Baltic Sea –Our Common Treasure

Economics of Saving the Sea

Rapport 2013:4

This report by the BalticSTERN Secretariat was commissioned by the Swedish Agency for Marine and Water Management

Ansvarig utgivare: Björn Risinger
Text: BalticSTERN Secretariat
Omslagsfoto: Fredrik Wulff/Azote
Tryckt i 300 ex, mars 2013, USAB Stockholm i mars 2013
ISBN: 978-91-87025-28-0
Havs- och vattenmyndigheten, Box 11 930, 404 39 Göteborg

Baltic Sea – Our Common Treasure
Economics of Saving the Sea

Havs- och vattenmyndighetens rapport 2013:4

Foreword

The Swedish Agency for Marine and Water Management (SWaM) has the overall responsibility for issues regarding marine and water management in Sweden. In this capacity, it is of interest to support the dialogue between researchers and decision makers, and communicate research findings to policy makers and the public.

The international research network BalticSTERN, with partners in all countries around the Baltic Sea, combines ecological and economic models to make cost-benefit analyses and investigate possible cost-effective solutions to the environmental problems of the Sea. SWaM has commissioned the BalticSTERN Secretariat at Stockholm Resilience Centre to synthesize the results in a report directed to decision makers. The report Baltic Sea – Our Common Treasure. Economics of saving the Sea will provide valuable contributions to the work on solving the environmental problems of the Baltic Sea including Kattegat.

Göteborg, March 2013

Anna Jöborn
Director
Science Affairs Department

Foreword

BalticSTERN (Systems Tools and Ecological-economic evaluation – a Research Network) is a research network with partners in all countries around the Baltic Sea. The aim of the network is to combine ecological and economic models to make cost-benefit analyses and identify cost-effective measures to improve the environmental state of the Sea. Results from BalticSTERN research during the period of 2009-2012 is presented in this final report aimed at decision makers. Supplementing this final report there are Background Papers (BG Papers), published on the BalticSTERN website and on the website of the Swedish Agency for Marine and Water Management. This final report gives an overview and presents main results, while the BG Papers explore policy and research questions, as well as methods and results in more detail. Focus is on eutrophication, but some case studies on fish and fishery, oil spills and invasive species have also been undertaken within BalticSTERN and are discussed in a wider perspective in this report.

Main coordinators of the different projects on eutrophication have been Kari Hyytiäinen at MTT Agrifood Research Finland (from 2009 to May 2011 Anni Huhtala), Berit Hasler at Department of Environmental Science and Baltic Nest Institute, Aarhus University in Denmark, and Linus Hasselström and Tore Söderqvist at Enveco Ltd, Sweden. Heini Ahtiainen and Janne Artell at MTT Agrifood Research Finland have together with coordinators at Enveco Ltd been responsible for studies on valuation of benefits. Lassi Ahlvik has been responsible for cost modeling at MTT Agrifood Research Finland. Anders Fonnesbech-Wulff and Jim Smart have worked with cost modeling at Aarhus University, and Louise Martinsen and Mohammed Alemu with benefit valuation at Aarhus University. Mikołaj Czajkowski has worked with cost modeling and valuation of benefits at University of Warsaw. Coordinators for the case study FishSTERN were Thorsten Blenckner at Stockholm Resilience Centre and Ralf Döring at Johann Heinrich von Thünen Institut, Germany. The chapters on the case studies in this report are based on Background Papers. Thorsten Blenckner, Jonas Hentati Sundberg, Marcus C. Öhman and Henrik Österblom at Stockholm Resilience Centre, Sweden, wrote the BG Paper *Fisheries management* Linus Hasselström, Enveco Ltd. and Scott Cole, Enviro Economics Sweden, wrote the BG Paper *Oil spills management*.

All partners in the BalticSTERN Network are listed in Appendix A. There are many scientific articles written based on the BalticSTERN research and these are listed in Appendix B.

The BalticSTERN research network has at this point published the following reports directed to decision makers:

- BalticSurvey – A study in the Baltic Sea countries of public attitudes and use of the sea – Summary of main results (Swedish EPA, 2010a)
- BalticSurvey – a survey study in the Baltic Sea countries on people´s attitudes and use of the sea – Report on basic findings (Swedish EPA, 2010b)
- FishSTERN – A first attempt at an ecological-economic evaluation of fishery management scenarios in the Baltic Sea region (Swedish EPA, 2011).

BalticSTERN research undertaken at MTT Agrifood Research Finland was financed by the Finnish Advisory Board of Sectoral Research through the research project *Protection of the Baltic Sea: Benefits, costs and policy instruments* (PROBAPS). BalticSTERN research at Aarhus University has been financed through the BONUS project RECOCA, the Danish Baltic Nest Institute and the research project Protection of the Baltic Sea: *Benefits, costs and policy instruments* (IMAGE). The Swedish Environmental Protection Agency financed the study Baltic Survey.

Funding of the valuation studies was received through the research project PROBAPS, funded by the Finnish Advisory Board for Sectorial Research, the research project *Managing Baltic nutrients in relation to cyanobacterial blooms: what should we aim for?*, funded by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), the research alliance IMAGE, funded by the Danish Strategic Research Council and the Danish Baltic Nest Institute, Aarhus University, the BalticSTERN Secretariat at the Stockholm Resilience Centre, Stockholm University, the German Federal Environment Agency (UBA) and the Swedish Environmental Protection Agency.

The BalticSTERN Steering Group has been chaired by Johan Rockström, Director of the Stockholm Resilience Centre. Members of the Steering Group are and have been Stefan Berggren, Swedish Ministry for the Environment (from September 2011–), Mike Elliott, Institute of Estuarine & Coastal Studies, University of Hull, Great Britain (from September 2010-), Anda Ikauniece, Latvian Institute of Aquatic Ecology (from April 2012-), Andrzej Jagusiewicz, Polish Ministry for the Environment (from September 2010–), Anna Jöborn, Swedish Agency for Marine and Water Management (from July 2011–), Fritz Holzwarth, German Ministry for the Environment (from September 2010–), Åsa Norrman, Swedish Ministry for the Environment (from September 2010 to November 2010), Sulev Nõmmann, Estonian Ministry for the Environment (from September 2010 to December 2011), Eeva-Liisa Poutanen, Finnish Ministry for the Environment (from September 2010–), Claude Rouam, EU Commission (from September 2010–), Kerry Turner, University of East Anglia (from September 2010–), Torben Wallach, Danish Ministry for the Environment/Agency of Nature (from September 2010–), Igor Zotov, Russian Ministry for the Environment (from September 2010 to April 2011).

The BalticSTERN Secretariat at Stockholm Resilience Centre has been responsible for overarching coordination and for communication. In its contract with the Swedish Environmental Protection Agency (September 2009–June 2011) and the Swedish Agency for Marine and Water Management (from July 2011), which have financed the Secretariat, it is stated that the Secretariat shall synthesize in a report results from BalticSTERN research and other available and relevant research regarding costs for reaching marine environmental targets, as well as the socioeconomic costs for society if the targets are not met. The report shall also reflect on relevant policy instruments. The report shall be directed to Governments, Parliaments and other decision makers.

Responsible for writing the report at the Secretariat have been Kerstin Blyh, (August 2011–July 2012), Marmar Nekoro (September 2009 -), Henrik Scharin (January 2010–) and Siv Ericsdotter, Head of Secretariat (November 2009–). Cornelia Ludwig assisted the Secretariat during the period July to November 2012.

Stockholm, March 2013

Johan Rockström
Chair of BalticSTERN Steering Group

/Siv Ericsdotter
Marmar Nekoro
Henrik Scharin
Kerstin Blyh

CONTENT

LIST OF ABBREVIATIONS

BAT	Best Available Technology
BAU	Business-As-Usual
BONUS	Baltic Organisations' Network for Funding Science
BNI	Baltic Nest Institute
BSAP	Baltic Sea Action Plan
BSRAC	Baltic Sea Regional Advisory Council
CaC	Command-and-Control
CAP	Common Agricultural Policy
CBA	Cost-Benefit Analysis
CBD	Convention on Biological Diversity
CFP	Common Fisheries Policy
CLRTAP	Convention on Long-Range Transboundary Air Pollution
DAISIE	Delivering Alien Invasive Species Inventories for Europe
DVM	Deliberative Valuation Method
EC	European Commission
EPA	Environmental Protection Agency
EU	European Union
GDP	Gross Domestic Product
GES	Good Environmental Status
HELCOM	Helsinki Commission
HELCOM MONAS	Monitoring and assessment group of HELCOM
ICES	International Council for the Exploration of the Sea
IGBP	International Geosphere-Biosphere Programme
Im	Input reducing measures
Inf	Informational
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPCC SRES	IPCC Special Report on Emissions Scenarios
IUU	Illegal, Unreported and Unregulated
MARPOL	International Convention for the Prevention of Pollution from Ships
MBI	Market-Based Instruments
MSFD	Marine Strategy Framework Directive
MSY	Maximum Sustainable Yield
NEFCO	Nordic Environment Finance Corporation
NERI	National Environmental Research Institute
NGO	Non-Governmental Organization
NPV	Net Present Value
NVZ	Nitrate Vulnerable Zone
OSPAR	Oslo - Paris Convention for the Protection of the Marine Environment of the North East Atlantic
Pm	Passive measures
POP	Persistent Organic Pollutants
P-ponds	Phosphorous sedimentation ponds
PSSA	Particularly Sensitive Sea Area
PPP	Polluter Pays Principle
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
Rm	Recycling measure
SEPA	Swedish Environmental Protection Agency
SLU	Swedish University of Agricultural Sciences
SYKE	Finnish Environment Institute
TAC	Total Allowable Catches
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UWWTD	Urban Waste Water Treatment Directive
VASAB	Vision and Strategies around the Baltic Sea 2010
WFD	Water Framework Directive
WWF	World Wildlife Fund
WWTP	WasteWater Treatment Plants

GLOSSARY

Abiotic factor. Physical, chemical and other non-living environmental factors essential for living plants and animals of an ecosystem.

Algae. Simple rootless plants that grow in sunlit waters in proportion to the amount of available nutrients. They can affect water quality adversely by lowering the dissolved oxygen in the water. They are food for fish and small aquatic animals.

Algal bloom. Intense growth of algae over a short period. The bloom drastically reduces transparency and sometimes also creates surface scum and odors; some such blooms, created by so-called harmful algae, may be toxic for marine organisms and poisonous to people.

Anoxia. Absence, or deficiency of oxygen.

Atmospheric deposition. The process by which chemical substances, such as pollutants from e.g. combustion of fossil fuels and evaporation of ammonia from manure or farms, are transferred from the atmosphere to the earth's surface through wet (gaseous) or dry (particulate) depositions.

Benthic. Adjective of benthos (see below).

Benthos. Organisms that live associated with the sea bottom, including both mobile and non-mobile forms such as burrowing clams, sea grasses, sea urchins, acorn barnacles.

Biodiversity. In its most general sense, biodiversity refers to all aspects of variety in the living world. Specifically, the term may be used to describe the number of species, the amount of genetic variation or the number of community types present in an area.

Bottom-up control. Refers to food webs where a control of a population comes from change lower in the web (e.g., control of a population of mussels by abundance of phytoplankton food).

Cost-effectiveness. A particular reduction target is reached at the lowest possible cost.

Denitrification. In the ocean this is the process by which bacteria use nitrate instead of oxygen as an oxidant of organic matter. It may be considered as the biological reduction of nitrate or nitrite to nitrogen or nitrous oxide. This takes place under low oxygen conditions.

Detritus. Decaying organic matter.

Diatom. Microscopic algae with a doubled cell wall built with silica, occurring as a single cell or as a chain of cells.

Diffuse (non-point) sources. Discharges that cannot be traced a geographical point, e.g. soil leaching from agriculture and storm water from urban areas.

Dinoflagellate. Dominant planktonic algal form, occurring as a single cell, often biflagellate.

Endemic. Describing a plant or animal species whose distribution is restricted to one or a few localities.

Epibenthic. Living on the surface of the bottom (epifaunal or epifloral).

Epiphyte. Micro algal organinorsm living on a surface (e.g., on a seaweed frond).

Eutrophic. Water bodies or habitats having high concentrations of nutrients.

Eutrophication. Defined as an increased input of nutrients causing an accelerated growth of planktonic algae and higher plant forms.

Food chain. An abstraction describing the network of feeding relationships in a community as a series of links of trophic levels, such as primary producers, herbivores, and primary carnivores.

Fucoid. Of or belonging to the order *Fucales*, brown algae (class *Phaeophyceae*).

Functional group. A group of species characterized by common traits or roles in the ecosystem. This applies to functions such as feeding behavior, occupation of a specific niche or the capacity to conduct certain biogeochemical processes.

Functional diversity. The range and value of the organisms in a given ecosystem (can be used to describe e.g. variations in functional characters of species, complexity of food webs and number of functional groups present).

Gross Domestic Product (GDP). GDP is the market value of all officially recognized final goods and services produced within a country in a given period of time.

Halocline. Depth zone within which salinity changes maximally.

Harmful algal bloom. A bloom of (usually) planktonic microalgae belonging to a strain of a species that has a toxic harmful to marine organisms or humans consuming marine organisms.

Hypoxia. State of deficient oxygen values, where long-term hypoxia corresponds to concentrations of oxygen below 2 ml l^{-1}.

Internal loading. Release of nutrients, mostly phosphorous, from the bottom sediments in lakes and the sea; internal loading may occur under anoxic conditions in deep water and on shallow, eutrophied bottoms at high summer temperatures.

Invertebrates. Animals without backbones.

Keystone species. Species that, relative to their abundance, have a disproportionately large effect on their environment. They play a critical role in maintaining the organization and diversity of the ecological community, and changes in their abundance and distribution thereby affects many other organisms in the food web.

Limnic. Fresh water systems, mainly lakes and rivers, with essentially no salt.

Littoral. The shallow water region around lake or sea shores where significant light penetrates to the bottom. Typically occupied by rooted plants. On sea shores it includes the intertidal zone.

Macroalgae. Multicellular algae (green, blue-green and red algae) having filamentous, sheet or mat-like morphology.

Macrobenthos. Benthic organisms (animals or plants) whose shortest dimension is greater than or equal to 0.5 mm.

Macrophyte. An individual alga large enough to be seen easily with the unaided eye.

Marginal cost. In this context, the cost of reducing inputs to the sea by one further unit.

Maximum Sustainable Yield (MSY). In fisheries biology, the maximum catch obtainable per unit time under the appropriate fishing rate.

Measure. A physical or behavioural change with the aim of reducing the nitrogen and phosphorus load on a receiving body of water. This may, for example, be growing catch crops, installing better treatment equipment in a wastewater treatmant plant or reducing fertilization.

Meiobenthos (meiofauna or meioflora). Benthic organisms (animals or plants) whose shortest dimension is less than 0.5 mm but greater than or equal to 0.1 mm.

Niche. The niche of an organism is defined by what it eats, its predators, salt tolerances, light requirements etc., i.e. abiotic and biotic factors.

Nitrogen fixation. The conversion of atmospheric nitrogen into an organic form usable by plants and other organisms.

Non-use values. The benefits derived simply from the knowledge that a particular ecosystem is maintained and/or can be enjoyed by others.

Oligotrophic. Refers to water bodies or habitats with low concentrations of nutrients.

Organic nutrients. Nutrients in the form of molecules synthesized by or originating from other organisms.

Pelagic. Open water system / living in the open water column.

Perennial. A plant that lives for more than two years.

Photic zone. The depth zone in the ocean extending from the surface to that depth permitting photosynthesis.

Phytoplankton. The photosynthesizing organisms/community residing in the plankton (e.g. algae, diatoms).

Plankton. Small, free-floating organisms living suspended in the water column and incapable of moving against water currents.

Point sources. Pollution that can be traced to a specific point such as a sewer or drain pipe.

Policy instrument. Policy instruments are central government tools to bring about implementation of measures. These can be broadly divided into command-and-control, such as laws and regulations, market-based instruments, such as taxes and fees, and information.

Primary production. The production of living matter by photosynthesizing organisms or by chemosynthesizing organisms. Usually expressed as grams of carbon per square meter per year.

Practical Salinity Units (PSU). A measure of the salt content of seawater (practical salinity), based upon electrical conductivity of a sample relative to a reference standard of seawater.

Regime shift. An ecosystem regime shift is an infrequent, large-scale reorganization, marking an abrupt transition between different states of a com plex system, affecting ecosystem structure and function and occurring at multiple trophic levels.

Resilience. Resilience is the capacity of a system (e.g. social or ecological) to cope with change and disturbance without shifting into a qualitatively different state, i.e. to withstand shocks and stresses and still maintain its characteristics and continue to develop.

Retention is the collective term for all processes that mean that only a certain proportion of the total quantity of phosphorus or nitrogen discharged from a particular source reaches the final receiving water body due to denitrification, uptake in biota or sedimentation.

Thermocline. Depth zone within which temperature changes maximally.

Top-down control. Refers to food webs where control of a population is mainly explained by consumption by a species or group of species at higher levels of the food chain (e.g., population change of population fish controlled by seal predation).

Trophic cascade. Changes in the relative abundances of multiple species in an ecological community as a result of changes in abundance of one species. Trophic cascades ensue from both direct predation and risk effects of predators.

Trophic level. In a food chain, a level containing organisms of identical feeding habits with respect to the chain (e.g., herbivores).

Use Values. The benefits derived from some kind of interaction with the environmental resource in question.

Watershed (Catchment, Drainage basin). The land area that is drained by a river or estuary and its tributaries.

Zooplankton. Small, sometimes microscopic animals that drift in the water column (e.g. protozoa, crustaceans, jellyfish and other invertebrates).

Summary

The Baltic Sea is a young, unique and vulnerable Sea victim to severe pressures during the latest century. This has lead to widespread eutrophication and hypoxia, hazardous substances, oil spills, invasive species, marine litter and subsequent changes in flora and fauna. Blue-green algae blooms have increased by ten times and sea bottoms with low oxygen (hypoxia) have also extended tenfold. These effects in combination with overfishing have resulted in several regime shifts in the food web. Climate change has caused sea surface temperature to increase by 0.7 °C during the 20th century. All of the above influences the ecosystem services of the Sea and thereby the benefits generated to people and society.

One of the severest environmental problems of the Baltic Sea is eutrophication caused by increased loads of nutrients to the Sea from agriculture, wastewater, industry and traffic. It is also a costly problem to deal with. It is therefore of interest to find cost-effective solutions to reach the targets, which have been set up through the HELCOM (Helsinki Commission) Baltic Sea Action Plan (BSAP). The nine littoral countries to the Baltic Sea reached an agreement in 2007 to reduce nutrient loads by specific targets for each country. This will be an important step to improve the Sea and to reach the goals of the EU Marine Strategy Framework Directive (MSFD) stating that all European Seas should be in a Good Environmental State (GES) by 2020.

Mitigation of eutrophication – a Cost-Benefit Analyses

The international research network BalticSTERN, with partners in all nine countries around the Baltic Sea, has combined ecological and economic models to make cost-benefit analyses regarding mitigation of eutrophication according to the BSAP targets.

To estimate the value of the benefits the BSAP nutrient reduction targets would generate, two surveys with representative samples of the populations in the nine Baltic Sea countries have been undertaken. In the first one, BalticSurvey, people were asked about their use of the Sea and their attitudes regarding the environmental situation. In the second survey, BalticSUN, they were asked how much they would be willing to pay for an improved state of the Baltic Sea.

The surveys show that the Baltic Sea is important to people. More than 80 per cent of the people living in countries around the Sea have spent leisure time at the Sea. Many are worried about the environmental situation and every second person of the respondents in the survey BalticSUN had themselves experienced the effects of eutrophication. The survey also shows that people attach a high value to improving the state of the Baltic Sea.

In total, the citizens of the Baltic Sea countries are willing to pay approximately 3 800 million Euros annually to achieve a less eutrophied Sea until 2050, with improved water quality, less blue-green algal blooms, underwater meadows with good conditions for fish spawning, more diverse and abundant

fish populations and less oxygen deficiency in deep sea bottoms.

BalticSTERN results indicate that some of the most cost-effective measures are reduced nutrient loads from wastewater treatment plants, reduced application of fertilizers, ponds serving as sinks for phosphorus, a ban on phosphorus in detergents, and investments in wetlands to reduce nitrogen leakage. Because of model limitations only nine types of measures were included in the model. According to the research conducted within this network, the total annual costs of reaching the targets for nutrient reductions with an allocation according to the BSAP agreement would amount to around 2 800 million Euros. Under a more cost-effective allocation of measures the costs would be 2 300 million Euros per year.

This means there would be a welfare gain of about 1 500 million Euros per year if a cost-effective allocation of the nine measures included were implemented. As the costs are probably overestimated and the benefits underestimated, this result, showing substantial welfare gains, can be regarded as robust.

