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Sustainable Shipping and Environment of the Baltic Sea region

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Report on analytical framework for assessment of shipping and harbours in the Baltic Sea

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Report on analytical framework for assessment of shipping and harbours in the Baltic Sea

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Report on analytical framework for assessment of shipping and harbours in the Baltic Sea

The project BONUS SHEBA aims to assess the environmental impact from shipping in the Baltic Sea region. The scientific assessments of the environmental impact from shipping are covered within the three Work Packages (WP) focused on emissions to air (WP2), emissions/discharges to water (WP3) and finally noise (WP4). In WP 5, the outcome of WP2, WP3 and WP4, is then used for an integrated assessment of shipping pressures on ecosystem services.

The aim of this report is to create a framework to understand and ultimately assess the linkages from the drivers of shipping in the Baltic Sea to its effects on ecosystem services and human wellbeing. Available Drivers Pressures State Impact Response (DPSIR) frameworks are analysed and adapted to shipping in the Baltic Sea. The developed DPSIR framework will be operationalised in further steps using available indicators. An adapted DPSIR framework and especially the reviewed indicators will be used to assess potential changes to ecosystem services compared to Business As Usual (BAU) and an integrated assessment and policy analysis to reduce pressures from shipping in the Baltic Sea.

This report is divided into the following sections:

- Section 1 provides an Introduction and background for the report as wella as delineates the approach and methodology, which was used to write this paper and to build the BONUS SHEBA framework.
- Section 2 shows the evolution of DPSIR framework.
- Section 3 presents how this framework was adapted to shipping in the Baltic Sea. Furthermore, the characteristics of Drivers (3.1), Pressures (3.2), State (3.3), Impact (3.4) and Response (3.5), as well as the links between them are shown. Much emphasis is given on the types of responses (3.5.1) and linking responses to the current policy framework (3.5.2)
- In Section 4, the DPSIR framework is operationalised for shipping in the Baltic Sea. In this part of the report also the interlinkages of the SHEBA DPSIR for shipping in the Baltic Sea (4.1) and indicators (4.2) are covered.
- Section 5 draws conclusions and describes the next steps of BONUS SHEBA.

Relevant policies for shipping in the Baltic are listed in the published BONUS SHEBA Deliverable 1.1 “Drivers for the shipping sector“[1]. The costs of environmental degradation from shipping in the Baltic Sea and future scenarios outlining potential responses will be refined and assessed in upcoming BONUS SHEBA assessments.

[1] See http://www.sheba-project.eu/imperia/md/content/sheba/deliverables/sheba-d1.1_final.pdf

1 Introduction

Background

The claims on the marine environment are today many, ranging from extraction of minerals, gas and oil, to fishing and aquaculture to renewable energy installations and finally shipping. Thus, there is a need to understand the pressures and impacts on the marine environment and to ensure overall sustainable use of marine resources. There is also a need to assess both the economic and social benefits as well as the potential associated costs of degradation to ecosystem services that stem from pressures on the marine environment.

To assess the interlinkages between the shipping activities and the Baltic Sea environment and encompassing both the domain of the natural environment and the social impact, the conceptual framework and the applied methodologies stem from available literature. The definitions and classifications necessary to operationalise future decisions is the first step for successfully balancing the environmental state with human welfare. The framework will provide a way to link the social sciences with the natural sciences with a common language and implies a generalisation and simplification of the natural complexity of an ecosystem.

One of the most common models for assessing human relationships with the environment is the DPSIR (Driver-Pressure-State-Impact-Response) framework. There are a variety of modified DPSIR frameworks available (Gari et al. 2015), and within BONUS SHEBA Task 5.1, the outline of the DPSIR is adapted to fit the purpose to assess the environmental impact from shipping and potential policy responses. Further, a guideline for use by WP2, WP3 and WP4 was constructed to ensure harmonized data input and handling from the different perspectives for the integrated assessment (i.e. indicators). An excel template for the semi-quantitative data collection from WP2, WP3 and WP4 was also constructed.

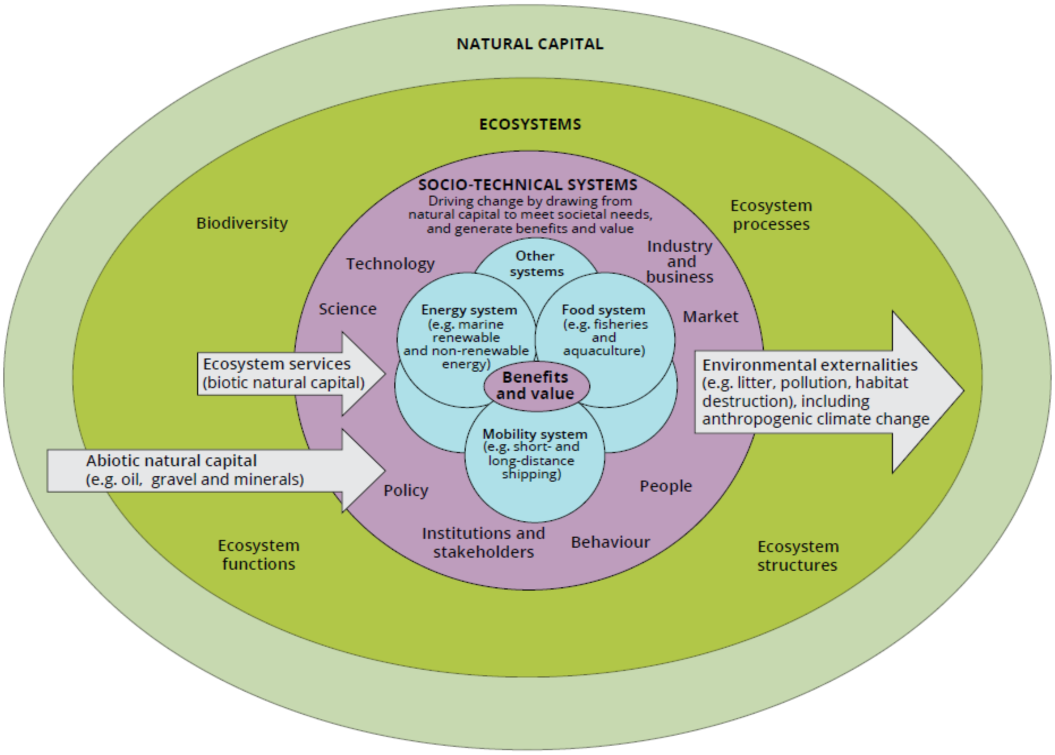
Because BONUS SHEBA is aiming to understand how policies can be used ensure human well being, a key concept is ecosystem services. According to the EEA, 2015 *'Ecosystem services are the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people. Marine ecosystem services include provisioning services (such as food from fish); regulation and maintenance services (such as the sea's ability to absorb greenhouse gases, thus regulating the climate); and cultural services (such as the availability of charismatic marine species to observe or to research). We get many benefits from these services such as nutrition, reductions in anthropogenic* CO_2*, and recreation'*.

The DPSIR framework will help to clarify the conceptual relationship between intermediate and final services (explained in Section 3.4) and the corresponding human welfare benefits also taking into account the pitfalls of double counting which is often ignored in ecosystem service assessments. An example of how to develop such a classification system is offered by Fisher, Turner and Morling (2009), which give a clear definition of the services and their characteristics as well as the decision context in which they are being used.

By building upon and refining the DPSIR framework, this report is used to build a systems approach focused on shipping in the Baltic Sea, providing quantitative and qualitative links between human welfare and the environment. A prioritization or ranking of the top ecosystem services affected by shipping should eventually be possible. This will also enable an estimation of the state changes of shipping as pressure on ecosystem services. In other words, whether shipping should be considered in policy responses seeking to reduce the degradation of ecosystem services. To do this, a system of indicators for the quantitative assessment is developed for shipping activities in the Baltic Sea.

Links between the social-technical system and the ecological system, particularly natural capital, can be seen in the figure below. Figure 1 provides a view of the relationship between natural capital, its ecosystems and the social-technical system. In the figure below, ecosystem services, biotic natural capital, as well as abiotic natural capital flow into the social-technical system where they have value. However, the social-technical system also creates environmental externalities which influence and change ecosystems (EEA, 2015).

Figure 1 Interactions between natural capital, its ecosystems and socio-technical systems



Note: Social-technical systems act as 'drivers of change': they use natural capital and its ecosystems as inputs to meet societal needs, generate benefits, which have economic and other value, and promote well-being, but the externalities from such use can damage ecosystems. Source: EEA, 2015

Approach and methodology

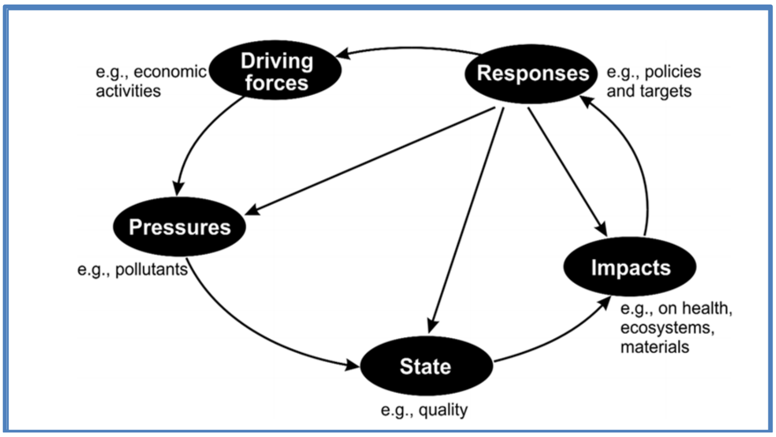
In order to develop an analytical framework for assessment of shipping and harbours in the Baltic Sea, including an adapted DPSIR framework, a multi step approach was used. This approach combined a literature review, an assessment, an interdisciplinary discussion and a survey. The literature review focused on the Drivers Pressure State Impact Response framework in order to build on scientific understanding and adapt the framework for use in SHEBA, and therefore shipping in the Baltic. This information was assessed concerning its suitability for shipping in the Baltic and then condensed to a background document. This background document was used for an internal and interdisciplinary discussion on a workshop in Berlin in February 2016. This discussion allowed to fine tune the framework, to prove it and to establish a common understanding across the different disciplines and scientists within SHEBA. The workshop resulted in the creation of a survey to be filled out by SHEBA scientists in an effort to understand the main pressures resulting from shipping activity and how these would in turn affect ecosystem services. This survey listed amongst others all relevant Drivers and Pressures, with information about their weight (or importance), indicators and links to ecosystem services which they affect. In addition, online research was conducted to identify and propose potential indicators which could be used to support the framework and future assessments.

2 The evolution of the DPSIR framework

The DPSIR framework (Figure 2) is a structured way to analyse the social-ecological system (SES) i.e. how different anthropogenic drivers influence ecosystems and how responses to changes in the ecosystem affect these drivers and the ecosystem in turn. It is a complex cycle of feedback loops and variables that interact within a larger system. The DPSIR is useful to structure information and understand the links within that system. There are at least a handful of European research consortia that have conducted ecosystem services assessment, e.g. ODEMM, KNOWSEAS, UKNEA, ELME, VALMER.[2] Although some of them, like the ODEMM project assess shipping, there is a gap of knowledge with respect to shipping. The BONUS SHEBA project aims to help fill this gap and the DPSIR approach is adapted to the case of shipping in the Baltic Sea and applied at a greater level of detail than previous efforts.

The DPSIR framework can be traced back to the Stress–Response framework developed by Statistics Canada in the late 1970s (Rapport and Friend, 1979), which was then further developed by the OECD (OECD, 1991and 1993) and United Nations (1996). The DPSIR framework itself was first elaborated in its present form in two studies by the European Environmental Agency (EEA, 1995; Holten-Andersen et al., 1995).

Figure 2 DPSIR Framework for reporting on environmental issues (EEA, 1995)



Source: EEA, 1995

The DPSIR framework assumes a causal chain from Driving forces in a socio-economic system, which is causing Pressures on the environment which affects its State and cause Impacts on society, ecosystems and economy. Responses potentially minimise these impacts by addressing either step of the causality chain. Hence, the EEA described the DPSIR framework as a “causal framework for describing the interactions between society and the

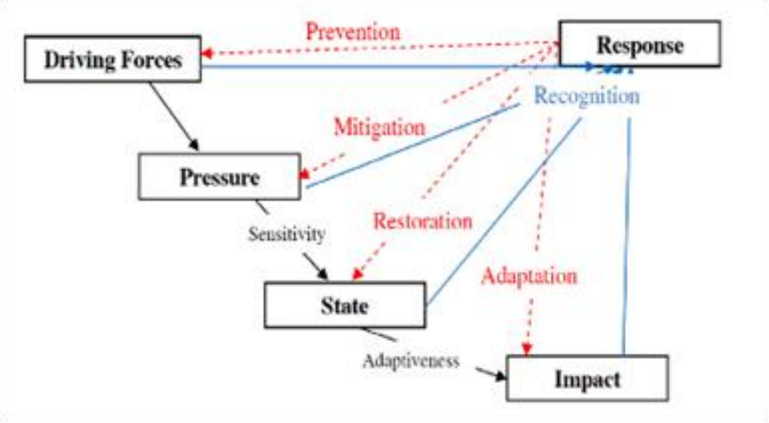
[2] ODEMM: http://odemm.com/ ; KNOWSEAS: http://www.knowseas.com/; UKNEA: http://uknea.unep-wcmc.org/; ELME: http://cordis.europa.eu/result/rcn/50751_en.html; VALMER: http://www.valmer.eu/

environment” (EEA, 2006). The parts of the framework are defined as follows (EEA, 2006; Spangenberg et al., 2015; Svarstad et al., 2007):

- **Driving forces**: social, economic or institutional changes (or changes of their links) which trigger, directly or indirectly, Pressures on the environment
- **Pressures**: consequences of human activities (e.g. extraction and use of resources, emissions etc.) which have the potential to cause or contribute to negative effects (IMPACTS) on the environment and the services it provides.
- **State**: quantity of (biological, physical or chemical) features of ecosystems, and its functions – (which might be affected by PRESSURES)
- **Impacts**: changes in ecosystem functions (caused by STATE changes), which are potentially affecting negatively the social, economic and environmental dimensions.
- **Response**: policy action to prevent, eliminate, compensate, reduce or adapt to IMPACTS by an intervention at DRIVING FORCES, PRESSURES, STATE or IMPACTS. The perception/recognition of the impacts (often linked with awareness) is often a condition for a RESPONSE.

