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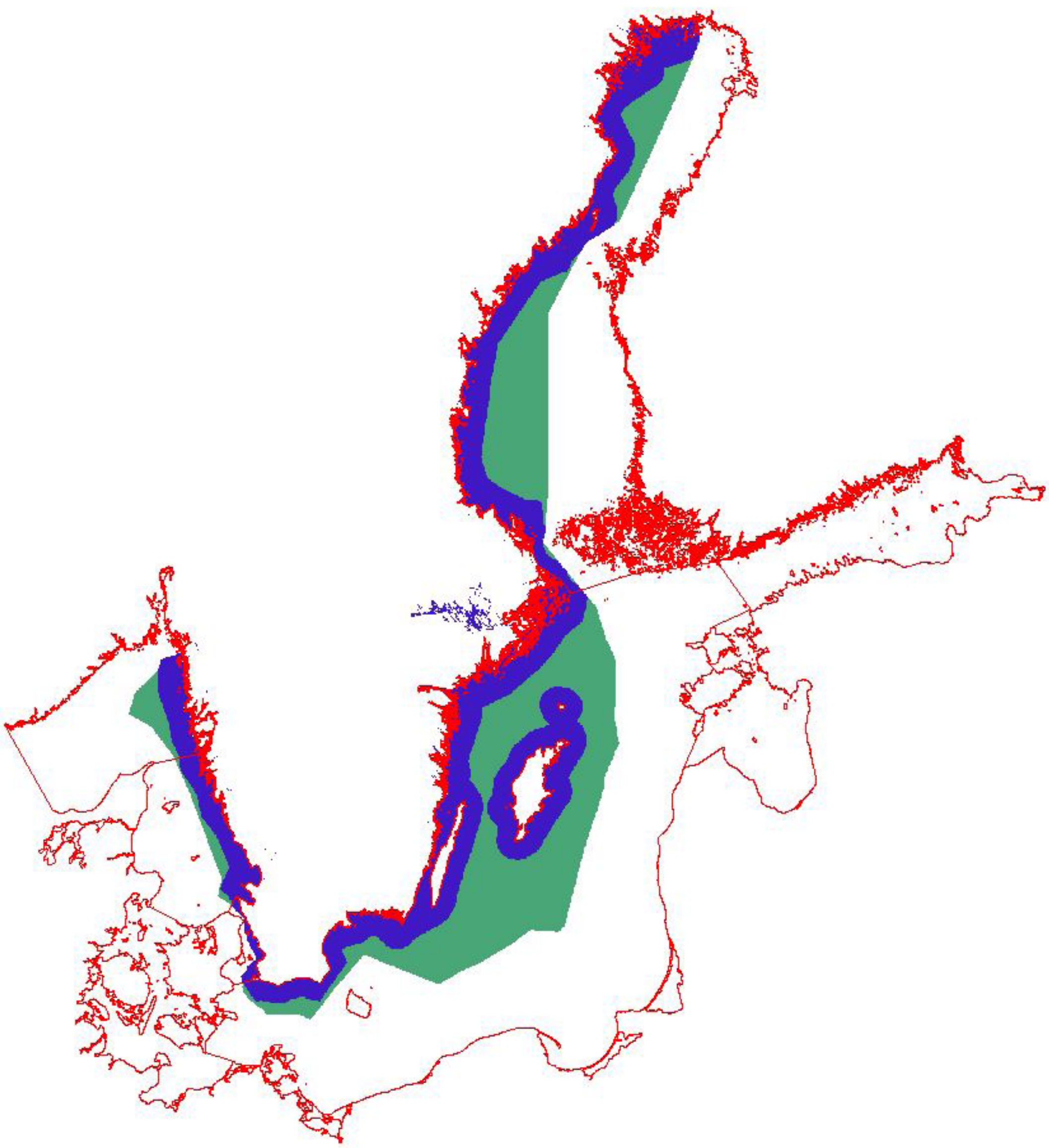
A literature study of human activities and pressures as well as ecosystem component layers available for Marine Spatial Planning and mapping of cumulative impacts in Swedish marine waters



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REPORT

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Abstract

We report a literature study on the needs for and the availability of data layers required for evidence-based Marine Spatial Planning (MSP) as well as mapping of the potential cumulative effects of multiple human activities. Specific focus is on data layers representing a variety of human activities and pressures as well as data layers representing ecologically-relevant species, habitats and communities. The aim of the study is to provide guidance for the Swedish SYMPHONY initiative and process, which ultimately is planned to result in a Swedish national data-driven 'system' for MSP and mapping of cumulative effects (Cumulative Effect Assessments; CEA). With this report and its conclusions and recommendations, the Swedish Agency for Marine and Water Management (SwAM) now holds the sufficient information required to – step by step – develop a nation-wide framework supporting evidence-based MSP and CEA. The crucial first step in this process is the build-up of an ecologically-relevant catalogue of pressure layers and ecosystem component layers.

4 keywords, Danish	4 keywords, English
1. Menneskelige aktiviteter og påvirkninger	1. Human activities and pressures
2. Økosystemkomponenter	2. Ecosystem components
3. Marin arealforvaltning	3. Marine Spatial Planning
4. Sverige	4. Sweden

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A literature study of human activities and pressures as well as ecosystem component layers available for Marine Spatial Planning and mapping of cumulative impacts in Swedish marine waters

Client: Swedish Agency for Marine and Water Management

Preface

We report a literature-based and interim catalogue of data layers representing human activities and pressures as well as ecologically relevant ecosystem components required for both evidence-based Marine Spatial Planning and mapping of potential cumulative effects of multiple human activities.

The catalogue is based on three projects aiming to map potential cumulative effects in the Baltic Sea and/or the eastern parts of the North Sea, i.e. the HELCOM HOLAS, HARMONY and SYMBIOSE projects.

It is our hope that this study and catalogue will serve as a basis for Swedish activities ultimately leading to the development of a broad-scale Decision Support Tool for evidence-based decisions in regard to the implementation of both the EU Maritime Planning Directive and the EU Marine Strategy Framework Directive.

We would like to thank Norman Green for critically reviewing an earlier version of this report and SMHI for giving us permission to use the map on the front cover.

Copenhagen, 22 February 2016

Jesper H. Andersen

Contents

Summary

We report a literature study on the needs for and the availability of data layers required for both evidence-based Marine Spatial Planning (MSP) as well as mapping of the potential cumulative effects of multiple human activities. Specific focus is on data layers representing a variety of human activities and pressures as well as data layers representing ecologically-relevant species, habitats and communities.

The study area is the Swedish Exclusive Economic Zone (EEZ) and outer territorial waters. For each listed data layers we have aimed to provide: (1) a short explanation and rating of relevance, (2) an indication of the required level of detail and data assumptions, (3) an indication of the method for calculating the spatial distribution from source (when relevant), (4) an overview of data sources/hosts, and (5) any other relevant information of use for planning and coordination of the production of maps/layers.

The study provides guidance for the Swedish SYMPHONY[1] initiative and process, which ultimately is planned to result in a Swedish national data-driven 'system' for MSP and mapping of cumulative effects (Cumulative Effect Assessments; CEA). With this report and its conclusions and recommendations, the Swedish Agency for Marine and Water Management (SwAM) now holds the sufficient information required to – step by step – develop a nation-wide framework supporting evidence-based MSP and CEA.

However, SwAM would have to consider the following:

- All existing pressure layers would have to be updated as they are either outdated or not covering the Swedish EEZ entirely.
- The ongoing HELCOM HOLAS II activity leading to a Baltic Sea-wide assessment of cumulative pressures and cumulative impacts will result in updated data layers and a close collaboration between HOLAS II and the SYMPHONY project should be carefully considered.
- A crucial first step in SYMPHONY process is the build-up of an ecologically-relevant catalogue of pressure layers and ecosystem component layers.
- The next steps include updating of the data layer – preferably is close collaboration with the HELCOM HOLAS II activity – as well as setting of pressure- and ecosystem-component-specific sensitivity scores.

[1] SYMPHONY: 'Et bedömningsverktyg för kumulativ miljöpåverkan inom svensk havsplanering'.

1. Introduction

The objective of this literature study has been:

- to provide an interim list of ecologically-relevant pressures and ecosystem components to be included in the SYMPHONY project.

The list can be used as a basis for data collection and production of maps/layers. The list will be based on completed projects and activities as well as ongoing projects and activities.

The deliverables of this literature study include:

- a comprehensive list of ecologically-relevant land- and sea-based pressures (and associated activities) and a comprehensive list of the most ecologically-relevant ecosystem components.

Area of interest is the Swedish EEZ and outer territorial waters. For each listed data layers we intend to provide: (1) a short explanation and rating of relevance, (2) an indication of the required level of detail and data assumptions, (3) an indication of the method for calculating the spatial distribution from source (when relevant), (4) an overview of data sources/hosts, and (5) any other relevant information of use for planning and coordination of the production of maps/layers.

The literature study is in principle based on three sources of information, the HELCOM HOLAS process (HELCOM 2010, Korpinen et al. 2010), the HARMONY project (Andersen & Stock (eds.) 2013) and the Danish SYMBIOSE project (Mohn et al. 2015).

In essence, this literature results in an interim catalogue of relevant data for a Swedish endeavour to carry out broad-scale Marine Spatial Planning (as described in the SYMPHONY project), but also for future CEAs. In order to facilitate these future activities, we propose a number of steps to ultimately support ecosystem-based management of the seas around Sweden.

1.1 Study area

The study area consists of the Swedish parts of the Skagerrak, Kattegat, the Sound, Arkona Basin, Bornholm Basin, Baltic Proper, Åland Sea, Bothnian Sea and the Bothnian Bay. The brief descriptions of the sub-basins that follow are mainly based on Wikipedia.

The study area and its environmental status is in general very well understood and documented (see HELCOM 2010, OSPAR 2010 and Havsmiljöinstitutet 2014). The environmental status is in general impaired due to excessive loads of nutrients (causing eutrophication), inputs and deposition of hazardous substances, overfishing, and physical modification – see Ærtebjerg et al. (2003), HELCOM (2010), OSPAR (2010), Korpinen et al. (2013) and Andersen et al. (2015, 2016) for details.