The challenge is to introduce policy instruments that could give incentives for a cost-effective allocation of the measures necessary for reaching the targets and at the same time be regarded as fair.

Other environmental problems

Eutrophication is, however, not the only environmental problem of the Baltic Sea. The benefits attained by reaching the BSAP targets for nutrient reductions could be jeopardized by overfishing, oil spills or by the effects of invasive species. For these threats with obvious linkages to eutrophication, BalticSTERN researchers have made case studies.

The study FishSTERN indicates that a decrease in fishing effort in Baltic Proper would be positive for profits and employment, as well as ecosystem health, given present capacity of fleets and present fish stocks. A dual management strategy, with better control of compliance for pelagic fishery using large vessels and more self-organization of local fishery using small vessels, could be a way forward.

Increased traffic on the Baltic Sea increases the risk for oil spills and may thereby threaten the Baltic Sea environment and thus ecosystem services and benefits provided. The BalticSTERN case study regarding risk for oil spills in the Gulf of Finland indicates that some of the benefits from mitigating eutrophication may be lost if a large oil spill would occur. The highly international context and regulations regarding maritime safety restrict manoeuvre room for national and regional action, but there are still possibilities for important action regarding implementation and compliance. There is also the option to form alliances and influence international rules. A parallel strategy could be to take actions to strengthen the resilience of the Baltic Sea ecosystem, thus improving its ability to recover from an oil spill.

Increase of sea traffic has brought alien species to the Baltic Sea and decline of native species has made the Sea more vulnerable to invasive species. Invasive species may threaten food-web balances of the Baltic Sea and may become more frequent with a warmer climate. The BalticSTERN case study on one species at one location revealed three distinct strategies regarding how to cope with invasive species: an adaptive strategy, which reduces the damage; a preventive strategy, which delays the invasion and the resulting damage; and a mitigation strategy, which puts effort into timely detection, control and eradication of the newly established population.

There is no lack of management frameworks and targets to deal with the different environmental problems. Even if there are still uncertainties there is also solid research results and knowledge on what needs to be done. Some measures have been undertaken, such as under the EU Urban Wastewater Treatment Directive, and have had good effects. But there is still a gap between what is done and what needs to be done. Therefore, there is need for new or strengthened policy instruments in order to implement necessary measures.

Given the linkages between ecosystem functions and services and also between the environmental pressures, it is important to take an ecosystem approach and a holistic view, to monitor the outcomes of different measures and the development of the ecosystem functions and services, and to be prepared for surprises.

Future risks

The Business-As-Usual (BAU) scenario used in the Cost-Benefit Analyses (CBA) is based on a relatively favourable development of the drivers, and does not take account of climate change which was estimated not to have large effects until 2050, the time span of this modelling exercise.

New information and long-term scenarios show that climate change will pose new challenges, changing temperature and salinity in the sensitive Baltic Sea, and that the effects will be seen earlier than before thought. Trends also point to that many of the drivers and pressures causing eutrophication of the Baltic Sea will increase. Traffic (shipping and land transport) is predicted to continue to expand. European agriculture production may increase in the north and the east of Europe if the production in southern Europe decreases due to climate changes. Global drivers such as growth of populations and economies may increase demand on food, which could lead to an intensified agriculture production also in the Baltic Sea region. The combined effects may trigger the ecosystem passed thresholds and into new states. Experience shows that such regime shifts may be difficult to reverse. As there may be non-linearities and not yet completely understood feed-back mechanisms in the system, there is even risk for collapse of parts of the ecosystem.

Studies regarding the development of the Baltic Sea up to 2100 highlight that there may be risks for passing thresholds leading to collapse of species like cod, intensified algae blooms and expansion of bottoms with low or no oxygen in a non-action scenario. To avoid such a scenario scientists underline the importance of reaching BSAP targets and to stick to stringent fishery management plans. To safeguard the quality of the water and the coasts it is important to also enforce measures to prevent oil spills and to handle the effects of these spills when they occur. With growth of drivers it is important to find effective and innovative ways of reducing pressures from the drivers and safeguard the ecosystem services generating highly valued benefits to people.

To conclude there is need for an ecosystem based, holistic and integrated management strategy with a common vision for a sustainable transformation of the Baltic Sea, which could safeguard ecosystem services and the benefits they provide to human societies. Flexible management is important since the action required is likely to change over time due to the dynamics of the ecosystem, as well as of the drivers.

I. Introduction

1. Background

This introductory chapter outlines challenges in achieving a healthier Baltic Sea, political goals and targets to cope with environmental deterioration of the Sea, as well as aims and scope of this report and the studies undertaken by the BalticSTERN network.

1.1 Challenges and targets

Global challenges

The population on our planet has doubled since the 1950s. The use of energy and other resources, such as phosphorous, minerals and freshwater, have shown steep upward trends during the same period according to the report Global Change and the Earth System (Steffen et al., 2004).

In the scientific article Planetary boundaries: exploring the safe operating space for humanity (Rockström et al., 2009) an attempt was made to quantify the safe biophysical boundaries outside which the scientists believe the Earth System cannot function in a stable state. The study identified nine such boundaries and suggested that three (climate change, biological diversity and nitrogen input to the biosphere) may already have been transgressed. In addition, it was emphasized that the boundaries are strongly connected – crossing one boundary may seriously threaten the ability to stay within safe limits of the others.

According to the report Resilient people, resilient planet: a future worth choosing (United Nations Secretary-General's High-Level Panel on Global Sustainability, 2012), the global population will grow from 7 billion to almost 9 billion by 2040 and the number of middle-class consumers will increase by 3 billion over the next 20 years, which will increase the demand for resources exponentially. The report also states that by 2030 the world will need at least 50 per cent more food, 45 per cent more energy and 30 per cent more water – all at a time when we are already approaching environmental boundaries.

Oceans worldwide already show signs of environmental problems such as eutrophication, acidification, overfishing, pollution through litter and hazardous substances, affecting benefits such as recreation and also influencing the possibilities for small-scale fishermen to earn their living.

The imminent increased demand for resources will certainly have effects also for the development in the Baltic Sea region and the pressures on the Baltic Sea ecosystems.

Challenges with regard to the Baltic Sea and its characteristics

The Baltic Sea is unique and vulnerable. It is of great value for the people living around the Sea, especially with regard to their recreation, as shown in Chapter 2. The Sea has changed drastically during the last centuries, affecting ecosystem services and the benefits provided to human societies.

The Baltic Sea is a complex ecosystem with a multitude of physical, chemical and biological interactions, functioning on various temporal and spatial scales. The Baltic Sea is the largest body of brackish water in the world, containing a mixture of saline seawater from the North Sea and freshwater from rainfall and rivers in the catchment area. Salinity is lower in the north and increases towards the southern parts. Salinity also varies with depth and increases from the surface down towards the seafloor. Between the low-saline surface waters and the high-saline bottom waters where the salinity rapidly changes a layer called the halocline forms. The depth of this layer varies, but in the Baltic Proper and Gulf of Finland it is usually formed at a depth of 50–80 meters. This stratifying layer forms a lid hindering the vertical mixing of water and thus the ventilation and oxygenation of bottom waters (HELCOM, 2007b, 2009b).

Connected to the Atlantic through the North Sea only via the narrow and shallow Danish Straits, water exchange in the Baltic Sea is very limited. The pulses of oxygen-rich water are episodic making renewal of bottom waters slow, which leads to residence times of up to 40 years. (HELCOM, 2007b, 2009b) Biodiversity has historically been considered low, but certain species can be relatively abundant. New research (Telesh et al., 2011) shows that Baltic Sea biodiversity is higher than previously thought. Diversity and species distribution is generally viewed as limited by salinity and the sea basins differ regarding species diversity, composition and biomass. In general biodiversity follows the salinity gradient increasing towards the south with a 20–40 times higher biomass of both fauna and flora in the Baltic Proper compared to that of the Bothnian Bay. (Jansson & Kautsky, 1977; Ojaveer et al., 2010)

Drivers which have caused accelerated pressures on the Sea during the last century are population growth in the catchment area, the establishment of industry and trade and the subsequent economic growth, changes in consumption patterns with more meat in the diet, intensified agriculture, as well as increases in energy use and traffic. As a result widespread eutrophication and hypoxia, hazardous substances, oil spills, invasive species, marine litter and subsequent changes in flora and fauna are environmental problems seen today. Both sea bottoms with low oxygen (hypoxia) and blue-green algae blooms have increased tenfold (Savchuk et al., 2008 and references therein). These effects, in combination with overfishing, have resulted in several regime shifts in the food web. Climate change has caused sea surface temperature to increase by > 0.7 °C during the 20th century. All of the above influences the ecosystem services of the Sea and thereby the benefits generated to people and society. See Chapter 9 and Background (BG) Paper *State of the Baltic Sea*.

As aforementioned there are complex inter-linkages between the different ecosystem services of the Sea, and the environmental problems also interact. Eutrophication influences the food web and fish stocks, while the composition and state of the food web also influences the capacity of the Sea to mitigate eutrophication by internal processes. Furthermore, oil spills and invasive species may reduce benefits obtained by mitigating eutrophication. At the same time, hazardous substances influence the quality and value of fish and litter reduces the recreational value.

Scenarios for the future show that the drivers behind the negative development of the Baltic Sea may very well increase in the future (see Chapter 10). Global demand on food combined with worsened conditions for agriculture in southern Europe and other cultivated areas on Earth caused by climate change may lead to increased and intensified agriculture in the Baltic Sea catchment areas. Shipping prognosis also point to increased traffic in the Sea. Climate change will further affect the conditions in the Sea through increasing temperature and reduced salinity. The challenge is therefore to not only cope with deterioration caused by drivers in the past and at present, but also to look ahead and foresee if further measures are needed to prevent pressures that may arise in the future.

The path of change in climate and in other drivers affecting the Sea is unprecedented and shows that there are possibly shifting baselines, which needs to be recognized when developing management strategies. Scenarios for the development of the Baltic Sea up to 2100 highlight that there may be a risk for passing thresholds leading to collapse of species like cod, intensified algae blooms and expansion of bottoms with low or no oxygen in a non-action scenario. See Chapters 10 and 11.

Inter-linkages of the ecosystem services that provide benefits to human societies, and inter-linkages between the environmental problems of the Baltic Sea make it important to apply a holistic perspective. These complexities combined with the risk of surpassing thresholds, which may cause negative regime shifts in the vulnerable Sea, make it an important and delicate task to foresee future developments and to take adequate action.

Natural systems are constantly changing and there will be transformations also within the Baltic Sea ecosystem. To obtain a healthy Baltic Sea and a long-term sustainable transformation, which could safeguard important benefits to human societies, a holistic ecosystem-based perspective is required. There is a need for the development of both holistic and specific management strategies, which are efficient and adjusted to the problems. See further discussion in Chapter 11.

Political decisions and targets

In order to reverse negative trends political decisions have been taken within the European Union, regionally and nationally. The EU Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) have set up targets to reach Good Ecological Status of all European waters by 2015 and Good Environmental Status of all European seas by 2020 respectively. Directives such as the Urban Waste Water Treatment Directive and the Nitrate Directive are important for actions to be taken. The Common EU policies for agriculture (CAP) and for fishery (CFP) are also of utmost importance as they influence economic incentives for dominant drivers behind environmental deterioration of the seas.

On a regional scale the HELCOM Baltic Sea Action Plan (BSAP) from 2007 was a breakthrough. The nine littoral countries around the Baltic Sea agreed on reductions of nitrogen and phosphorous to the Sea and each country undertook to fulfill specific country-wise targets (HELCOM, 2007b).

The coming years will be decisive for the future of the Baltic Sea and for the development of the benefits the Sea provides to human societies in the region. According to the MSFD, plans for actions should be decided and reported by 2015 and the BSAP is to be revised with regards to country-specific targets at the HELCOM Ministerial Meeting autumn 2013.

At the UN Conference on Sustainable Development in Rio de Janeiro in June 2012 (Rio +20) it was agreed to undertake measures to reach better environmental status of the Earth´s seas by 2025 based on scientific results (UN, 2012). The Baltic Sea is one of the most polluted seas on Earth and surrounded by some of the richest countries. If a good status is achieved in the Baltic Sea it could prove as a positive example to the rest of the world. On the other hand, if we do not succeed this would set a bad example and could pose as an excuse for other, poorer, countries not to take action.

What are the challenges and the management options for reaching the goals and targets under different premises regarding the future development of drivers and pressures? How can the targets be achieved in the most cost-effective ways? What are the benefits at risk if the targets are not reached? This report aims to help answer some of these questions.

1.2 Why BalticSTERN – history

In September 2008 a statement was made by the Nordic Ministers for the Environment asking for socio-economic analysis to be produced for the Nordic Seas. This was inspired by the report *The Economics of Climate Change – The Stern Review* (Stern, 2006) presented by Sir Nicholas Stern to the British Prime Minister regarding costs of action and non-action for coping with climate change.

On assignment from the Swedish Government the Swedish Environmental Protection Agency (Swedish EPA) launched several reports based on existing socio-economic knowledge regarding benefits provided by the sea and costs of mitigation. In its final report *What is in the sea for me* (Swedish EPA, 2009a) the Swedish EPA concluded that more research was needed regarding for example benefits and costs of mitigation. An application for further research was made by the research network BalticSTERN in 2008 (Söderqvist, 2008) and a pre-study was made in 2009 (Huhtala et al., 2009). Funding for full-scale research on ecological-economic evaluations was granted from governmental funds in Finland, Sweden and Denmark and the research was started in the autumn 2009.

1.3 Objectives and assignment

The purpose of BalticSTERN research is to combine ecological and economic models in order to be able to make cost-benefit analyses and to identify cost-effective measures of reaching certain targets. These analyses will contribute to the requirements of the Marine Strategy Framework Directive to undertake economic and social analyses of the use of marine waters and the cost of degradation, as well as to the identification of measures and their costs.

The task of the BalticSTERN Secretariat has been to coordinate and communicate BalticSTERN research, to identify other relevant research and

to contribute to both policy-science dialogue and communication with stakeholders. According to the assignment the need for policy instruments should also be analyzed. The ultimate aim is to find ways forward to reach a healthier Baltic Sea.

The Secretariat has arranged coordinating meetings with partners in the network at decisive occasions in the scientific process. Through the Steering Group, which have met four times during the three-year period of BalticSTERN research, there has been a successive dialogue between scientists in the network, prominent international scientists and representatives from Governments in Baltic Sea countries and from EU Commission regarding methods and outcome of BalticSTERN research. The Secretariat has taken part in several scientific conferences and has communicated BalticSTERN research at meetings, seminars and conferences, where different stakeholders have participated. An initiative was also taken for a workshop and a working group with other Baltic Sea research projects to identify relevant studies and options for cooperation. As a result a survey regarding scenario work in Baltic Sea research projects was conducted. Through contacts with BONUS EEIG the Secretariat has made input to the BONUS Strategic Research Agenda. Several articles and press releases have been written on BalticSTERN results and published in newspapers and journals. In October 2012 a stakeholder seminar with representatives from more than twenty organizations was arranged at Stockholm Resilience Centre by the Secretariat. See Appendix C.

In the assignment for the Secretariat it is stated that a synthesis report based on results from BalticSTERN research and other relevant research should be compiled. The report should contribute to analyses of the costs of implementing the measures that are necessary for reaching certain targets, the gains for society of reaching the targets and the costs of not reaching them, as well as potential need for new policy instruments. Target groups for the report are Governments, Parliaments and other decision makers.

1.4 Framework and scope

Ecosystem services and benefits

The benefits that human societies receive from uses of the Sea are dependent on well-functioning ecosystems and ecosystem services.

Figure 1.1 illustrates the different ecosystem services of the Sea. Some of these are final services giving direct benefits to human societies, such as fish stocks for food, clear water for recreation and waterways for shipping. Others are intermediate, for example food webs and biodiversity, air and climate regulation and resilience. These intermediate services are often of vital importance for the final services and human benefits. These inter-linkages are further explained in Chapter 2 and in the BG Paper *Benefits of mitigating eutrophication.*

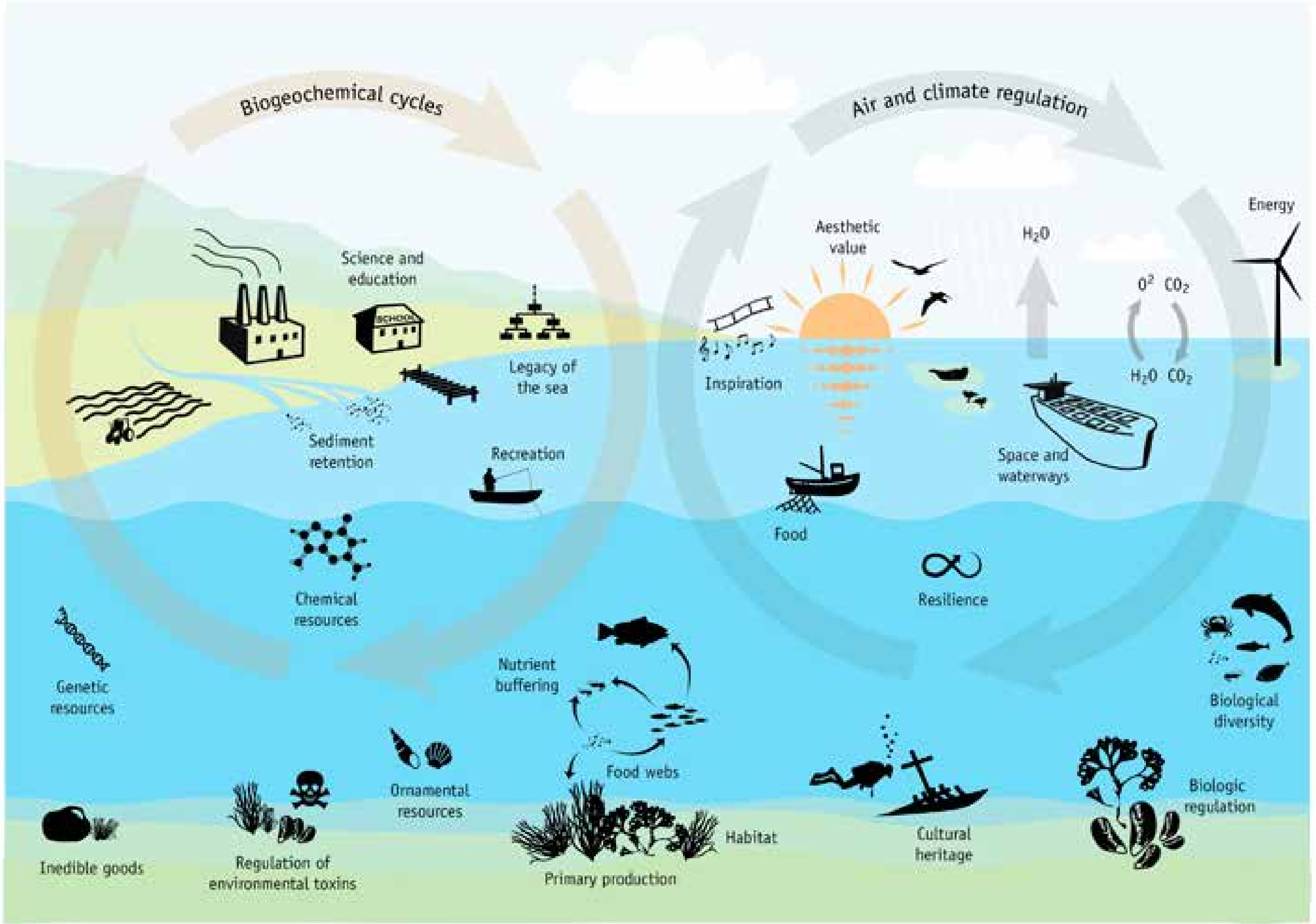


Figure 1.1. Ecosystem services provided by the Baltic Sea. (Illustration: J.Lokrantz/Azote)

Spatial area covered

The cost-benefit analyses on eutrophication covers the whole Baltic Sea and Kattegat and their respective drainage basins (except for the catchments of Belarus and Ukraine). In this report the term Baltic Sea will be used as including the Kattegat region.

In Figure 1.2 the map show the countries sorrounding the Baltic Sea and the drainage area covered.

Environmental problems covered

The main focus of BalticSTERN has been on eutrophication, which is regarded as one of the most severe environmental problems facing the Baltic Sea. It is also a problem that will be costly to solve and it is therefore important to find cost-effective solutions. In the Cost-Benefit Analyses (CBA) regarding eutrophication a Business-As-Usual (BAU) scenario is compared with a scenario where the nutrient reduction targets of Baltic Sea Action Plan are obtained. The benefits of the latter are compared with the costs for achieving these reductions.

