	FMI, HELCOM DMS
Photosynthetically Active Radi- ation at seabed	In-situ			N/A	N/A	N/A	EU Sea Map 2016 / EMODNET
Secchi depth	In-situ			1980–1998	N/A	0.1 m	HELCOM DMS

Secchi depth scenario runs	Model	On request	Entire Baltic	1978–2007 2069–2098	N/A	0.1 m	Meier et al. 2012

*Details in Tab. 6.4.

HELCOM database layer on IUCN classification contains 208 records of IUCN categories assigned to 174 MPA. Altogether, more than one IUCN category was assigned 41 sites, out of them 3 sites have more than four IUCN categories. On the other hand, 29 sites do not have assigned IUCN categories and these will need to be examined screening additional information sources. The major difficulty to define IUCN category for most of these individual MPA's is restricted access to the legal designation documents or management plans, where detailed description of conservation targets and/or conservation measures can be found. Nevertheless, both data layers on MPA boundaries and IUCN categories serve as good background for further analysis of MPA network.

Assessment of the distribution of planned management measures under MSFD Article 13 is highly dependent on the level of details. Although Programs of measures developed by all Member States contain measures relevant to MPA network, the level of details provided in the description of these measures is far from sufficient for assessment of their contribution to the network coherence. These measures can be classified into three categories: i) extension of MPA network; ii) development/update of management plans; iii) development of specific management measures (management plans for selected species; measures to mitigate critical pressures etc.). None of these measures are georeferenced and therefore their distribution will remain unknown (except for discrimination between EEZ and territorial waters) until certain phase of measure implementation will be reached (e.g. inventory and assessment of offshore sites for MPA designation is completed). Development of management plans and specific measures are also very broad and cannot be assessed in terms of intensity, to which they will contribute to the MPA network coherence. Summarising above, the level of detail provided in the Programs of measures is inadequate for assessment of their contribution to any of four coherence criteria of the MPA network.

4.3.2 Physical variables

Salinity

Salinity is one of the main factors shaping biodiversity of the Baltic Sea and therefore of high importance for coherence assessment of MPA network and climate change effects on protection of species. There is a relatively dense network of coastal stations and also offshore oceanographic platforms providing operational salinity data, however due to high spatio-temporal variability of the parameter most of these data are used for small scale short-term studies and validation of modelled salinity results. Modelled salinity layers are typically used for assessments or studies focused on larger spatial scales (incl. the regional assessments of MPA network and habitat suitability studies) due to full coverage of the Baltic Sea. There are several datasets of modelled salinity values covering the whole Baltic Sea. Mean annual bottom salinity modelled by BALANCE project (Al-Hamdani, Reker, 2007, see Fig. 4.3 left) is divided into 6 categories covering oligohaline (<5, 5-7.5 psu), mesohaline (7.5-11, 11-18 psu), polyhaline (18-30 psu) and euhaline (>30 psu) salinity intervals. Although these categories have very clear ecological explanations (Cod and marine algae reproduction limits, etc.), salinity resolution is obviously too coarse for the Challenge tasks. EMODNET also provides modelled average salinity (for year 2000-2008) data layer at a resolution of approx. 5.5 km. This salinity information satisfies minimum adequacy requirements for implementation of Tasks 1 and 2, but precision of the parameter can limit Task 3 implementation in cases were very detailed information is needed. High-resolution monthly means of the Baltic Sea salinity distributions for the period from 1989 to 2014 are available from HIROMB model through COPERNICUS platform. Potentially, these 25 years data are the most precise readily available information on salinity fluctuations, however for the Challenge purposes integration of data would be needed.

Climate driven salinity changes have been simulated for 1961-2099 with three models (Meier et al., 2012): the BAltic sea Long Term large-Scale Eutrophication Model (BALTSEM), the Ecological Regional Ocean Model (ERGOM) and the Swedish Coastal and Ocean Biogeochemical model coupled to the Rossby Centre Ocean circulation model (RCO-SCOBI). The ERGOM and RCO-SCOBI are three-dimensional circulation models with uniformly high horizontal resolution of 5.6 and 3.7 km, respectively, while BALTSEM resolves the Baltic Sea spatially in 13 dynamically interconnected and horizontally integrated sub-basins with high vertical resolution. Simulations were based on six-hourly atmospheric and monthly river runoff data from four climate projections with the time steps of 150 s -3 hours. This dataset fully fits for purpose of the Challenge to analyse climate change effects on MPA network.

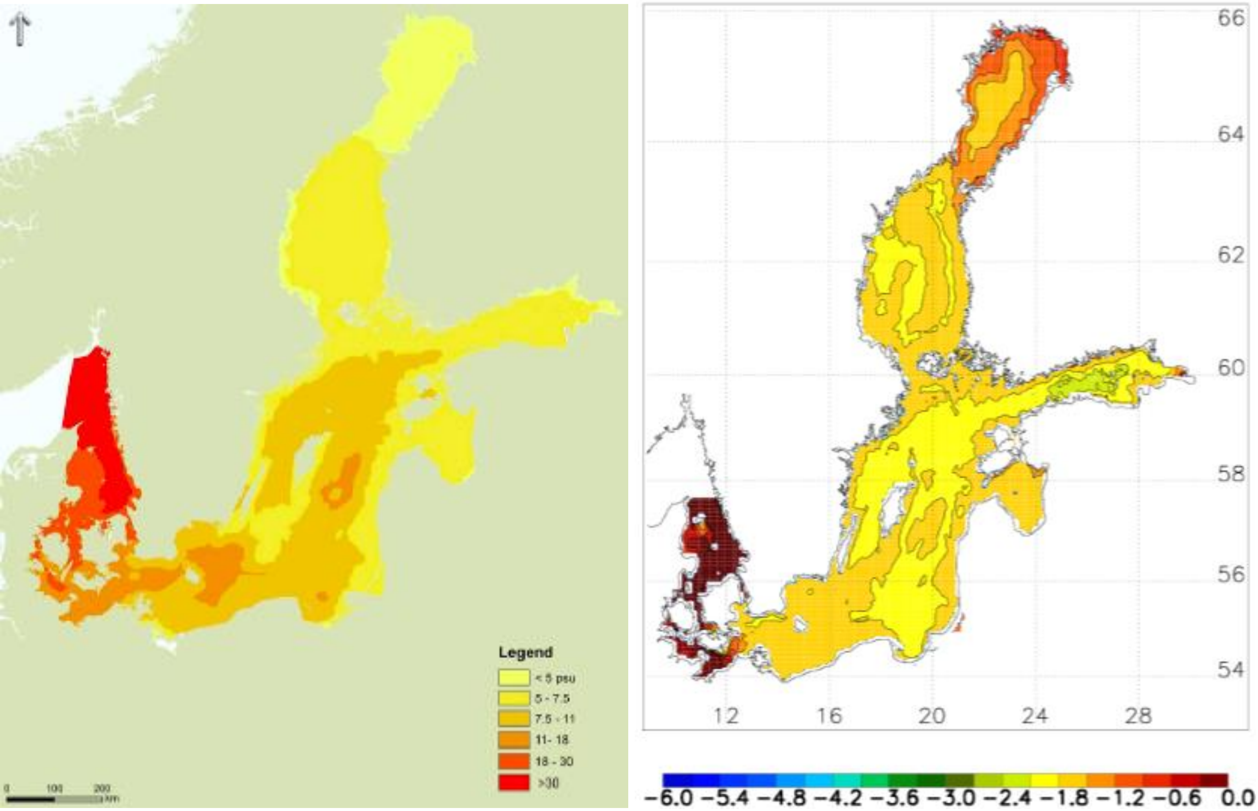

Figure 4.3. Modelled bottom salinity (psu) (From: Al-Hamdani, Reker, 2007; Data source: NERI/Denmark) (left) and projected annual mean ensemble average sea bottom salinity change (in g kg^{-1}) (right) from 1978–2007 to 2069–2098 (from Meier et al. 2012) (right).

Bathymetry

Depth data will support assessment of PoM contribution to coherence of MPA network. Several datasets are available for the use in the Challenge work. Bathymetric Data Model for the entire Baltic (Fig. 4.4 left) is based on modelled data with 0.5x0.5 km resolution (Baltic Sea data and map service, 2016). It is based on various national data from the countries around the Baltic Sea. Sub-regional data were of highly different resolution from 50 m (for Danish, German and Estonian waters) up to 200-500 m (for Swedish and Finnish waters). Higher resolution Baltic Sea bathymetry with the output grid of 250 m was computed from the original Digital Topography of the Baltic Sea (IOWTOPO) database produced by the Baltic Sea Research Institute of Warnemunde (Fig. 4.4 right). Both datasets deliver similar results and fully suit for Challenge task 2 in respect to resolution and available format.

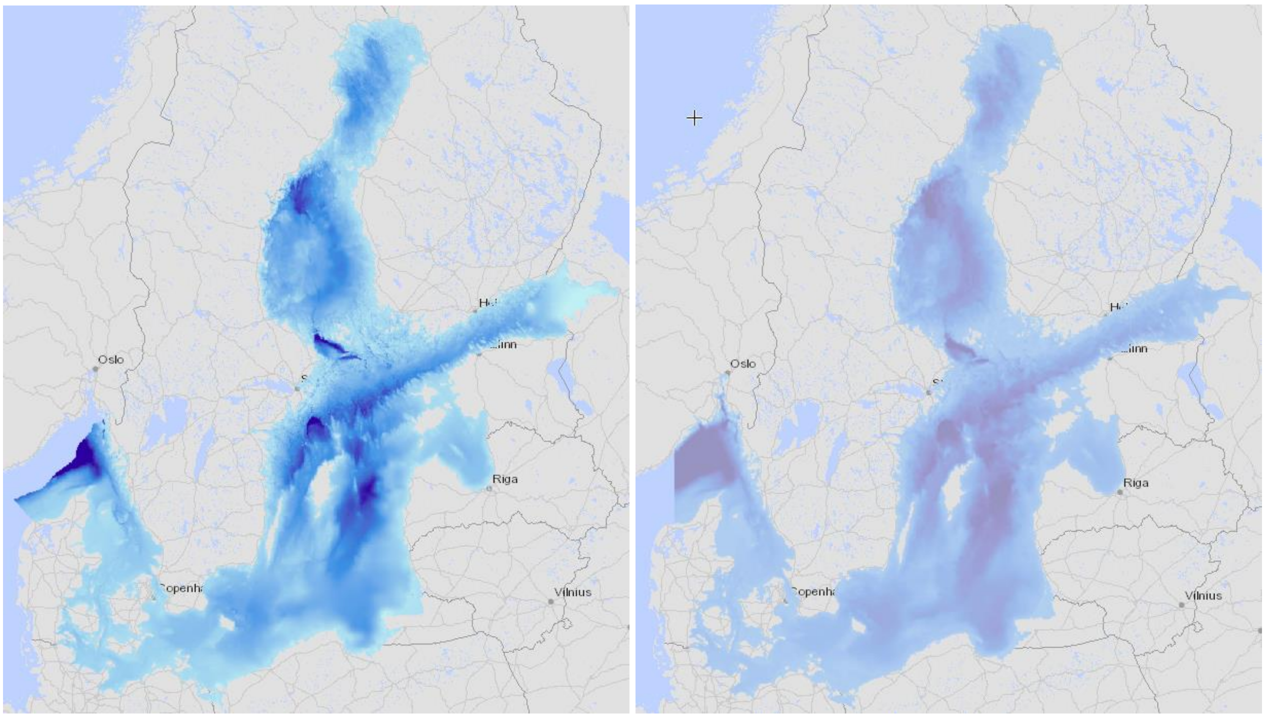

Figure 4.4. Bathymetric based on Bathymetry Data Model (left) and Digital Topography of the Baltic Sea database (Source: Baltic Sea data and map service, 2016)

Secchi depth (transparency)

Water transparency is a proxy of light conditions at the seabed, which is important for MPA coherence assessment and delineation of areas suitable for benthic vegetation species (including threatened and protected species). Two measures of Secchi depth are frequently used to reflect water transparency conditions: directly measured Secchi depth (m) and depth of 1% mean annual irradiance (m) typically estimated from Secchi depth (historical time series available). The latter indicates the depth where at least 1% of the surface light reaches the seabed and is called photic depth. Both measures are suitable to analyse water transparency conditions in the MPA network.

Spatial Secchi depth data have been extensively utilised by BALANCE project (Fig. 4.5), using period from 1980–1998 (March to October) with approx. 20,000 point based records. This number was reduced to approx. 2800 after averaging data per station and the remaining records have been spatially interpolated to cover the Baltic Sea and Kattegat. The lowest accuracy occurs for the Baltic Proper, Gulf of Riga and southern Baltic, but the data can be used for Challenge Tasks as a background layer. This dataset layer was updated by DHI within EU SeaMap project (based on unpublished modelled data) and polygon shape file (converted from original raster file) is available from HELCOM database. Since modelled data have been used to produce the data layer, true spatial resolution depends on empirical input data and therefore less relevant for the Challenge.

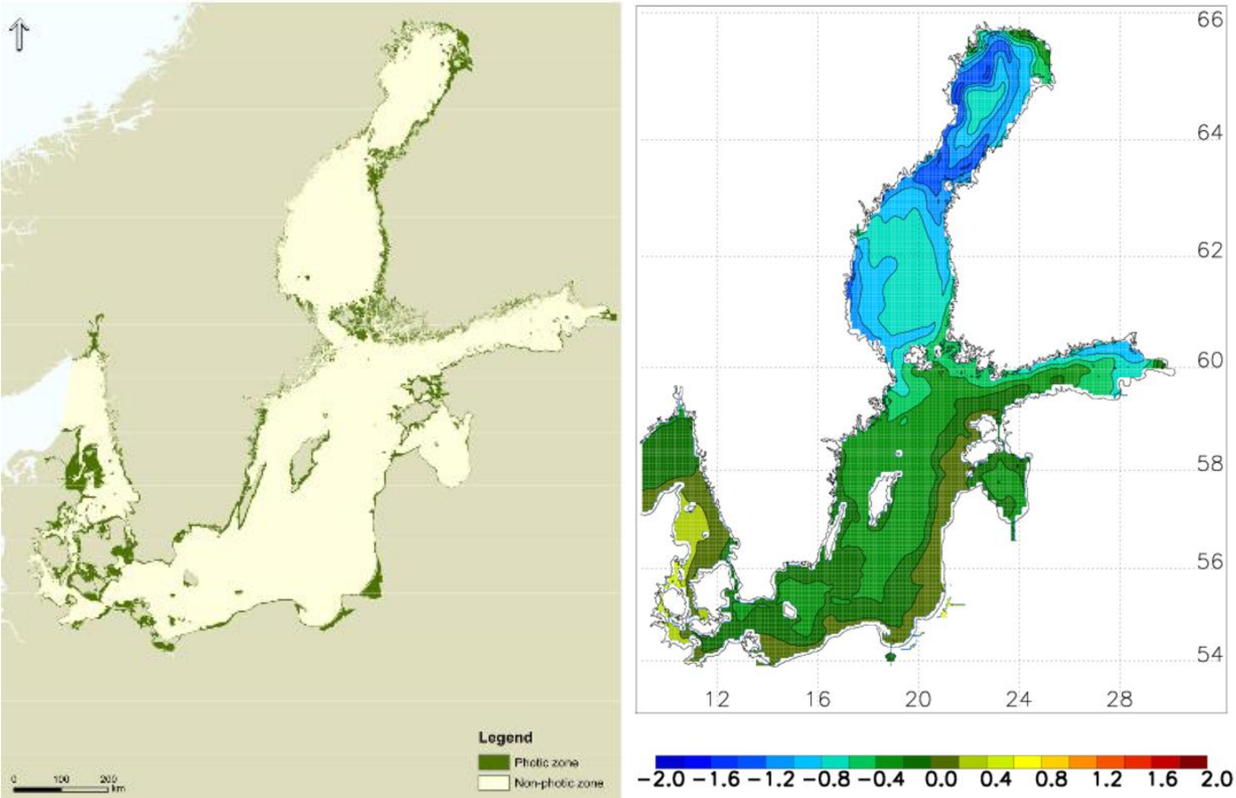

Figure 4.5. Modelled distribution of the photic zone (1.9xSecchi Depth) with at least 1% available light at the seabed (From: Al-Hamdani, Reker, 2007; Data source: DHI Water /Environment/Health and ICES) (left) and projected changes in annual mean ensemble Secchi depth (m) according to reference nutrient load conditions (right) from 1978–2007 to 2069–2098 (from Meier et al. 2012)

Substrate

Substrate maps serve as important background information in coherence assessment of MPA network (e.g. replication, connectivity, representativity of habitats). Although there is a number of local and sub-regional high-resolution sediment maps, the only map for the entire Baltic Sea bottom sediment was produced by BALANCE project (Al-Hamdani, Reker, 2007). This map was created in ArcGis vector format after integrating different resolution data and reclassifying national sediment classes used by different Baltic countries (Fig. 4.6 left). The map mainly integrates interpolated point data and shows distribution of five major substrate classes (bedrock, hard bottom complex, sand, clay and mud). Substrate classes do have ecological meaning and relation to the habitat types (e.g. reefs), type of benthic macrofauna (infaunal, epifaunal, mixed) and vegetation (attached forms, angiosperms), feeding strategies of some marine bird species. The resolution is relevant for regional assessments, but obviously too rough for analysis of individual MPA’s as well as smaller scale sub-regional MPA networks (e.g. Kattegat).

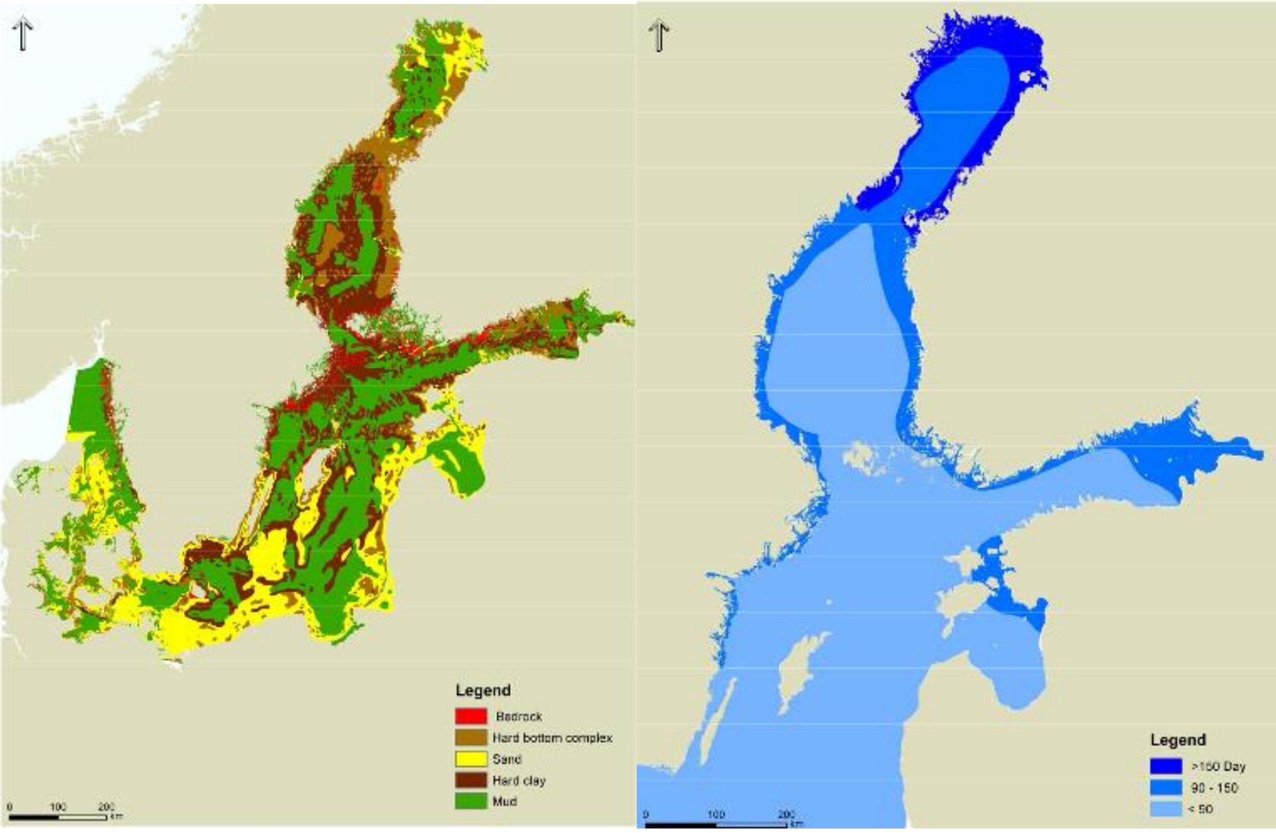

Figure 4.6. Distribution of 5 aggregated substrate classes (From Al-Hamdani, Reker, 2007, data sources: Geological Survey of Sweden, Geological Survey of Finland and Geological Survey of Denmark and Greenland) (left) and average ice cover within the Baltic Sea region (From Al-Hamdani, Reker, 2007, data sources: Metria/Sweden and Leppäranta et al. (1988)) (right).

Ice cover

Ice cover has multiple relations to marine organisms. However in respect to protected features of MPA network ice cover is directly related the conservation status of the ringed seal (*Pusa hispida* ssp. *botnica*). Ringed seal breeding distribution and reproduction success is closely linked to the extent and duration of the ice cover. This species breeds in broken consolidated ice that traps snow heaps and this habitat remains important for 5-7 weeks after breeding in April. The species is set under protection by several MPA's in the northern Baltic under Habitat Directive. Since reproduction success of the species depends on duration of ice cover, therefore the spatial change in the end date of the ice period would ideally fit for assessment of climate change effect on protection of this species by MPA network. Distribution and duration of ice cover in the Baltic is also related to the distribution habitats of several wintering bird species, targeted by MPA network (see below).

Ice cover dataset was produced by BALANCE project (Al-Hamdani, Reker, 2007). The data for this map was originally acquired from Metria/Sweden for the Swedish part of the Bothnian Bay, and this layer was combined with ice cover data for the period 1963/64-1979/1980 from Leppäranta et al. (1988). The data are integrated into three arbitrary chosen categories for ice cover (Fig. 4.6): I. 0–90 days of ice cover; II. 90–150 days of ice cover; III. >150 days of ice cover. Higher resolution of ice cover duration is provided with HELCOM map service dataset, where GIS layer contain ice cover duration (in days) intervals up to 160 days divided into 8 categories with the time step of 20 days. Since ice cover categories of both datasets have little relevance to species and habitat protection, their use for evaluation of climate change effects on MPA network is not straightforward and hardly interpretable. In addition, metadata on the parameter are not provided therefore technical details remain unknown. Other ice datasets include maximum and minimum extent of the cover for two five year periods 1960-64 and 2005-2009 (Fig. 4.7). The later was derived from satellite observations, whereas older data were compiled from historical records. These datasets can be directly used for analysis of the climate change effects on selected targets of MPA network (ringed seal and wintering birds) based on historical records from the last decades.

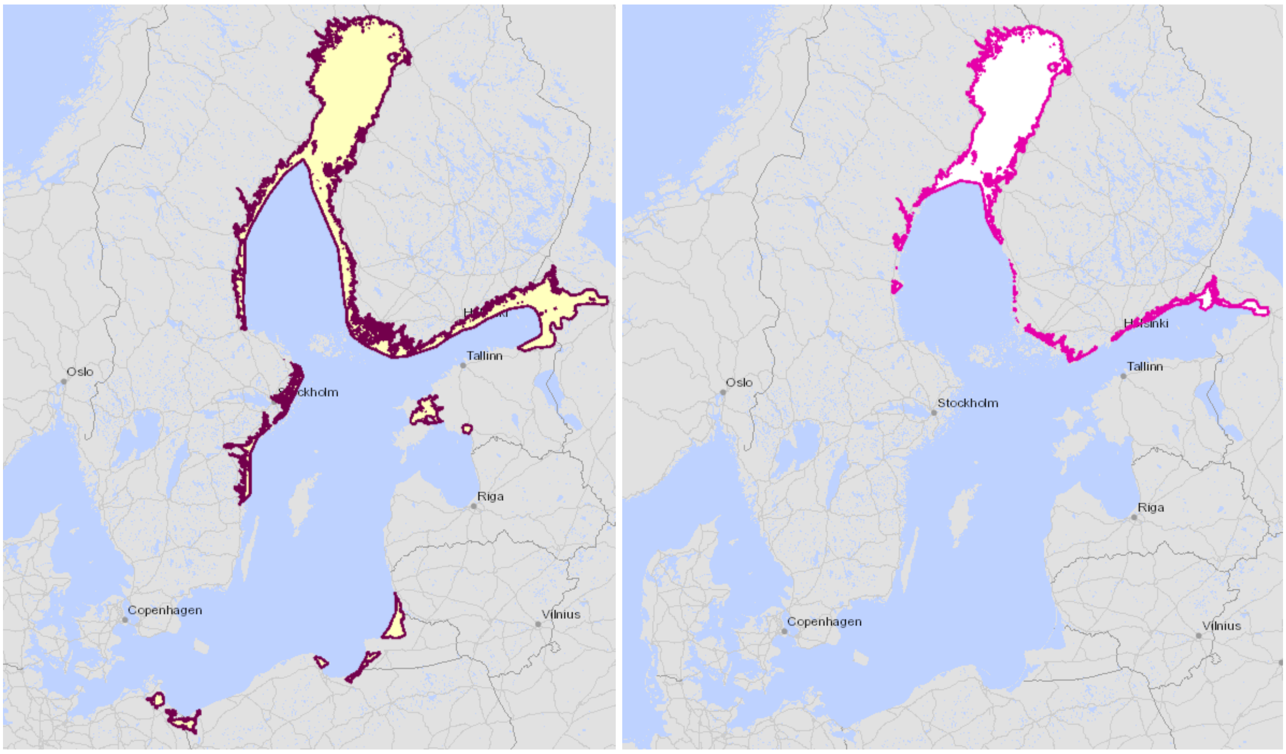

Figure 4.7. Baltic Sea ice cover minimum based on historical weather service observations for the period 1960-64 (left) and from satellite observations for the period 2005-2009 (right) (From: Baltic Sea data and map service, 2016; data source: Finnish Meteorological Institute).

4.3.3 Conservation features

Conservation features of the Baltic Sea MPA network addressed by the Challenge include protected species (Habitat Directive, Bird Directive), threatened species (HELCOM Red List) and protected habitat types/biotope complexes (Habitat Directive).

Protected species (Habitat and Bird Directives)

Approx. 20 aquatic species inhabiting various parts of the Baltic Sea are listed in the Habitat or Bird Directives. Baltic Sea data and map service is the major source of distribution data for these species. Data type of spatial distribution varies between species from sub-regional presence/absence data up to point based data of different accuracy. The most detailed data layers containing data on point based species quantity is available for few species only, e.g. ringed seal (Fig. 4.8, left) and those covered by assessment of waterbird populations and pressures in the Baltic Sea (Skov et al., 2011). Presence/absence data with 10x10 km grid or polygon data are also available for several species, mostly birds (Fig. 4.8). For fishes and mammals typical datasets are of 100x100 km grid and therefore of little use for MPA network analysis. For other taxonomic groups data quality varies from species to species, however 10x10 km grid data and polygon data are the most characteristic. This information is of suitable quality for regional assessments on coherence of MPA network and climate change effects on the species conservation, however should be cross-validated with the species distribution data of HELCOM MPA database. This database contains information on the species presence within individual MPAs. Although distribution of the species within MPA is not available, countries provided information on species status (migratory, breeding, wintering, occasional, resident). Information on species presence within individual MPA can be treated as being of the highest accuracy for those, which are submitted to the list as justifying the site designation. Although all the data have been provided at the time of site designation and therefore of very low temporal consistency between species records in various sites, so far this dataset is of the highest quality for further analysis of MPA network.

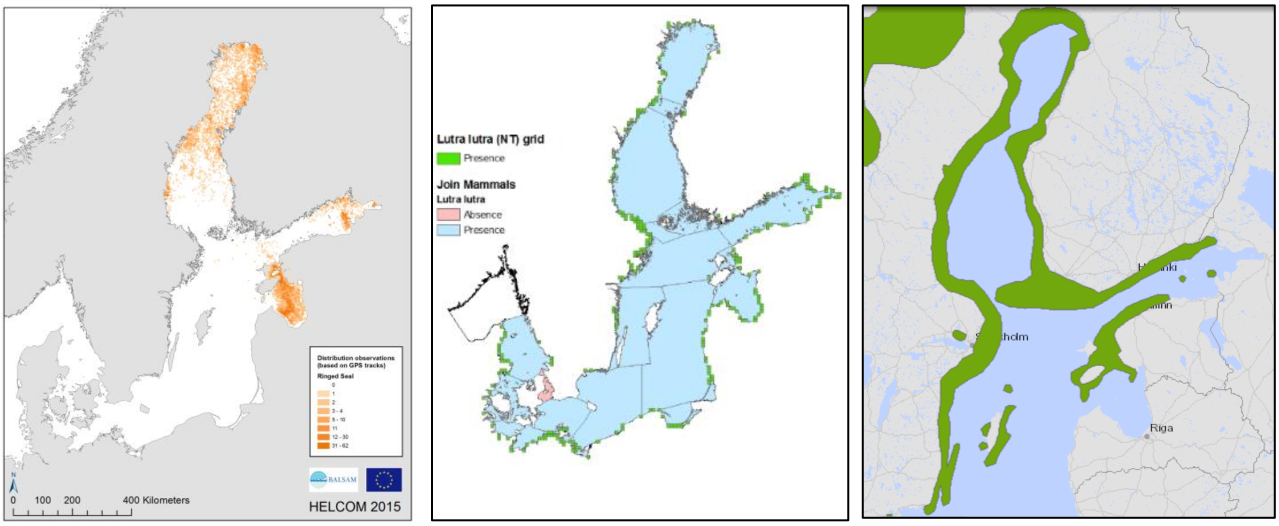

Figure 4.8. Examples of data layers on distribution of Habitat or Bird Directive species in the Baltic Sea: point based quantitative data on Ringed seal (*Pusa hispida* spp. *botnica*) compiled by BALSAM project (2015), presence/absence 10x10 km grid data for European Otter (*Lutra lutra*) and polygon data on presence of Velvet Scooter (*Melanitta fusca*) compiled HELCOM Red List project (2015).

Threatened species (HELCOM Red List)

Dataset of threatened HELCOM Red-List species contain information on distribution of 51 Red listed species, classified into three categories of critically endangered, endangered and vulnerable species. Distribution maps for 80% of threatened species is available at Baltic Sea map and data service. Grid resolution of 10x10 km is mainly available for distribution layers of benthic macroinvertebrates and macrophytes. Birds distribution datasets typically contain polygon data and therefore can be used for assessment of all coherence criteria of MPA network: replicability, size, representativity and connectivity. Datasets on distribution of benthic macroinvertebrates and macrophytes are suitable only for assessment of replication and partly for representativity within a known species range derived from presence based grid data. Datasets for distribution of fish and mammal species are of 100x100 km grid and therefore of little use for MPA network coherence analysis.

Habitat types/Biotope complexes (Habitat Directive)

Seven habitat types included into Annex I of the Habitat Directive (and denoted as biotope complexes by HELCOM) are exclusively distributed in the marine environment: Reefs (1170), Large shallow inlets and bays (1160), Coastal Lagoon (1150), Mudflats and sandflats not covered by seawater at low tide (1140), Estuaries (1130), Boreal Baltic narrow inlets (1650), Submarine structures made by leaking gases (1180). Baltic Sea map and data service provides data on the presence of the habitat type within a grid of 100x100 km resolution (Fig.4.9), but this is far too coarse for examining their coverage by network of protected areas. HELCOM MPA database contains information on presence of the habitat type within the individual MPA classifying records into those where the habitat type justifies designation of a particular site. Such records are of high certainty for the habitat presence in the given area, while accuracy of other records (indicating NO or N/A) has lower accuracy. Currently habitat dataset classifies presence of Reefs for 133 territories, Sandbanks for 103, Lagoons for 88, Large shallow inlets and bays for 64, Mudflats and sandflats not covered by seawater at low tide sandbanks for 44, submarine structures made by leaking gases for 8, Boreal Baltic narrow inlets for 5. Although for some habitat types Presence within individual MPA provides higher spatial resolution, therefore will be used for the Challenge tasks.

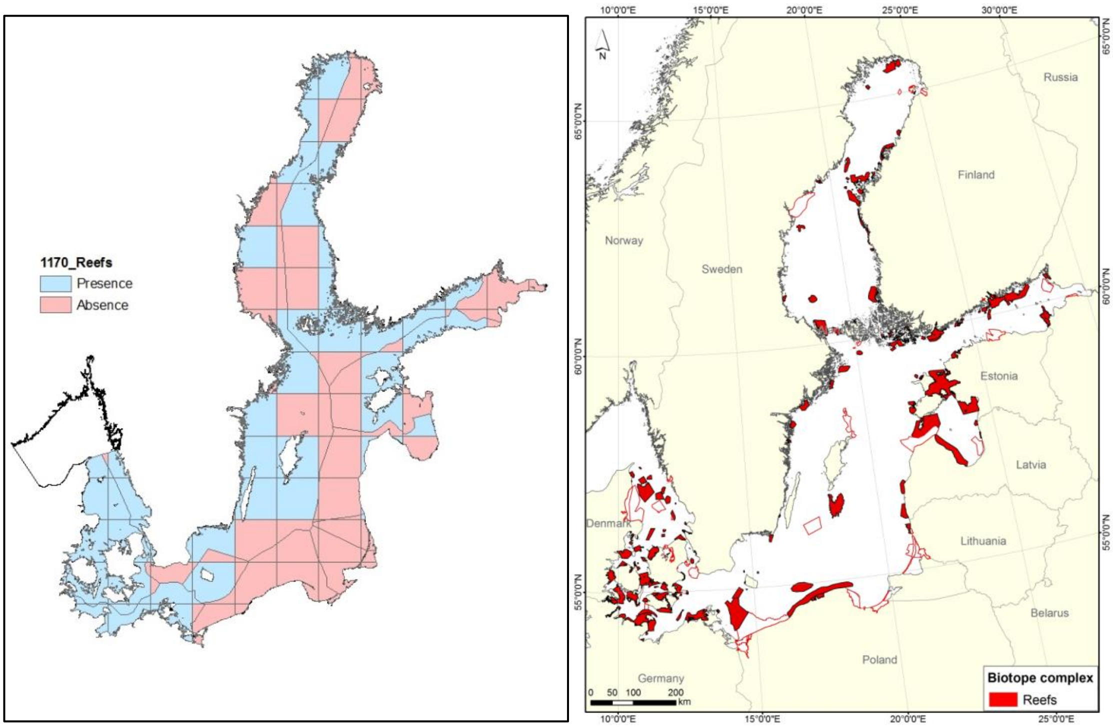

Figure 4.9. Example Data layer on Baltic wide distribution of reefs with 100x100 km grid (From: Baltic Sea data and map service, 2016) and reef presence within individual MPA’s (Data source: HELCOM MPA database).

Table 4.4. Data adequacy for “Marine Protected Areas”

Variable	Data type	Accessibility	Completeness / coverage	Resolution	Precision	Data provider
		Delivery type/time	Spatial Temporal	Hor./Ver./Temp.		
MPA boundaries	Legal boundaries	Downloadable	Adequate	N/A	FFU*	HELCOM MPA-DB
		Downloadable	Adequate	N/A	FFU	Natura 2000 database
IUCN categories	Derived	Downloadable	Update needed	N/A	FFU	HELCOM MPA-DB
MSFD Programs of measures	Legal document	Downloadable, English summaries available (except for LV)	Adequate	N/A	Not adequate	Websites of MS MoE
Substrate	Model	Downloadable		Not adequate for analysis within MPA’s	FFU	HELCOM DMS
Bathymetry	Interpolated	Downloadable		Adequate	FFU, but not for climate change effects	BSBD
Bathymetry		Downloadable by request		Adequate		EMODNET
Distribution of threatened HELCOM Red List species	Model	Downloadable		Not adequate for coherence assessment due to data availability for MPA only	Partly	HELCOM MPA-DB, DMS
Distribution of Bird Dir. and Habitat Dir. Species	In-situ Obs.	Downloadable			Partly	HELCOM MPA-DB
Distribution of Habitat Dir. Annex I Habitats	Model	Downloadable			partly	HELCOM MPA-DB
Distribution of Bird Dir. species	Model	Not available		Adequate	FFU	Skov et al., 2011
Salinity	In-situ	Downloadable			FFU	EMODNET
Salinity, Ice cover	Model	On request or open, downloadable			FFU	See Tab. 6.4
Ice cover, historical	In-situ	Downloadable			FFU	HELCOM DMS
Photosynthetically Active Radiation at seabed	In-situ				N/A	EU Sea Map 2016 / EMODNET
Secchi depth	In-situ				FFU	HELCOM DSM
	Model	On request			FFU	Meier et al. 2012

*FFU – Fit-for-the-use

4.4 Conclusions

This study assesses different data availability and adequacy for the three MPA Challenge tasks defined in the BSCP project. The data adequacy are summarised in Tab. 4.4. Information required for identification of IUCN categories for approx. 15% of MPA's is not readily available, scattered among different sources and mostly in national languages. However, when access to the needed information is set, data are usually adequate for assigning IUCN categories. In opposite, information for assessment of the network coherence according to Article 13 in the Marine Strategy Framework Directive is currently not adequate. Level of details provided in countries MSFD reports (last reports approved by March 2015) on spatial protection measures do not allow assessment of their intensity and spatial distribution at any finer scale than countries territorial/EEZ waters. This is obviously too coarse information for Task implementation at the moment.

Information availability and adequacy for Task 3 fully satisfies the needs and is not considered to limit implementation.

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5 Data adequacy for Oil platform leaks

5.1 Introduction

In the “Oil platform leak” Challenge area, following tasks are involved in the application:

1. Issuing and reporting an Oil platform leak warning
2. Forecasting the 3D trajectory of the spilled oil
3. Forecasting the ocean-weather conditions for oil cleaning operation
4. Forecasting and assessing the environmental and social-economic impact of the oil leak

The above tasks will be carried out in a form of real time demonstration. The procedure is that the EC will issue a warning of a virtual oil spill to BSCP. Upon receiving necessary oil platform leak information, BSCP consortium will perform the above tasks and submit reports to the EC after 24, 48 and 72hours respectively.

5.2 Data requirement analysis

The data usage in the challenge area “Oil platform leak” is described in Tab. 5.1. When the “oil platform leak” is reported, the leaked location, depth, oil types, amount and period are needed. Upon receiving the information, BSCP will start weather, ocean-ice and oil trajectory forecasts. Among them, weather and ocean-ice forecast are similar to routine forecasts in met-ocean agencies but need to be with sufficient resolution and quality, especially for oil leak in the coastal waters. Winds, currents (3D) and ice are most essential variables. The requirements for these variables are listed in Tab. 5.2. Near real time data products are needed. The forecast is preferably updated 4 times a day but update of every 3 hours may be needed. If the oil leak is caused by a ship and happens in coastal waters, it is very important to predict the time, location and amount of oil landed in the coasts. This will need very high-resolution (up to a few hundred meters) weather-ocean-ice models to provide water winds and currents. The precision of winds and currents are essential for the correct prediction of the oil drift trajectories. If the oil leak happens in icing waters, accurate ice forecast and oil weathering processes in the ice become important.

Table 5.1. Key variables and data usage in “Oil platform leak”

Tasks	Parameters	Observation type	Providers
Issuing warning	Oil types, leaking amount, location	In-situ, satellite	Oil company, EMSA
METOC forecast	Winds, visibility, precipitation, ice, waves, currents	Model	Met offices, CMEMS
Trajectory forecast	Winds, 3D ocean status, ice, bathymetry, coastline, oil types & characteristics	Model, satellite, in-situ	Met. Offices, CMEMS
Impact assessment	Sensitive areas, tourist beaches,	GIS data	EMODNET Human activity, HELCOM
Oil cleaning operation	METOC conditions Trajectory forecast, On-going human activities (eg navigation)	Model, in-situ, satellite, GIS data	Met. Offices, CMEMS, maritime agencies, HELCOM

After the oil drift trajectory forecast is made, real time validation of the model products is needed. This needs observations on oil slicks, either from in-situ or satellite, to identify the location, size and amount of the oil slick distribution. An assessment of potential environmental and ecological impacts of oil leak is also required. This is currently done by integrating information of the forecasts and the important human activity areas, e.g., MPA, tourist beach, fish spawning areas etc. In BSCP project, only a preliminary investigation is carried out to tell if the oil slicks will affect these sensitive areas but not on how the environment and ecosystem will be affected.

Table 5.2. Data requirements in “Oil platform leak”

Key variable	Data type	Accessibility	Completeness/ coverage	Resolution		Precision
				Spatial	Temporal	
Winds	Model, in-situ, satellite	Open, free, online, real time	Baltic-North Sea	H: max. 3km V: 10m height	Hourly	Critical but unspecified
Meteo data	Model			H: max. 3km	Hourly	Unspecified
Currents	Model		Baltic	H (offshore): max. 2km H (coastal): max. 1km V: 1m at surface/ bottom layers	15minutes	Critical but unspecified
				H: max. 1km		
T/S	Model		Baltic	3km	Hourly	Unspecified
Ice concentration	Model, satellite		Baltic	H: Same as currents V: N/A	Hourly	Critical but unspecified
Sea Level	Model		Baltic	H: 3km V: N/A	Hourly	Unspecified
Coastline	In-situ	Open, free, online	Baltic	H: ~10^{1-2}m	N/A	Critical but unspecified
Bathymetry	In-situ		Baltic	H: max. 500m	N/A	Critical but unspecified
Sensitive areas	GIS data		Baltic	As requested	N/A	Unspecified
Tourist beaches	GIS data		Baltic	As requested	N/A	Unspecified
Leaked Oil characteristic s	In-situ	Real time	14 oil types	N/A	Most updated	Unspecified
Oil features used in model	Parameter s	Open, free			Static	Unspecified
Oil slicks and spills	Remote sensing	Open, free, online, near real time (max. 24h delivery time)	As requested	As requested	Most updated	Critical but Unspecified

Table 5.3. Data availability in “Oil platform leak”

Key variable	Data type	Accessibility	Completeness/coverage	Resolution		Precision
				Spatial	Temporal	
Winds	Model foreacst, in-situ	Met. Offices: real time, on request	Baltic-North Sea	H: max. 3km V: 10m height	Hourly	1-2m/s
	Satellite	CMEMS/KNMI, Open, free, online, 1day delay		H: 12.5-25km V: 10m height	6hourly – daily	1-2m/s
Meteo data	Model	Met. Agencies: Real time		H: max. 3km	Hourly	Unspecified
Currents	Model	CMEMS: open, free, online, real time	Baltic	H (offshore): max. 2km H (coastal): max. 1km V: 1m at surface/ bottom layers H: max. 1km	15min.	Critical but unspecified
T/S	Model		Baltic	3km	Hourly	RMSE: T: ~1°C S: <2psu
Ice concentration	Model, satellite		Baltic	H: Same as currents V: N/A	Hourly	Unspecified
Sea Level	Model		Baltic	H: 3km V: N/A	Hourly	Unspecified
Coastline	In-situ	GSHHG: open, free EMODNET/BSBD: open, free	Baltic	H: ~10^{1-2}m	Updated in 2016	Critical but unspecified
Bathymetry	In-situ		Baltic	H: max. 500m	Updated in 2016	Min. (10m, 10% of the depth)
Sensitive areas	GIS data		Baltic	As requested	N/A	Unknown
Tourist beaches	GIS data		Baltic	As requested	N/A	Unknown
Leaked Oil features	In-situ	Real time	8-14 oil types	N/A	Most updated	Unspecified
Oil features in model	Parameters	SINTEF: on request			Static	Unknown
Oil slicks and spills	Remote sensing	EMSA: Open, on request, near real time (max. 24h)	As requested	As requested	Most updated	Unknown

Finally the met-ocean-ice and oil trajectory forecasts (together with the uncertainty estimate) and the impact assessment will be provided to oil leak combatting agencies to support their field operations and decision-making.