Spangenberg et al. 2015 altered the DPSIR framework to show that the framework is not merely ciclicle but that Responses for example can be linked to all other elements of the DPSIR framework depending on what is targeted. They depicted the this as follows:

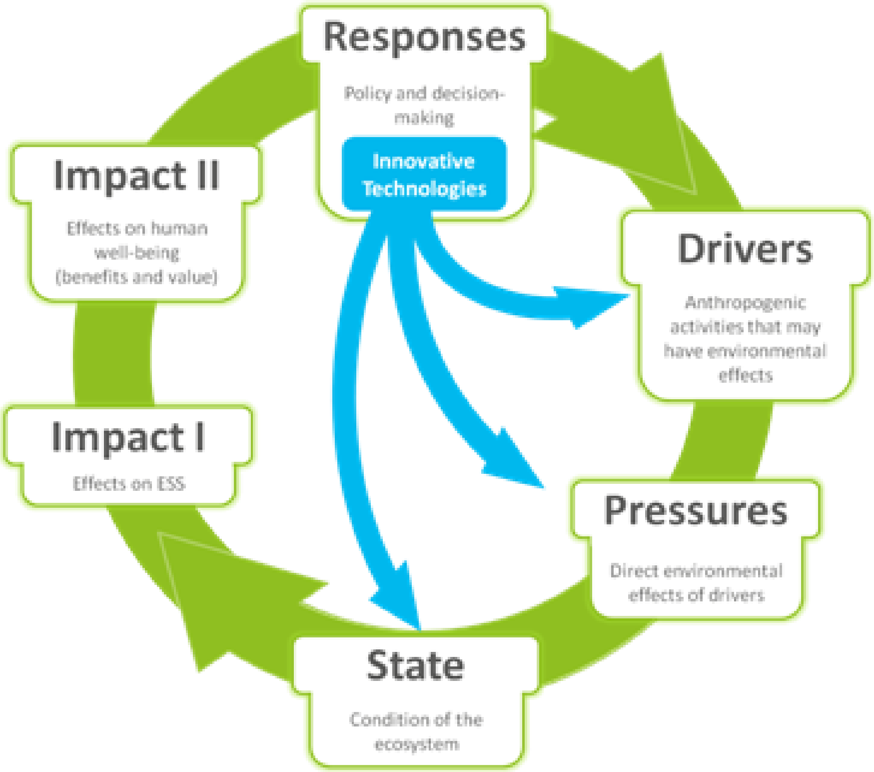
Figure 3 DPSIR Framework according to Spangenberg et al. 2015



Source: Spangenberg et al. 2015

Not only the different types of responses, but also the different impacts can be differentiated, see Figure 4. The Conceptual approach of the DESSIN Ecoystem Servcies (ESS) Evaluation Framework distinguishes between impacts on ecosystem services and (human) well-being. This highlights the ‘chain of impacts’, where environmental impacts often lead to economic and social impacts.

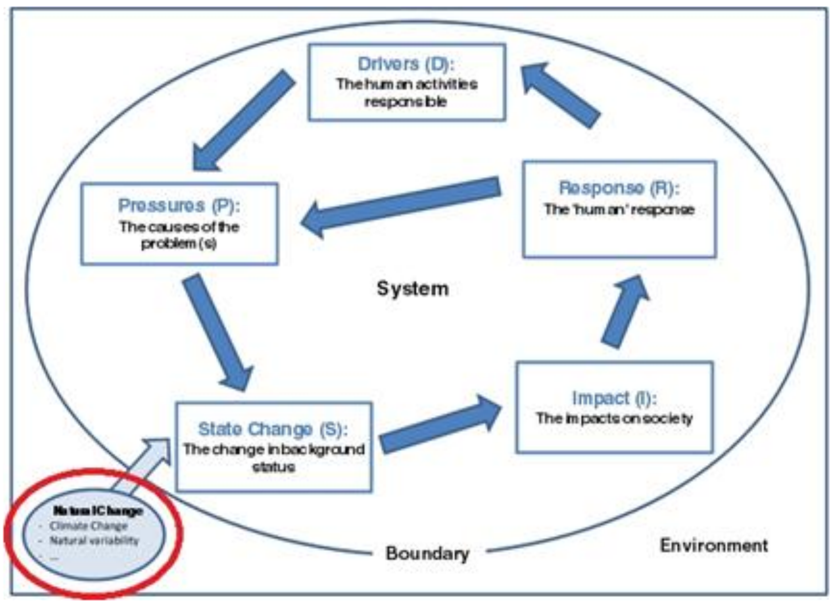
Figure 4 Conceptual approach of the DESSIN ESS Evaluation Framework



Source: DESINN, 2016 based on Müller and Burkhard, 2012, Van Oudenhoven et al., 2012 and Haines-Young and Potschin, 2010; 2013

Since the EEA's first iteration of the DPSIR framework, many versions have been developed which upate definitions and take on new modulations of the elements (Gari et al., 2015). Like all models, the DPSIR framework simplifies reality in order to provide a systematic overview. There are many variations of this framework, with regard to different ecosystems or study areas. Atkins et al. 2011 sought to expand the framework beyond human drivers and include other major drivers that potentially lead to significant pressures that could be overlooked. To address this, Atkins et al. 2011 proposed to include natural change as a factor, see Figure 5.

Figure 5 The DPSIR framework including natural change



Source: Atkins et al. 2011

Svarstad et al. 2015, evaluated the DPSIR framework with regard to a specific issue (biodiversity preservation), focusing on four different discourse types (preservationist, win-win-discourse, traditionalist and promethean). They found that the DPSIR framework is limited by the expanse of stakeholders/experts and the views they bring to the discourse. Thus it is crucial to bear in mind, that the DPSIR framework is as objective in depicting 'reality' as different stakeholders with different views are included.

Spangenberg et al. 2015 furthermore suggested a double-DPSIR scheme to depict the so-called 'society-to-biology loop', which emerges when a response is not effective anymore (in minimizing the drivers), but becomes a pressure itself. Their example is insecticide spraying against grasshoppers in order to increase rice yields, which is a rather specific example. It is useful to keep possible dynamics in mind, which might emerge when the system runs various times 'through' the DPSIR cycle.

Table 1 Overview of changes and adaptations to the DPSIR framework

Author/ institution	Year	Description of changes and adaptions to DPSIR framework
Rapport and Friend,	1979	Stress–Response framework is developed by Statistics Canada (a basis for DPSIR) – further develped by OECD (1991 & 1993) and United Nations (1996).
EEA & Holten-Andersen et al.	1995	DPSIR framework itself was first elaborated in its present form
Atkins et al.	2011	Natural change is inlcluded as a factor to compensate the focus of this model to human-caused drivers
Spangenberg et al.	2015	Different types of responses were differentiated Double DPSIR scheme is presented, to depict the so-called 'society-to-biology loop' (to include the case when a response becomes a pressure itself)
Svarstad et al.	2015	DPSIR is adapted to various contexts – e.g. to biodiversity preservation

When trying to apply the general DPSIR framework with the categories described above to the case of shipping in the Baltic Sea it can be seen that there is a need to provide more detail and fine tune the framework. This will be explored in the next section.

3 Adapting the DPSIR framework for shipping in the Baltic Sea

This section outlines the considerations and adaptations made in an effort to apply the DPSIR framework in a more detailed manner to shipping in the Baltic. The adapted DPSIR framework for shipping in the Baltic Sea region is shown in Figure 6. The sub-categorization is important since the emission factors of both nutrients, acidifying substances, contaminants and biology (alien species) are determined by factors such as ship type, operation mode, used/installed subsystem, number of passengers etc. Example of shipping related subsystems that will be used to calculate emission factors of nutrients, acidifying substances, contaminants, litter and biology (alien species) are shown in Fig 6-8 and in Table 2.

To derive adequate information for the DPSIR shipping framework, experts in the work packages responsible for emissions to air (WP2), emissions to water (WP3) and underwater noise (WP4) answered a questionnaire. The questions were designed to draw expert knowledge on the most important drivers, pressures, state and impacts for the respective field. WP2 (air pollution) will calculate concentrations of different pollutants on city scale and regional scale (PM, O3, NO2, and several others). An assessment of some of the indicators, in particular premature mortality and attainment of limit values will be conducted.

Figure 6 The DPSIR framework for shipping in the Baltic Sea region

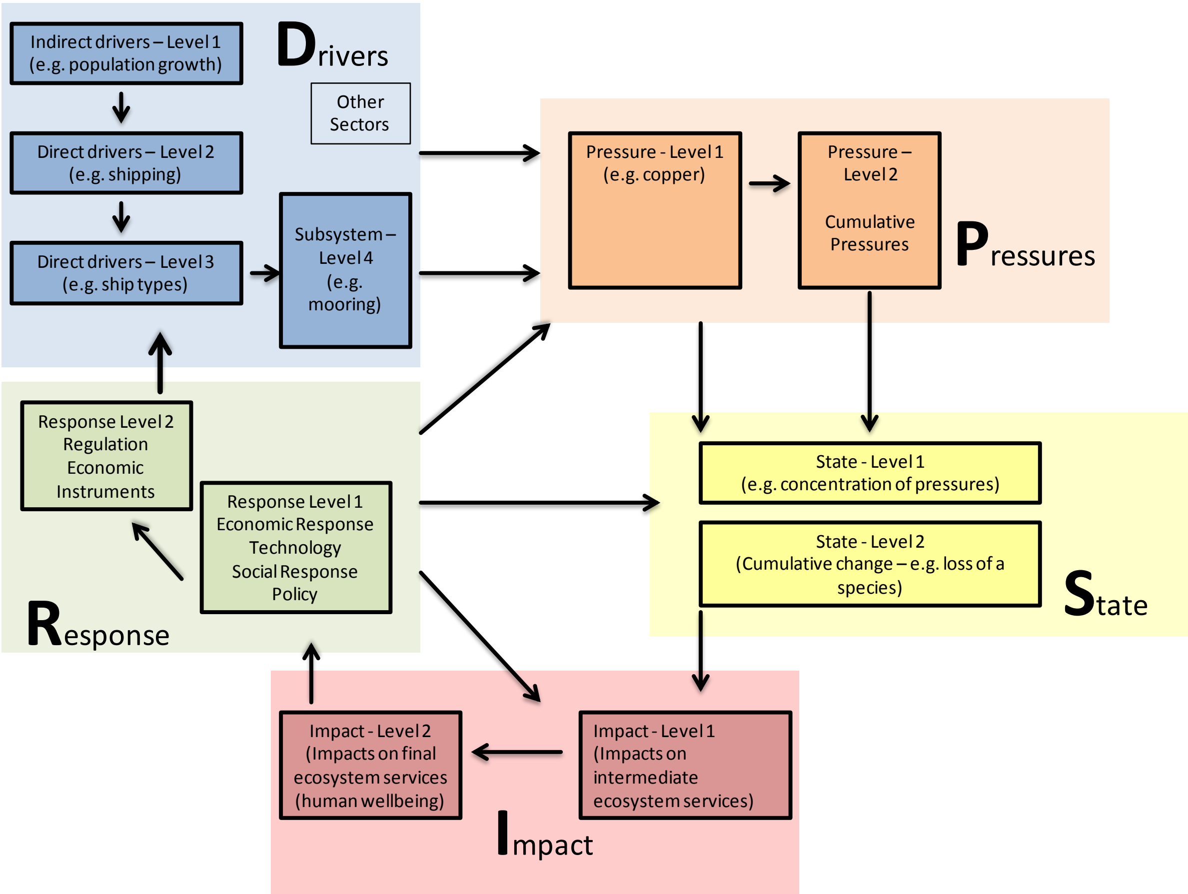


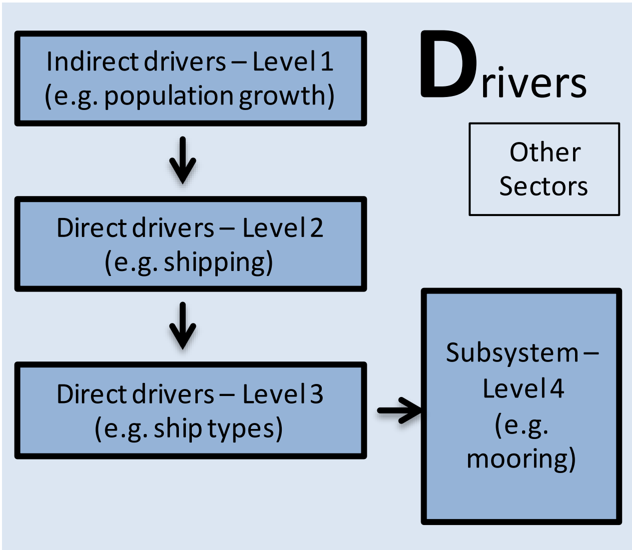
Table 2 DPSIR concept for shipping with classes, levels and subcategories