Skagerrak
The Skagerrak is a strait running between the southeast coast of Norway, the southwest coast of Sweden, and the Jutland peninsula of Denmark, connecting the North Sea and the Kattegat area, which leads to the Baltic Sea. The Skagerrak is 240 km (150 mi) long and between 80 and 140 km (50 and 87 mi) wide. It deepens toward the Norwegian coast, reaching over 700 m depth in the Norwegian Trench.

Kattegat
The Kattegat is a 30 000 km^2 sea area bounded by the Jutlandic peninsula to the west, the Straits islands of Denmark to the south and the provinces of Västergötland, Scania (also known as Skåne), Halland and Bohuslän in Sweden to the east. The Baltic Sea drains into the Kattegat through the Danish Straits. The

sea area is a continuation of the Skagerrak and may be seen as a bay of the North Sea, a bay of the Baltic Sea or - as in traditional Scandinavian usage - neither of these. Kattegat is a rather shallow sea and can be very difficult and dangerous to navigate, due to the many sandy and stony reefs and tricky currents that often shift. In modern times, artificial seabed canals have been dug, many reefs have been dredged by either sand pumping or stone fishing, and a well-developed light signalling network has been installed, to safeguard the very heavy international traffic of this small sea.

The Sound
The sound is a narrow strait between Zealand and Scania with a mean depth of 11 m. It is through The Sound that approximately 25 % of the change of water between Kattegat and the Baltic Sea goes. The primary direction of flow is northerly, however near the bottom the flow is reversed, which bring salty water into The Baltic Sea.

The Baltic Sea
The Baltic Sea is bounded by the Swedish part of the Scandinavian Peninsula, the mainland of Europe, and the Danish islands. It drains into the Kattegat by way of the Sound, the Great Belt and the Little Belt.

Arkona Basin:
The Arkona Basin extends from Kiel Bight to the eastern Gotland Basin, to the isles of Falster and Zealand. It has a maximum depth of 55 m.

Bornholm Basin:
The Bornholm Basin is located in the southwestern Baltic Sea separated by a sill between Scania and Bornholm. The Bornholm Basin is east of Bornholm, with depths primarily varying between 60-80 m and a maximum depth of 105 m. Shallow areas with depths on 20 m can be found in the area south-west of Bornholm.

Baltic Proper:
The Baltic proper is the area south of Åland Sea, west of the Gulf of Riga and north of Bornholm basin. The salinity is between 5 and 7, and is thereby brackish. The Baltic Proper has a maximum depth on 459 m, a mean depth of 62 m. It has a surface area of 211 069 km^2.

Åland Sea:
Åland Sea is the area between Åland Island (Finland) and Sweden and connects the Baltic Proper with the Bothnian Sea. It consists of 2 basins and 3 sills, with a maximum depth of 301 m.

Bothnian Sea:
North of the Åland Sea and the Archipelago Sea, is the Bothnian Sea. Water is primarily exchanged through deep channels in the Åland Sea, since the archipelago sea is rather shallow. The north of the Bothnian Sea is the Bothnian Bay, just separated be the Quark. The Bothnian Sea has a mean depth of 60 m and is brackish with salinities between 5 and 6.

Bothnian Bay:
The Bothnian Bay is the most northern part of the Baltic Sea with a surface area on 36 800 km^2 located between Finland and Sweden. To the south it is separated from the Bothnian Sea by the Quark. The mean depth is 43 m and the greatest depth, found in one of the two depressions, is 147 m. The salinity is very low around 0.30-0.35, due to the input of freshwater from streams and rivers entering the bay.

1.2 Abbreviations and acronyms

To support understanding of the report and its key massages, the abbreviations and/or acronyms used throughout the report, the tables and annexes are explained in Table 1.

Table 1: Abbreviation and acronyms used in this report.

BIAS	Baltic Sea Information of the Acoustic Soundscape
BSII	Baltic Sea Impact Index
BSPI	Baltic Sea pressure Index
BSAP	Baltic Sea Action Plan
CEA	Cumulative Effect Assessment
CIA	Cumulative Impact Assessment
EEZ	Exclusive Economic Zone
GEnS	Good Environmental Status
HARMONY	Human Uses, Pressures and Impacts in The Eastern North Sea
HELCOM	Baltic Marine Environment Protection Commission - Helsinki Commission
HOLAS	HELCOM Initial Holistic Assessment
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Planning
MSPD	Maritime Spatial Planning Directive
NSII	North Sea Impact Index
NSPI	North Sea Pressure Index
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
SYMBIOSE	*Økosystem-baserede marine strategier: Udvikling af et værktøj for vurdering af kumulative belastninger og beslutningsstøtte* [Ecosystem-based marine strategies: Development of a tool for cumulative effect assessments and decision support]
SYMPHONY	Analytic tool for cumulative effects assessment within the Swedish Marine Spatial Planning
TAPAS	Development of HELCOM Tools and Approaches for the Second Holistic Assessment of the Ecosystem health of the Baltic Sea

2. Where are we now?

Since about 2007, EU Member States have had an increasing focus on ecosystem-based management of marine ecosystems. A key policy driver has been the EU Marine Strategy Framework Directive (MSFD; Anon 2008), by which Member States are required to implement the Ecosystem Approach, e.g. by assessing 'cumulative pressures' and 'good environmental status' and nationally by implementing so-called 'Marine Strategies' ultimately supporting or leading to a healthy status on the sea. Further, the HELCOM Baltic Sea Action Plan (BSAP; HELCOM 2007) has been an important driver for the interpretation and implementation of the Ecosystem Approach - firstly by the adoption of the BSAP, secondly, by carrying out the first ever assessment of ecosystem health of the Baltic Sea (HELCOM 2010).

In combination, the MSFD and the BSAP have not only resulted in the collation of many data sets representing human stressors and ecosystem components but also large-scale endeavours to map the potential effects of multiple human stressors on the marine environment in the seas surrounding Sweden.

Since the adoption of the EU Maritime Spatial Planning Directive in 2012 (MSPD; Anon 2014), there has been a growing awareness that MSFD and MSPD are tightly linked and, perhaps most importantly, have overlapping data needs.

2.1 HELCOM HOLAS

HELCOM Initial Holistic Assessment (HOLAS) was a process which so far has led to the production and publication of the first ever assessment of "Ecosystem Health of the Baltic Sea" (HELCOM 2010).

Based on the approach originally developed by Halpern et al. (2008), the HOLAS report assessed the potential cumulative effects of multiple human stressors on key ecosystem components using the Baltic Sea Impact Index (BSII) and the Baltic Sea pressure Index (BSPI) (Korpinen et al. 2010, Korpinen et al. 2012). The approach is a stepwise approach: (1) Data layers representing ecologically relevant anthropogenic pressures are combined with (2) ecologically relevant ecosystem component layers via (3) sensitivity scores. In principle, the 'system' is a big matrix linking pressure data with ecosystem component data through pressure and ecosystem-specific setting of sensitivity scores (see conceptual model in Figure 1 and results in Figure 2).

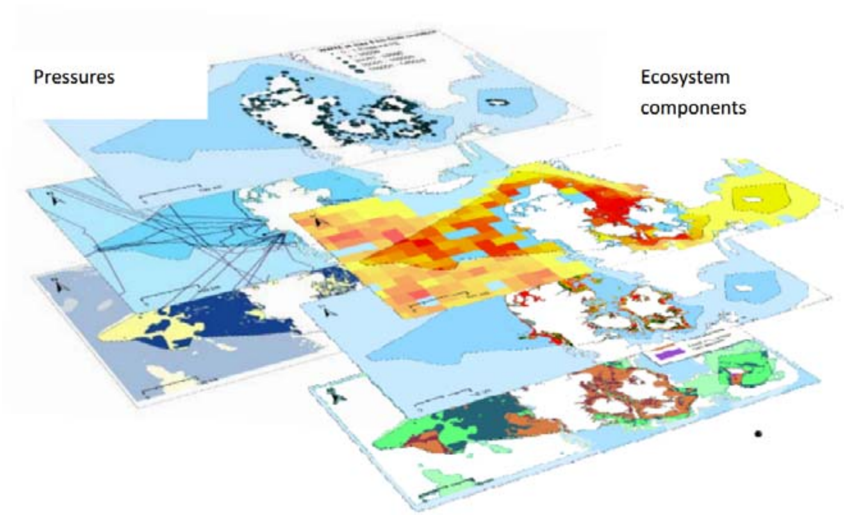


Figure 1: Sketch of the process of combining data layers of different pressures with data layers of ecosystem components (from Mohn et al. (2015). For details regarding the methodology, please confer with Korpinen et al. (2012) and Andersen & Stock (2013).

The approach has subsequently been developed further by the HARMONY project (see below) and used for a variety of other purposes, e.g. assessing sea-floor integrity (see Korpinen et al. 2013) or assessing the correlations between the status of biodiversity and human activities (see Andersen et al. 2015).