5.3 Data adequacy assessment

The data adequacy in the Oil drift study is reviewed by combining model, remote sensing and in-situ measurements. This is to remind that the adequacy of the data is reviewed based on an integrated way. So the data necessary for improving the integration methods will also be included, e.g., for validation and/or assimilation.

5.3.1 Winds at 10m elevation

The 10m winds (including forecast) are mainly derived from models. Considering high quality and resolution of existing weather forecasts from Met. Offices in the Baltic Sea region, the availability, resolution and resolution can meet the user requirements in most of the cases. For example, DMI is currently providing several types of weather forecasts for the Baltic Sea, as shown in Tab. 5.4. The root-mean-square error of 10m wind forecast is between 1-1.5m/s.

Table 5.4. Wind forecasts currently available in DMI

Forecast model	Resolution	Update frequency	Assimilation
HIRLAM	3km, hourly	4 times per day, 60h forecast	Satellite & in-situ data
HARMONIE	2.5km, hourly	8times per day, 60h forecast	Satellite & in-situ data
HIRLAM ensemble (21)	5km, hourly	4times per day, 60h forecast	Satellite & in-situ data

Other Met. Agencies e.g., ECMWF, SMHI and FMI etc. have their own weather forecasts which also have good quality meeting the requirements. Of course, different model has different skills in different areas on the wind forecasts. There are cases that wind forecasts go wrong. In such cases, it is important to use winds from different models (multi-model ensemble) which may effectively reduce the uncertainty of oil drift trajectory forecast.

High-resolution wind forecast in coastal waters are important for predicting oil drift near shore. It is essential that the NWP model can provide winds over water rather than land-sea mixed winds.

5.3.2 Physical variables: T, S, currents, sea level, sea ice

The physical variables are needed in making oil trajectory forecast, which includes variables from 3D ocean model (i.e., currents, sea level, water temperature and salinity) and ice model (ice concentration). The state-of-the-art Baltic Sea 3D ocean forecast are made by BSH and DMI by using HBM model and SMHI using NEMO-Nordic. The hourly forecast (in 1nm resolution) is freely available from CMEMS data portal. The quality of the currents and 3D ocean are normally good for oil drift trajectory prediction but still subjective to extensive validations. The quality of the existing oil spill case in the Baltic Sea has been proved in several existing oil spill cases (Christiansen, 2003, also see http://ocean.dmi.dk/case_studies/index.uk.php) but still lack of quantitative validations. Use of multi-model forecasts has shown with added values (Broström et al., 2011).

There haven't been oil spill cases in the icing waters yet, hence the quality of ice forecast data have not been validated for the oil drift forecast. Since the mesoscale dynamics has not been implemented in the ice model, it is expected that the current ice prediction will be able to generate realistic feature in kilometre scales.

5.3.3 Coastline and Bathymetry

A Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG) Version 2.3.6 is released in August 19, 2016. The data are freely available and can be downloaded from http://www.soest.hawaii.edu/pwessel/gshhg/. The resolution and quality is similar to what one can find in Google maps, which are sufficient for using in the weather, ocean, ice and oil drift models. The availability of bathymetry data have been described in Chapter X. In the Baltic Sea, the BSBD, EMODNET and HELCOM are using similar dataset which is generated by BSHC. The resolution is 500 meters. Although each country has data higher than 500m resolution, they are not always available. For oil drift forecast, the existing bathymetry is sufficient for offshore cases. For oil spill cases in catchment-coast-sea continuum with complicated topography, bathymetry with higher resolution is needed.

5.3.4 Human activity data

Existing data (sensitivity areas and tourist beaches in the Baltic Sea) are found sufficient for a descriptive impact study of oil spill cases. These data are available from EMODNET Human activity web portal and HELCOM Maps and Data web portal. Since BSCP only use these data to identify if sensitive areas are affected by the oil slicks, they seem to be adequate for the phase 1 applications.

5.4 Conclusion and remarks

For oil platform leak application, the marine observations are used together with satellite and numerical models to predict the trajectory of oil slicks and their impacts on the coastal environment. It should be noted that in the Baltic Sea. There are almost no active offshore oil platforms. However, the Baltic Sea is loaded with very heavy marine traffic. The risk of oil leak from ships is fairly high comparing with other regional seas in Europe. The data needs and adequacy assessment for the “ship oil leak” and “oil platform leak” are similar but with slightly difference in identify the location and amount of the oil leak. Satellite images and AIS data are essential in this case.

For oil platform leak application, In general, the sea surface winds and currents are lack of validation., and more wind and current observations are needed for validating the optimising the weather and ocean models. The amount and location of the stations needed, however, are still unknown and subjective to detailed model verification study and optimal sampling design study.

For oil spill in coastal waters and icing waters, more data requirements are identified in comparing to open water oil spill. For the icing waters, the quality and resolution of ice forecast should be further improved. For oil spill in catchment-coast-sea continuum, the publicly available bathymetry will not be sufficient. However, this may not be an issue as each country has its own bathymetry database with much higher resolution than 500m, which can be used in the national oil spill combatting. The ocean and weather prediction will need resolution in a few hundreds of meters. Their quality, especially forecast of surface currents should be extensively validated and improved.

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6 Data adequacy for climate change

6.1 Data requirement assessment

6.1.1 Description of challenge area "Climate change"

The objectives of challenge area 4, Climate Change, are to apply existing Baltic Sea monitoring data and identifying their adequacy for establishing time series of change in average temperature on a grid over past 10/50/100 years, of annual temperature at sea surface and bottom, of internal thermal and kinetic energy, of average extent of ice cover over past 5/10/50/100 years on maps, of total ice cover in kilograms over past 100 years and of phytoplankton abundance of three species. During the work the biota part was extended to cover four representative species - spring bloom diatom *Achnanthes taeniata* and dinoflagellate *Peridiniella catenata*, and summer bloom cyanobacterium *Nodularia spumigena* and dinoflagellate *Heterocapsa triquetra*.

The reliability and utility of the data and products were also to be assessed. Whenever possible, uncertainty statistics were to be provided as well. The suitability of the existing data for trend analysis should also be examined.

The intended products will serve as basic background for further analyses of the response of the Baltic Sea to climate change. The users of the provided time series should then be aware of the fit-for-purpose, the gaps and the usefulness of the data for that kind of work. It should be noted that the work done within this challenge was not aimed to give an analysis of the climate change or trends in the described parameters as such.

6.1.2 Data usage and requirements of challenge area "Climate change"

The Baltic Sea area is over 1200km long from south to north and over 600km wide from west to east. The Sea is located in a prevailed westerly zone between 53-66N, but have different weather conditions in its southern and northern parts. Surrounded by the Baltic catchments with more than 70 major rivers, it consists of many sub-basins and connects with the North Sea through the narrow and shallow Danish Straits. The water depth is up to 450m but with an average of 50m. Steered by these features, Baltic Sea climate variability is dominated by atmospheric forcing, river discharge and water exchange with the North Sea. Small characteristic scales in a few kilometres, upwelling, inter-sub-basin exchange and seasonal thermo- and haloclines feature their internal dynamics. These dynamic features change with climate. The forming and melting of seasonal ice are also strongly affected by climate change. For monitoring Baltic Sea climate variability, high-resolution observations and models are needed. Typical requirements for the spatial resolution are 1km in horizontal, 1m in layers of upper and bottom 20m and pycnocline, and hourly or daily in temporal resolution.

To produce the intended basic products for climate change, data from seawater temperature, salinity, current, sea ice and phytoplankton are needed (Tab. 6.1). In the table, the requirements for the data are also listed.

Table 6.1. Data requirements for climate change

Variable	Data type	Accessibility		Completeness/ coverage		Resolution			Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
Sea ice extent	Obs./ model	Delayed, Open, free	On request	Baltic Sea	As long as possible, >50 yr	N/A	N/A	Annual	Not available
Sea ice thickness	Obs./ model	Delayed, Open, free	On request	Baltic Sea	As long as possible Obs.: >1 yr Model: >50yr	Point data or Max. 50km	N/A	Daily	0.05m
SST	Obs./ model	Delayed, Open, free	On request	Baltic Sea	>20yr	Point data or 1-5km	N/A	Hourly - daily	0.1°C
Sea temperature	Obs./ model	Delayed, Open, free	On request	Baltic Sea	5-100yr	Point data or 1-5km	N/A	Hourly - daily	0.1°C
Sea Salinity	Obs./ model	Delayed, Open, free	On request	Baltic Sea	5-100yr	Point data or 1-5km	N/A	Hourly - daily	0.1
Currents	Obs./ Model	Delayed, Open, free	On request	Baltic Sea	Obs.: >1yr Mod.: >50 yr	Point data or 1-5km	1m	Hourly	0.01m/s Relative error10%
Phytoplankton	Obs.	Delayed, Open, free	On request	Baltic Sea	>36yr (1980 ->)	At least 15 observations per sub-basin per season/year			Not available

* Delivery time is the interval between the time when the data are measured and time when the data can be accessed. The requirement of the delivery time depends on the frequency of the assessment/trend analysis.

We have identified and used sea ice data, seawater temperature and salinity, current and phytoplankton data in our analyses and as described in Tab. 6.2.

6.1.2.1 Weather conditions

Weather conditions over the Baltic Sea characterise the climatic regime where the Baltic Sea belongs to at each point in time. Usually the weather patterns and winds that come from the North Atlantic dominate the Baltic Sea conditions. Sometimes especially in winter the cold air masses from Siberia flow to the northern Baltic Sea areas causing periods of very cold weather. The routes of the weather patterns, like storms, on their way from the North Atlantic to the southern and central Baltic Sea are essential for the water exchange between the world ocean and the Baltic Sea, especially for the major saline water inflows that enhance the conditions of the deep waters.

Weather information is needed both from observations and from numerical weather models in climate studies. True observations are needed to relate the in-situ observations from the sea to the driving forces. Numerical atmospheric model data is required as forcing fields for the hydrodynamic ocean models that are used to study the climatological variability of the Baltic Sea in scales from years to several decades.

Table 6.2 Data usage in climate change

Variable	Data type	Usage
Sea ice extent	In-situ Obs.	Producing annual maximum ice extent time series, model validation
	Model	Not used, but may be utilised for estimations of ice amount
Sea ice thickness	In-situ Obs.	Producing annual ice amount time series (in kg), model validation
	Model	Producing ice amount estimations
Sea Surface Temperature	Blended satellite and in-situ	SST long-term time series and climate variability
Sea water temperature	In-situ Obs.	DIVA analyses, model validation, assimilation
	Model	Constructing internal energy time series
Sea bottom water temperature	In-situ Obs.	DIVA analyses, model validation, assimilation
Sea water salinity	In-situ Obs.	DIVA analyses, model validation
	Model	Constructing internal energy time series
Currents	In-situ Obs.	Model validation
	Model	Calculating kinetic energy
Phytoplankton abundance	In-situ Obs.	Trend analysis

6.1.2.2 Sea water temperature, salinity and currents

Relevant climate change signals: The Baltic Sea is a strongly stratified sea area that has a significant seasonal cycle in its upper layer temperature. Below the upper layer there is always a cool intermediate layer, often called as the old winter water. Both this layer and upper layer have short thermal memory, because they are mixed twice a year. The deeper waters below the old winter water, and especially those below the halocline, are thermally more stable, though weak signals of seasonal cycle are also seen below the halocline at least in many areas.

Salinity is a more conservative parameter than temperature, but in the Baltic Sea the upper layer salinity has a seasonal cycle, too. This is because of the freezing and melting of sea ice and spring floods of the rivers at least in stations that are near to big river mouths.

For climatic studies the form of the seasonal cycle and their interannual and interdecadal variability is of interest. Such variability is strongly coupled with external forcing, mesoscale dynamics and inter-sub-basin exchange. The horizontal hydrodynamic scales of the Baltic Sea, when described with the internal Rossby-radius of deformation, vary from sub-basin to sub-basin but in order of 10^0 km. The fronts and mesoscale eddies that have these characteristic length scales complicate even more the analysis of the spatially sparse observations. To make the case even more complicated, some physical processes, like upwelling, can change the surface layer temperature rapidly, and those events have to be considered in analyses of mean temperatures at least in the coastal areas.

T/S data requirements: these features of the thermal and halo regime of the Baltic Sea must be taken into account in the analyses of the climate change. Therefore dense time series of temperature from certain dynamically representative areas are necessary for reliable trend analyses.

The representativeness of the profile stations of the fixed oceanographic observations should be analysed, but it is difficult from observations only, because usually the profile observations are not horizontally dense. On the other hand, the bottom topography and coastlines may force certain dynamic feature to certain locations and thus the representativeness of the stations may be estimated. For HELCOM Baltic Sea Environment Assessment, it is required at least 15 profile observations should be available per season per basin. This can also be used as the minimum requirements for temperature and salinity profile observations.

Nevertheless, it is not possible to have sufficient T/S profile measurements to resolve important mesoscale dynamics. To resolve the impacts of mesoscale dynamics on the climate change, numerical modelling and data assimilation approach should be used. The state-of-the-art Baltic ocean-ice model has reached a horizontal resolution of 1km and vertical resolution of 1 m and is capable of resolving the mesoscale dynamics in the Baltic Sea.

High-resolution measurements are essential for resolving mesoscale dynamics. Such measurements are available for surface temperature and salinity from satellites and ferrybox lines although their periods are limited. The mesoscale signals from the surface observations can be introduced into the numerical models through data assimilation which helps in reconstructing the three-dimensional mesoscale features.

Precision requirements: The monitoring methods on sea water T/S profiles have changed considerably during the scientific oceanography era. However, the T/S data are still considered to be relatively comparable with each other in different measurement techniques periods after necessary corrections are made. However, one should be careful with the climate analyses for salinity. The international recommendation is that data should be stored and exchanged as practical salinity, but in scientific publications absolute salinity should be used. The conversions between these are offered by TEOS-10.

Currents: knowledge on sea currents is vital in understanding the exchange and mixing of the water masses. The horizontal hydrodynamic scales are rather small in the Baltic Sea, which makes impossible the real observations of the current field. Long-term, high-resolution (hourly) current observations are required for model validation. Similar data are needed at locations with strategic importance for water exchange, such as Danish Straits, Stolpe Channel and entrances to the Gulfs.

6.1.2.3 Sea ice
Traditionally the importance of sea ice is first considered in winter navigation. For climate research, the existence of ice changes the surface heat fluxes to the atmosphere and ocean dramatically. In last decades the sea ice biology is a research topic that has gained attention. Sea ice offers ground for many species and moving ice redistributes substances and plankton species by converging them or diverging them depending on the situation.

For above reasons, long-term sea ice observations are needed including concentration, extent, thickness and drift of the ice.

6.1.2.4 Phytoplankton abundance
The amount and distribution of phytoplankton species are measures to determine the ecological state of the sea. Their changes also describe how the reductions of nutrient loads have affected the sea and what climate change may cause. Phytoplankton abundance, biomass and species composition vary fast and therefore monitoring requires frequent sampling. Phytoplankton data gathered by observations should be

spatially distributed as much as possible in a non-biased way. According to the HELCOM monitoring requirements at least 15 observations in every sub-basin per year/season could be needed for reliable assessment.

Under challenge ”Climate change” the data adequacy analysis of Baltic Sea phytoplankton abundance was done using four species – two spring species (*Achnanthes taeniata* – diatom; *Peridiniella catenata* – dinoflagellate) and two 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.

6.2 Data adequacy assessment

6.2.1 Temperature and salinity

The *in-situ* temperature and salinity (T/S) data for the Baltic Sea is available from the listed sources, HELCOM, ICES, SeaDataNet, EMODnet. The data begins in HELCOM and ICES from 1898.

HELCOM/ICES/SeaDataNet Data: The HELCOM dataset (HELCOM 2016, ICES, 2016a) is a subset of ICES data (ICES 2016b). HELCOM data includes, by 28 July 2016, over 110,000 profiles from the Baltic Sea of which a little over 15,000 is from Skagerrak and Kattegat. The ICES database contains over 386,000 profiles of bottle data and almost 20,000 profiles of CTD data from the Baltic Sea. The SeaDataNet Baltic Sea data contains about 358.500 profiles (SeaDataNet 2015 http://dx.doi.org/10.12770/1610aa44-0436-4b53-b220-98e10f17a2d4). The spatial distribution of the available data is far from even. The amount and spatial coverage of temperature and salinity data is the smaller the more north in the Baltic Sea we go (Fig. 6.1). The observing stations are mainly standard stations that are rather sparse in the Gulf of Bothnia. This is natural, because of the ice cover in the winter reduces the possibilities of research ship monitoring in winter. The same is the case in the temporal distribution of the SeaDataNet T/S data, too, in the northern parts of the Baltic Sea though the seasonal distribution of data seems to be more even (Figs. 6.2). The yearly amount of data increased fast in mid 1980’s. There were large international projects that collected a lot of data and in 1990’s there were Gulf of Bothnia Year (1991) and Gulf of Finland Year (1996) that may also have contributed on the amount of data.

The ICES data includes both the ship data and fixed oceanographic stations, though it has turned out that it does not contain all the profiles that exist in national institutes (at least that is the case of some Finnish fixed oceanographic stations).

It is found that the data availability is quite uneven in time. Before 1960, there are only about 100 profiles per year. During 1961-1975, the number of profiles per year increases to $10^{2\text{-}3}$. This amount of profiles is ~$10^{3\text{-}4}$ in 1976-1997. In years 1993 and 1998-2007, more than 10^{4} profiles per year were measured. After 2007, the number of profiles returns to below 10000 profiles per year.

EMODNET data: EMODNET T/S data are similar to SeaDataNet data but more frequently updated with operational T/S observations from CMEMS.

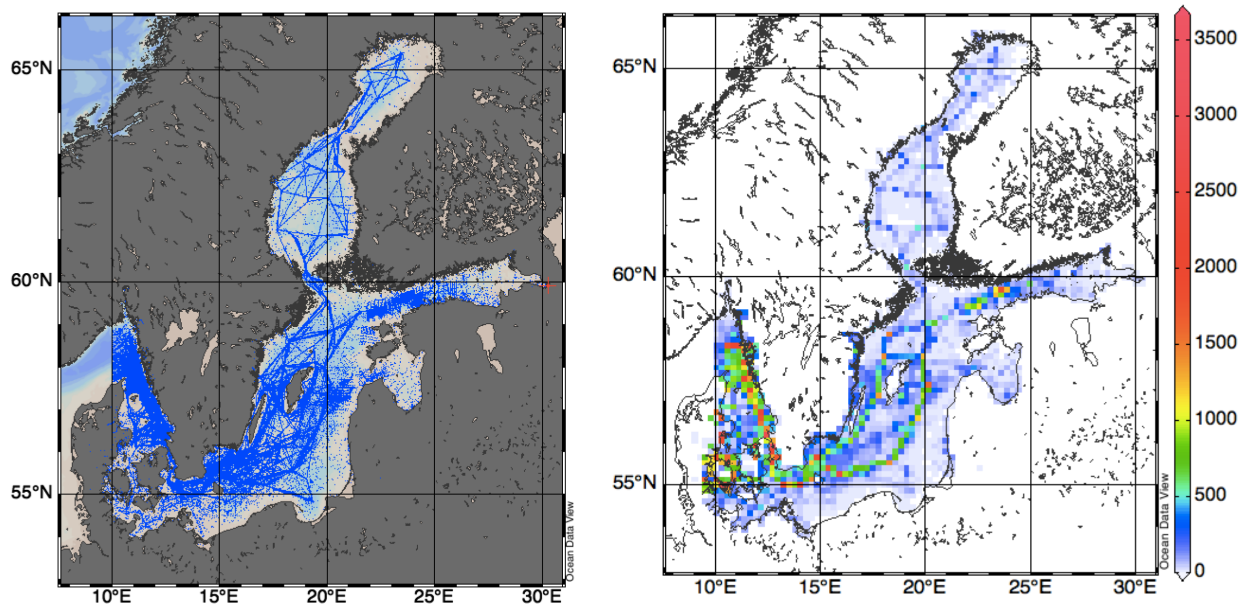


Figure 6.1. Spatial distribution of stations (left) and the number of profile observations of the SeaDataNet T/S data in the Baltic Sea.

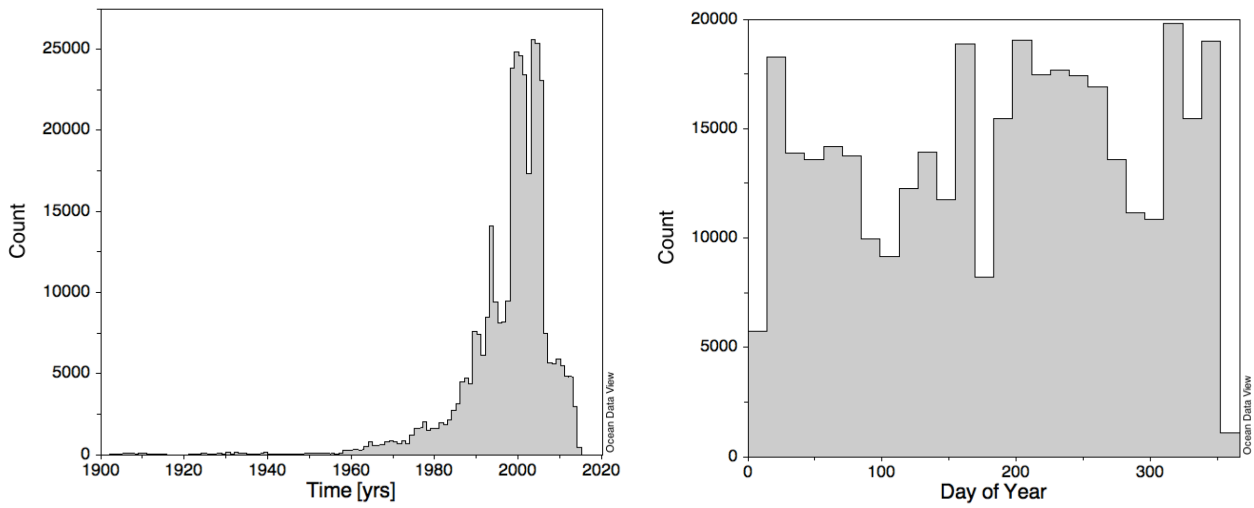


Figure 6.2. Annual (left) and seasonal (right) distribution of SeaDataNet Baltic Sea data.

National data: At least in Finland seawater temperature has been regularly measured in coastal stations. Those stations were chosen to be as deep as possible in an easily reachable area. However, the changes in the society have diminished the permanent inhabitants of the outer archipelagos and thus the number of volunteer observations has decreased drastically. On the other hand open sea depth observations have mostly been done from research ships in the Baltic Sea. In last two decades the increasing use of autonomous buoy stations has made possible to acquire regular and dense time series of vertical temperature profiles at some locations.

Thus spatial and temporal coverage of the seawater temperature data is still poor for easy analyses of long-term changes.

In transition waters, Danish light ships have measured a comprehensive historical dataset for temperature and salinity, the station list and monitoring periods are shown in Tab. 6.3.

Sea Surface Temperature (SST) and Sea Surface Salinity (SSS): in addition to T/S profile measurements conducted using coastal stations, autonomous buoys, tidal gauge stations and research vessels, satellites can measure SST with good spatial and temporal coverage. Additionally, ferrybox systems have been utilised for the SST and SSS measurements already from the beginning of the 1990's in the Baltic Sea. These data are available from CMEMS via free internet access.

Most of the temperature data are accessible from the data portals of BOOS, CMEMS, EMODNET and SeaDataNet. The *in-situ* measurements, although sparse, are essential for climate change studies. They are also used to model validations and thus give confidence on model results that can then complete the picture of temperature changes.

It is recommended that profiling buoys with regular observations should be used in some representative and/or dynamically important locations in each sub-basin of the Baltic Sea.

At present there are new data sources, like Argo-buoys that produce data that are openly available through the Internet that are not included in the analysis of present project.

The SST data used in the climate change is from CMEMS, a 3km resolution, daily level product blended from multiple satellites and *in-situ* measurements. The dataset covers a period from 1982-2013. It also provides analysis error estimate for each data value.

6.2.2 Sea Ice

The systematic ice observations began from practical needs and the ice services around the Baltic Sea have followed and recorded the ice conditions at their best for decades. There are many data sources: coastal observations, *in-situ* observations, air reconnaissance, satellite images and coastal radars. The high variety of observations has given a good picture of the ice extent and partly on the ice thickness, too. At present many ice models deliver model data on ice conditions (see Tab. 6.4).

Especially one time series of sea ice has been used to describe the ice conditions and their long-term changes. This is the annual maximum ice extent of the Baltic Sea (Fig. 6.3). It gives the area of the ice cover in the day when the ice cover was largest in a winter (see Fig. 6.4). This is one of the longest time series which begins from the winter 1719/20. The data sources within the series are many, beginning from proxy data like old logbooks from archipelago postal services and news in public newspapers. R. Jurva from Finnish Institute of Marine Research constructed the early part of the series till 1950's (Palosuo 1953, see data and description from Seinä and Palosuo 1996). It is now continuously updated in the Finnish Ice Service (run by FMI). Though there are several things that may affect the accuracy of the time series, it is generally considered to be a useful dataset for long-term studies of winter conditions. During latest decades the ice services have done even daily ice maps from where the internal dynamics of the ice winters can be analysed. Swedish and Finnish ice services constructed in 1970's a gridded dataset of the ice cover and produced a climatological ice atlas (SMHI and FIMR, 1982). FIMR also published a complementing ice atlas that describes the typical ice conditions according to the natural phases of the ice winter in contrast to the other ice atlas that describes the course of the ice winter on a calendar basis (Leppäranta et al. 1988). Unfortunately, the gridded data set was not updated regularly since then. At present new gridded data is available via FMI/CMEMS and a process to fill the data gaps is going on, though the process is somewhat slow.

Table 6.3. Swedish and Danish lightships in the Baltic Sea. Stations 7 - 11 were Swedish and the other were Danish ones

St. num.	Start date	End date	Lat.	Lon.	Name	Small moves
07	1923-09-01	1951-08-31	56.1167	16.5667	Ölands Rev	
08	1923-01-01	1972-11-30	55.3000	12.7833	Falsterbo Rev*	
09	1923-01-01	1961-12-12	55.5833	12.8500	Oskarsgrundet	
10	1923-01-01	1960-10-05	56.1667	12.5167	Svinbådan	
11	1948-01-01	1969-11-09	57.1667	11.6667	Fladen	
6037	1931-01-01	1977-09-02	57.7667	10.7333	Skagens Rev	1945-09-04, 1955-01-01
"	1977-09-03	1979-10-09	57.7833	10.7667	" *	
6047	1931-01-01	1943-04-13	57.4733	11.3350	Læsø Trindel*	
"	1943-04-14	1945-04-11	57.5150	11.2600	" *	
"	1945-08-23	1961-12-31	57.5333	11.3417	Læsø Nord	1949-01-01
"	1962-01-01	1975-09-03	57.5333	11.3417	"	
"	1975-10-05	1977-11-24	57.4667	11.4167	Læsø Trindel*	
6057	1931-01-01	1943-03-31	57.2133	10.6933	Læsø Rende	
"	1943-04-01	1962-02-06	57.2083	10.7333	"	1945-09-01, 1949-01-01, 1955-01-01
"	1962-02-07	1965-11-30	57.2000	10.7333	"	
6067	1931-01-01	1942-12-31	56.9733	10.8950	Østre Flak*	
"	1943-01-01	1973-02-28	56.8500	10.8000	Aalborg Bugt	1945-09-05, 1949-01-01, 1956-01-01, 1960-01-01
6077	1931-01-01	1944-12-31	56.1483	11.1867	Schultz's Grund	
"	1945-01-01	1971-09-03	56.1000	11.1500	Kattegat SW	1949-01-01, 1956-01-01, 1960-01-01
6087	1931-01-01	1945-04-22	56.7667	11.8633	Anholt Knob	
"	1945-09-01	1948-08-20	56.7500	11.9917	"	
"	19480821	1961-12-31	56.8500	11.8000	Anholt Nord	1949-01-01
"	1962-01-01	1975-03-09	56.8500	11.8000	"	
"	1975-03-10	1985-08-08	56.7500	11.8833	Anholt Knob	
6097	1961-01-01	1969-07-31	55.4000	6.9500	ER	1966
6107	1931-01-01	1939-12-31	55.3667	7.6833	Vyl	
"	1945-01-01	1948-12-31	55.4000	7.6167	" *	
"	1949-01-01	1975-03-06	55.4000	7.5667	"	1961
"	1975-03-07	1980-04-15	55.5667	7.3333	Horns Rev*	
6127	1931-01-01	1973-08-31	55.3367	11.0467	Halsskov Rev	1949-01-01, 1950-12-08, 1955-02-01
6147	1931-01-01	1939-12-31	54.4533	12.1833	Gedser Rev	
"	1945-01-01	1955-04-18	54.4200	12.1467	" *	
"	1955-04-19	1976-03-31	54.4533	12.1833	"	
"	1976-04-01	1979-01-24	54.7833	12.7500	Kadetrenden*	
"	1979-01-25	1988-12-12	54.8000	12.7833	Møn SE*	
6148	1987-07-01	1988-01-31	54.6167	11.0167	Femernbælt*	
6157	1966-01-01	1975-03-03	56.2500	12.2500	Kattegat Syd	
6167	1931-01-01	1969-06-30	56.0667	12.6333	Lappegrund	19390116, 19510421
6183	1900-01-01	1937-06-12	55.5333	12.7167	Drogden Fyrskib	
"	1937-06-13	1998-09-30	55.5333	12.7167	Drogden Fyr	

*Not used for isopleths

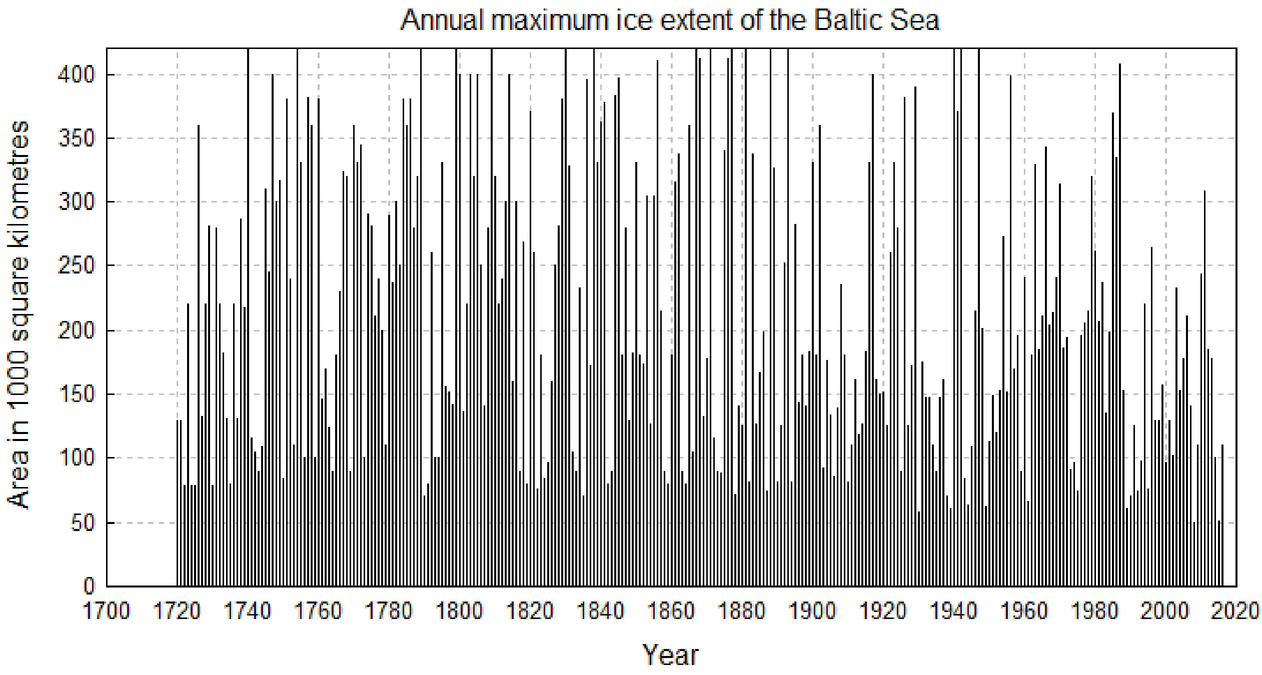


Figure 6.3. Annual maximum ice extent of the Baltic Sea.

The extent of ice does not tell on the mass of the ice cover. The question of the total mass of ice in the Baltic Sea is much more challenging. At present the data is not digitized, but is in the form of ice charts. Even there the mass is not given, but estimates of ice thickness and that is difficult to change into definite numbers in the whatsoever grid. The ice thicknesses are provided as some range and in the ice charts, the boundaries of the thickness ranges are not drawn. In FMI there is work going on to digitize the old ice charts. To give an idea of the task: the ice winter lasts from October/November until May, which makes in total 6 – 7 months and about 30 weeks. At present the digitization project includes 2 charts from each week. Digitization of one chart takes 0.5 working days, which means that it takes three weeks to digitize one years ice charts. Actually there exist even more charts, the daily ones.

There is ice thickness information from single observation sites around the Baltic Sea. In Finland, such data is monthly mean from seven stations from 1890 onwards. From SMHI there is freely available daily ice data from 402 stations around the coasts of Sweden from years 1987 till 2011. That data is coded according to Baltic Sea Ice Code, which includes the ice thickness only in nine different classes.

There also exists a data set of monthly mean values of Baltic ice coverage and thickness in 1956-2005. The data is calculated from digitalized ice charts by Natalija Schmelzer and Jürgen Holfort, BSH, Rostock and is published with the book by Feistel et al (2008). That dataset may be used in calculating ice masses for that period, too.

It is recommended that the high number of existing ice charts are digitized to a new gridded digital dataset.

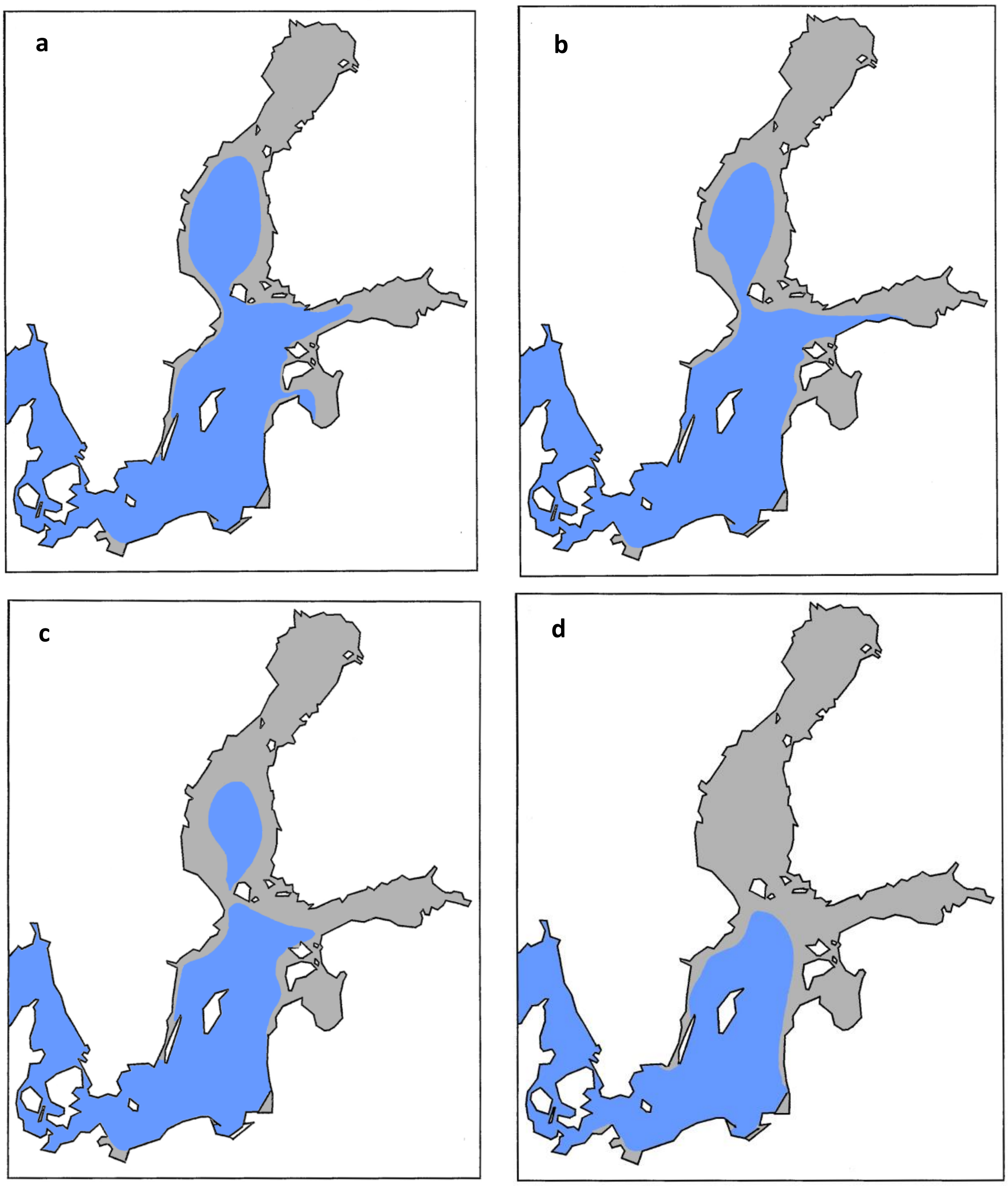


Figure 6.4. Mean annual maximum ice extent in the Baltic Sea in last a) 5 years, b) 10 years, c) 50 years and d) 100 years.

6.2.3 Data from numerical models

During recent decades several numerical ocean models that have coupled ice modules have been developed and used to generate decadal hind casts, gridded reanalysis and climate scenario time series for the Baltic Sea. These have usually been validated against single stations with reasonable temperature time series. The models include e.g. HIROMB, HBM, NEMO-Nordic, GETM and COHERENS. Usually, these models have also been used for operational forecasting and therefore their behaviour should be known at least in normal conditions and in extreme events. Part of these model runs are summarized in Tab. 6.4.

Table 6.4. A summary of existing ocean-ice model runs for the Baltic Sea

Model name	Period	Forcing	References	Type of runs	Resolution
DMI BSHcmod	1960-1990	HIRHAM downscaled climate run	Madsen, 2009	Climate run	6-1nm, hourly
DMI BSHcmod	2070-2100	HIRHAM downscaled A2 scenario run	Madsen, 2009	Scenario run	6-1nm, hourly
HBM	1990-2009	HIRHAM hind cast - downscaled ERA-I	Fu et. 2012	Hind cast	6-1nm, hourly
HBM	1990-2009	HIRHAM hind cast - downscaled ERA-I	Fu et al. 2012	Reanalysis (T/S profiles assimilated)	6-1nm, hourly
HBM	1958-2008	HIRHAM hind cast - downscaled ERA-I	DMI, SUNFISH project, 2010	Hind cast	6-1nm, hourly
HBM-HIRHAM	1990-2010	ERA-I	Tian et al. 2013	Coupled hind cast run	6-1nm, hourly
HBM-HIRHAM	1960-2100	CMIP 5 EC-Earth Climate scenario run	Tian et al. 2016	Coupled climate, scenario run	6-1nm, hourly
HIROMB	1989-2014	HIRLAM reanalysis	CMEMS	Reanalysis run	5.5km, hourly
RCO-SCOBI	1970-1999	Hind cast downscaled from ERA-40	Liu et 2014, SMHI	3D ocean-biogeochemical Reanalysis run	4km, hourly
NEMO-Nordic	1961-2007	Hind cast downscaled from ERA-40	FMI	Hind cast	2nm, hourly

The numerical model data of temperature, salinity and currents used in the BSCP Climate change challenge area is from the FMI NEMO climatological runs, covering the years 1961-2007 with 2 nm (nautical mile) horizontal and 40-layer vertical resolutions. The model data have the strong seasonal cycle in temperature as expected (Fig. 6.5). The development of the salinity during the simulation may not reflect changes in nature, but some model related property (Fig. 6.6).

6.2.3.1 Currents

In the first half of 1900’s regular observations of currents were done from lights ships in the ice-free seasons. Those observations include data from a couple of depths in vertical. At least in Finland the light ships stopped to operate in 1950-60’s and so stopped those observations, too. After that era, the currents have been measured in distinct projects and in certain hotspots in the Baltic Sea.

Short periods of the light ship observations were used in the first half of 1900’s to produce maps of “general circulation” in the northern Baltic Sea (Witting 1912 Palmen 1930). Those publications have shaped the thinking of average current field of the Baltic Sea. They also include the persistence of the currents to give an idea of how variable the currents are in space and time. The persistency was also given to different ice-free seasons.

One important measurement of the currents is the integrated volume flow through the Belts that DMI and SMHI deliver. It is a measure of the water exchange between Baltic Sea and North Sea.

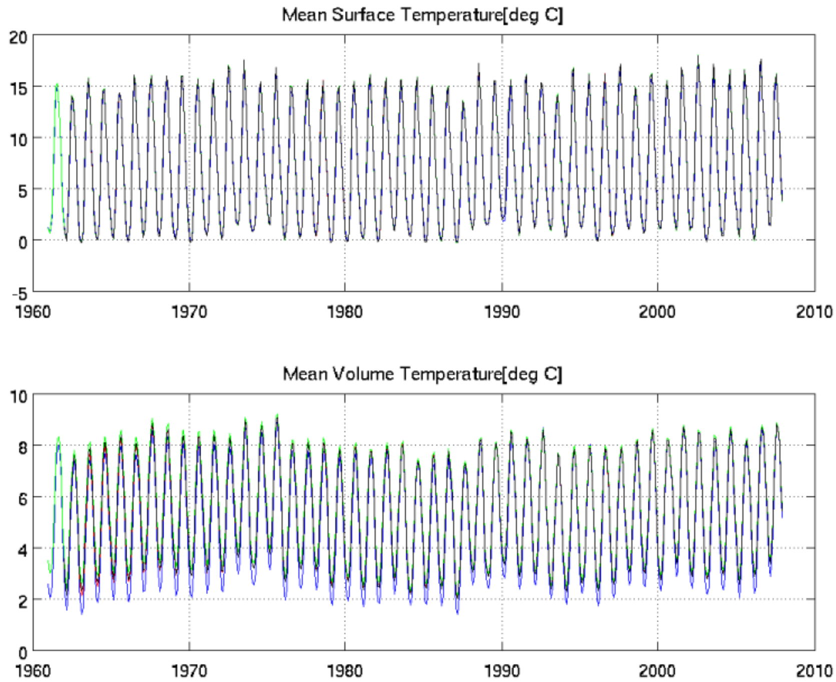


Figure 6.5. Mean surface and volume temperatures of the whole Baltic Sea according to NEMO model climatic simulation in FMI.

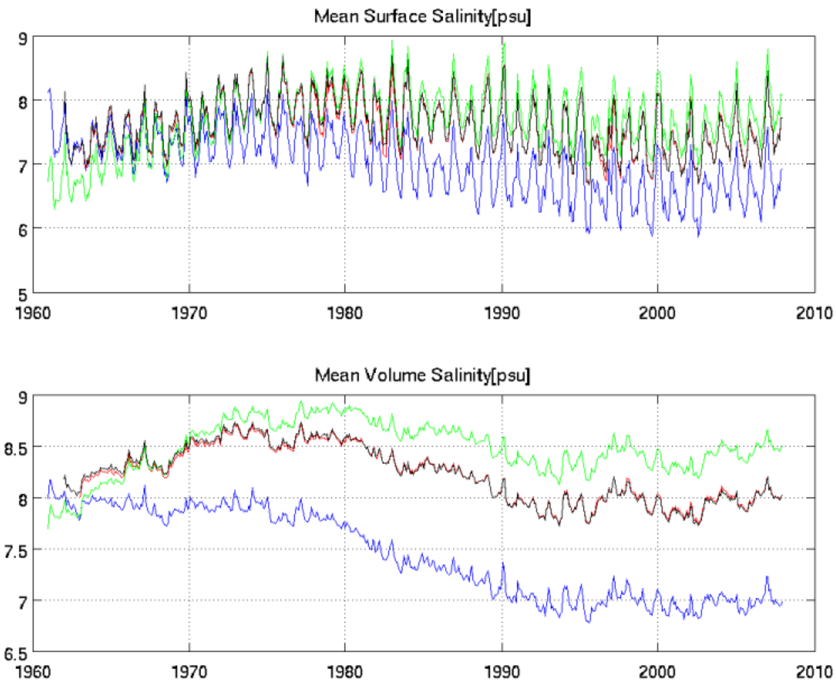


Figure 6.6. Mean surface and volume salinity in the NEMO model climatic simulation in FMI. The lines represent different model versions and the green, uppermost line is the latest version in the simulations.