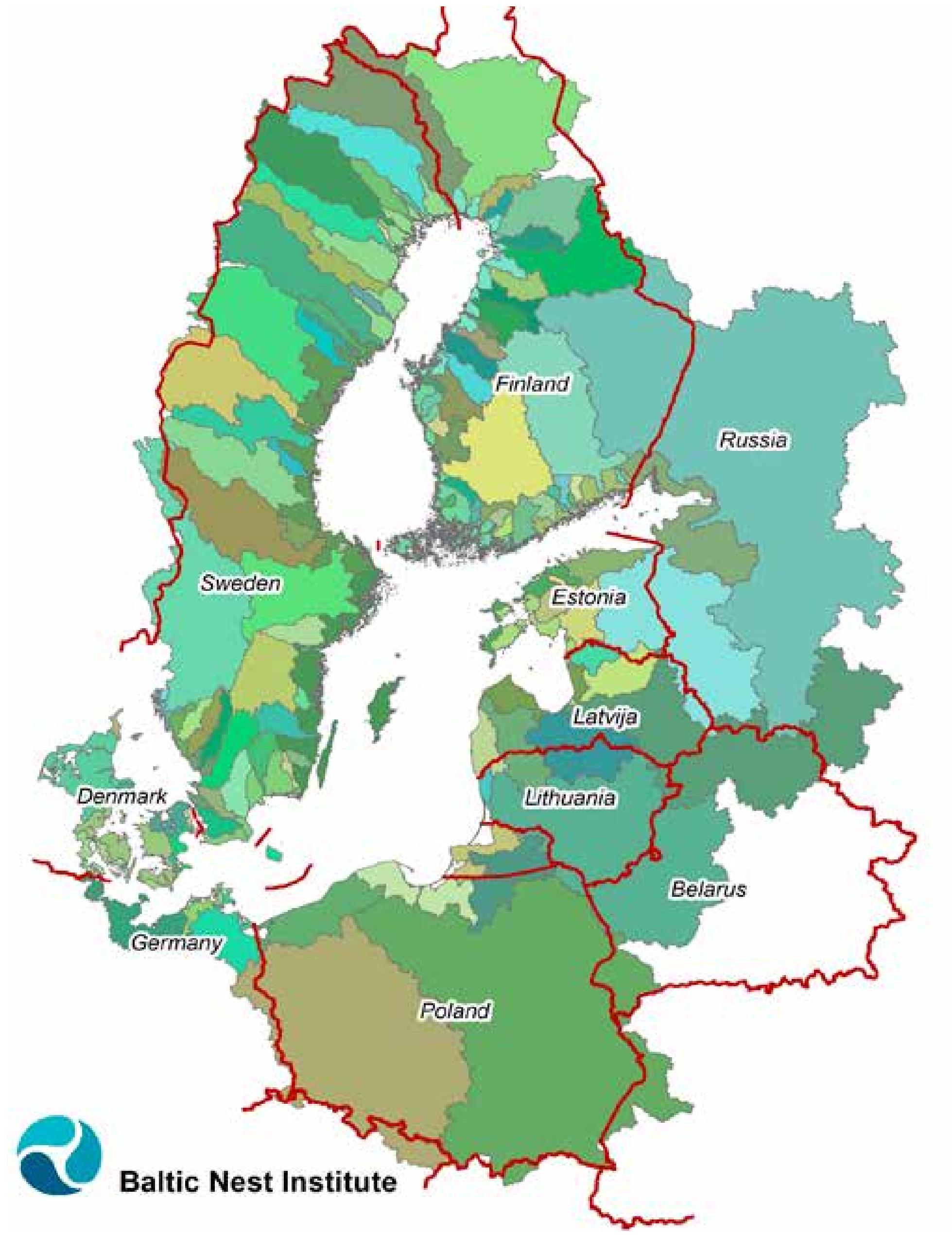


Figure 1.2. The Baltic Sea drainage area, colours showing different areas according to the EU Joint Research Centre. (Source: Baltic Nest Institute Sweden)

The development of drivers and pressures causing eutrophication is partly of a global character in the form of climate change and global demand on resources. The BAU- scenario used in the CBA is based on a relatively environmentally favourable development of drivers in economic sectors. Furthermore, this scenario does not take climate change into account as it was estimated not to have large effects until 2050, the time span of this modelling exercise.

However, new information and long-term scenarios show that climate change will pose challenges by changing temperature and salinity in the sensitive Baltic Sea and that the effects will be seen already before 2050. These new conditions in the Sea may interact with eutrophication and other environmental problems in ways not yet completely understood. There may also be feedback mechanisms that could push the ecosystem to surpass thresholds and trigger regime shifts. Climate change may also affect land-use, precipitation, surface water run-off, and other factors that might lead to changes of drivers and pressures (e.g. agricultural production and nutrient loads). Trends also suggest that many of the drivers and pressures causing eutrophication of the Baltic Sea will increase.

If one assumes a less favourable or worst case scenario, more actions will be required in order to reach the state of the Baltic Sea that BSAP aims for, and which could fulfil the Good Environmental Status of MSFD. The situation could be illustrated as in Table 1.1. Costs and benefits covered in the cost-benefit analyses undertaken are shadowed and the estimated values will be presented in the Chapters 2 and 3 of this report, and finally in an equivalent table in the last Chapter 11 together with a discussion regarding the scenarios not included in the cost-benefit analysis.

Table 1.1. Scope of the report regarding costs and benefits under different scenarios.

		Costs	Benefits
No further action	Assume positive BAU scenario		
	Assume worst-case BAU scenario		
Actions reaching BSAP targets for nutrient loads			
Action+	Assuming worst-case scenario – then BSAP measures are insufficient		

As already stated, there are also other environmental problems than eutrophication, which needs to be tackled. Some of these have been investigated within BalticSTERN through different case studies (see Section III). These case studies have focused on fisheries, oil spills and invasive species, which were estimated to be the most important problems that might jeopardize the benefits obtained by mitigation of eutrophication.

Figure 1.3 illustrates the main environmental problems affecting the Baltic Sea. Those studied by BalticSTERN are marked with yellow margins.

A case study on fish and fisheries was undertaken for the Baltic Proper with the purpose of estimating the effects of different management strategies. The effects of oil spills have been studied in the Gulf of Finland, and management strategies to avoid harm to the food web by invasive species were discussed based on the possible invasion of one species at a certain area by the Finnish coast.

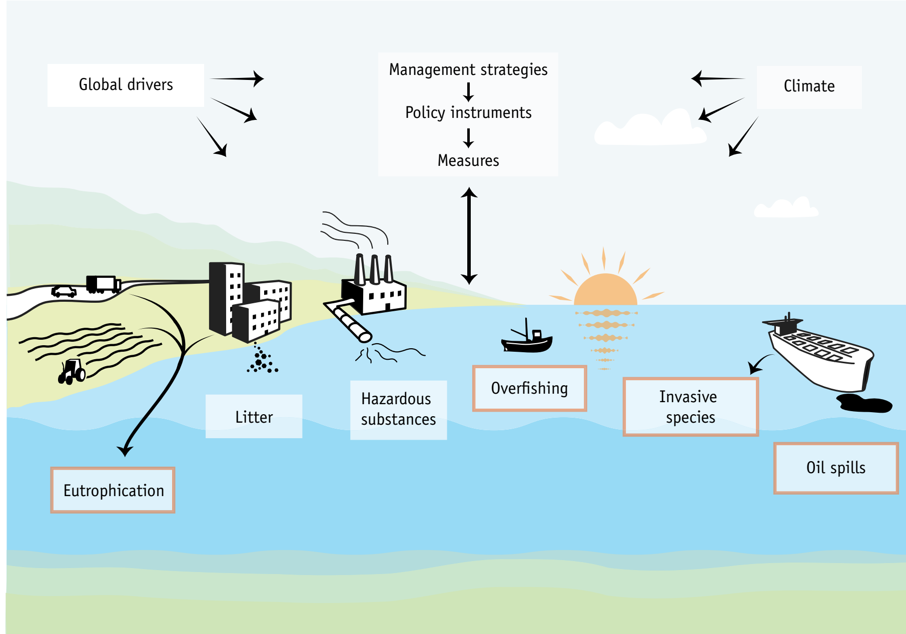


Figure 1.3. Environmental problems of the Baltic Sea and their drivers. Problems that are included in the BalticSTERN research are marked by orange margins. (Illustration: J. Lokrantz/Azote)

These studies are described in Section III of this report. There they are discussed in a wider perspective, also analyzing management options to cope with these environmental problems. Other problems such as hazardous substances and litter are also addressed to some extent in Sections IV and V of this report.

The need to address all problems in a holistic manner must once again be emphasized, as reducing one environmental effect may have both synergistic and contradictive effects on other problems. See also Chapters 9 and 11.

Drivers covered

To identify effective measures for mitigating the problems one needs to identify the drivers and pressures causing the effects. For this purpose the DPSIR-framework (Drivers-Pressures-State-Impact-Response) can be used, as illustrated in Figure 1.4.

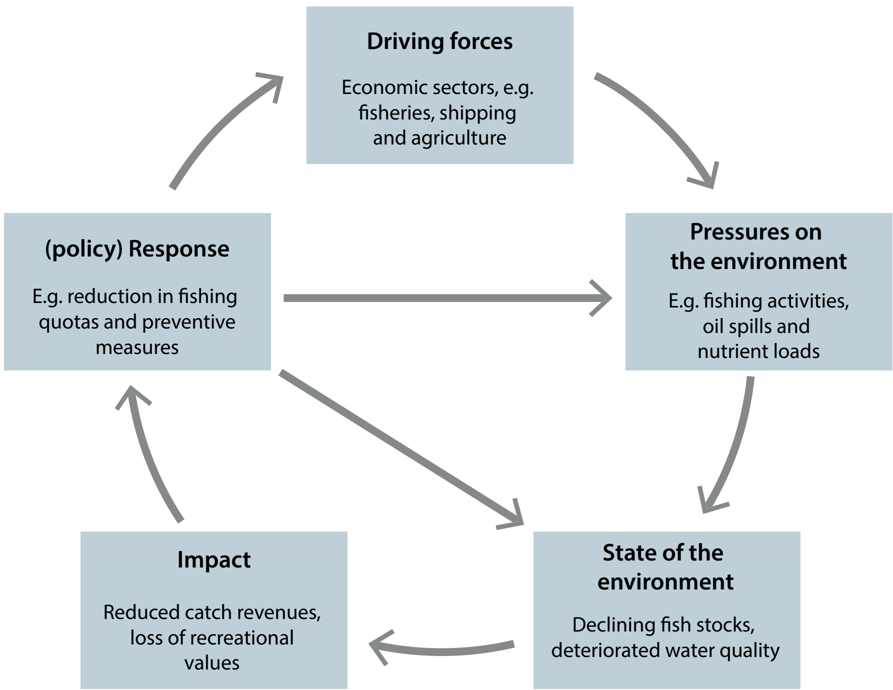


Figure 1.4. Illustration of the DPSIR framework.

Drivers could be actors in economic sectors, such as agriculture, fisheries and shipping. They cause Pressures in the form of nutrient loads, overfishing, NOx emissions and oil spills. These pressures affect the State of the Sea, which have Impacts on the welfare of human societies. To reduce these Impacts Governments and other actors may respond by for instance restrictions targeting Drivers (e.g certain types of agriculture in sensitive areas) or Pressures (e.g. restrictions on fishing). Response may also be directed towards State (e.g. protected habitats) or Impacts (e.g. compensation paid to those affected by an oil spill).

The measures discussed in this report would require actions by drivers in several economic sectors - mainly agriculture, fishery, wastewater treatment and shipping - as will be further discussed in the following chapters. Other economic sectors of importance are industry and forestry, as well as production and use of energy, including land transportation. Consumption patterns such as composition of diets can influence these sectors and consumption behaviour also affects the Sea through, for instance, waste and wastewater.

1.5 Partners and components

BalticSTERN include partners in all Baltic Sea countries. A list of all partners is available in Appendix A.

The main coordination regarding the studies on eutrophication was done by MTT Agrifood Research Finland, Enveco Ltd in Sweden and the Baltic Nest Institute (BNI)/ National Environmental Research Institute (NERI) at the University of Aarhus.

The study on *fish and fishery,* which covered the Baltic Proper, investigated the effects of different management strategies and was coordinated by the Baltic Nest Institute, Stockholm Resilience Centre in Sweden and the Johann Heinrich von Thünen Institut in Germany.

The case study on oil spills covering the Gulf of Finland was undertaken by MTT Agrifood Research Finland in collaboration with the Finnish Environment Institute (SYKE) and the Finnish Meteorological Institute. MTT and SYKE also undertook the case study on invasive species, which analyzed the effects regarding one specific species, Asian clam, in a thermal pollution area outside Kemi in the Northern Baltic Sea.

Table 1.2. Overview of aspects covered by BalticSTERN and coordinating partners.

Environmental issue	Coverage	Coordinators/Partners	Components
Eutrophication	Baltic Sea (including Kattegat)	- MTT Agrifood Research Finland - Finnish Environment Institute (SYKE) - BNI/NERI, Aarhus University - Enveco Ltd - University of Warsaw - Catchment data from Baltic Nest Institute - Partners in all Baltic Sea countries involved in the benefit studies (see Foreword and Appendix A)	1. Ecologic-economic modelling - Marine model, SYKE - Economic/combined model, MTT 2. Benefits - Baltic Survey, Enveco - WTP Study, MTT Enveco 3. Measures and costs - Dynamic model, MTT - Static model, BNI/NERI, University of Warsaw
Fish/fishery	Baltic Proper	- Baltic Nest Institute, Stockholm Resilience Centre - Johann Heinrich von Thünen Institut - Partners in all countries around the Baltic Proper	1. Combined ecological/ economic model 2. Food web model 3. Collection of economic data on fleets, fish landing and profits
Oil spills	Gulf of Finland	- MTT Agrifood Research Finland - Fisheries and Environmental Management - Group (FEM) at University of Helsinki	
Invasive species	Local area Finnish Coast	- MTT Agrifood Research Finland - Finnish Environment Institute (SYKE)	

1.6 Outline of the report

The report is divided into five sections.

Section I Introduction

In this *Chapter 1*, the only chapter under Section I, background, objectives, components and partners of BalticSTERN are briefly presented.

Section II Mitigation of eutrophication

Section II presents the results of the Cost-Benefit Analyses (CBA) regarding mitigation of eutrophication.

Chapter 2 Benefits covers results of the valuation studies undertaken and of a survey regarding use and attitudes, as well as a description of the connections between benefits and ecosystem services.

Chapter 3 Measures to avoid eutrophication and their costs describes measures covered by the analyses and the costs for those.

Chapter 4 Costs-Benefit Analyses compares costs and benefits.

Chapter 5 Policy instruments discusses possible efficient policy instruments to combat eutrophication.

Section III Other environmental problems

As mentioned earlier, there have also been some case studies undertaken regarding environmental problems besides eutrophication. These case studies are discussed in a wider context in the chapters in Section III.

Chapter 6 Fish and Fisheries presents results of the case study FishSTERN, which looked at different fishery management options and discusses future policy options given the present situation and scenarios for the future.

Chapter 7 Oil spills describes a case study on the implications that an oil spill could have on the benefits of eutrophication mitigation, and discusses the risk of oil spills and possible responses in a broader perspective.

Chapter 8 Invasive species presents the case study on invasive species and possible management strategies.

Section IV Long-term perspectives

Section IV looks at how the Baltic Sea has developed in the past and what can be expected in the future.

Chapter 9 Past and present state of the Baltic Sea outlines how the state of the Sea has changed up to present date.

Chapter 10 Scenarios for the Baltic Sea discusses how global and regional scenarios might affect the state of the Baltic Sea.

Section V Discussion and conclusions

Section V finally discusses what strategies and policy instruments could be used to reach politically decided targets for the future.

Chapter 11 Management strategies discusses possible managment strategies to cope with the environmental problems of the Baltic Sea.

II. Mitigation of eutrophication

The people living in the nine littoral Baltic Sea countries are willing to pay about 3 800 million Euros annually for a less eutrophied Baltic Sea, fulfilling the targets of the Baltic Sea Action Plan. This exceeds the costs for reaching the targets with 1 000 – 1 500 million Euros annually. The higher amount refers to a solution where the most cost-effective allocation of measures is chosen.

The Baltic Sea has, during the last century, undergone a regime shift changing the Sea from an oligotrophic (i.e. nutrient poor) to a eutrophic (i.e. nutrient rich) state. This has influenced the benefits that human societies receive and which are provided by the Baltic Sea through its ecosystem services.

Eutrophication is defined as an increased input of nutrients causing an accelerated growth of planktonic algae, (i.e. algae that float or drift in the water column) and higher plant forms. Thus eutrophication leads to increasing total primary production of organic matter, with negative effects on phyto- and zoobenthic communities (i.e. those communities of flora and fauna, respectively, living in or on the sea bed).

Eutrophication has had a negative impact on water clarity and has also increased summer algal blooms and caused oxygen depletion of sea bottoms. More information about the status of the Sea and how it has developed as a result of eutrophication can be found in Chapter 9 and BG Paper *State of the Baltic Sea.*

As stated in Chapter 1 eutrophication is regarded as one of the most severe environmental problems threatening the Baltic Sea. It is one of the main problems addressed in the HELCOM Baltic Sea Action Plan (BSAP), in which an agreement to reduce nutrient emissions was reached. As such reductions are costly, it is important to find cost-effective solutions and to estimate the benefits of reducing eutrophication. This section presents the results from such a Cost-Benefit Analysis (CBA) and also discusses options regarding policy instruments.

Figure II illustrates the different components in the Cost-Benefit Analysis (CBA). Benefits have been studied through surveys regarding the use of the Baltic Sea *(BalticSurvey)* and the willingness to pay for a less eutrophied Sea *(BalticSUN)*. Cost functions have been developed for measures to cope with eutrophication. Benefits and costs are based on scenarios regarding the development of drivers and state of the Sea until 2050. These results are input to the ecological-economic modeling giving the cost-benefit results.

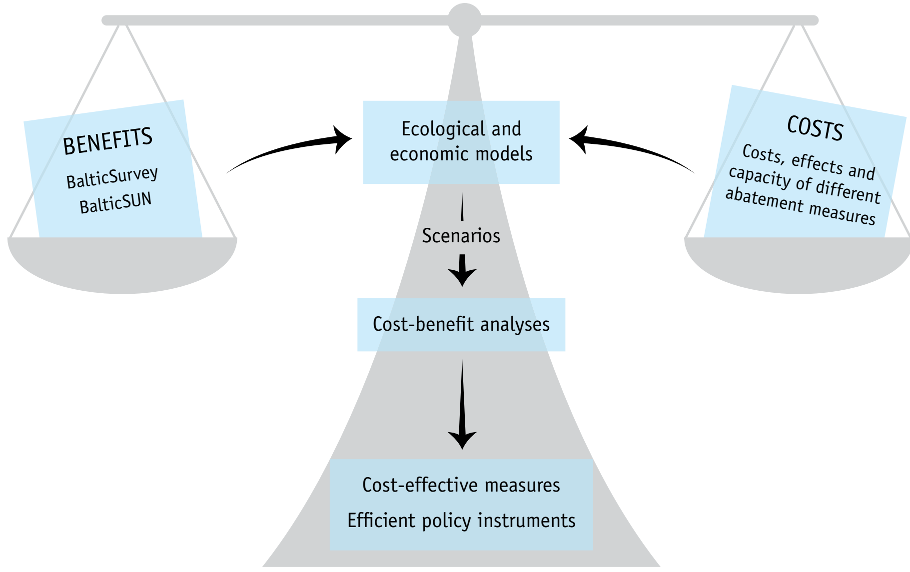


Figure II. Components in the Cost-Benefit Analysis regarding mitigation of eutrophication.

2. Benefits

People are willing to pay 3 800 million Euros annually for a better environment in the Baltic Sea with less eutrophication. Swedes are willing to pay the most, in average 110 Euros per person annually, followed by Finns and Danes who are willing to pay 55 and 52 Euros respectively. Least willing to pay are people in Latvia, Russia, Lithuania and Poland with less than 10 Euros on average per person and year.

Aggregating the Willingness-To-Pay (WTP) estimates to the national adult populations, Germans are willing to pay the most with approximately 1 870 million Euros annually, followed by Swedes who are willing to pay in total about 840 million Euros per year.

2.1 Benefits at risk

Benefits at risk and cost of degradation

The economic valuation survey *(BalticSUN)* was performed in 2011 and investigated the benefits of reducing eutrophication in the Baltic Sea (Ahtiainen et al., 2012). For the first time people in all nine countries around the Baltic Sea were simultaneously asked what they would be willing to pay for reduced eutrophication of the Sea. The results show that the majority is willing to pay for an improvement of the environmental state.

The study used the survey-based contingent valuation method, one of the few methods that can capture both use- and non-use related values. Non-use values refer to that also those who do not use the Sea may attach a value to having a healthy Sea to pass on to future generations, or may merely enjoy knowing that the Sea will recover from its environmental problems. Non-use values are thus important to take into account in an economic analysis. More about the contingent valuation method can be found in the BG Paper *Benefits of mitigating eutrophication*.