Classes	Levels	Description
Indirect Drivers	1	Economic growth, population growth, urbanisation, trade, fuel prices, climate change, etc.
Direct Drivers	2	Shipping and leisure boating
	3	Ship types: Tug, Vehicle carrier, Ice breaker, Service/Pilot vessel, Tanker, Reefer, Container ship, Passenger cruiser, Passenger ferry, General Cargo, Search and rescue, Yacht (leisure boat)
Subsystem	4	Subsystems: Antifouling, Ballast water, Biofouling on ships, Bilge water, Cooling water, Black water, Grey water, Food waste, Scrubbing water, Stern tube oil, Litter, engine operation, boiler operation in ports
Pressures	1	Pollutants: Contaminants, nutrients, invasive species, acidification, litter and underwater noise, air pollution
	2	Cumulations of pollutants
State	1	Concentrations and levels of pollutants in the Baltic Sea and the surrounding atmosphere
	2	The cumulative effect to the environment: E.g. loss of algal species, crustaceans and fish
Impacts	1	Effects on ecosystem services: e.g. maintaining nursery populations and habitats
	2	Effects that changes in ecosystem services have on human wellbeing: e.g. reduced fish stocks, impacts on tourism
Response	1	Changes in techonolgy, society, economy, policy
	2	Specific measures/instruments

3.1 Drivers

This section outlines drivers of change to be assessed in BONUS-SHEBA. Generally, drivers can be understood as anthropogenic activities that may have an effect on the environment. These include indirect drivers, direct drivers, and their subsystems as shown in the figure below.

Figure 7 Drivers



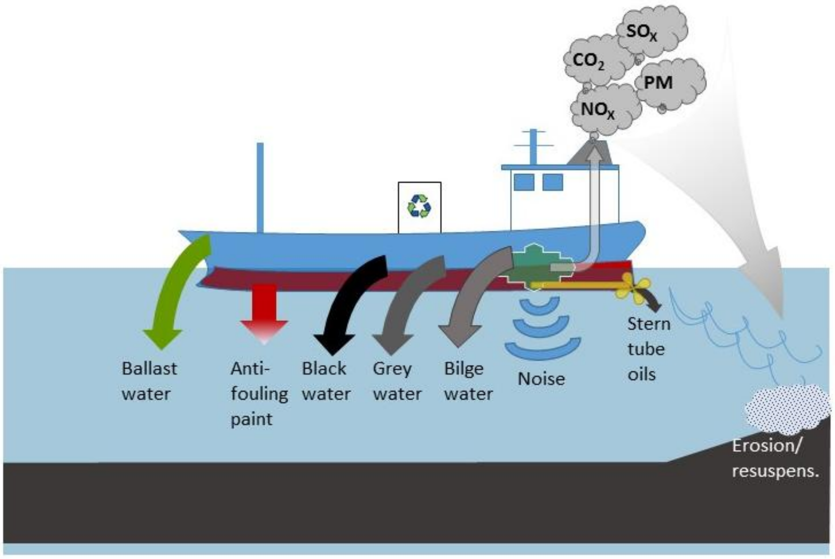
Indirect drivers are socioeconomic factors such as economic growth, population growth, and technology, or the cost of shipping. These indirect drivers are representing the socioeconomic situation as well as social dynamics (such as changing awareness, changing demand and purchase behaviour, etc.) and technological developments in the Baltic Sea and beyond. While highly relevant and influential for shipping activities, indirect drivers are not defined or classified in detail in this report and the starting point for assessment is direct drivers. This is because the objective of BONUS SHEBA is to identify and recommend policy options related to shipping activities, and not those drivers that effect shipping (e.g. economic growth). Direct drivers are shipping activities in the Baltic Sea, namely shipping and leisure boats. Within this definition, shipping activities can be split into certain ship types. Ship types container/cargo ships, tankers, fishing vessels, ro-ros, ferries, cruise ships, and leisure boats. See Table 3.

Table 3 Ship types relevant for shipping in the Baltic Sea

Ship type	Description
Container/cargo ships	Ships which carry cargo in containers (non-bulk cargo) and bulk cargo. Container ships and bulk carriers are with tankers the largest commercial vessels.
Tankers	Tankers are vessels which transport liquids and gases. Main types are oil tanker, chemical tanker and gas carrier.
Ro-ros	Ro-ros are Roll-on/roll-off ships which are designed to carry, cars, trucks, semi-trailer trucks (wheeled cargo). The vehicles are driven on and off the ship.
Fishing vessels	A ship or boat to catch fish in the sea.
Ferries	A ferry is mainly used to carry passengers. Additional to passengers, vehicles and cargo are transported as well. Ferries mostly operate in a regular service.
Cruise ships	A cruise ship is a passenger ship used for pleasure voyages. The amenities of the ship are part of the experience.
Leisure boats	Leisure boats are smaller boats used for leisure (e.g. max about 24 metres). These can be small sail boats, sailing yachts, power boats or motor yachts.

To derive direct links to shipping pressures, the detailed subsystems which directly cause the environmental effect must be identified. For water emissions, the subsystems comprise anti-fouling, ballast water, biofouling on ship hulls, bilge water, black water, grey water, food waste, scrubbing water, stern tube oil and litter.

Figure 8 Example of shipping related subsystems that will be used to calculate emission factors of nutrients, acidifying substances, contaminants and biology (alien species).



Air emissions are mainly caused by the main engine operation, auxiliary engine operation in ports and boiler operations in ports. The main subsystem regarding noise from ship engine operation (loud continuous noise from 10 Hz to 10kHz). According to van der Graaf et al. (2012)[3] leisure boats are not considered as a driver for underwater noise.

Table 4 Subsystems related to direct drivers

Subsystems	Description
Anti-fouling (water emissions)	Use of anti-fouling systems containing biocides, e.g. Cu
Ballast water (water emissions)	Discharge of ballast water mainly in port, transfer of biological pollutants (contaminants and nutrient pollutants).
Biofouling on ship hulls (water emissions)	Ship hull as hard substrata for attachment surface of marine organisms, transfer of biological pollutants.
Bilge water (water emissions)	Bilge water often contains oil, detergents, solvents, etc. which is pumped out in ports.
Black water (water emissions)	Sewage (nutrient pollutants, pharmaceuticals and pathogens)
Grey water (water emissions)	Waste water (excluding sewage)
Food waste (water emissions)	Waste from food supply of ship’s crew and passengers
Scrubbing water (water emissions)	Water used in scrubber (cleaning of exhaust gases)
Stern tube oil (water emissions)	Oil used for stern tube (connection between propeller and ship’s engine room)
Litter (water emissions)	Ship Waste
Engine operation (air emissions)	Operation from ship’s engine at the open sea

[3] Van der Graaf AJ, Ainslie MA, André M, Brensing K, Dalen J, Dekeling RPA, Robinson S, Tasker ML, Thomsen F, Werner S, (2012): European Marine Strategy Framework Directive - Good Environmental Status (MSFD GES): Report of the Technical Subgroup on Underwater noise and other forms of energy.

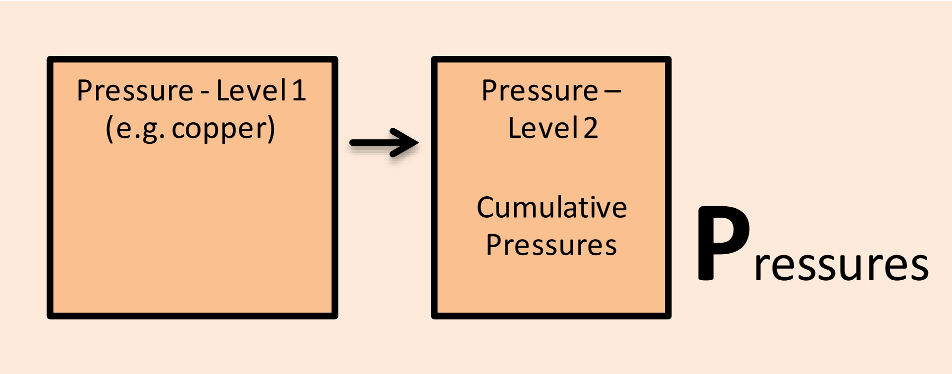
Subsystems	Description
Auxiliary engine operation in ports (air emissions)	Engine operation in ports during loading and unloading
Boiler operation in ports (air emissions)	Boilers are used for several ship's machinery and services.
Engine operation (noise)	Loud continuous noise from 10 Hz to 10kHz stemming from engine operations.

Regarding cumulative and cross-sectoral effects, also drivers of other sectors are influencing environmental effects of shipping, such as air emissions from other transport modes or underwater noise from construction work of offshore wind farms, but are not taken into account within this assessment.

3.2 Pressures

Pressures describe how the driver and subsystems link to the environment see Figure 9. The pressures are characterized as a certain emission, discharge or load in the environment such as level of copper in the water. Pressures act not only individually, but also as cumulative pressures, including their interlinkages, dilution or strengthening. There are different groups of pressures from shipping, e.g. contaminants, nutrients, invasive species, litter, and noise, which are briefly described in the following paragraph.

Figure 9 Pressures



Emissions/discharges/load in the environment (e.g. level of copper). Information will be derived in WP2 (D2.3.), WP3 (D3.3.) and WP4 (D4.7.). Emission factors from different ship types and subsystems will be derived from WP2, WP3 and WP4 and coupled to AIS data. With that approach, we will be able to produce pressure maps in the Baltic Sea for the respective pollutant (categorized under contaminants, nutrients, invasive species, acidification, litter and underwater noise.). Hence, this approach will allow us to produce cumulative pressure maps where the total load of a specific pollutant from all different subsystems will be taken into account.

Contaminants

Contaminants consist of several pollutants present in different subsystems spanning from metals and organic biocides in antifouling paints to PAHs and tensides in bilge water (appendix 1a). Contaminants from engine exhaust gases can also be deposited to the Baltic Sea (appendix 1b). Hence, pressure data will be derived from both WP3 and WP2.

Nutrients

The total pressure from nutrients, i.e. nitrogen (N) and phosphorous (P), will be determined by combining 1) atmospheric deposition of nutrients 2) discharge directly to sea, i.e. from grey water, food waste, and potentially ballast water and bilge water. Nutrients are of importance for eutrophication in the Baltic Sea with the major contributing elements nitrogen (N) and phosphorous (P) (appendix 1a). The ratio of the nutrients N:P used by marine algae are in general 16:1 and the limiting nutrient varies both between the different sub-basins of the Baltic Sea and seasonally.

Invasive species

Invasive species can be spread from shipping to the Baltic Sea primarily via the subsystems "ballast water" and "hull". The pressure will be derived in WP3 mostly via literature search.

Acidification

The emissions of SO_X and NO_X from engine exhaust gases will lead to formation of sulphate and nitrate in the atmosphere. The deposition of these acidifying substances on the Baltic Sea will be determined in WP2. An extreme case of the atmospheric deposition is seawater scrubber discharge where acidifying gases are washed out and discharged in the sea. The input of acidifying substances from shipping will partly be derived from the ongoing research project ShipH (http://www.lighthouse.nu/project/shiph) coordinated by Gothenburg University, Sweden. Emission factors of the subcategory "Scrubbing water" will be determined in WP4.

Litter

Litter will be determined at three different size classes; 1. Macro-litter from waste handling on sea and in harbours, 2. Micro-litter from e.g. antifouling paint particles 3. Nano-litter, mostly from combustion particles. Today, little is known about how much of the litter is coming from shipping and leisure boats. To bridge this gap field studies will be performed in harbours, marinas and shipping lanes with the aim to collect and analyse litter in the different size classes. The data will be used to derive emission factors.

Underwater noise

In WP3, Noise source models will be conducted, in particular taking into consideration the recent research activities in the projects SONIC, AQUO and BIAS. The objective being to identify a model for the ship sound spectrum, which has a suitable level of complexity for the objectives of the present project. A new developed model code for noise emission sources will be developed in and used to generate Baltic Sea wide maps of noise sources from commercial shipping.

Air pollution

In WP2 dispersion, transport and deposition of air pollutants emitted from the operational shipping will be studied with an ensemble of atmospheric chemistry models. The emitted species studied will be SO_2, NOx, CO, volatile organic compounds (NMVOCs), polyaromatic hydrocarbons (PAHs) and particulate matter (PM) with its constituents black carbon (soot), organic carbon, sulphate, ash and metals. The models will also assess the formation of secondary species in the atmosphere, such as ozone and secondary PM including nitrate, secondary sulphate and secondary organic aerosol. The models will provide maps of deposition of these species on the Baltic Sea and on surrounding land areas. WP2 will, partly in collaboration with the Interreg project ENVISUM, assess impacts of the shipping-related air pollution on acidification and eutrophication of land ecosystems and on human health in the region. The health impact will be studied both, on a regional scale and on a local scale, for several harbour cities.