Table 6.5. Data availability for climate change

Variable	Data type	Accessibility		Completeness/ coverage	Resolution			Data provider
		Delivery type	Delivery time	Spatiotemporal	Hor.	Ver.	Temp.	
Sea ice extent	Obs.	On request Open, free	Months	Baltic Sea 1719/20 - now	N/A	N/A	Annual	FMI, CMEMS
	Model	On request Open, free	Online	Baltic Sea 1961-2014	4-5.5 km	N/A	daily	CMEMS, DMI, FMI
Sea ice thickness	Obs.	On request from Finland		sites around Finnish coasts 1900 -	N/A	N/A	monthly	FMI
	Obs	Freely available SMHI	Online	stations around Swedish coasts 1987 – 2011	N/A	N/A	daily	SMHI
	Obs	Book, Germany	Static	Baltic Sea 1956 - 2005	30 NM	N/A	monthly	IOW
	Model	On request Open, free	Online	Baltic Sea 1961-2014	4-5.5 km	N/A	daily	CMEMS, DMI, FMI
SST	Blended L4	On request Open, free	Online	Baltic Sea 1982-2013	3km	N/A	daily	CMEMS
	Model	On request Open, free	Online	Baltic Sea 1961-2014	4-5.5 km	N/A	daily	CMEMS, DMI, FMI
Sea temperature	In-situ	On request Open, free	Online	Baltic Sea 1900 -2016	-1960: <100 profiles/y (p/y) ~1961-1975: 10^{2-3} p/y ~1976-1999: 10^{3-4} p/y 1993, 1998-2007: >10^4 p/y 2007 – now: 10^{3-4} p/y			CMEMS, EMODNET, ICES SeaDataNet
	Model	On request Open, free	Online	Baltic Sea 1961-2014	4-5.5 km	Multilayers	daily	CMEMS, DMI, FMI
Sea salinity	In-situ	On request Open, free	Online	Baltic Sea 1900-2016	-1960: <100 profiles/y (p/y) ~1961-1975: 10^{2-3} p/y ~1976-1999: 10^{3-4} p/y 1993, 1998-2007: >10^4 p/y 2007 – now: 10^{3-4} p/y			CMEMS, EMODNET, ICES SeaDataNet
	Model	On request Open, free	Online	Baltic Sea 1961-2014	4-5.5 km	Multilayers	daily	CMEMS, DMI, FMI
Currents	In-situ	On request Open, free	Online	Baltic Sea 1990- 2016	Hourly sparsely distributed stations			EMODNET
	Model	On request Open, free	Online	Baltic Sea 1961-2014	4-5.5 km	Multilayers	daily	CMEMS, DMI, FMI
Phytoplankton	Obs. Spring	Delayed, on request, free	1-2 year	Baltic Sea 1979-2014	0-20m Some seasons/years lack data or data are very sparse			ICES/ HELCOM
	Obs. Summer	Delayed, open, free	1 year	Baltic Sea 1979-2014	0-20m Some seasons/years lack data or data are very sparse			ICES/ HELCOM

At present many operational numerical models give the currents in gridded fields. Many publications have given estimates of the current fields in different sub-areas of the Baltic Sea in a higher resolution than the models that cover the whole Baltic Sea. By this the complicated structures of the currents have become visible. However, the results of the different models differ from each other and with the lack of real observations it is difficult to say how well the models reproduce the true current field and which models manage best. Such knowledge is essential, because models could then be used to define the most useful monitoring sites for currents. In any case model data seems to be the only way to estimate the changes of current field in changing the climate and in estimating the distribution of human originated substances in the sea.

6.2.4 Phytoplankton species

The data adequacy in the Climate change phytoplankton study looked for completeness of historical phytoplankton dataset in the ICES/HELCOM database. Even for assessment of Baltic Sea environment status, there are no core indicators defined for phytoplankton; several are in the status of pre-core (seasonal succession of functional phytoplankton groups; cyanobacterial surface accumulations) or candidate (phytoplankton community composition as a food web indicator) indicator. Phytoplankton data used in the present report were gathered from ICES/HELCOM databases for the period 1979-2014.

ICES Data: The ICES/HELCOM database contained phytoplankton time series for 1979-2014 during the last download on the 11th of April 2016. The spatial coverage of data is the whole Baltic Sea (Fig. 6.7), data are collected either monthly or yearly from HELCOM coastal and open sea stations from the surface layer (mostly integrated water samples from a depth of 0-10 or 0-20 m) but in many cases also samples from discrete depths are included into the database

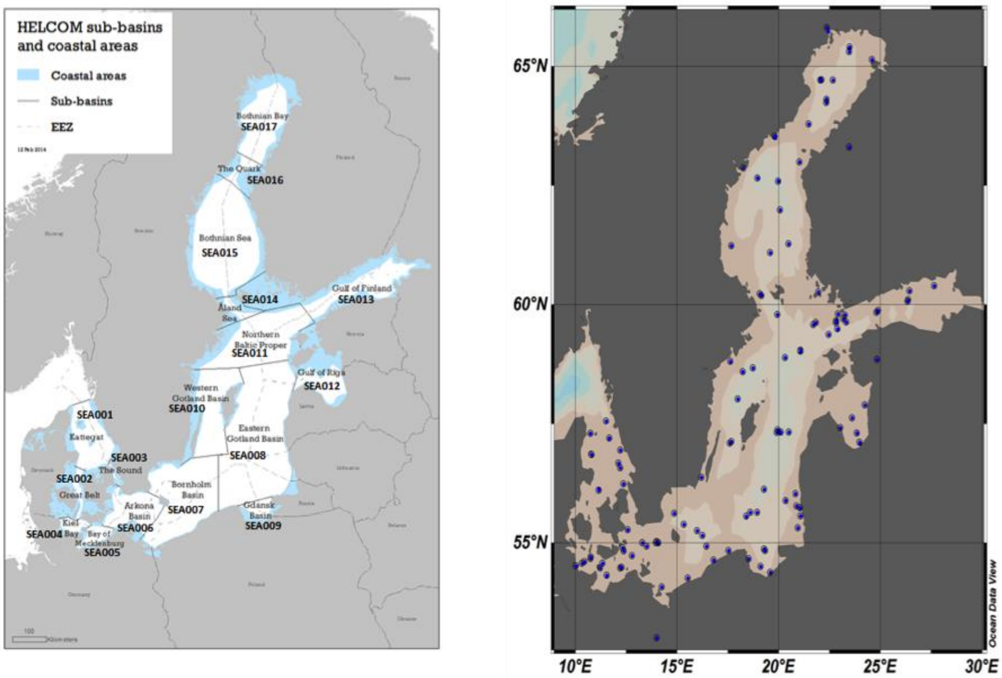


Figure 6.7. HELCOM open sea sub-basins used for phytoplankton trend analysis (left panel); source: www.helcom.fi (with added sub-basin numeration. Location of stations used in the phytoplankton spring species analysis (right panel).

ICES data accessibility: The data used 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 at ICES. 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.

ICES data completeness: The origin of data is necessary to analyse the completeness of the dataset. The project identified a lot of missing data in the ICES/HELCOM phytoplankton database. Also, the station map (Figure 6.7) seems to be pretty well spatially covered with sampling stations, often the temporal coverage is very poor. By looking for the reason for missing data, it was discovered that it is not always due to the data providers not submitting the data. Very often, there has 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 is crucial to be solved as soon as possible to increase the usage of this database for different purposes.

EMODNET data: Baltic Sea Checkpoint has also identified several international and national databases, which may be used for completing the ICES/HELCOM database to increase both the spatial and temporal coverage of the data. Phytoplankton data in the EMODNET Biology database cover the years 1983-2013. The data in the EMODNET database are free with on-line access and data source always available. The data can be downloaded by species under interest but in that case, the trend analysis is impossible to accomplish. This is because the target species is not always observed in all samples taken, and no "zeros" are reported as samples not containing the target species are not taken into account in the analysis. The data available at the present are mostly provided by SMHI or ICES. Hence, even the coverage on a map might look promising, after closer examination of the data, these are not yet suitable for the Baltic Sea-wide trend analysis, and therefore not used by the present project.

National data: BSCP project has also searched for additional phytoplankton data from National databases in Estonia, Latvia, Finland, Sweden and Poland. The database from Estonian Environmental Agency contains phytoplankton data from national marine monitoring stations in the Estonian EEZ for 1993-2014. These data were entirely missing in the ICES/HELCOM database during the download in April 2016. Swedish national data was downloaded directly from the publicly accessible SMHI database Sharkweb. The data were partly available in the ICES/HELCOM database, but several years were missing due to the current "pending status". After personal communication with Latvian data holder LHEI, the project identified that data from only a few stations had been submitted to the ICES/HELCOM database so far. Hence, for the more reliable Baltic Sea-wide or Gulf of Riga analysis, additional phytoplankton monitoring data should be requested for directly from the Latvian national data holder for better spatial and temporal coverage. In Finland, all monitoring data are freely available, but there is no web-page to download these. Instead one has to turn directly to the data providers (there are several). The project has also asked about the data policy in Poland, but even though the monitoring data should be freely available, the response to the data request was not positive.

Project-based data: Two major databases compiled during EU funded past projects were also identified: 1) Characterization of the Baltic Sea Ecosystem: Dynamics and Function of Coastal Types (CHARM-EVK3-CT-2001-00065), and 2) 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 considering there are no publicly available on-line databases.

6.2.4.1 *Spring species* – Achnanthes taeniata *and* Peridiniella catenata

Several problems and mistakes using the ICES/HELCOM database were identified. In a couple of occasions, the stations appeared on land. There is no uniformity in units of data values – the values are presented in 3 different ways: a) number of counting units with coefficient in separate column – abundance values need to be calculated before analysis; b) units per litre; c) units per cubic decimetre. Sometimes the coefficient is absent, meaning these data rows should be excluded from the analysis (e.g. in present case 29 data rows for spring diatom *Achnanthes taeniata* were removed). Data are often presented by species size classes in separate rows – there is a need to sum first the values of different size classes before the analysis. Quite often data having the same date, coordinates, station and depth parameters had two different values. As these two values were one order of magnitude different, these were not treated as parallel samples, meaning the values were not averaged but were summarised instead to get only one row per station. In the present data adequacy analysis of spring species data 45 stations (1,9%; mostly German data from 1982) from 2376 had sampling depth higher than 200m in sub-basins not that deep: e.g. in Kiel Bay in depth range 200-280 m, in Bay of Mecklenburg samples from depth range 200-250 m, in Eastern Gotland Basin samples from up to 900 m (!) depth. These depth ranges seem to be typing errors, and these data were excluded from the analysis.

6.2.4.2 *Summer species* - Nodularia spumigena *and* Heterocapsa triquetra

Data from the summer period June – August 1979-2014, was extracted from the ICES/HELCOM database. Zeros were added whenever the target species was absent in a specific sample. The depths varied from single depth 0 meters to 910 meters! A considerable amount of data was without depths of which a lot was Danish data. Maybe there is depth information somewhere that is lacking in the current dataset. There were variable integrated depths as well from 0-1 to 0-20 meters. In some cases, the depths seemed to be switched so the shallower depth was in the max depth column, whether the data is truly switched or wrong is not known. All depths considered nonsense or absent should be deleted if not the parameter can be provided in any way.

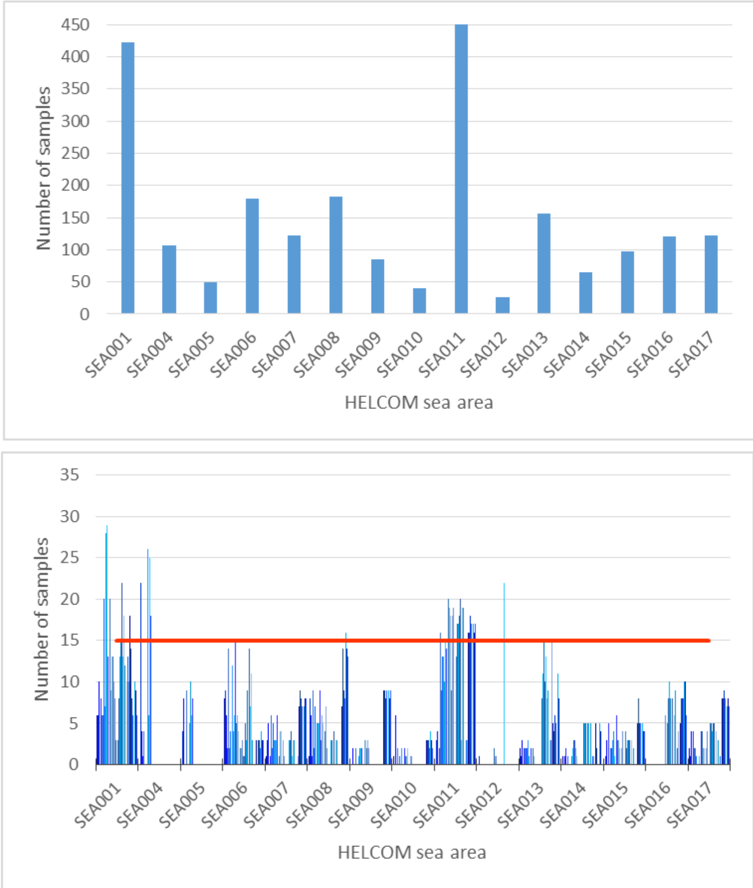
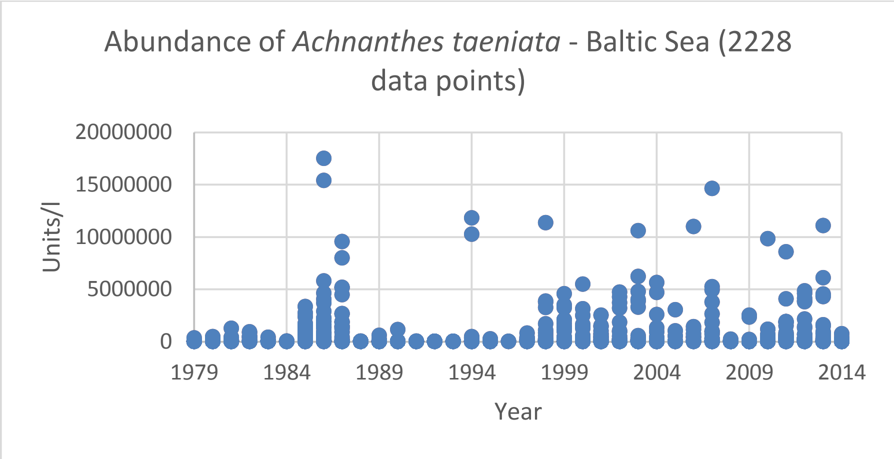


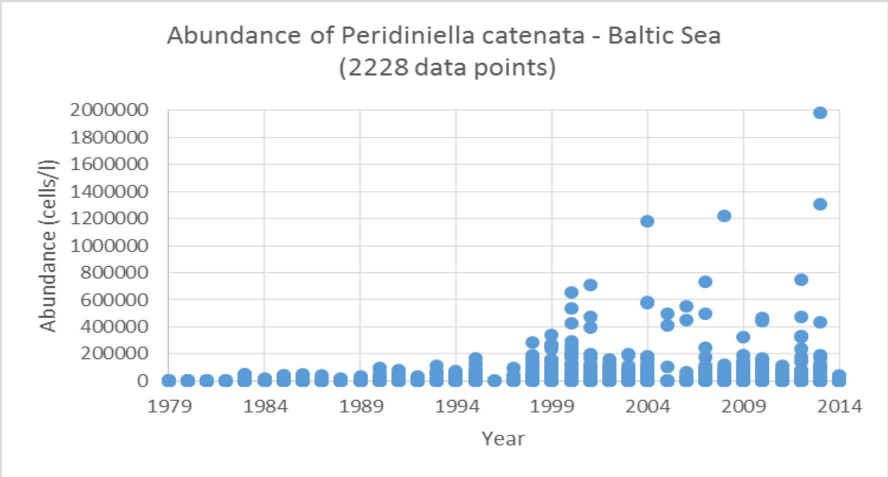
Figure 6.8. A total number of samples (upper panel) and the yearly available number of samples (lower panel) per HELCOM sub-basin for March-May 1979-2014.

The same issues as for the spring species were also found for the summer species, come to i) variability in units, ii) absent coefficient when only number of cells have been reported and iii) different size classes from the same occasions that need to be summed up before analysis. So, care has to be taken before data are processed in order not to lose useful data or wrongfully use the available data.

The number of spring samples per HELCOM sub-basins and yearly spring sample numbers are presented in fig. 6.8. There are only two sub-basins with a sufficient number of yearly samples to qualify to the HELCOM recommendations (15 samples per season/year per sub-basin). As the spring phytoplankton bloom progresses in time from south to north, the time frame for analysis is probably slightly different for different areas (e.g. inclusion of February and exclusion of May data to/from the southern sub-basins analysis).

For spring bloom diatom *Achnanthes taeniata* and dinoflagellate *Peridiniella catenata (Fig. 6.9)*, 2 228 samples were identified in the ICES/HELCOM database, of which the target species were found in 775 (34.8 %) and 1017 (45,6 %) samples respectively. The summer bloom species *Nodularia spumigena* and *Heterocapsa triquetra* were observed in 869 (39 %) and 640 (29 %) summer samples respectively, uncertain depths included. Unfortunately the available data have many spatial and temporal gaps and are not suitable for the challenge Climate change reliable trend analysis.





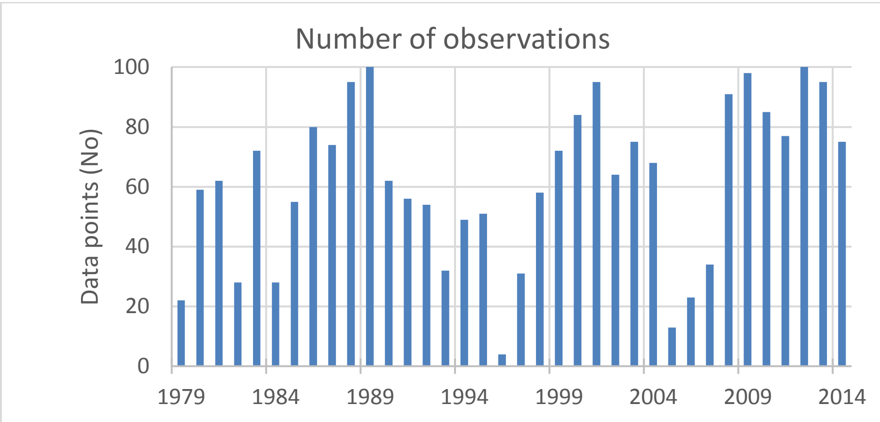


Figure 6.9. The abundance of spring diatom *Achnanthes taeniata* (upper panel) and dinoflagellate *Peridiniella catenata* (middle panel) in March-May in the entire Baltic Sea and the number of observations for the same period available at the ICES/HELCOM database (lower panel) (data downloaded on the 11th of April 2016).

6.3 Conclusions and discussions

Data adequacy assessment looks mostly *in-situ* data from SeaDataNet, ICES and HELCOM. SeaDataNet is somewhat behind the EMODnet physics, too. We downloaded the available dataset and for phytoplankton, asked also from local institutes for additional data. Sea ice data was downloaded from published source and institutes (FMI, SMHI, IOW (book)).

The temperature and salinity data can be downloaded in OceanDataView-format (Schlitzer 2015) and ODV-software includes options to visualize some statistics of the data, too. That is done in this report.

It is seen that spatial and temporal distributions of open sea data are biased and thus constructing long time-series is possible only for some representative locations. The temporal resolution of the temperature and salinity data is such that episodic processes, like upwelling, may disturb the interpretation of the data in a climatic sense. The phytoplankton dataset in the ICES/HELCOM database needs to be improved by data providers via inclusion of more monitoring data.

In future monitoring, there is a need to guarantee the existence of some representative stations with observation with high temporal resolution so that the annual cycles are known and sparse open sea observations can be interpreted according to them. This development is going on with water physical parameters when the number of autonomous profiling buoy stations is increasing. Spatial coverage of observations of temperature and salinity is also going on as well because Argo-floats are taken into use in the Baltic Sea. Still, phytoplankton monitoring efforts need to be increased to fulfil the HELCOM minimum requirements. For future phytoplankton monitoring the shared efforts of neighbouring countries should be discussed.

Ice data is systematically collected in ice services around the Baltic Sea and after digitization of the existing ice charts, the datasets will be adequate for different kinds of climatic analyses. The amount of ice masses in the sea will be difficult to observe e.g. because of the ridging of ice and because the ice thickness is given as a range rather than a single value. On the other hand, remote sensing methods improve the quality of the charts and models continuously.

The 3D numerical model data is adequate both in space and time. The data used in this project is from climatic runs of the already older version of NEMO model, and it is not clear how well the models reproduce e.g. the salinity field. Model development is rapid, and we recommend doing climatic runs every now and then.

Table 6.6. Data adequacy for climate change

Variable	Data type	Accessibility		Completeness/ coverage		Resolution			Precision	Data provider
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.		
SST	Blended L4	FFU	FFU	FFU	FFU	FFU	FFU	FFU	FFU	CMEMS
Sea water temperature	*In-situ*	FFU		Unevenly distributed		Sparse in time and space			FFU	EMODNET, ICES, HELCOM
	Model	FFU		FFU		2 NM, 5 m, hourly			FFU	CMEMS, FMI, SMHI
Sea water salinity	*In-situ*	FFU		Unevenly distributed		Sparse in time and space			FFU	EMODNET, ICES, HELCOM
	Model	FFU		FFU		2 NM, 5 m, hourly			FFU	CMEMS, FMI, SMHI
Spring phytoplankton	*In-situ*	FFU, but lot of data lacking, some of which are available on request if you know from where to ask, many data not easily accessible		Spatially unevenly distributed data, some sub-basins under sampled. Often too short or fragmental temporal coverage		In some sub-basins FFU, in most too fragmental.			FFU	Often too fragmental.
Summer phytoplankton	*In-situ*	FFU, but lot of data lacking, some of which are available on request if you know from where to ask, many data not easily accessible		Spatially unevenly distributed data, some sub-basins under sampled. Often too short or fragmental temporal coverage		In some sub-basins FFU, in most too fragmental.			FFU	Often too fragmental. Variable integrated depths!

*FFU – Fit-for-the-use

Acknowledgements are given to Inga Lips, Ann-Turi Skjevik and Magnus Wenzer for their inputs to the chapter.

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7 Data adequacy for coastal protection

7.1 Data requirement assessment

7.1.1 Description of applications

The objective of the application is to establish time series of long-term sea level variation (in 100yr scale) and sediment balance per Baltic Sea coastal stretch. The objective of determining past sea level change and variability for all stretches of the Baltic Sea coastline is to allow assessment of environmental and social impacts and consequences of future sea level rise. This includes coastal erosion and risk of flooding, and planning of coastal structures.

Methods used in sea level study is to reconstruct 100 year sea level variation in the Baltic Sea coast by integrated in-situ tidal gauge data, modelled sea level and land rise. Sea level records for tide gauges in the Scandinavian region consist of signals of both hydrodynamic change as well as land rise. Number of tidal gauge stations is less than 20 with records longer than 100 years. In order to reconstruct the long-term sea level in the coastal region where tidal gauges are not available, a regression model is established by using relative in-situ sea level data and model reanalysis, to reflect the relationship between the two datasets.

Local reference level has been corrected so that data from different stations can be compared with model data. Independent validation on the reconstructed sea level time series was carried out.

Methods used in sediment balance study is to use sea level data derived in the project together with national coastal monitoring data to evaluate the changes to the dry beach based on the hindcast of divergence and convergence of wave-driven longshore sediment transport. A complementary estimate for the budget of underwater sediment volume in the active beach profile will be obtained by combining inverse Bruun Rule, numerically evaluated closure depth, location of coastline and hindcast or forecast of sea level. The results will be validated at selected locations (Peraküla Beach, Pirita Beach in Estonia) against similar estimates derived from emerging technique of aerial laser scanning measurements and merged with the database of results of national coastal monitoring activities from Germany, Poland, Latvia and Lithuania.

The outputs from the application in the project are i) spread sheets and digital datasets of average annual sea-level rise per stretch of coast (absolute and relative to the land) and for 10, 50 and 100yr; ii) spread sheets and digital datasets of average annual sediment balance (mass gained or lost per stretch of coast) for a multi-decadal period.

The key variables used in coastal protections are sea level, coastal wave height and period, coastline evolution, sediment and lithology, land rise, geoid change due to land rise, digital elevation maps of the coastal zone, and foreshore/backshore evolution. For phase-I DAR, only the data adequacy for the reconstruction of sea level time series is assessed. Adequacy of other variables will be assessed in the DAR-II.

The land rise model used in this study is the Milne model, which was a special-relativistic cosmological model proposed by Edward Arthur Milne (1935). GPS observations were used to correct the model. The relative sea level can be obtained by extracting the land rise from the observed tidal gauge data (absolute sea level). The 100 year time series of monthly mean relative sea level is then reconstructed by using a statistical regression model. Among all the 34 tidal gauge stations with data in 1915-2014, only 7 stations were used for establishing the regression model (marked in Fig. 7.1 as black). The rest of the stations are used as independent source for model validation. The results are shown in Fig. 7.1. The results show that, the correlation coefficients between the reconstructed data and observations are between 0.85-0.95 for the transition waters but greater than 0.95 in rest of the areas.

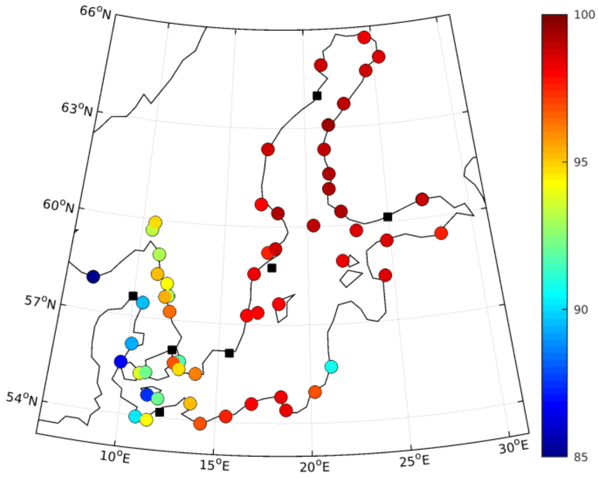

Figure 7.1. Correlation between the reconstructed monthly mean sea level and observations. Stations in black are those which observations have been used to construct the regression model.

The preliminary results of the trends of absolute and relative sea level rise are obtained by using the reconstructed time series and land rise data. The results are shown in Fig. 7.2.

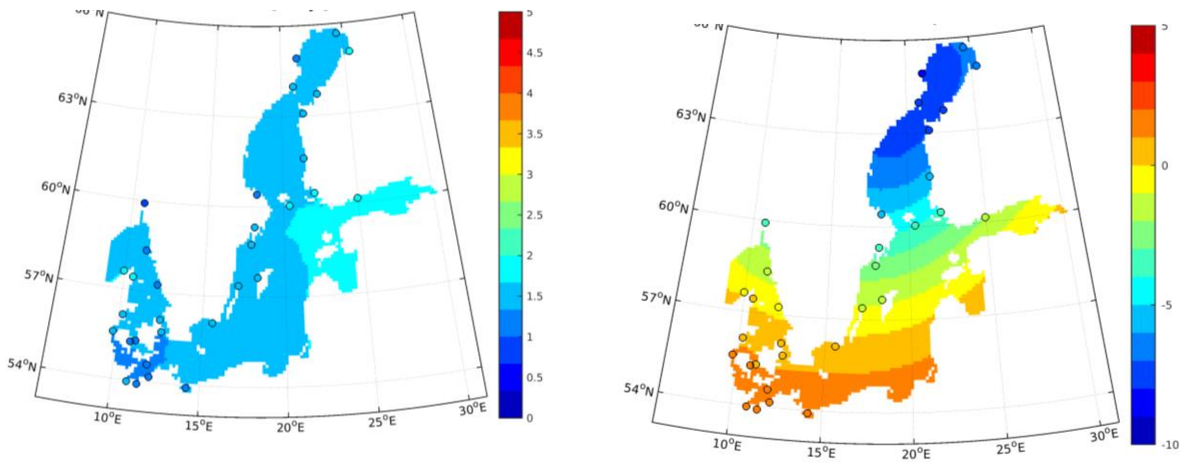

Figure 7.2. Trends of absolute (left) and relative (right) sea level rise during 1915-2014.

7.1.2 Data requirements

The sea level trend analysis combines measurements of century-long sea level observational records from selected tide gauges with model reanalysis of the sea level to produce sea level information for all parts of the Baltic Sea. To assess the separate effects of sea level rise and land rise, accurate information on land rise especially from glacial isostatic adjustments is essential in the Baltic Sea region, as the land rise signal varies throughout the region. The land rise is larger than past sea level rise in the northern part of the region, resulting in apparent sea level fall. Remote sensing complements this method of sea level reconstruction and allows independent assessment of the open-water sea level variability during the satellite altimetry era (1992 – present). At the same time, the combined tide gauge – reanalysis model product is highly suitable for validating the quality of the satellite data in more coastal regions. The results of in-situ data usage and requirement assessment are summarized in Tabs. 7.1 and 7.2.

Table 7.1. Data usage of sea level for coastal protection

Variable	Data type	Usage
Land rise and geoid change	Model	For estimating land rise correction of sea level reconstruction
	In-situ Obs.	
Sea level-1	In-situ Obs.	Model/RS validation, regression model for sea level reconstruction; estimating closure depth
	Model	Regression model for sea level reconstruction, estimating closure depth

Table 7.2. Data requirements for coastal protection

Variable	Data type	Accessibility		Completeness/ coverage		Resolution	Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor./Ver./Temp.	
Land rise and geoid change	Model	Delayed, open, free	N/A	Global	Stationary	H: 10 km T: Single	0.5 mm/ yr
	Obs.		Months-years	Baltic	>10 yr	H: 100km T: Monthly-yearly	0.2 mm/ yr
Sea level	Obs.			Selected Baltic Sea sites	100 yr	H: 10-200 km alongshore T: Monthly	0.01 m
	Model			Baltic Sea	>20 yr	H: 10 km T: Monthly	~0.05 m

7.2 Data adequacy assessment

The adequacy of sea level is assessed in this section by combining model, remote sensing and in-situ measurements. The Baltic Sea is one of the best monitored areas of the world when it comes to sea level, but the coverage of the last century does not include all stretches of the coast. Here, 3 data sources are combined to provide this coverage: In-situ tide gauge observations, model reanalysis and satellite altimetry observations. The data availability and adequacy are summarized in Tabs. 7.3 and 7.4.

7.2.1 Tide gauge observations

The EMODNET physics database includes near real time (NRT) hourly sea level observations as a parameter and delayed mode monthly and annual mean sea level observations from the Permanent Service for Mean Sea Level (PSMSL) database as a product. Many long records of tide gauge observations exist from the Baltic Sea. For this study, 59 tide gauges with unique records with at least 49 years of data after year 1900 have been identified from the PSMSL dataset (Fig. 7.3), and supplemented with 4 stations from the Estonian coast, made available from the Estonian Environmental Agency. Thus, the overall data coverage is good. However, the stations are not evenly distributed and especially south-eastern stretches of coastline lack coverage of high quality digitized data, especially before the 1950'es. Many Baltic sea level stations are also included in the NRT sea level parameter. However, many stations from Lithuania, Poland and Kaliningrad Oblast are still missing (Fig. 7.3 left). The period of the NRT data is from 1960 and onwards, with many records starting later.

To calculate trends of the combined effects of sea level rise and general land rise from sea level records, it is mandatory to adjust for small vertical movements of the station by referring all data to a local reference level. This has been done for all PSMSL data in EMODNET, but not for the NRT sea level parameter. To further calculate the sea level rise without land rise effects (the absolute sea level rise), the land rise of the local benchmark must also be known.

It is recommended that i) EMODNET should expand its sea level database for the Baltic Sea to include as many as possible stations from Poland and Lithuania; ii) Some historical data may be recorded in paper, therefore will need digitization; iii) The gap between the NRT parameter and the PSMSL product is bridged by providing a research quality sea level parameter with hourly data and consistent monthly and annual means, and local reference level corrections applied (following PSMSL standards); iv) The network of high quality tide gauges is maintained throughout the region.

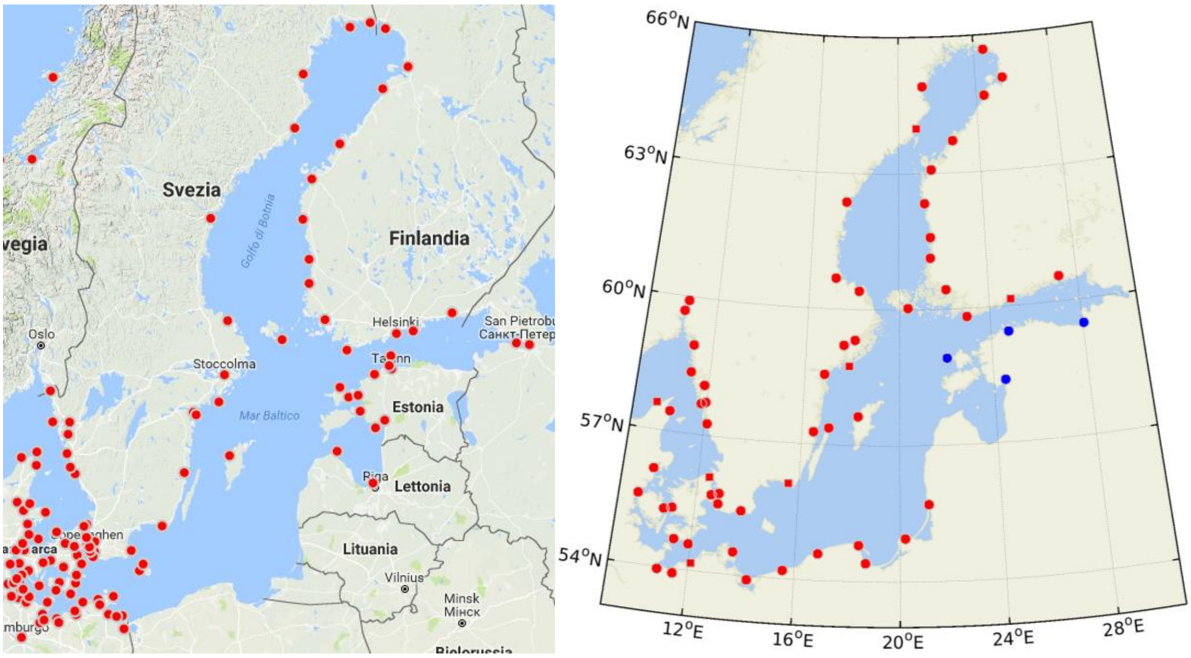

Figure 7.3. Baltic sea level stations from EMODNET-physics (left) and sea level stations with long records used in the present study (right, red: PSMSL stations, blue: Estonian stations)

7.2.2 Sea level from models

Several reanalysis products of the Baltic sea level exist. For this study, two reanalysis products both based on hydrodynamic modelling with the HBM (Fu et al. 2012) and HIROMB (http://marine.copernicus.eu/documents/QUID/CMEMS-BAL-QUID-003-008.pdf, Axell and Liu, 2016) models have been compared. These models have been used for operational forecasting and therefore have been calibrated regularly both for normal conditions and extreme events. The HIROMB ocean-ice reanalysis is available in CMEMS with 5.5 km horizontal resolution for the period of 1989-2014, while the HBM-based reanalysis covers year 1990-2012 and is available from DMI. Validation performed within this study show that both model systems sufficiently resemble the observed long term variability of the sea level with root-mean-square-error around 6-7cm and correlation of 0.86-0.88. None of the simulations include effects of land rise and long-term external sea level variability and rise. *It is recommended that* *future ocean-ice reanalysis products for the Baltic Sea accurately include effects of external sea level variability and land rise.*

7.2.3 Remote sensing of sea level using satellite altimetry

Several different sea level rise products based on satellite altimetry exist. Here, we focus on the ESA sea level CCI product, which is widely used also within Copernicus. Within this study, the variability of the satellite product will be validated against the developed combined in-situ – reanalysis sea level product. The validation will assess which parts of the Baltic Sea the satellite product is useful, and especially identifying the size of the coastal zone where the product is not optimal. *It is recommended that future satellite-based sea level rise products specifically target the coastal zone identified.*

Table 7.3. Data availability for coastal protection

Variable	Data type	Accessibility		Completeness/ coverage		Resolution	Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor./Ver./Temp.	
Land rise and geoid change	Model (Milne)	Delayed, open, free		Global	Stationary	H: >10 km T: Single	~0.5 mm/yr
	In-situ (DTU)	Restricted, free; Delivery in months-years		Selected N. Europe sites	< 30 yr	H: 100-500 km T: Yearly	0.2 mm/yr
	Satellite (DTU)	Restricted, free; Delivery in months		Global	~10 yr	H: ~500 km T: Monthly	unknown
Sea level	In-situ EMODNET	NRT delivery , open, free		>50 stations	1960 or later-now	Hourly	0.01 m from instrument, estimated 0.05 m from reference level, estimated 0.5 mm/yr for trends
	In-situ PSMSL/ EMODNET	Restricted, free; Delivery in months-years		>50 stations	1900-now	Monthly	0.01 m and 0.2 mm/yr for trends
	In-situ EMI	On request, free delivery in months-years		4 stations	~1950-now	Monthly	Estimated 0.05 m from reference level and 0.5 mm/yr for trends
	Model CMEMS	Open, free delivery in months-years		Baltic Sea	>20yr	H: 10km T: Monthly	~0.05 m

7.3 Conclusions

This study shows that, by integrating in-situ and satellite observations together with land rise and 3D ocean models, the long (100 year), monthly time series of both absolute and relative sea level can be reconstructed with reasonable quality, for identifying trends of the sea level rise. In general, existing data availability fit for the purpose of use although some issuse can still be improved.

For in-situ observations, it is recommended that i) EMODNET should expand its sea level database for the Baltic Sea to include as many as possible stations from Poland and Lithuania; ii) Some historical data may be recorded in paper, therefore will need digitization; iii) The gap between the NRT parameter and the PSMSL product is bridged by providing a research quality sea level parameter with hourly data and consistent monthly and annual means, and local reference level corrections applied (following PSMSL standards); iv) The network of high quality tide gauges is maintained throughout the region.

For modelled sea level, it is recommended that future ocean-ice reanalysis products for the Baltic Sea accurately include effects of external sea level variability and land rise.

For satellite sea level, it is recommended that future satellite-based sea level rise products specifically target the coastal zone identified.

Table 7.4 Data adequacy for coastal protection

Variable	Data type	Accessibility	Completeness/ coverage	Resolution	Precision
		Delivery type/time	Spatiotemporal	Hor./Ver./Temp.	
Land rise and geoid change	Model	FFU*	FFU	FFU	FFU
	In-situ (DTU)	FFU but data are restricted	FFU	Acceptable	FFU
	Satellite (DTU)	FFU	FFU	FFU	FFU
Sea level	In-situ NRT EMODNET	FFU	Need long-term data in SE Baltic coast	FFU	FFU
	In-situ PSMSL/ EMODNET	FFU	Too short temp. coverage	Some coastal sections lack data	Info needed on reference level
	In-situ Non-EMODNET	FFU but some data on request	FFU	FFU	Info needed on reference level and quality control
	Model CMEMS	FFU	FFU	FFU	Ok, info needed on reference level

*FFU – Fit-for-the-use

References

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8 Data adequacy for fisheries management

8.1 Data requirement assessment

In the Baltic Sea Checkpoint project, the “Fishery management” Challenge area aims to establish time series of whole sea-basin of:

- Mass and number of landings of fish by species and year.
- Mass and number of discards and bycatch (of fish, mammals, and seabirds) by species and year.

The produced tables will be based on data from before and after the Data Collection Regulation came into force. The time-series will be as long as possible for each considered species. The final aim is to provide an overall picture of the trends over the years of landing, discard and by-catch by species.

This section describes key variables used and requirements of data for the challenge area. For each key variable, it describes how the data are used in fisheries management context, and which spatial-temporal coverage, resolution, etc. are required to fit the purpose. The results of data requirement assessment are summarized in Tab. 8.2.

8.1.1 Introduction

The main target species in commercial fisheries in the Baltic Sea are cod, herring and sprat. These constitute about 95% of the total catch. 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, eel and sea-trout. In the Kattegat, commercially important species include sole and *Nephrops.*

The fisheries for cod, sprat, herring, flatfish and salmon in the Baltic Sea are internationally managed. Most of the coastal fish species are subject to national regulations. The major management measure in internationally regulated fisheries is annual Total Allowable Catch (TAC). However, not all stocks are regulated by using the TAC, some stocks are only regulated by minimum landing size (flounder, brill, turbot). Until 2015, TAC has only been applied for commercial landings. Since 2015, the EU Landing Obligation is in place in the Baltic Sea, which aims at reducing discards of quota species (EC, 2014). Landings obligation was implemented for sprat, herring, cod and salmon in January 2015 and for plaice it is intended to be implemented in 2017.

Technical measures such as restrictions for minimum landings size, mesh size of gears, closed areas and seasons and effort regulations are commonly applied for both internationally and nationally regulated fisheries. These measures are intended to additionally protect the target species or reduce bycatch of unwanted fish species as well as marine mammals and sea-birds.

Data on fisheries are currently collected by Member States under the EU data collection framework program (EC, 2008). Fisheries catch of a species within a management area is key information for fisheries management. For stocks for which quotas are in place, fisheries landings are directly regulated by fisheries management. Also, fisheries catch data provide key information for assessing the status of fish stocks, by representing removals from the stock by fisheries. The quality of catch data is therefore of major importance for sustainable management of fish resources. Further, information on the amount of bycatch provides information on the efficiency of management measures in minimizing the fisheries related mortality of non-commercial fish species or marine mammals and seabirds.

The objective of this report for Fisheries management Challenge is to identify adequacy of existing Baltic Sea fishery monitoring data for establishing time series of whole sea-basin of mass and number of landings and discards of fish and bycatch of mammals, and seabirds by species and year.

The main data sources for these variables have been identified in BSCP Literature Review Report. Additional fisheries related variables relevant in the context of fisheries management but not covered in this section, such as fishing effort, are addressed under Fishing Impact challenge (Chapter 9).

8.1.2 Use of key variables for fisheries management

8.1.2.1 Mass of fisheries landings

Fisheries landings are generally recorded in mass (tons), except for salmon which are reported in numbers. Landings statistics is therefore usually available in weight units, and provide information on the amount of fish removals from the sea that is landed. Temporal development in fisheries landings, together with an index of stock dynamics, provides an estimate of changes in exploitation intensity, which is key information for fisheries management to facilitate appropriate management actions.

For the species and stocks where the amount of landings to be taken is regulated by quotas, landings statistics allows monitoring the correspondence between management regulations and the actual level of fishing. Further, in data-limited situations where additional information on a fish stock is not available, development in fisheries landings can provide an indication of the status of a particular stock (ICES 2012). In a more data-rich situation, i.e. for stocks for which a full quantitative stock assessment is conducted, fisheries landings are used directly as input to stock assessment models to evaluate the status of fish stocks. Resulting stock assessment outputs in terms of stock size and fishing mortality are then in turn used as basis for fisheries management advice. Fisheries landings thereby provide central information for fisheries management cycle.

Fisheries management measures are generally directed towards commercial fisheries. In addition to commercial fisheries, in some cases a substantial part of total landings of a fish stocks are taken by recreational fishermen. In the context of evaluating the status of a fish stock and conducting stock assessments for management purposes, it is important to take into account also the catch by recreational fisheries. This is in order to get reliable estimates of stock dynamics, where all removals from the stock should be accounted for. Also, in cases where landings by recreational fisheries are substantial, these need to be taken into account in fisheries management, including addressing issues such as resource allocation between commercial and recreational fishermen (Strehlow et al. 2012).