Connection to MSFD

The monetary benefits of reaching Good Environmental Status are of importance in several phases of implementation of the EU Marine Strategy Framework Directive; for example, in analyzing the costs of degradation of the marine environment and the CBA of new measures. The cost of degradation can be understood as the benefits forgone if the status of the Sea does not improve. There is therefore a need to estimate these benefits and one way of capturing them is to ask people what they would be willing to pay for a certain ecosystem improvement.

A Business-As-Usual (BAU) eutrophication scenario (non-action scenario) for the state of the Baltic Sea anno 2050 was developed, and people were asked to compare it to a scenario where the nutrient load targets specified in the Baltic Sea Action Plan (BSAP) were fulfilled. Maps were used to illustrate the predicted state of the open Baltic Sea under the two different scenarios (Figure 2.1). The levels of eutrophication were described using a five-step water quality scale, where blue colours represent the best situation and red the worst. The description was based on the expected levels of five characteristics in each quality class: level of water clarity, extent of blue-green algal blooms, the state of underwater meadows, fish species composition and oxygen conditions in deep-sea regions.

BAU Non-action scenario. **Baltic Sea Action Plan fulfilled.**

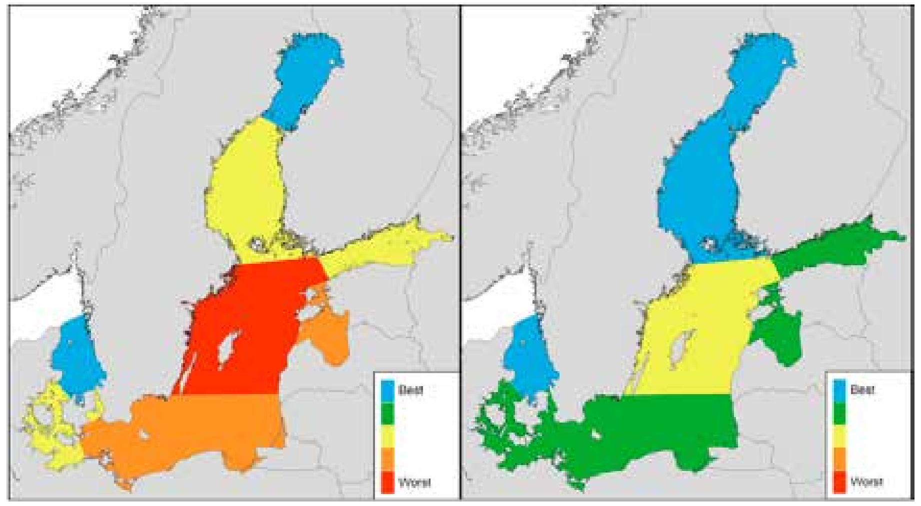


Figure 2.1. Maps showing the eutrophication scenarios of Business-As-Usual (left) and the Baltic Sea Action Plan fulfilment (right), respectively.

People in each of the nine littoral countries were asked how much they would be willing to pay each year[1] for obtaining a future in which the BSAP targets were achieved and eutrophication was reduced compared to the BAU future. Thus, a monetary estimate was obtained of the value individuals attach to reaching the BSAP targets on nutrient loads. In total, 10 564 interviews were conducted through face-to-face interviews or Internet panels. The samples were drawn from the total populations, thus covering the whole country areas.[2]

[1] The payment would be made as a special Baltic Sea tax, collected from each individual and company in all Baltic Sea countries, and earmarked for reducing eutrophication. This tax would be in addition to other existing taxes. No end-year was specified, implying payments for the rest of the respondents' lives.

[2] When aggregating WTP, we only included the European parts of Russia (the Central, Southern, North-western and Volga Federal Districts) to maintain a conservative estimate. Hence there is a slight difference between the results presented here and the results presented in Ahtiainen et al. (2012), which amounted to 4 000 million Euros annually.

Table 2.1. The five-step water quality scale used in the BalticSUN valuation survey.

	Description of the effects of eutrophication				
Water quality	**Water clarity**	**Blue-green algal blooms**	**Underwater meadows**	**Fish species**	**Deep sea bottoms**
Best possible water quality	Clear	Seldom	Excellent condition Good for fish spawning and feeding	Cod, herring and perch common	No oxygen deficiency Bottom animals common
	Mainly clear	Sometimes	Patchy vegetation Good for fish spawning and feeding	Cod, herring and perch common	Oxygen deficiency in large areas Bottom-living animals common
	Slightly turbid	In most summers	Cover a small area Less good for fish spawning	Fewer cod, but herring and perch common More roach, carp and bream	Oxygen shortages often in large areas Some bottom-living animals rare
	Turbid	Every summer	Cover a small area Bad for fish spawning	Fewer cod, herring and perch More roach, carp and bream	Oxygen shortages often in large areas Some bottom-living animal groups have disappeared
Worst possible water quality	Very turbid	On large areas every summer	Almost gone Not suitable for fish spawning	Almost no cod, fewer herring and perch Lots of roach, carp and bream	Oxygen shortages always in large areas No bottom-living animals in many areas

The results from the BalticSUN survey are illustrated in Table 2.2.

Table 2.2. Willingness-To-Pay for reducing eutrophication in the Baltic Sea by fulfilling the Baltic Sea Action Plan (BSAP).

Country	Adult population (in millions)	Annual mean WTP per person for BSAP (€)	National WTP per year for BSAP (M€)
Denmark	3.958	52	205
Estonia	0.989	18	17
Finland	3.617	56	201
Germany	68.321	27	1870
Latvia	1.690	4	7
Lithuania	2.516	6	16
Poland	24.624	9	211
Russia	81.476*	6	473
Sweden	7.564	110	838
Total	194.746		3838

* Includes the Central, Southern, Northwestern and Volga Federal Districts in Russia.

As expected, the average WTP varies significantly between countries. Swedes are willing to pay on average 110 Euros per person each year, while people in Latvia were only willing to pay 4 Euros (see Table 2.2 and Diagram 2.1). Income differences explain part of the results, but cultural and other factors might also have an effect. The percentage of people that would be willing to pay at least something for an improvement ranged from a little over 75 per cent for Sweden, to just over 30 per cent for Russia, with a total average of approximately 55 per cent.

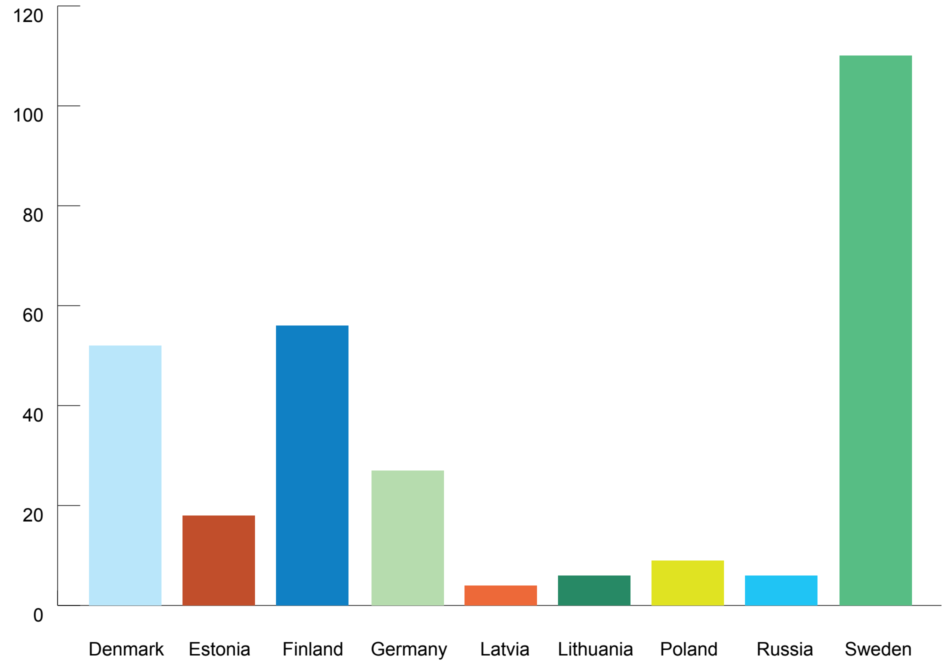


Diagram 2.1. Average Willingness-To-Pay per person in the different Baltic Sea countries expressed in Euros/year.

Aggregated to the national adult populations (see Table 2.2 and Diagram 2.2), people in Germany would be willing to pay the most, 1 870 million Euros annually, for a healthier marine ecosystem in the Baltic Sea, including improved water transparency, less algal blooms, healthier underwater meadows, less oxygen deficiency in deep-sea bottoms, as well as diverse and abundant fish populations. Sweden comes next with a willingness to pay of about 840 million Euros per year, while people in each of the countries Estonia, Lithuania and Latvia are willing to pay less than 20 million Euros annually. These figures are naturally affected by the population size, as the results were aggregated to the whole adult population in each country, as well as the proportion of people willing to pay in each country.

The total WTP is a relatively conservative estimate, as it is assumed that those who stated that they were not willing to pay anything do not attach a value to an improvement of the Baltic Sea environment. In reality, some of them may value the improvement, but still state that they are not willing to pay because they oppose some of the preconditions in the study. For example, they may think that someone else (e.g. polluters) should pay for reducing eutrophication, or oppose the suggested Baltic Sea tax.

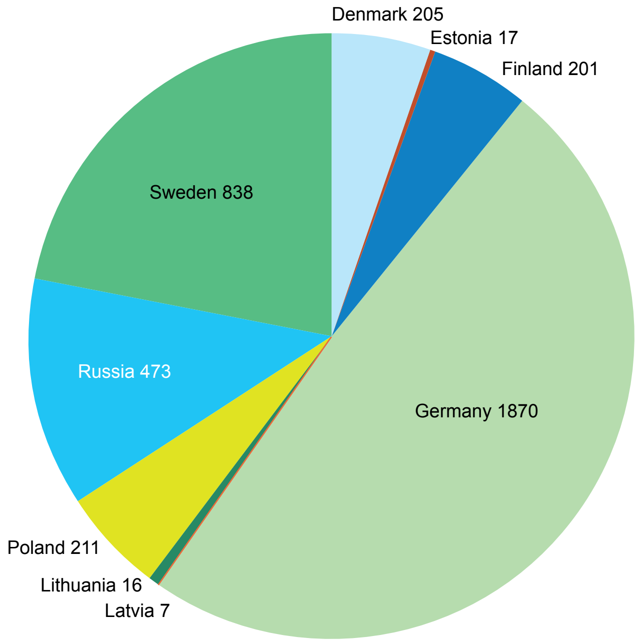


Diagram 2.2. Total Willingness-To-Pay (WTP) aggregated to the national adult population in the different Baltic Sea countries expressed in million Euros/year.

It is interesting that in all countries a majority of the respondents willing to pay place a value on having the entire Baltic Sea in a healthier state, and not only their own local areas. Furthermore, the distance to the Sea is not generally decisive for whether people are willing to pay, indicating that the Baltic Sea environment is important also to people not living close to the Sea, and that non-use values are substantial. More about the results can be found in the BG Paper *Benefits of mitigating eutrophication* and in Ahtiainen et al. (2012).

Compared to earlier attempts to estimate the value of the benefits of reduced eutrophication in the Baltic Sea, the valuation study BalticSUN is based on primary data from all nine littoral countries, with over 10 000 survey responses. This makes the study one of the most extensive international WTP studies to-date. In addition, the benefit estimates are directly linkable to the costs in the cost-benefit analysis. There are, as in all studies, uncertainties. Sampling and choice of models for estimating average WTP are two important sources of uncertainty. Compared to the average national population, the respondents were to a higher degree representing larger households, and with higher income and higher education levels. These overrepresentations were corrected by using population averages when computing national WTP. As with regard to choice of models, two different modelling methods were used to estimate average WTP. The two models were shown to give similar results, which contribute to reduce this source of uncertainty.

All in all, the study gives a comprehensive picture of the benefits of reducing eutrophication for decision makers to consider when they decide on the appropriate extent and focus of measures and policy instruments. There is reason to believe that the benefits are underestimated, as improvements that would be provided in inland waters and lakes if BSAP targets are reached, are not accounted for. (Also there may be additional shared values as discussed in 2.3. See also BG Paper *Shared Values*.)

2.2 Use of the Baltic Sea

Some 80 per cent of the people living in the Baltic Sea region have spent leisure time at the Baltic Sea. Common activities are walking at the beach, swimming and fishing. Many people around the Baltic Sea are worried about the marine environment and see it as necessary that polluters take actions to improve the Baltic Sea environment.

It is not surprising that people are willing to pay for an improvement of the environmental situation of the Baltic Sea as a majority has visited the Sea for recreation, and many are worried about the environmental degradation.

The importance of the Baltic Sea for the citizens of the surrounding countries was shown in the BalticSTERN study BalticSurvey (Swedish EPA, 2010a, b, see also Ahtiainen et al., 2013), which investigated public attitudes and use of the Sea. More than 80 per cent of the respondents in the survey had visited the Sea at least once to spend leisure time. The highest percentage, 98 per cent, was found in Sweden. The time people spent at the Sea was on average 9-35 days during the summer months April to September 2009 (e.g. in Lithuania 9 days, Coastal Russia 16 days and Sweden 35 days). The most common activities people enjoyed were being at the beach or seashore for walking, sunbathing or similar. Swimming, going on cruises or boat excursions and recreational fishing were also frequent activities.

The survey further showed that many people in the region are worried about the environmental problems affecting the Baltic Sea (see Diagram 2.3). There was also a tendency in most countries to agree on there being deterioration rather than an improvement of the Baltic Sea environment. People in Finland (FI) were the most worried (77%). Many were worried also in coastal Russia (RU-c, 71%), Estonia (EE, 69%) and Sweden (SE, 63%). People in Poland (PL) and Germany (DE) were the least worried, but still more than one third of the population in these countries were worried (37 and 39% respectively).

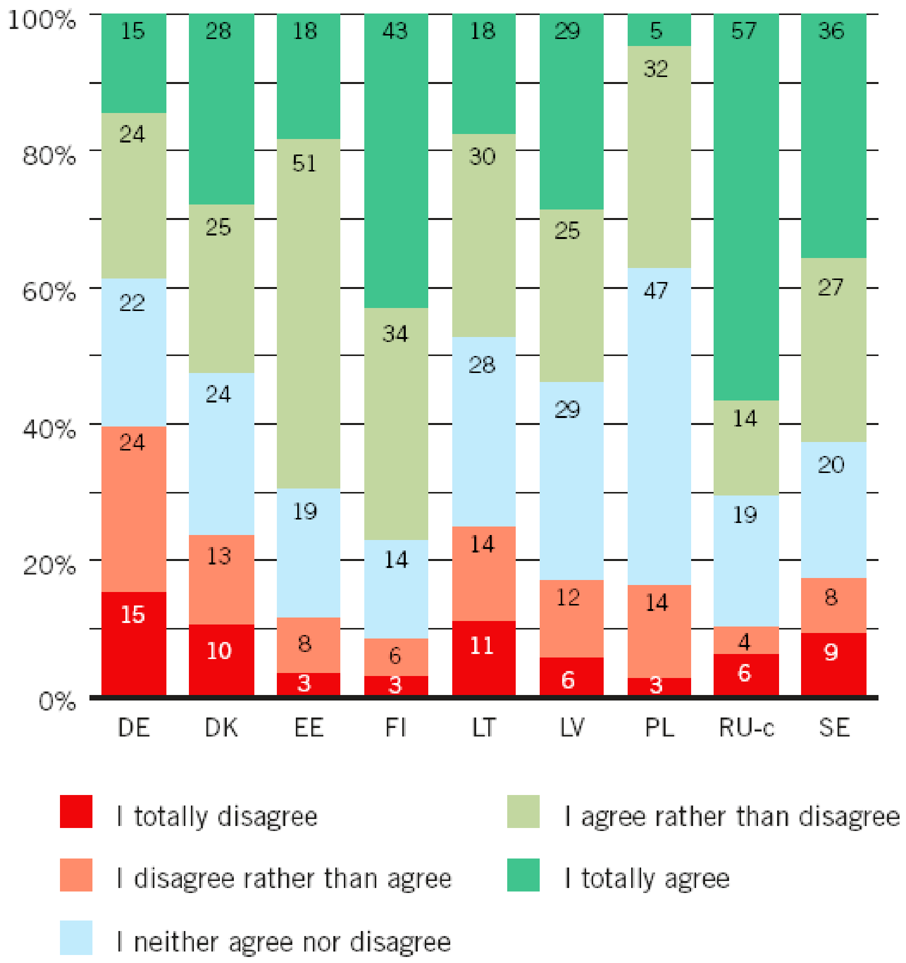


Diagram 2.3. Percentage of the population that agree or disagree to the statement "I am worried about the Baltic Sea environment". (Source: Swedish EPA, 2010a)

The survey is the first coordinated survey of comparable information in all Baltic Sea countries regarding public use of the Baltic Sea and people's attitudes towards the marine environment and towards responsibilities for improving the environment.

It was carried out between April and June 2010 in all nine Baltic Sea countries and included over 9000 interviews. (Swedish EPA, 2010a) Marine litter is an issue that was regarded as a big problem by a majority of the respondents in all countries. The same was true in at least seven countries for "damage to flora and fauna in the Sea", "heavy metals and other hazardous substances", "small everyday oil leakages", "possibility of major oil spill" and "algal blooms".

The results from BalticSurvey were confirmed in the study BalticSUN where people were also asked about their use of the Sea and their attitudes toward the environmental situation. More than 80 per cent of the respondents had visited the Sea to spend leisure time. The most common activity was being at the beach. Many were worried about the environmental situation (the overall figure was 3.89 on a five-point scale; most worried were people in Sweden (SE) 4.41, Lithuania (LT) 4.35, Estonia (EE) 4.29 and Finland (FI) 4.14 respectively).

BalticSUN also showed that many have experienced the consequences of eutrophication, and that many also have good knowledge of what kind of consequences eutrophication causes. In general, every second person in the Baltic Sea region has personally experienced the consequences, mostly in terms of decreased water transparency and algal blooms.

A majority of the respondents in BalticSurvey see it as necessary that their own country's waste water treatment plants, industries, maritime transports, ports, farmers and professional fishermen take actions to improve the Baltic Sea environment. A majority in all countries also considers increased charges on pollution emissions to be an acceptable way of funding actions to improve the environment. There is thus widespread support in the region that the polluters should bear the costs for their pollution. Increases in taxes or water bills are not popular, although people are in general less negative towards making payments that are paid by everyone and are earmarked for funding actions.

There are also economic sectors, such as fishing, tourism, shipping and energy producers, which use the Baltic Sea. For some of those sectors, e.g. tourism and fishery, eutrophication may lead to profit reductions. As the respondents of the valuation survey BalticSUN can be expected to have included tourism and recreational fishery in their WTP to some degree, those benefits of reduced eutrophication may to some extent have been accounted for. However, there may be benefits of reduced eutrophication that have not been accounted for by the BalticSUN study.

2.3 Shared Values

An indication was found of potential existence of shared values regarding the Baltic Sea resources and the services it provides, which is distinct from and supplementing the conventional individual values typically captured in a WTP study.

A pilot study was conducted to test for the possible existence of "shared values." See BG Paper *Shared values*. Shared values are those that extend beyond conventional economic values based on individual consumer motivations. For example, Fish et al. (2011) suggest that:

> *Shared values concern the values people hold for ecosystem services as 'citizens'; that is as 'social beings' capable of expressing preferences for ecosystem services not simply in terms of individual costs and benefits, but in terms of social rights and wrongs. (p. 1184)*

Considering such preferences, and the values they imply, through experiments such as this one, is consistent with the recent recommendations for improved benefits assessment in both the US and the UK. For example, the US EPA's "integrated and expanded approach to valuation" suggests that:

Non-economic methods could be used to provide supplemental information outside the strict benefit-cost analysis about sources of value that might not be fully captured in benefit measures that come from economic valuation, such as moral or spiritual values. [...] Even if not part of a formal benefit-cost analysis, information about non-economic values may be useful to both EPA and the public. (US EPA 2009, p. 23)

The study followed a Deliberative Valuation Method (DVM), (see BG Paper *Shared values*), in which the objective was to identify the types of values at stake in protecting the Baltic Sea, and to explore their underlying motivations. The experiment relies on two focus group discussions in June 2012 around the theme of environmental values.

The discussions focused on five research questions:

Values - What types of values are at stake?
Motivations - What are the key motivations for different value types?
Prioritizing values - Are some values more important than others?
Intensity of values - How much of society's resources should be spent?
Distribution - Who should pay?