Table 5 Examples of pressures stemming from shipping

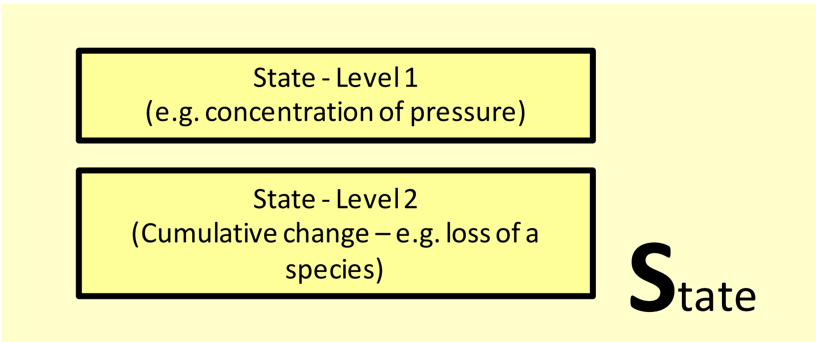
Pressures	Description
NOx emissions (to air)	Emissions occur during combustion of marine fuels.
PM emissions to air	Emission of particulate matter (PM) occur during combustion of the marine fuels. PM is microscopic solid or liquid matter suspended in the Earth's atmosphere. PMs is emitted to air. If scrubbers are installed, PMs are emitted to water via scrubbing water. In the atmosphere parts of the emitted gases are oxidised to species with very low volatility and these contribute to air pollution as secondary PM. Even with low sulphur fuel (0.1%) the secondary PM derived from the fuel sulphur may be higher than the directly emitted PM.
Sulphur emissions to air	Include mainly sulphur dioxide which is oxidised to sulphate in the atmosphere. Sulfate contributes to acidification of land and sea ecosystems and is part of the atmospheric PM.
PAH emissions to air	Polycyclic aromatic hydrocarbon (PAH) emissions result from incomplete combustion of marine fuels and lubricants.
GHG emissions	Greenhouse gas emissions from shipping include CO_2-emissions from fuel combustion.
Abnormally high level of underwater noise - ranging from 10 Hz to 10 kHz	Some mammals (like e.g. harbor porpoises, selas) are sensitive to sounds up to tens of kHz. This leaves part of the sound spectrum outside MSFD D11.
Cu	Copper is emitted in water via continuous leakage of toxic substances and "point realease" at hull cleaning (anti-fouling), bilge water and scrubbing water.
Zn	Zinc is emitted in water via continuous leakage of toxic substances and "point realease" at hull cleaning (anti-fouling), bilge water and scrubbing water.
CuPT	Copper pyrithione is emitted in water via continuous leakage of toxic substances and "point realease" at hull cleaning (anti-fouling).
ZnPT	Zinc pyrithione is emitted in water via continuous leakage of toxic substances and "point realease" at hull cleaning (anti-fouling).
DCOIT	Dichlorooctylisothiazolinone is emitted in water via continuous leakage of toxic substances and "point realease" at hull cleaning (anti-fouling).
ZINEB	Zineb is emitted in water via continuous leakage of toxic substances and "point realease" at hull cleaning (anti-fouling).
Zooplankton (500um)	Zooplankton is heterothrophic plankton, which is emitted in water during discharge of untreated ballast water.
Phytoplankton (10um)	Phytoplankton is photosynthesizing plankton which is emitted in water during discharge of untreated ballast water.
Invertebrate larvae	Invertebrates are animals that neither possess nor develop a backbone (a vertebral column). They are emitted to water during operation and during hull cleaning due to biofouling on ship hulls.
Macroalgae	Macroalgae are marine algae such as seaweed. As invertebrates they are emitted to water during operation and during hull cleaning due to biofouling on ship hulls.
Microalgae (benthic)	Benthic microalgae are microscopic algae living at hard substrata (thereamong artificial structures like ship hull) in the Baltic Sea. They are emitted to water during operation and during hull cleaning due to biofouling on ship hulls.
Bacteria	Bacteria are discharged via ballast water and due to biofouling at ship hulls.
PAH	Polycyclic aromatic hydrocarbons (PAH) are emitted into water via stern tube oil and bilge water. They are mainly emitted as particulate matter.
Cr	Chromium is a metal, which is emitted into water via bilge water.
Pb	Lead is a metal, which may be emitted into water via scrubbing and bilge water.
Co	Cobalt is a metal, which is emitted into water via bilge water.
Tensides	Tensides lower the surface tension between two liquids or between a liquid and a solid. They are emitted into water via grey and bilge water.

Pressures	Description
Suspended solids	Suspended solids are small solid particles which remain in suspension in water as a colloid or due to the motion of the water. They are emitted into water via bilge water.
Nutrients (NH_4^+, NO_2^-, NO_3^-, PO_4^{3-})	Nutrients are components in foods that an organism uses to survive and grow, e.g. Ammonium, Nitrite, Nitrate, Orthophosphates. Nutrients are emitted into water during discharge of both treated and untreated ballast water, scrubbing water, grey water, black water, bilge water and food waste.
Pharmaceuticals	Pharmaceutical drugs are emitted into water via black water.
Pathogens	Pathogens describe an infectious agent such as a virus, bacterium, prion, a fungus, or even another micro-organism which are emitted into water via black and grey water.
Particles (as microplastics)	Plastic particle water pollution is marine debris including microplastic from cosmetic products and peeling. Particles are emitted into water via grey water.

3.3 State

The state represents the condition of the ecosystem. It refers to concentrations or intensity of substances in the environment (e.g. the concentration of a certain substance such as copper) (State Level 1). The accumulation of several individual concentrations could then lead to further changes such as loss of species of algae, birds or fish (State Level 2), see Figure 10 and Table 6.

Figure 10 State



Contaminants

For contaminants the STATE will be determined both as modelled concentrations in different areas of the Baltic Sea, e.g. harbors, marinas, shipping lanes and reference sites (level 1) but also as effects on the environment, e.g. loss of species of algae, fish etc. (level 2). For the level 2 assessment impact data from scientific literature and from environmental risk assessment reports will be used to identify the most sensitive groups of species. For example, several algal species are known to be sensitive to low copper concentrations and thus, if our modelled data suggest that the concentration in certain areas can be above the predicted no-effect concentration one can conclude that the cumulative discharge of copper may result in adverse effects for algal species and communities.

Nutrients

For nutrients the STATE will be the summarized contribution of nutrients from shipping, with N from NOx (air deposition), Sewage and Food waste and P from Sewage, Food waste and Lubricant oil (air deposition) (level 1) and the grade of eutrophication/ depletion of oxygen at sea floor/ density-distribution of algal blooms (level 2).

Invasive species
Modelling work on the spread of invasive species from shipping has until just recently been lacking. However, in a recent publication by Seebens et al (2016), the authors developed a conceptual model to calculate the risk of spreading invasive species from shipping. That model will be will be used in SHEBA to obtain Level 1 and Level 2 data.

Acidification
Modelled data set and maps of surface water pH changes attributed to shipping related input of acidifying substances will be determined in d.3.6 (Level 1). The cumulative change to the environment (Level 2) will be determined via literature and in collaboration with the ShipH project where effects of scrubber water on Baltic Sea algae communities are assessed.

Litter
The concentration and characteristics of marine litter (Level 1) will be determined at field campaigns in shipping lanes, harbors and marinas. As the marine litter differ both in size and chemical composition it is a great challenge to assess what effect the litter may have on the marine environment (Level 2).

Underwater noise
Underwater noise maps from the Baltic Sea shipping fleet will be developed (d.4.5). Under water noise impacts to fish and marine mammals in the Baltic Sea will also be determined (d.4.7) (appendix 1c).

Air pollution
Maps with concentrations of air pollutants, deposition maps and air quality indicators such as exceedances and cumulative above-threshold concentrations will describe the state on Level 1. The impact of air pollution on the marine environment will be assessed through the categories above, which adopt the atmospheric deposition of pollutants. Effects of air pollution will be assessed as exceedances of critical loads for acidification and eutrophication of land ecosystems and as health effects, i.e. increases of mortality and morbidity caused by air pollution related to shipping. For Level 2 assessment the methodology developed in the Thematic Strategy for Air Pollution (TSAP) (Holland et al., 2008) will be used as a starting point and further developed in collaboration with the ENVISUM project.

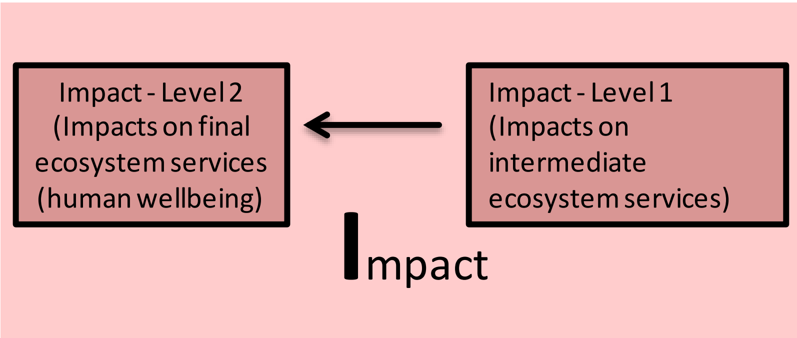
Table 6 State Level 2 changes

State Level 2 changes	Description
Loss of biodiversity (marine)	Concentrations of pollutants leading to a change in behaviour, spawning, etc. which leads to a decrease in a species (plant or animal). For example if the keystone species Bladderwrack disappears due to toxins.
Food web structure change (marine)	For example, competition/predation from new species with strong completive ability or lack of predators.
Eutrophication -Algal blooms (cyanobacteria) and oxygen depletion	Excessive richness of nutrients in marine waters leading to dense growth of plant life and death of animals from lack of oxygen.
Acidification (air, marine)	Leads to the decrease in the pH level of marine waters - particularly through sulphuric and nitric acid formation. Acidification can also have adverse effects on calcifying species
Reduced visibility (air)	Through PM formation and light scattering leads to reduced visibility.

3.4 Impact

Under impact, effects on ecosystem services are identified. This can be understood as Impact Level 1 (e.g. including maintaining nursery population and habitats) or impacts on supporting ecosystem services and Impact Level 2 or impacts on final ecosystem services that affect human wellbeing such as changes in recreational potential, food production, biodiversity (Figure 11 and table 7). The ecosystem services concept and approach reveals the dependencies between ecosystem services, defined as the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people (Fisher et al., 2009; Haines-Young and Potschin, 2013; Maes et al., 2013), and the ecosystem structures (or components), processes and functions underpinning them (see EEA, 2015 for detail on service generation).

Figure 11 Impact



The Common International Classification of Ecosystem Services (CICES) classification contains three main categories of ecosystem services: provisioning, regulation and maintenance, and cultural services (CICES, 2016). According to EEA, 2015, provisioning services can be described as all material and biota which represents tangible outputs from marine ecosystems. These can be consumed or traded. They can be further split in nutrition (outputs that can be used as food e.g. seafood) and material (marine biotic material that is used for manufacturing goods). Nutrition can be further specified into biomass from marine plants, algae and animals and their outputs e.g. nutritients dispersed by ships can impact oxygen depletion at larval nursery grounds that could lead to reduced fish stocks (cod) and their yields used as food. Changing species population and food web structure, e.g. caused by invasive species, could be for example reduce fish stock and fish yields. Also acidification, marine litter and underwater noise could influence biotic parameters and reduce fish yields of shellfish and other fish species. Materials as raw materials from marine environment, such as fibres, material for agriculture, genetic materials for biochemical or pharmaceutical processes could be influenced by shipping activities.

Regulation and maintenance services are the effect of marine biota and ecosystems on biotic and abiotic parameters that are defining people's environment ("ambient" environment). These outputs of the ecosystem affect the performance of individuals, communities or populations but are not consumed. These comprise the neutralization or removal (mediation) of waste, toxicants or other nuisances, the mediation of flows and the maintenance of physical, chemical and biological conditions. The mediation of waste by marine biota or ecosystems has a detoxifying effect to the marine environment, examples are filtration, storage or accumulation by algae, plants or animals or mediation of smells, noise or visual impacts by the marine ecosystem. The mediation of flows include the stabilization and control of erosion rates, coastal flood protection as a control of liquid flows as wells as air ventilation and transpiration. The maintenance of physical, chemical and biological conditions contributes to sustainable human living conditions, such as pest and disease control, habitat an gene-pool protection and seed and gamete dispersal, soil formation and composition, chemical conditions of salt water, regulation of micro- and regional-climate as well as global climate regulation. Shipping impacts these type of ecosystem services, e.g. via emission of greenhouse gas emission, which cause climate change, including changed streams, flooding patterns, increased coastal erosions, etc. Furthermore, different pressures from shipping can influence the marine biota, which may disable the mediation of waste by algae or plants.