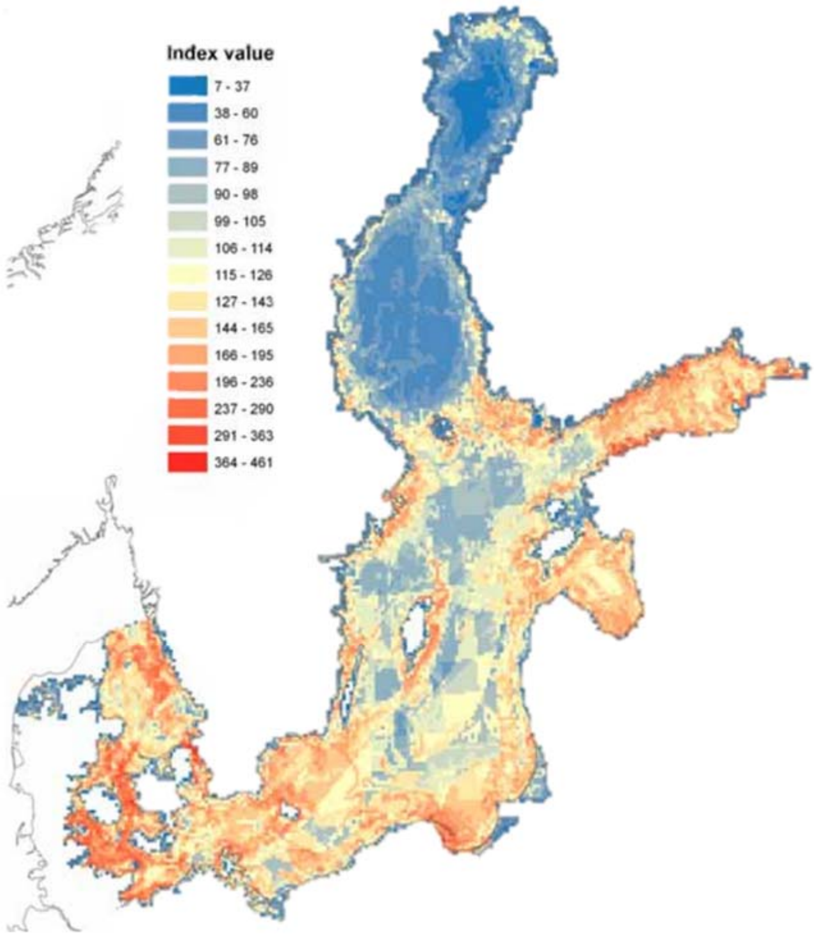


Figure 2: Map from HELCOM HOLAS, showing the Baltic Sea Impact Index (BSII). The red colours show areas of potential impact of anthropogenic pressures; the higher the number the greater the impact. The map is constituted of 52 pressure data layers on 14 biological ecosystem data layers. The spatial resolution is 5 km × 5 km. Source: HELCOM (2010).

The BSII and BSPI should be regarded as a first attempt to map cumulative pressures and impacts. Although the results have been widely used, there are still room for improvement. Key areas to improve include: (1) gaps in pressures layers (e.g. marine litter, SST and SSS) should be bridged, (2) the ecosystem component layers should include all ecologically relevant species, habitats and communities, and (3) the setting of sensitivity scores should be carried out as an online survey (cf. HARMONY).

2.2 HARMONY and SYMBIOSE

The HARMONY project was a Danish, German, Norwegian and Swedish project started in 2010 and aimed at harmonizing the implementation of the EU Marine Strategy Framework Directive (Anon. 2008) in the eastern parts of the North Sea. A key HARMONY deliverable was the North Sea Pressure Index (NSPI) and the North Sea Impact Index (NSII). NSPI and NSII build on BSPI/BSII and provides outputs for a number of activities, cumulative (additive) impacts and also impacts for ecosystem components specifically. Hence, NSPI and NSII represent significant steps forward compared to the original methodology (see Andersen & Stock 2013). A promising spin off output of the HARMONY project is an open source ImpactMapper (Stock, in press).

A key HARMONY product was the mapping of potential cumulative effects, i.e. the NSII (See Figure 3).

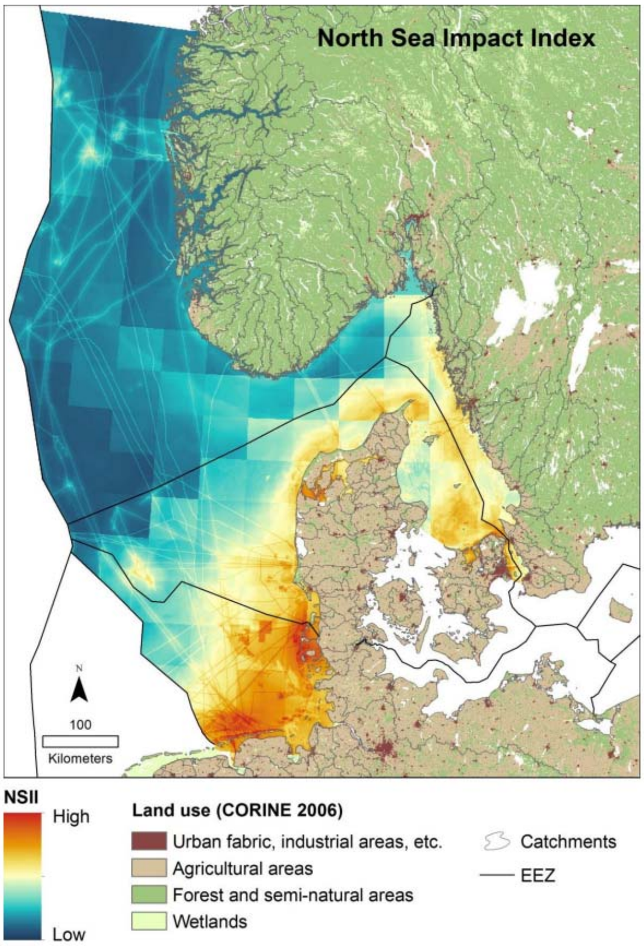


Figure 3: The North Sea Impact Index (NSII) developed by HARMONY. A high value is indicated by red colour tones, and means that there is a high level of impact exists due to many pressures and presence of sensitive ecosystem components. A low value, illustrated by the blue colours, indicates that there are either few pressures or few sensitive ecosystem components present (see also Andersen & Stock 2013).

Compared to HELCOM HOLAS, HARMONY shows a considerable improvement; for example, in terms of the availability of ecosystem component data layers, the methodology used for setting of the sensitivity scores linking pressures and ecosystem components, and the documentation of data layers (a catalogues was build and published).

Following up on HARMONY, the Danish SYMBIOSE projectaimed to compile a national catalogue of pressures and ecosystem-component data layers (see Mohn et al. 2015). SYMBIOSE ecosystem components covers *inter alia* plankton, benthic communities, fish, birds and mammals, and together with HARMONY, represent the current state-of-the-art with regard to the availability of ecologically-relevant data layers for mapping of cumulative effects and downstream for evidence Marine Spatial Planning (*sensu* Anon 2014).

2.3 MSFD and MSPD requirements

Implementation of EU's Marine Strategy Framework Directive (MSFD; Anon. 2008) and EU's Maritime Spatial Planning Directive (MSPD; Anon 2014) rely on the best available knowledge and multiple data sets, the latter being critically important as the MSFD is rooted in an Ecosystem-based Approach as well as the fact that the MSFD is regarded as the environmental pillar of the MSPD.

2.3.1 Marine Strategy Framework Directive

The aim MSFD is ambitious and aims to protect more effectively the marine environment across Europe. The Directive sets out to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. It is the first EU legislative instrument related to the protection of marine biodiversity. It contains the explicit regulatory objective that "biodiversity is maintained by 2020", and it is the cornerstone for achieving GES.

In order to achieve GES by 2020, each Member State is required to develop a strategy for its marine waters (or Marine Strategy). In addition, because the Directive follows an adaptive management approach, the Marine Strategies must be kept up-to-date and reviewed every 6 years.

A key element in the MSFD planning is the regular production of so-called Initial Assessments of the current environmental status of national marine waters and the environmental impact and socio-economic analysis of human activities in these waters. Initial Assessments are required to include an assessment of cumulative pressures (see art. 1bii). So far Member States have been relying of regional or sub-regional inputs, and for some Member States, HOLAS and HARMONY have been taken on board in this regard.

In order to prepare for the next round of Initial Assessment various activities and projects have been carried out or are initiated, i.e. (1) further use and development of the Danish SYMBIOSE (2) HELCOM HOLAS II aiming to update the BSII and BSPI mapping and address the gaps identified in HOLAS I and (3) further use and development of the Swedish SYMPHONY.

2.3.2 Maritime Spatial Planning Directive

MSPD was adopted in 2014 and and each EU country will be free to plan its own maritime activities. However, local, regional and national planning in shared seas would be made more compatible through a set of minimum common requirements.

The MSPD is about planning when and where human activities take place at sea – to ensure these are as efficient and sustainable as possible. There is competition for maritime space – for renewable energy equipment, aquaculture and other growth areas – which has highlighted the need for efficient management, to avoid potential conflict and create synergies between different activities.

The benefits of maritime spatial planning include: (1) reduce conflicts between sectors and create synergies between different activities, (2) encourage investment – by instilling predictability, transparency and clearer rules. This will help boost the development of renewable energy sources and grids, establish Marine Protected Areas, and facilitate investment in oil and gas, (3) increase coordination – between administrations in each country, through the use of a single instrument to balance the development of a range of maritime activities. (4) increase cross-border cooperation – between EU countries, on cables, pipelines, shipping lanes, wind installations, etc., and (5) protect the environment – through early identification of impact and opportunities for multiple use of space.

As for the MSFD, an evidence-based implementation of the MSPD rely on access to a broad range of ecologically relevant data layers, i.e. data representing human activities and pressures and data representing ecosystem components (e.g. species, habitat and communities). It is at the moment clear that the work in relation to the MSFD ideally could support the implementation of the MSPD.

3. SYMPHONY – from Cumulative Effect Assessment to Marine Spatial Planning

The Swedish SYMPHONY project has the potential to coordinate and support the implementation process of both the MSFD and the MSPD ultimately leading not only to a better use of resources but also to a reduction of uncertainty in the knowledge base. SYMPHONY should build on what has already been done. MSFD, with a has 6–year head start on MSPD, has already resulted in a substantial work documenting locations and impacts on multiple human activities and pressures on the marine environment. Further, key sources of information should include the activities above (cf. chapter 2) with regard to HOLAS I and HARMONY and to some degree also SYMBIOSE. Many and also very comprehensive data sets have been collated, cf. Table 2.

Table 2: Total number of ecosystem components and 'pressures'[1] included in HOLAS, HARMONY and SYMBIOSE.

	HOLAS I	HARMONY	SYMBIOSE
Ecosystem components	14	16	40
'Pressures'	40*	29	38

[1] The quotation marks are added as the 'pressures' cover a wide range of activities, stressors and anthropogenic pressures. * In the report 52 pressures are identified, however, some activities results in more than a single pressure.