8.1.2.2 Fisheries landings in numbers

For most species, fisheries landings are recorded in mass and fisheries management regulations providing catch options are also operating with weight units. An exception in the Baltic Sea is salmon, where the allowable catch and catch statistics are provided in numbers of individuals.

However, for stocks with an analytical assessment, landings in numbers are needed as input to stock assessments to evaluate the status of the stocks. The estimation procedures in quantitative age- or length-based stock assessment models are operating with numbers of individuals, rather than with mass. Therefore, landings in weight need to be converted to landings in numbers, using samples of length/age structure and mean body weight of the fish. Stock assessments provide estimates of stock size in numbers of individuals and fishing mortalities that are calculated based on numbers of fish in different year-classes. The numbers of individuals in the stock are then translated into biomass that is used as an indicator for stock size. However, the underlying calculations, including the catch options provided for fisheries management advice are based on numbers of individuals. Landings in numbers are therefore essential information for stock assessment and fisheries management advice, for stocks for which full analytical assessments are conducted. For stocks with no analytical assessment, biological information for landings (i.e. length/age structure and mean body weight of fish) that are the basis for deriving landings in numbers, still provide important information in the context of fisheries management.

8.1.2.3 Fish discards in mass and in numbers

Discards are fisheries catch that is not retained on board of commercial fishing vessel but is returned to the sea. The fish which are discarded represent an unwanted part of the catch, consisting of unmarketable species, individuals which are below minimum landing size, fish that has a lower marketable value than the target species or size or belong to species which fishermen are not allowed to land, for instance due to quota restrictions.

In the Baltic Sea, among the species that are regulated by catch limits, discards are an issue for cod and plaice. In addition, substantial discards of non-quota regulated flatfish species, such as flounder occur. The discards of salmon in the Baltic Sea are considered very small, and discards of herring and sprat are negligible. In the Baltic Sea the EU discard ban was implemented for sprat, herring, cod and salmon in January 2015 and plaice is intended to be covered from 2017 onwards. Non-quota regulated and bycatch species and fish offal can be still discarded after the introduction of a Landing Obligation.

From a fish stock assessment and fisheries management perspective, it is relevant to consider whether the discarded individuals are likely to survive or will die. Discards representing mortality need to be included in stock assessment to get reliable estimates of stock dynamics and exploitation intensity. Discards in weight contribute to the total amount of removals from the stock taken by fisheries which is taken into account in fisheries management when setting fishing quotas. Discards in numbers of individuals are included in catch input data into analytical stock assessments, similarly to landings in numbers. Information on discards is thereby contributing to reliable assessments of stock status and appropriate management measures.

8.1.2.4 Bycatch of marine mammals and seabirds

The species of marine mammals where incidental bycatch in fishing gear is of concern include harbour porpoises and seals (HELCOM 2015). The bycatch risk is highest in various types of gillnets. For seals, in addition to gillnets, fyke-nets are also of concern (Vanhatalo et al. 2014). Concerning seabirds, fishery bycatch is a high pressure to long-tailed duck, scoters and some other seabird species (HELCOM 2015). Bycatch in gillnet fisheries can in certain places result in high bird mortality, especially in areas with high concentrations of resting, moulting or wintering seabirds (Zydelis et al. 2009, 2013, Bellebaum et al. 2012).

Marine mammals and seabirds are included in several policy documents aiming for their protection. Seabirds are included in EU Bird directive (1979). Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) aims to achieve and maintain a favourable conservation status of small cetaceans. The EU Habitats Directive lists harbour porpoise as a strictly protected species (Annex II, IV), meaning that the species requires strict protection. The three seal species (grey seal, harbour seal and ringed seal) are listed in Annex II, meaning that they are to be protected by the means of the Natura 2000 network (HELCOM 2015).

One of the ecological objectives in the Baltic Sea Action Plan (BSAP) is 'Viable populations of species', which includes a target that the by-catch of harbour porpoises, seals and seabirds should be significantly reduced with the aim to reach bycatch rates close to zero. Bycatch of marine mammals and seabirds is one of the core indicators in HELCOM in the context of measuring Good Environmental Status (HELCOM 2015).

Potential measures to reduce bycatch include avoiding use of specific fishing gears with high bycatch rates (Bellebaum et al. 2012); specific design and modifications to fishing gear (Dagys et al. 2009) or spatio-temporal fishing restrictions in areas and seasons with high bycatch rates. To evaluate the status of bycatch and design appropriate management measures including measuring the progress towards the goal of minimizing bycatch requires consistent and reliable data on the amount of bycatch.

Table 8.1. Data requirements for Fisheries Management

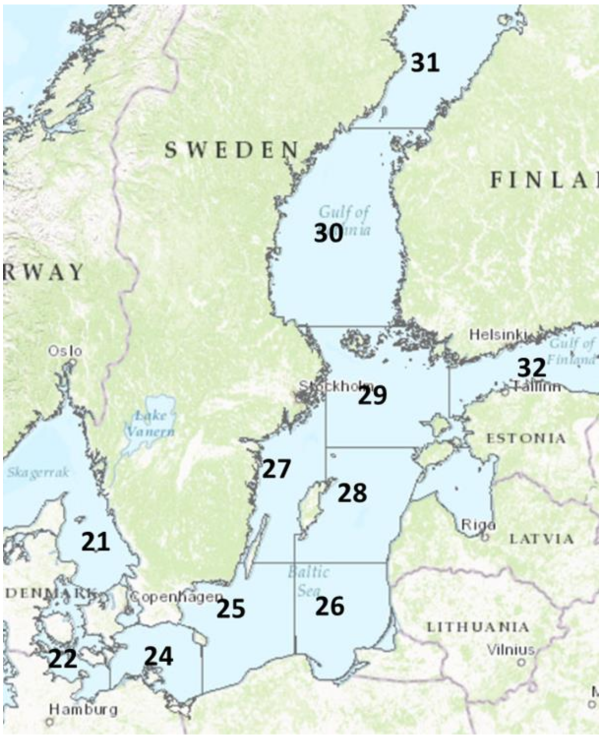
Variable	Data type	Accessibility		Completeness/ coverage		Resolution		Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Temp.	
Mass of landings of fish species	Official statistics	Delayed/ open	Months	Management area of a stock	Min. 5-10 years, preferably longer	Min. management area of a stock	Min. annual	tons
Landings of fish species in numbers	Official statistics combined with monitoring	Delayed/ open/on request	Months	Management area of a stock	Min. 5-10 years, preferably longer	Min. management area of a stock	Min. annual	Numbers (thousands)
Mass of discards of fish species	Monitoring	Delayed/ open/on request	Months	Management area of a stock	Min. a year, preferably longer	Min. management area of a stock	Min. annual	tons
Numbers of discards of fish species	Monitoring	Delayed/ open/on request	Months	Management area of a stock	Min. a year, preferably longer	Min. management area of a stock	Min. annual	Numbers (thousands)
Bycatch of marine mammals	Monitoring	Delayed/ on request	A year	Population distribution area	Min. a year	Min. distribution area of the population	Seasonal	numbers
Bycatch of seabirds	Monitoring	Delayed/ on request	A year	Population distribution area	Min. a year	Min. distribution area of the population	Seasonal	numbers

8.1.3 Spatiotemporal requirements

8.1.3.1 Spatial coverage and resolution

The Baltic Sea is divided in several Subdivisions (see Fig. 8.1), which are used to define fish stock assessment and management units. For quota-species, TACs are set by these management areas, which definitions differ by species. For example, cod is managed in three units, i.e. eastern and western Baltic cod and cod in the Kattegat, that correspond to ICES Subdivisions 25-32; 22-24 and 21, respectively. Sprat is managed as one unit in the Baltic Sea (SD 22-32) and the sprat found in Kattegat is managed together with sprat in Skagerrak. Herring is managed by five different units, i.e. central Baltic Sea (SDs 25-29), Gulf of Riga, Bothnian Bay, Bothnian Sea and western Baltic herring including Kattegat and Skagerrak. In some cases there is a discrepancy between the fisheries management unit for which TACs are set and the distribution area of a biological stock which status is assessed in ICES providing a basis for scientific advice on TAC. This is for example the case for cod, where both eastern and western stock are fished in SD 24, which belongs to the management area of western Baltic cod (ICES 2016). For plaice, management is conducted by the areas of SD 22-32 and SD 21, in contrast to biological stock units that cover SD 21-23 and 24-32.

The spatial units used for fisheries management or fish stock assessment define the spatial units and the most coarse spatial resolution for which fisheries landings and discard data should, as a minimum, be available, to be useful for fisheries management purposes. Data on a finer spatial resolution (e.g. by ICES rectangles) are not required for setting total annual catch limits. However, data on finer spatial resolution are relevant for other management measures, such as defining closed areas, or evaluating fishing impacts at local scales (see Fishing Impact challenge). Landings and discards are supposed to represent total removals from the stock or from a given management unit, thus all landings and discards taken in a given area should be recorded to get reliable estimates of total catch for fisheries management purposes.



The bycatch of marine mammals and seabirds is evaluated in HELCOM using HELCOM assessment scale 2 which consists of 17 Baltic Sea sub-basins. On the one hand the situation of bycatch needs to be assessed on a scale that allows for identification of problem areas where actions should be taken (e.g. within the MSFD framework), but on the other hand take into account the high mobility of marine mammals and seabirds, and the distributional range of these populations (HELCOM 2015). For example, in the case of the harbour porpoise, two management units exist: i) the population of the Western Baltic, Belt Seas and Kattegat and i) the Baltic Proper population. However, to be able to relate bycatch to both fishing effort and abundance of mammals and birds, monitoring of occurrence of bycatch and related fishing effort need to be carried out on a fine spatial scale (HELCOM 2015).

Figure 8.1. ICES Subdivisions in the Baltic Sea used to define fisheries management areas.

8.1.3.2 Temporal coverage and resolution

Fisheries management usually operates on an annual basis. Thus, yearly data on different catch components (landings and discards) are required to update evaluations of fish stock status and provide catch opportunities for a coming year. A higher temporal resolution of catch data (quarterly, monthly) would be necessary in the context of other management measures, such as seasonal closures, for example to evaluate their effects on fisheries. Similarly, monitoring of bycaught marine mammals and seabirds should enable the estimation of annual (or seasonal if relevant) mortality from specific fisheries to be compared to the population dynamics of the respective species (HELCOM 2015).

To evaluate long-term changes in fisheries catch and bycatch, as long as possible time series of data are advantageous. In fish stocks for which quantitative stock assessments are conducted where fisheries landings and discards are essential input data, the time series should roughly not be less that ten years long to be able to conduct a stock assessment, preferably longer. However, in order to understand the relative importance of different drivers on fish stock dynamics, longer time series would be required to possibly cover a variety of driver combinations and intensities. For example for Baltic cod, analyses of long time series of fisheries catch statistics, combined with biological data to derive catch in numbers as input to extended stock assessment, revealed the responses of cod to fishing as well as to human-induced trophic changes and climate (Eero et al. 2011). Understanding the drivers of fish population dynamics is of major importance for making appropriate management decisions, both in single-species and in an ecosystem context. Long time series of fisheries data are a prerequisite to facilitate process understanding of fish dynamics.

8.2 Data adequacy assessment

This section assesses the data availability and adequacy per key variable under fisheries management challenge. The results are summarized in Tabs. 8.2 and 8.3.

8.2.1 Landings in mass

For most fish species, major part of fisheries removals are taken by commercial fisheries, and fisheries management measures are usually only regulating the commercial part of the fisheries. Therefore, this report is mainly focusing on the adequacy of commercial fisheries data. Additionally, for some stocks, a substantial part of fisheries catch can be taken by recreational fishermen, and recreational catches, being part of removals from the stock, affect fish stock status and thereby fisheries management. Therefore, the adequacy of recreational catch data is briefly addressed as well.

8.2.1.1 Commercial landings

For fisheries landings in the Baltic Sea, long annual time series are available. ICES (International Council for Exploration of the Sea) has been gathering and publishing fisheries landings statistics since 1904. 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. This information is on a national basis provided from logbooks (in the Baltic vessels above 8 meters, and 10 meters in Kattegat) and sale statistics.

The geographical breakdown of landings is according to the ICES system of subareas, divisions and subdivisions. However, the spatial units by which the data are provided may have changed over time for some species. The landings of both internationally and nationally regulated fish species are included in the database. ICES Catch Statistics dataset is updated every year.

The resolution of landings statistics by year and by stock units and/or management area (see Fig. 8.1) is usually sufficient for fisheries management purposes in terms of setting fishing quotas. Additionally, a finer resolution data are available, gathered by the Expert Working Group on Fisheries Dependent Information in EU STECF (e.g. STECF 2015) to address specific management questions that may require a finer spatial and temporal resolution of landings data. The use of fisheries data, including data on fishing effort, at a finer resolution is addressed in further details under Fishing Impact Challenge.

Fisheries landings statistics is supposed to record the total amount of fish landed of a given species. This is different from many other variables for a marine system that are measured via sampling programs. Thus, issues related to sampling design and respective errors do not apply for landings statistics. Another difference between sampling programs and landing statistics is that landings statistics is census information, at least in theory, indicating that all vessels within a given length group are reporting all their landings. However, an important source of error that may occur in fisheries landings statistics is related to misreporting. This can for example be non-reporting of landings of a certain species, or incorrect reporting of the area where the amount of landings have been taken. Incentives for misreporting may rise in-situ stations where quotas are restrictive, and fishermen could catch more than allowed by management regulations. Data presented in the official landings statistics have not been corrected for non-reported landings, where these may have occurred. In such cases the official landings statistics may differ from the data used for stock assessment purposes in ICES where some corrections to landings may have been applied. Quantifying the amount of misreporting is usually very difficult. In the Baltic Sea, non-reporting of landings has historically been an issue for eastern Baltic cod (ICES 2016a; e.g. Fig. 8.2), and is reported to occur also for salmon (ICES 2016b). The ICES estimates of unallocated landings are generally based on anecdotal and expert information, and are therefore relatively uncertain providing only a rough estimate. Some investigations suggest that misreporting of pelagic species in the Baltic Sea has potentially occurred as well (Hentati-Sundberg et al. 2014).

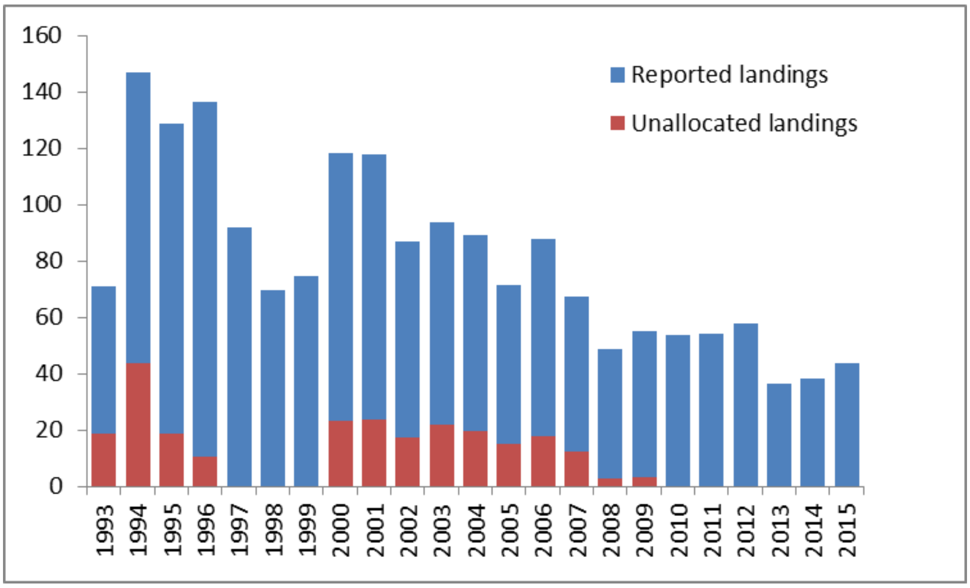


Figure 8.2. Comparison of reported and unallocated landings of eastern Baltic cod (ICES 2016a).

8.2.1.2 Recreational landings

For some species, a significant part of total catch is taken by recreational fisheries, for example western Baltic cod (Strehlow *et al*., 2012; Eero et al. 2015) and salmon (ICES 2016b). There is presently no official statistics for the total number of recreational fishers or their catches in the Baltic and therefore this information needs to be collected via recreational fishing surveys. Recreational data collection is associated with a number of challenges: (i) lack of central registration of recreational fishers, (ii) non-documentation of recreational catches (no sales slips due to prohibition of marketing catches), and (iii) recreational fishers fish in remote and hard to access areas (iv) many people can be involved in recreational fisheries with a low number of fish caught per person. As a result, recreational fishing surveys are complex and difficult to conduct. Many national surveys are still incomplete or lacking completely (ICES, 2015a). Further challenges arise from the inconsistency of data over time and an unclear understanding of catch, which includes harvested and released components. The ICES Working Group on Recreational Fisheries Surveys (WGRFS) role is to summarise and quality assure recreational fishery data collected under the EU Data Collection Framework (DCF-EC 199/2008 and 2010/93/EU) and control regulations (EC 1224/2009).

For western Baltic cod, German recreational catches are currently included in stock assessment. Additionally, the quality of Danish and Swedish national recreational catch sampling schemes are being evaluated by WGRFS (ICES 2015a), though these data are not yet ready for being used in stock assessment context. Recreational catch estimates of salmon in freshwater and marine habitats have been included in the assessment for many years. However, catch estimates of the recreational salmon fishery are uncertain, incomplete or missing for several Member States. Recreational catches of Baltic trout are known with little accuracy and are considered underestimated (ICES, 2016b).

8.2.2 Landings in numbers

Apart from the few fish stocks where landings statistics is directly recorded in numbers of individuals (salmon), deriving information on landings in numbers requires biological samples of landings. In order to translate the landings in mass into numbers requires information on the size/age structure of landings and corresponding mean weights. ICES has established a range of expert groups whose primary role is to coordinate and promote the collection of high-quality data based on sound scientific and statistical procedures (e.g. ICES 2013a). During 2002, the ICES Planning Group on Commercial Catches, Discards and Biological Sampling (PGCCDBS) was established to provide support for the EU Data Collection Framework (DCF), focusing specifically on quality assurance of fishery sampling data and biological parameter estimates. Additionally, Regional Coordination Meetings (RCM) take place, also in the Baltic region, whose main purpose is to coordinate the data collection carried out by EU Members States (MS) in the region concerned. Fisheries data collection is moving towards a statistically sound sampling design to improve the quality of the samples (in terms of bias and precision)

The most important elements of design-based sampling are documentation of design, implementation, a random drawlist, relevant stratification, recording of refusal rate, methods to handle data gaps etc. Statistically sound sampling programmes (Design-based sampling) in the Baltic Sea region have at present time been (partly) implemented by Denmark, Sweden and Germany. Poland, Lithuania and Estonia have made some preparatory steps to implement the design-based sampling in the near future. Latvia and Finland, due to the characteristic of their fisheries, do not consider changes to their current sampling designs (RCM Baltic 2015).

For internationally regulated stocks for which analytical stock assessments are conducted, such as cod, herring, sprat, flatfishes, total landings in numbers are compiled and available from ICES reports and Intercatch database. For nationally managed species (mostly coastal fish, e.g. perch, pikeperch, pike), the data sampled under DCF on size/age structure and mean weight of landings, that are needed to derive landings in numbers, are stored in Regional Database FishFrame, which is hosted and maintained by ICES.

8.2.3 Discards in mass and in numbers

Under the Data Collection Framework (DCF) (CR No. 199/2008, CD 2010/93/EU) national on-board observer programmes were designed to estimate the catch of commercial marine fisheries, including the amounts discarded at-sea. For most countries in the Baltic region, discard estimates are obtained from scientific observers sampling catches on commercial vessels. Since 2015 it has also been mandatory to report the amount of discards in the logbooks, however as the value obtained from the scientific observers and the logbook estimate are not similar, it is the information from the scientific observers that are used in stock assessments. Also the biological information on discards (size structure, mean weight of the fish etc.) is based on data collected by scientific observers on board commercial fishing vessels. These estimates are included in many fish stock assessments, so that the contribution of discards to the fishing mortality is taken into account in management measures. The discard sampling programs and the quality of data has been addressed by several expert groups in ICES, such as a Study Group on Practical Implementation of Discard Sampling Plans (SGPIDS) (ICES 2013b).

In the Baltic Sea, discards are mainly an issue for cod and flatfishes. The quality of discards estimates for cod are considered sufficient from 1996 onwards, and these data are included in stock assessments. For plaice, discard estimates with sufficient quality to be included in stock assessments are available from 2002 onwards. For flounder, the quality of discard estimates has been questioned until recently (ICES, 2014). The main problem was very high discards, which exceed the landings or sometimes are even 100% of the catch, and high variability in the discard ratio between countries, gear types, and quarters. As discarding practices of flounder are controlled by factors such as market price and cod catches. Since 2014, discards have been estimated by a new method which raises discard rate by all demersal fish landings. In cases when there is no discard rate available for a stratum, it is borrowed from other strata, considering differences in discard patterns between subdivisions, countries, gear types and quarters. Consequently, the quality of discard estimates is considered improved and discard estimates for 2015 were used in ICES advice (2016, Book 8).

Discards are generally considered more uncertain catch component compared to landings, as the discards are based on samples. Thus, for stocks where discards are low (e.g. western Baltic cod), uncertainties in discards are less of an issue for fisheries management, compared to stocks with high amounts of discards, such as Kattegat cod, where discards are estimated to exceed landings (Fig. 8.3). Further, discard estimates for species under the new landing obligation may become more uncertain. There is an incentive for the fishermen to discard the unwanted catch of a trip as landing of lower-value unwanted catch is discounted from the quota of the vessel. As a consequence, the level of refusal of observers by the skippers may be high (e.g. for cod in 2015, ICES 2016a) and even if an observer is onboard, the sampled fishing trip may be biased due to changed behavior compared to trips with no observer onboard (RCM Baltic 2015).

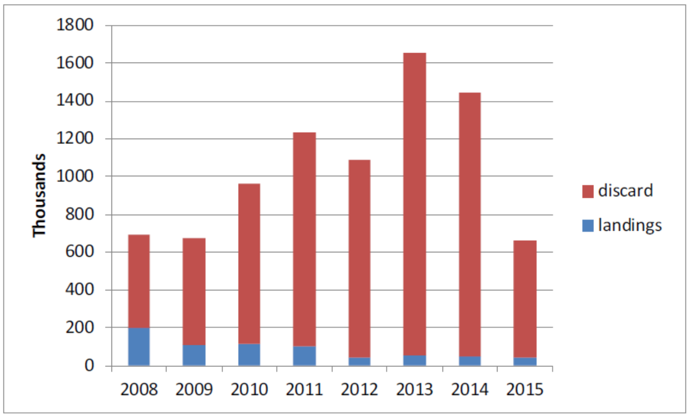


Figure 8.3. Estimates of discards (Denmark and Sweden combined) for Kattegat cod compared to reported landings (ICES 2016a).

8.2.4 Bycatch of marine mammals and seabirds

The number of drowned marine mammals and seabirds in fishing gear is a core indicator in HELCOM to measure whether the mortality due to bycatch is within limits that enable reaching Good Environmental Status (GES). A detailed evaluation of the availability and adequacy of bycatch data is therefore provided in HELCOM (2015). In general, no regular monitoring data on numbers of drowned seabirds and mammals exist. Therefore only limited data from scientific and pilot studies are available so far.

Until 2017 it has not been mandatory in the national discard/bycatch monitoring programmes carried out under the EU data collection framework (DCF) to sample marine mammal and bird bycatches. EU Regulation 812/2004 (European Commission 2004) obliges Member States to monitor cetacean bycatch in gillnets. However, mainly larger vessels are covered by the observer programme and the majority of Baltic gillnet fisheries is carried out by small vessels, where the risk of bycatch for mammals and birds can be high (ICES 2013c). ICES collates information on bycatch under the Working Group on Bycatch of Protected Species (WGBYC), which 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. Information on bycatch on other species, such as seals and seabirds is sporadic and scares.

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. 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 2015b).

It has been estimated that a minimum of 300 grey seals, 80 ringed seals and 7–8 harbor seals annually drown as bycatch in the Baltic Sea (Korpinen & Bräger 2013). A later study suggests that around 2180-2380 individual seals were bycaught in 2012, probably representing at least 90% of the total bycatch in the whole Baltic Sea (Vanhatalo et al. 2014). ICES report from WGBYC expert group (ICES 2015b) includes some estimates on harbor purpose bycatch. A rough estimate on seabirds suggests that 100,000-200,000 seabirds drowning annually in the North and Baltic Seas, of which the great majority refers to the Baltic Sea (Žydelis et al. 2009, 2013, Bellebaum et al. 2012). Locally, bycatch rates have decreased during the last two decades, likely as a result of declined abundance of wintering seabirds (Bellebaum et al. 2012).

Lack of regular consistent monitoring data on bycatch prevents proper assessment of the trends in the bycatch rates, and also evaluating the level of mortality due to bycatch in relation to the target of reaching Good Environmental Status (GES) for marine mammals and seabirds (HELCOM 2015).

8.3 Conclusions and remarks

The data on fisheries landings in mass is recorded as official fisheries statistics; the data are generally available and adequate, issues related to misreporting may occasionally occur.

Landings in numbers are derived by combining official fisheries statistics with regular monitoring data on fisheries catch that records size structure of the catch of a species and mean weight of the fishes. The data are needed for stocks for which analytical stock assessments are conducted and the data are considered adequate when used in stock assessment; monitoring programs are subject to continuous improvements.

Information on discards is collected via observer programs. Discards are generally considered more uncertain catch component compared to landings. The data are considered of acceptable quality when used in stock assessments, for some fish stocks a time series of discards of acceptable quality are available, for others, data are considered adequate for only latest years.

There is no regular monitoring on bycatch, only sporadic data from scientific and pilot studies exist.

Table 8.2. Data availability for Fisheries Management

Variable	Data type	Accessibility	Completeness/ coverage		Resolution		Precision	Data provider
		Delivery type/time	Spatial	Temporal	Hor.	Temp.		
Mass of landings of fish species	Official statistics	Open, delayed in months	Management area of a stock	>10 years	Management area of a stock (partly SD, ICES square)	Annual (partly quarterly)	Tons	National statistical officials; EUROSTAT; ICES
Landings of fish species in numbers	Official statistics + monitoring	Open/on request, delayed in months		>10 years, where available	Management area of a stock (partly by SD)	Annual (partly quarterly)	Numbers (thousands)	National fisheries labs; ICES; STECF
Mass of discards of fish species	Monitoring			Varies by species	Management area of a stock		Tons	
Numbers of discards of fish species	Monitoring			Varies by species	Management area of a stock		Numbers (thousands)	
Bycatch of marine mammals	Monitoring	Open/on request, irregularly updated	sporadic	Sporadic	sporadic	sporadic		National labs; compiled in ICES, HELCOM
Bycatch of seabirds	Monitoring		sporadic	Sporadic	sporadic	sporadic		

Table 8.3. Data adequacy for Fisheries Management

Variable	Data type	Accessibility		Completeness/ coverage		Resolution		Precision	Data provider
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Temp.		
Mass of landings of fish species	Official statistics	Adequate; webpages		Generally adequate		FFU*	FFU	Generally adequate, issues with misreporting may occur for some stocks	National statistical officials; EUROSTAT; ICES
Landings of fish species in numbers	Official statistics combined with monitoring	Adequate, where available; ICES reports		Adequate for stocks where relevant/available and used for stock assessment;		FFU	FFU	Adequate for stocks where relevant/available and used for stock assessment;	National fisheries labs; ICES; STECF
Mass of discards of fish species	Monitoring	Adequate, where available; ICES reports		Adequate for stocks where relevant/available and used for stock assessment;		FFU	FFU	Adequate for stocks where relevant/available and used for stock assessment;	National fisheries labs; ICES; STECF
Numbers of discards of fish species	Monitoring	Adequate, where available; ICES reports		Adequate for stocks where relevant/available and used for stock assessment;		FFU	FFU	Adequate for stocks where relevant/available and used for stock assessment;	National fisheries labs; ICES; STECF
Bycatch of marine mammals	Monitoring	Limited availability; Access via ICES reports , scientific literature		Sporadic		Sporadic	sporadic	N/A	National labs; compiled in ICES, HELCOM
Bycatch of seabirds	Monitoring	Limited availability; Access via ICES reports , scientific literature		Sporadic		sporadic	sporadic	N/A	National labs; compiled in ICES, HELCOM

*FFU – Fit for the use

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9 Data adequacy for fishery impact

Recent developments in EU fisheries policy have seen a move towards an Ecosystem Approach to Fisheries Management, and a need to consider and better understand the dynamics of fishery impact. Aside from the animals caught in nets (target species and bycatch), one of the main impacts to marine ecosystems occurs in the form of physical disturbance to the seabed. Fishery types which come into contact with seabed (benthic) systems include beam trawls, demersal seines, dredges, and otter trawls. Other forms of demersal fishing gear used include gill and fyke nets, and traps (such as pots and creels), however, these impacts are considered to be minimal and not considered in the following analysis.

Fishing pressure can impact benthic ecosystems in a number of ways. To estimate the scale of this disturbance, the following aspects are typically considered; i) the spatial extent of fishing activity ii) the fishing intensity – the frequency of fishing in a given area iii) gear type – this may affect the depth of seabed penetration or impact iv) the sensitivity of the habitat to fishing pressure - e.g. a biogenic habitat vs mobile sediments, and v) environmental variables – such as depth and bottom salinity.

To assess the impact of fishing activity at regional scales, and to meet the requirements of the Marine Strategy Framework Directive (MSFD), member states are in the process of developing various indicators relating to biodiversity and seabed integrity. Initiatives such as BENTHIS (http://www.benthis.eu/en/benthis.htm) have developed state of the art methods for estimating fishing pressure on seafloor components to help meet these needs. The products form this project will represent a benchmark for this Challenge. Data sources required to estimate fishery impact are the focus of this Challenge, and the following document outlines currently available open source data, in terms of its accessibility, coverage and usability.

9.1 Data requirement assessment

The aim of the Challenge is to examine a number of key variables relating to fishery impact in the Baltic Sea. This will include an assessment of the availability, adequacy, and completeness of data sources for these variables, and the identification of adequacy for establishing time series data and GIS based data layers. These key variables are listed in Table 9.1. The objective of the Challenge is to estimate the extent of fishery impact to the sea floor in terms of:

- The area disturbed by bottom trawling (number of disturbances per month);
- Changes in level of disturbance (over the past ten years)
- Damage to the sea floor (to both living and non-living components).

Table 9.1. Data usage in Fishery Impact

Variable	Data type	Usage
Bottom water salinity	In-situ	Model/RS validation
	Model	Estimate salinity associated with habitats
EUNIS habitats ≥ level 4	Blended	Estimate the distribution and type of seabed habitat
Habitat Directive benthic species and habitat	In-situ	Provide information on endangered and vulnerable species in the Baltic Sea
Bathymetry	Blended	Estimate the depth of habitats in the Baltic Sea
Substrate	Blended	Estimate the substrate composition of habitats
Near bed light intensity	Blended	Estimate the photic zone within the Baltic Sea
Baltic Marine Landscapes	Blended	Estimate the substrate types, photic zone and salinity within the Baltic Sea
EUNIS habitats ≤ level 3	Blended	Estimate the distribution and type of seabed habitat
VMS for vessels ≥15 m (2005-2011)	Monitoring	Estimate the spatial and temporal distribution of fishing vessels >15m in the Baltic Sea
VMS for vessels ≥12 m (2012-)	Monitoring	Estimate the spatial and temporal distribution of fishing vessels >12m in the Baltic Sea
Logbook data for vessels ≥8 m	Monitoring	Couple with VMS data to estimate fishing activity and gear type for vessels ≥ 12 (and ≥15) meters. For vessels up to 12 meters the fishing activity and gear type can only be analysed at the scale of ICES rectangle
National sales slip data of landings for vessels <8 m	Monitoring	For vessels less than 8 meters fishing activity and gear information is only accessible from national sales slips at the ICES area scale

In order to meet the Challenge objectives, related data will need to be openly available and provided at spatial and temporal resolutions compatible with the objectives. Table 9.2 provides an outline of the data requirements needed to meet the objectives of the Challenge.

9.2 Data adequacy assessment

9.2.1 Data availability

The availability of data related to the Challenge is summarised in Table 9.3. The following sections outline these sources and the adequacy of data. The key variables have been grouped and described under environmental data, habitat data, and fisheries data for. Where relevant, recommendations are provided in terms of future monitoring.

Table 9.2. Data requirements for Fishing Impact

Variable	Accessibility		Completeness/ coverage		Resolution			Precision
	Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
Bottom water salinity (in-situ)	Open, free access, delivered within months		Baltic Sea	No specific requirement	Selected sites	N/A	Daily/weekly /monthly	Unspecified
Bottom water salinity (model)				Approx. 10y	Approx. 1 km x 1 km	N/A	Daily/weekly /monthly	
EUNIS habitats level ¾	Open, free access	Updated when new data is available		No specific requirement	Approx. 1 km x 1 km	n/a	No specific requirement	Habitat / biotope type
Habitat Directive benthic species and habitat					Approx. 1 km x 1 km	n/a		Annex 1 habitat type / species
Bathymetry					Approx. 1 km x 1 km	n/a		Meters
Substrate					Approx. 1 km x 1 km	n/a		Sediment type
Near bed light intensity					Approx. 1 km x 1 km	n/a		Photic /non photic or Secchi depth (meters)
Baltic Marine Landscapes					Approx. 1 km x 1 km	n/a		Landscape type
VMS for vessels ≥15 m (2005-2011)		Within months		Min. 10y	1 minute x 1 minute	n/a	Monthly	Hours / sweep area ratio
VMS for vessels ≥12 m (2012-)				Min. 10y	1 minute x 1 minute	n/a	Monthly	Hours / sweep area ratio
Logbook data for vessels ≥8 m				Min. 10y	Min. ICES rectangle	n/a	Monthly	Various
National sales slip data of landings for vessels <8 m				Min. 10y	Min. ICES management area	n/a	Monthly	Tons

Table 9.3. Data availability for Fishery Impact

Variable	**Accessibility**		**Completeness/ coverage**		**Resolution**			**Precision**
	Delivery type	**Deliver y time**	**Spatial**	**Tempora l**	**Hor.**	**Ver.**	**Temp.**	
Bottom water salinity(in-situ)	Open/delayed or NRT CMEMS, ICES, BOOS, and EMODnet		Selected Baltic Sea sites	1960 - present	Selected sites	Varying	hours - months	Variable
Bottom water salinity (model)	Open/Daily CMEMS, BOOS partners		Baltic Sea	1989 – present	2 k.m	Varying	Hourly-daily	0.01
EUNIS habitats level ¾	Open, delayed with Periodical update, EMODnet		Baltic, excludes Kattegat	Update in 2012	0.003 degrees	n/a	n/a	Habitat classification
Habitat Dir. benthic species and habitat	Open, delayed with Periodical update, HELCOM / NORDEN		Baltic Sea	Update in 2009	Varying	n/a	n/a	Not defined
Bathymetry	Open, delayed with Periodical update, BSBD/EMODNET			Publishe d in 2013	500 m	n/a	n/a	Varying
Substrate	Open, delayed with Periodical update, EMODNET			Lasted update 2015	1/25000 0 and 1/1M scale	n/a	n/a	Folk classification
Near bed light intensity (model)	Open, delayed with Periodical update, HELCOM/BALANCE			1980 - 1998	1 km	n/a	n/a	Photic / non photic
Baltic Marine Landscapes	Open, delayed, update in 2007, HELCOM			Publishe d in 2007	200 m x 200 m	n/a	n/a	Habitat type classification
VMS for vessels ≥15 m (2005-2011)	Open, delayed, via data call, Irregular updated. ICES		Baltic – excluding Russia	2009 - 2013	0.05 x 0.05 degree	n/a	Yearly, Quarterly (2013 only)	Hours / swept area ratio
VMS for vessels ≥12 m (2012-)						n/a		Hours / swept area ratio
Logbook data for vessels ≥8 m	Delayed /open / on request access EU-STECF Electronic data annex tables		ICES rectangle	>10 years, where available	30’ x 30’	n/a	Yearly or quarterly	Not defined
National sales slip data of landings for vessels <8 m					ICES manage ment area	n/a	Yearly or quarterly	tons

9.2.2 Environmental data

Bottom salinity

The Baltic Sea is a small and shallow semi-enclosed sea which experiences sharp gradients in salinity, both from west to east, but also vertically within the water column. Average salinity can range from near open ocean conditions in the Kattegat to near freshwater conditions in the Bay of Bothnia (0.5 psu). In what is a predominantly brackish system, bottom water salinity is one of the most important environmental variables that influence benthic species composition and abundance.

Real time and historic data

In-situ measurements of bottom water salinity are collected from various platforms across the Baltic, including fixed oceanographic stations, and data collected from survey and research vessels. The data collected are hosted by a number of providers such as ICES, HELCOM, BOOS, SMHI and EMODnet. The data providers host data from overlapping data sources. Despite the wide coverage and comprehensiveness of temperature data for the Baltic, the coverage of in-situ bottom data water is spatially sparse. There are few fixed sources that provide regular water profile data, and the remaining in-situ bottom salinity data is composed of data collected from research and survey vessels. In terms of the accessibility, the data is open source and can be freely accessed. However, none of the aforementioned providers offer an option to define, or search by, data sets which contain bottom water salinity data.

Modelled data

Models for bottom water salinity in the Baltic include GETM (General Estuarine Transport Model) and the DMI's operational hydrodynamic HBM (HIROMB-BOOS-Model). HBM is a state of the art model covering the North Sea and Baltic region. Open source models based on the HBM are freely available, such as the Baltic Sea Physics Analysis and Forecast accessible through CMEMS (only registration with Copernicus is required). This model product is available for the Baltic only, but provides a 1 nautical mile resolution and 2 m top layer. The model provides a two year hindcast, although a longer forecast can be requested from Copernicus. *Although there is variable coverage of in-situ bottom water salinity data, there is adequate (openly available) modelled data. The CMEMS model provides a suitable spatial and temporal resolution and coverage for the Challenge.*

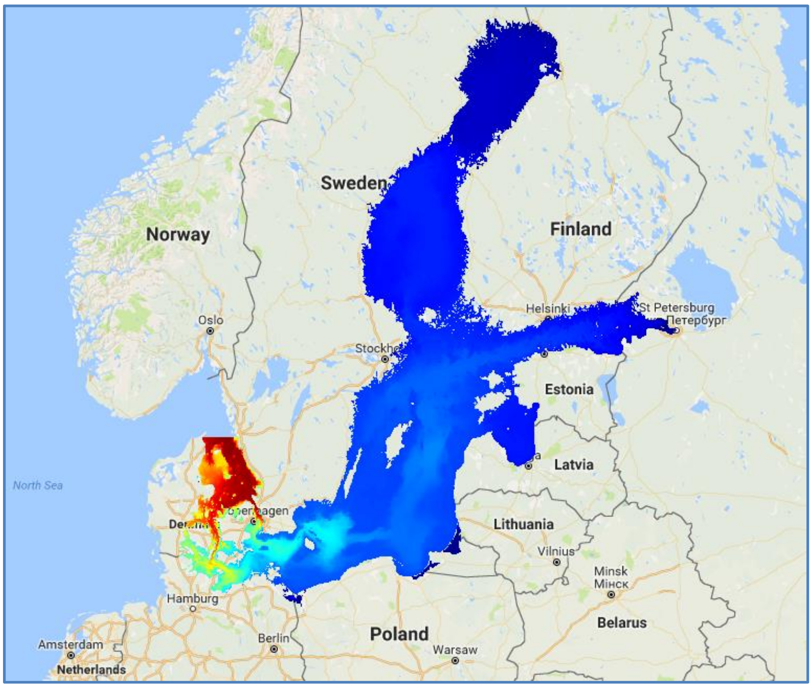


Figure 9.1. Modelled bottom water salinity based on the DMI's HBM circulation model. Image from the EMODnet Baltic Sea Checkpoint Data Portal (http://www.emodnet-baltic.eu/map/)

Bathymetry

Publicly available bathymetry are available from BSHC (The Baltic Sea Hydrographic Commission) and EMODnet. The BSHC has produced a Baltic Sea Bathymetry Database (BSBD) based national contribution of gridded bathymetry data from 50m-500m resolution covering their EEZ and territorial waters. In addition, EMODnet Bathymetry hosts its own dedicated mapping portal at http://www.emodnet.eu/bathymetry which provides Baltic wide bathymetry data at 500m resolution. This portal provides a single access point to bathymetric products, Digital Terrain Models and survey data sets, and composite DTM data. Data sources and background information relating to Bathymetry for the Baltic Sea are discussed in more detail as part of Challenge 10 (Bathymetry). *The bathymetry data provided by the EMODnet Bathymetry Portal is adequate of the Challenge.*

Near bed light intensity

The delineation of the photic zone is a parameter used in habitat classification, such as those used by EUSeaMap (EUNIS) and EU BALANCE (Baltic marine landscapes) projects. The spatial distribution of the photic zone within the Baltic is provided by the EU BALANCE project ("Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning). The dataset contains information on light availability and is divided into photic and non-photic bottoms (areas where 1% of available light reaches the seabed). The maps have been calculated using Secchi disc transparency data for the Kattegat and Baltic Sea. The measurements of Secchi Depth used to producing this dataset are recognised as being lacking in areas such as the Gulf of Riga and southern Baltic, and the dataset used for modelling was collected in 1980-1998. *Although the spatial and temporal resolution of this data source could be updated and improved, the data is considered adequate for the Challenge.*

Habitat data

Habitat data and maps are used in fishery impact to describe or predict the type of seabed environment which may be impacted by fishing activities. As habitat maps derived from survey data are costly and time consuming to produce, low resolution maps and models are used to create 'predictive' seabed maps. These maps estimate habitat in areas lacking ground truthed data, and are often refined by using water depth, sediment type, photic levels, and salinity data, as well as modelling and statistical analysis. The availability of spatially accurate habitat data is considered to be a primary knowledge need for improving the understanding of seabed impacts from fishing (Kaiser *et al*, 2016). Habitat and species data which are available for the Baltic Sea are summarised below.

EUNIS

The EUNIS habitat classification system is a pan-European scheme for managing species, site, and habitat information, with specific subdivision for marine habitats. The classification was developed originally by the European Environment Agency (EEA), and has continued through schemes such as MESH (Mapping European Marine Habitats) and EUSeaMap, and is designed to provide a 'common language' for seabed habitats. At present, EMODnet Seabed Habitats is responsible for the next stage of EUNIS classification, and is in the process of developing the next stage of the product.

The most recent update of EUNIS habitat mapping for the Baltic Sea was a predictive seabed habitat map produced in 2012. The map is comprised of four pre-processed input datasets: substrate, biological zone, energy and salinity. This product is based on a modified version of the EUNIS 2007-11 classification system, and is displayed using:

- the most detailed energy-based classifications predicted by the model;
- the most detailed salinity-based classifications predicted by the model, and;
- simplified classifications that can be compared to the equivalent maps in the Celtic, North and western Mediterranean Seas.

The production of large scale habitat maps can be problematic, due to the variations of coverage and data quality used in model predictions. The Baltic, in particular, has suffered from some issues regarding coverage and data confidence when compared to adjacent regions. This has been attributed to poor data coverage (e.g. 2012 maps do not include the Kattegat area), limited biological information, and a classification which is not fully compatible with other regions. The latest model is based on cell sizes of 0.003 decimal degrees (or approximately 167m x 333m), and the data is freely available for open use.