Cultural services include outputs from marine ecosystems that have spiritual, intellectual, cultural, physical or experiential significance. They are non-material. These are physical and experiential interactions with marine biota, such as diving or snorkelling. Furthermore, interactions relating to science, education, entertainment or heritage as well as spiritual and religious benefits. An example of the impact of shipping on these ecosystem services could be algal blooms caused by nutrients leading to a loss in tourism numbers because of a negative impact on beach-activities like camping, swimming, recreational fishing, boating. Tourism could also be influenced by changing species population due to invasive species transported by ships, but depends on the specific invasive species and the biotic and abiotic properties of the environment. Changing shares of species populations and their relevant effects on recreational value of recreational fishing, boating, etc. can be influenced by different shipping related pressures, such as water emissions (litter, etc.), air emissions (e.g. NOx, SOx) and underwater noise.

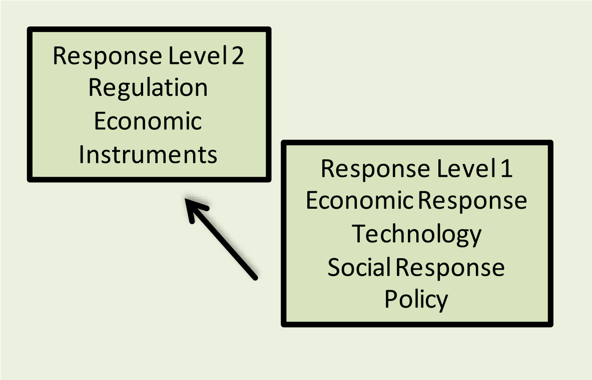
Table 7 Impact I and Impact II

Impact I	Impact II
Mediation of waste, toxicants and other nuisances	Mediation by biota (marine micro-organisms, plants, algae, and animals): bio-remediation, filtration/sequestration/accumulation Mediation by ecosystems: filtration/sequestration/storage/accumulation, mediation of smells/noise/visual impacts
Physical and intellectual interactions with marine plants, algae, animals, ecosystems, and seascapes	Intellectual and representational interactions: scientific, educational, heritage, entertainment, aesthetic
Maintenance of physical, chemical and biological conditions	Life-cycle maintenance, habitat and gene-pool protection Pest and disease control
Decrease of population size in areas with high level of noise	Noisy areas avoided by animals, fish
Masking of sound based underwater communication	Difficulties in mating, communication
Temporary or permanent loss of hearing	Difficulties in mating, communication
Clean air in cities	Potential impacts on human health
Clean air in the BSR	Potential impacts on human health
Clean water	Potential impacts on human health and other loses (e.g. bathing)
Visibility	Potential impacts on transportation and other services
Food production	Potential impacts on food production
Stable climate	Potential impacts due to weather or climate variations
Water availability through rainfall	Potential impacts due to changes in water availability

3.5 Response

Within the BONUS SHEBA analytical framework, responses refer to all possible actions or reactions by society, economic actors and governments to address and cope with drivers, pressures, changes in state and impacts. These may include responses by the private sector as well as broader social responses from the public (see Figure 12). Responses incorporate all possible strategies, such as societal adaption to new conditions (e.g. reducing car use in response to global climate change), economic responses (e.g. slow steaming to reduce costs when fuel prices go up), as well as policies (e.g. international targets for CO_2) and instruments (e.g. taxes on fuel use) to reduce or mitigate pressures. Those who are "responding" include policy makers, public authorities, economic actors (e.g. private companies), scientists as well as individuals and society. Hence, the following types of responses exist: social response, economic response, technology and policy, which include economic instruments and regulation.

Figure 12 Response



Responses can have different characteristics and be highly interactive. They are usually interlinked, e.g. social responses such as behavioural changes can happen independentally from policy changes because consumers become aware of a certain problem such as climate change. But the change can also be initiated or supported by an approved and implemented policy such as tax on fuels or improved efficiency of cars due to advances in technology.

In BONUS SHEBA *social response* refers to a voluntarily or deliberate change within society triggered independently from policy. In this case, this means changes in awareness followed by behavioral changes regarding identified challenges and changes. Awareness and action stem from perceived social, economic or environmental changes. In other words, awareness effects how individuals and societies behave and act which may also affect the demand for goods and services. An example of a social response is the decreased or discontinued use of antifouling paints by leisure boat owners as they become aware the environmental affects this has on local marine ecosystems.

Economic responses cover responses by private companies. In many ways these are similar to social responses, but imply that private companies are acting as separate economic actors within society. Again, these responses are trigged independently from policy. For example, slow steaming by shipping companies may be a response taken to reduce costs in response to fuel price increases.

Technology refers to shifts in technological innovation. These may be triggered from society (e.g. universities) or private companies. In this way they can be seen as part of social responses or economic responses. However, because technological innovation is a critical factor in the current and future activities of the shipping industry, technology is identified as a separate response.

Policy refers to responses or actions by government. These are top-down decisions made by public bodies in response to perceived social, economic, or environmental changes. Policy responses include normative policies, procedural policies, and specific instruments (or implementation of the normative policies). Within BONUS SHEBA normative policies are understood as high level political decisions which are described in strategic documents, communication documents, and recommendations or guidance documents by government bodies. These types of policies can be seen as public intention or preference, while they are not binding or backed by law. In the EU, an example of this is the Integrated Maritime Policy. Procedural policies refer to policies which are backed by legislation and may or may not provide specific instruments of action, for example the EU's Marine Strategy Framework Directive (MSFD) (RESPONSES, 2012). Finally, specific instruments refer to the implementation of procedural policies. These are concrete actions which should lead to observable change. Within this group there are instruments which focus on information, as well as regulation and economic instruments.

Regulations are policies which create standards for or ban specific actions, for example, banning the use of a certain chemical in paints. Regulations can provide clarity on the expected behavior and can make it easier to identify non-compliant behavior. But uniform standards ("one size fits all" approach) may not consider the variation in compliance costs across different operators or companies, which can lead to inefficiencies and increase implementation costs of the policy (EU Commission, 2015). Additional examples are MARPOL regulations on SO_X and NO_X from ships, including concrete limits, the Anti-fouling system convention and the Ballast water convention (IMO, 2015b).
Economic instruments target the market and its actors. According to the OECD, they are a '*means by which decisions or actions of government affect the behaviour of producers and consumers by causing changes in the prices to be paid for these activities.'* (UN et al, 2005). Economic instruments create economic incentives to encourage certain behavioral change but leave the choice for the concrete implementation measure to the different individuals or companies. Therefore, the economic instrument initiates voluntary action such as changes of technology or practices (Delacámara et al, 2013).

Information oriented instruments are generally considered soft approaches to policy. These may include information and publicity campaigns, guidelines, education workshops or programmes or disclosure requirements (EU Commission, 2015). The instruments are easy to adapt to changing situations and tend to be cost-effective. They are mainly used in situations where a main driver of the problem is a lack of information. Furthermore, information oriented instruments can support regulation which are interlinked with lacking information also on how to comply with it (EU Commission, 2016).

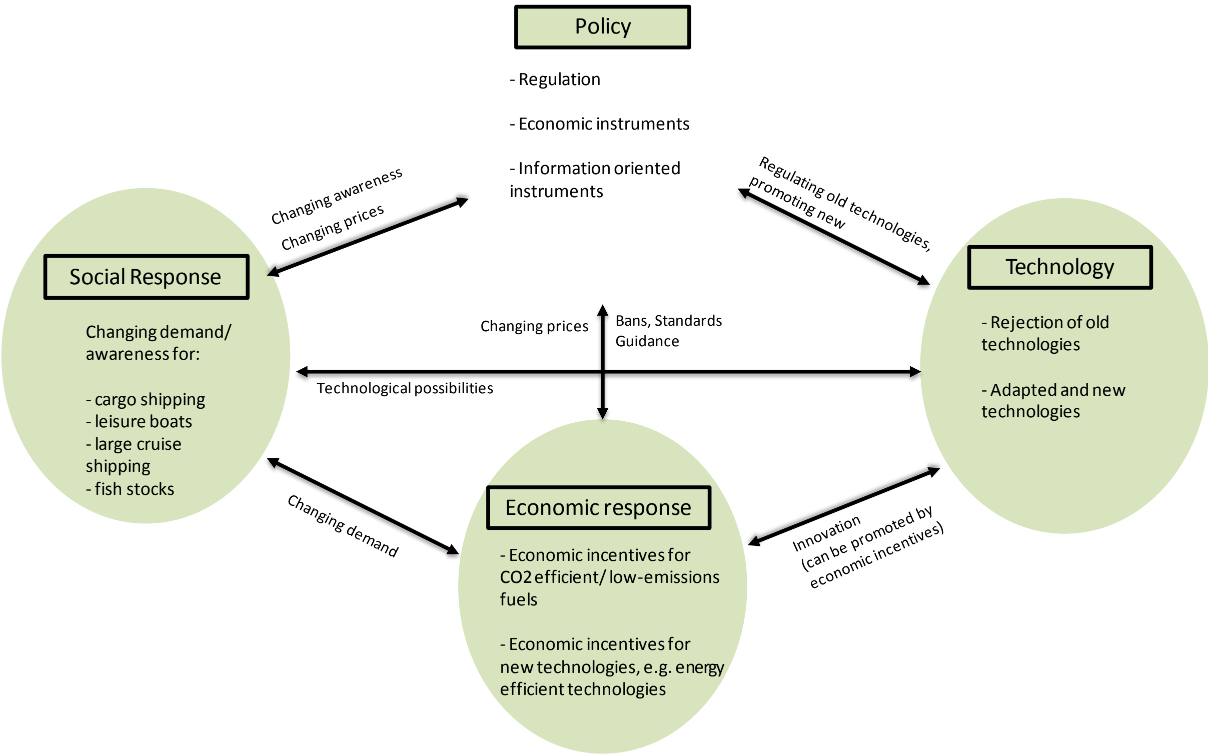
Economic instruments can be taxes, subsidies, tariffs, charges, and the creation of markets or trading schemes as well as cooperation agreements or risk-based mechanisms. Tariffs, charges, taxes and subsidies are pricing mechanisms which introduce incentives (Delacámara et al, 2013). Tariffs are paid for a given quantity of a resource or a service, e.g. water or sanitation service, by different actors, such as households or industries. On the one side, a tariff motivates technological or behavioral changes which lead to a reduction of resource use or polluting a resource. On the other side, it generates revenues for public authorities. Taxes can be a compulsory payment to the fiscal authority for a behavior that leads to the degradation of the environment, e.g. fuel taxes should increase the fuel price and therefore reduce the demand. The instrument should lead to an alternative behavior, such as using less-polluting techniques and products. Environmental charges (or fees) are a mandatory payment for a service directly or indirectly associated with the degradation of the environment. An example are environmentally differentiated harbour fees which are based on the energy efficiency of ships. Payments from the government are summarized under subsidies. Subsidies can relate to products or practices. Innovative products or practices (such as specific production process) can be supported by the government (Delacámara et al, 2013). Examples could be subsidies for scrubbers or energy efficient technologies.

Trading relies on the exchange of rights or entitlements for abstracting or using resources, or polluting the environment (UNEP, 2014). Tradable offsets and permits have the major advantage that they are flexible and cost-effective (EU Commission, 2015). An example is the European Emissions Trading System which gives a price to CO_2 emissions and encourages the reduced emission of these gases. Another type of economic instruments are cooperative mechanisms which reduce environmental pressures by voluntary implementation of new practices. They are often supplemented with some form of payments, e.g. subsidies (Delacámara et al, 2013). The first years of the Ship Energy Efficiency Management Plan (SEEMP) is an example for a voluntary cooperation agreement. Since 2013 the SEEMPs are mandatory and therefore not anymore a voluntary mechanism (IMO, 2011a).

Risk-based mechanisms represent different risk levels based on insurance premiums and compensation levels. Insurances give the insured person or entity an income stabilization, but should also clearly interlink the premium with different risk levels and discourage risk increasing behavior (Delacámara et al, 2013). For example, typical P&I insurances (Protection and indemnity insurance) include risks of environmental damage such as oil spills and pollution (Depré et al, 2016).

The different social and economic responses, policies and technologies, which are described above, are highly interlinked. As seen in Figure 13, economic instruments can potentially increase prices, e.g. fuel taxes or trading systems, which would initiate social responses based on changing demand, e.g. preference for shorter cruising tours due to increased prices. Besides changes in demand, changes in (public) awareness is an important social response; e.g. people might be more interested in regional products due to higher environmental awareness. Policies can also influence this level of awareness e.g. via information oriented instruments such as information campaigns for eco-labelled or as regional labelled products, see Figure 13.

Figure 13 Responses and their interlinkages



However, policies may only trigger social responses, but also economic responses and technological responses. Relevant policies include the regulation of shipping areas (such as marine protected areas), practices (such as shipping speed) and technologies in use (e.g. NOx and SOx limits). The latter comprise the promotion of new technologies and bans on old technologies which lead to innovative technology developments or the adjustments of existing technologies (e.g. scrubber technologies to reduce SOx emissions, investments in research and development e.g. purely electric ferries), see Figure 13.

Based on technological development and innovations again social and economic responses are motivated. Available adapted and new, innovative technologies, for example more energy efficient engines, might be used by companies to reduce emissions and save costs. The incentive to decrease emissions and other negative externalities by companies might be due to changed consumer demand (social response), Figure 13. As explained, this demand by consumers is highly depending on changes in public awareness, which can be promoted especially by information oriented policy instruments.