It should be noted that the terms 'activity', 'pressure' and 'stressor' are interpreted in slightly different ways in the various projects and that the number in Table 1 may differentiate from the information and numbers provided by the individual projects. This might potentially pose problems, not for mapping of cumulative impacts, but for MSP as the activities are closely related to the human activities rather than the 'pressures'.

3.1 Identification of priority pressure layers

We have assessed the geographical cover of the pressure layers (also known as stressor layers or activity layers) based on the information from the reporting of the projects (Korpinen et al. 2010, 2012, Andersen & Stock 2013 and Mohn et al. 2015). Further, we have rated the relevance of each specific layer and pri-oritized the layers in three categories ((high, medium and low) based on the ranking from HOLAS I and HARMONY (HELCOM 2010, Andersen & Stock 2013). Finally, we have estimated the workload in three categories (high, medium and low) that is required to combine, update or collate each pressure layer based on the experience from HOLAS I, HARMONY, and SYMBIOSE.

The results are shown in Table 3.

3.2 Identification of ecologically-relevant ecosystem component layers

As for the pressure layers the assessment of geographical cover of ecosystem component layers is based on work from HOLAS, HARMONY and SYMBIOSE (i.e. Korpinen et al. 2012, Andersen & Stock 2013 and Mohn et al. 2014). Ecosystem component-specific relevance and workload is estimated in the same way as for pressure layers. As can been seen in Table 2 the availability of ecologically relevant data layers has been an issue in HOLAS I. Many of the gaps identified in HOLAS I are being addressed in HOLAS II and EUSeaMap 2.

The results are shown in Table 4.

Table 3: Provisional assessment of geographical cover and relevance for human activity data sets from HOLAS, HARMONY and SYMPIOSE. Cover is 'complete', fragmented covering either the Baltic Sea (from HOLAS) or the North Sea (from HARMONY) or referred to as 'geo-referenced' which indicates that the precise location of where the data was derived is provided, otherwise more general positions are indicated where DK = Denmark, BS = Baltic Sea, KAT = Kattegat, SKA = Skagerrak and SOU = the Sound. Relevance and workload have three categories: H = high, M = moderate and L = low. H+ indicates a top priority data layer. The overview is based on work from HOLAS, HARMONY and SYMBIOSE (see Annex 1 and 3).

Pressures (including stressors and human activities	Geographical Cover	Relevance	Work load	Recommendations/comments
Bridges and coastal dams	Geo-referenced	H+	M	National data
Coastal defence structures	Geo-referenced	M	M	National data
Coastal population density	Complete	M	L	National data or CORINE
Climate anomalies (SST, SSS)	Baltic Sea not included	H+	L	A pan-European data set is produced annually by EEA's ETC ICM
Disposal of dredged materials	Geo-referenced	H+	M	National data
Coastal waste water treatment plants	Geo-referenced	H+	L	National data
Industrial and ferry ports	Geo-referenced	H+	L	National data
Marine aquaculture sites	Geo-referenced	H+	L	National data
Military areas	Geo-referenced	M	L	National data
Microplastic in sediment	DK	H/M	H	Under development
Noise: Ship continuous 63 Hz	DK	H+	L	Produced by the BIAS project?
Noise: Ship continuous 125 hz	DK	H+	L	Produced by the BIAS project?
Recreational boating and sports	DK, SOU, BS, KAT	M	H	Produced by HOLAS II?
Cables and pipelines (construction phase)*	DK, SOU, BS, KAT	M	M	National data
Wind farms, oil platforms, bridges (construction phase)*	DK, SOU, BS, KAT	H+	M	National data
Power plants with warm-water outflow	Geo-referenced	M	M	National data
Offshore wind turbines	Geo-referenced	H+	L	National data
Sea cables	Geo-referenced	M	L	National data
Sediment extraction sites	Complete	H+	M	National data
Oil terminals, refineries, oil platforms	Geo-referenced	H+	L	National data
Pipeline placement and operation	Geo-referenced	M	L	National data
Oil rigs (operational)	BS, KAT	M	L	National data
Coastal shipping	BS, KAT	M	L	Produced by HOLAS II?
Offshore shipping	BS, KAT	M	L	Produced by HOLAS II?
Shipping intensity	DK. SKA, KAT, SOU	H+	L	National data
Recreational shipping	DK, SKA, KAT, SOU	M	M	National data?
Passenger ships outside 12 nm	BS, KAT	M	?	Produced by HOLAS II?

Pressures (including stressors and human activities	Geographical Cover	Relevance	Work load	Recommendations/comments
Input of hazardous substances (synthetic): Riverine input of synthetic pollutants	DK, SKA, KAT	H+	H	Some data available from HELCOM and OSPAR – model needed?
Input of hazardous substances (synthetic): Polluting ship accidents*	DK, SKA, KAT	H+	M	HELCOM data
Input of hazardous substances (synthetic): Atmospheric deposition of dioxins	KAT, SOU, BS	H+	L	Produced by EMEP
Input of hazardous substances (non-synthetic): Illegal oil spills	Complete	H+	M	Data from HELCOM or Bonn Agreement
Input of hazardous substances (non-synthetic): Atmospheric deposition of heavy metals	Complete	H+	L	Produced by EMEP
Input of hazardous substances (non-synthetic): Waterborne heavy metals	DK, BS, SOU, KAT	H+	M	Data available from HELCOM and OSPAR – model needed?
Introduction of radioactive substances	Complete	M	H	HELCOM MORS / IAEA
Dumped munition	DK. SKA, KAT, SOU	L	M	HELCOM
Nutrient enrichment	SKA, KAT, SOU	H+	L	See under waterborne imputs
Atmospheric deposition of nitrogen	DK, BS, SOU, KAT	H+	L	EMEP or national data
Waterborne input of Nitrogen	BS, SOU, KAT	H+	L	HELCOM, OSPAR, national data
Waterborne input of Phosphorous	BS, SOU, KAT	H+	L	HELCOM, OSPAR, national data
Riverine input of organic matter	BS, SOU, KAT	H	L	HELCOM, OSPAR, national data
Bathing sites	BS, SOU, KAT	M	M	National data
Game hunting (birds, mammals, turtles)	BS, SOU, KAT	H	H	National records
Hunting of Seals	BS, SOU, KAT	H	M	National records
Potting	DK, SKA, KAT, SOU	M	M	National data and/or ICES data
Fishery effort from the "other trawl"	SKA, KAT, SOU	H+	L	National data and/or ICES data
Fishery effort from the dredge segments	SKA, KAT, SOU	H	M	National data and/or ICES data
Beam trawl mesh size <32 mm	SKA, KAT, SOU	H+	M	National data and/or ICES data
Beam trawl, mesh size >80 mm	SKA, KAT, SOU	H+	M	National data and/or ICES data
Beam trawl, mesh size ≥ 100 mm	DK	H+	M	National data and/or ICES data
Netting (setnet, gillnet)	DK, BS, KAT	M	M	National data and/or ICES data
Demersal long lines	DK	M	M	National data and/or ICES data
Pelagic long lining	DK	M	M	National data and/or ICES data
Pelagic trawling	SKA, KAT, SOU	H+	L	National data and/or ICES data
Pelagic trawling: mesh size 16-32 mm	KAT, SOU, DK	H	L	National data and/or ICES data
Pelagic trawling: mesh size: 33-80 mm	KAT, SOU, DK	H	L	National data and/or ICES data

Pressures (including stressors and human activities	Geographical Cover	Relevance	Work load	Recommendations/comments
Benthic trawling	KAT, SOU	H+	L	National data and/or ICES data
Benthic trawling: Mesh size <16 mm	DK	H	L	National data and/or ICES data
Benthic trawling: Mesh size 16-32 mm	DK	H	L	National data and/or ICES data
Benthic trawling: Mesh size 33-69 mm	DK	H	L	National data and/or ICES data
Benthic trawling: Mesh size 70-99 mm	DK, SKA, KAT, SOU	H	L	National data and/or ICES data
Benthic trawling: Mesh size ≥100mm	DK, SKA, KAT, SOU	H	L	National data and/or ICES data
Fishery from coastal stationary gear	BS, SOU, KAT	M	M	National data
Mussel dredging	DK	H+	H	National data

* Indicates that the pressure occurs as periodic events.

Table 4: Provisional assessment of the geographical cover and relevance for various existing ecosystem component data sets. Cover is 'complete', fragmented covering either the Baltic Sea (from HOLAS) or the North Sea (from HARMONY) or referred to as 'geo-referenced' which indicates that the precise location of where the data was derived is provided, otherwise more general positions are indicated where DK = Denmark, BS = Baltic Sea, KAT = Kattegat, SKA = Skagerrak and SOU = the Sound. Relevance and workload have three categories: H = high, M = moderate and L = low. H+ indicates a top priority data layer. The overview is based on work from HOLAS, HARMONY and SYMBIOSE (see Annex 2 and 3).