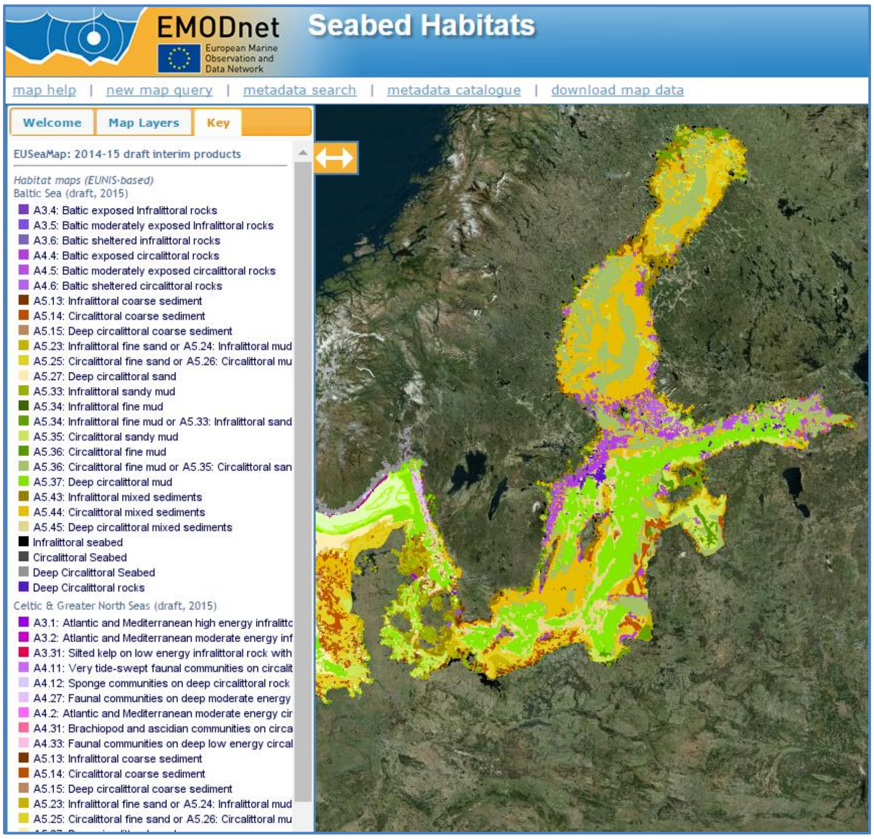


Figure 9.2. EUNIS 2015 draft interim habitat map (final version to be released in September 2016). Image taken from EmodNet Seabed Habitats (http://www.emodnet-seabedhabitats.eu/default.aspx?page=1974)

It is anticipated that the currently available maps will be updated in September 2016. The 2016 maps will be produced to a higher resolution and improved confidence layers available for the dataset (which describes the underlying uncertainty in the model). Additionally, the Kattegat area will also be resolved. The spatial resolution of the updated is expected to be roughly 250m. A draft version of the 2016 layers is currently viewable via EMODnet Seabed Habitats, but it is not available for downloadable. The adequacy of the 2016 update will be assessed after the release in September, but the following improvements are expected:

- The input layers used to create the model will be improved for survey boundary artefacts, sediment classification, overlapping sediment polygons, and previous substrate gaps.
- Enhanced accuracy of threshold values used to determine Baltic biological zones (e.g infralittoral, circalittoral, deep circalittoral).
- Much improved confidence layers for the dataset, which will describe any underlying uncertainty in the model.

Issues with EUNIS habitat mapping for the Baltic region exist due to a lack of suitable data available for model predictions, which therefore impacts confidence in the data layers. Habitat mapping over large geographic regions is likely to be subject to inconsistencies in accuracy, however, the Baltic region has been of lesser quality than adjacent regions. The main issues are expected to be resolved with the latest update of the product, scheduled in September 2016, and this will represent a significant step forward. *Due to the importance accurate habitat information for fishery impact, it is recommended that this aspect is prioritised and improved as much as possible using available data.*

Habitat Directive (designated habitats and species)

The EU Habitat Directive was adopted to ensure the survival of endangered and vulnerable species at a European wide level. Data sources and background information regarding habitats and species covered by the Directive are discussed in more detailed as part of Challenge 2 (Marine Protected Areas). Annex I habitat types which occur within the Baltic region, and which have the potential to overlap fishing activities include:

- 1110 Sandbanks which are slightly covered by seawater all the time
- 1130 Estuaries
- 1140 Mudflats and sand flats not covered by seawater at low tide
- 1150 Coastal lagoons
- 1160 Large shallow inlets and bays
- 1170 Reefs
- 1180 Submarine structures made by leaking gas
- 1610 Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation
- 1620 Boreal Baltic islets and small islands
- 1650 Boreal Baltic narrow inlets

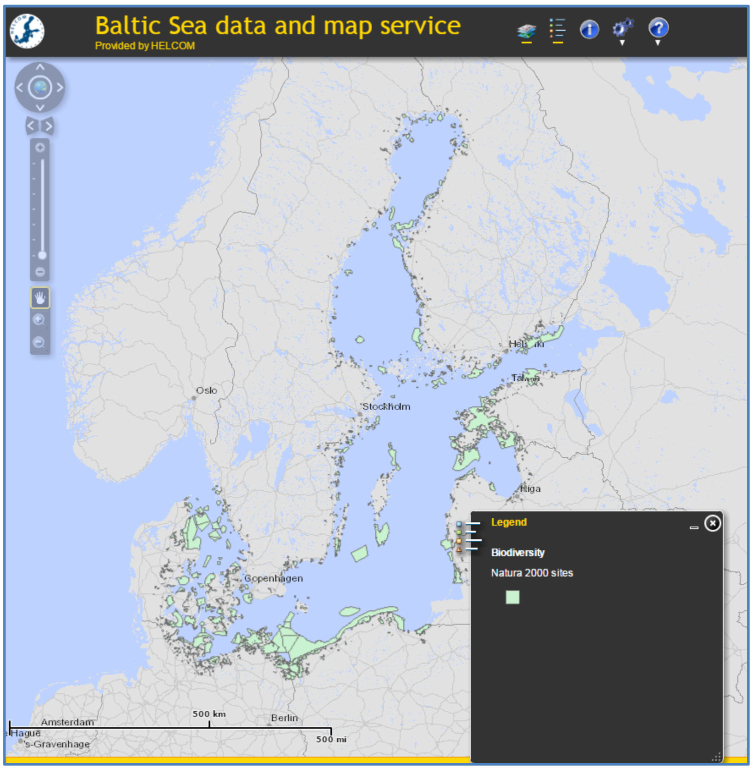


Figure 9.3. Location of Natura 2000 areas in the Baltic Sea. Image from the HELCOM Biodiversity Data and Maps Service **(http://maps.helcom.fi/website/mapservice/index.html)**

The location of Natura 2000 areas (which these features are contained within) in the Baltic can be viewed by HELCOMs Data and Maps Service (Figure 9.3). The European Commission's Natura 2000 viewer also displays the location of these areas, and also provides links to the standard data forms (information on the designating features of Natura 2000 sites). However, it is not possible to search by specific Annex I habitat (such as those listed above) using either portal, as it is understood that not all features have been accurately mapped over all Natura 2000 sites.

In addition to habitat data, a number of species are also protected under the Habitat Directive Annexes II, IV, and V. Habitat Directive species which occur in the Baltic include fish and lampreys species (such as European eel *Anguilla anguilla* and Atlantic Salmon *Salmo salar*), and benthic species (maerl *Lithothamnion* spp. and *Phymatolithon* spp.). The locations of records for these species are provided by the EMODnet Biology portal (for species listed under Annexes II and IV of the Directive). The species data provided by EMODnet Biology portal is somewhat disparate, providing the location of records of designated species occurring in the Baltic. There are few records of benthic species within this database.

As outlined in Figure 9.3, spatial information pertaining to Annex I features are displayed as polygons defining the extent of the Natura 2000 areas. *This data could be improved, from the perspective of fishery impact, by delineating the extent or location of the Annex I habitats, where possible.*

Substrate

Seabed substrate is a significant factor influencing the distribution of benthic species. Hard substrates provide a stable surface for the attachment of benthic species, while soft substrate can be penetrated by borrowing species. Another important property from the point of fishery impact is the sediment grain size.

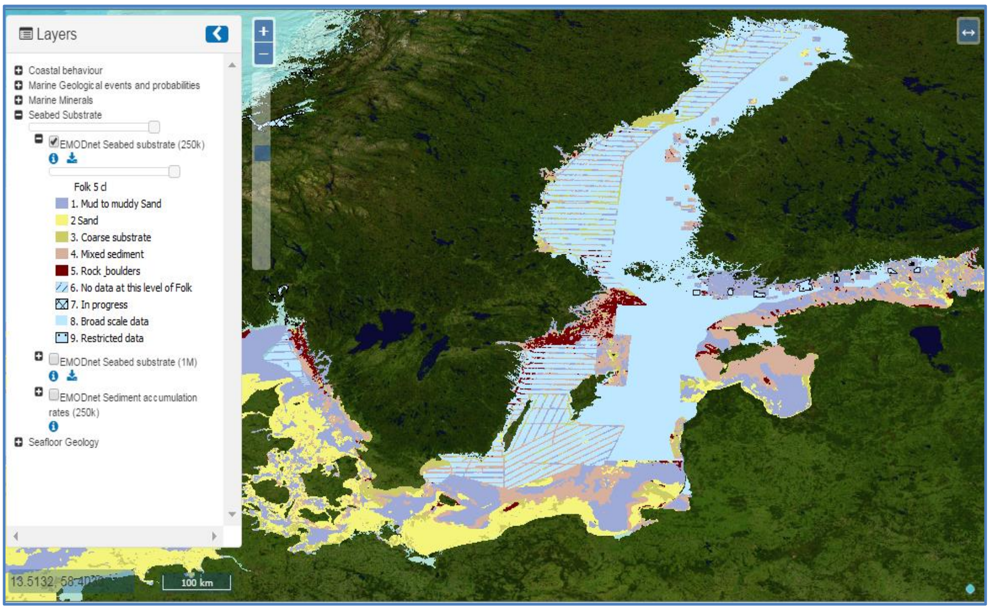


Figure 9.4. EMODnet 1:250,000 seabed substrate map for the Baltic Sea showing gaps in coverage in the eastern Baltic and Gulf of Bothnia. The image is from the EMODnet Geology Portal (**http://www.emodnet-geology.eu/geonetwork/srv/dut/catalog.map**)

The EMODnet Geology portal provides seabed substrate maps at scales of 1:250,000 and 1:1,000,000. The maps are collated and harmonized from seabed substrate information within the EMODnet-Geology project (e.g. the 1M substrate maps are based on ~400 separate seabed substrate maps). Where possible, the existing seabed substrate classifications have been translated to a scheme that is supported by EUNIS. This EMODnet reclassification scheme consists of five seabed substrate classes. Four substrate classes are defined on the basis of the modified Folk triangle (mud to sandy mud; sand; coarse sediment; and mixed sediment) and one additional substrate class (rock and boulders).

The EU BALANCE project provides marine seabed sediment for the Baltic area. The data was compiled from sediment information provided by GUES, GSF, and SGU. The classification scheme consists of five sediment types – bedrock, hard bottom complex, sand, hard clay, and mud. Seabed sediment maps from offshore and coastal areas are available at scales from local (1:20,000) to regional (1:1,000,000). The data is available directly from the Balance website (http://balance-eu.org/), and is also hosted by the HELCOM Maritime Spatial Planning Portal.

The EMODnet 1:250,000 substrate map displays large gaps in substrate coverage in the eastern Baltic (Figure 9.4), although it should be noted that the 1:1,000,000 maps provide coverage for these areas. *It is recommend that gaps in the higher resolution mapping be resolved if possible.*

Baltic Marine Landscapes

The Baltic Marine Landscape dataset was produced by the EU BALANCE project and combines over 60 broad scale habitat types defined according to different combinations of bottom substrate, photic zone and salinity level. The approach to marine landscape mapping is based on the use of physical, chemical and hydrographic data to produce ecologically meaningful maps for areas with little or no biological information. The maps were produced by the Geoloigcal Survey of Denmark and Greenland (GEUS) between 2005 and 2007, and access to the data (and downloads) are provided directly from the EU BALANCE website, and also hosted by HELCOM and their Marine Spatial Planning Portal (Figure 9.5).

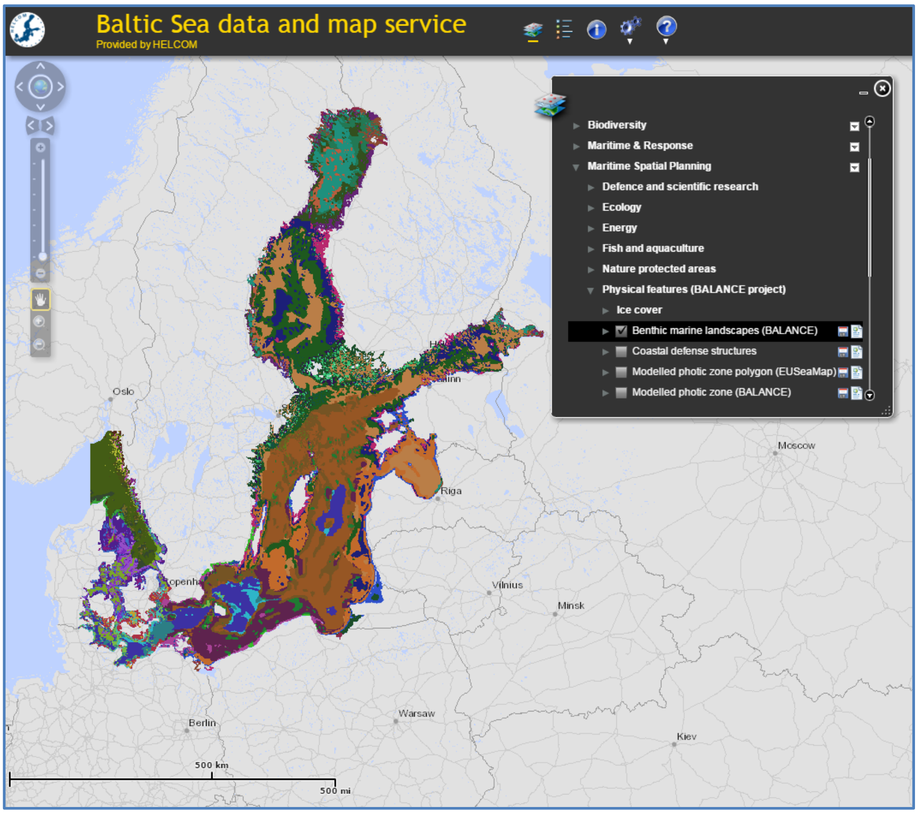


Figure 9.5. Baltic Marine Landscape map produced for the Baltic Sea by the EU Balance Project. The image is taken from the HELCOM Marine Spatial Planning Portal.

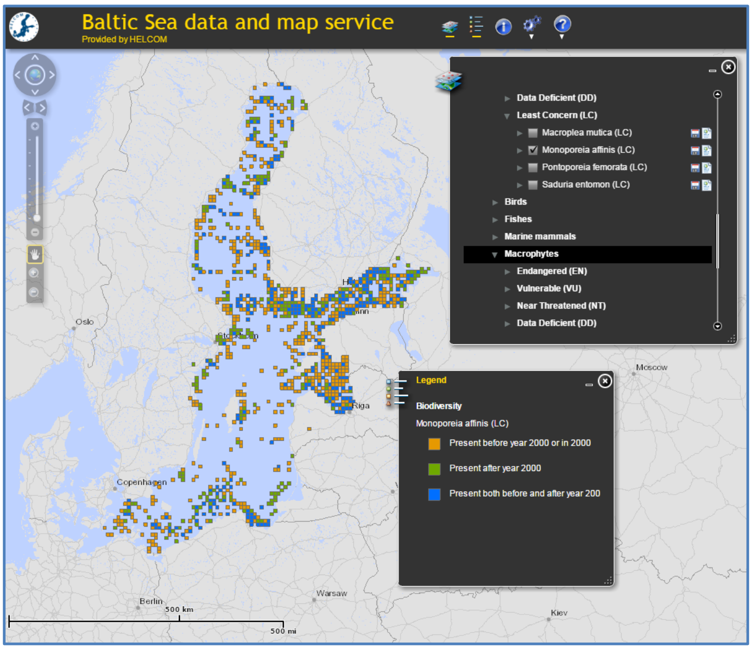
The adequacy of the dataset is somewhat hampered by its limited resolution. The quality of data collated ranges from high to low resolution data, with some modelled datasets at a 7km resolution, while others have ~600m resolution. For the purposes of the Baltic Marine Landscape product, datasets were re-gridded to a 200 × 200m grid to ensure data continuity. *The Baltic Marine Landscape product integrates data relating to sediment type, photic zone and salinity, and is suitable for use in the assessment of fishery impact.*

As outlined above, the coverage and resolution of habitat data over the Baltic is somewhat variable. Habitat classifications such as the EUNIS classification and Baltic Marine Landscapes maps provide suitable coverage, however, there are some considerations when using these classifications in terms of prediction confidence, lack of ecological data, and the large degree of extrapolation made in data poor areas. In addition to this, assessments which are made using spatial information from different sources can be complicated by problems of scale. As habitat and species data is often classified based by the area they occupy, the finer the scale at which these features are mapped, the more likely a smaller area will be described for the presence of habitats/species (IUCN, 2001). In the case of fishery impact, this means that coarse resolution mapping will reveal fewer unoccupied areas – which results in overestimation of fishing impact.

Fishing impact assessments made by BENTHIS (benchmark output) are made at the scale of 1 minute x 1 minute cells. This resolution is considered acceptable for the description of fishing pressure over large geographic areas (such as the North Sea or Baltic), as it is assumed pressure will be uniformly distributed within a grid cell at this resolution (Rijnsdorp *et al*., 1998; Lee *et al*., 2010). However, habitat and species data are not collected uniformly over large geographic areas, and are therefore subject to varying degrees of coverage and uncertainty.

9.2.3 Other sources of habitat and species data for the Baltic (non-key variables)

HELCOM red list



HELCOM provides 'red list' evaluations for Baltic species groups and habitats considered vulnerable to human pressure. This has included evaluations for features relevant to this assessment, such as benthic invertebrates and benthic biotopes (threatened and/or declining underwater biotopes, habitats and biotopes complexes). The evaluations are made using criteria outlines by the IUCN, and products include detailed information sheets, distribution maps, and downloadable layers for each red listed species (HELCOM, 2007) and habitat/biotope (HELCOM, 2005).

Figure 9.6. Spatial distribution of records for Monoporeia affinis for the Baltic Sea. Image from the HELCOM Biodiversity Data and Maps Service **(http://maps.helcom.fi/website/mapservice/index.html)**

A total of 51 benthic species were red listed as part of these assessments. Figure 9.6 provides an example of the Baltic distribution of the widely occurring amphipod *Monoporeia affinis*.

Red listed habitats includes offshore (deep) waters below the halocline, shell gravel bottoms, sea grass beds, macrophyte meadows and beds, gravel bottoms with *Ophelia* species, sandbanks, reefs, bubbling reefs, maerl beds, and sea pens with burrowing megafauna. Out of a total of 209 biotopes assessed in the Baltic, 59 were red listed as being as being currently threatened by anthropogenic activity (including fishing activity). The location and distribution of these features are displayed and downloadable from the HELCOM Biodiversity Portal. However, these are provided in 100 km x 100 km grids where the habitat is known to occur.

The HELCOM red list project provides a useful catalogue of species and habitat vulnerable to fishing pressure in the Baltic Sea. *The reports and information sheets which accompanies the species and habitat data are comprehensive. However, as seen with the 100 km x 100 km grids provided for habitat data, the spatial resolution of habitat/biotope data is too course for use in assessment of fishery impact.*

OSPAR / HELCOM Baltic Sea Action Plan

The OSPAR habitat database, available through the EMODnet Biology portal, provides spatial data for the presence of features such as sea-pen and burrowing megafauna communities, horse mussel *Modiolus modiolus* beds, maerl beds, and *Zostera* beds. However, this data is spatially restricted to the Kattegat area (which overlaps with the OSPAR area), and is therefore not useful for remaining Baltic region. The HELCOM Baltic Sea Action Plan provides spatial information on the presence of species such as eelgrass *Zostera marina* and mussel species *Mytilus trossulus* and *Mytilus edulis* (Figure 9.7).

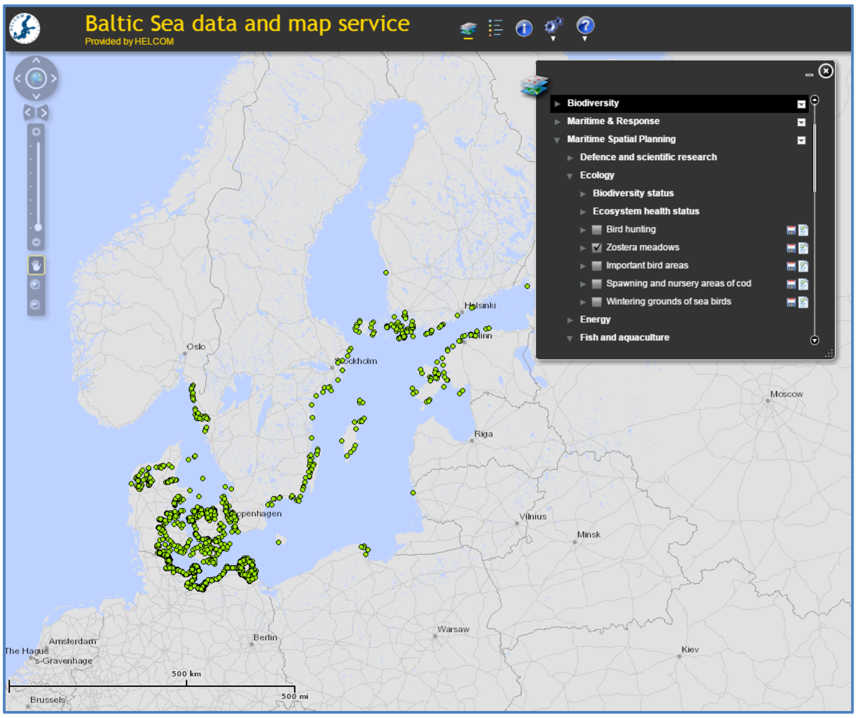


Figure 9.7. Location of eelgrass Zostera marina beds in the Baltic Sea. The species is listed as a HELCOM Baltic Sea Action Plan species. Image from the HELCOM Biodiversity Data and Maps Service (**http://maps.helcom.fi/website/mapservice/index.html**)

EMODnet Biology Portal

The EMODnet biology data portal provides access to temporal and spatial data records of marine species for all European regional seas. The portal provides the platform to search for individual species or records, or for datasets by group (including benthos).

Although records are displayed spatially on an interactive map, it is not possible to search for records within a given geographical area (for example, the Baltic Sea). To search for a species or group within a given area, the full dataset must be downloaded, and then the coordinates of the record checked against that of the preferred area.

Downloadable datasets contain information such as species counts, the year and month collected, geographic coordinates, and a catalogue number. Possibly due to the variety of data sources used to collate the data, unfortunately there are inconsistencies in the information provided (depth records, size (or area) of sample, sample replication, and mesh size used to process the sample), making comparisons between surveys and sources difficult. *It is recognised that the datasets can only display information that has been provided, however, greater consistency in the attribute fields associated with records would represent a significant improvement in the usability of the resource.*

9.2.4 VMS and logbook data

Vessel monitoring systems (VMS) collect data on the location and heading of individual fishing vessels, at predetermined time intervals. The systems were originally adopted and used on fishing vessels as a fisheries surveillance and monitoring tool. In recent years, the data gathered by these systems have been used to quantify fishing pressure/intensity for the purposes of assessing fishery impact.

Typically for vessel operating in the Baltic region, a VMS position is sent every 1-2 hours (depending on national requirements) containing information on the location and heading of the vessel. The data can then be coupled with logbook information, and an indication of fishing activity (and intensity) derived. As this spatially accurate data is linked to individual fishing vessels, this type of data is commercially sensitive, and there are some considerable obstacles in making this data openly available. At present, VMS data is collated and held by the national fishery institutions for each nation. The way that data is collated and made available regionally is via data calls to the national institutions - formally made by institutions such as ICES/HELCOM/OSPAR. The data is then collated from individual nations by ICES, synthesised, and released in the form of 'advice'. The most recent data call in relation to the Baltic Sea region was published in August 2015 (ICES 2015), with a second version published in January 2016. For this release, the data was provided in the following format:

- Total fishing intensity by year (2009 – 2013);
- Fishing intensity by fishing activity (mobile bottom contacting gear, pelagic fisheries etc) by year (2009 – 2013), and;
- Total fishing intensity by quarter (2013 only).

This aggregated VMS data and logbook data is provided in the form of fishing pressure maps (as ESRI shapefiles). This can be presented as hours fishing, or using an indicator such as the swept area ratio (SAR) - the average number of times a unit area is swept per year. These indicators are described in terms of fishing abrasion - surface and subsurface. Surface abrasion is defined as the damage to seabed surface features (top 2 cm), and subsurface abrasion is the penetration and/or disturbance of the substrate below the surface of the seabed (below 2 cms). Data coverage for the Baltic is good, with all nations providing data with the exception of Russia (Figure 9.8).

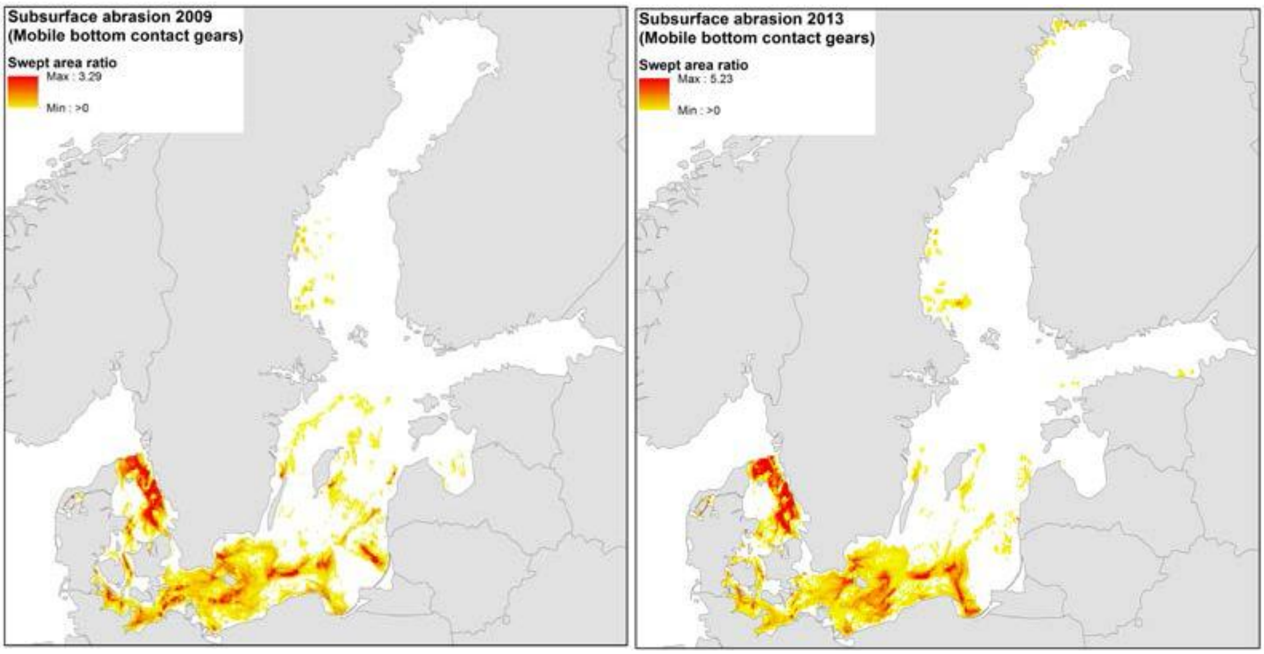


Figure 9.8. Fishing pressure maps (subsurface abrasion) in 2009 and 2013 from vessels using mobile bottom-contacting gear (ICES, 2015)

A summary of data adequacy for the Fishery Impact is provided in Table 9.4.

Table 9.4. Data adequacy for Fishery Impact

Variable	**Accessibility**	**Completeness/ coverage**	**Resolution**	**Precision**
	Delivery type/time	**Spatial/ Temporal**	**Hor./Ver./Temp.**	
Bottom water salinity (in-situ)	FFU*	Spatial coverage is variable across the Baltic	FFU	FFU
Bottom water (model)	FFU	FFU	FFU	FFU
EUNIS habitats level 3/4	FFU	Kattegat area not covered, although this should be rectified in the coming months	FFU	Currently available data not accompanied by confidence layers, although this should be rectified in the coming months
Habitat Directive benthic species and habitat	FFU	Habitat data does not delineate the extent or location of the Annex I habitats.	FFU	FFU
Bathymetry	FFU	FFU	FFU	FFU
Substrate	FFU	The EMODnet 1:250,000 substrate map displays large gaps in substrate coverage in the eastern Baltic	FFU	FFU
Near bed light intensity	FFU	Dataset used for modelling was collected in 1980-1998. Dataset recognised as lacking in some areas such as the Gulf of Riga and southern Baltic	FFU	FFU
Baltic Marine Landscapes	FFU	Some modelled datasets used to produce the landscapes are of a coarse resolution.	FFU	FFU
VMS for vessels ≥15 m (2005-2011)	Only available through data calls / ICES advise	Limited to 2009-2013.	Data only available as total for each year (2009 – 2013), except 2013 (provided quarterly)	FFU
VMS for vessels ≥12 m (2012-)				FFU
Logbook data for vessels ≥8 m	Adequate for coupling with VMS data	Adequate for coupling with VMS data	Adequate for coupling with VMS data	Adequate for coupling with VMS data
National sales slip data of landings for vessels <8 m	FFU	FFU	FFU	FFU

*FFU – Fit-for-the-use

Due to sensitive nature of the data, aggregated VMS data (release via data calls) are spatially and temporally restricted. Spatially, the data is currently provided at a grid size of 0.05 x 0.05 degree squares (or roughly 10 km x 5km in the Baltic). This level of resolution has been adopted as it has been deemed acceptable by member states in terms of confidentiality. Some initiatives, such as the BENTHIS programme, have managed to collate raw VMS data from nations at finer scales for certain years, and have produced outputs at the scale of 1 minute x 1 minute. This grid cell size was selected based on studies which show that bottom trawling can be considered to be uniformly distributed within a grid cell at this resolution (Rijnsdorp *et al*., 1998; Lee *et al*., 2010). In term of the temporal resolution, the latest data call provides fishing intensity data annually for the years 2009 – 2013. The only exception to this being 2013, where the data is provided on a quarterly basis.

The logbook data which is used to define the type of fishing activity that being undertaken is available for the Baltic Sea from the EU-STECF (Scientific, Technical and Economic Committee for Fisheries). Logbook data of catch and effort for the Baltic Sea (vessels ≥ 8 m) are available by ICES rectangles (approx. 30’ x 30’ resolution). For some of the vessels below 8 meters, the same spatial scale applies (ICES rectangle), but for others 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). Information is currently available for the years between 2003 and 2013 for variable such as gear used, fishing effort, activity, landings, vessel length and state. This information is combined with aggregated VMS data by ICES when producing information for data calls, such as described above.

From the point of view of fishery impact, the spatial and temporal restrictions applied to VMS data represent the main obstacle in meeting the objectives of the Challenge. In order to meet the objectives of the Challenge, it is recommended that the data is provided for the past 10 years, and at a temporal resolution suitable for analysis on a monthly basis.

9.3 Conclusions and discussions

The availability and adequacy of environmental data sources relevant to fishery impact (bottom water salinity, bathymetry, and near bed light intensity) are considered to be suitable for use in the assessment of fishery impacts. Habitat and species data for the Baltic Sea is considered adequate, although it can be variable in terms of its coverage and quality. This is mainly as a result of prediction confidence in the modelled data, a lack of ecological data, and the large degree of extrapolation made in data poor areas. Updates in September 2016 are expected to represent an improvement for habitat data for the Baltic Sea, and this will be reviewed as part of the DAR II report.

From the point of view of fishery impact, the spatial and temporal restrictions applied to VMS data represent the main obstacle in meeting the objectives of the Challenge; in terms of describing the area disturbed by the number of disturbances per month, and describing changes in level of disturbance over the past ten years. Data can be analysed for the periods for which data is available (2009 – 2013), but beyond this fishery impact analysis is problematic. Prior to the introduction of VMS, data was aggregated at the level of the ICES squares, and which represents a very coarse level resolution of fisheries data. From the point of view of this Challenge, the unrestricted provision of VMS data would represent an ideal situation – allowing for assessment at much greater spatial and temporal scales. However, due to the commercial (and associated political nature) of VMS data, this is considered unlikely at any time in the near future.

Table 9.5. Conclusions and recommendations from the data adequacy report

Variable	Adequacy in general	Adequacy in EMODnet	Recommendations
Bottom water salinity	Adequate	Adequate	No recommendations proposed
EUNIS habitats level 3/4	Adequate. There are some issues relating to coverage (Kattegat) and confidence of predicted habitat types in the Baltic, however, an anticipated update in September 2016 is expected to further improve adequacy.	Adequate. There are some issues relating to coverage (Kattegat) and confidence of predicted habitat types in the Baltic, however, an anticipated update in September 2016 is expected to further improve adequacy.	No recommendations proposed
Habitat Directive benthic species and habitat	Adequate	Not provided by EMODnet	Where possible, it would be useful to delineate the spatial extent and location of Annex I habitats within Natura 2000 areas.
Bathymetry	Adequate	Adequate	No recommendations proposed
Substrate	Adequate	Adequate	If possible, gaps in coverage of the higher resolution mapping provided by EMODnet (1:250,000) should be resolved.
Near bed light intensity	Adequate	Not provided by EMODnet	No recommendations proposed
Baltic Marine Landscapes	Adequate	Not provided by EMODnet	No recommendations proposed
VMS for vessels ≥15 m (2005-2011)	Restrictions prevent the ability to meet the Challenge objectives	Not provided by EMODnet	In order to meet the objectives, data would need to be provided for the past 10 years, and at a temporal resolution suitable for analysis on a monthly basis.
VMS for vessels ≥12 m (2012-)	Restrictions prevent the ability to meet the Challenge objectives	Not provided by EMODnet	In order to meet the objectives, data would need to be provided for the past 10 years, and at a temporal resolution suitable for analysis on a monthly basis.
Logbook data for vessels ≥8 m	Adequate	Adequate	No recommendations proposed
National sales slip data of landings for vessels <8 m	Adequate	Adequate	No recommendations proposed

To try and best meet the objectives of the Challenge, other avenues have been explored. One likely solution is the BalticBOOST project; a currently ongoing initiative that will help bridge data gaps for the Baltic Sea. The project is coordinated by HELCOM, and is focussed with boosting the coherence of marine strategies across the Baltic through improved data flow, assessments, and knowledge. One of the main project themes is to provide information on the physical loss and impact to the seabed in the Baltic, and to investigate ways to determine how much disturbance specific seabed habitats can tolerate from different activities (while remaining in GES – a key measure of the MSFD) (BalticBOOST, 2016). The project will also deliver a quantitative inventory of fishing gears and their interactions with the seabed habitats. This tool will contain detailed spatial information on fishing activities and associated pressures (fishing coverage and intensity by gear types) as well as spatially explicit interactions between fisheries and habitats and species in representative test cases in the Baltic, with a particular focus towards seabed integrity. The tool will be based on the methods developed by BENTHIS, and will then apply these methods directly to the Baltic Sea. This will result in the production of a number of outcomes, including seabed impact descriptors from fishing data (trawling footprint, trawling aggregation, untrawled seabed), and a seafloor integrity index for the Baltic. These products, which will be available in 2017, are closely aligned to the aims of the Challenge, and will help meet the Challenge objectives. Table 9.5 provides an outline of the finding of the data adequacy report.

Acknowledgments: Grete E. Dinesen, Ole E. Eigaard, Francois Bastardie and Asbjørn Christensen from DTU-Aqua have provided input to the Data Adequacy Report.

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10 Data adequacy for eutrophication

10.1 Data requirement assessment

The goal of the eutrophication studies in BSCP is to assess the data adequacy per key variable using available in-situ data from 2005 to 2014. Available in-situ data is gathered from ICES/HELCOM and EMODnet Chemistry databases and possible deviations between the two data sources are analysed regarding assessments and its confidence. Assessments are carried out using HELCOM eutrophication assessment methods - eutrophication core indicators and assessment tool HEAT 3.0 (HELCOM, 2014).

Entire Baltic Sea is affected by eutrophication which is driven by anthropogenic enrichment of nutrients (nitrogen and phosphorus) and climate change. Excess nutrients and/or changed nutrient ratios increase algal and plant growth, turbidity and oxygen depletion in bottom waters, also the species composition is changed and nuisance blooms of algae can be observed (HELCOM, 2014).

The open sea sub-basins (Fig. 10.1.) are assessed by integrating status data from HELCOM core indicators (Tab. 10.1.1.) on nutrients (DIN – Dissolved Inorganic Nitrogen; DIP – Dissolved Inorganic Phosphorus), chlorophyll-a, water transparency (Secchi depth) and oxygen conditions (bottom waters' oxygen debt) (HELCOM, 2014).

Figure 10.1. HELCOM open sea sub-basins used for this eutrophication assessment. Source: www.helcom.fi (with added sub-basin numeration).

Table 10.1.1. Data usage in 'Eutrophication'

Variable	Data type	Usage
DIN	In-situ Obs.	For estimating seasonal averages for the eutrophication assessment
DIP	In-situ Obs.	For estimating seasonal averages for the eutrophication assessment
Chlorophyll-a	In-situ Obs.	For estimating seasonal averages for the eutrophication assessment
Secchi depth	In-situ Obs.	For estimating seasonal averages for the eutrophication assessment
Dissolved oxygen (salinity, temperature as supporting parameters)	In-situ Obs.	For estimating annual averages for the eutrophication assessment

Due to the limited exchange of water between the Baltic Sea and the North Sea, data gathered by observations should be spatially distributed in a non-biased way. According to HELCOM monitoring requirements at least 15 observations in every sub-basin per year/season should be made for every core indicator e.g. see the DIN core indicator web-page (Pyhälä et al., 2014) (Tab. 10.1.2.).

Table 10.1.2. Data requirements for 'Eutrophication'

Variable	Data type	Accessibility		Completeness/ coverage		Resolution	
		Delivery type	Delivery time*	Spatial	Temporal	Ver.	Horizontal/ Temporal
DIN	Obs.	Delayed, on request, open, free	6months	Baltic Sea	2005-2014 winter	Samples from the surface layer (0-10m)	At least 15 observations per sub-basin per season
DIP	Obs.	Delayed, on request, open, free	6months	Baltic Sea	2005-2014 winter	Samples from the surface layer (0-10m)	
Chlorophyll-a	Obs.	Delayed, on request, open, free	6months	Baltic Sea	2005-2014 summer	Samples from the surface layer (0-10m)	
Secchi depth	Obs.	Delayed, on request, open, free	6months	Baltic Sea	2005-2014 summer	N/A	
Dissolved oxygen	Obs.	Delayed, on request, open, free	6months	Baltic Sea	2005-2014 whole year	Samples (and T,S-profiles) from throughout the water column	

* Delivery time is the interval between time when the data are measured and time when the data can be accessed. The requirement of the delivery time depends on the frequency of the Eutrophication assessment. Here yearly assessment is assumed.

To assess the eutrophication status of the Baltic Sea, data on nutrients are gathered from the surface layer (0-10m) during winter (from December to February; no production) to assure the accurate display of nutrient concentrations. Data on direct effects (chlorophyll-a from surface layer 0-10m and Secchi depth) of the eutrophication are gathered during summer, from June to September. Data on indirect effects (oxygen debt) are gathered throughout the year from the whole water column.

10.2 Data adequacy assessment

The data adequacy in the eutrophication study should be reviewed through the viewpoint of HELCOM eutrophication assessment methods. For assessing eutrophication status, a set of core indicators have been developed. Core indicators describe not only their initial parameters but also the monitoring requirements and background conditions of the parameters. For every parameter spatial and temporal requirements have been defined and based on them a general data adequacy assessment can be derived.

Data used in the assessments were gathered from two databases – ICES/HELCOM and EMODnet Chemistry for the time period 2005-2014 (Tab. 10.2.1.). Additionally, oxygen data was gathered from CMEMS database. In both databases, ICES/HELCOM and EMODnet, there are data missing when considering the 15+ measurement temporal condition per season and per sub-basin in HELCOM assessment methods.

In ICES/HELCOM database the data is downloadable as a .xls file which is very convenient. Although the downloadable file lacked the field 'sub-basin', which is essential for the assessments, it was provided by ICES upon request. Acquiring data from EMODnet is a very time consuming activity – due to the limitations on displayed fields on one page and the 'basket' size. The request manager service is a very welcome feature although it would be more convenient if requested data would be organised in a manner which makes it possible to differentiate between requested parameters. Also when requesting specific parameters, it would be most welcomed to receive only those requested parameters and not some additional data. A metadata field for sub-basins could be added in the EMODnet data.

When preparing the data, a small number of duplicates were found in both databases. When pooling data from ICES/HELCOM and EMODnet, removing the duplicates turned out to be a bit more complicated due to slight differences in time/coordinates/parameter values in duplicate samples. Nevertheless, the data was merged in Ocean Data View (ODV) by limiting the maximum difference of longitude and latitude to 0.004 degrees and time to 0.0033 hours.

Subsequently data are assessed per parameter by describing the temporal and spatial coverage of selected assessment data. For each parameter the status assessment results for years 2005-2014 are presented in tables together with data confidence classes. The status assessments are compared to existing eutrophication assessments put together by HELCOM for period 2007-2011. When comparing data confidence classes between assessments it should be noted that the assessments produced in this paper include "data confidence classes" but HELCOM assessments include "assessment confidence classes" (Tab. 10.2.2.). More than 15 measurements per season gives the data high confidence. The confidence of the status assessments depends on the core indicators' target confidence and the observations count (data confidence) per season(Tab. 10.2.3.)

Table 10.2.1. Data availability for 'Eutrophication'

Variable	Data type	Accessibility		Completeness/ coverage		Resolution		Data provider
		Delivery type	Delivery time	Spatial	Temporal	Vertical	Horizontal/ Temporal	
DIN	Obs.	Delayed, on request, free	1-3 years	Baltic Sea	2005-2014*	0-10m**	Some seasons lack data (data count below 15 observations per season and per sub-basin)	EMODNET
	Obs.	Delayed, open, free	1 year	Baltic Sea	2005-2014*	0-10m**		ICES/ HELCOM
DIP	Obs.	Delayed, on request, free	1-3 years	Baltic Sea	2005-2014*	0-10m**		EMODNET
	Obs.	Delayed, open, free	1 year	Baltic Sea	2005-2014*	0-10m**		ICES/ HELCOM
Chlorophyll-a	Obs.	Delayed, on request, free	1-3 years	Baltic Sea	2005-2014*	0-10m**		EMODNET
	Obs.	Delayed, open, free	1 year	Baltic Sea	2005-2014*	0-10m**		ICES/ HELCOM
	Obs.	NRT, Open, free	<24h	Ferrybox lines	2005-now	Surface	Number of liens varies from 3-5, twice per week	CMEMS
	Obs.	NRT, open, free	<24h	Western Baltic	2015-now	Multiple vertical layers	Two stations with hourly data	CMEMS/ MARNET
Secchi depth	Obs.	Delayed, on request, free	1-3 years	Baltic Sea	2005-2014*	N/A	Some seasons lack data (data count below 15 observations per season and per sub-basin)	EMODNET
	Obs.	Delayed, open, free	1 year	Baltic Sea	2005-2014*	N/A		ICES/ HELCOM
Oxygen	Obs.	Delayed, on request, free	1-3 years	Baltic Sea	2005-2014*	Top to bottom profiles with high and low vertical resolution, and single observations		EMODNET
	Obs.	Delayed, open, free	1 year	Baltic Sea	2005-2014*			ICES/ HELCOM
	Obs.	Delayed, open, free	Near real time	Baltic Sea	2005-2014*	Surface layer data mostly. Some high-resolution profiles		CMEMS

* Time period used for the eutrophication assessment; ** Data from vertical layer used for assessment

Table 10.2.2. Status and data confidence classes: WFD – Water Framework Directive; MSFD – Marine Strategy Framework Directive.