This study found an indication of existence of shared values regarding the Baltic Sea and the services it provides, which is distinct from and supplementing the conventional individual values typically captured in a contingent valuation study. This evidence is based on an interpretation of the group discussions; including individuals' word choice and their general beliefs, opinions, and expectations. Several discussion points can be linked to citizen-like attitudes:

- A sense of moral responsibility to act, or a collective guilt from failing to act.
- The uniqueness (un-substitutability) of the Baltic Sea as an important reason for protection.
- An emphasis of the Sea as a common resource that is shared by all. Respondents expressed this sentiment repeatedly. They also often used the collective voice (e.g., *"We have a common resource in our land. We Swedes are proud of this."*)
- Recognition of citizen empowerment and improved mental health that can come from protecting the Baltic Sea.
- A belief in the Baltic as a symbol and forum for promoting peace and co-operation with neighbouring countries, that provides true social benefits.

This analysis suggests that contingent valuation approach to valuation, in conjunction with a Cost-Benefit Analysis (CBA), may fail to capture some values associated with the Baltic Sea resources. If the benefits of undertaking certain measures are higher than the BalticSUN survey suggests, then a CBA may incorrectly suggest that further water quality improvement measures are not socially profitable. This could mistakenly prevent a social welfare-enhancing project. This may be the case if the monetized values captured by the BalticSUN survey represent only a portion of the total value society holds for affected resources.

2.4 Ecosystem services and benefits

The quality of benefits, such as recreational activities, is highly dependent on the ecosystem services the Baltic Sea generates, which in turn are interlinked.

The benefits people and human societies receive from the Sea are, directly and indirectly, dependent on the wide array of ecosystem services that the Baltic Sea provides, and thereby also on how well the marine ecosystem functions. People benefit from these ecosystem services in many different ways. For example, the Baltic Sea provides food (e.g. fish), waterways for shipping, raw material for energy, as well as recreational opportunities.

In the project *Economic Marine Information*, 24 marine ecosystem services were identified in the Baltic Sea (Swedish EPA, 2008a). These include services such as primary production, biogeochemical cycling, food production, and waterways for transport and shipping, as well as maintenance of biodiversity and resilience (Figure 2.2). According to the project only 10 of the 24 identified services are functioning properly, and 7 are severely threatened. The threatened ones are: food web dynamics, biodiversity, habitats, food, genetic resources, aesthetic benefits and resilience (Swedish EPA, 2008a). The ecosystem services in the Baltic Sea are related to each other in various ways, and can therefore not be viewed separately. A negative impact on one service will most likely also affect other services. It is therefore of relevance to understand how these services are interlinked. Figure 2.2 illustrates the identified ecosystem services in the Baltic Sea.

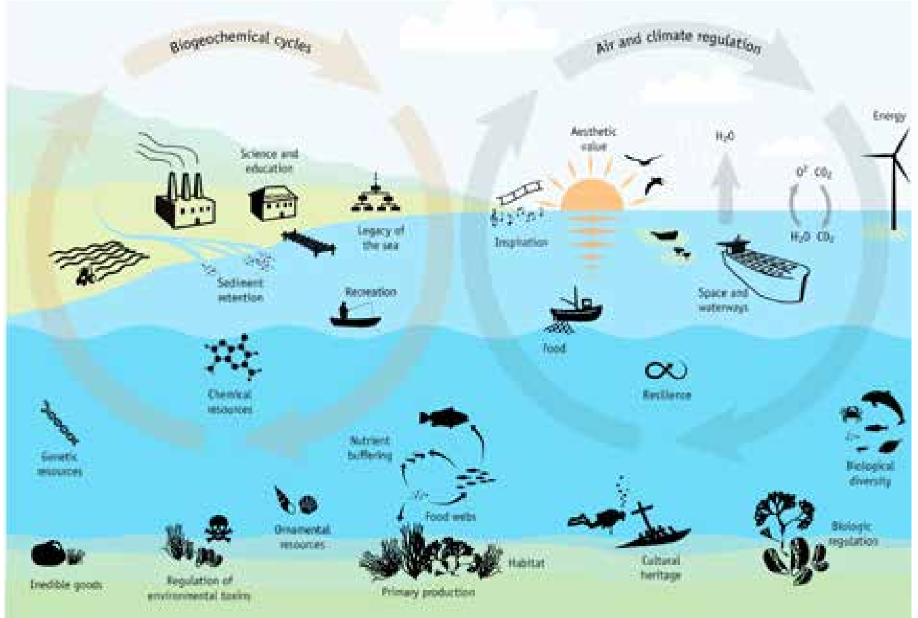


Figure 2.2. Ecosystem goods and services provided by the Baltic Sea ecosystem. (Illustration: J. Lokrantz/Azote)

Ecosystem services and benefits

For socioeconomic assessments there is a need to distinguish between ecosystem services and benefits. Ecosystem services can be seen as the link between ecosystems and things that humans benefit from. Ecosystem services are thereby not the benefits themselves. Ecosystem processes and functions only become services if there are humans that (directly or indirectly) benefit from them.

Fisher et al. (2009) clarifies this distinction stating that *"ecosystem services are the ecological phenomena, and the benefit is the realization of the direct impact on human welfare, as ecosystem services are the aspects of ecosystem utilized (actively or passively) to produce human wellbeing."*

In economic analysis of ecosystem services, the services are often divided into intermediate and final services. Final services are those that directly generate a benefit to humans, such as fish stocks for fishing, water quality for bathing or fish-stocks for fishing and raw materials for energy (see BG Paper *Benefits of mitigating eutrophication*). Intermediate services, such as well functioning habitats and the Sea's capacity to mitigate eutrophication, enable final services in a supporting or regulating way, and thereby influence human wellbeing indirectly. An intermediate service for one specific benefit can be a final service for another benefit. For example, water quality is an intermediate service for fish stocks, but a final service for bathing. (Fisher et al., 2008; Turner et al., 2010)

Table 2.3 illustrates an example of the connection between the benefit of enjoying the recreational activity swimming, and the final and intermediate services swimming might depend on. The beneficiaries could be the tourism sector and the general public.

Table 2.3. Examples of intermediate and final services linked to recreational swimming. (Source: Adapted from Fisher et al., 2008)

Intermediate Services	Final Services	Benefits
Nutrient cycling	Water quality	Recreational swimming
Retention storage of sediments, nutrients and contaminants		
Regulation of water flow		
Regulation of hazardous substances		

The main final service that can be linked to the benefit people obtain from performing the recreational activities identified in BalticSurvey is water quality. In a Baltic Sea context, the provisioning of water quality might be viewed as being primarily dependent on the capacity of the marine ecosystem to buffering nutrients and to regulate environmental toxins (Enveco et al., 2012). These ecosystem services are in turn dependent on some of the threatened services, such as biological diversity and resilience. See BG Paper *Benefits of mitigating eutrophication.*

3. Measures to avoid degradation and their cost

The cost of reaching the BSAP targets is estimated to 2 300 million Euros annually in a cost-effective allocation of measures. Applying allocations between countries according to the BSAP country quotas would increase the costs by about 500 million Euros, leading to total annual costs of 2 800 million Euros. Some of the most cost-effective measures are reduction by wastewater treatment plants, wetlands, ban of phosphorus in detergents, and reduced application of fertilizers.

3.1 BSAP nutrient reduction targets

Recent estimates of the nutrient loads to the Baltic Sea indicate that the total load of both nitrogen and phosphorus has decreased. However, cost estimates for reaching the targets in the year 2050 need to take into account possible future changes of these loads by developing a base line scenario. Such a scenario might indicate that countries have to abate more or less than what the present gap between current loads and the targeted loads imply, due to predicted future increases in nutrient loads.

The benefits described in Chapter 2.1 are based on fulfilling the eutrophication objective of the Baltic Sea Action Plan (BSAP) agreement (HELCOM, 2007a). The BSAP sets a reduction target for nitrogen and phosphorus to each basin of the Baltic Sea (see Figure 3.1 and Table 3.1). The maximum allowable nutrient input to the Baltic Sea is based on calculations in the Baltic Nest model (developed by the Baltic Nest Institute) regarding what is needed in order to achieve good environmental status.

The column named "1997-2003" in the table 3.1 gives the load to the basins under this time period, on which the BSAP country reduction quotas were based. The column "2004-2008" is based on the most recently monitored loads of the period 2004-2008 (HELCOM, 2011), while the column "Target" represents the targeted load of the BSAP. The table shows that the total load of nitrogen as well as phosphorus has been reduced, which might be explained by differences in surface water run-off between the two periods and/or by the effect of recently implemented abatement measures. The difference between the number of "2004-2008" and "Target" indicates the present reduction required to each sea basin. If the "2004-2008" load is less than the target, as it for example is for phosphorus to the Bothnian Bay, no reduction is required.

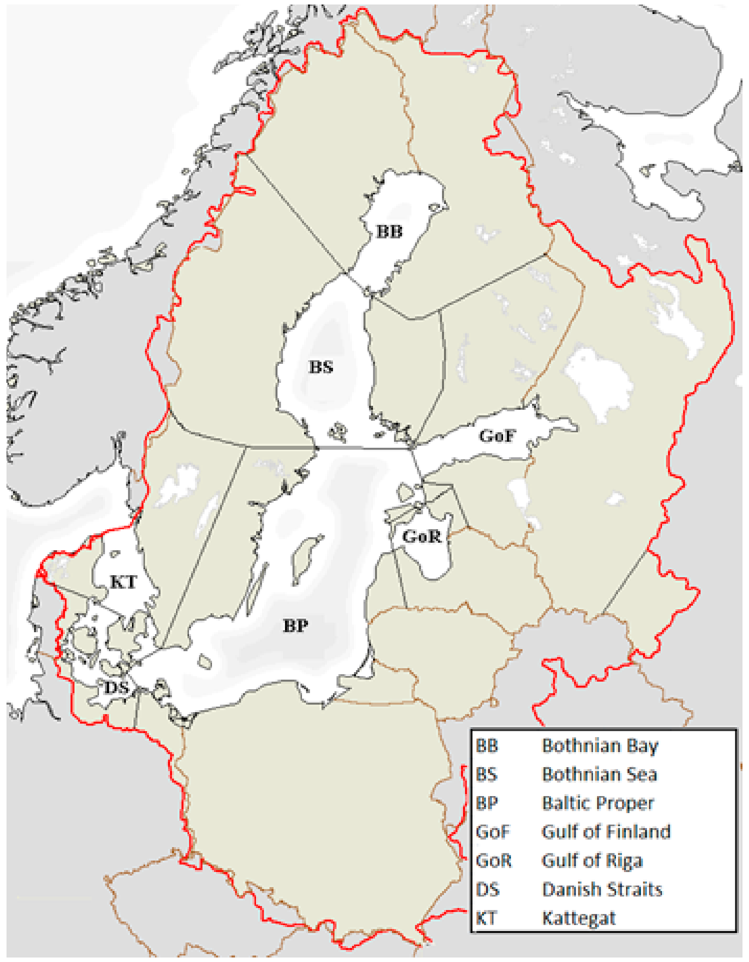


Figure 3.1. Baltic Sea sea basins and catchments.

Table 3.1. Nutrient loads (1997-2003 and 2004-2008) and targeted loads for the different sea basins of the Baltic Sea in tons per year.

Sea basin	Nitrogen			Phosphorus		
	1997-2003	2004-2008	Target	1997-2003	2004-2008	Target
Bothnian Bay	51 440	53 844	51 440	2 580	2 335	2 580
Bothnian Sea	56 790	55 396	56 790	2 460	2 186	2 460
Baltic Proper	327 260	294 893	237 013	19 250	15 999	7 956
Gulf of Finland	112 680	116 872	106 680	6 860	6 267	4 860
Gulf of Riga	78 400	86 141	78 400	2 189	2 985	1 880
Danish Straits	45 890	42 307	30 890	1 410	1 385	1 410
Kattegat	64 260	57 252	44 260	1 570	1 563	1 570
Total	736 720	706 705	605 473	36 319	32 719	22 716

In order to reach the sea basin targets, the total nitrogen load has to be reduced by 102 625 tons/year and the total phosphorus load by 10 555 tons/year (i.e. the sum of the reductions required to meet the sea basin targets). Furthermore, BSAP divided these basin load targets between the countries so that each country has a load reduction quota it must meet. Taking into account the latest nutrient load data (HELCOM, 2011), Ahlvik et al. (2012) updated the country quotas of the agreement. The obtained load reductions quotas for each country are shown in Table 3.2. Since loads have changed from the 1997-2003 level, on which the BSAP targets are based, the required nutrient load to different sea-basins from different countries have also changed. Because of changes in agricultural sectors, population, and the recent nutrient abatement activities, the gap between the most recent loads (2004-2008) and the targeted loads is different compared to the earlier period (1997-2003). To meet the required BSAP load targets for the different sea-basins some countries might therefore have to do less and some countries more, in comparison to the original quotas, with regard to nitrogen and phosphorus abatement.

Any measures implemented after 2008 (i.e. the end year of the period 2004-2008) could not be considered in the cost estimates below, implying that the load reduction of such measures should be subtracted from the load reductions, required according to Table 3.4, in order to determine how much needs to be done at present date.

Table 3.2. BSAP national nutrient reduction quotas in tons per year.

	BSAP	
Country	**Nitrogen**	**Phosphorus**
Denmark	8 607	0
Estonia	1 490	201
Finland	1 768	224
Germany	4 856	0
Latvia	1 782	1 618
Lithuania	13 263	1 656
Poland	40 638	6 828
Russia	5 326	1 354
Sweden	16 656	180

Poland is the country that will stand for the largest reduction of both nutrients, which could be explained by its large proportion of the drainage area to the Baltic Sea and its relatively large population.

In order to identify possible measures to reach the targets, the sources behind these loads need to be identified. Nutrients originate from various human activities, for example, atmospheric emissions, discharges from point sources along the coast (e.g. industry and water treatment plants) and from diffuse discharges (e.g. agriculture or scattered settlements).

The major source for nitrogen to the Baltic Sea originates from diffuse sources (71% of the total load) with agriculture alone contributing with 80 per cent to these loads. The largest phosphorus loads originate from point sources (56%), with municipalities as the main source (90% of the total point source discharges) followed by diffuse sources (mainly agriculture). About 75 per cent of the nitrogen and at least 95 per cent of the phosphorous arrives via rivers or as direct discharges to the Baltic Sea. (HELCOM, 2009a)

Any possible future increase (or decrease) of nutrient loads from different sources will imply a need to reduce more (or less) then indicated in the tables

above in order to meet the targeted load to the different sea basins. Therefore, a Business-As-Usual (BAU) scenario was developed for illustrating future changes of nutrient loads if no further abatement measures towards the BSAP targets are implemented. This scenario incorporated the estimated development of population and agricultural sectors of all countries, which will have an effect on the nutrient load to the Baltic Sea. The scenario generated future predictions for nutrient loads to the different sea basins of the Baltic Sea, thereby indicating the amount of measures that would be needed in order to meet the BSAP targets in the year 2050.

3.2 Measures

Nine measures have been included in this study in order to estimate the costs of meeting the BSAP reduction targets for nutrients. Seven measures target the load from agriculture, while two measures target the load from wastewater treatment plants.

The BSAP nutrient reduction targets require the implementation of several measures. A measure is defined as a physical or behavioural change that generates a reduction of the nitrogen and phosphorus load to the Baltic Sea. For example, installing better treatment equipment in a sewage treatment or reducing the amount of fertilizers applied on farmed land.

A majority of the measures used in this study target the nutrient discharges of the agricultural sector, since this sector stands for a large proportion of the nutrient load to the Baltic Sea (HELCOM, 2004). These measures could either target the application of fertilizers on agricultural land or the leakage caused by this application. Measures could also aim at improving the buffer capacity of nutrients between the source and the Baltic Sea. Measures to reduce the load from agricultural sources included in the cost-benefit analysis are reduced application of inorganic fertilizers, catch crops, wetlands, sedimentation ponds and reduced livestock holding (cattle, pigs and poultry) leading to reduced application of organic fertilizer (i.e. manure).

Wastewater discharges is another major source of the nutrient load, and is addressed by the measures: connecting unconnected households to waste-water treatment, improving the effectiveness of existing plants, as well as banning the use of phosphorus in detergents. In 2013 the EU will ban the use of phosphorus in laundry detergents followed by a ban of phosphorus in dish detergents in 2017 (Regulation (EC) 648/2004). However, Sweden, Germany and Finland already have a ban on phosphorus in laundry detergents and this measure will therefore not have an effect in these countries in this study.

While some measures against eutrophication reduce the inputs of nutrients to the system (e.g. reduced fertilization, ban on phosphorus in detergents), other measures recycle the nutrients within the system (e.g. catch crops, phosphorus ponds). Finally, passive measures, in one way or another just parks the nutrients in the system over a shorter or longer period of time (e.g. wetlands).

Due to the heterogeneity of the industrial point sources, making it hard to establish a general cost function for their abatement of nutrients, measures towards this sector were not included in this study. Furthermore, since the loads the current BSAP targets are based on do not include atmospheric deposition, measures towards sources behind these emissions (e.g. shipping, traffic, combustion power plants) were also not included in this study.

3.3 The cost of reaching the targets

The total cost of reaching the BSAP nutrient targets was estimated for the country quotas as well as for a cost-effective allocation of measures in reaching the sea basin targets. The cost of the latter amounted to about 2 300 million Euros a year, while the cost of the former amounted to about 2 800 million Euros a year. For all countries except Denmark and Estonia a cost-effective allocation would lead to less costs compared to the country quotas.

Measures rarely come without a cost, and it is the total cost of all the measures needed that are to be compared with the estimated value of the benefits. In this report, the total cost of reaching the basin targets was estimated under two objectives:

1. Fulfil the country quota allocation given by the BSAP (Table 3.2) and the sea area-specific targets (Table 3.1),
2. Reach the required sea basins targets (Table 3.1) in a cost-effective way, without the obligation to meet the country quotas.

The cost-effective allocation generates the lowest possible cost of reaching the basin nutrient reduction targets of BSAP, and will, therefore, be lower than the costs of the country quotas if they are not cost-effective.

Table 3.3 illustrates the allocation of costs and nutrient loads for the two objectives. The annual cost of reaching the country quotas by measures included in the study amounts to about 2 800 million Euros. However, the results indicate that for Latvia and Lithuania the required BSAP country reduction quotas (Table 3.2) cannot be met (only about half the quota can be reached) with the measures included in this study.

When aiming at the country quotas for all countries except Poland the reduction of one or both nutrients exceeds the targeted country quota (i.e. difference between columns 2004-2008 and country quotas in Table 3.2). One explanation behind this is the fact that certain measures that are implemented to reach the target load for one nutrient also generate reduction of the other. For example, the nitrogen reduction of Estonia exceeds its quota due to the fact that measures required for reaching the phosphorus quota also reduces nitrogen. Another explanation is that the aim is to reach a certain load level in the future. Countries can carry out active policies to reach present reduction targets, but there is also a development of nutrient loads that is independent on whether the BSAP is carried out or not. This development was taken account of by developing the Business-As-Usual scenario for 2050, and thus included in the cost estimates.

Under the cost-effective allocation for reaching the BSAP basin targets, ignoring the countries assigned quotas, the targeted maximum load to the Baltic Sea can be reached at an annual cost of about 2 300 million Euros. To put the total cost estimates in perspective it might be worth knowing that in 2008 the Baltic Sea EU Member States obtained 12 600 million Euros in farm subsidies from EU.[3]

It can be seen from Table 3.3 that compared to an allocation according to the country quotas the total cost is reduced by almost 500 million Euros annually under the cost-effective solution. However, the cost for two of the countries (Denmark and Estonia) will increase in comparison to their cost of meeting the country quotas, while it will decrease for all other countries (Finland, Germany, Latvia, Lithuania, Poland, Russian and Sweden).

Table 3.3. Allocation of costs (million €/year) and nutrient load (ton/year) between Baltic Sea countries.

	Cost (Million €/year)		Nitrogen load (Ton/year)			Phosphorus load (Ton/year)		
	Country quotas	Cost-effective	2004-2008	Country quotas	Cost-effective	2004-2008	Country quotas	Cost-effective
Denmark	620	630	48900	38640	38540	1719	1368	1353
Estonia	36	78	33650	28420	24950	1240	1039	891
Finland	49	23	78110	73860	75270	3358	3057	3120
Germany	651	480	20080	15230	18220	478	164	224
Latvia	123[1]	85	81810	69890	70710	2994	2120	2143
Lithuania	134[1]	101	46630	31170	26260	2111	1135	1194
Poland	753	544	193590	152960	159210	11790	4962	5733
Russia	113	105	87750	82050	83090	5537	3980	3830
Sweden	326	290	116190	98960	101610	3492	3076	2822
Total	2805	2336	706710	591180	597860	32719	20901	21310

1 Target could not be reached; constraint was relaxed by 48%
2 Target could not be reached; the constraint is relaxed by 49%

Total costs were also estimated using the Baltcost model (Hasler et al., 2012), described in BG Paper *Costs of mitigating eutrophication*. The estimated annual cost of reaching the BSAP target using this model amounted to 1 400 million Euros for a cost-effective allocation of measures. The difference in costs between the two models is to a large extent explained by differences in assumptions regarding some of the abatement measures, for example, capacity and effect of wetlands, and that the model by Ahlviks et al. (20102) is dynamic and considers the interdependency between some of the measures.