Ecosystem component	Geographical cover	Relevance	Work load	Recommendations
Benthic habitats	Complete	H+	L	Could be based on EUSeaMap 2
Boulder reefs	DK	H	L	Could be based on EUSeaMap 2
Photic rock or other, photic sand and coarse or mixed sediments)	BS, SOU, KAT	H	L	Could be based on EUSeaMap 2
Photic water column	BS, SOU, KAT	H	L	Could be based on EUSeaMap 2
Non-photic water column	BS, SOU, KAT	H	L	Could be based on EUSeaMap 2
Mussel beds	BS, SOU, KAT	H	M/L	Could be based on HOLAS II?
Broad-scale coastal ecosystems	SKA, KAT, SOU	M	M/L	Could be based on EUSeaMap 2
Zostera meadows/eelgrass distribution	DK, BS?, SOU, KAT	H+	M/L	Could be based on HOLAS II?
N/P ratio winter	DK	L	M	SMHI
Plankton communities	SKA, KAT, SOU, DK	H+	M/L	SMHI
Cod	Complete	H+	L	National data and/or ICES data
Coalfish	DK	M	M/L	National data and/or ICES data
Common Hooknose/monkfish	DK	M	M/L	National data and/or ICES data
Common sole	DK	H	M/L	National data and/or ICES data
Dab	DK, SKA, KAT, SOU	H	M/L	National data and/or ICES data
Common dogfish	DK	M	M/L	National data and/or ICES data

Ecosystem component	Geographical cover	Relevance	Work load	Recommendations
Spiny Dogfish	DK	M	M/l	National data and/or ICES data
Flounder	DK	H	M/L	National data and/or ICES data
Haddock	DK, SKA, KAT, SOU	M	M/L	National data and/or ICES data
Herring	DK, SKA, KAT, SOU	H+	L	National data and/or ICES data
Lumpfish	DK	M	M/L	National data and/or ICES data
Mackerel	DK	M	M/L	National data and/or ICES data
Nothern Prawn	DK	M	M/L	National data and/or ICES data
Norway Lobster	DK	H	M/L	National data and/or ICES data
Plaice	DK, SKA, KAT, SOU	H	M/l	National data and/or ICES data
Shrimp	DK	M	M/L	National data and/or ICES data
Sperling	DK	M	M/L	National data and/or ICES data
Sprat	DK	H+	L	National data and/or ICES data
Starry Ray	DK	M	M/L	National data and/or ICES data
Turbot	DK	M	M/L	National data and/or ICES data
Whiting	DK, SKA, KAT, SOU	M	M/L	National data and/or ICES data
Norway Pout	SKA, KAT, SOU	M	M/L	National data and/or ICES data
Saithe	SKA, KAT, SOU	M	M/L	National data and/or ICES data
Biomass distribution of Rays and Skates	SKA, KAT, SOU	H	M	National data and/or ICES data
Biomass distribution of large Rays and Skates	SKA, KAT, SOU	H	M	National data and/or ICES data
Sandeel fishing grounds	SKA, KAT, SOU	H	L	National data and/or ICES data
Abundance of sensitive non-assessed fish species	SKA, KAT, SOU	H	M/H	National data and/or ICES data
Large Fish indicator (LFI)	SKA, KAT, SOU	H+	M	ICES? Or HOLAS II?
Size spectrum height	SKA, KAT, SOU	L	H	Complicated – to be considered
Size spectrum slope	SKA, KAT, SOU	L	H	Complicated – to be considered
Species evenness	SKA, KAT, SOU	L	H	Complicated – to be considered
Species richness	SKA, KAT, SOU	M	H	Complicated – to be considered
Auks: Guillemot, Razorbill	DK, SKA, KAT, SOU	H	M/L	National data and SDM
Common scoter	DK	H	M/L	National data and SDM
Divers: Red throated diver, black-throated diver	DK	H	M/L	National data and SDM
Eider	DK	H+	M/L	National data and SDM
Fulmar	DK, SKA, KAT, SOU	H	M/L	National data and SDM
Garnet	DK, SKA, KAT, SOU	H/M	M/L	National data and SDM
Kittiwake	DK, SKA, KAT, SOU	H	M/L	National data and SDM
Wintering grounds for seabirds	BS, SOU, KAT	H+	M/L	Ongoing HELCOM survey

Ecosystem component	Geographical cover	Relevance	Work load	Recommendations
Long-tailed Duck	DK	H	M/L	Ongoing HELCOM survey
Red-breasted merganser	DK	H	M/L	Ongoing HELCOM survey
Grey seal	BS, SOU, KAT, DK	H+	M/L	National data and SDM
Harbour seal	BS, SOU, KAT, DK	H+	M/L	National data and SDM
Ringed seal	BS, SOU, KAT,	H+	M/L	National data and SDM
Harbour porpoise	Complete	H+	L	National data and SDM
Minke whale	DK, SKA, KAT, SOU	M	M	National data and SDM
White-beaked dolphin	DK, SKA, KAT, SOU	M	M	National data and SDM

The methods and data behind the H+ data layers are described in details the following three reports:

- Korpinen, S., L. Meski, J.H. Andersen & M. Laamanen (2010): Towards a tool for quantifying anthropogenic pressures and potential impacts on the Baltic Sea marine environment. A background document on the method, data and testing of the Baltic Sea Pressure and Impact indices. Baltic Sea Environmental Proceedings No. 125. 73 pp.

- Andersen, J.H. & A. Stock (eds.), S. Heinänen, M. Mannerla & M. Vinther (2013): Human uses, pressures and impacts in the eastern North Sea. Aarhus University, DCE – Danish Centre for Environment and Energy. Technical Report from DCE – Danish Centre for Environment and Energy No. 18. 134 pp.

- Mohn, C., C. Göke, K. Timmermann, J.H. Andersen, K. Dahl, R. Dietz, L. I. Iversen, L. Mikkelsen, I.K. Petersen, J.K. Rømer, T.K. Sørensen, P. Stæhr, S. Sveegaard, J. Teilmann & J. Tougaard (2015): SYMBIOSE. Ecologically relevant data for marine strategies. Aarhus University, DCE – Danish Centre for Environment and Energy. Technical Report from DCE – Danish Centre for Environment and Energy No. 62, 102 pp.

Taking decision on which method(s) to use or not is at the moment associated with some uncertainties. The reason for this is that HELCOM has initiated a broad data collection process with regard to both pressure layers and ecosystem component layers under the HELCOM TAPAS project, an activity feeding into HOLAS II and the update of the BSPI/BSII.

It would, from a resource perspective be relevant to link upcoming SYMBIOSE data collection activities to the TAPAS/HOLAS II activities in order to ensure the best possible coordination and optimal use of apparently limited resources.

Given that TAPS will end in 2016 it seems prudent to place SYMPHONY data collection activities downstream the TAPAS process, or at least to the extent possible, to tap in on the TAPAS data products.

4. Discussion and conclusions

SYMPHONY is a Swedish initiative to obtain an overview and ultimately a catalogue of ecologically-relevant activity and pressure data layers and ecosystem component data layers. The discussion below provides guidance through four recommendations as to how this might be achieved.

From scrutinizing the data on which HOLAS I, HARMONY and SYMBIOSE are based it is evident that a lot of individual pressure layers and ecosystem component layers have been developed and applied in a CEA context. However, the vast majority of these data layers need to be updated. The SYMPHONY should avoid the issues that have hampered the success of other projects with regard to data availability and quality. Inspiration to achieve this can be found in the HARMONY and SYMBIOSE reports (e.g. Annex 4).

- **Recommendation 1:** SYMPHONY should begin by building a nation-wide catalogue with descriptions and documentation of all available data layers.

The selection of data layers can be inspired by work from HOLAS I and HAMONY. A key conclusion is that nearly all pressure layers need to be updated to fit the purpose and context of SYMPHONY. For example many important data-layers need to be expanded to cover the entire Swedish EEZ. Top prioritized pressures layers, identified by this study, are listed in Table 5, while key ecosystem component layers are listed in Table 6.

Table 5: Overview of top prioritized pressures layers for SYMPHONY with indication of potential sources and methods on which these data layers can be based.

Pressures	Potential source(s)	Suggested method(s)
Inputs of nutrients (RID + atm.)	National / EMEP	Mixed methods
Inputs of hazardous substances	National / EMEP	Mixed methods
Fishing incl. mussel dredging	National / HOLAS II?	Await HOLAS II
Bridges and coastal dams	National	Geo-referenced data
Climate anomalies (SST, SSS)	EEA	Not relevant
Disposal of dredged material	National	Geo-referenced data
Industrial and ferry ports	National	Geo-referenced data
Marine aquaculture sites	National	Geo-referenced data
Military areas	National	Geo-referenced data
Low frequency noise	BIAS project?	Modelled by BIAS
High frequency noise	BIAS project?	Modelled by BIAS
Wind farms, oil platforms, bridges, etc.	National	Geo-referenced data
Sediment extraction sites	National	Geo-referenced data
Shipping intensity	National surveillance data	Geo-referenced data
Dumped munition	HELCOM/OSPAR	Geo-referenced data

Table 6: Top prioritized ecosystem component layers for SYMPHONY as well as potential sources and methodology.

Ecosystem component	Potential source(s)	Suggested method(s)
Benthic habitat	EUSeaMap 2	See EUSeaMap 2
Eelgrass meadows	HOLAS II or national data	See Mohn et al. (2015)
Plankton communities (Chl-a)	SMHI	See Mohn et al. (2015)
Cod, Heering, Sprat	ICES	Await HOLAS II
Large Fish Indicator (LFI)	SLU?	See Mohn et al (2015)
Sea birds	HOLAS II?	Await HOLAS II
Marine mammals	HOLAS II?	Await HOLAS II

There is a technical challenge to develop a nation-wide catalogue as suggested with Recommendation 1. This should be a database or a GIS-system. The paper-based versions produced by HARMONY and SYMBIOSE might work with relatively few data layers and in a project context, but would not be too realistic if the potential outcome of SYMPHONY is to develop an operational national Decision Support System.

The review of especially HOLAS I and HARMONY revealed that the same feature could be referred to by different terms and the same term could refer to different features. There is a need in SYMPHONY, and also CEA activities, to ensure that there is a clear understanding of features and terms that are used.

- **Recommendation 2:** Organize the activities and pressures within SYMPHONY by creating a national 'catalogue' of data layers and including a 'key' or 'model' for linkages between activities and pressures.

Asking the question "Will a specific human activity cause pressures that may have impacts on ecosystem components?" will serve as a guide to identify the links necessary to address Recommendation 2. The schematic in Figure 4 provides an example of how this might be done. Such analyses are required for all 'human activities' (or whatever they will be denoted) in SYMPHONY.