Thus, the different responses can affect each other. Hence, when analysing responses, it is also important to check whether there are adverse effects or trade-offs between the different responses. A policy that reduces shipping speed, for example, could not only lead to an increase in ship number or size (Corbett et al., 2009), but also to a negative social response, since ship travel durations would be prolonged.

Depending on the results obtained under primarily State and Impact, different policy instruments can be used. For example, if the cumulative pressure of contaminants from shipping results in concentrations exceeding environmental quality standards (EQS) according to the Marine Strategy Framework Directive (State Level 1), the emissions may be regulated (Response Level 2) via ship discharge limits of the contaminant, or in a complete prohibition of the discharge.

The Baltic Sea is under severe stress due to eutrophication and a set of directives was adopted by the EU (Marine Strategy Framework Directive and Water Framework Directive) to reduce the input of nutrients to the Baltic Sea to achieve good environmental status (Response Level 1). The Response Level 2 could be NOx Emission Control Areas (NECAs), Sewage discharge restrictions for passenger ships in the Baltic Sea, MARPOL Annex IV, Baltic Sea special area (for reduction of N and P to water). The Ballast Water Management Convention (IMO 2004) will require treatment of ballast water for ships in route between two countries (Response Level 2). For the Baltic Sea Exemptions from this requirement have been discussed within HELCOM and a Joint Harmonized Procedure have been developed to achieve a standardized requirements between Baltic Sea countries

Examples of Response Level 2 to reduce the contribution by shipping on ocean acidification could be to prohibit the use and discharge of open-loop scrubbers. Today, there are ongoing discussions on port, national and EU level if open-loop scrubbers should be restricted in specific areas. Marine litter is a global concern, affecting all oceans of the world. One of the sources of marine litter highlighted under The MSFD Descriptor 10 "Marine litter does not cause harm" is shipping and fishing industry (Response Level 1). A Response Level 2 response could be restrictions on the discharge of litter. The MSFD states "Introduction of energy (including underwater noise) does not adversely affect the ecosystem" (e.g. fish and marine mammals) is a Level 1 Response. Noise from shipping can for example have impact on harbour porpoise population in the Baltic Sea. If, for example, a Natura 2000 area is established it could in the strictest case imply that permission is needed to conduct activities (shipping) in this area (Response Level 2).

4 Operationalising the DPSIR framework for shipping in the Baltic Sea

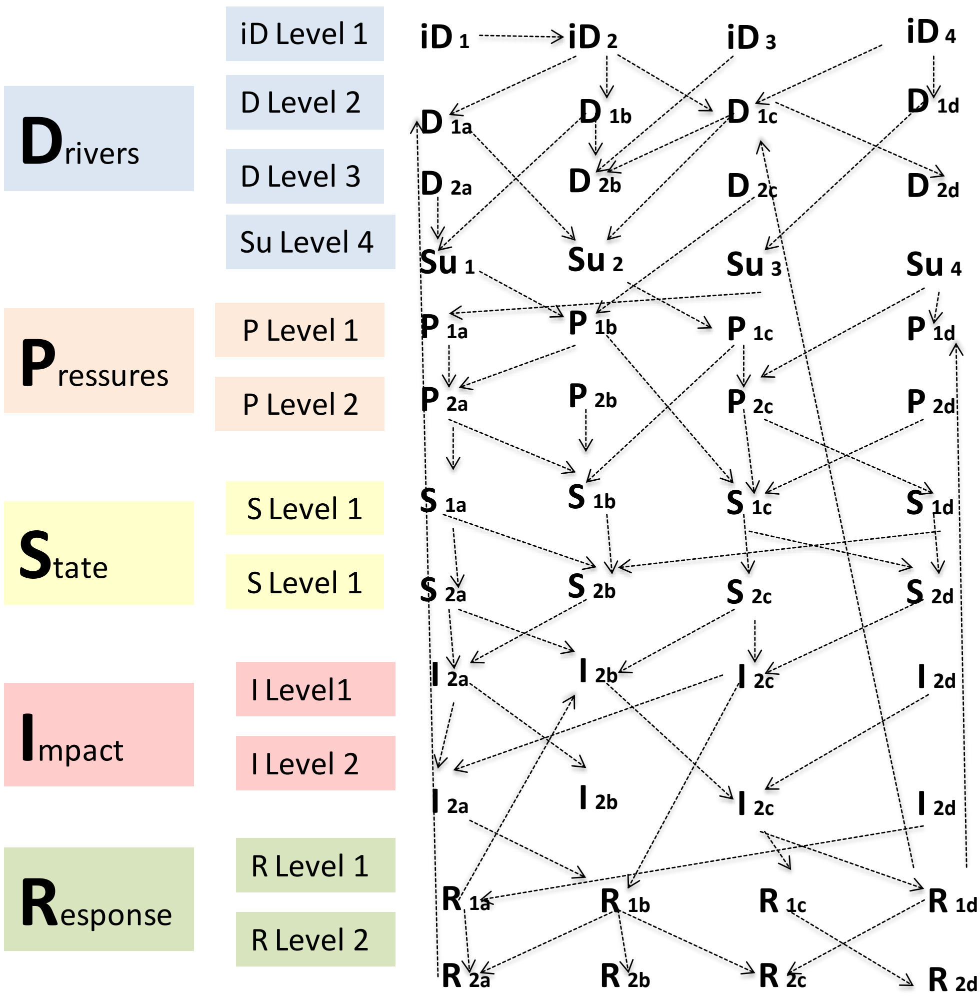
The previous sections presented the general conceptual framework of DPSIR for the ecosystem service assessment of shipping. This section aims to further develop the DPSIR framework to an operational framework to facilitate the upcoming work of BONUS SHEBA. It first present the interlinkages within the DPSIR framework and then proposes a frist set of indicators, i.e. statistical measures, to measure and assess shipping activities in Baltic Sea.

4.1 The interlinkages of the DPSIR for shipping in the Baltic Sea region

The DPSIR framework highlights the causal chains of interaction between human activities and the state of the environment. It also reveals that indicators to measure the chains are closely interlinked with the framework. The DPSIR framework aims "to provide information on all of the different elements within the DPSIR chains, to demonstrate their interconnectedness and estimate the effectiveness of responses " (EEA, 2007). In a more complex scheme, the DPSIR framework allows for the organiation of information and integrationg social-economic and ecological elements by addressing relationships between categories. We apply the integrated assessment suggested by Cooper (2013) in order to explain the interlinkages within the elements in a shipping context.

Figure 14 below demonstrates the myriad of interlinkages between the indivdiual elements of the DPSIR framework for shipping in the Baltic Sea. It can be seen that the multiple elements are connected and interteracting in parallel with one another. This displays the complexity of the system and the significant challenge to assess it.

Figure 14 SHEBA analytical framework with multiple levels and interactions. The sublevels are explained in more detail in Table 2



Note: The above shows potentential interlinkages between the SHEBA anayltical framework, it is meant to provide an example and does not reflect all possilbe conections.

4.2 Identifying indictors

The links between shipping activities and the environment are complex, as illustrated under the DPSIR framework. It is possible to use accounting data to quantify these relationships if such data are available. Another way to measure and evaluate the links between shipping and environmental issues is to use the indicators, which are applied in many studies of transport sustainability (e.g. Dobranskyte-Niskota et al. 2007; EEA 2005; Litman 2007). These indicators will be used in further BONUS SHEBA work on ecosystem service assessments and policy development.

Indicators are defined as tools to "simplify, measure and communicate trends and process (Eckersley, 1997) or as "quantitative measures that can illustrate and communicate complex phenomena simply, including trends and progress over time" (EEA, 2005). In the SHEBA project, the indicators are used to identify trends, predict problems, assess opinions, set performance targets, and to evaluate different scenarios of shipping activities developed in WP1.

The integration of transport issues into sustainability indicators and the development of specific transport indicators are observed in many national and international initiatives (see Dobranskyte-Niskota et al. 2007 for a review). The indicators within the DPSIR framework will be developed, based on international initiatives (i.e. EC sustainable development strategy, OECD, Eurostat). We first use the approach implemented by Dbranskyte-Niskota et al. (2007) that develop the indicators in five major themes. These indicators are then assigned into the five elements of the DPSIR framework. Five major themes of indicators for assessing transport sustainability are: economic dimensions; soical dimensions; environmental dimensions; technical and operation dimensions; and institutional dimensions.

Economic dimensions consist of shipping demand and intensity, transport cost and price, and infrastructure. The demand and intensity relates to the causal effect of maritime transport and GDP growth. Thus, taxation and economic policies could be used to create shifts toward sustainable shipping. For example, an energy cost and price structure could positively contribute to maritime sustainability in a way of modal shift toward more environmental friendly transport means.

Social dimensions are focused on accessibility and mobility, affordability, health impacts, risk and safety and employment within the shipping sectors. Accessibility, affordability and mobility are interconnected issues and play an important role in transport sustainability.

Environmental dimensions account for shipping emission, energy efficiency, impact on environmental resources, environmental risk and damages. These themes are closely interconnected. In principle, policies of pollution prevention aims at meeting transport needs without generating emission threatening public health, marine environments, biodiversity, and integrity of essential ecological process.

Technical and operational dimensions include occupancy of transportation and technology status such as age and size of ships, load factors for freight transport, etc.

Institutional dimensions include themes of measures to improve shipping sustainability and institutional development. The measures may involve research and development of cleaner technology, promotion of environmentally friendly shipping technology and energy, or policies to improve maritime and pollution prevention.

The potential indicators are categorised according to five major dimensions and assigned to the DPSIR framework as presented in Table 8 in the Annex. The indicators will be refined and used in the next steps of the project that is to assess changes to ecosystem services compared to Business As Usual (Task 5.2) and to conduct the integrated assessment and policy analysis to reduce pressures from shipping in the Baltic Sea (Task 5.3).

5 Conclusions

For the development of the analytical framework for assessing shipping in the Baltic Sea the DPSIR framework has been studied and further refined. The literature review of different DPSIR framework iterations showed that different approaches have been developed during the last years (see Table 1). As adjusting the framework to shipping in the Baltic Sea, it could be seen that a higher resolution for the different components (DPSIR) was necessary in order to assess shipping and its pressures on marine ecosystems as well as air. Based on research and discussion, the five common main components - Drivers, Pressures, State, Impact and Response - were further subdivided into levls or sub-components. Drivers was divided into indirect drivers, direct drivers (two levels) and concrete emitting subsystems such as anti-fouling, scrubbing water. Pressures were also split into two levels - individual pressures and cumulative pressures. State was in parallel divided into levels - concentration of specific substances and cumulative changes. Impacts were split into impacts on intermediate ecosystem services (Level 1) and impacts on human wellbeing (Level 2) or final ecosystem services. Responses were divided in different levels such as social responses e.g. by users or consumers, economic responses by companies, technology developments and policy options. Policy options were further divided into another level as economic instruments and regulation.

The DPSIR framework contains the main drivers: container/cargo ships, tankers, ro-ros, fishing vessels, ferries, cruise ships and leisure boats. Included pressures are (1) air emissions e.g. NO_X, Sulphur emissions, CO_2-emissions (2) emissions to water such as: different metals, invasive species, nutrients, particles such as microplastics, (3): noise emissions such as high level of underwater noise. As State mainly increased concentrations of the pressures are described, further detailed in: e.g. loss of marine biodiversity, change in marine food web structure, algae blooms, eutrophication and acidification. Impacts will also be further developed in following BONUS SHEBA assessments. Further, final ecosystem services are mentioned such as filtration, sequestration function or intellectual and representational interactions for recreation. For responses, the different types of responses are described, also their strengths and weaknesses and their interlinkages are discussed which shows that different entry or initiating points for responses are existing and that the different responses affect each other.

As mentioned, to discuss impacts and policy options will be done in the next steps in the BONUS SHEBA project. To prepare this further use of the DPSIR framework, a first review of indicators are proposed which could be used to measure the different DPSIR components. The indicators are grouped in different dimensions: economic, social, environmental, technical and operational and institutional dimension. Moreover, the initial assessment conducted here showed that for many indictors it may not be possible to find quality data for the desired component of the framework or that is explicit (e.g. spatially relevant) to the assessment.

Different challenges for the further economic analysis can be described. One of the challenges is that it is still quite uncertain in what quality the data will be available and which components can be integrated in the further analysis. Furthermore, interlinkages between different Drivers, Pressures, State, Impacts and Response are also uncertain, due to missing natural scientific results about consequences of concrete concentration changes or changes in food web structure.

The final outcome of this framework will be to assess the effects on ecosystem services in relation to an overall baseline. The further analysis of ecosystem services and the impact of different policy options on ecosystem services will be based on this framework.

References

Atkins, J., P., Burdon, D., Elliott, M., Gregory, A., J., 2011, 'Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach' *Marine Pollution Bulletin* Vol. 62 Issue 2 February 2011 215–226, doi:10.1016/j.marpolbul.2010.12.012.

CICES, 2016, 'The Common International Classification of Ecosystem Services (CICES) V4.3' (http://cices.eu/) accessed 04 August 2016.

Cooper, P., 2013, 'Socio-ecological accounting: DPSWR, a modified DPSIR framework, and its application to marine ecosystems' *Ecological Economics*, *94*, 106-115.