WFD status	MSFD status	Data confidence	
HIGH	GES	HIGH	More than 15 observations per season
GOOD		MODERATE	5 to 15 observations per season
MODERATE	SubGES	LOW	Less than 5 observations per season
POOR		NO DATA	
BAD			
NO DATA	NO DATA		

Table 10.2.3. Relationship between data confidence, target confidence and indicator assessment confidence

Data confidence	Target confidence	Indicator assessment confidence
HIGH	HIGH	HIGH/100%
HIGH	MODERATE	HIGH/75%
HIGH	LOW	MODERATE/50%
MODERATE	MODERATE	MODERATE/50%
MODERATE	LOW	LOW/25%
LOW	LOW	LOW/0%

In the end, the data confidence and status assessment confidence will not differ from each other that much because for nutrients and chlorophyll-a the target confidence is *moderate* which will not change the status assessment confidence. Regarding Secchi depth, with target confidence *high*, the status assessment confidence will be one class higher than the data confidence class.

10.2.1 DIN

For DIN estimates wintertime (Dec-Feb) samples from the uppermost layer of 10 metres are used for the assessment. According to the HELCOM core indicator methods at least 15 observations per season (Dec-Feb) per sub-basin are needed for the highest data confidence level.

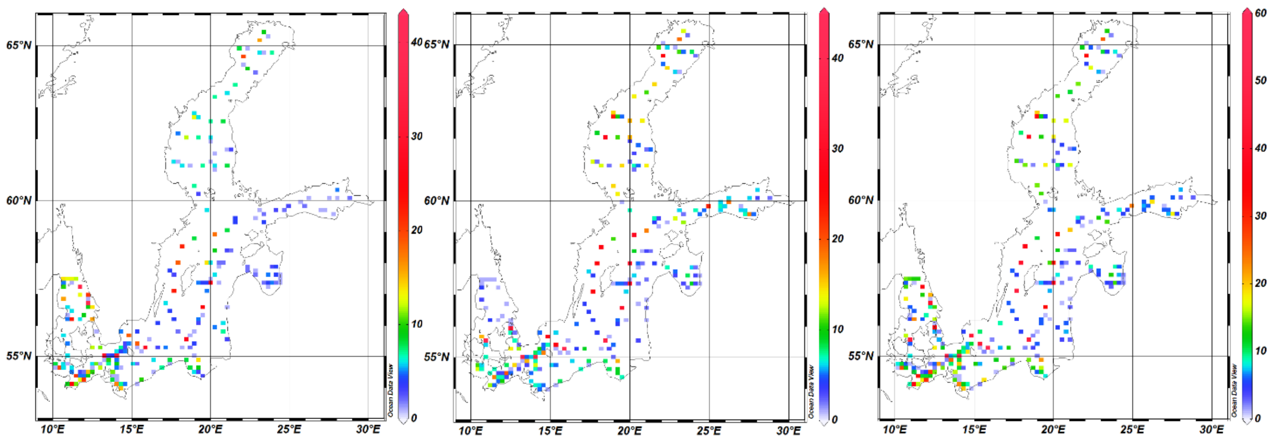


Figure 10.2.1.1. DIN assessment data distribution (sample count per station) for 2005-2014. From left to right: 1) ICES/HELCOM data; 2) EMODnet Chemistry data; 3) ICES/HELCOM and EMODnet Chemistry data pooled. Please note the different scales.

Comparing the spatial coverage of ICES and EMODnet data (Figure 10.2.1.1.) it can be seen that it is quite evenly distributed for the whole assessment period with sample count per station ranging from 1 to close to 60.

When looking at the different seasons of the assessment period it is evident that EMODnet data for some of them are missing (e.g. in SEA001) (Fig. 10.2.1.2.). On the other hand, for some sub-basins (e.g. SEA011, SEA012 etc.) have more in EMODnet database than in ICES/HELCOM database. It should also be noted that the data count of many seasons is not sufficient for the highest data confidence class in both databases.

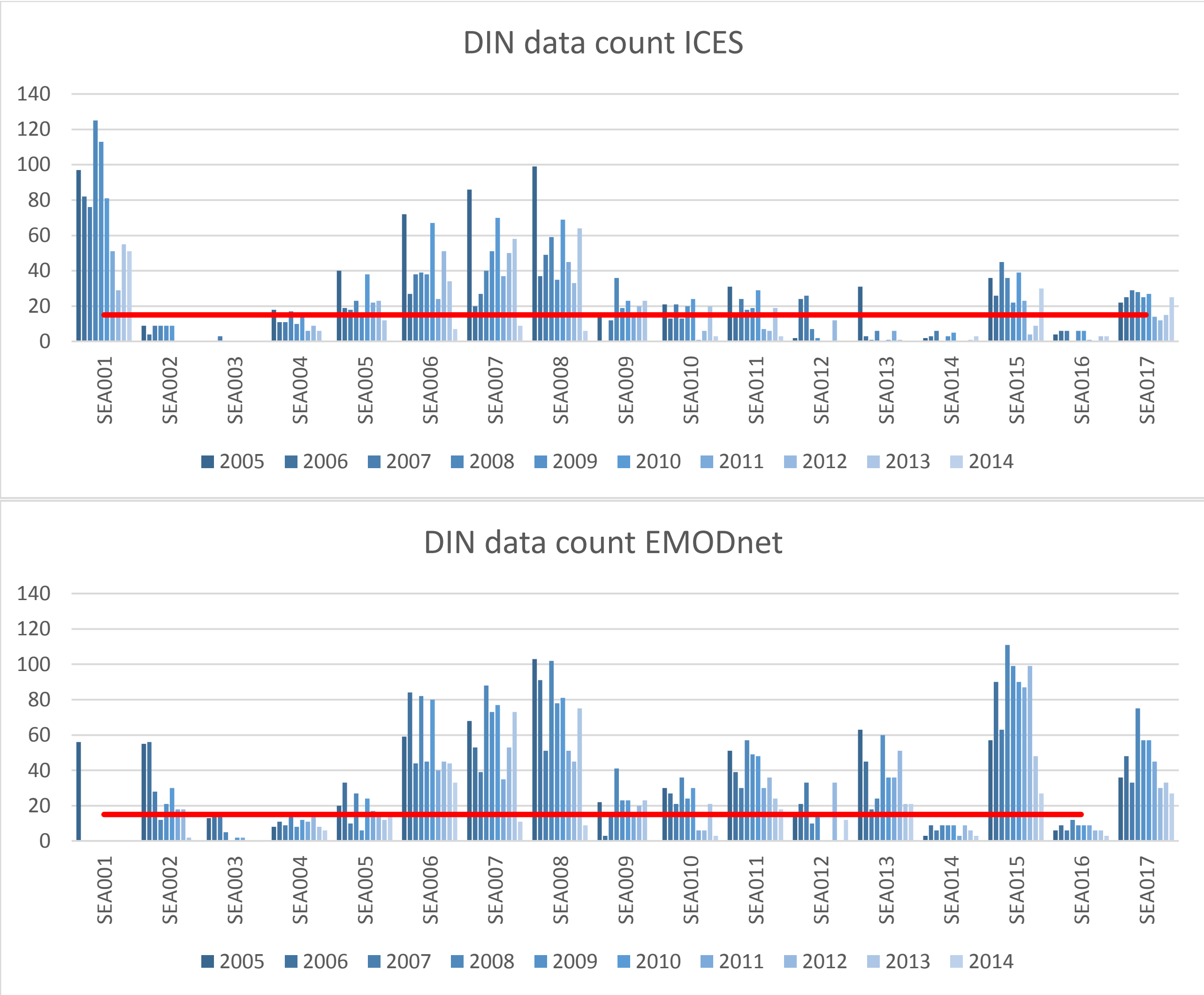


Figure 10.2.1.2. DIN assessment data count per year and per sub-basin from ICES/HELCOM and EMODnet Chemistry databases. The red line marks the 15 observation threshold which has to be fulfilled every year/season for every assessment unit (sub-basin) during the assessment period in order to get the data assessments with high confidence.

Due to the lack of data in some sub-basins/seasons high data confidence can be given to less than a half of sub-basins (Tab. 10.2.4.). Given status assessment is compared to HELCOM Eutrophication Status of the Baltic Sea (BSEP143) results and to HELCOM EUTRO-OPER assessment results and all the results are coinciding pretty well except for SEA009 assessments. For SEA009 ICES data status assessment is 'GOOD' and EMODnet data results in a 'MODERATE' assessment but when data is pooled from the aforementioned databases the assessment result is ‘POOR’. This ‘POOR’ assessment is right on the border of ‘MODERATE’ and ‘POOR’ and is most likely due to the ODV data merging conditions.

Table 10.2.4. DIN status assessments and data confidence for 2005-2014 based on data from ICES and EMODnet databases. For comparison two HELCOM assessments: 1) Eutrophication status of the Baltic Sea (BSEP 143) for 2007-2011; 2) EUTRO-OPER assessment for 2007-2011. Red indicates the SubGES (Good Environmental Status not achieved) areas based on different data. Green stands for achieved GES. * Status assessment confidence.

Sub-basin	ICES 2005-2014		EMODnet 2005-2014		ICES & EMODnet pooled 2005-2014		2007-2011 BSEP 143		2007-2011 EUTRO-OPER
	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence*	Assessment
SEA001	MODERATE	HIGH	MODERATE	LOW	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA002	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	HIGH	MODERATE
SEA003	BAD	LOW	POOR	LOW	POOR	LOW	SubGES	HIGH	BAD
SEA004	MODERATE	LOW	MODERATE	MODERATE	MODERATE	MODERATE	SubGES	HIGH	MODERATE
SEA005	MODERATE	LOW	MODERATE	MODERATE	MODERATE	MODERATE	SubGES	HIGH	POOR
SEA006	MODERATE	MODERATE	MODERATE	HIGH	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA007	POOR	MODERATE	POOR	MODERATE	POOR	HIGH	SubGES	HIGH	BAD
SEA008	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA009	GOOD	LOW	MODERATE	LOW	POOR	LOW	SubGES	HIGH	GOOD
SEA010	MODERATE	LOW	MODERATE	LOW	MODERATE	MODERATE	SubGES	HIGH	POOR
SEA011	MODERATE	LOW	POOR	HIGH	POOR	HIGH	SubGES	HIGH	POOR
SEA012	BAD	LOW	POOR	LOW	BAD	LOW	GES	HIGH	BAD
SEA013	BAD	LOW	BAD	HIGH	BAD	HIGH	SubGES	HIGH	BAD
SEA014	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	HIGH	MODERATE
SEA015	MODERATE	LOW	MODERATE	HIGH	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA016	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	HIGH	MODERATE
SEA017	MODERATE	MODERATE	MODERATE	HIGH	MODERATE	HIGH	SubGES	HIGH	MODERATE

In the future more wintertime observations should be made in the smaller sub-basins (SEA003, SEA014, SEA016) in order to get the data confidence level ‘high’ for the assessments.

10.2.2 DIP

For DIP estimates wintertime (Dec-Feb) samples from the uppermost layer of 10 metres are used for the assessment. According to the HELCOM core indicator methods at least 15 observations per season (Dec-Feb) per sub-basin are needed for the highest confidence level of the assessment.

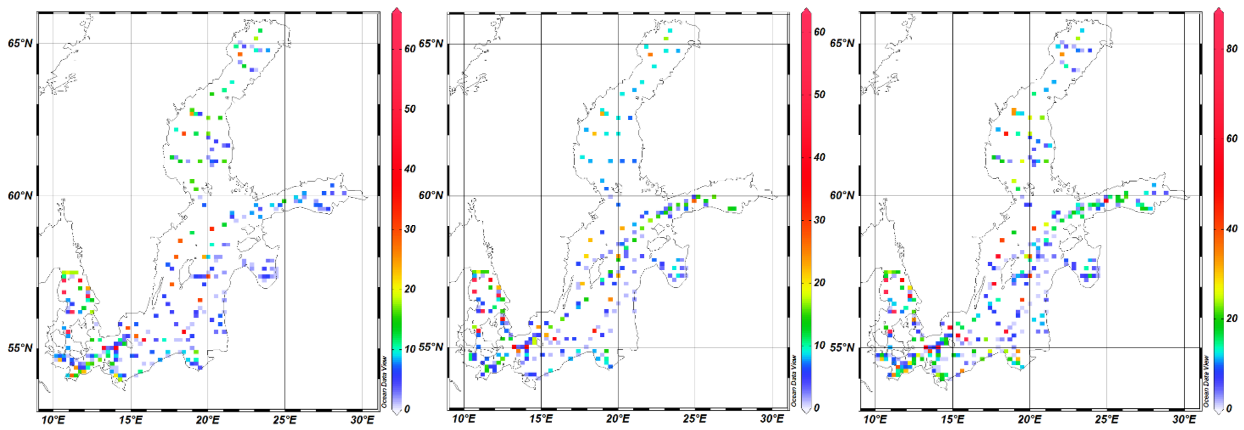


Figure 10.2.2.1. DIP assessment data distribution (sample count per station) for 2005-2014. From left to right: 1) ICES/HELCOM data; 2) EMODnet Chemistry data; 3) ICES/HELCOM and EMODnet Chemistry data pooled. Please note the different scales.

Comparing the spatial coverage of ICES and EMODnet data (Fig. 10.2.2.1.) it can be seen that it is quite evenly distributed for the whole assessment period with sample count per station ranging from 1 to over 60.

When looking at the different seasons of the assessment period it is evident that EMODnet is missing some data compared to ICES/HELCOM, e.g. for sub-basins SEA006, SEA009 etc. For some sub-basins EMODnet has more data than ICES/HELCOM, e.g. SEA003 and SEA012. The data count, in both databases, for some of the sub-basins is bordering the 15 samples per season and this is also not sufficient in many cases for the high confidence class for data (Fig. 10.2.2.2.).

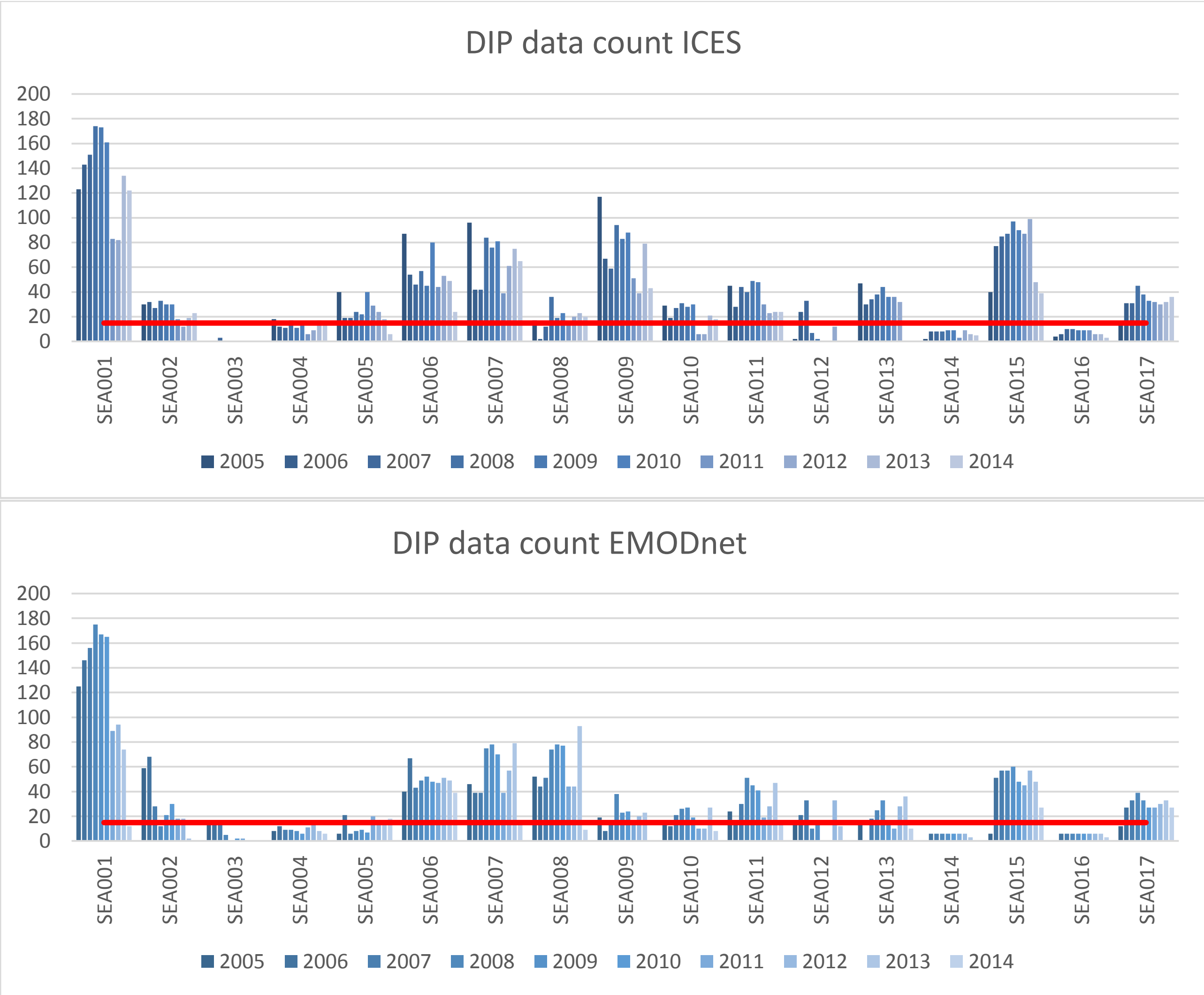


Figure 10.2.2.2. DIP assessment data count per year and per sub-basin from ICES/HELCOM and EMODnet Chemistry database. The red line marks the 15 observation threshold which has to be fulfilled every year/season for every assessment unit (sub-basin) during the assessment period in order to get the data assessments with high confidence.

The status assessment results between ICES and EMODnet databases are coinciding very well and the HELCOM assessment don't differ from them that much (Tab. 10.2.5.). When combining ICES and EMODnet data the data confidence is high for over half of the sub-basins but when looking at EMODnet data separately the data confidence is high for only two sub-basins.

Table 10.2.5. DIP status assessments and data confidence for 2005-2014 based on data from ICES and EMODnet databases. For comparison two HELCOM assessments: 1) Eutrophication status of the Baltic Sea (BSEP 143) for 2007-2011; 2) EUTRO-OPER assessment for 2007-2011. Red indicates the SubGES (Good Environmental Status not achieved) areas based on different data. Green stands for achieved GES. * Status assessment confidence.

Sub-basin	ICES 2005-2014		EMODnet 2005-2014		ICES & EMODnet pooled 2005-2014		2007-2011 BSEP 143		2007-2011 EUTRO-OPER
	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence*	Assessment
SEA001	MODERATE	HIGH	MODERATE	MODERATE	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA002	MODERATE	MODERATE	MODERATE	LOW	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA003	POOR	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	HIGH	MODERATE
SEA004	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	SubGES	HIGH	MODERATE
SEA005	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA006	POOR	HIGH	POOR	HIGH	POOR	HIGH	SubGES	HIGH	POOR
SEA007	BAD	HIGH	BAD	HIGH	BAD	HIGH	SubGES	HIGH	BAD
SEA008	POOR	LOW	POOR	MODERATE	POOR	HIGH	SubGES	HIGH	POOR
SEA009	POOR	HIGH	POOR	LOW	POOR	HIGH	SubGES	HIGH	MODERATE
SEA010	POOR	MODERATE	POOR	MODERATE	POOR	HIGH	SubGES	HIGH	POOR
SEA011	BAD	HIGH	BAD	MODERATE	BAD	HIGH	SubGES	HIGH	BAD
SEA012	BAD	LOW	POOR	LOW	POOR	LOW	SubGES	HIGH	POOR
SEA013	MODERATE	LOW	MODERATE	LOW	MODERATE	MODERATE	SubGES	HIGH	MODERATE
SEA014	POOR	LOW	BAD	LOW	BAD	LOW	SubGES	HIGH	POOR
SEA015	MODERATE	HIGH	MODERATE	MODERATE	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA016	BAD	LOW	BAD	LOW	BAD	LOW	GES	HIGH	BAD
SEA017	GOOD	HIGH	GOOD	MODERATE	GOOD	HIGH	GES	HIGH	HIGH

In the future more wintertime observations should be made in some sub-basins (SEA003, SEA014, SEA016) in order to get the data confidence level 'high' for the assessments.

10.2.3 Chlorophyll-a

For Chlorophyll-a estimates summertime (June-Sept) samples from the uppermost layer of 10 metres are used for the assessment. According to the HELCOM core indicator methods at least 15 observations per year per sub-basin are needed for the highest confidence level of the assessment.

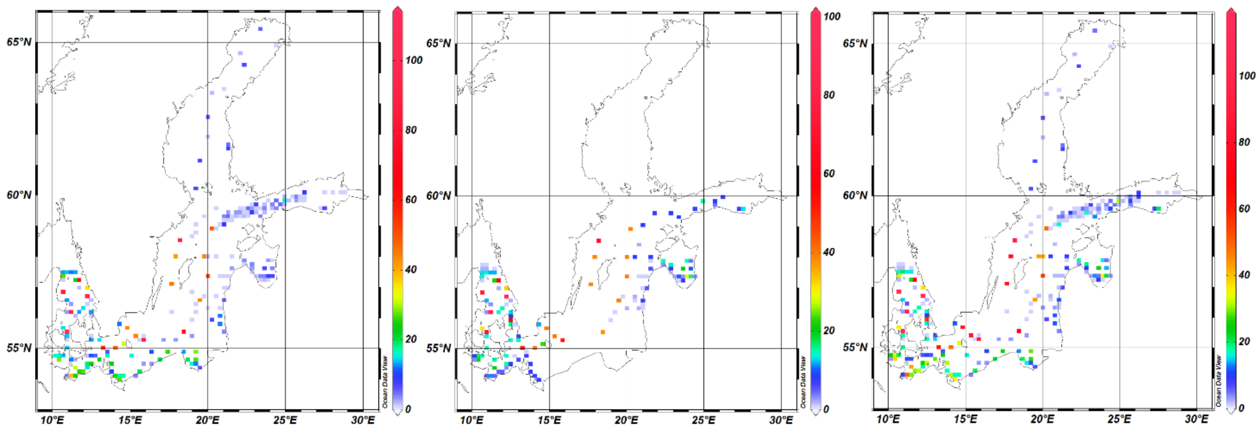
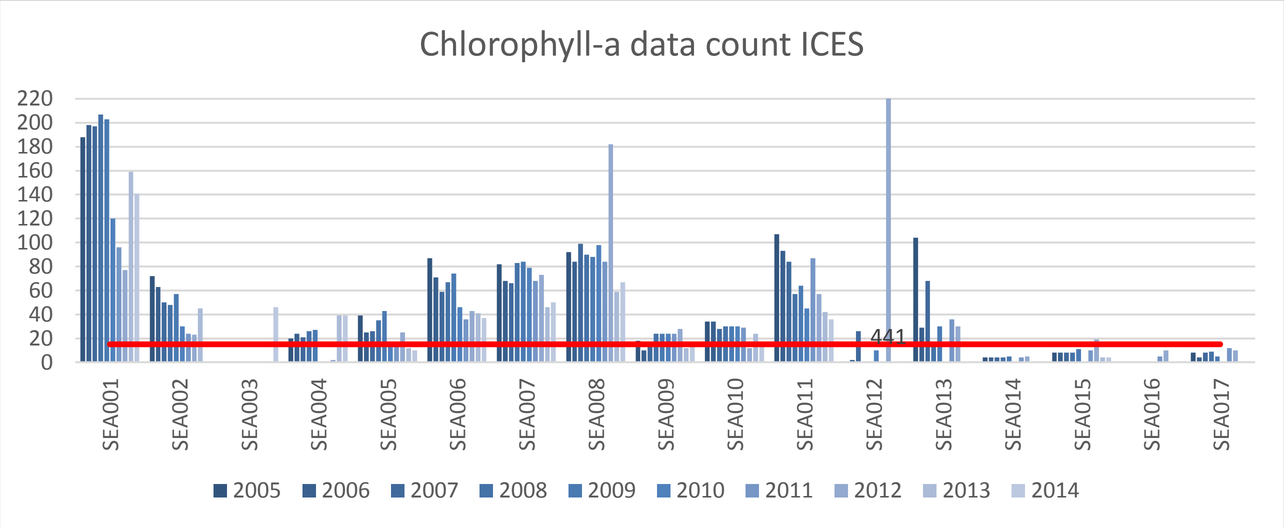


Figure 10.2.3.1. Chlorophyll-a assessment data distribution (sample count per station) for 2005-2014. From left to right: 1) ICES/HELCOM data; 2) EMODnet Chemistry data; 3) ICES/HELCOM and EMODnet Chemistry data pooled. Please note the different scales.

The spatial coverage of ICES and EMODnet data (Fig. 10.2.3.1.) is unevenly distributed both in EMODnets' case (whole sub-basins are missing data) and in ICES' case (northernmost sub-basins have few stations). For the whole assessment period the sample count per station ranges from 1 to over 100.

When looking at the different seasons of the assessment period it is evident that EMODnet data for some of them is lacking and even to an extent that the last four sub-basins (SEA014 to SEA017) have no data at all. On the other hand, in EMODnet SEA012 and SEA003 are covered with more data than ICES/HELCOM database (Fig. 10.2.3.2.).



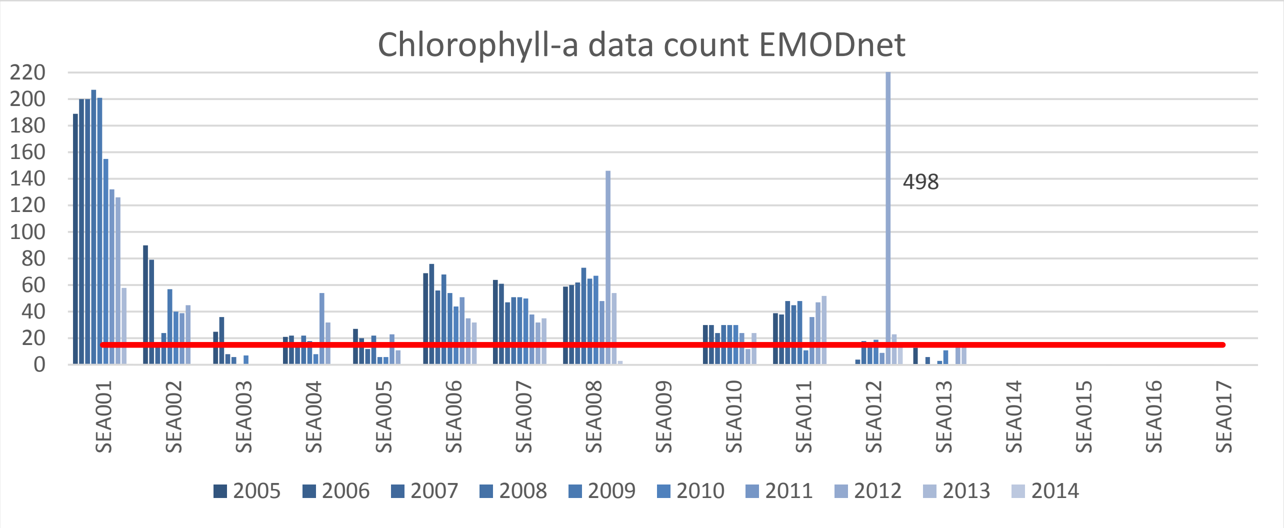


Figure 10.2.3.2. Chlorophyll-a assessment data count per year and per sub-basin from ICES/HELCOM and EMODnet Chemistry database. The red line marks the 15 observation threshold which has to be fulfilled every year/season for every assessment unit (sub-basin) during the assessment period in order to get the status assessments with high confidence. Please note the SEA012 data count is off the chart for 2012.

EMODnet chlorophyll-a data confidence is low or the data is missing. Low confidence comes from when on one or more seasons the data count per sub-basin has been less than 5. The status assessments are coinciding well between different assessments (Tab. 10.2.6.).

Table 10.2.6. Chlorophyll-a status assessments and data confidence for 2005-2014 based on data from ICES and EMODnet databases. For comparison two HELCOM assessments: 1) Eutrophication status of the Baltic Sea (BSEP 143) for 2007-2011; 2) EUTRO-OPER assessment for 2007-2011. Red indicates the SubGES (Good Environmental Status not achieved) areas based on different data. Green stands for achieved GES. * Status assessment confidence.

Sub-basin	ICES 2005-2014		EMODnet 2005-2014		ICES & EMODnet pooled 2005-2014		2007-2011 BSEP 143		2007-2011 EUTRO-OPER
	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence*	Assessment
SEA001	GOOD	HIGH	GOOD	LOW	GOOD	HIGH	GES	MODERATE	MODERATE
SEA002	MODERATE	LOW	MODERATE	LOW	MODERATE	HIGH	SubGES	MODERATE	POOR
SEA003	POOR	LOW	MODERATE	LOW	POOR	LOW	SubGES	LOW	NO DATA
SEA004	MODERATE	LOW	MODERATE	LOW	MODERATE	MODERATE	SubGES	MODERATE	MODERATE
SEA005	MODERATE	MODERATE	POOR	LOW	MODERATE	MODERATE	SubGES	HIGH	MODERATE
SEA006	MODERATE	HIGH	MODERATE	LOW	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA007	POOR	HIGH	MODERATE	LOW	MODERATE	HIGH	SubGES	HIGH	POOR
SEA008	POOR	HIGH	POOR	LOW	POOR	HIGH	SubGES	HIGH	POOR
SEA009	MODERATE	MODERATE	NO DATA	NO DATA	MODERATE	MODERATE	SubGES	MODERATE	POOR
SEA010	BAD	MODERATE	BAD	LOW	POOR	HIGH	SubGES	MODERATE	BAD
SEA011	BAD	HIGH	POOR	LOW	BAD	HIGH	SubGES	HIGH	POOR
SEA012	POOR	LOW	MODERATE	LOW	MODERATE	LOW	GES	LOW	POOR
SEA013	BAD	LOW	BAD	LOW	BAD	LOW	SubGES	LOW	BAD
SEA014	BAD	LOW	NO DATA	NO DATA	BAD	LOW	SubGES	LOW	POOR
SEA015	POOR	LOW	NO DATA	NO DATA	POOR	LOW	SubGES	LOW	MODERATE
SEA016	MODERATE	LOW	NO DATA	NO DATA	MODERATE	LOW	SubGES	LOW	MODERATE
SEA017	GOOD	LOW	NO DATA	NO DATA	GOOD	LOW	SubGES	LOW	MODERATE

In the future more observations are needed in the northernmost sub-basins.

10.2.4 Secchi depth

For Secchi depth estimates summertime (June-Sept) observations are carried out. According to the HELCOM core indicator methods at least 15 observations per year per sub-basin are needed for the highest confidence level of the assessment.

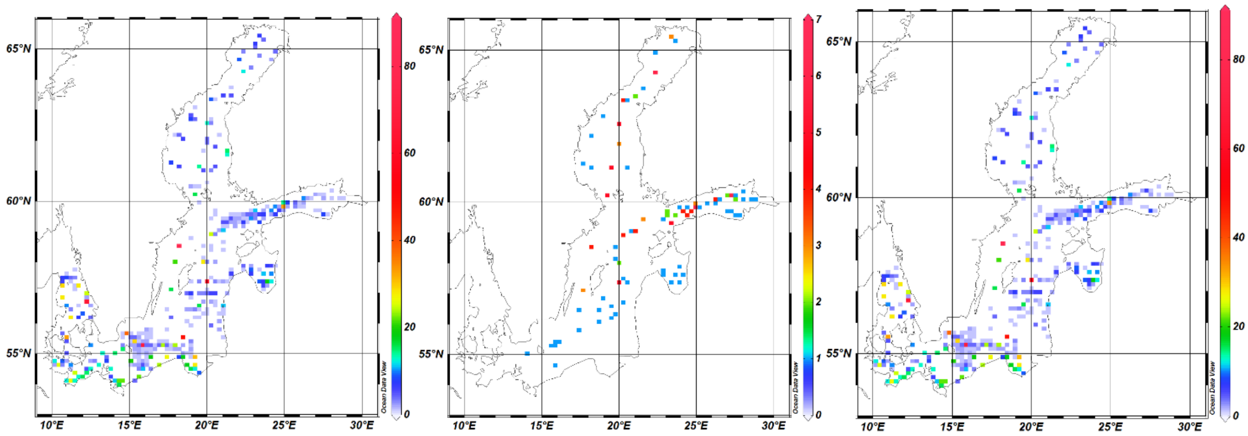


Figure 10.2.4.1. Secchi depth assessment data distribution (sample count per station) for 2005-2014. From left to right: 1) ICES/HELCOM data; 2) EMODnet Chemistry data; 3) ICES/HELCOM and EMODnet Chemistry data pooled. Please note the different scales.

When looking at the spatial coverage of ICES and EMODnet data (Fig. 10.2.3.1.) it can be seen that it is quite evenly distributed (except for some sub-basins without any data in EMODnets' case) although the number of data per station differs largely between ICES and EMODnet databases (note the different scales on the figure).

Secchi data is very scarcely represented in EMODnet database, both between seasons and between sub-basins. Also the number of observations per season rarely exceeds the 15 count threshold (Fig. 10.2.4.2.).

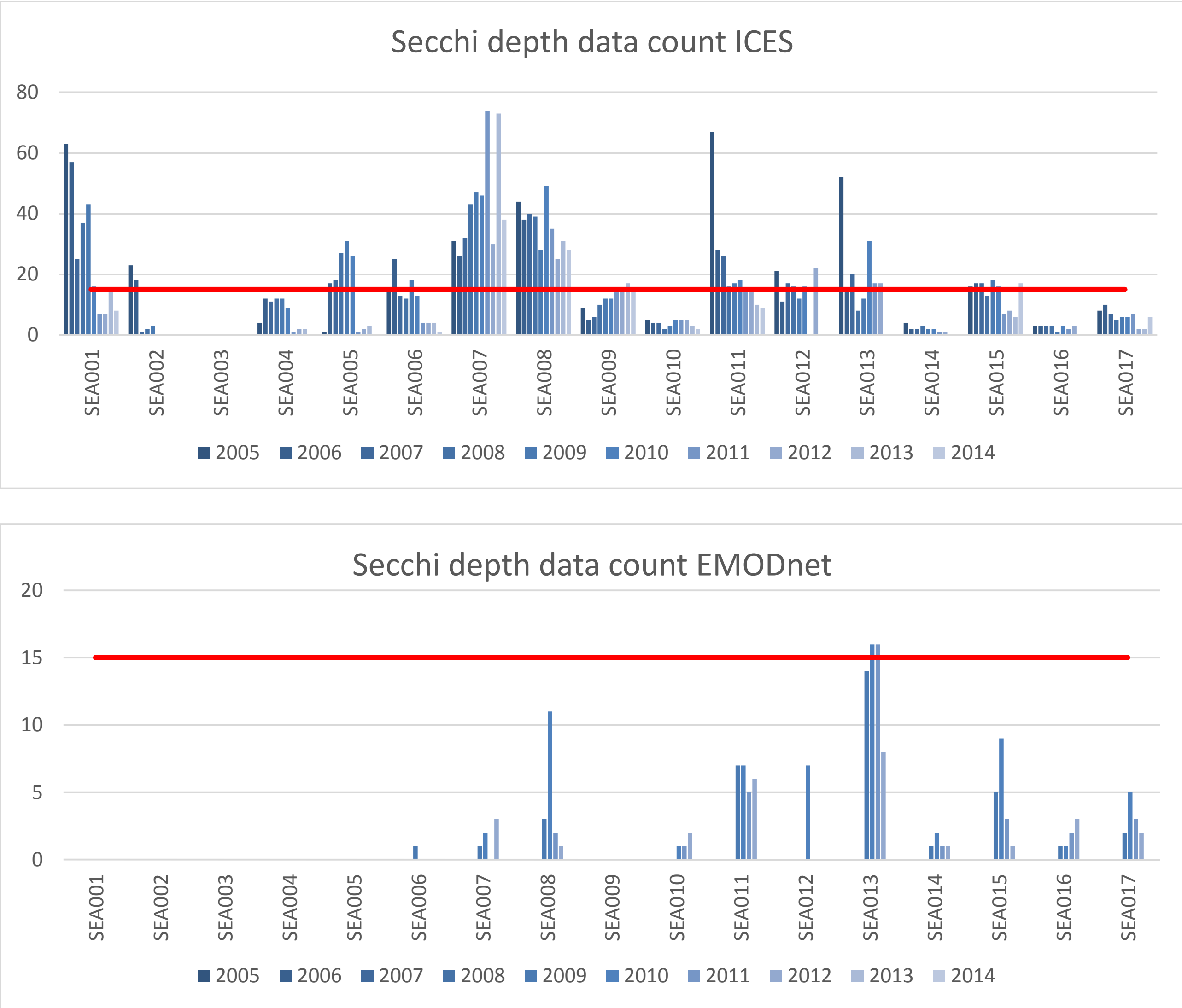


Figure 10.2.4.2. Secchi depth assessment data count per year and per sub-basin from ICES/HELCOM and EMODnet Chemistry database. The red line marks the 15 observation threshold which has to be fulfilled every year/season for every assessment unit (sub-basin) during the assessment period in order to get the status assessments with high confidence. Please note the different scales.

Secchi depth status assessments coincide fairly well between different assessments, but only two sub-basins get the 'high' data confidence score in ICES assessment. In EMODnet assessment 6 out of 17 sub-basins are missing data for the assessment period and the remaining 11 sub-basins have data confidence scoring of 'low' due to one or more seasons where data count was less than 5 (Tab. 10.2.7.).

Table 10.2.7. Secchi depth status assessments and data confidence for 2005-2014 based on data from ICES and EMODnet databases. For comparison two HELCOM assessments: 1) Eutrophication status of the Baltic Sea (BSEP 143) for 2007-2011; 2) EUTRO-OPER assessment for 2007-2011. Red indicates the SubGES

(Good Environmental Status not achieved) areas based on different data. Green stands for achieved GES.
* Status assessment confidence.

Sub-basin	ICES 2005-2014		EMODnet 2005-2014		ICES & EMODnet pooled 2005-2014		2007-2011 BSEP 143		2007-2011 EUTRO-OPER
	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence	Assessment	Confidence*	Assessment
SEA001	GOOD	MODERATE	NO DATA	NO DATA	GOOD	MODERATE	GES	MODERATE	GOOD
SEA002	MODERATE	LOW	NO DATA	NO DATA	MODERATE	LOW	SubGES	MODERATE	MODERATE
SEA003	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	SubGES	HIGH	MODERATE
SEA004	MODERATE	LOW	NO DATA	NO DATA	MODERATE	LOW	SubGES	MODERATE	MODERATE
SEA005	MODERATE	LOW	NO DATA	NO DATA	MODERATE	LOW	SubGES	MODERATE	MODERATE
SEA006	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	HIGH	MODERATE
SEA007	MODERATE	HIGH	MODERATE	LOW	MODERATE	HIGH	SubGES	MODERATE	MODERATE
SEA008	MODERATE	HIGH	MODERATE	LOW	MODERATE	HIGH	SubGES	HIGH	MODERATE
SEA009	MODERATE	MODERATE	NO DATA	NO DATA	MODERATE	MODERATE	SubGES	MODERATE	MODERATE
SEA010	MODERATE	LOW	POOR	LOW	MODERATE	LOW	SubGES	LOW	MODERATE
SEA011	MODERATE	MODERATE	MODERATE	LOW	MODERATE	MODERATE	SubGES	HIGH	MODERATE
SEA012	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	HIGH	MODERATE
SEA013	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	HIGH	MODERATE
SEA014	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	LOW	MODERATE
SEA015	MODERATE	MODERATE	MODERATE	LOW	MODERATE	MODERATE	SubGES	HIGH	MODERATE
SEA016	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	SubGES	LOW	MODERATE
SEA017	MODERATE	LOW	MODERATE	LOW	MODERATE	LOW	GES	MODERATE	GOOD

More Secchi depth measurements are needed in approximately half of the sub-basins.

10.2.5 Dissolved oxygen, temperature, salinity

One of the characterizing aspects of eutrophication is the developing hypoxia in bottom waters. To estimate the vertical and areal extent of hypoxia, dissolved oxygen observations should be carried out yearly throughout the entire water column. Considering this most of the Copernicus data can be left aside when assessing oxygen debt because these data originate mainly from vessels and are gathered from the surface layer.

The spatial distribution of ICES/HELCOM and EMODnet Chemistry oxygen data is quite uniform. ICES has more stations but EMODnet data has higher sample count per station (Fig. 10.2.5.).

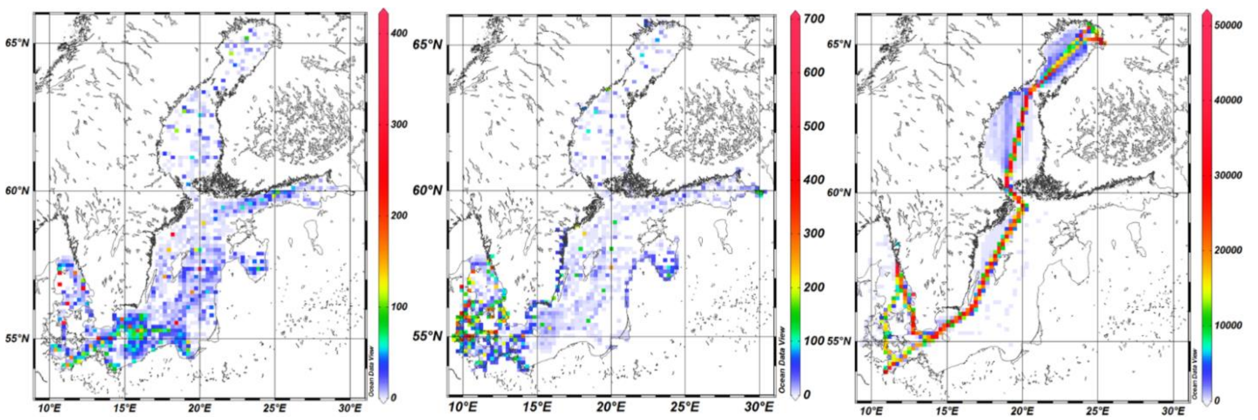


Figure. 1.2.5. Oxygen data distribution (sample count per station) for 2005-2014. From left to right: 1) ICES/HELCOM data; 2) EMODnet Chemistry data; 3) Copernicus data. Please note the different scales.

For assessing the oxygen debt status dissolved oxygen has to be co-measured with salinity and temperature in order to determine the oxygen debt value below the halocline (HELCOM, 2013). The application of HELCOM developed core indicator, oxygen debt, which has been used in the previous eutrophication assessments, has been proven to be complicated due to the need of special programming and statistical skills (HELCOM, 2015). An alternative indicator is needed for the fore mentioned reasons and because this oxygen debt indicator is restricted to deep basins. In the HELCOM EUTRO-OPER process an alternative indicator has been proposed concentrating on the oxygen consumption for the summer season below the productive layer but above the halocline (HELCOM, 2015). The EUTRO-OPER indicator has yet to be finalized due to data aggregation and some other questions.

10.3 Conclusions and discussions

Data adequacy assessment starts with the availability of data which in ICES/HELCOM case is pretty straight-forward with the one downloadable .xls file. When dealing with large amount of data and concerning EMODnet Chemistry the process of acquiring data might drive someone to search for other data sources.

Concerning data adequacy, proceeded from HELCOM assessment methods, a very general description of spatial distribution of data can be made visually – either the data is distributed in an un-biased way or not. Temporal adequacy is more defined and by implying the 15+ measurements threshold for high data confidence, the sub-basins which need more observation data can be defined. Generally, the smaller sub-basins were lacking sufficient amount of data for the high confidence assessments. Also when comparing the two data sources, ICES/HELCOM and EMODnet, the data shortages between the databases can be defined, e.g. ICES/HELCOM having data for some of the sub-basins and EMODnet lacking them.