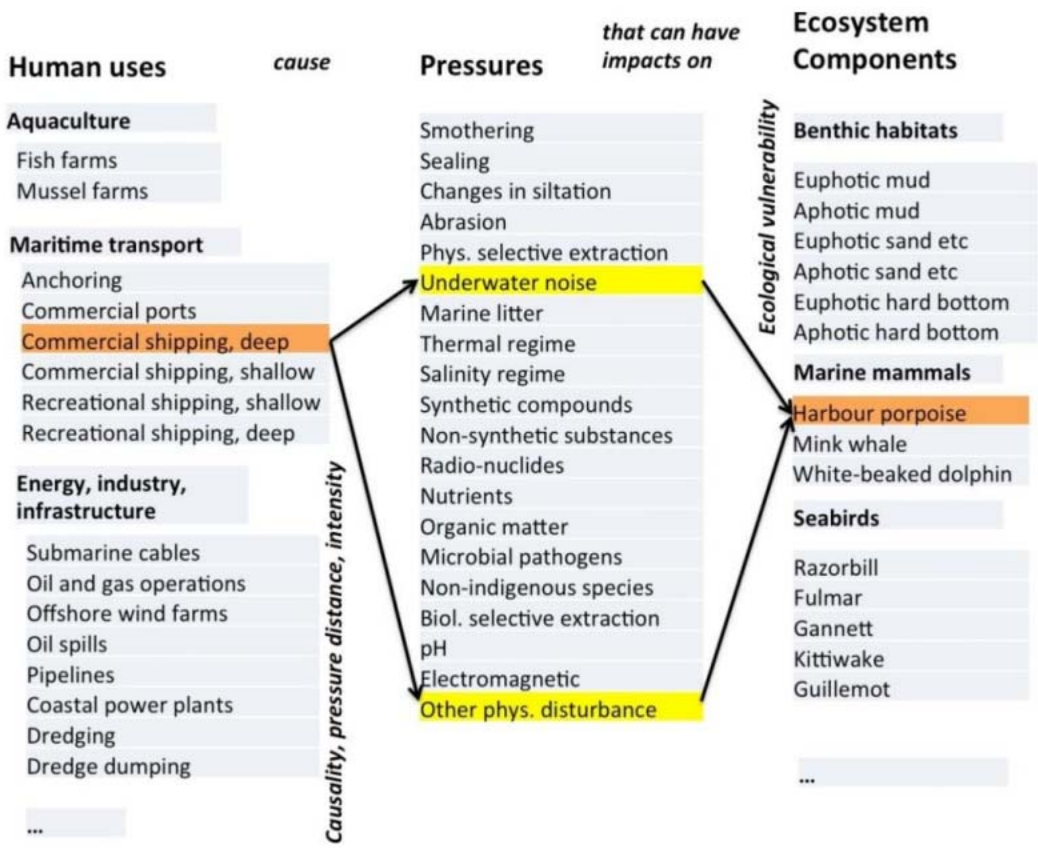


Figure 4: A schematic showing the relation between activity (human uses), pressures and ecosystem components from HARMONY. For example, commercial shipping would impact underwater noise and physical disturbance which could in turn affect the Harbour porpoise.

Accepting that existing data layers from especially HOLAS I and HARMONY are not up to date, it becomes vital to identify a cost-effective process of getting ecologically relevant and updated data layers on-board SYMPHONY. An efficient initial action would be coordinate upcoming SYMPHONY activities with the planned work in HOLAS II.

- **Recommendation 3:** SYMPHONY should to the largest degree possibly liaise with ongoing HOLAS II activities, especially the HELCOM TAPAS project and the subsequent update of both data layers and the BSPI/BSII.

Recommendation 3 should consider a minor extension of the HOLAS II study area to include the Swedish parts of the Skagerrak, which would mean that the entire Swedish EEZ would be covered.

Linking of pressure layers and ecosystem component layers, e.g. the arrow linking 'underwater noise' and 'other physical disturbance' with harbour porpoise in Figure 4, are in the context of CEA and mapping of potential cumulative effects based on the setting of sensitivity scores.

- **Recommendation 4:** SYMPHONY should review existing sensitivity scores for HOLAS I, HARMONY and the ongoing HOLAS II activities in order to identify: (1) if existing values are suitable for the purpose of SYMPHONY, (2) new values that emerge from ongoing activities of TAPAS and HOLAS II and (3) pressure and ecosystem-specific interactions that have not been published or likely to emerge from ongoing activities.

Recommendation 4 will be a basis for planning downstream SYMPHONY activities, especially if gaps are being identified. Here, it should be noted, that sensitivity scores from CEA-work have so far been generic, i.e. a score would apply for the entire study area and not for basin-specific values, something SYMPHONY should strive for.

SYMPHONY has, if these four recommendations are implemented and if it is populated with ecologically relevant 'pressure layers' and 'ecosystem component layers', a built-in potential for developing a broad-scale and operational MSP Decision Support System.

5. References

Andersen, J.H. & A. Stock (eds.), S. Heinänen, M. Mannerla & M. Vinther (2013): Human uses, pressures and impacts in the eastern North Sea. Aarhus University, DCE – Danish Centre for Environment and Energy. Technical Report from DCE – Danish Centre for Environment and Energy No. 18. 134 pp.

Andersen, J.H., J. Carstensen, D.J. Conley, K. Dromph, V. Fleming, B. Gustafsson, A. Josefson, A. Norkko, A. Villnäs & C. Murray (2015): Long-term temporal and spatial trends in eutrophication status of the Baltic Sea. Biological Reviews.

Andersen, J.H., C. Murray, M.M. Larsen, N. Green, T. Høgåsen, K. Gustavson, E. Boalt, E. Garnaga, M. Haarich, J. Manio, J. Strand & S. Korpinen (2016): Development and testing of a prototype tool for integrated assessment of chemical status in marine environments. Environmental Monitoring and Assessment. DOI: 10.1007/s10661-016-5121-x

Anon. (2008): Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Communities L 164/19.

Anon. (2014): Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning. Official Journal of the European Union L 257/135.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E, Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R. 2008. A Global Map of Human Impact on Marine Eco-systems. Science 319(5865):948-952.

Havsmiljöinstitutet (2014): Havet 2013/2014. 104 pp.
http://havsmiljoinstitutet.se/digitalAssets/1482/1482074_havet_2013_14.pdf

HELCOM (2007): HELCOM Baltic Sea Action Plan. Helsinki Commission.

HELCOM (2010): Ecosystem Health of the Baltic Sea 2003-2007. HELCOM Initial Holistic Assessment. Baltic Sea Environment Proceedings No. 122. 63 pp.

Korpinen, S., L. Meski, J.H. Andersen & M. Laamanen (2010): Towards a tool for quantifying anthropogenic pressures and potential impacts on the Baltic Sea marine environment. A background document on the method, data and testing of the Baltic Sea Pressure and Impact indices. Baltic Sea Environmental Proceedings No. 125. 73 pp.

Korpinen, S., L. Meski, J.H. Andersen & M. Laamanen (2012): Human pressures and their potential impact on the Baltic Sea ecosystem. Ecological Indicators 15:105-114.

Korpinen, S., M. Meidinger & M. Laamanen (2013): Cumulative impacts on seabed habitats: An indicator for assessments of good environmental status. Marine Pollution Bulletin 74(1):311-319.

Mohn, C., C. Göke, K. Timmermann, J.H. Andersen, K. Dahl, R. Dietz, L. I. Iversen, L. Mikkelsen, I.K. Petersen, J.K. Rømer, T.K. Sørensen, P. Stæhr, S. Sveegaard, J. Teilmann & J. Tougaard (2015): SYMBIOSE. Ecologically relevant data for marine strategies. Aarhus University, DCE – Danish Centre for Environment and Energy. Technical Report from DCE – Danish Centre for Environment and Energy No. 62, 102 pp.

OSPAR (2010): Quality Status Report 2010. OSPAR Commission. 175 pp.

Stock, A. (submitted): Open source software for mapping human impacts on marine ecosystems with an additive model. Manuscript submitted to Journal of Open Research Software.

Ærtebjerg, G., J.H. Andersen & O.S. Hansen (2003): Nutrients and Eutrophication in Danish Marine Waters. A Challenge to Science and Management. National Environmental Research Institute. 126 pp.

Annex 1: Pressure layers used in the context of HELCOM HOLAS, HARMONY and SYMBIOSE.

Activity	HOLAS I	HARMONY	SYMBIOSE
Bridges and coastal dams	+	1km	1*1km
coastal defence structures	+		
Coastal population density	+	1km	1*1km
Climate anomalies			1*1 km smoothening factor 20 km
Disposal of dredged materials	+	Unknown	point data (unknown scale)
Coastal waste water treatment plants	+	Unknown	10 km
Industrial and ferry ports	+	1:1000000	point data (unknown scale)
Marine aquaculture sites	+	Unknown	Unknown
Military areas		Unknown	Unknown
Microplastic in sediment			1:500000
Noise: Ship continuous 63 Hz			-
Noise: Ship continuous 125 hz			-
Recreational boating and sports	+		0.5 degree lat * 1 deg long (3500 km2)
Cables and pipelines (construction phase)	+		
Wind farms, oil platforms, bridges (construction phase)	+		
Oil Rigs (operational)	+		
Power plants with warm-water outflow	+	Unknown	
Offshore wind turbines	+	Unknown	point data (unknown scale)
Sea cables		Unknown	Unknown
Sediment extraction sites (sand, boulder, gravel)	+	Unknown	Unknown
Oil and gas industry infrastructure (oil terminals, refineries, oil platforms)	+	Unknown	point data (unknown scale)
Pipeline placement and operation	+	Unknown	Unknown
Offshore shipping	+		
Coastal shipping	+		
Shipping Intensity	+	1km	1km
Recreational shipping		1km	1km