The cost estimates for a cost-effective nutrient reduction to the Baltic Sea obtained in this study is within the range of cost estimates obtained in

[3] http://farmsubsidy.org

previous studies (Gren et al., 1997; Elofsson, 1999; Ollikainen & Honkatukia, 2001; Schou et al., 2006; COWI, 2007; Gren, 2008).

The different measures implemented in order to reach the cost-effective allocation of nutrient reduction in each country are illustrated in Table 3.4 (see BG Paper *Costs of mitigating eutrophication* for a more detailed description of these measures). In order to reach the BSAP reduction targets it is necessary to implement all of the nine measures to various degrees.

The most cost-effective measures to reduce the nitrogen load are wetlands, catch crops and wastewater treatment plants, as well as certain reduction of the fertilization. Reduction of livestock (e.g. cattle, pigs and poultry) and large reduction of fertilization proves to be the most expensive measures.

The most cost-effective measures to reduce the phosphorus load are phosphorus ponds (P-ponds), ban of phosphorus in detergents, wastewater treatment plants and relatively small reductions of application of fertilization. As with nitrogen, livestock reduction is deemed to be the least cost-effective measure to reduce phosphorus. As opposed to in the case of nitrogen abatement, wetlands and catch crops turn out to be very costly for reducing phosphorus.

The cost of reducing the application of fertilization is very low for any initial reduction, while it increases with high levels of reduction. This is explained by the fact that the losses in yields, and thereby profits, due to this reduction is exponentially increasing with the degree of reduced application. Looking at each measure's contribution to the load reduction is not as straightforward with regard to fertilizer reduction, since such reduction can be obtained by either livestock (cattle, pig and poultry) reduction, which reduces the application of manure, or reduction of inorganic fertilizers. Since these are interlinked, reduction numbers are only obtained for "total fertilization", which is a combination of both reduced inorganic and organic fertilization, in Table 3.4.

Table 3.4. Reduction (ton/year) and cost (million €/year) for different measures in a cost-effective solution.

	Cost		Nitrogen reduction		Phosphorus reduction	
	Million €/year	Per cent	Ton/year	Per cent	Ton/year	Per cent
Fertilization	672.4	28.8 %	41 420	38 %	1 112	9.7 %
Cattle	242.5	10.4 %				
Pig	176.7	7.6 %				
Poultry	41.4	1.8 %				
Catch crops	60.3	2.6 %	2 708	2.5 %	36	0.3 %
P-ponds	45.3	1.9 %	0	0 %	900	7.9 %
Wetlands	387.7	16.7 %	28 818	26.5 %	364	3.2 %
Detergents	45.2	1.9 %	0	0 %	1 279	11.2 %
WWTP	664.6	28.5 %	35 904	33 %	7 718	67.7 %

It can be seen from Diagram3.1. that as much as 38 per cent of the nitrogen reduction, but less than 10 per cent of the phosphorus reduction, is achieved though reduced fertilization. This measure stands for 46.8 per cent of the total cost, which is not surprising since reduced fertilization by livestock reduction

is a very expensive measure, and so is reducing organic fertilizer for large reduction quantities.

Wetlands' share of the total costs amounts to 16.7 per cent, and account for a large part of the nitrogen and smaller part of phosphorus reduction (26.5 respective 3.2%). Wastewater treatment plants account for 33 per cent of the nitrogen reduction and 67.7 per cent of the phosphorus reduction, but only 28.5 per cent of the total cost.

A relatively small share of the costs is caused by catch crops (2.6%), phosphorus ponds (1.9%) and ban on phosphorus in detergents (1.9%). While the latter two only have an effect on the phosphorus target, the former (i.e. catch crops) mainly have an effect on nitrogen. Even though they are relatively inexpensive measures, their part of total nutrient reduction is not that high, which can be explained by their limited capacity to reduce the load.

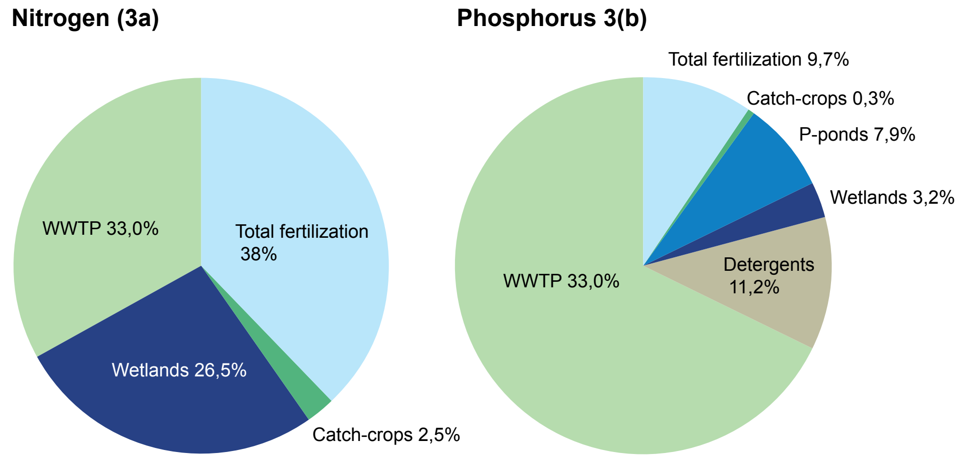


Diagram 3.1. Different measures' total proportion of reduction in percentage for nitrogen (3a) and Phosphorus (3b)

The cost-effective allocation of measures also differs between the countries. For example, in Poland wastewater treatment plants account for 88 per cent of its phosphorus load reduction and 72 per cent of its nitrogen load reduction, while the corresponding numbers for Sweden are 58 and 8 per cent respectively. The share of a country's nitrogen load reduction that is achieved by reduced fertilization (organic and inorganic) ranges from 1 per cent for Poland to almost 99 per cent for Finland. These differences in allocation of measurers can be explained by variations regarding the capacity and costs of a measure between the different countries. These variations can to a large extent be explained by the degree at which countries have implemented different measures until present date. That is, the more a country have already done to reduce the load, the higher the cost will be for any further abatement. For a more detailed description regarding the allocation of measures within countries see BG Paper *Costs of mitigating eutrophication*.

A specific measure implemented where the impact on the Baltic Sea is the largest (i.e. retention is small) will be less costly (i.e. cost per kg load reduction) compared to if the same measure with the same cost where implemented where the impact is lower (i.e. retention is high). In general this means that measures implemented closer to the coast are more cost-effective. So, in a cost-effective solution, initially low cost measures implemented in locations with large effect on the load will be implemented, while costly measures located where the impact on the Baltic Sea is small are only implemented for very high reduction targets.

3.4 Conclusions

The obtained cost estimates should be treated with some caution since they are based on a number of assumptions and therefore are likely to differ from actual costs. However, it is likely that the estimated total cost is an overestimation rather than an underestimation due to the limited number of measures included in the analysis.

The reliability of the cost figures above is dependent on a lot of factors. For example, there is always a degree of uncertainty (economic, technical or biological) related to the measures. With regard to wetlands, for example, the construction cost exhibits large variations depending on location (economic uncertainty), as well as their abatement effect (biological uncertainties). The cost data used should therefore not be regarded as an absolute number, but rather an average with a great interval.

For wastewater treatment plants, the uncertainties regarding the abatement measures' effect on the load, and its cost are likely to be smaller, implying a smaller cost interval compared to most other measures. Moving to actual implementation of the measures within each country, more site-specific data regarding, for example, retention and other location specific variables can be used. Thereby, these uncertainties can, to some extent, be reduced. See BG Paper *Costs of mitigating eutrophication* for a further description of these uncertainties.

Regardless of reduction target, the total cost is also very much affected by the assumption regarding the capacity of the measure. For example, how many hectares can be transferred to wetlands, or to what degree can the livestock be reduced. The smaller the capacity assumed for a measure found to be cost-effective, the more will be required by another, more costly measure, increasing the total cost of meeting the targets. Furthermore, the capacity constraint of a measure also explains to what extent this measure can be used within a specific country. For example, a country that have already invested in improving the nutrient abatement capacity of its wastewater treatment plants will be forced to implement other measures in order to reduce the nutrient load, in comparison to a country which has a large capacity of improving its wastewater treatment plants. This becomes clear when comparing the implementation of this measure between Sweden and Poland, where the capacity of wastewater treatment plants to reduce the nutrient load is much lower for Sweden compared to the costs in Poland (see BG Paper *Costs of mitigating eutrophication*).

The total cost is also restricted by the types and numbers of measures included in the analysis. Due to the large scale of the analysis and the limitations of the optimization program, only nine measures have been analysed in calculating the total cost. There are a large number of measures (e.g. manure storage, reduced soil preparation, adapted feeding of livestock, abatement of industrial discharges) that are not included in this study. If these omitted measures had been included in a cost-effective solution, the total cost of meeting the BSAP targets would be less than the cost obtained in this study. There is also a possibility that new technological innovations might lead to lower costs in the future.

As mentioned above, these costs are also based on assumptions regarding how the loads would evolve in the future, that is whether they would increase, decrease or remain the same. If future loads in a Business-As-Usual scenario would turn out to be larger (or smaller) than assumed in this study, then costs are under- (or over-) estimated (see Chapter 10 and BG Paper *Scenarios*).

In summary, the total cost estimates must be interpreted with respect to the limitations and assumptions on which they are based. It might, therefore, be wise to focus on the variations of costs between different measures and different geographical locations, and see the total cost estimates as approximations. That is, the results can be used as a guideline for identifying which measures that can be considered low-hanging fruits, in that they are likely to be low-cost measures for meeting the BSAP targets. If anything, the total costs estimates are likely to be overestimations because of the restricted number of abatement measures included.

4. Cost-benefit analysis

Comparing the estimated cost of reaching the Baltic Sea Action Plan (BSAP) with the benefits obtained, indicates total welfare gains of about 1 500 million Euros annually under a cost-effective allocation and about 1 000 million Euros annually under the BSAP country quotas. However, on a national level the costs for some countries will exceed the benefits they obtain. When comparing the costs and benefits with the GDP of each country it is clear that they represent a modest part of the whole economy, even though these numbers vary between countries.

4.1 Welfare gains

A Cost-Benefit Analysis (CBA) of the Baltic Sea Action Plan (BSAP) nutrient reduction targets was performed based on the results regarding benefits and costs described in chapters 2 and 3. The benefits of reaching the BSAP amounted to 3 800 million Euros annually, while the estimated costs were 2 300 million Euros annually in a cost-effective allocation of measures and 2 800 in an allocation according to the BSAP country quotas. By subtracting the total cost estimates from the total benefit estimate it is clear that substantial welfare gains of 1 000–1 500 million Euros a year could be obtained by reaching the nutrient targets of the BSAP.

4.2 Country allocation of costs and benefits

How benefits and costs would be divided between the countries for a cost-effective reduction of nutrients to the Baltic Sea is illustrated in Table 4.1. The table shows that even though the total welfare gain amounts to about 1 500 Euros annually, some countries will experience costs that exceed their benefits, under the assumption that each country is financially responsible for the measures taken within their country. Germany, Russia, Sweden, and Finland would obtain welfare gains (i.e. Benefit/Cost >1) for this solution, while Denmark, Poland, Lithuania, Latvia and Estonia would experience welfare losses (i.e. Benefit/Cost <1). These results for a cost-effective solution corresponds quite well to a comparison with previous studies (Gren et al., 1997; Ollikainen & Honkatukia, 2001; Gren, 2001, 2008), where Sweden and Finland are net-gainers while Poland and Lithuania are net losers in all previous studies. Latvia and Russia are net losers in most studies, while Denmark is a net loser in half of the studies and Germany is net loser in one study.

However, the allocation of costs illustrated in Table 4.1 should only be regarded as an indication of which country these measures need to be taken in. The final allocation of the financial burden between countries does not necessarily need to correspond to the allocation of measures. In order to make all Baltic Sea countries experience welfare gains (i.e. national benefits exceeding national costs) of reaching the BSAP target, some reallocation of financial resources is needed from countries experiencing a net gain compared to those that experience a net loss (i.e. national costs exceeds national benefits). Sweden could, for example, finance measures in Estonia to the extent that both countries achieve a net gain (i.e. benefits exceeds costs).

Table 4.1. Distribution of benefits and costs (million €/year) between countries under a cost-effective solution.

Country	Benefits (Million €/year)	Costs (Million €/year)	Net (Million €/year)	Benefit/Cost ratio
Denmark	205	630	– 425	0.3
Estonia	17	78	– 61	0.2
Finland	201	105	178	8.7
Germany	1 870	480	1 406	3.9
Latvia	7	85	– 78	0.1
Lithuania	16	101	– 85	0.2
Poland	211	544	– 333	0.4
Russia	473	105	368	4.5
Sweden	838	290	548	2.9
Total	3 838	2 336	1 740	1.7

It might be of interest to compare the cost-effective allocation of costs shown in Table 4.1 with the allocation of costs when meeting the BSAP country quotas. As previously shown the total cost of the latter is higher by 500 million Euros annually. This solution would give the same outcome regarding whether a country is a net loser or a net gainer, but the welfare gains would be smaller and the welfare losses higher for all countries except Denmark and Estonia. The reason behind this is that all countries, except Denmark and Estonia, are subject to higher costs in the country quota solution, while the benefits remain the same. See BG Paper *Costs of mitigating eutrophication*.

In terms of Gross Domestic Product (GDP) the costs correspond to between 0.007 to 0.432 per cent of GDP, while benefits correspond to a proportion of the GDP of between 0.031 to 0.193 per cent for the different countries.

4.3 Conclusion

This is the first large-scale international cost-benefit analysis for an environmental policy target (i.e. the BSAP) in which both costs and benefits have been estimated for all Baltic Sea countries. Despite the uncertainties related to the benefits and the cost estimates, the result in terms of positive total welfare gains seems robust due to the large difference between benefits and costs.

The measures behind the cost estimates of this study will, apart from the effect on the Baltic Sea, also have positive effects on the nutrient load to upstream water bodies (i.e. lakes, rivers, streams). These effects are likely to generate additional benefits beyond those considered in this study, implying even larger benefits as results of the BSAP than the ones captured in the BalticSun survey. This indicates that the benefits obtained are probably underestimations.

In summary, as benefits exclude upstream effects and the cost calculations only consider a limited number of abatement measures, the benefits are probably underestimated and the costs likely to be overestimated. Therefore, the result that the Baltic Sea Action Plan generates welfare gains can be regarded as robust. However, in order to make the BSAP beneficial for all countries around the Baltic Sea international collaboration is necessary.

5. Policy instruments

In the case of eutrophication, policy instruments that create incentives not only for target fulfilment but also for cost-effectiveness and innovation of new abatement measures are desirable. Combining market based with command-and-control instruments could be recommended.

5.1 Introduction

Previous studies indicate that the current policy instruments aimed at eutrophication do not generate a cost-effective allocation of measures, which might be explained by the fact that they often are very sector specific and that spatial differences are not taken into account.

With regard to the eutrophication problem, the BSAP and the Marine Strategy Framework Directive (MSFD) are vital, since they put pressure on the Baltic Sea countries to take action. The directives and agreements governing the national water bodies and major inland sources of eutrophication are also of significance, such as the EU Water Framework Directive (WFD), EU Urban Waste Water Treatment Directive (UWWTD), EU Nitrate Directive and EU's Common Agricultural Policy (CAP). These EU directives are in effect for all EU members and thus for all Baltic Sea countries except for Russia. For more information on these see BG *Paper Management Frameworks.*

The cost estimates of Chapter 3 were based on a number of possible measures that could be used to reach the Baltic Sea Action Plan (BSAP) nutrient targets. A target, such as the BSAP nutrient reduction quotas, will not in itself guarantee that the objective is reached, but relies on the Baltic Sea countries to use some kind of policy instrument(s) to actually implement the measures required.

Policy instruments are in this report defined as those tools that create the incentives for measures to be implemented. That is, the incentive that the actor supposed to implement the measure is confronted with (e.g. price signal, legislation or information). Directives setting targets and/or describing the actions needed to be taken (e.g. MSFD, Nitrate directive) or funding of research are therefore not considered to be policy instruments in this report since they do not confront the actors with a direct incentive to implement measures.

Categories and criteria of policy instruments

There is a wide range of policy instruments that can be used to generate the necessary incentives. This chapter discusses possible policy instruments relevant for the specific measures included in the Cost-Benefit Analysis (CBA) described in Chapters 3 and 4.

Policy instruments are usually divided into *command-and-control* (CaC) (e.g. legislation, standards, best available technology), *market-based instruments (MBI)* (e.g. taxes, fees, subsidies) or *informational (Inf)* (e.g. education, information campaigns) instruments. These different policy instruments are described more in depth in BG Paper *Management Frameworks*.

Three principal criteria are generally used when assessing the effectiveness of policy instruments:

- *Target fulfilment:* the potential of the policy instrument to attain the established objective.
- *Cost-effectiveness:* the target being fulfilled at the lowest possible socio-economic cost.
- *Dynamic cost-effectiveness:* the incentives that the policy instrument provides for the development of new and cheaper measures.

Other aspects to consider include how to handle distributional effects, uncertainties, flexibility and political feasibility of the policy instrument(s). All these aspects are discussed in more detail in the BG Paper *Management Frameworks.*

No single policy instrument (e.g. tax, legislation) will perform optimally with regard to all the possible aspects to be considered. The optimal choice of policy instrument will depend on what criteria that are considered important under each specific case. When choosing policy instrument, consideration has to be taken regarding the characteristics of the measure, the sector targeted, as well as the characteristics of the environmental problem one aims to solve, in this case eutrophication.

Existing policy instruments

The possibility of reaching the BSAP reduction targets with existing policy instruments might be limited, indicating the need to strengthen the effect of these (by e.g. increasing subsidies/taxes, standard requirements etc), as well as considering new policy instruments in order to get the necessary measures implemented.

Several studies have shown that the measures implemented against the eutrophication of the Baltic Sea are not always the cheapest possible measures (Gren, 1993; Gren & Zylicz, 1993; Gren et al., 1997; Brady 2003; Elofsson, 2003).

Reasons behind this lack of cost-effectiveness are:

- Most existing instruments are to a large extent country- and sector-specific, and comparisons are rarely made between costs of measures in different sectors or countries.
- Most instruments do not take into account that the environmental effects on the receiving water body of a particular discharge quantity varies depending on where the discharge takes place.

5.2 Discussion on policy instruments

When choosing policy instrument it is important to consider the characteristics of both the eutrophication problem and the targeted measures and sectors.

Characteristics of the problem

There are some characteristics of the eutrophication problem that are of relevance when deciding on policy instruments:

- Measures differ regarding the abatement cost.
- The final impact on the Sea differs between different locations of measures.
- Long-term effects of the different measures.
- The majority of the loads originate from diffuse sources.
- Some sectors sell their products on a global market.
- There are seasonal variations in the surface flow of nutrients.
- The risk of regime shifts in the ecosystem of the Baltic Sea.

In Chapter 3 it was established that there are large differences in load abatement costs between different measures, as well as for the same measure in different locations. The reason behind the former is that some measures (e.g. catch crops) have much lower cost per reduced unit then others (e.g. live stock reduction). The reason behind the latter is that the effect a specific measure has on the load to the sea differs between different locations, due to the retention[4]. Ignoring these two aspects when designing policy instruments would lead to larger total cost of reaching the BSAP nutrient targets. See BG Paper *Costs of mitigating eutrophication*.

The fact that a major part of the nutrient load originates from diffuse sources, mainly agriculture, has implications for the choice of policy instrument. Enforcing compliance of policy instruments aimed at diffuse sources may be more difficult for some instruments than others.

From a policy instrument point of view there are some significant differences between the sectors targeted by the measures. For example, while the products of the agricultural sector are sold on an international market, wastewater treatment plants possess a kind of monopoly situation with regard to the service they sell (treatment of household wastewater). This implies that compared to the wastewater treatment sector the agricultural sector might be more sensitive to the increase in production cost that the requirement of certain abatement measure might generate. For an analysis of

[4] Retention is the collective term for all processes that mean that only a certain proportion of the total quantity of phosphorus or nitrogen discharged from a particular source reaches the final receiving water body due to denitrification, uptake in biota or sedimentation.

this aspect see Swedish EPA (2012).

The seasonal variations of the nutrient load, as well as the seasonal effect on the Baltic Sea, must also be considered in the choice of policy instrument. The variations in surface flow of the nutrients might be reason to take into consideration certain measures' ability not only to reduce the load, but also the variation of the load. For example, wetlands have, on certain locations, the ability to reduce not only the total load but also the annual variance of this load to the Baltic Sea, thereby acting as an uncertainty limiting abatement option (Gren et al., 2000b).