Through this exercise sub-basins with less data were identified and this can serve as a guide to determine if the data is missing from the database due to lack of observations or because it has not been uploaded/provided etc. The data adequacy for Baltic Sea eutrophication assessment can be summarized in Tab. 10.3.1

Table 10.3.1. Data adequacy for 'Eutrophication'

Variable	Data type	Accessibility		Completeness/ coverage		Resolution			Data provider
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
DIN	Obs.	Quick delivery – downloadable .xls file		Baltic Sea coverage. Some data missing for some sub-basins		More obs. In sub-basins SEA002, 003, 013, 014, 016			ICES
	Obs.	Delivery could be faster and better organized to fit exactly the users requests		Baltic Sea coverage. Some data missing for some sub-basins		More obs. In sub-basins SEA001, 003, 014, 016			EMODNET
DIP	Obs.	Quick delivery – downloadable .xls file		Baltic Sea coverage. Some data missing for some sub-basins		Mor obs. In sub-basins SEA003, 012, 014, 016			ICES
	Obs.	Delivery could be faster and better organized to fit exactly the users requests		Baltic Sea coverage. Some data missing for some sub-basins		Mor obs. In sub-basins SEA003, 004, 014, 016			EMODNET
Chlorophyll-	Obs.	Quick delivery –		Baltic Sea		Mor obs. In sub-			ICES

a		downloadable .xls file	coverage. Some data missing for some sub-basins	basins SEA003, 014, 015, 016 and 017	
	Obs.	Delivery could be faster and better organized to fit exactly the users requests	Baltic Sea coverage. Some sub-basins are missing data	Mor obs. In sub-basins SEA003, 009, 013, 014, 015, 016 and 017	EMODNET
Secchi depth	Obs.	Quick delivery – downloadable .xls file	Baltic Sea coverage.	Mor obs. In sub-basins SEA002, 003, 005, 010, 014, 016 and 017	ICES
	Obs.	Delivery could be faster and better organized to fit exactly the users requests	Baltic Sea coverage. Some sub-basins are missing data	Mor obs. In all sub-basins, esp. in SEA001-006, 009, 012	EMODNET
Oxygen	Obs.	Quick delivery – downloadable .xls file	Baltic Sea coverage.	High vertical resolution top to bottom profiles are needed	ICES
	Obs.	Delivery could be faster and better organized to fit exactly the users requests	Baltic Sea coverage.	High vertical resolution top to bottom profiles are needed	EMODNET
	Obs.	Quick delivery - downloadable .nc files. Lacks the opportunity to choose the exact data needed.	Baltic Sea coverage.	High vertical resolution top to bottom profiles are needed – vessel data are excluded.	CMEMS

It should be notified that most of the CMEMS operational data are included in EMODNET. However, a large amount of observations of the surface chl-a have been made available through the ferrybox platforms, which are not used in this study. With assimilating ferrybox and profile measurements in a high quality biogeochemical model, more robust estimates of eutrophication indicators can be espected. The integrated assessment by using ICES and operational observations, satellite data and models is yet to be developed for the Baltic Sea.

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11 Data adequacy for river input

11.1 Data usage and requirement assessment

The goal of challenge 9 - River input is to quantify fluxes of fresh water, nutrients (Nitrogen and Phosphorus), sediment and salmon to the Baltic Sea. Due to lack of data for the sediment and salmon, only river temperature, discharge and nutrient data will be investigated in the first DAR report. It seems that EMODNET does not have relevant river data. Therefore no data adequacy assessment will be made for current EMODNET database.

Both observation and model data are available for river temperature, river discharge and nutrient concentrations. The hydrological model E-HYPE uses precipitation, temperature, agricultural land managements, atmospheric deposition and point sources as inputs to calculate the discharge and nutrient load for the catchments. The observations are also important for verifying and calibrating the models. For the BSCP project, in order to estimate the fluxes to the sea, the data needed should be at the river mouth. The usage of the data in the challenge area is summarised in Tab. 11.1. Ideally, the data of river temperature, discharge and nutrient concentration are needed at the river mouth for all Baltic Sea Rivers.

Table 11.1. Data usage in river input

Variable	Data type	Usage
River temperature	In-situ Obs.	**To determine the temperature of freshwater influxes to the Baltic Sea Important for animals and plants, affects the physical environment**
	Model	Models can infill temporal and spatial gaps in observations
Discharge	In-situ Obs.	To determine fluxes of fresh water entering the Baltic Sea. This is of particular importance for determining the salinity of the Baltic Sea
	Model	Models can infill temporal and spatial gaps in observations
Nutrients	In-situ Obs.	Nutrient concentrations observations are used together with discharge observations to calculate nutrient loads to the Baltic Sea. This is particularly important for eutrophication, to monitor compliance with international agreements such as the Baltic Sea Action Plan and to discover any long-term trends in nutrient emissions to the sea.
	Model	Models can infill temporal and spatial gaps in observations. In particular, nutrient concentration sampling is often too sparse to calculate loads without the help of advanced statistical techniques and /or models
Sediment	In-situ Obs.	As for concentration, sediment observations are used together with discharge observations to calculate sediment loads to the Baltic Sea. Sediment loads to the sea affect visibility depths
	Model	Models can infill temporal and spatial gaps in observations. In particular, sediment concentration sampling is often too sparse to calculate loads without the help of advanced statistical techniques and /or models
Salmon	In-situ Obs.	N/A
	Model	N/A

The temporal resolution should be at least monthly. The details of the data requirements are described in Tab. 11.2.

Table 11.2. Data requirements for Riverine inputs

Variable	Data type	Accessibility		Completeness/ coverage		Resolution			Precision
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.	
River temperature	Obs.	Open. free to download		Major rivers	min. 1yr	Major rivers	N/A	Monthly	0.1°C
	Model			Full coverage	10^{0-2}yr	Full coverage		Monthly	1-2 °C or <(river-sea)temperature different
Discharge	Obs.			Major rivers	min. 1yr	Major rivers		Daily	Unknown
	Model			Full coverage	10^{0-2}yr	Full coverage		Daily	Varying
Nutrients	Obs.			Major rivers	min. 1yr	Major rivers		Monthly	Unknown
	Model			Full coverage	10^{0-2}yr	Full coverage		Monthly	Varying

11.2 Data adequacy assessment

In this section, the data availability, i.e., what data are already available and how they can be accessed, will be assessed. Then the data adequacy will be assessed based on the existing data availability against the data requirements. A summary of data availability is described in Tab. 11.3.

11.2.1 River temperature

River temperature data for Sweden is available as observations from SMHI flow gauging stations up until late 1990s. Data from the region is available in the UNEP GEMS Water database (http://www.unep.org/gemswater/Home/tabid/55762/Default.aspx). Observations are both regular and irregular. There might be more data available at national institutes in the countries draining to the Baltic Sea but these are currently not openly available in for download (at least not in English).

In 2016 stream water temperature was included in the hydrological model E-HYPE application for the first time. Johan Strömqvist, Researcher at SMHI made an evaluation of stream water temperature simulations in E-HYPE version 3.1.1. Results and monitoring stations used are shown in Figure 11.1 and 11.2 below.

The observations in Sweden were used to calibrate the E-HYPE model. As seen in Figure 11.2 there are no observations for the Baltic countries in the dataset used.

The model performance is considered sufficient but it would be good for modelling purposes to increase the availability of existing datasets.

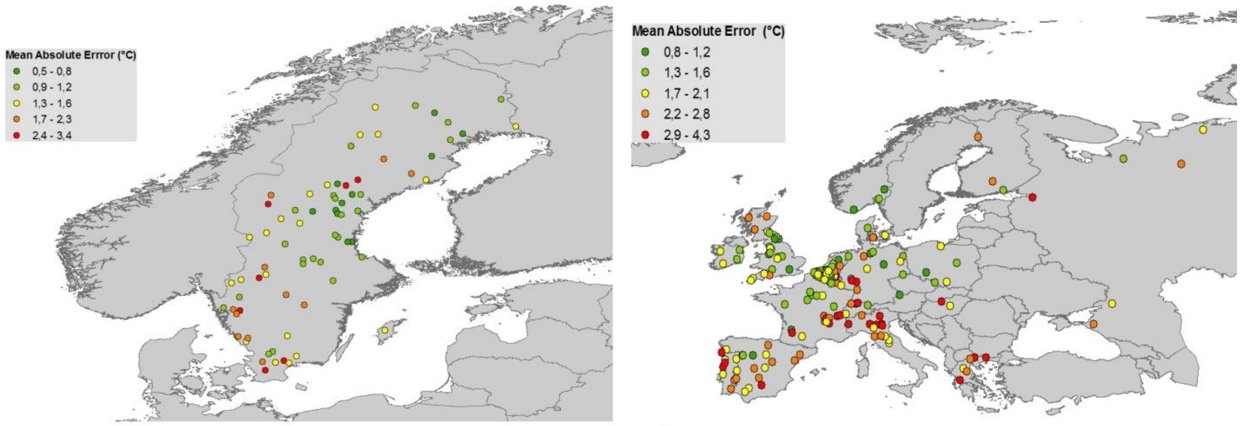

Figure 11.1. Mean absolute error of simulated water temperature at sites in Swedish rivers (left) and European rivers (right)

Table 11.3. Data availability for Riverine inputs

Variable	Data type	Accessibility		Completeness/ coverage		Resolution			Precision	Data provider
		Delivery type	Delivery time	Spatial	Temporal	Hor.	Ver.	Temp.		
River tem-perature	Obs.	On request		Small	Small	N/A	N/A	Variating	Unknown	UNEP GEMS Water
	Model	Excel Free to download		Full coverage	2000-2010	N/A	N/A	Monthly	0.5-4.3°C	SMHI
Discharge	Obs.	Text, one file per station	Manual orders and Email response	Major data gaps	N/A	N/A	N/A	Daily, Monthly	Unknown	GRDC
		Excel			N/A	N/A	N/A	Daily, Monthly	Unknown	Baltex BHDC
		Text, one file per station			N/A	N/A	N/A	Daily, Monthly	Unknown	EWA
	Model	Excel	Free to download	Full coverage	1981-2014	N/A	N/A	Daily	Unknown	SMHI
Nutrients	Obs.	Database	Free to download			N/A	N/A	Aggregated to seasonal and annual means	Unknown	HELCOM EEA
	Model	Excel	Free to download	Full coverage	1981-2014	N/A	N/A	monthly	Unknown	SMHI

11.2.2 Discharge

There are many databases on river discharge. The Global Runoff Data Center (GRDC) manages 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 stored hydrological data from the countries draining into the Baltic Sea however this data set was only updated during the BALTEX project and is no longer managed. Daily and monthly discharge data is available for some years only.

The European Water Archive (EWA) contains daily discharge data and catchment information for smaller catchments in more than 4000 stations in 30 countries in Europe.

To help infill and extend the available observation data, models can be used. For the Baltic Sea region, simulated discharges from the E-HYPE model (Donnelly et al. 2016) are openly available from SMHI. The data can be easily downloaded from a web interface for the drainage area of the Baltic Sea. Nutrient load for phosphorus and nitrogen is also available (http://balt-hypeweb.smhi.se/balthype/uc_downloadtimeseries/index.html).

An evaluation of the E-HYPE model performance has been made and is available to explore through Hypeweb (http://hypeweb.smhi.se/europehype/model-performance/).

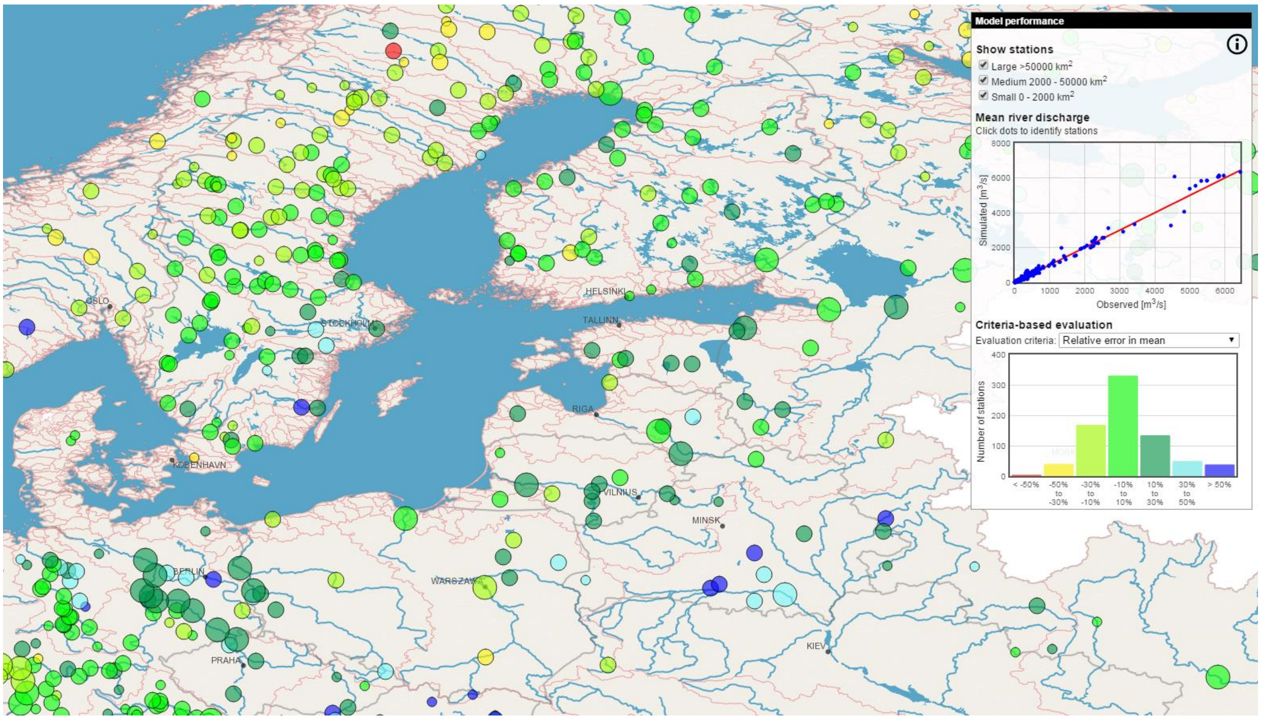

Figure 11.2. Location of observation data and model performance. Color shows relative error in mean and the highest number of stations, about 340, is found within the -10 to +10 % interval.

Figure 11.2 shows the observation stations and model data quality. Generally over the Baltic Sea drainage area the results appear to be within 10 %, but with overestimations in the south east and under in the northern part. The overestimations can be caused by underestimations of water extraction for irrigation, leaving more water available in the river system. Underestimations in northern Europe are related to poor estimation of precipitation in the model´s forcing data. In this region part of the precipitation falls as snow and the input precipitation dataset does not include corrections for undercatch, an important factor when measuring snow, and there is an underrepresentation of observations at high altitudes (Donnelly et al. 2016).

Seasonality is well captured by the E-HYPE model for the Baltic Sea and the inter-annual variations are well reproduced, making the E-HYPE model useful as input to oceanographic models (Donnelly et al. 2016).

Temporal model quality is poor in Scandinavia because many of the rivers are regulated. The E-HYPE model tries to simulate the monthly redistribution of discharge by damming but doesn't attempt to get the correct daily variability (Donnelly et al. 2016, Hundecha et al. 2016).

11.2.3 Nutrient load

To further improve the model homogeneous datasets for human impact such as water abstraction and river regulation schemes is needed (Donnelly et al. 2016, Hundecha et al. 2016). In the Baltic Sea region better data availability from the south east; Poland and Russia is needed and denser data from Finland.

Nitrogen and phosphorous load in monitored rivers in the Baltic Sea catchment area can be found at HELCOM (PLC data) and EEA. There is inhomogeneity in HELCOM dataset as different methods are used to calculate loads in different countries. Data from EEA are not flow weighted which can lead to errors in calculations. Figure 11.3 shows the location of observation cites in HELCOM data

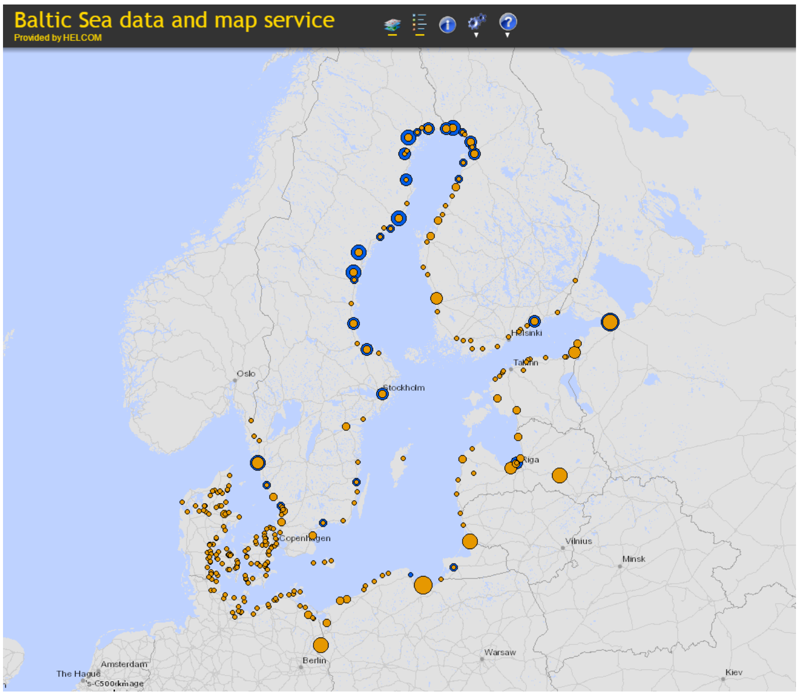

Figure 11.3. A dataset mainly collected during the later part of year 2009 by HELCOM Secretary. Containing flow and nutrient loads in the rivers (HELCOM, 2010).

It is a challenge to estimate accurate nutrient loads from the nutrient concentration data. Nutrient loads cannot be measured since they are the product of concentration and discharge. Observations are available for discharge, nitrogen and phosphorus where the major river inflows to the sea.

The observed concentrations and discharges are not always available for the same site e.g. at a river mouth. There are less observations and data availability for nutrient data compared to discharge. The temporal extent also differs as concentrations are often only measured weekly or monthly while discharge is measured daily.

The spatial distribution of monitoring cites can fail in capturing the nutrient load. Unmonitored small coastal catchments with agricultural land or cities can have high nutrient loads as retention is low (Figure 11.4).

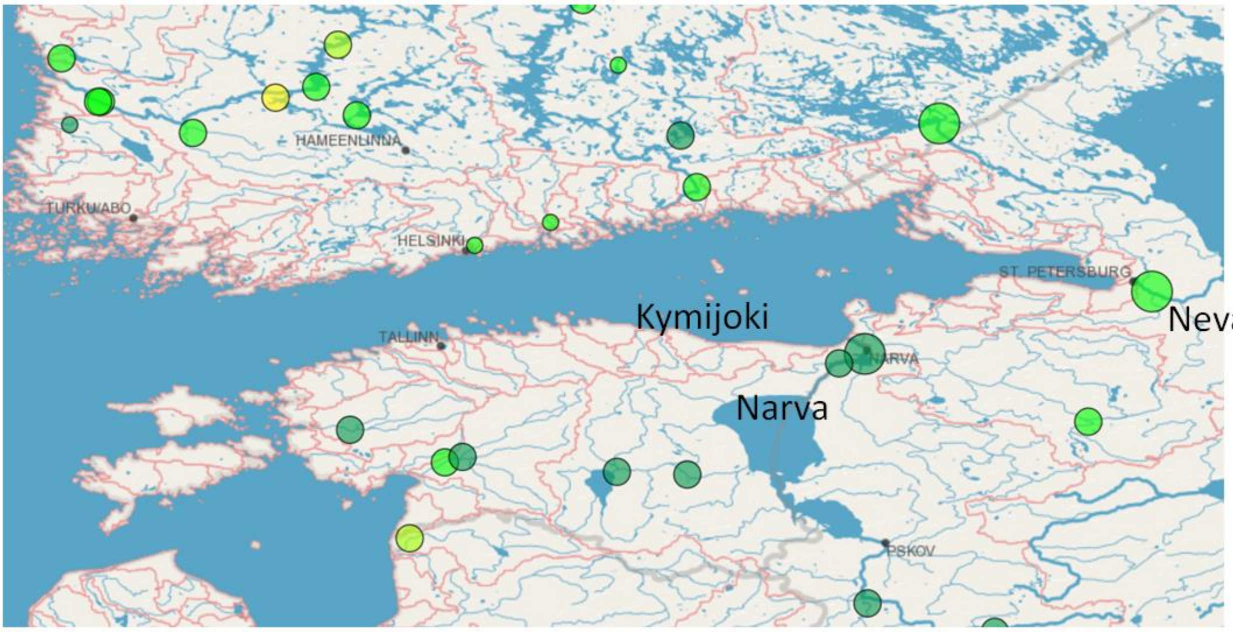

Figure 11.4. Interpolation in space, an example from Gulf of Finland. Showing observation cites of discharge data in major rivers and ungauged catchments in-between. (http://hypeweb.smhi.se/)

When observations are unavailable, simulated discharge can be used together with observed (and simulated) concentrations to estimate loads. The E-HYPE model simulates the flow of water and nutrients through the soil profile (Fig. 11.5).

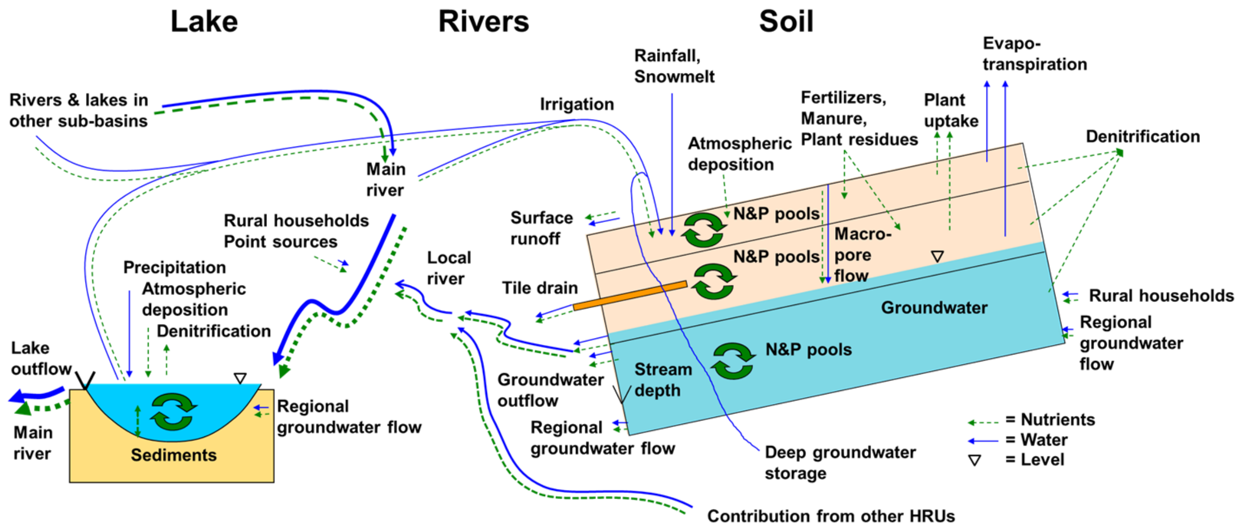

Figure 11.5. Schematic description of HYPE model (http://www.smhi.se/en/research/research-departments/hydrology/hype-1.7994)

Given the limited availability of observation data, particularly long continuous nutrient concentration time-series, simulated discharge and nutrient fluxes, for example, from E-HYPE model are probably the best available data to estimate total fluxes to the Baltic Sea. When using this data, however, the user should be aware of the known biases, for example, if the discharge is over/under estimated the nutrient load will be too. The E-HYPE model is under constant development and improvement, and new versions are released each year. The model developers are constantly expanding the observation database to which the model is tuned and evaluated and as this improves, so do the simulated discharges and loads. Calculating loads from observations is also very uncertain, particularly for TP when sampling frequency is low and not targeted to high flows. It is recommended that in the future the observation quality for nutrients should be improved.

11.3 Conclusions

Challenge 9 River input is to quantify fluxes of fresh water, nutrients (Nitrogen and Phosphorus), sediment and salmon to the Baltic Sea. To determine fluxes of fresh water and nutrient entering the Baltic Sea Temporal resolution of the key variables needed is at least monthly but daily values might be of interest for some applications. Spatial coverage needed is data for the outlet of major rivers as a minimum. Preferably more detailed data. River temperature, discharge and nutrients all have observations and model data available. A summary of the data adequacy for the Riverine input challenge is given in Tab. 11.4.

Table 11.4 Data adequacy for Riverine inputs

Variable	Data type	Accessibility	Completeness/ coverage	Resolution	Precision	Data provider
		Delivery type/time	Spatial/ Temporal	Hor./Ver./Temp.		
River tem-perature	Obs.	FFU*	More observations needed	More data needed	FFU	UNEP GEMS Water
	Model	FFU	FFU	FFU	To be improved	SMHI
Discharge	Obs.	FFU	More observations needed	More data needed	FFU	GRDC, EVA Baltex BHDC
	Model	FFU	FFU	FFU	Fit for use	SMHI
Nutrients	Obs.	FFU	More observations needed	More data needed	Quality needs to be improved	HELCOM, EEA
	Model	FFU	FFU	FFU	Data usable but quality to be improved	SMHI

*FFU: Fit-for-the-use

The available river temperature dataset has few observations of varying spatial and temporal coverage. The E-HYPE model is now simulating river temperature, model performance is considered sufficient but it could be improved by increasing the availability of existing datasets.

Discharge observations are available from different databases but with major data gaps. The Baltex BHDC is no longer updated. The E-HYPE model is used to fill in the gaps and has shown good results over the Baltic Sea drainage area but with overestimations in the south east and under in the northern part. To further improve input data on human impact: water extraction and river regulations are recommended to increase the performance.

Nutrient load is calculated using discharge and nutrient concentration. The observed concentration is often too sparse to calculate loads without the help of advanced statistical techniques and /or models. The E-HYPE model can b used to fill in the gaps with a good result. Improvements, extended monitoring and homogenization of input datasets would further improve the performance.

There are still some unknown numbers in the Tables 2 and 3, some of them will be identified in DAR II. Efforts will also be made to find data of missing variables and if succeeded, their data adequacy will be assessed.

Acknowledgments are given to Chantal Donnelly in SMHI for her inputs to the report.

References

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12 Data adequacy for bathymetry

12.1 Data requirement assessment

Bathymetry (depth) is a fundamental dataset required for a lot of use cases including most of the other challenges in the Baltic Sea Check Point. Data adequacy for bathymetric data is totally dependent on the requirements of each individual use case and requirements for use cases differ extremely.

In general the challenge with bathymetry in the Baltic Sea region is to provide information regarding if an adequate bathymetric dataset exists or not in the area of interest and if it exist whether or not it is possible to get access to the bathymetry data for the use case concerned.

Each possible use case has a set of requirements on the bathymetry data needed. It is essential to analyse existing datasets against requirements and evaluate if available data is fit for purpose. The cost of operations to acquire new and higher quality bathymetric surveys is always considerable and it makes good sense to use existing datasets for multiple purposes whenever possible.

In Table 12.1, the general direction of requirements is listed for some examples of use cases. Note that it is not an exact description of requirements and it is by no means an exhaustive list of use cases.

Table 12.1. Requirements on bathymetry data from different application areas

Application area	Resolution	Depth quality	Positional quality (X,Y)	Comment
Circulation modeling	>100 m	Moderate (1 m)	Moderate (10m or less)	Gridded data enough and harmonized cover for large areas and basins.
Habitat, Fishery	10-50 m	Moderate (1 m)	Moderate (10 m)	
Marine geology	5-10 m	High (< 1 m)	Good (5 m)	Resolution important to reveal structures
Nautical charting, navigation, generally	10-20 m	Very high (< 0.3 m)	High (< 1 m)	Reliable information on minimum depth
Navigation shallow water	2-10 m	Very high (< 0.3 m)	Very high (0,5 m)	Margins important for e.g. port entrance
Engineering	1 m	Very high (< 0.3 m)	Very high (0.5 m)	Requirements changes in the construction process
Marine archaeology	0.1 m	High (< 1 m)	Good (5 m)	Resolution most important. Raw measured data preferred.

12.2 Data adequacy assessment

12.2.1 Data availability

We see that within the Baltic Region the national Hydrographic Offices responsible for nautical charting also are the most relevant sources and contact points for bathymetry data in their respective country.

There are 9 nations surrounding the Baltic Sea. All but one of them, Russian Federation, are members of the EU. The International Hydrographic Organization (IHO) is a global inter-governmental organisation for cooperation concerning primarily hydrography and nautical charting. All but one of the nations (Lithuania) are members of the IHO.

Within the IHO regional cooperation is organised by regional hydrographic commissions (RHCs) and all 9 nations are members (Lithuania as associate member) of the Baltic Sea Hydrographic Commission (BSHC).

The BSHC is a quite active commission and has several very stable working groups. The tasks of some of these working groups are very relevant to bathymetry.

The Baltic Sea Bathymetry Database WG (BSBDWG)

The Swedish Hydrographic Office was specifically tasked by the Swedish government to use the IHO network (i.e. BSHC) to create a depth model for the Baltic Sea. Following a suggestion from Sweden the BSBDWG was started by BSHC in 2009 to work with this task.

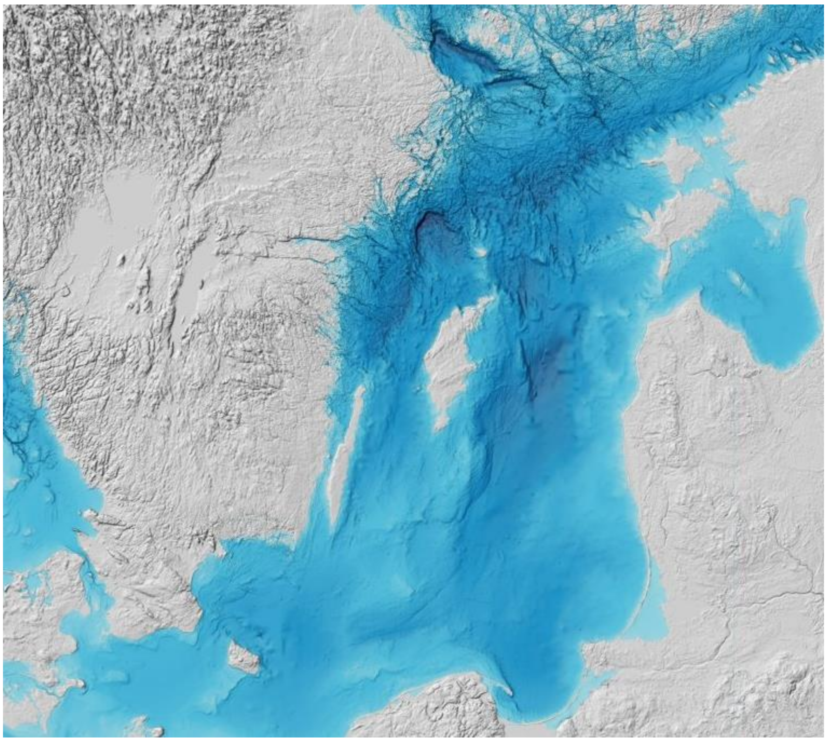


Figure 12.1. Example display from Baltic Sea Bathymetry Database

The work of this WG has resulted in a harmonised gridded bathymetry model (Broman et al, 2016; Hell and Jackbson, 2011) and a website with some useful functionality to explore this dataset (see http://data.bshc.pro). From the website it is possible to download depth data and it also provides (serves) geodata services as WMS and WCS[1]. The website also provides information on how the model has been produced etc.

The dataset produced for the site is very much a "least common

[1] Open Geospatial Consortium (OGC) Web Map Service and Web Coverage Service

denominator" of the various conditions in the 9 nations concerned especially with regard to allowed access to bathymetry. It is also very close to "Open Data", data is free of charge and only a few restrictions apply.

To provide input data for the harmonised data set the working group had to decide on a resolution that is (or was at the time) acceptable to the nations that actively participated in the group. See more on accessibility to bathymetry data in other paragraph. The decision taken to compile the current version of BSBD was to produce a 500m gridded data set. Ideally this should be based on actual measured soundings (depth values) with 500m density or better.

The BSBD also supplies the dataset to EMODNET Bathymetry so for the most part of the Baltic the same dataset is in use. EMODNET region North Sea has an overlap with the coverage of BSBD so west of the longitude 12°30"E EMODNET Bathymetry have used other sources as well.

The Baltic Sea HELCOM Monitoring Working Group (MWG)

As a result of higher level commitments within the HELCOM cooperation, stated in several ministerial declarations, there is a common joint program to perform hydrographic (bathymetric) surveys for the major shipping lanes ("Motorways of the sea") within the Baltic Sea area. The BSHC has adopted the task to manage and develop the program and monitor the progress of the program and provide the HELCOM secretariat with regular reports.

The program (or survey scheme) consists of areas to be surveyed and a planned time line. Areas are sorted into three categories where categories 1 & 2 are the most important areas for commercial shipping. All other areas fall in to category 3 (Fig.12.2). It is important to note that all nations are asked to provide their plans and time lines for hydrographic surveys of all categories. To do surveys of especially category 3 areas in mostly very shallow waters is a huge undertaking and completion is decades away unless substantial resources are created.

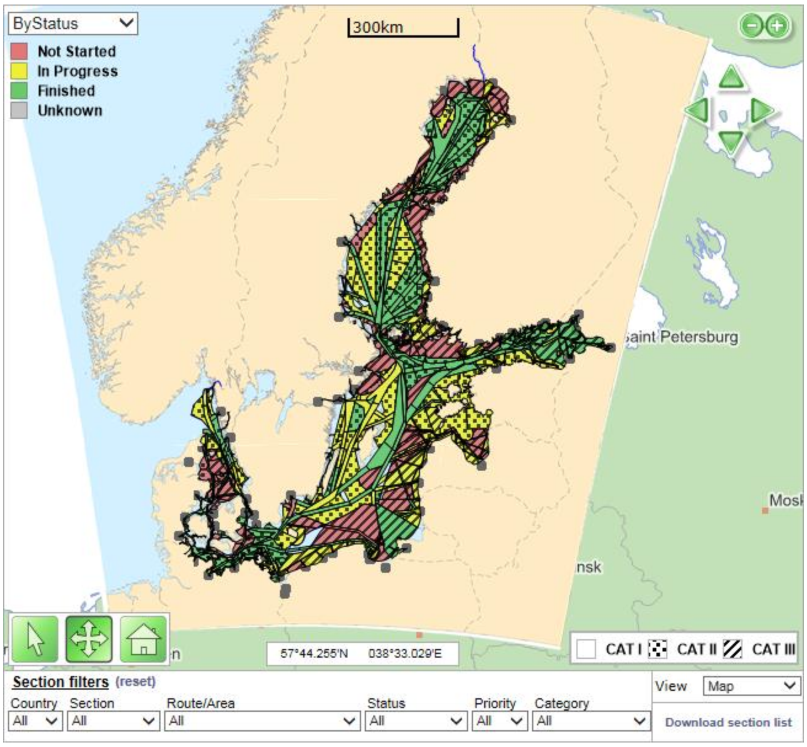


Figure 12.2. The Baltic Sea HELCOM Resurvey Scheme Database

The MWG has created a database of planned and performed survey areas and members in the WG are committed to regularly update the status. The current version of the website used is http://HELCOMresurvey.sjofartsverket.se/HELCOMresurveysite/ and is available for public use. Note that a new version of the web application is planned for near release and this has caused members to delay the update of data until the new version exists. Note also that areas marked as finished should fulfil the IHO

S-44 standard for hydrographic surveys and resulting bathymetry data sets should be adequate for a large range of use cases. See more under paragraph "Data Quality" below.

12.2.2 Data Accessibility

When dealing with bathymetry data sets several nations, such as Sweden and Finland, have the position that knowledge of detailed bathymetry in certain areas is regarded as an issue of interest for the national defence. This also means that there is an administrative process where an application has to be approved before access to such classified data is granted. For Sweden these restrictions concern bathymetry data in the territorial waters.

For some of the Baltic Sea nations (e.g. Sweden) there are also costs involved to get access to bathymetry data, it is not made available free of charge.

There are also Baltic Sea nations that to various degrees apply Open Data policies. In Germany for example there is an open access to the raw source bathymetry data collected by their Hydrographic Office.

12.2.3 Data quality

It is obvious that existence of high quality, high-resolution bathymetry data is very heterogeneously distributed within the Baltic Sea area and that a totally reliable picture of available data is hard to generate. The HELCOM Resurvey Scheme described earlier is one attempt to provide a description of the status of performed and planned bathymetry surveys of the Hydrographic Offices around the Baltic Sea.

Table 12.2. Details of Finnish-Swedish implementation of S-44

	Exclusive order	Special order	Order 1a	Order 2
Aids to navigation and significant topography[3]	0.5	1.0	2.0	5.0
Coastline and topography less significant to navigation horizontal uncertainty (m)	5	10	20	20
Depth horizontal uncertainty[4] (m)	2.0	2.0	5.0 + 5% of depth	20 + 10% of depth
vertical uncertainty $\pm\sqrt{a^2+(b\cdot d)^2}$ (m)	a = 0.15 b = 0.004 d = depth	a = 0.25 b = 0.0075 d = depth	a = 0.50 b = 0.013 d = depth	a = 1.0 b = 0.023 d = depth
Cubic feature detection capability[5]	> 0.5 m >0.2m (bar sweeping)	> 0.7 m >0.3m (bar sweeping)	at least > 2 m or 10% of depths	> 10% of depths
"Full sea floor search"	**required**	**required**	**required**	**required**
Fairway areas[6]	Exclusive decision	0 - 20 m	20 - 100 m	100 m -
Other depth areas[7]	Exclusive decision	-	0 - 100 m	100 m -

The IHO has established a standard " S-44 IHO Standards for Hydrographic Surveys" where naturally the use case "nautical navigation" is in focus. All areas registered as done/ready in the HELCOM Resurvey Scheme data base should fulfil S-44. We note that S-44 may be slightly differently implemented in the various nations concerned but S-44 requirements generally calls for high quality surveys and especially in shallower fairway/seaway areas. Finland and Sweden have established a joint implementation (Finish-Swedish IHO Standard) FSIS-44 described in the Tab. 12.2.

The available bathymetry data around the Baltic Sea is a mix from various epochs and the survey technologies and methods have changed and improved over time. On the Swedish Maritime Administration (SMA) external website the map below is found (Fig. 12.3). The existing bathymetry data at the SMA Hydrographic Office has been divided into three categories with regard to age and significant technology shifts. The **green** colour represents hydrographic surveys from approximately 1990 and forward where multi-beam echo sounder has been used and data fulfils FSIS-44. The areas with the **yellow** colour represents various technologies from about 1940 and forward with single beam sonar , LIDAR and other technologies, quite reliable data but it does not fulfil FSIS-44. The third category is marked with **red** colour, it represents surveys (mostly lead line) earlier than 1940 or generally unknown origin.

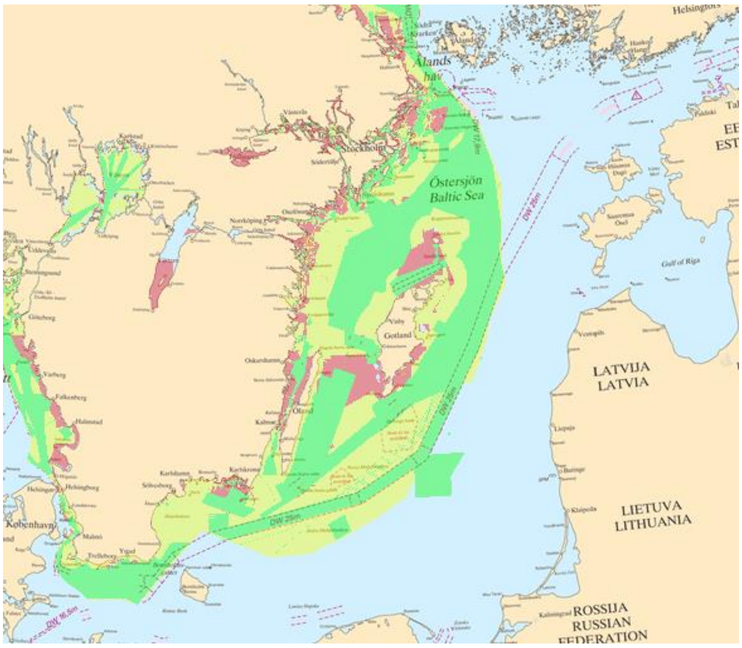
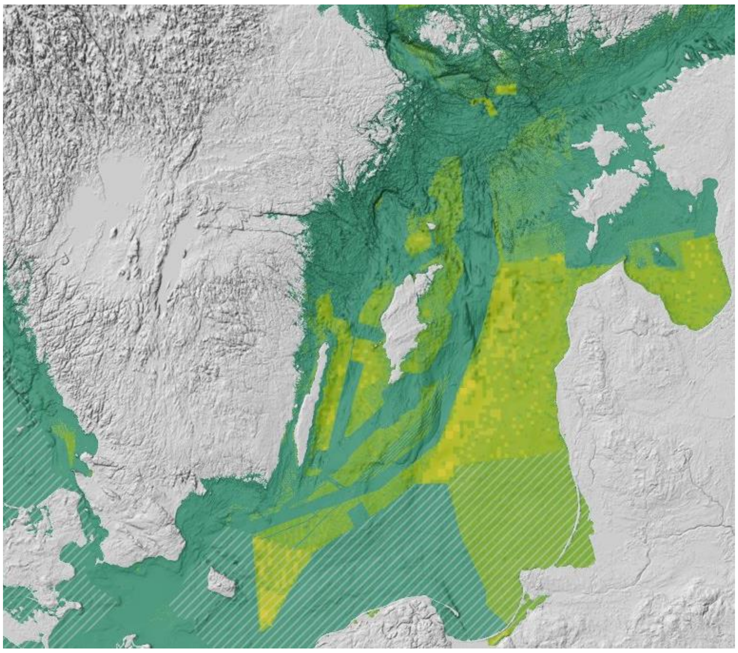


Figure 12.3. Example describing different epochs of survey data

The original source data for the Baltic Sea Bathymetry database, which is a modelled (gridded) dataset is also somewhat heterogeneous. Ideally the source should consist of measured soundings with a density similar or better compared to the resulting grid, in this case 500m. The site http://data.bshc.pro provides a presentation of the underlying source data where green describes that source density approximately corresponds to resulting grid and yellow to red indicates sparser source data (Fig. 12.4). In the areas with a hatched pattern the source itself is also already gridded data.



Figur2 12.4. Display from Baltic Sea Bathymetry Database portraying source density for harmonised model

12.3 Conclusions

A heterogeneous overall picture

There are 9 coastal nations around the Baltic Sea and the national regulations and policies concerning open geographic data in general and bathymetry in particular varies greatly between countries.

The existence of good quality bathymetric data sets is gradually improving but bathymetric surveys are expensive and time consuming operations. In a substantial area of the Baltic Sea the quality of available bathymetry is still low. This seems to be especially the case for shallower waters that are not of interest for commercial shipping.

For important aspects of bathymetric data such as availability, accessibility and data quality the situation in the Baltic Sea as a whole is heterogeneous and this may result in confusion and hindrance for the end user looking for suitable data.

Possible results of the BSCP Bathymetry challenge

This project as such **cannot** change the situation concerning available bathymetric data in the region. However, it is possible to improve the situation concerning available metadata and the visibility of metadata.

It should be possible to describe the national variations regarding distribution of bathymetry. This should include positions for open data, military classified data and business models. A list of national primary contact points for bathymetry data should be included.

We should investigate within the Baltic Sea nations the possibility to describe existing "non S-44" bathymetric data sets in a somewhat harmonised way.

Several of the initiatives referred to in this report will be able to provide geodata services to the BSCP web portal and contribute to improved metadata published in the portal.

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IHO standards for Hydrographic Surveys. http://www.iho.int/iho_pubs/standard/S-44_5E.pdf

13 Data adequacy analysis for Alien Species

13.1 Data requirement assessment

13.1.1 Introduction

Alien species (synonyms: non-indigenous, non-native, exotic, introduced) are species, subspecies or lower taxa introduced outside of their natural range (past or present) and outside of their natural dispersal potential (Olenin et al. 2010). This includes any part, gamete or propagule of such species that might survive and subsequently reproduce. The term, most frequently used in current scientific and administrative documents, including the Marine Strategy Framework Directive (MSFD), is "non-indigenous species" (NIS). Presence of NIS in a given region is always due to intentional or unintentional introduction resulting from human activities, such as shipping, aquaculture, life food trade, etc. Natural shifts in distribution ranges, e.g. due to climate change or dispersal by ocean currents, do not qualify a species to be a NIS. However, secondary spread of NIS from the area(s) of their first arrival may occur without human involvement due to dispersal by natural means. In some cases the true origin of a species remains obscure because of insufficient taxonomic knowledge, lack of early introduction records or other reasons. Such cryptogenic species (CS), i.e. those which cannot be ascribed as being native or alien (*sensu* Carlton, 1996) should be also taken into account, especially, then precautionary measures or risk assessment tools are being developed.