Activity	HOLAS I	HARMONY	SYMBIOSE
Passenger ships outside 12 nm	+		
Input of hazardous substances (synthetic): Riverine input of synthetic pollutants		1km	1km
Input of hazardous substances (synthetic): Polluting ship accidents	+		
Input of hazardous substances (synthetic): Atmospheric deposition of dioxins	+		Unknown
Input of hazardous substances (non-synthetic): Illegal oil spills	+	1km	
Input of hazardous substances (non-synthetic): Atmospheric deposition of heavy metals	+	1km	-
Input of hazardous substances (non-synthetic): Waterborne heavy metals		1km	1km
Input of hazardous substances (non-synthetic): Waterborne cadmium	+		
Input of hazardous substances (non-synthetic): Waterborne lead	+		
Input of hazardous substances (non-synthetic): Waterborne mercury	+		
Input of hazardous substances (non-synthetic): Waterborne zinc	+		
Input of hazardous substances (non-synthetic): Waterborne nickel	+		
Input of hazardous substances (non-synthetic): Atmospheric deposition of mercury	+		
Input of hazardous substances (non-synthetic): Atmospheric deposition of cadmium	+		
Input of hazardous substances (non-synthetic): Atmospheric deposition of lead	+		
Introduction of radioactive substances	+	1km	1km
Dumped munition		Unknown	Unknown
Nutrient enrichment		1/9 deg lat * 1/6 deg long	
Atmospheric deposition of nitrogen	+		-
Waterborne input of Nitrogen	+		
Waterborne input of Phophorous	+		
Riverine input of organic matter	+		
Bathing sites	+		
Game hunting (birds, mammals, turtles)	+		

Activity	HOLAS I	HARMONY	SYMBIOSE
Hunting of Seals	+		
Potting		0.5 deg lat * 1 deg long	
Fishery effort from the "other trawl"		0.5 deg lat * 1 deg long	
Fishery effort from the dredge segments		0.5 deg lat * 1 deg long	
Beam trawl mesh size <32 mm		0.5 deg lat * 1 deg long	5km
Beam trawl, mesh size >80 mm		0.5 deg lat * 1 deg long	
Beam trawl, mesh size ≥ 100 mm			5km
Netting (setnet, gillnet)	+		5km
Demersal long lines			5km
Pelagic long lining			
Pelagic trawling	+	0.5 deg lat * 1 deg long	
Pelagic trawling: mesh size 16-32 mm	+		5km
Pelagic trawling: mesh size: 33-80 mm	+		5km
Benthic trawling			
Benthic trawling: Mesh size <16 mm			5km
Benthic trawling: Mesh size 16-32 mm			5km
Benthic trawling: Mesh size 33-69 mm			5km
Benthic trawling: Mesh size 70-99 mm		0.5 deg lat * 1 deg long	5km
Benthic trawling: Mesh size ≥100mm		0.5 deg lat * 1 deg long	5km
Fishery from coastal stationary gear	+		
Mussel dredging			5km

Annex 2: Ecosystem component layers used in the context of HELCOM HOLAS, HARMONY and SYMBIOSE

Ecosystem component	HOLAS	HARMONY	SYMBIOSE
Benthic habitats	+	250 m	1 km
Boulder reefs			1km*1km
photic rock or other, photic sand and coarse or mixed sediments)	+		
Photic water column	+		
Non-photic sand	+		
Photic sand	+		
Non-photic water column	+		
Non-photic mud and clay	+		
Photic mud and clay	+		
Mussel beds	+		
Broad-scale coastal ecosystems		1km	
Zostera meadows/Eelgrass distribution	+		0.003*0.003
N/P ratio winter			1*1 km and smoothing factor 20 km
Plankton communities		1km (original chlorophyll data: 4km)	1*1 km and smoothing factor 20 km
Cod	+	depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	30 km
Coalfish			30 km
Common Hooknose/monkfish			30 km
Common sole			30 km
Dab		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	30 km
Common dogfish			30 km
Spiny Dogfish			30 km
Flounder			30 km
Haddock		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	30 km
Herring		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	30 km
Lumpfish			30 km
Mackerel			30 km

Ecosystem component	HOLAS	HARMONY	SYMBIOSE
Nothern Prawn			30 km
Norway Lobster			30 km
Plaice		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	30 km
Shrimp			0.05 degrees
Sperling			30 km
Sprat			30 km
Starry Ray			30 km
Turbot			30 km
Whiting		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	30 km
Norway Pout		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	
Saithe		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	
Biomass distribution of Rays and Skates		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	
Biomass distribution of large Rays and Skates		depth map used for prediction: 0.0166*0.0166 decimal degrees (app. 1.85km)	
Sandeel fishing grounds		?	
Abundance of sensitive non-assessed fish species		1 deg long*0.5 deg lat	
Large Fish indicator (LFI)		1 deg long*0.5 deg lat	
Size spectrum height		1 deg long*0.5 deg lat	
Size spectrum slope		1 deg long*0.5 deg lat	
Species evenness		1 deg long*0.5 deg lat	
Species richness		1 deg long*0.5 deg lat	
Guillemot		10 km	500*500 m
Razorbill		10km	
Common scoter			500*500 m
Divers: Red throated diver, black-throated diver			500*500 m
Eider			500*500 m

Ecosystem component	HOLAS	HARMONY	SYMBIOSE
Fulmar		10 km	10 km
Garnet		10 km	10 km
Kittiwake		10 km	10 km
Wintering grounds for seabirds	+		
Long-tailed Duck			500*500 m
Red-breasted merganser			500*500 m
Grey seal	+		1*1 km and smoothing factor 20 km
Harbour seal			1*1 km and smoothing factor 20 km
Ringed seal			
Harbour porpoise	+	10 km	1*1 km and smoothing factor 20 km
Minke whale		10 km	10 km
White-beaked dolphin		10 km	10 km

Annex 3: Stressor definitions

In the following table a description of every stressor is presented, these descriptions are based on HOLAS, HARMONY and SYMBIOSE.

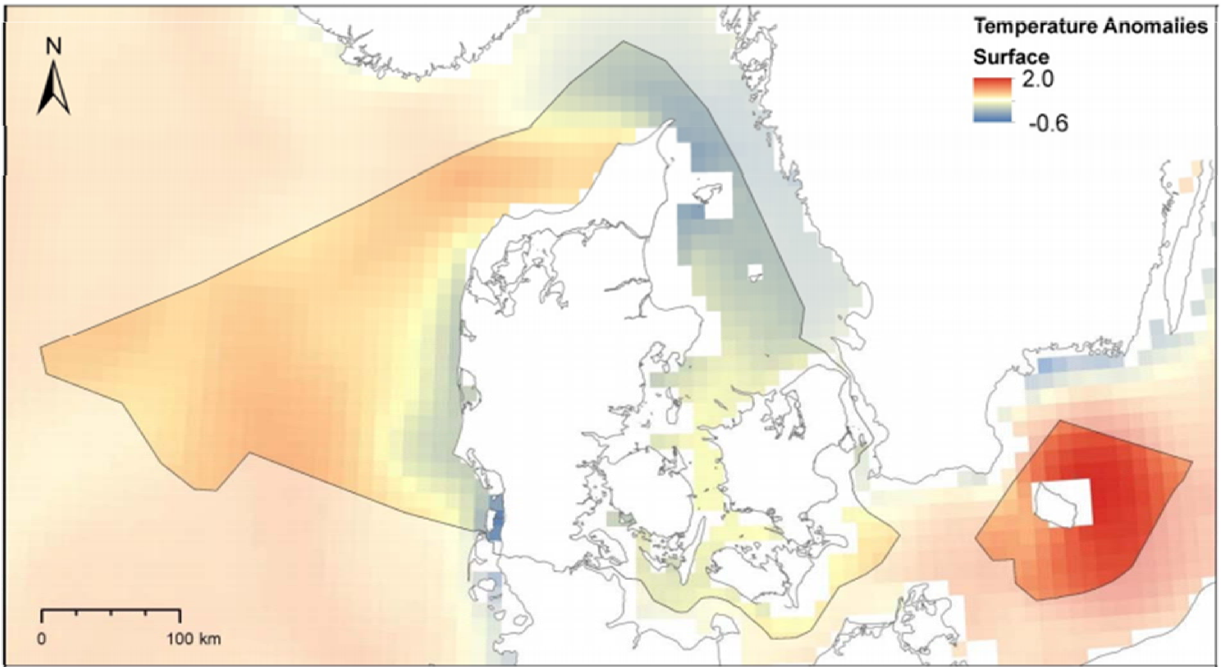
Stressor/Human Activities	Description
Bridges and coastal dams	Occurrence of bridges and coastal dams. They have importance since they can seal sea floor habitats
Coastal defense structures	Wave breakers, which reduce flooding, natural erosion, and also coastal wave dynamics are considered as coastal defence structures. It is the length of the structure that determines the pressure value.
Coastal population density	Population density in the coastal areas (25 km from the coastline)
Climate anomalies	Anomalies in Sea Surface Temperature (SST) from the 1900-1996 long-term mean SST (modeled).
Disposal of dredged materials	Authorized locations for disposal of dredged material
Coastal waste water treatment plants	The placing of these can result in nutrient input and input of hazardous substances. Waste water treatment plants located in a 5 km distance to the sea is considered as coastal.
Industrial and ferry ports	Location of industrial ports (receiving and shipping of goods). The annual average total cargo throughput is used as basis for the pressure value.
Marine aquaculture sites	Covering both shellfish and fish production. These farms are included since it can affect the input of organic matter.
Military areas	Military areas on sea where training and periodic activities take place
Microplastic in sediment	Content of microplastic in the upper 23 cm of the sediment.
Noise: Ship continuous 63 Hz	Based on AIS data.
Noise: Ship continuous 125 Hz	
Recreational boating and sports	
Cables and pipelines (construction phase)*	Number of bang days of construction work
Wind farms, oil platforms, bridges (construction phase)*	
Power plants with warm-water outflow (nuclear power plants).	These numbers of active reactors serves as the pressure value. The outflow of warm water results in changes in the temperature regime
Offshore wind turbines	Placing of offshore wind turbines and the number of turbines.
Sea cables	Placing of sea cables.
Sediment extraction	Authorized locations for extraction of sediment and the amount of dredged material.
Coastal oil and gas industry infrastructure (oil terminals, refineries, oil platforms)	Localities with established oil and gas installations.