Corbett, James J., Haifeng W., Winebrake, J.J., 2009, 'The effectiveness and costs of speed reductions on emissions from international shipping' *Transportation Research Part D: Transport and Environment* 14.8 2009 593-598.

Delacámara, G., Dworak, T., Gómez, CM., Lago, M. Maziotis, A., Rouillard, J., Strosser, P., 2013, *EPI-Water Deliverable 5.3: Guidance on the design and development of Economic Policy Instruments in European water policy* EPI-Water - Evaluating Economic Policy Instruments for Sustainable Water Management in Europe.

Depré, E., Reniers, G. L. L., Zamparini, L., 2016, *Multimodal transport insurances* Szyliowicz, J. S.; Zamparini, L.; Reniers, G. L.L.; Rhoades, D. L.: Multimodal Transport Security: Frameworks and Policy Applications in Freight and Passenger Transport, Edward Elgar Publishing, 64-82.

DNV, 2012, 'Shipping 2020. Det Norske Veritas (DNV) report' (http://www.dnv.nl/binaries/shipping%202020%20-%20final%20report_tcm141-530559.pdf) accessed online 13 November 2015.

Dobranskyte-Niskota, A., Perujo, A., Pregl, M., 2007, 'Indicators to Assess Sustainability of Transport Activities' JRC Scientific and Technical Reports.

Eckersley, R., 1997, 'Perspectives on progress: Is life getting better?' Resource Futures Program, Working Paper Series 97/27, Resource Futures Program, Commonwealth Scientific and Industrial Research Organisation, Canberra.

EEA, 1995, *Europe's Environment: the Dobris Assessment.* European Environment Agency, Copenhagen.

EEA European Environment Agency, 2006, 'EEA Glossary' (http://glossary.eea.eu.int/EEAGlossary/D/DPSIR) accessed 08 August 2016.

EEA, 2011, 'Common International Classification Of Ecosystem Services (CICES): 2011 Update' Paper prepared for discussion at the expert meeting on ecosystem accounts organised by the UNSD, the EEA and the World Bank, London, December 2011Contract No: No. EEA/BSS/07/007, November 2011.

EEA, 2013, *The Impact of International Shipping on European Air Quality and Climate Forcing* EEA Technical Report, No 4/2013. European Environment Agency. Copenhagen, Denmark.

EEA, 2015, State of Seas report, EEA Report No 2/2015, Copenhagen, Denmark.

EEA/NSV/13/002 *ETC/ICM Technical Report: Initial Assessment of European Seasbased on Marine Strategy Framework Directive Article 8 reporting*.

EC 2016, 'Mapping and Assessment of Ecosystems and their Services – MAES' (http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm) accessed 09 August 2016.

EUR 23041 EN – 2007 Indicators to Assess Sustainability of Transport Activities
Part 1: Review of the Existing Transport Sustainability Indicators Initiatives and Development of an Indicator Set to Assess Transport Sustainability Performance

EU Commission, 2015, 'Tool #15: The Choice of Policy Instruments' (http://ec.europa.eu/smart-regulation/guidelines/tool_15_en.htm) accessed 09 August 2016.

EU Commission, 2016, 'Ecodesign and Energy Labelling' (http://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign/index_en.htm) accessed 09 August 2016.

Fisher, B., Turner, R. K., Morling, P., 2009, 'Defining and classifying ecosystem services for decision making' *Ecological economics*, *68*(3), 643-653.

Gari, S.R., Newton, A., and Icely, J.D., 2015, 'A review of the application and evolution of the DPSIR framework with an emphasis on coastal social-ecological systems' *Ocean and Coastal Management* 103, pp. 63-77.

Haines-Young, R., Potschin, M., 2013, *Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012*, EEA Framework Contract No. EEA/IEA/09/003.

Holten-Andersen, J., Paalby, H., Christensen, N., Wier, M., Andersen, F.M., 1995, *Recommendations on strategies for integrated assessment of broad environmental problems.* Report submitted to the European Environment Agency (EEA) by the National Environmental Research Institute (NERI), Denmark.

Litman, T., 2016, *Developing Indicators for Sustainable and Livable Transport Planning*. Victoria Transport Policy Institute, Canada.

Litman, T., 2007, *Well Measured: Developing Indicators for Comprehensive and Sustainable Transport Planning*. Victoria Transport Policy Institute, Canada.

IMO 2004 Ballast water Management Convention

IMO, 2008. 'Report of the Marine Environment Protection Committee on its Fifty-eighth Session. MEPC 58/23. Annexes 13 and 14' (http://www3.epa.gov/nonroad/marine/ci/mepc58-23-annexes13-14.pdf) accessed 13 November 2015.

IMO, 2011a, 'International Convention for the Prevention of Pollution from Ships (MARPOL) - Inclusion of Regulations on Energy Efficiency for Ships in MARPOL Annex VI. Resolution MEPC.203(62). Annex 19. Adopted on 15 July 2011' (2015:http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/eedi%20amendments%20RESOLUTION%20MEPC203%2062.pdf) accessed 13 November 2016.

Rapport, D., Friend, A., 1979, *Towards a Comprehensive Framework for Environmental Statistics: a Stress–response Approach.* Statistics Canada Catalogue 11-510. Minister of Supply and Services Canada, Ottawa

RESPONSES Project, 2012, 'European responses to climate change: deep emissions reductions and mainstreaming of mitigation and adaptation, Deliverable 5.2 A matrix of biodiversity indicators' (http://www.responsesproject.eu/pdf/5.2%20RESPONSES%20project%20report.pdf) accessed 09 August 2016.

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M. L., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P. H., Condé, S., Schägner, J. P., San Miguel, J. et al., 2013, *Mapping and Assessment of Ecosystems and their Services: An Analytical Framework for Ecosystem Assessments under Action 5 of the EU Biodiversity Strategy to 2020*, Publications Office of the European Union, Luxembourg.

OECD, 1991, *Environmental Indicators, a Preliminary Set*. OECD, Paris.

OECD, 1993, *OECD core set of indicators for environmental performance reviews*. OECD Environmental Directorate Monographs No.83.

ODEMM, 2011, 'ODEMM Linkage Framework' (https://www.liv.ac.uk/media/livacuk/odemm/docs/ODEMM-Linkage-Framework-V2.pdf) accessed 09 August 2016.

Seebens et al., 2016, 'Predicting the spread of marine species introduced by global shipping' *PNAS* vol.113 5646–5651.

Svarstad, H., et al., 2007, 'Discursive biases of the environmental research framework DPSIR' *Land Use Policy* doi:10.1016/j.landusepol.2007.03.005.

Spangenberg et al., 2015, 'Escaping the lock-in of continuous insecticide spraying in rice: Developing an integrated ecological and socio-political DPSIR analysis' *Ecological Modelling* 295, 188–195, http://dx.doi.org/10.1016/j.ecolmodel.2014.05.010.

UNEP, 2014, *The Use of Economic Instruments in Environmental Policy: Opportunities and Challenges* United Nations Publication. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank, 2005. Handbook of National Accounting: Integrated Environmental and Economic

Accounting 2003, Studies in Methods, Series F, No.61, Rev.1, Glossary, United Nations, New York, para. 6.5.

United Nations, 1996, *Indicators of sustainable development*. Division for Sustainable Development.

United Nations, 2016, ‘System of Environmental-Economic Accounting (SEEA), (http://unstats.un.org/unsd/envaccounting/seea.asp) accessed 09 August 2016.

Annex 1 Potenial indicators for operationalising the analytical framework

Table 8: Potential Indicators Used for DPSIR Assessment of Baltic Sea Shipping (D-Driver, P-Pressure, S-State, I-Impact, R-Response

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
Economic dimension	1	Volume of transport relative to GDP (tone km: passenger km)	D	
	2	Total per capita transport expenditure	D/R	
	3	Marine transport for good and passengers (tone-km, passenger-km)	D	-Worldbank: Liner shipping connectivity index (maximum value in 2004 = 100) [http://data.worldbank.org/indicator/IS.SHP.GCNW.XQ] Worldbank: Container port traffic (TEU: 20 foot equivalent units) [http://data.worldbank.org/indicator/IS.SHP.GOOD.TU] -Maritime transport of passengers by NUTS 2 regions (tran_r_mapa_nm) Maritime transport of freight by NUTS 2 regions (tran_r_mago_nm) [http://ec.europa.eu/eurostat/web/transport/data/database] -Eurostat: Passengers embarked and disembarked in all ports by direction - annual data [http://ec.europa.eu/eurostat/en/web/products-datasets/-/MAR_MP_AA_CPHD] -Short Sea Shipping - Country level - Gross weight of goods transported to/from main ports, by direction (mar_sg_am_cwd) [http://ec.europa.eu/eurostat/web/transport/data/database] -UNCTAD STAT: Container port throughput, annual, 2008-2014 [http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=13321] -UNCTAD STAT: World seaborne trade by types of cargo and country groups, annual, 1970-2014 [http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=32363] -Gross weight of seaborne goods handled in European main ports, broken down by reporting country (Source: Eurostat - Goods mar_go; http://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_transport_of_goods_-_quarterly_data) -UNCTAD STAT: Merchant fleet by flag of registration and by type of ship, annual, 1980-2016 [http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=93] -UNCTAD STAT: Merchant fleet by country of beneficial ownership, annual, 2014 – 2016 [http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=80100] -Eurostat: Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95) (water transport: turnover, surplus etc.) [http://ec.europa.eu/eurostat/en/web/products-datasets/-/SBS_NA_1A_SE_R2] -Eurostat: Fishing Fleet, Number of Vessel [http://ec.europa.eu/eurostat/web/products-datasets/-/tag00116] -Eurostat: Short Sea Shipping - Country level - Gross weight of goods transported to/from main ports, by direction [http://ec.europa.eu/eurostat/web/products-datasets/-/mar_sg_am_cws] -Eurostat: Production value of the maritime manufacturing sector by main NACE Rev 2 activities -Eurostat: Economic accounts by maritime regions (mare_eco) Economic accounts by maritime regions (mare_eco)

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
				Gross domestic product (GDP), market prices (mare_e3gdp) Gross value added at basic prices (mare_e3vab95r2) [http://ec.europa.eu/eurostat/web/maritime-policy-indicators/data/database] -Eurostat: Production in main maritime industry NACE Rev. 2 activities, EU-28, 2005–14 [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sts_inpr_a&lang=en] -Eurostat: Annual growth rates in main maritime industry NACE Rev. 2 activities, EU-28, 2005–14 (%)
	4	Fuel prices and taxes	D/R	-EEA: Fuel prices (not specific to ships and boats) [http://www.eea.europa.eu/data-and-maps/indicators/fuel-prices-and-taxes]
	5	Direct user cost by leisure boats/ferries (passenger transport)	R	
	6	External cost of shipping activities (emission cost, safety cost)	R	
	7	Internalization of costs (for implementing economic policy tools with a direct link to the marginal external costs)	R	
	8	Subsidies to maritime transport	D/R	-World Bank: Subsidies and other transfers (current LCU) (not broken down on shipping) [http://data.worldbank.org/indicator/GC.XPN.TRFT.CN]
	9	Taxation of ships and boats and ship and boat use	R	
	10	% of GDP contributed by the maritime transport	D	-Eurostat: Gross domestic product (GDP), market prices (coastal region) [indicator is not perfectly fitting] & Gross domestic product per inhabitant at current market prices by NUTS 3 regions, 2012 [http://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_economy_statistics_-_coastal_regions_and_sectoral_perspective] -Eurostat: Gross domestic product (GDP) at current market prices by NUTS 2 regions [http://ec.europa.eu/eurostat/web/products-datasets/-/nama_r_e2gdp]
	11	Investment in maritime infrastructure (per	D/R	-OECD: Infrastructure investmentSea, Euro (absolute numbers, Euro) [https://data.oecd.org/transport/infrastructure-investment.htm] -EEA: Investments in transport infrastructure (sea, harbours etc. included) [http://www.eea.europa.eu/data-and-maps/indicators/infrastructure-investments/assessment-2]

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
		capita or as share of GDP)		
	12	Harbour quality- fair/good condition	D	
	13	Total length in km by maritime transport (number ships x length)	D	UNCTAD STAT: World seaborne trade by types of cargo and country groups, annual, 1970-2014 [http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=32363]
	14	Fish catch value	D	-Eurostat: Landings of fishery products (split by EU member state) -Eurostat: Catches - Major fishing areas (from 2000 onwards) [http://ec.europa.eu/eurostat/web/products-datasets/-/fish_ca_main]
	15	Fishing effort (f), Fishing intensity (f/unit area), Fishing mortality)	D	-The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Fishing days [https://stecf.jrc.ec.europa.eu/reports/economic] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Days at sea [https://stecf.jrc.ec.europa.eu/reports/economic] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Fuel consumption [https://stecf.jrc.ec.europa.eu/reports/economic] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Energy consumption (million litre of fuel) and Energy consumed per fish landed (litre/tonne) by MS and fishing activity, 2008-2014 [https://stecf.jrc.ec.europa.eu/reports/economic] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): EU Baltic Sea fleet capacity and effort by MS and fishing activity: 2013 [https://stecf.jrc.ec.europa.eu/reports/economic]
	16	Number of visitors, GDP (%, total) by tourism	D	-Eurostat: Number of establishments, bedrooms and bed-places by coastal and non-coastal area (from 2012 onwards) [proxy for tourism] [http://ec.europa.eu/eurostat/web/products-datasets/-/tour_cap_natc]
	17	Wild capture Seafood	D	-Eurostat: Value added of processing and preserving of fish, crustaceans and molluscs, by country, 2012 (EUR million)
	18	Material from marine plants, algae	D	
	19	Energy/benefit generated	D	
	20	Aquaculture share (%) of GDP	D/S	-Eurostat: Production from aquaculture excluding hatcheries and nurseries (from 2008 onwards) [http://ec.europa.eu/eurostat/web/products-datasets/-/fish_aq2a] -Eurostat: Production of fish eggs for human consumption from aquaculture (from 2008 onwards) [https://data.europa.eu/euodp/data/dataset/IexxNEn7Uhv2yXTYlaog] -Eurostat: Input to capture-based aquaculture (from 2008 onwards) [http://ec.europa.eu/eurostat/web/products-datasets/-/fish_aq3]