Invasive alien species (IAS) is a commonly accepted term to indicate a subset of established NIS and/or cryptogenic species, which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse impact on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions (Olenin et al. 2010). Sometimes the term "invasive species" is used as a synonym to all NIS. This is not correct, because only a small part of NIS may reach high abundances and cause harm.

The adverse effect of IAS on quality of aquatic environment is called biological pollution (biopollution), which may include impacts at several levels of biological organization: an individual organism (internal biological pollution by parasites or pathogens), a population (by genetic change, e.g. hybridization of native species with IAS; or shifts in size/age structure due to predation), a community (by structural shift, i.e. dominance of IAS, replacement or elimination of native species), a habitat (e.g. by modification of physical-chemical conditions) or an ecosystem (e.g. by alteration of energy and organic material flow). Biopollution may also cause adverse economic consequences and impacts on human health (Elliott, 2003; Olenin et al., 2007, 2010).

MSFD specifically addresses the problem of alien species in the Good Environmental Status (GES) descriptor 2: "*Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem*". Thus, the absence or minimal level of biological pollution is one of the goals of achieving a GES of the Baltic Sea. Among the vast spectrum of potential NIS, it is practically impossible to predict which species may become invasive. Therefore, precaution is recommended as species introductions are irreversible, they accumulate over time, and no control of IAS without affecting other components of the marine ecosystem is feasible once an invasion process is underway.

13.1.2 Data requirement

The objectives of the Alien species studies in the BSC project require different types of data and methods; however no one needs real in-situ measurements of oceanographic parameters (Tab. 13.1.). The Objective 1, divided into two different tasks (Taxonomy and Introduction history) needs specific information on species classification and taxonomic nomenclature, as well as data on species first observations in different countries and vectors involved in introduction. The real in-situ data is needed only one task (digital map). Fulfillment of the objectives 2, 4 and 5 is based on systematic reviews, based on published literature sources. There are no data on that tasks (Impacts, Indicators, New technology) at EMODnet, ICES data center or at other centralized data portals, therefore, the data adequacy for that objectives is not considered in the present report.

Table 13.1. Data requirement assessment for the Challenge Alien Species; n/r – not relevant

Objectives in BSCP	Task	Data type	Spatial & temporal coverage
1. Collate and verify information on the Baltic Sea alien species taxonomy and their introduction history.	Taxonomy	Expert judgement, DNA sequence	Entire Baltic Sea; years, decades
	Introduction history	Published source, observation	
2. Compile and analyse data on alien species impacts on ecosystem and economy.	Impacts on ecosystem and economy	Published source, BPL index	Entire Baltic Sea, different sub-regions
3. Produce a digital map of alien species distribution in the Baltic Sea area.	Digital map	In-situ record (geographical coordinates)	Entire Baltic Sea
4. Identify knowledge gaps in relation to alien species and identify most suitable indicators to determine their impacts on marine ecosystem and economy.	Indicators	Published source	n/r
5. Review new technologies allowing early detection and more accurate identification of alien species.	New technology	Published source	n/r

13.2 Data adequacy analysis

13.2.1 Alien species taxonomy and introduction history

13.2.1.1 Information system on aquatic non-indigenous and cryptogenic species AquaNIS

The main data source for the alien species taxonomy and introduction history is the Information system on aquatic non-indigenous and cryptogenic species AquaNIS (2016) (Fig. 13.1.). The system was developed as part of the EU funded project VECTORS (Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors, FP7/2007-2013). In addition to the data gathered within VECTORS, AquaNIS inherited and incorporated multiple NIS/CS 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"; EU FP6 and FP7 projects ALARM, DAISIE, IMPASSE, MEECE; European Census of Marine Life (2009-2010), Baltic Sea Alien Species Database (1997-2012).

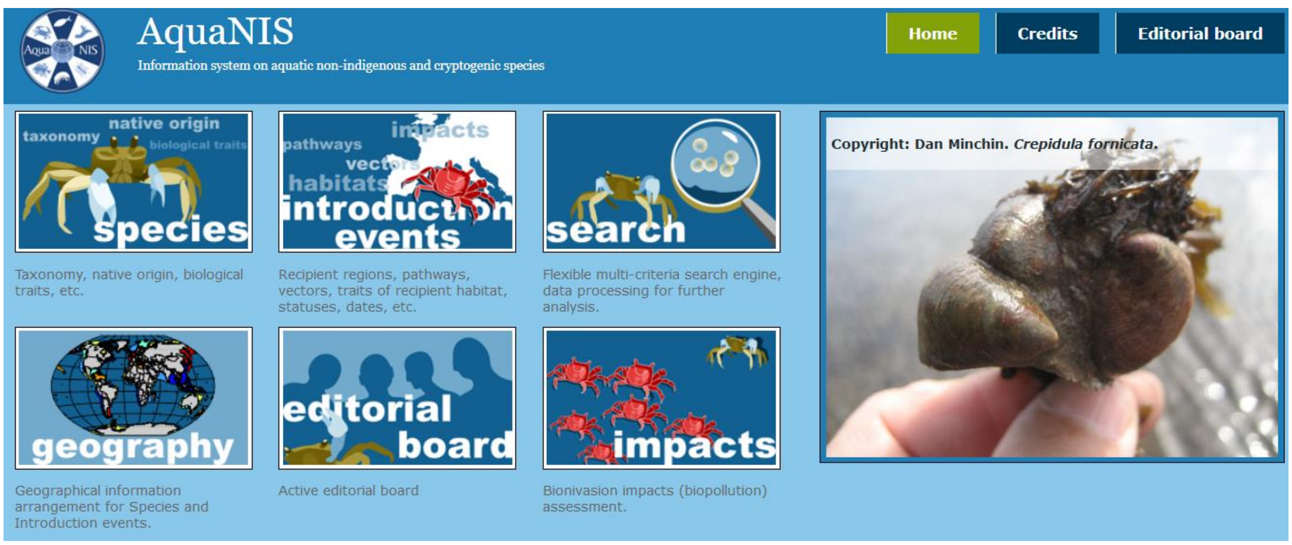


Figure 13.1. Front page of the online Information system on aquatic non-indigenous and cryptogenic species AquaNIS. Assessed at www.corpi.ku.lt/databases//aquanis (2016-08-29).

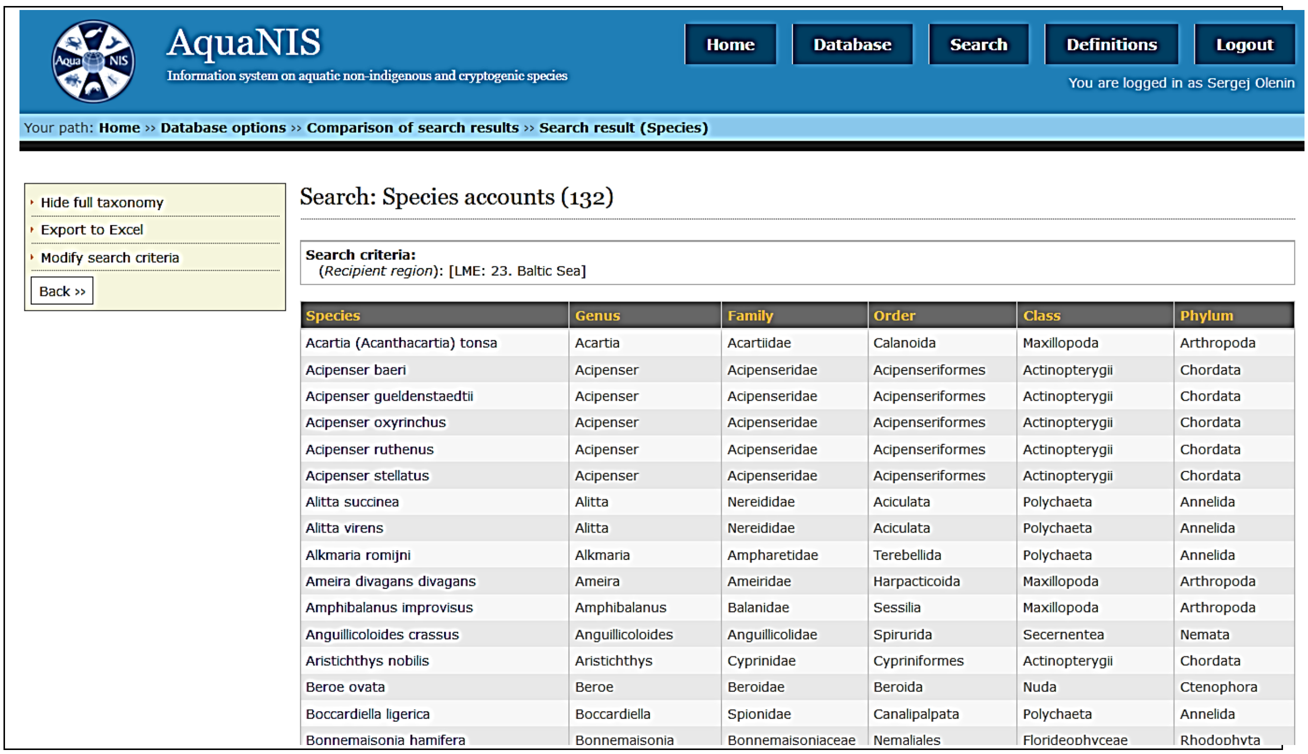
AquaNIS is designed to assemble, store and disseminate comprehensive data on NIS, and assist the evaluation of the progress made towards achieving management goals (Olenin et al. 2014). The system differs substantially from existing NIS information sources in its organizational principles, structure, functionality, and output potential for end-users; it seeks to ensure the long-term maintenance and reliability of the database by continuous update and scientific validation of its data. The ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) since 2013 is annually updating records on NIS findings in all Member States, including the Baltic Sea, North Sea and Atlantic coast countries (WGITMO, 2013). In addition, AquaNIS contains data on NIS and CS in other European regional seas (incl. the Black Sea and the Mediterranean Sea) as well as in some other marine regions of the

World (Canadian Arctic, New Zealand, North East Pacific countries), which makes possible interregional comparisons and tracing the global spread of NIS.

Currently, AquaNIS (2016) contains in public access data on 992 species involved in 2933 introduction events in > 50 regions around the World. The data on species records in recipient regions is completed with information on their taxonomy, reproduction mode, life form, association with ballast water, availability of molecular data, etc.

13.2.1.2 Taxonomy and life forms

AquaNIS is linked and regularly updated from the species accounts in a global database the World Register of Marine Species, WoRMS (2016). Taxonomic information can be retrieved for all species registered in the Baltic Sea (Fig. 13.2.).



Species	Genus	Family	Order	Class	Phylum
Acartia (Acanthacartia) tonsa	Acartia	Acartiidae	Calanoida	Maxillopoda	Arthropoda
Acipenser baeri	Acipenser	Acipenseridae	Acipenseriformes	Actinopterygii	Chordata
Acipenser gueldenstaedtii	Acipenser	Acipenseridae	Acipenseriformes	Actinopterygii	Chordata
Acipenser oxyrinchus	Acipenser	Acipenseridae	Acipenseriformes	Actinopterygii	Chordata
Acipenser ruthenus	Acipenser	Acipenseridae	Acipenseriformes	Actinopterygii	Chordata
Acipenser stellatus	Acipenser	Acipenseridae	Acipenseriformes	Actinopterygii	Chordata
Alitta succinea	Alitta	Nereididae	Aciculata	Polychaeta	Annelida
Alitta virens	Alitta	Nereididae	Aciculata	Polychaeta	Annelida
Alkmaria romijni	Alkmaria	Ampharetidae	Terebellida	Polychaeta	Annelida
Ameira divagans divagans	Ameira	Ameiridae	Harpacticoida	Maxillopoda	Arthropoda
Amphibalanus improvisus	Amphibalanus	Balanidae	Sessilia	Maxillopoda	Arthropoda
Anguillicoloides crassus	Anguillicoloides	Anguillicolidae	Spirurida	Secernentea	Nemata
Aristichthys nobilis	Aristichthys	Cyprinidae	Cypriniformes	Actinopterygii	Chordata
Beroe ovata	Beroe	Beroidae	Beroida	Nuda	Ctenophora
Boccardiella ligerica	Boccardiella	Spionidae	Canalipalpata	Polychaeta	Annelida
Bonnemaisonia hamifera	Bonnemaisonia	Bonnemaisoniaceae	Nemaliales	Florideophyceae	Rhodophyta

Figure 13.2. Retrieving taxonomy information for species registered in AquaNIS: Genus, Family, Order, Class and Phylum are indicated for all 132 non-indigenous and cryptogenic species recorded in the Baltic Sea

While most of taxonomic information registered in WoRMS is based on traditional qualitative or quantitative comparisons of morphological features of species (including also notes on their behavior, ecology, etc.), also DNA sequence data is increasingly used for species identification. The molecular data is available for 30 % of species registered in AquaNIS (39 out of 132).

Besides taxonomy, it is equally important to include life form characteristics of the species into the analysis (Tab. 13.2.). All species recorded in AquaNIS can be ascribed to ten life forms: neuston, zoobenthos, phytobenthos, zooplankton, phytoplankton, benthopelagos, nekton, ectoparasite, endoparasite and symbiont (non parasitic). At different life history-stages (adult, juvenile, larva, egg and resting stage) a species may belong to different life forms, e.g. most benthic invertebrates at larval stage belong to zooplankton and turn to zoobenthos at the adult stage. Knowledge on the life forms at different life history-stages is essential for risk assessment of NIS spread, e.g. possibility to be transferred by ballast water, prioritizing the most invasive species and other purposes (Cardeccia et al. 2016).

Table 13.2. Life forms of alien species at different life history-stages (A - adult, J - juvenile, L -larva, E - egg and R - resting stage): an example (extraction from AquaNIS) for 14 species

Species	Life forms									
	Neuston	**Zoobenthos**	**Phytobenthos**	**Zooplankton**	**Phytoplankton**	**Benthopelagos**	**Nekton**	**Ectoparasite**	**Endoparasite**	**Symbiont**
Acartia (Acanthacartia) tonsa		E R		A J L						
Acipenser baeri		E		L			A J			
Acipenser gueldenstaedtii		E		L			A J			
Acipenser oxyrinchus							A			
Acipenser ruthenus							A J			
Acipenser stellatus							A J			
Alitta succinea		A		L						
Alitta virens		A								
Alkmaria romijni		A J L E								
Ameira divagans divagans				A						
Amphibalanus improvisus		A		J L E R						
Anguillicoloides crassus									A E	
Aristichthys nobilis				J L			A			
Beroe ovata				A J L E						

13.2.1.3 Species status and population status

The species status is defined as non-indigenous (alien) or cryptogenic (see sub-chapter 1.1). There are 132 NIS and CS recorded in the Baltic Sea: 119 NIS and 13 CS (AquaNIS, 2016). Of them, 7 species have both NIS and CS status in different recipient regions, e.g. species were registered as CS in one Baltic Sea country and as NIS in another.

The population status of a species is indicated for each introduction event as:

- Established - a species is known to form a reproducing population in a wild;
- Not established - there is no evidence of a species' reproducing population in a wild, or
- Unknown - there is no reliable information on population status of a species.

Information on the species population status is needed to rank the most impacting NIS, prioritize management options and implementation of invasive species policies. Also, the population status should be taken into account for the analysis of species distribution and projection of their spread (see sub-chapter 2.3). Currently, 59% of all NIS and CS are established at least in one country surrounding the Baltic Sea.

13.2.1.4 Introduction events records

The introduction histories of NIS and CS in the Baltic Sea also are being registered in AquaNIS. The basic data entry is an introduction event record, documenting a species introduction into a recipient region. There are ten such regions: nine countries bordering the Sea with Russia being represented by two regions (the Kaliningrad region located at the south-eastern part of the Baltic, and St. Petersburg region in the easternmost part of the Gulf of Finland). The date of the first record indicates when a species presence was noticed in a region, according to different levels of certainty (year, decade or century). In AquaNIS only the first record of a NIS arrival to a recipient region is recorded, i.e. multiple arrivals of the same species into the same recipient region are not documented, but may be remarked upon in the comment boxes provided. Thus, the introduction history for each species may be traced both at the level of individual recipient regions, and at the level of the entire Baltic Sea. Currently, Germany has the highest (66) and Lithuania the lowest (33) number of recorded species introductions. On average, 27 NIS/CS are currently established (with min/max of 20 and 42 species in Latvia and Germany, respectively), while 13 species have been unable to establish self-sustaining populations per country (Tab. 13.3.).

Table 13.3. Status of non-indigenous and cryptogenic species in the Baltic Sea by countries.

Country/Region	Established	Not established	Unknown
Denmark	25	10	4
Estonia	25	8	1
Finland	24	20	1
Germany	42	11	13
Latvia	20	17	3
Lithuania	22	10	1
Poland	32	17	7
Russia/SEB	26	12	5

Russia/GoF	21	14	3
Sweden	31	10	8
Average	27	13	5

To address certain management requirements, e.g. ballast water management related risk assessment, an even more detailed occurrence of NIS can be documented in AquaNIS to the level of ports and port vicinities (Olenin et al., 2014; 2016).

13.2.1.5 Reason for introduction: pathways and vectors

A reason for introduction is a pathway and a vector. A pathway is the route that a NIS toFFU to enter or spread to a recipient region, while a vector is a transfer mechanism or the physical means by which a species was transported (Minchin et al., 2009). Each pathway may have a number of vectors. For example, the pathway “vessels” includes such vectors as “ballast water”, “ballast tank sediments”, “sea chests” and “ship’s hull”; the pathway “Culture activities“ comprises vectors “Aquaculture equipment”, “Associated water & packaging material”, “Intercontinental stock movement”, “Regional stock movement”, “Unintentional release & escapees“. More than one pathway and several vectors may be involved in a transfer of a species. Also, there is a pathway “Natural spread from neighboring countries”, which is ascribed for species, which were introduced as NIS elsewhere (e.g. in the North Sea) and then spread to the Baltic.

According to AquaNIS (2016) definition, an introduction event should be ascribed to a pathway/vector with the defined level of certainty:

- The highest certainty (“direct evidence”) is applied, when a NIS was actually found associated with the specific vector(s) of a pathway at the time of introduction to a particular locality.
- The “very likely” is applied where the species appears for the first time in a locality where a single pathway/vector(s) is known to operate and where there is no other explanation that can be argued for a NIS presence except by this likely pathway/vector(s).
- If an introduction event cannot be convincingly ascribed to a single pathway/vector, because more than one pathway could be involved and/or different life stages of the same species may be transported by different vectors of the same pathway, the lowest level of certainty (“possible”) is applied.

Knowledge on pathways and vectors is important for risk assessment and management as it helps to prioritize transfer mechanisms and prevent other NIS to use the same vector in the future. Data on pathways and vectors are stored in AquaNIS database for each introduction event (Fig. 13.3).

13.2.2 Alien species distribution

The mapping of the spread of NIS between and within Large Marine Ecosystems (LMEs, *sensu* Sherman and Duda, 1999), such as the Baltic Sea, is needed to identify principle pathways and vectors of introduction within countries and LMEs, define the most invasive species as well as “next pests” (*sensu* Hayes et al., 2005) to provide target lists for NIS monitoring. Also, such data is essential to measure the

SPECIES / DATE	
Species	Pontogammarus robustoides
Date of the first record (?)	1962

REGIONS	
Recipient region (?)	Country: Lithuania LME: 23. Baltic Sea
Source region (?)	Country: Ukraine

PATHWAY / VECTOR	
Pathway / Vector (?)	Level of certainty: Direct evidence Pathway: Culture activities Vector: Regional stock movement **References (not structured):** Gasiunas I. 1964. Acclimatisation of forage crustaceans into the Kaunas waterpower plant reservoir and possibility of their migration into other waters of Lithuania [Aklimatizacija kormovykh rakoobraznykh v vodokhranilische Kaunasskoj GES i vozmozhnost ikh migracii v drugije vodojemy Litvy. Trudy Ak.Nauk Lit.SSR, Serija B, 1(30) (in Russian) **Comments:** Intentionally introduced into the inner water bodies of Lithuania along with other Ponto-Caspian crustaceans

SPECIES / DATE	
Species	Cercopagis (Cercopagis) pengoi
Date of the first record (?)	1992

REGIONS	
Recipient region (?)	Country: Estonia LME: 23. Baltic Sea
Source region (?)	LME: A2. Caspian Sea --> LME sub-region: Caspian Sea

PATHWAY / VECTOR	
Pathway / Vector (?)	Level of certainty: Highly likely Pathway: Vessels Vector: (Highly likely) Ballast tank sediments Vector: (Highly likely) Ballast water

Figure 13.3. An example of information retrieval on pathways and vectors in AquaNIS. Above: Species Pontogammarus robustoides, introduced in 1962 to Lithuania' coastal waters from Ukraine; pathway "Culture activities", vector "Regional stock movement"; level of certainty "Direct evidence". Below: Species "Cercopagis (Cercopagis) pengoi, introduced in 1992 to Estonia; pathway "Vessels", vector "Ballast water tank sediment" or "Ballast water", level of certainty "Highly likely".

effectiveness of legislative and administrative instruments, such as MSFD, EU Regulation on Invasive Alien Species, and the International Convention for the Control and Management of Ship's Ballast Water and Sediments, in prevention of new introductions (Olenin et al., 2016).

In producing the digital maps, the priority should be given to the established NIS, which are known to form reproducing populations in a wild. In this study, we are compiling georeferenced data and environmental tolerance data for alien species, which are known to be established in the Baltic Sea.

Data on NIS and CS distribution is of different origin. The exact coordinates on species findings may be extracted from monitoring data provided by the ICES Data portal (Fig. 13.4.).

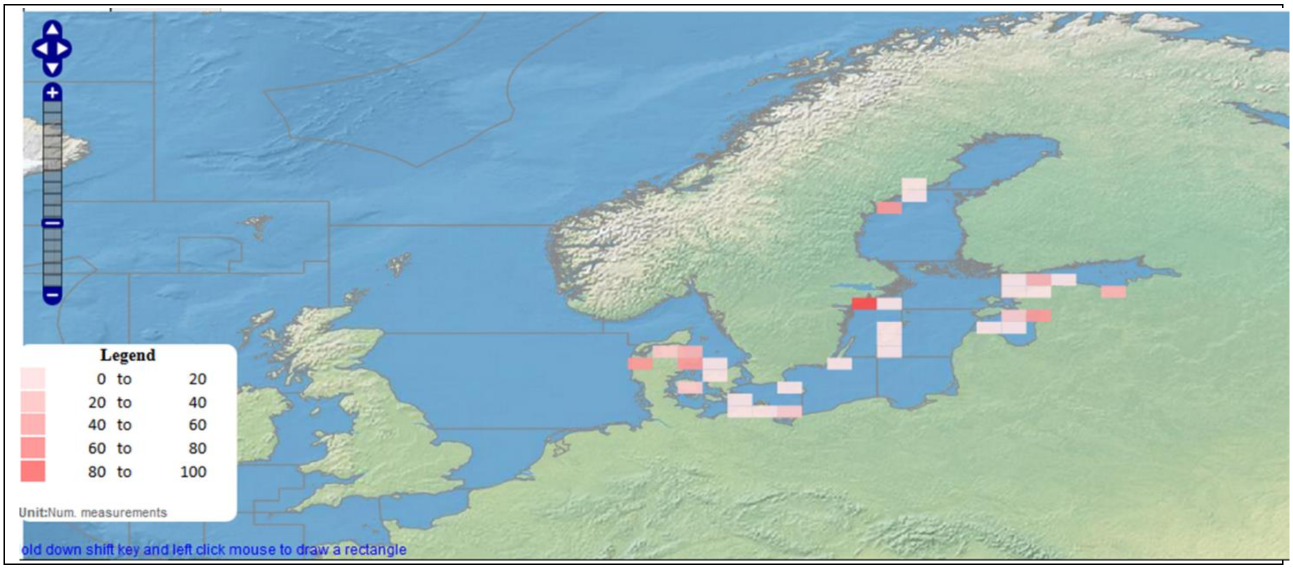


Figure 13.4. An example of data availability visualization at the ICES Data portal. Legend shows number of measurements made in different geographical areas (rectangles), where a species was recorded (in this case - *Amphibalanus improvisus*).

It is important to note, that incomplete data on species distribution may lead to incorrect visualization (digital maps), and, consequently, wrong conclusions about total number of NIS present in a country, most invasive species, effectiveness of management measures, etc. For example, in this very case (Fig. 13.3.), the conclusion can be made that *Amphibalanus improvisus* is not recorded at the coasts of Poland, Russia (Kaliningrad), Lithuania and Latvia. This is not correct, because that species has established abundant populations at those coasts (AquaNIS, 2016 and references therein).

Not all NIS have been recorded at standard biological monitoring stations, many of them were first discovered in port areas, on coastal and offshore artificial structures, in canals, aquaculture sites, which usually are not monitored. Thus, in order to produce a realistic map the geographical data should be completed from published sources of information.

For many early introduction events, only a recipient region is indicated, e.g.: "*the species X was released in the coastal waters of Latvia*". Sometimes, a map is provided showing sampling stations, where a species was found. Such information may be used to derive coordinates, recognizing a certain ambiguity involved. In recent publications, geographical coordinates of species records usually are presented.

Thus, the georeferenced data can be obtain in three different ways:

1) "exact coordinates" - geographical coordinates of a sampling point where a species was found, extracted from the data provider source;
2) "map digitalization" - coordinates extracted manually from the published map(s) using software such as Google Maps;
3) "expert judgment" - extraction of data by an expert based on verbal description of a finding location (e.g. a species was found in the northern part of the Curonian Lagoon".

Table 13.4. Availability of geo-referenced data on alien and cryptogenic species distribution in the Baltic Sea (as per 2016-08-22)

	Exact coordinates	Map digitalization	Expert judgment
Number of species	28	12	16
Number of geo-referenced points	2759	46	46

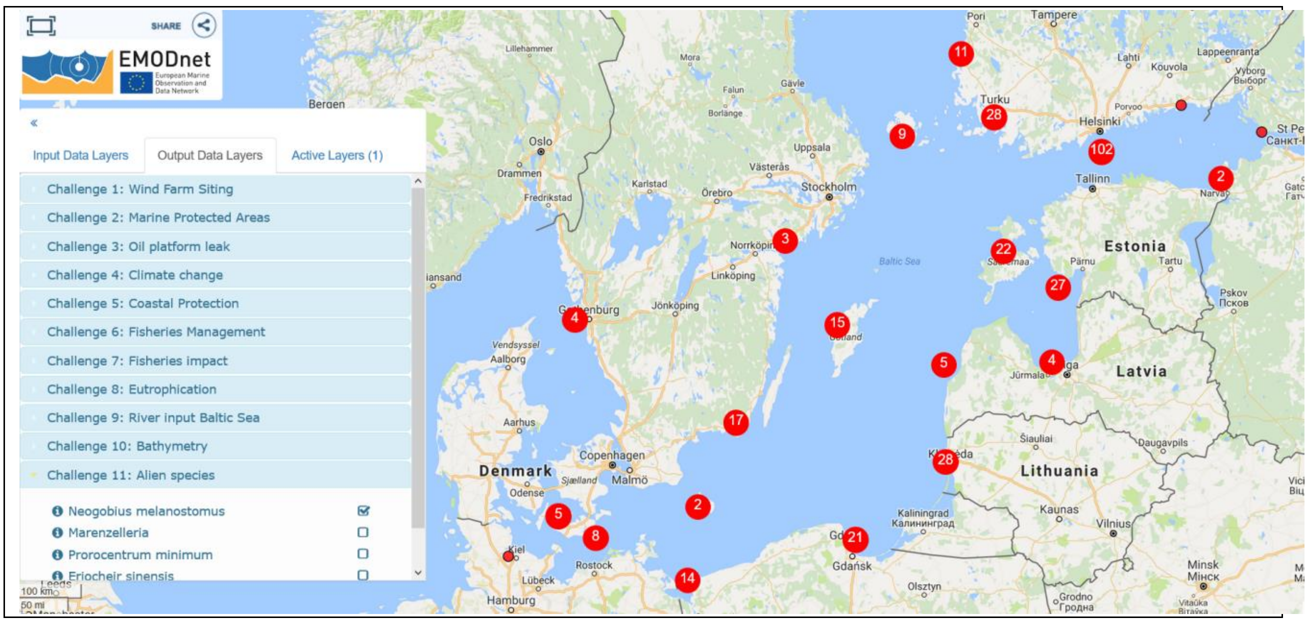


Figure 13.5. Digital map showing distribution of the round goby *Neogobius melanostomus,* available at http://www.emodnet-baltic.eu/Map/. Coordinates received from the authors of a recently published paper (Kotta et al., 2016)

Currently at least some geo-referenced data is available for 49 species, i. e. for 56% all established NIS and CS. The total number of geo-referenced points is 2863 (Tab. 13.4.). The exact coordinates for 27 species were retrieved from the ICES Data portal, while for one species (*Neogobius melanostomus*) geo-referenced data was obtained as supplementary material to the published source on request from the authors (Fig. 13.5.). This work is ongoing; the aim is to obtain at least one geo-referenced point for each established NIS in a recipient region, where this species was recorded.

13.3 Conclusions and discussions

In conclusion, it should be noted that, even if monitoring data is completed by the geo-referenced information from literature sources, such point data (geographical coordinates) will be still far from revealing real species distribution. Sampling sites rarely are dense and evenly distributed within study area to use simple interpolation techniques for the creation of spatial maps (Li and Heap, 2008). Therefore, more realistic picture can be obtained using empirical modeling. Species distribution models relate the occurrence or abundance of organisms with the environment factors that limit their distribution and can predict the species potential habitat using environmental data (Šiaulys and Bučas, 2013). Hence, point information should be completed by empirical modelling to show the areas where NIS are already present and may spread in the future.

An environmental matching method, which is being increasingly used for risk assessment (RA) of NIS spread (David et al., 2013 and references therein) is applicable also for selection of parameters for the empirical modeling. Salinity and water temperature are two most frequently used parameters in RAs, with the salinity being the only parameter common to all RAs conducted in the past (David et al., 2013). The Baltic Sea has relatively low biodiversity, and temperature and salinity are the major environmental factors regulating the distribution of both the indigenous and non-indigenous biota (Ojaveer et al. 2010). For example, in a recent study, the impacts of changing climate on the non-indigenous invertebrates in the northern Baltic Sea by end of the twenty-first century were examined (Holopainen et al., 2016). The authors used the results of RCO-SCOBI model and the original Swedish Meteorological and Hydrological Institute simulation data, imported for further calculations to ArcMap 10.1 programme, to determine the summer means (June–August) for temperature and salinity in present (years 2005–2009) and future conditions (years 2095–2099).

The essential precondition for the empirical modeling is the availability of the physiological tolerance data for NIS, i.e. data showing the limits of environmental parameters for their survival and normal functioning such as feeding, reproduction and larval development. Data mining on species physiological limits and empirical modeling of species distribution is beyond the scope of the current project, however the necessity of such maps for NIS assessments and prognosis, should be taken into account in the future.

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Acronyms

3D	Three dimension
3D-VAR	Three Dimensional Variational data assimilation method
ADCP	acoustic Doppler current profiler
AIS	Automatic Identification System, Marine Transportation
ALARM	Assessing large-scale environmental risks for biodiversity with tested methods
AquaNIS	Information system on aquatic non-indigenous and cryptogenic species
ASCII	American Standard Code for Information Interchange
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
BACC	Assessment of Climate Change for the Baltic Sea, report
BAL MFC	Baltic Marine Forecasting Centre, Copernicus Marine Service (CMEMS)
BALANCE	Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning
BaltAn65+	Baltic Sea high-resolution reanalysis data-base 1965-2005
BALTEX	The Baltic Sea Experiment, now Baltic Earth
BaltiBOOS	Baltic Sea project to boost regional coherence of marine strategies through improved data flow, assessments, and knowledge base for development of measures
BALTSEM	BAltic sea Long Term large-Scale Eutrophication Model
BASREC	Baltic Sea Region Energy Cooperation
BED	Baltic Environment Database
BENTHIS	Benthic Ecosystem Fisheries Impact Studies
BHDC	BALTEX Hydrological Data Center
BMP	Baltic Monitoring Programme, HELCOM
BOOS	Baltic Operational Oceanographic System
BSBD	Baltic Sea Bathymetry Database
BSBD	Baltic Sea Bathymetry Database
BSBDWG	The Baltic Sea Bathymetry Database WG
BSCP	Baltic Sea Check Point, project
BSEP 129 A3	Baltic Sea Environment Proceedings No 129 (Baltic Marine Environment Protection Commission)
BSH	Bundesamt für Seeschifffahrt und Hydrographie (German Federal Agency for Sea-Shipping and Hydrography)
BSHC	The Baltic Sea Hydrographic Commission)
BSPA	Baltic Sea Protected Areas
CD	Compact Disk
CERSAT	Centre ERS d'Archivage et de Traitement
CFSR	Climate Forecast System Reanalysis
CHARM	Developing Reference Conditions for Phytoplankton in the Baltic Sea Coastal Waters project
CHATM-EVK3-CT-2001-00065	Characterisation of the Baltic Sea Ecosystem: Dynamics and Function of Coastal Types

chl-a	Chlorophyll a
CLS	Collective Localisation Satellites
CMEMS	Copernicus Marine Service
CNR, CNR-ISAC	Consiglio Nazionale delle Ricerche, Institute for Atmospheric Science and Climate
COHERENS	COupled Hydrodynamical Ecological model for REgioNal Shelf seas
COMBINE	Cooperative Monitoring in the Baltic Marine Environment, HELCOM
COPERNICUS	European Program for the Establishment of a European capacity for Earth Observation
CORESET	HELCOM-CORESET, core indicator project
CORINE	Coordination of information on the environment
COSMO	The Consortium for Small-scale Modeling
COSMO-REA6	COSMO Regional Reanalysis-System (6 km)
CS	Species, with origin that cannot be reliably demonstrated as being introduced or native
CTD	Conductivity, Temperature and Depth measuring device
DAISIE	Delivering Alien Invasive Species Inventories for Europe
DAR	Data Adequacy Report
DAS	Data Assimilation System
DB	Database
DCE	Denmark’s Centre for Environment and Energy
DCF	Data Collection Framework
DDT	dichlordiphenyltrichlorethan
DEHP	Bis(2-ethylhexyl) phtalate
DG JRC	EU Director General - Joint Research Centre
DG MARE	European Commmission Directorate-General for Maritime Affairs and Fisheries
DMI	Denmark’s Meteorological Institute
DMS	Data and Map Service
DOC	Dissolved Organic Carbon
DOE	Department of Energy
DSMW	Digital Soil Map of the World
DTM	Digital Terrain Model
DTU	Denmark’s Technical University
DWD	German Weather Service
EASME	Executive Agency for Small and Medium size Enterprises
EC	European Commission
ECAD	European Climate Assessment Dataset
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
E-Hype	European scale river model for the drainage basin of Europe (SMHI)
EIDOS	European Directory of the initial Ocean-observing Systems
EIONET	European Environment Information and Observation Network

EMO	Demand File Format
EMODnet, EMODNET	European Marine Observation and Data Network
EMSA	European Maritime Safety Agency
EOOS	European Ocean Observing System
ERA-I	ECMWF Ranalysis ERA-Interim
ERGOM	Baltic Sea Ecosystem model
ESA	European Space Agency
ESDB	European Soil Data Base
ETOPO	Global Earth Relief Model, including land topography and ocean bathymetry
EU	European Union
EU STECF	European Commission Scientific, Technical and Economic Committee for Fisheries
EUMETSAT	European Organisation for the Exploration of Meteorological Satellites
EUNIS	European Nature Information System
EuroGOOS	European Global Ocean Observing System
EUSeaMap	Preparatory Action for development and assessment of a European broad-scale seabed habitat map
EU-STECF	Database of STECF
EUTRO-OPER	Project on making HELCOM eutrophication assessments operational
EWA	European Water Archive
FAO	Food and Agricultural Organisation
FFU	Fit-for-the-use
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
GEAR, HELCOM-Gear	HELCOM permanent working group on the implementation of the Ecosystem Approach
GEBCO	General Bathymetric Chart of the Ocean
GES	Good Environmental Status
GES-REG	Good Environmental Status through Regional coordination and capacity building project
GETM	General Estuarine. Transport Model
GHG	Green House Gas
GLC	Global Land Cover 2000 Project
GLWD	Global Lakes and Wetlands Database
GMES	Global Monitoring for Environment and Security
GOCE	Global Change and Ecosystems
GRDS	Global Runoff Centre Data System
H2S	hydrogen sulphide
HARMONI	Hirlam Aladin Regional Mesoscale Operational. **NWP** In Europe
HBCD	Hexabromocyclododecane
HBM	HIROMB-BOOS Model
HBM-ERGOM	ERGOM based ecosystem model, implemented in HBM

HC	Hindcast
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohaxane
HELCOM	Helsinki Commission, the Baltic Marine Environment Protection Commissions
HELCOM FISH-PRO	Project for the Baltic Wide Assessment of Coastal Fish Communities in support of an Ecosystem Based Management
HELCOM-Agri, Fish, VASAB	HELCOM time-limited working groups on Agriculture, Fisheries and Marine spatial planning, page 55
HELCOM-AIS EWG, EWG OWR EWG, EWG SHORE, OSPAR TG BALLAST	HELCOM Expert Working Groups (EWG), page 55
HELCOM-CORESET	HELCOM core indicator project, Baltic Sea Environment Proceedings No136
HELCOM-Gear, Maritime, Pressure, Response, State and Conservation	HELCOM permanent working groups, page 55
HELCOM-HOLAS	HELCOM Holistic Assessment of the Ecosystem Health of the Baltic Sea project
HELCOM-IWGAS, MORS EG, PRF, SAFE NAV, SEAL, SUBMERGED	HELCOM Expert Working Groups (EWG), page 55
HELCOM-MORE	Revision of the HELCOM monitoring Programme project
HF radar	High Frequency Radar
HIRLAM	High Resolution Local Area Modelling for numerical weather prediction
HIROMB	High Resolution Operational Model for the Baltic Sea
HydroSHED	Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales
ICES	International Council for the Exploration of the Sea
IHO	International Hydrographic Organisation
IMO	International Maritime Organisation
IMPASSE	Environmental Impacts of Alien Species in Aquaculture
INSPIRE	infrastructure for spatial information in Europe
IOC	Intergovernmental Oceanographic Commission
IOW	Institute for Baltic Sea Research Warnemünde
IOWTOPO1/2	IOW ocean topography 1/2
IPCC	Intergovernmental Panel on Climate Change
IROC	ICES Report on Ocean Climate
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
JPL	Jet Propulsion Laboratory
KDI	Denmark’s Coastal Authorities
LAS	Linear Alkyl Sulphates
LiDAR	*Light Detection and Ranging*
LRIT	Long Range Identification and Tracking

LUKE	Natural Research Institute Finland
MARLIN	Baltic Sea Marine Litter project
MARLISCO	Marine Litter in European Seas
MARNET	Marines Umweltmessnetz, Marine environmental measurement Network
MEECE	Marine Ecosystem Evolution in a Changing Environment
MERSEA	Marine Environment and Security for European Area project
MetOp-SG	MetOp Second Generation Programme satellite mission
MFC	Marine Forecasting Centres, Copernicus Marine Service (CMEMS)
MIRCA2000	global monthly irrigated and rain fed area around the year 2000
MLSP D-6	Russian Oil Platform
MPA	Marine Protected Areas
MS	Member States
MSCP	Mediterranean Sea CheckPoint
MSFD	Marine Strategy Framework Directive
MSFD	Marine Strategy Framework Directive
MSI	Marine System Institute at Tallinn Technical University
MSP	Marine Spatial Planning
MTG	Meteosat Third Generation, Eumetsat
MW	MegaWatt
MWG	The Baltic Sea HELCOM Monitoring Working Group
MyOcean, MyOcean2, MyOcean Follow On	GMES projects for the development of a integrated Pan-European capacity for ocean monitoring and forecasting
N/A	Not Applied
NAO	North Atlantic Oscillation
NASCO	North Atlantic Salmon Conservation Organisation
NCEP	National Centre of Environment Prediction
NEAFC	North East Atlantic Fisheries Commission
NEMO	Nucleus for European Modelling of the Ocean
NERC	UK Natural Environment Research Council
NetCDF	software libraries for self-describing, machine independent data formats
NGO	Non-Governmental Organization
NIS	Non-Indigenous Species (Alien Species)
NOC	UK National Oceanography Centre
NODC	National Oceanographic Data Centre
NOOS	North west shelf Operational Oceanographic system
NREL	National Renewable Energy Laboratory
NWP	Numerical Weather Prediction
ODON	Optimal Design of Observational Networks project
ODV	Ocean Data Viewer
OGC	Open Geospatial Consortium
OPEC	Operational Ecology Project
OSE	Observing System Experiment

OSPAR	Oslo Paris Commission
OSSE	Observing System Simulation Experiment
OWF	Offshore Wind Farm
PAH	Polyaromatic hydrocarbons
PAPA	Program for a BAltic network to assess and upgrade an Operational observing and forecAsting system in the Baltic
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphelyls
PFOS	Perflurooctane sulphonate
ph	power of hydrogen, ph-value
PLC	pollution load assessment
POC	Particulate Organic Carbon
PoM	Programs of Measures
PSML	Permanent Service for Mean Sea Level
Q	river discharge
QUID	Quality Information Document, MyOcean and now Copernicus Validation Procedure
RAN	Reanalysis
RCM	Regional Coordination Meeting for the Long Distance Fisheries
RCO-SCOBI	Rossby Center Ocean-Swedish Coastal and Ocean BIogeochemical model
RDB	Regional Fisheries Database
REM	Remote Electronic Monitoring fisheries observer
ROOS: Arctic ROOS, BOOS, NOOS, IBI-ROOS,MONGOOS	Regional Operational Oceanographic system for the Arctic, Baltic, North West Shelf, Ireland Biscay-Iberian and Mediterranean Sea
SeaDataNet	Pan-European infrastructure for ocean and marine data management project
Seatrack Web	Official HELCOM oil drift forecasting system
SINTEF	Stiftelsen for Industriel og Technisk Forskning, Foundation for Scientific and Industrial Research
SMHI	Swedish Meteorological and Hydrological Institute
SOLAS	International Convention for the Safety of Life at Sea
SOWBAS	Status Of wintering Waterbirds populations in the Baltic Sea
SRES A18	Strong Response IPCC scenario
SST	Sea Surface Temperature
SSW	Sea Surface Winds
STECF	Scientific, Technical and Economic Committee for Fisheries
SUNFISH	Sustainable Fisheries project
SYKE	Finnish Environmental Institute
T, T/S	Temperature, Temperature/Salinity
TAC	annual Total Allowable Catch, Fisheries
TAC	Thematic Assembly Centres, Copernicus Marine Service (CMEMS)
TBT	Tributyltin

TG	Task Group
THRESHOLDS	Thresholds of Environmental Sustainability
TN	Total Nitrogen, nitrite and Nitrate
ToR	Terms of Reference
TP	Total Phosphorus
UERRA	Uncertainties in Ensembles of Regional ReAnalysis
UK	United Kingdom
UNESCO	United Nation Educational, Scientific and Cultural Organisation
USGS	United States Geological Survey
VECTORS	Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors
VELMU	Finish Inventory Programme for the Underwater Marine Environment
VOS	The WMO Voluntary Observing Ships
VMS	Vessel Monitoring System
WDS	World Data Service
WG	Working Group
WGBFAS	ICES Working Group on Baltic Fisheries Stock Assessment
WGBYC	ICES Working Group on Bycatch of Protected Species
WMS	Web Map Service
WoRMS	World Register of Marine Species
WRD	World Register of Dams
WWF	World Wildlife Fund
XYZ	unformatted digital data format: lat, lon, depth