The risk of regime shifts due to an increase in the concentration of nutrients in the Baltic Sea is vital to consider, and makes target fulfilment an important criteria. See BG Paper *State of the Baltic Sea*.

It may be important in the long run to implement policy instruments that create incentives for measures reducing the inputs of nutrients (im) to the system (e.g. reduced fertilization, ban on phosphorus in detergents) followed by measures recycling the nutrients (rm) (e.g. catch crops, phosphorus ponds). Policy instruments targeting so-called passive measures (pm), that in one way or another just parks the nutrients in the system over time, (e.g. wetlands), should maybe only be regarded as short-term solutions. (Einarsson, 2012)

Agriculture

Since an initial reduction of fertilization is a relatively low-cost measure that also reduces the input of nutrients to the system (im), a policy instrument targeting this measure is important. Implementing a command-and-control instrument, such as limits to the amount of fertilizers being applied, might not be efficient since it is very costly to monitor the compliance of such a regulation. A price signal, in terms of a tax on fertilizers, might be preferable since it will not require the same degree of monitoring. A tax might also generate a more efficient use of fertilizers as inputs, which will be of importance in a future where phosphorus will be of limited availability and where nitrogen fertilizers might become more expensive if energy prices increase. On the other hand, the effect of a tax on the nutrient load is likely to vary with changes in crop prices.

Catch crops and phosphorus ponds are recycling measures (rm) that only reach their full effect if their implementation indirectly generates a reduced application of organic and inorganic fertilizers. Subsidies or other types of financial support towards catch crops have so far been the most common instruments in the Baltic Sea region.

Wetlands as a measure can be considered as a passive measure (pm) since it, in a sense, just parks the nutrients in the nutrient cycle. In this report wetlands are constructed/restored on agricultural land and are characterized by large uncertainties regarding effect and cost. However, it is possible to steer this measure towards the locations where it gives most reduction for its cost. Therefore, any policy instrument aiming at this measure should be able to control the location. Catch-crops, phosphorus ponds, and wetlands could be targeted by either market-based instruments (MBI), such as subsidies, or

command-and-control (CaC), such as best agricultural practices. Information (Inf) to the farmers might also have a potential to get these measures implemented to some extent.

A market based policy instrument that could generate cost-effective solution towards diffuse source, might be a permit fee system including a broker, such as the one described in Swedish EPA (2009b).

A possible command-and-control policy instrument towards the diffuse sources of the agricultural sector might be to link some requirements to certain agricultural activities located in areas with a large impact on the Baltic Sea. For example, requiring farmers, growing potatoes in leakage sensitive locations, to cultivate catch crops and/or implement other measures toward leakage. Such requirements could be combined with a permit fee system in which the farmer can choose between meeting this requirement and paying a fee that finances a compensatory measure somewhere else.

It is possible that the agricultural production in the region will increase in the future (see BG Paper *Scenarios*). Therefore, measures and policy instruments targeting this sector are vital and any policy instrument implemented should preferably be flexible and create strong incentive for innovation of new and cheaper abatement measures. In the long-run it will be important to manage the agricultural production in a way that is capable of meeting new challenges in terms of climate change, increased agricultural production, and phosphorus peak. It is vital that the reformed CAP promotes a production that reduces the leakage of nutrients from agriculture. As pointed out by Hassler et al. (2011) "*When it comes to effective governance in mitigating eutrophication, reforming CAP is a priority*".

Wastewater treatment

Wastewater treatment plants are point sources of nutrients, implying that it is fairly easy to monitor their discharges and thereby the effect of abatement measures taken. It is also easy to monitor their compliance with different policy instruments. The impact on the Baltic Sea from wastewater treatment can be expected to decrease in the future due to the implementation of EU's Urban Waste Water Treatment Directive (UWWTD). This directive can be regarded as a command-and-control instrument decided by the European Union. However, abatement beyond the requirements of the UWWTD might still be cost-effective in meeting the BSAP targets (Hautakangas & Ollikainen, 2011), therefore a strengthening of the requirements in the directive or some additional policy instrument might be motivated.

As shown in Chapter 3, a ban on phosphorus in detergents is a cost-effective policy instrument to reduce the nutrient load to the Baltic Sea from wastewater treatment. Furthermore, this is a measure that reduces the input of nutrients (im) to the system.

Upgrading the abatement at wastewater treatment plants can be regarded as a recycling measure (rm) in the case where the residuals of this removal are used as fertilizer. But if that is not the case it should be regarded as a passive measure (pm).

Wastewater treatment plants act on a very local scale and possess a kind of monopoly situation allowing them to forward the abatement costs towards their customers. The financial impact on the wastewater sector of price signals in terms of a tax or permit price is therefore likely to be marginal. One could therefore combine a command-and-control instrument with a market-based instrument, such as the nutrient credit trading system proposed by NEFCO (2008) or the permit fee system proposed by the Swedish EPA (2009b). While the UWWTD would provide a minimum standard for abatement, a fee or permit price would provide incentives to abate above such a standard in a cost-effective way within the sector.

Table 5.1 focuses on the drivers and measures addressed within the Cost-Benefit Analysis (CBA) of Chapters 2, 3 and 4 of this report. Certain frameworks related to the drivers analysed are also included in the table as well as suggestions regarding what types of policy instruments that can be appropriate for getting the different measures implemented (see BG Paper *Management Frameworks*).

Table 5.1. Frameworks, measures and possible policy instruments towards drivers of eutrophication. Notations: (im) input-reducing measures, (rm) recycling measures, (pm) passive measures. (MBI) Market based instruments, (Inf) Information, (CaC) Command-and-Control.

	Frameworks	Measures	Possible policy Instruments
Drivers			
Agricultural production	BSAP MSFD CAP Nitrate directive WFD	Reduced fertilization (im)	MBI, Inf
		Catch crops (rm)	MBI, CaC, Inf
		P-ponds (rm)	MBI, CaC, Inf
		Wetlands (pm)	MBI, CaC
Wastewater treatment	BSAP MSFD UWWTD WFD	Abatement (rm,pm)	MBI, CaC
		Ban of phosphorus in detergents (im)	CaC

Possible other measures/sectors

The inclusion of other measures/sectors compared to the ones covered in the cost analyses of this report is likely to imply lower total costs of meeting the BSAP reduction targets, than the ones estimated in this report. There are a number of other measures towards agriculture than the ones included in the cost estimates of this study. For example, structural liming, decrease of nutrient content in fodder, buffer strips, precision farming, controlled drainage and manure storage are abatement measures that could reduce the leakage of nutrients from this sector (see http://www.balticdeal.eu/measures/). Policy instruments should therefore be able to target the implementation of these measures if they are deemed to be cost-effective.

Reduction of nitrogen oxide emissions from combustion sources within traffic, industry and shipping may offer cost-effective measures. Policy instruments towards these sectors are therefore needed in order to reach the BSAP target at such a low cost as possible. A cross-sector permit fee system could be designed as to include cost-effective measures in those sectors.

5.3 Conclusion

There is a need for new or strengthened policy instruments to meet the BSAP targets. In order to achieve cost-effective solutions market-based instruments should be introduced. A tax on fertilizers is a priority, and testing a permit fee system on a smaller scale could be recommended. It is important that implemented policy instruments are flexible and designed so that they can be adjusted to changes in drivers, pressures and state.

While the Water Framework Directive (WFD) strongly advices pricing policies for water use, in accordance with the "Polluter-Pays-Principle" the Marine Strategy Framework directive (MSFD) is not as clear in its guidance for policy instruments even though it calls for the establishment of economic incentives in reaching good environmental status.

Eutrophication is a difficult problem to address as there are drivers in different economic sectors and many sources are diffuse in character. As many of the possible measures are quite costly and the costs vary much between different measures and also for the same measure at different locations, it is important to find cost-effective solutions and create strong incentives for innovation and implementation of new measures. This favours market-based instruments creating a price incentive for innovations in the form of either a tax, fee, subsidy or tradable permit, that leaves it up to the regulated part to choose between paying (receiving) the tax/fee, permit price (subsidy) or reducing its impact on the Baltic Sea implementing the measure of their choice. For example a tax on the prime factor behind the problem, namely fertilizers, would give a signal to all users to reduce the input of nutrients to the system, and should therefore be a priority in any management strategy. However, a policy instrument should also lead to a high degree of target fulfilment (which could be especially important due to the risk of regime shifts), something a tax cannot guarantee. A good management strategy might therefore need to include both command-and-control and market based instruments.

The nutrient credit trading suggested by NEFCO (2008) or the permit fee system suggested by Swedish EPA (2009b), which to some extent are similar in their design, are examples of policy instruments combining command-and-control and price signals. Such systems could be worth testing on a smaller scale, for instance in a catchment area, including all major relevant sectors. Applied on a larger scale, such a system could be cross-national and designed as to allow a country to finance more cost-effective measures in another country and still add it to its own quota, allowing for a cost-effective solution regardless of the initial allocation of country reduction quotas.

Some of the measures (especially those targeting diffuse sources from agriculture) are characterized by large uncertainties with regard to cost, effect and capacity. Any policy instrument towards these measures should therefore be designed in a way that reduces such uncertainties. The system suggested by the Swedish EPA (2009b) includes a broker agency capable of reducing these uncertainties, as it includes communication, learning–by-doing and monitoring of the effects.

Any policy instrument must be able to respond to possible changes in abatement requirements caused by future developments. There are two possible ways future developments can influence required abatement measures, and thereby the possibility and cost of reaching the ecological objectives of the BSAP.

Firstly, if there is reason to believe that one or several of the main drivers (e.g. agricultural production, traffic) will increase in the future, it will be important to implement a policy instrument that is capable of handling such a possibility. Changes in land-use, population and other drivers might require the implementation of more measures, leading to larger costs, in order to reach the target load. This emphasizes the need for a flexible policy instrument, which, when confronted with changes in the drivers or new information (regarding e.g. the effect of measures), can adapt in order to make sure that the environmental objectives of the policy are not threatened.

Secondly, in the long run the policy instruments must be capable to deal with so called moving targets. The nutrient reduction required for meeting the environmental objectives of the BSAP might increase due to an increased impact from other pressures than the nutrient load (e.g. climate, food-webs,) as well as due to dynamic changes in the ecosystem of the Baltic Sea. Therefor the ecological objectives of the Baltic Sea might require an increased reduction of the nutrient load to the Baltic Sea even if there is no future increase of the drivers behind this load.

In summary, there is a need for new or strengthened policy instruments to meet the BSAP targets. In order to achieve cost-effective solutions market-based instruments should be introduced. A tax on fertilizers is a priority, and testing a permit fee system on a smaller scale could be recommended. It is important that implemented policy instruments are flexible and designed so that they can be adjusted to changes in drivers, pressures and state.

There are other pressures besides the nutrient load, for example fishing pressure, which might have an impact on the degree of eutrophication in the Baltic Sea (see e.g. Casini et al., 2008; Norkko et al., 2012). Due to the possible negative effects caused by these other pressures, a reduction of the nutrient load in accordance with the BSAP targets does not necessarily imply that the environmental state of the Baltic improves to the state that the targets were supposed to fulfil. Complementary policy instruments addressing measures towards reducing these pressures are, therefore, likely to be required.

III. Other environmental problems – interconnections and management options

As indicated in Chapter 1, eutrophication is not the only environmental problem threatening the Baltic Sea. It has not been possible to make full-scale Cost-Benefit-Analyses (CBA) for all environmental Baltic Sea problems within the scope of the present phase of BalticSTERN research. However, case studies have been made for problems that risk to hamper the improvements obtained by reducing eutrophication in accordance with the Baltic Sea Action Plan (BSAP) targets.

Case studies were undertaken on fishery management for the Baltic Proper, effects of an oil spill in the Gulf of Finland and an invasive species at a locality on the coast of Finland. In the following Chapters 6, 7 and 8 these case studies are presented together with a discussion, in a broader perspective, regarding possible management strategies and policy instruments.

6. Fish and fishery

Fish resources provide ecosystem services for different user groups, but diverse driving forces influence fish stock dynamics. Sustainable use requires policy coherence between environmental, agricultural and fisheries policies and novel approaches to fisheries governance.

6.1 Fish, food web and biodiversity

Biodiversity is of utmost importance as it underpins many other ecosystem services. The food web has undergone several regime shifts during the last century; from seal dominated to cod dominated, and since the late 1980s dominated by sprat and herring.

Fish stocks provide a range of ecosystem functions, but are primarily used for their provisioning services. Besides commercial fishing, recreational fishing is important in several of the Baltic Sea countries. In addition to provisioning services, fishing can also be regarded as a cultural service and fish clearly also play important roles in sustaining the structure and function of the ecosystems.

Until the middle of the 20th century, fishing was carried out on a fairly small scale, but technical advances around that time paved the way for substantial increases in catches. This lead to overfishing and partly regime shifts. Many commercially valuable fish stocks, such as cod, have been overexploited, but the cod stock has recently started to show signs of recovery

(ICES, 2012). The hunting pressure on seals has also been intensive during the last centuries. In combination with pollution and deseases such as viruses, this has lead to a decline in populations of grey and ringed seals. There has been some recovery of seal populations during the latest decade, although this trend now seems to stagnate. This has also had an effect on the size of the different fish stocks. Recently though, seal populations have been increasing.

Recent data suggests continued overcapacity in commercial fishery, leading to low profitability and noncompliance with fishing regulations (European Commission, 2007, 2012; CFCA, 2010). Today, as is shown in the FishSTERN report (Swedish EPA, 2011), fishing vessels operating in the Baltic Sea range in size. There are coastal vessels, using passive fishing gears and landing small amounts of high-quality fish for human consumption, and large ocean-going pelagic vessels, using trawls to catch great quantities of sprat and herring for producing fish meal and fish oil.

6.2 FishSTERN

A lower fishing pressure would be positive for profits and employment, as well as ecosystem health, given present capacity of fleets and fish stocks.

The study FishSTERN was conducted during 2010 and the results were published in the report FishSTERN - *A first attempt at an ecological-economic evaluation of fishery management scenarios in the Baltic Sea region* (Swedish EPA, 2011). Economic fisheries-related data from seven countries around the Baltic Proper were collected, and formed the basis for modelling the outcome of four different management strategies: maximization of fisheries profit (Net Present Value (NPV)), maximization of social benefits (expressed as number of jobs per catch value), maximization of ecosystem health, and a combination of all three previous management strategies equally weighted.

Fleet efforts were optimized for the simulation period 2006-2026 in the four above-mentioned management strategies, providing four different scenarios. The profit scenario resulted in a higher total fleet net present value compared to the other management scenarios, while the employment scenario resulted in the highest landings per fleet. The ecosystem health scenario resulted in the lowest landings value per fleet of the four management scenarios. The fishing effort of all fleet segments except of one (the fleet with the highest cod catches) was close to zero after the optimization of the above-mentioned management strategies.

The optimization results in the four scenarios are generally as expected; the total fleet net present value is expected to be highest in the profit scenario, and the total fleet landings value is expected to be highest in the employment scenario, while the ecosystem health scenario should decrease the fishery substantially for all fleets. Overall, the fishing intensity needed to be reduced drastically in all scenarios as the cost of the fishing effort would otherwise be too high to make profits.

These management scenarios illustrate the interaction between effort cost and fish resources available. Long-term profitable and sustainable fishery implies adjusting fishing effort to fish stocks. That is, when the fish biomass is low, fishing effort should be low. A low fishing pressure would lead to an increase in the fish stock, in particular for cod, which will in the long-run lead to a higher profit.

Finally, it must be noted that the data collected for the study was in some respects inadequate as cost indicators were lacking for some countries. Furthermore, it was obvious that the aggregated total landing data for the fleets did not correspond to the ICES landings data in the Central Baltic Sea. It is suspected that these data problems may be a reason for the unrealistic result, for example, that all fleets but one are forced to stop fishing under all management optimizations. To improve this kind of fisheries-related ecological-economic evaluation, more adequate economic data are needed and a regional Baltic economic assessment is required, and is most probably needed also for the Marine Strategy Framework Directive (MSFD).

6.3 Management strategies

Better coherence between different goals in management of fisheries, in EU regionally and nationally, is important. Specific targets need to be defined for Baltic Sea fish stocks based on the Ecosystem Approach. A dual management strategy, with more self-organization of local fisheries using small vessels and better control of compliance for pelagic fisheries using large vessels, could be a way forward.

Existing governance and character of fishery

Whereas the HELCOM Baltic Sea Action Plan (BSAP) has a focus on measures relating to eutrophication, the MSFD has a broad approach incorporating all relevant areas influencing the ecosystem health. The Common Fisheries Policy (CFP) is the most important policy tool for Baltic Sea fisheries.

Fisheries can be seen as complex adaptive systems with interacting social, ecological and economic variables. Managing such complexity requires a fit-for-purpose understanding of the system's dynamics, but also management tools that can deal with complexity and adapt policy depending on context and requirements.

Alternative fisheries governance

Taking system complexity into account when designing policy may also be achieved through combining regulatory instruments, and instruments that allow for self-organization (Mahon et al., 2008). In practice, Mahon et al. (2008) suggest an approach where fisheries governance moves away from a "one size fits all" approach. Instead they suggest an approach where management focuses on either top-down management or enabling bottom-up management, depending on the characteristics of the fleets involved.

A classic top-down approach is best suited for controllable resources and actors with predictable behaviour. To work well it requires data on both the economics, as well as the respective ecosystem, and relies on increased monitoring and enforcement.

The alternative approach is more dynamic, less driven by top-down control and more focused on bottom-up driven self-organization of the fisheries system. This type of management is better suited to dynamic, unpredictable and complex smaller fisheries and therefore rather applies to the local level. Methods within this management approach include shared information gathering, transparency and inclusion and empowerment of stakeholders (Mahon et al., 2008).

A governance mix between regulatory (command-and-control) and enabling bottom-up management may be a way forward in searching for a sustainable policy for the diverse fisheries of the Baltic Sea region. Some fleets identified in the FishSTERN report are large-scale, efficient and homogenous, and probably have the largest ecological impact as they account for the highest proportion of catches. Increased monitoring, control and data collection, as well as effective regulatory management of such fleets would be a viable alternative. In contrast, small-scale fleets, often considered important for local communities for socioeconomic or cultural reasons, with multiple target species, low efficiency and high heterogeneity, are much more complicated to understand, predict and control. Therefore, management styles more focused on enabling bottom-up management and self-organization, rather than top-down regulatory approaches, may be appropriate.

Figure 6.1 illustrates the diversity of Baltic Sea fleets. As two contrasting examples, the pelagic fishing fleet, with vessels over 24 meters, caught 55 per cent of the total catches in the period 2005-2007, but represented only 3 per cent of the vessels. In contrast, the passive gear segment, with vessels below 12 meters, represented 74 per cent of the Baltic Sea fleet but caught only 6 per cent of the total quantity. In the pelagic trawl, with vessels over 24 meters, full compliance with regulations is necessary as the ecological impact is so large. In contrast, the bulk of the fishing fleet of small passive gear vessels has a relatively low ecosystem impact, but is probably more important for local economies, employment etc.

Ways forward

Fishery management is on all levels driven by both ecological targets and targets for a viable fishing sector, in EU through CFP and MSFD. The policy specifies no priorities between social, economic and ecological goals and this far, the results of the efforts to balance ecological and socio-economic goals in policy have not been satisfactory. Re-defining socio-economic goals in cohesion with ecosystem goals, making trade-offs between goals and dividing responsibility between international, national and local decision bodies can be a first step towards a coherent ecosystem based management of the Baltic Sea.