Stressor/Human Activities	**Description**
Pipeline placement and operation	Main oil and gas pipeline.
Shipping intensity	Based on AIS for water depths less than 10 m and deeper than 10 meters or within 12 nautical miles and outside the border of 12 nautical miles. This distinction is made since it is expected that shipping on shallow water has a higher impact than on deeper waters.
Recreational shipping	Estimates of recreational shipping are based on distance to marina.
Input of hazardous substances (synthetic): Riverine input of synthetic pollutants	Introduction of synthetic compounds that can influence the marine environment such as pesticides, antifoulants, pharmaceuticals. These can originate from ships, atmosphere, rivers and from biologically active substances.
Input of hazardous substances (synthetic): Polluting ship accidents*	The pressure is based on the amount of pollution (in m3).
Input of hazardous substances (synthetic): Atmospheric deposition of dioxins	The average deposition of dioxins is the pressure value. It is important because it bioaccumulates and biomagnifies in organisms.
Input of hazardous substances (non-synthetic): Illegal oil spills	These can be fx. heavy metals or hydrocarbons from polluting ship accidents, oil, gas and mineral exploration and exploitation, atmospheric deposition or from riverine input.
Input of hazardous substances (non-synthetic): Atmospheric deposition of heavy metals	
Input of hazardous substances (non-synthetic): Waterborne heavy metals	
Introduction of radioactive substances	Riverine input of radionuclides.
Dumped munition	Official dumping sites and encounters outside the official sites.
Nutrient enrichment	Input of fertilisers and other compounds rich on nitrogen and phosphorous. The sources can be agriculture, aquaculture or atmospheric deposition.
Atmospheric deposition of nitrogen	
Waterborne input of Nitrogen	
Waterborne input of Phosphorous	
Riverine input of organic matter	Based on the biochemical oxygen demand from river mouths.
Bathing sites	The number of bathing sites pr. area makes up the pressure.
Game hunting (birds, mammals, turtles)	Hunting of cormorants (*Phalacrocorax carbo*), eiders (*Somateri molissima*), and long-tailed ducks (*Clangulam hymalis*).
Hunting of Seals	Number of seals shot.
Potting	National effort (kW-days) and “hours fished” constitute the basis for the estimation of the pressure.
Fishery effort from the "other trawl"	
Fishery effort from the dredge segments	
Beam trawl mesh size <32 mm	
Beam trawl, mesh size >80 mm	
Beam trawl, mesh size ≥ 100 mm	
Netting (setnet, gillnet)	
Demersal long lines	
Pelagic long lining	
Pelagic trawling	
Pelagic trawling: mesh size 16-32 mm	

Stressor/Human Activities	Description
Pelagic trawling: mesh size: 33-80 mm	
Benthic trawling	
Benthic trawling: Mesh size <16 mm	
Benthic trawling: Mesh size 16-32 mm	
Benthic trawling: Mesh size 33-69 mm	
Benthic trawling: Mesh size 70-99 mm	
Benthic trawling: Mesh size ≥100mm	
Fishery from coastal stationary gear	
Mussel dredging	Mussel dredging effort

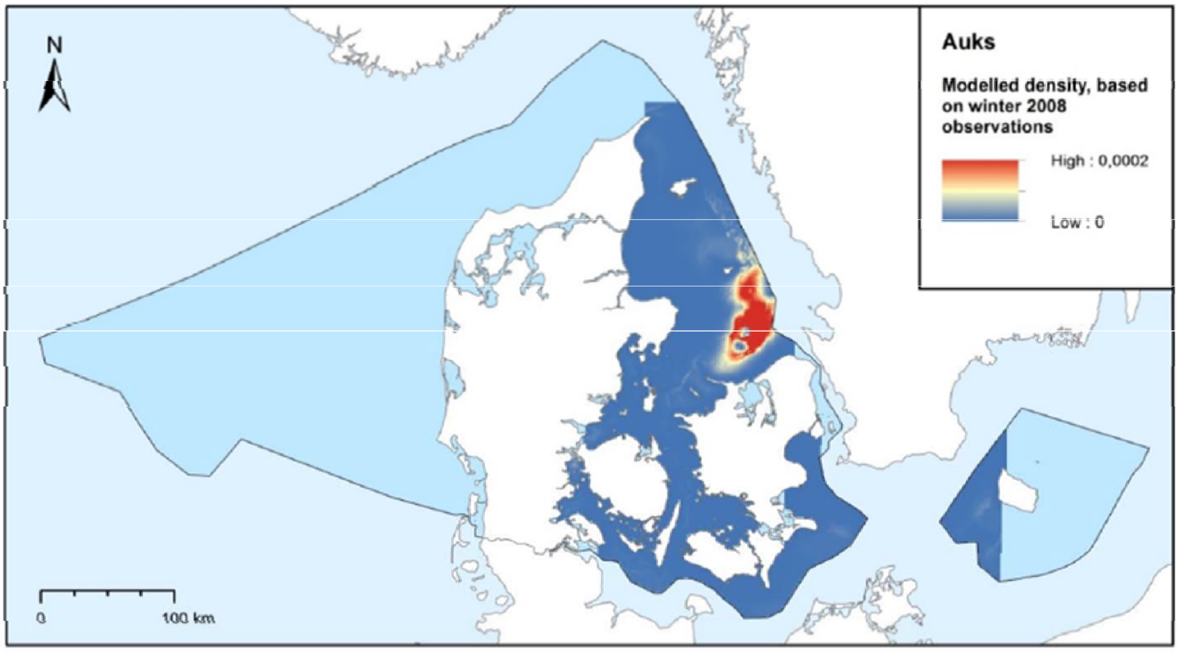
Annex 4: Examples of data layer summaries

A2 - Climate anomalies



Map showing the sea surface temperature (SST) anomaly (°C, 2009-2010 average). SST anomalies were calculated from model hindcasts relative to the 1900-1996 long-term mean SST. In addition, anomalies for the same period were calculated for bottom temperature, seas surface salinity and bottom salinity (not shown, but available).	
Data sources and methods Sea surface and sea bottom anomalies of temperature (T) and salinity (S) were calculated from 2009 and 2010 T/S data. The T/S data were extracted from the output of the 3D ocean circulation model HIROMB-BOOS (HBM). The model domain covers the North Sea and Baltic Sea with a 6 nm horizontal resolution. The vertical grid has 50 layers with an average resolution of 2 m in the top 50 m of the water column. The model output is thoroughly validated against observation from North Sea and Baltic Sea monitoring stations (Maar et al., 2011). Surface and bottom T/S anomalies were calculated relative to the 1900-1996 T/S climatology by Janssen et al. (1999). The T/S climatology is on a 10 km x 10 km grid was interpolated to match the 6 nm resolution of model grid prior to calculation of the anomalies. The interpolation resulted in occasionally too high anomaly values at a few coastal and bottom locations due to the minor mismatch of the different coastline and bathymetry.	
Spatial coverage Original data are available for the entire Baltic (including Skagerrak, Kattegat and Belt Sea) and North Sea region. The spatial resolution of the original data is 6 nautical miles HBM model) and 10 km (T/S climatology) respectively.	
References Janssen F, Schrum C., Backhaus J. (1999) A climatological data set of temperature and salinity for the Baltic Sea and the North Sea. Deutsche Hydrographische Zeitschrift, 51 (9 supplement), 5 -245. Maar M, Møller EF, Larsen J, Madsen KS, Wan Z, She J, Jonasson L, Neumann T. (2011). Ecosystem modelling across a salinity gradient from the North Sea to the Baltic Sea. Ecological Modelling, 222 (10), 1696-1711.	
Scale or resolution	ArcGis output raster: 1 x 1 km and smoothing factor: 20 km.
Time period	2009 – 2010 (2 year average)
Data access	Original data are accessible.
Responsible institution	DCE/AU
Contact person	Christian Mohn
E-mail	chmo@bios.au.dk
Key words	Temperature and salinity anomalies, HBM model

E1 – Auks (*Alkefugl*): Guillemot (Uria aalge, *Lomvie*), Razorbill (Alca torda, *Alk*)



Map showing the density and distribution of wintering Razorbill / Guillemot (Alca torda / Uria aalge) in Danish waters based on line-transect counts in the specified area (January - March 2008). There were an estimated total number of 76,573 birds within the model area.

Data sources and methods

Data originates from the Danish NOVANA monitoring programme. Waterbird counts were conducted primarily in the form of line-transect counts in large parts of the Danish waters. This is a sampling method that permits density calculations using the Distance Sampling method in combination with subsequent spatial modeling to describe the geographical distribution. Counts were made at predefined parallel transect lines, either orientated east-west or north-south and in most cases with a distance of 5 km. Densities were calculated with the Distance Sampling software and distributions are described using spatial modeling. To calculate the densities, a detection function was calculated describing the decreasing probability of detecting a given bird with increasing distance away from the counting route. To calculate the function, variables were used that are significant for detection probability, such as wave activity and flock size. Further, environmental variables, such as water depth and distance to the shore, were used for modeling of the spatial distribution of the birds.

Spatial coverage

The open ocean parts of the inner Danish waters. The waters east of Bornholm were not covered, as well as small parts of the Kattegat. Topographically complex areas such as the Limfjord, larger fjord systems, the 'Smålandsfarvandet' (a bay between the islands of Zealand and Lolland) and the southern Fyn archipelago were counted using total-counting methods. Therefore, densities and spatial distribution could not be generated for these particular areas.

References

Petersen, I.K., Nielsen, R.D., Pihl, S., Clausen, P., Therkildsen, O., Christensen, T.K., Kahlert, J. & Hounisen, J.P. 2010. Landsdækkende optælling af vandfugle i Danmark, vinteren 2007/2008. Danmarks Miljøundersøgelser, Aarhus Universitet. 78 s. – Arbejdsrapport fra DMU nr. 261. http://www.dmu.dk/Pub/AR261.pdf

Petersen, I.K. & Nielsen, R.D. 2011. Abundance and distribution of selected waterbird species in Danish marine areas. Report commissioned by Vattenfall A/S. National Environmental Research Institute, Aarhus University, Denmark. 62 pp.

Scale or resolution	ArcGis output polygon: 500 x 500 m
Time period	Januar - March 2008.
Data access	Original data are accessible.
Responsible institution	AU Bioscience, DCE
Contact person	Ib Krag Petersen
E-mail	ikp@bios.au.dk
Key words	Guillemot, Razorbill, *Alca torda*, *Uria aalge*, Denmark, Baltic Sea, Skagerrak, Kattegat, Danish waters, biodiversity

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