Dimension s	No	Common indicators	D, P, S, I, R	Potential data sources
				-Eurostat: Aquaculture production in quantities (1984-2007) - tonnes live weight [http://ec.europa.eu/eurostat/en/web/products-datasets/-/FISH_AQ_Q]
	21	Number of people employed	D	-Eurostat: Youth employment rate by sex, age and NUTS 2 regions [http://ec.europa.eu/eurostat/web/products-datasets/-/yth_empl_030] -Eurostat: Employment rate of the age group 15-64 by NUTS 2 regions[http://ec.europa.eu/eurostat/en/web/products-datasets/-/TGS00007] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Employment: Total employed and FTE by MS and fishing activity, 2008-2014 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf] - UNCTAD STAT: Ships built by country of building, annual, 2014-2015
	22	Maintenance of physical, chemical & biological conditions	D/R	
	23	Revenues of fishing vessels	D	-The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Revenue (million €) and GVA (million €) [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): EU Baltic Sea fleet landings and revenue by MS and fishing activity: 2013 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf]
Social dimension	24	Average passenger journey time/length by maritime transport	D	
	25	Quality of transport for disadvantaged people (low income, children)	D	
	26	Volume of passengers	D	-Eurostat: Maritime transport - passengers - detailed annual and quarterly results (mar_pa) [http://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_transport_of_goods_-_quarterly_data]
	27	Personal mobility (daily or annual person miles and expenditure on trips by income groups)	D	
	28	Population exposed to noise, water pollution, ect.	I	
	29	Contribution of the sector to employment growth	D	
	30	Cases of chronic respiratory diseases, cancer, headaches	I	

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
	31	Private boat ownership	D	
	32	Affordability (portion of households income devoted to maritime transport)	D	
	33	Number of maritime accidents per year	D/I	
	34	Recreation & leisure (number of leisure boat, visitors)	D	
	35	Inspiration (culture, art, design)	D	
	36	Spiritual experience	D	
	37	Information for cognitive development	D	
	38	Cultural heritage and identity	D	
	39	People working in the fishing industry (%) & people (%) working in the ship industry	D	-(Eurostat: Youth employment rate by sex, age and NUTS 2 regions [http://ec.europa.eu/eurostat/web/products-datasets/-/yth_empl_030] -Eurostat: Employment rate of the age group 15-64 by NUTS 2 regions[http://ec.europa.eu/eurostat/en/web/products-datasets/-/TGS00007] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Employment: Total employed and FTE by MS and fishing activity, 2008-2014 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf]) -Eurostat: Labour market statistics by maritime regions (mare_lmk) [http://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_economy_statistics_-_coastal_regions_and_sectoral_perspective] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Employment: Total employed and FTE by MS and fishing activity, 2008-2014 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf]
	40	Deaths and injuries by ship accidents (Deaths/year, injuries/year)	I	
	41	Damages due to flooding (Damages in €/year)	I	
	42	Noise in harbours/waterways (humas affected)	P	

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
	43	Recreational impacts (bathing)	I	
	44	Interactions-Experiences (Number of whale watchers, divers etc)	D/I	
	45	Job quality - sea-related jobs	I	
Environmental dimension	46	Underwater noise	P	
	47	Mooring/anchoring/ beaching/launching (interaction with the seafloor)	P	
	48	Ballast water	P	
	49	Emissions to air (NOx, VOCs, O3, CO_2…)	P	-CO_2: EEA Energy efficiency and specific CO_2 emission [http://www.eea.europa.eu/data-and-maps/indicators/energy-efficiency-and-specific-co2-emissions/energy-efficiency-and-specific-co2-5]
	50	Emissions to water	P	
	51	Bottom trawling	P	
	52	Mooring	P	
	53	Fishing fleet pressure	P	-EEA: Fishing fleet pressure [http://www.eea.europa.eu/data-and-maps/indicators/fishing-fleet-capacity-2] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Inactive versus active fleet: capacity in 2013 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Top 10 species in terms of weight and value landed for MS fleets operating in the Baltic Sea, 2013 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Top 5 species landed in terms of weight and value as a proportion of the total landings in the Baltic Sea region, 2013 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): Landings, in weight and value, by Baltic Sea MS fleet over the period 2008-2013 [https://stecf.jrc.ec.europa.eu/documents/43805/1034590/2015-07_STECF+15-07+-+AER+2015_JRCxxx.pdf] - Marmoni indicator database: Seafloor exploitation index
	54	Smothering	P	
	55	Abrasion	P	
	56	Sulphur emissions	P	
	57	Copper	P/S	

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
		concentration		
	58	Marine litter	P	
	59	Anti fouling substances	P	
	60	Invasive species	P/S	-EEA: Invasive alien species in Europe [http://www.eea.europa.eu/data-and-maps/indicators/invasive-alien-species-in-europe/invasive-alien-species-in-europe] -EEA: Pathways of introduction of marine non-indigenous species [http://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species/assessment] -EEA: Trends in marine non-indigenous species [http://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species-mas-2/assessment] -Marmoni indicator database: Abundance and impact of non-native fish species (round goby example) [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html]
	61	Organic waste from ships (including Food Waste)	P	
	62	Oil spills	P	-EEA: EN15 Accidental oil spills from marine shipping [http://www.eea.europa.eu/data-and-maps/indicators/en15-accidental-oil-spills-from-1] -Marmoni indicator database: Proportion of oiled waterbirds [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html]
	63	State of mammal population	S	-Helcom: Abundance of waterbirds in breeding season [http://www.helcom.fi/baltic-sea-trends/indicators/]
	64	Habitat & ecosystem disruption	P/S	-Marmoni indicator database: Habitat diversity index[http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html] EEA: Marine protected areas in Europe's seas [http://www.eea.europa.eu/data-and-maps/indicators/marine-protected-area-mpa-network-coverage/assessment]
	65	Loss of biodiversity	S	-Red List of Baltic Sea underwater biotopes, habitats and biotope complexes [http://www.helcom.fi/baltic-sea-trends/biodiversity/red-list-of-biotopes-habitats-and-biotope-complexes]
	66	Food web structure change	S	
	67	Algal blooms (cyanobacteria) and oxygen depletion	I	-Marmoni indicator database: Cyanobacterial surface accumulations - the CSA-index [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html]
	68	Ocean Acidification	S	-EEA: Ocean Acidification [http://www.eea.europa.eu/data-and-maps/indicators/ocean-acidification/assessment-1]
	69	State of algae	S	-Marmoni indicator database: Accumulated cover of perennial macroalgae [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html] -Marmoni indicator database: Indicator of macroalgal community structure [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html] -Marmoni indicator database: Depth distribution of selected perennial macroalgae [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html] -Marmoni indicator database: Phytoplankton taxonomic diversity (Shannon95)

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
				[http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html]
	70	Fish stocks	S	-EEA: Status of marine fish stocks [http://www.eea.europa.eu/data-and-maps/indicators/status-of-marine-fish-stocks-2] -Helcom: Abundance of coastal fish key functional groups [http://www.helcom.fi/baltic-sea-trends/indicators/] -Helcom: Abundance of salmon spawners and smolt [http://www.helcom.fi/baltic-sea-trends/indicators/] -Helcom: Abundance of key coastal fish species [http://www.helcom.fi/baltic-sea-trends/indicators/] -Marmoni indicator database: Long term abundance and distribution of demersal fish in relation to benthic communities (fourhorn sculpin Myoxocephalus quadricornis and eelpout Zoarces viviparous example) -Marmoni indicator database: Abundance and distribution of juvenile flounder [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html] -The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): List of species under quotas for North East Atlantic, Fishing TACs and Quotas, EC, 2013
	71	Hazardous substances	S	-EEA: Hazardous substances in marine organisms [http://www.eea.europa.eu/data-and-maps/indicators/hazardous-substances-in-marine-organisms/hazardous-substances-in-marine-organisms-1]
	72	State of bird population	S	-Marmoni indicator database: Wintering waterbird index (WWBI) [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html]
	73	Nutrients in transitional, coastal and marine waters”	P/S	-Marmoni indicator database: Spring bloom intensity index [http://www.sea.ee/marmoni/marmoni_pulk/start_indicator_database.html]
	74	Introduction of synthetic compounds	P/S	
	75	Introduction of non-synthetic compounds	P/S	
	76	Introduction of microbial pathogens	P/S	
	77	Particle motion under water	S	
	78	Gene pool	S	
	79	Genetic resources	S	
	80	Medicinal resources	S	
	81	Ornamental ressources	S	
	82	Sea water ? What should be measured?	S	

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
	83	Chlorophyll (Eutrification)	S	-EEA: Chlorophyll in transitional, coastal and marine waters [http://www.eea.europa.eu/data-and-maps/indicators/chlorophyll-in-transitional-coastal-and-2/assessment] -Helcom: Chlorophyll-a [http://www.helcom.fi/baltic-sea-trends/indicators/]
	84	Noisy areas avoided by fish	P	
	85	Expansion of species due to increasing temperature	P/I	
	86	Sea level rise	S	
	87	Changes in mass flows	S	
Technical and operational dimension	88	Load factors for freight transport	D	
	89	Average age of ships	D	-The 2015 Annual Economic Report on the EU Fishing Fleet (STECF 15-07): EU Baltic Sea fleet structure and economic performance estimates by fishing activity and Member State in 2013 -Eurostat: Fishing fleet by age, length and gross tonnage [- by country http://ec.europa.eu/eurostat/en/web/products-datasets/-/FISH_FLEET_ALT] -UNCTAD STAT: Ship scrapping by country of demolition, annual, 2014-2015
	90	Size of ships	D	-Eurostat: Fishing fleet by age, length and gross tonnage [- by country http://ec.europa.eu/eurostat/en/web/products-datasets/-/FISH_FLEET_ALT]
	91	Difficulties in mating, communication	D/I	
	92	Filtering, storage, bio-remediation, sequestration	D	
	93	Changed cycles due to increasing temperature	I	
	94	Changing routes in winter (due to temperature increase)	I	
	95	Fleet productivities	D	-Eurostat: Fishing fleet by age, length and gross tonnage [- by country http://ec.europa.eu/eurostat/en/web/products-datasets/-/FISH_FLEET_ALT] -Eurostat: Fishing fleet by type of gear and engine power [http://ec.europa.eu/eurostat/en/web/products-datasets/-/FISH_FLEET_GP] -Fishing fleet, by country, 2000–14 (number of vessels); Source: Eurostat (fish_fleet) [http://ec.europa.eu/eurostat/statistics-explained/index.php/Fishery_statistics_in_detail]

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
	96	Updated technologies-demand and regulations	R	
Institutional dimension	97	Uptake of strategic environmental assessment & regulation	R	
	98	R and D expenditures on "eco-technologies"	R	-(Eurostat: Eco-innovation Index [not sea-specific] - http://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rt200) -Eurostat: Governments environmental and energy R&D appropriations and outlays (% of GDP) [not sea-specific] [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=gba_nabsfin07&lang=en] -Eurostat: Firms having implemented innovation activities aiming at a reduction of energy input per unit output (% of total firms) [not sea-specific] [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis6_eco&lang=en] -OECD: Green Patents, Index 1990=100 [not sea-specific] [http://stats.oecd.org/Index.aspx?DataSetCode=GREEN_GROWTH] -Eco-Innovation Observatory: Eco-Innovation Scoreboard [not sea-specific] [http://database.eco-innovation.eu/#view:scoreboard/indicators:269/countries:250,15,22,34,55,57,58,59,68,73,74,81,84,99,105,108,121,127,128,136,155,176,177,181,200,201,206,212,232/rScales:/chartType:BarGraph/year:2013/indicatorTabs:269,270,271,272,273,274/order:269]s UNCTAD STAT: Liner shipping connectivity index, annual, 2004-2016 UNCTAD STAT: Liner shipping bilateral connectivity index, annual, 2006-2015
	99	Total expenditure on pollution prevention and clean-up	R	
	100	Asthetic information	R	
	101	Air purification	R	
	102	Biological control	R	
	103	Coastal erosion protection	R	
	104	Waste treatment	R	
	105	Regulation of water flows	R	
	106	Disturbance prevention	R	
	107	Climate regulation	R	
	108	Pest and disease	R	

Dimensions	No	Common indicators	D, P, S, I, R	Potential data sources
		control		
	109	Water conditions	R	