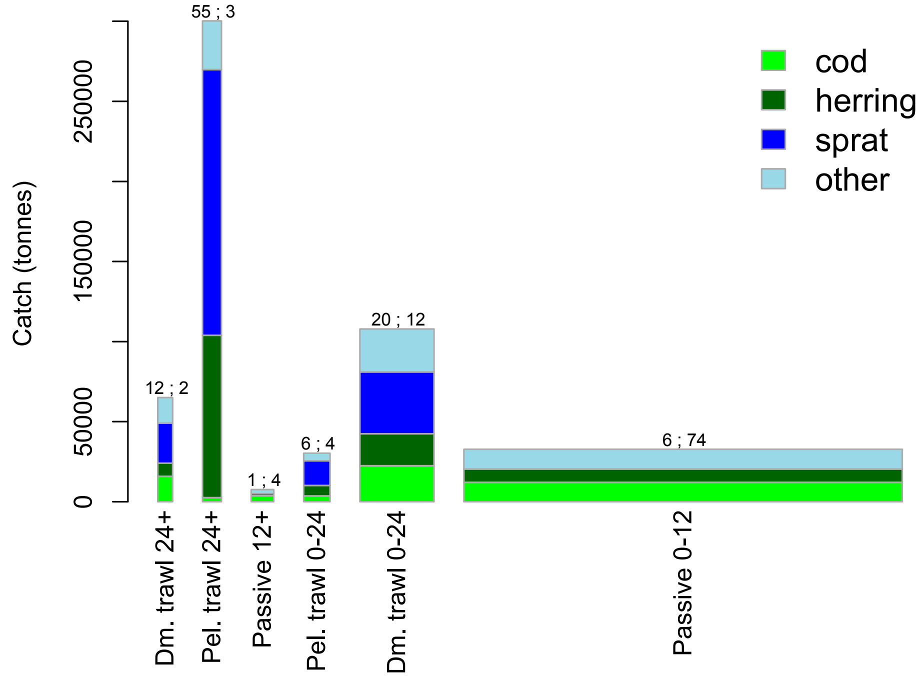


Figure 6.1. Data on the size of the fishing fleets and catches for Denmark, Estonia, Germany, Lithuania, Poland and Sweden. Data shown is the average for 2005-2007, except for pelagic vessels, which show data for 2006 only. Width of bars represents size of the fishing fleet segment during this time period. Numbers above bars show percentage of the total catch quantities and percentage of the total fleet, respectively. Fleets are ordered with increasing number of vessels per fleet from left to right.

While the HELCOM BSAP clearly states goals regarding reduced eutrophication of the Baltic Sea, no specific long-term targets have been defined for Baltic Sea fish stocks. However, the ecological interactions between eutrophication and fisheries points to the need for coordination of goals. At EU level the implementation of the MSFD will also raise the issue of integration between different goals (e.g. combining Maximum Sustainable Yields (MSY) advice for fish stocks with other ecosystem requirements for sustained function of ecosystems).

The lack of targets poses a problem also for models in science, and limits the use of multi-species assessment and advice tools as they additionally struggle with shifting baselines and variations of fish stocks.

Fishing pressure is not the only influencing variable for the health of fish stocks. Eutrophication and water quality are also of importance. Climate plays a strong role, especially on a longer timescale. The goals for fish stocks thus have to be realistic and take these interacting drivers of change into account.

HELCOM has initiated cooperation in a Fisheries/Environment group in order to address issues related to ecosystem considerations relevant to fisheries, while other organizations, including the Baltic Sea Regional Advisory Council (BSRAC), are also increasingly developing their understanding of the ecosystem approach. Other relevant institutions include BaltFish, a recently established forum for cooperation between fisheries ministers in the region.

Bringing together fisheries and the above listed bodies would contribute to consistency in how these diverse policy frameworks and institutions address fish stocks and environmental aspects related to fisheries, and should therefore be a priority.

A way forward could be that BaltFish, in collaboration with the BSRAC and HELCOM, initiate an inclusive process to define long-term goals.

Marine spatial planning is increasingly used as a method to facilitate ecosystem considerations in relation to fisheries. HELCOM and Vision And Strategies around the Baltic Sea 2010 (VASAB) are currently engaged in cooperatively developing a strategy for the development of this tool for the Baltic Sea, and several national agencies progressively use this methodology in the region. However, implementation of marine spatial planning may fall short of an ecosystem approach, as it often focuses primarily on specific issues (i.e. either conservation or e.g. offshore wind farm development). Ecosystem based marine spatial planning should be developed in collaboration across sectors, and benefit from international and national databases including social, economic and ecological information.

7. Oil spills

Increased traffic on the Baltic Sea increases the risk for oil spills and may thereby threaten the Baltic Sea environment and thus ecosystem services and benefits provided.

7.1 Risk of oil spills

The risk of oil spills is becoming an increasing concern due to the significant increase in shipping in the Baltic Sea. Oil transport makes up a large percentage of the increase in sea transports, and the amount of oil transported to and from the Baltic Sea doubled during the period 2000-2009 (HELCOM, 2010b). The pressure on the marine environment from oil spills also originates from non-tankers and port activities.

The Baltic Sea accounts for up to 15 per cent of the world's shipping cargo transportation and is one of the busiest seas in the world. At any moment there are about 2000 ships afloat in the Baltic Sea and prognosis points to a doubling by 2030. The size of these vessels is also expected to increase substantially. (HELCOM, 2009c) These factors combined imply a dramatic increase of the risks for oil spills under a Business-As-Usual (BAU) scenario.

As the Baltic Sea is particularly sensitive to releases of chemicals and oil due to its "enclosed" characteristics, its brackish water, and its fairly species-poor mixture of freshwater and marine species, it has been listed by IMO as a Particularly Sensitive Sea Area (PSSA), needing special protection.

Assessing these risks and the costs that may be the consequences of oil spills is therefore relevant when discussing how to safeguard human benefits provided by the Baltic Sea.

7.2 Case study on oil spills

Inadequate responses to oil spills may be costly and can erode the benefits of reduced eutrophication in the areas affected, temporarily or for longer periods.

BalticSTERN case study

Within BalticSTERN a case study has been undertaken for the Gulf of Finland *Combating eutrophication in coastal areas at risk for oil spills* (Hyytiäinen & Huhtala, 2011). The case study assessed how the risk of oils spills may influence the profitability of nutrient abatement measures in the Gulf of Finland. The authors used a model that integrates loads of nutrients from agriculture, nutrient dynamics in the sea basins, oil spill risk and the recreational value of the Sea.

The study investigated how the profitability of unilateral (Finnish) or joint (Finnish, Estonian and Russian) nutrient abatement measures is affected when the risk for major oil spill events is present. The underlying assumption is that an oil spill would lower the recreational value of the coastline for a period of time, thus undermining the benefits created by nutrient abatement.

The results reveal that Finnish unilateral investments in nutrient abatement measures are not profitable when the risk of recreational losses due to oil spills is included in the model. However, for the case with joint efforts by Finland, Estonia and Russia, the efforts are profitable. Generally, the models indicate that even a low risk of oil spills may reduce the expected net present value of nutrient abatement significantly in the area affected.

The conclusion is that improving management of coastal areas requires analyses that simultaneously tackle all the relevant environmental threats.

Other case studies on oil spills

There are additional case studies on oil spills in the Baltic Sea regarding its effects on different kinds of species and at different localities, and also regarding efficiency of different combating tools (Hassler, 2011; Helle et al., 2012; Hyytiäinen & Huhtula, 2012; Ihaksi et al., 2011; Lecklin et al., 2011). These case studies are described briefly in BG Paper *Oil spills management* and are part of the bases for the discussion of management strategies as regards oil spills.

Studies estimating costs of oil spills are available internationally, but few studies exist regarding the Baltic Sea. Some studies covering the Stockholm archipelago and the Swedish west coast outside Bohuslän indicate cleanup costs of 20-50 million Euros for an oil spill of 25-30 000 tons (Forsman, 2003, 2006, 2007). In addition there are market costs for losses in tourism (17–160 million Euros) and commercial fishery (17–160 million Euros). A study among Finns estimated a willingness to pay of about in total 110 million Euros for improved oil spill response capacity (Ahtiainen, 2007).

7.3 Management strategies

The highly international context and regulations regarding maritime safety restrict manoeuvre room for national and regional action, but there are still possibilities for important action regarding implementation and compliance. There are also the option to form alliances and influence international rules. A parallel strategy could be to take actions to strengthen the resilience of the Baltic Sea ecosystem, thus improving its ability to recover from an oil spill.

Introduction

Though studies on oil spills in the Baltic Sea are few, and these contain assumptions and limitations, it could still be concluded that there are significant values at risk. These values can be lost completely or partially as a consequence of future oil spills in the Baltic Sea. A failure to pay enough attention to these values may result in welfare losses.

Possible measures

Measures can be directed towards drivers, pressures and the state of the Sea.

Measures directed at drivers range from reductions in sea transport to development of alternative energy sources, and thus reduced tanker transports. Also, a transition to natural gas as fuel in shipping could be seen as a measure directed at a driver. Such measures are of a long-term character and might create ancillary benefits. For example, many of these measures are consistent with actions needed to meet climate policy targets.

Many measures have been targeted at pressures. Measures directed at pressures are those that focus directly on the goal of reducing the probability of a spill, or improving the response once a spill has occurred. Examples of the former may include limiting tanker traffic in specific areas, improved technical standards, safer navigation procedures including better training of crews, and increased use of piloting. Improved spill response capacity could be obtained by for example training of cleanup crews and by better cooperation both locally and regionally.

Measures directed at the state of the environment can reduce the effect of an oil spill in the long run, usually by improving the ecosystem's ability to recover. These measures can be thought of as buying insurance, that is investing in measures that improve an ecosystem's resilience will reduce the social cost of future spills. Such measures could, for example, be restoration of marine ecosystems and protection of biodiversity or removing stressors, through protected areas and reduced fishing pressure.

Recommendations

The highly international context of shipping complicates measures targeted at, for example, maritime safety. While national legislation cannot overrule or modify international regulations, national policies can potentially affect how the international regulations are implemented locally. For example, strict enforcement of existing measures (e.g. rigorous harbour police controls, enforcing penalties for non-compliance, satellite surveillance, etc.) may provide significant benefits to society in terms of avoiding future losses of ecosystem services. In some cases, individual countries (or regional blocks of countries) may also be able to influence the development of certain regulations through international political action. Further, many measures that improve port routines and response preparedness are driven locally.

Improve existing measures targeted at Pressures

Measures targeted at pressures are the 'conventional' measures combating oil spills and have a long track record, dating from the early 1970s in response to several high profile oil spill cases. Despite this long track record, there is room for improvement.

One way of enhancing safety is by enforcing Port State Control regulations on the local level, considering the incentives of operators, so that they actually implement the desired measures. An important fact is that human error seems to be a common cause of accidents. Humans make mistakes by nature, which means that the technological and procedural system should improve its built-in redundancy. There is need to analyze the most common types of human errors in the Baltic Sea, and to find ways to adapt the system, in order to minimise consequences of such errors. (Hassler, 2011)

Although measures directed at pressures are critical to an oil spill management regime, the existing international conventions might have already "picked much of the low-hanging fruit" and measures may risk being duplicative. For example, double-hull ship requirements are requested under various international and regional regulations. Further, there is redundancy in regulations addressing operational spills at ports. An effective way forward may be to better integrate similar or overlapping governance structures, so that regulations and the consequences of failing to implement them become clearer for relevant actors.

Develop measures targeted at the environmental State

Newer and more creative ways of avoiding adverse impacts on social welfare from oil spills are required. While measures directed at pressures play an important role in avoiding oil spills or reducing ecological impacts, they do little to bolster or strengthen the affected environment itself. Strengthening ecosystem resilience may be a way forward.

Despite society's best efforts, the risk of oil spills will remain non-zero, which means that insurance against inevitable damage through building resilience into the ecosystem may provide an attractive complement to other measures. For example, reducing overfishing may be a cost-effective alternative to large investments in response capacity in order to protect weak fish populations.

Strengthening ecosystem resilience also provide a buffer capacity against other environmental problems (e.g. eutrophication, invasive species, hazardous substances), which is an important argument for taking an ecosystem services approach to environmental management. Such an approach implies the management of the system as a whole.

Improving knowledge concerning the ecological impacts from oil spills is also important, and may be crucial for future management. For example, safeguarding threatened species against oil spill risks requires better knowledge concerning how these species behave, where they are located and how best to protect them.

An ecosystem services approach to management, as advocated for example by the Marine Strategy Framework Directive (MSFD), requires knowledge regarding which ecosystem services and benefits are seen as the most valuable. This is particularly relevant in the discussion of response capacity in ecologically sensitive areas. An ecosystem services approach would also require that spatial analyses be performed concerning particularly valuable areas, which deserve particular attention in management. Choosing between different types of measures requires new valuation estimates. Both economic and ecological valuation may be needed (see e.g. Pascual et al., 2012). Without such estimates, it is difficult to prioritize among available management options. Simulation models have proven to be an important tool to guide decision-making concerning oil spill risks, as they have the potential of gathering many types of information and illustrating interdependencies between ecological variables. These models can also be used when conducting socioeconomic analyses.

Further, there is a need for more economic data concerning the value of Baltic Sea ecosystem services. Databases could be used to help collect information. The costs associated with lack of data (or inaccessibility of existing data) are incurred in terms of omitted information and/or high search cost. This can lead to inadequate policy appraisal or weak liability procedures against polluters.

Measures aimed at Drivers

Measures aimed at *drivers* (e.g. reducing fossil fuel demand) and environmental state (e.g. reducing overfishing) have historically received little attention. There are, however, examples of studies that emphasize the importance of these somewhat non-conventional and indirect perspectives on oil spill management. Concerning measures targeted at drivers, such as reducing the demand for fossil fuel and transportation, and supporting alternative energy sources, these would probably never suffice to replace other more direct measures due to strong market forces. However, the benefits of reducing oil spill risks should be included in the cost-benefit calculations of measures aimed at drivers.

8. Invasive species

Invasive species may threaten food-web balances of the Baltic Sea and may become more frequent with a warmer climate.

8.1 Invasive species in the Baltic Sea

Increase of sea traffic has brought new species to the Baltic Sea and the decline of native species has made the Sea more vulnerable to invasive species.

The increase in sea and canal traffic has contributed significantly to the migration of species to new areas, and also increased the number of species in the Baltic Sea. From the 19th century to the beginning of the 21st century a large number of alien species entered the Baltic Sea, of which a majority have remained permanently. Between the years 1800 and 1900 the Baltic Sea were colonized by 17 alien species, of which 13 (e.g. the crustacean *Balanus improvisus*, the mollusk *Dreissena polymorpha* and the fish *Salvelinus fontinalis*) established themselves in the Baltic Sea ecosystem. (Baltic Sea Alien Species Database, 2012)

The decline and absence of native communities of species left the ecosystem vulnerable to further colonization by invasive species, and of the 89 species that invaded the Baltic Sea between 1900 and 2000, 61 established themselves in the ecosystem. Species include crustaceans (e.g. *Acartia tonsa, Gammarus ssp*), fish such as the round goby (*Neogobius melanostumos*) and different species of salmonides (*Oncorhynchus* ssp.), as well as the polychaete worm *Marenzellaria* ssp., which has become one of the dominant taxa in the northern Baltic Sea. (Elmgren, 2001; Baltic Sea Alien Species Database, 2012; Norkko et al., 2012)

Climate change increases the probability of new invasions as water temperature is increased and the ecosystem becomes suitable for a larger number of potential new species. See BG Paper *State of the Baltic Sea*.

8.2 Case study on invasive species

A case study on one species at one location revealed three distinct strategies regarding how to cope with invasive species: an adaptive strategy, which reduces the damage; a preventive strategy, which delays the invasion and the resulting damage; and a mitigation strategy, which puts effort into timely detection, control and eradication of the newly established population.

Invasions of new, harmful marine species is a similar environmental.

problem as major oil damages in the sense that the probability of occurrence is small, but the potential damages and impacts to the future provision of important ecosystem services can be vast. Managing such threats requires balanced efforts in reducing the probability of future incidences, and preparing to effectively mitigate and adapt to the negative impacts after an invasion has occurred. The problem also involves shifting baselines of biodiversity. Whenever a new species enters the area and its consequences are realized, a re-evaluation of the next steps is required.

A proper Cost-Benefit Analysis (CBA) on efficient strategies to address the threat of aquatic invasive species at the scale of Baltic Sea would require more comprehensive data compared to what is currently available. An existing database is the AIS (DAISE - Delivering Alien Invasive Species Inventories for Europe). Data requirements for a CBA would, however, need to include detailed lists of potential new species, the likelihood of their invasion and population dynamics in the new environment, potential impacts on the existing marine and coastal ecosystems in the Baltic Sea, as well as how they affect future provisioning of important ecosystem services. In addition to this, information would be needed regarding the effectiveness and costs of measures to prevent future invasions and to mitigate, eradicate and adapt to the existing invasions. Instead of aiming at a full CBA of managing the risk of new invasions in the Baltic, a modelling framework was built up for optimizing the management of potential invasions in smaller enclosed areas. The framework was parameterized for a potential invasion of the Asian clam (*Corbicula fluminea*) in the warm water discharge area of a nuclear power plant planned on the northern shores of the Baltic Sea (see details in Hyytiäinen et al. 2012). For methods of detection and control of biological pollution, see also Olenin et al. (2011).

The modelling framework can be used to investigate when and to what extent a society should engage in efforts to reduce the likelihood of an invasion, to control and eradicate a newly established population, and to adapt to damages. In addition to the costs of management activities, the damages incurred to the private sector (clogged pipelines in an adjacent nuclear power plant) and the adjacent society (impaired recreation possibilities and health problems) was accounted for. The results revealed three distinct strategies: an adaptive strategy, which reduces the damage that an existing invasive species population causes the private sector; a preventive strategy, which delays the invasion and the resulting damage; and a mitigation strategy, which puts effort into timely detection, control and eradication of the newly established population. Choosing the optimal strategy was found to be highly sensitive to the unit costs of the measures required and the externalities (i.e. damages), as well as to the size of the clam population after the invasion has been detected. Choice of strategy may turn out to be a very important decision to society, as different strategies lead to different likelihoods of invasion and expected level of damage after invasion. For example, choosing either mitigation or adaptive strategies means that a society accepts the fact that invasion is very likely and does nothing to prevent it.

8.3 Conclusions and recommendations

Investors should identify and internalize the external costs of a potential invasion when making any large-scale investment plans that could influence the risk for invasions.

The case study describes a situation where installation of a new nuclear power plant on the seashore potentially leads to additional external costs in the form of an increased risk of invasive species. The results emphasize the need for the energy sector to identify and internalize the external costs of a potential invasion when making any large-scale investment plans. The probability distribution of such external costs provides valuable information, and should be explicitly accounted for when considering alternative locations for a plant and also when weighing the pros and cons of different sources of energy.

The risk of invasion by an invasive aquatic species, owing to heat pollution in water discharge areas, reduces the competitiveness of nuclear power, and other energy forms that require large quantities of cooling water, and thus alter the adjacent aquatic ecosystem.

The framework developed can have a wider use as it can be parameterized to other potential species or groups of species at different spatial scales. The International Maritime Organization (IMO) is coordinating a ratification process of the International Ballast Water Management Convention aiming at reducing the transfer of harmful aquatic organisms and pathogens. When realized, this Convention will be a major advancement in reducing the likelihood of marine invasions globally.

IV. Long term perspectives

The Baltic Sea environment has been drastically affected during the last centuries by the accelerated pressures from human activities. Scenarios for the future show that the drivers behind this development may very well increase in the future, which emphasize the need to decrease the pressures these drivers cause.

9. Past and present state of the Baltic Sea

An increasing population in the catchment area, the establishment of industry and trade and the subsequent economic growth, have affected the Baltic Sea ecosystem by accelerated pressures during the last century. Widespread eutrophication and hypoxia, hazardous substances and marine litter and subsequent changes in flora and fauna, are some of the environmental problems seen.

This chapter shortly describes some of the environmental problems affecting the Baltic Sea. For more detailed descriptions of these problems, and information on other environmental problems not covered in this report, see BG *State of the Baltic Sea*.

9.1 Human influence – eutrophication

Due to its special geographical, climatological and oceanographic characteristics, the Baltic Sea is sensitive to environmental pressures, such as nutrient enrichment. Humans began to influence the coastal ecosystems of the region in prehistoric times, for example through discharge of wastewater into the Baltic Sea. During the modern historical period (AD 1800 to present) the impacts on the marine environment slowly began to show.

The establishment of small industries and trade, the development and intensification of agriculture and other changes in land-use, in combination with changing climate, are some factors that permitted a gradual increase in the human population during the 18th and 19th centuries.

For a long time, agriculture only had a moderate impact on the marine environment, but as increasing areas of land were used for cultivation, the effects of pollution began to show. The expansion of agriculture led to extensive drainage of wetlands and lakes, which together with growing use of agricultural fertilisers led to increased transport of nutrients to the Sea. Growing populations and industrialization also led to increases in wastewater discharge.

Higher loads of nutrients stimulated increased production of phytoplankton and fish, but the Baltic Sea remained classified as oligotrophic (i.e. nutrient poor), with clear water, oxygenated deep waters and favourable conditions for cod reproduction during the 19th century (e.g. Wulff et al., 2007; Österblom et al., 2007). In the early 20th century nutrient levels in the Baltic were still relatively low, but during the course of the century loads of nitrogen and phosphorus increased four- and eightfold respectively, accentuated after the Second World War as a result of the introduction of artificial fertilizers. (Larsson et al., 1985; Green et al., 2000a) Phytoplankton blooms were encountered close to the large cities, and in the 1950s they appeared also in offshore areas.

9.2 Regime shifts and ecosystem effects

During the 20th century, the Baltic Sea underwent drastic changes, so called *regime shifts*. In the Baltic Sea the elevated nutrient concentrations, led to increased organic production and shifted the Baltic Sea from an oligotrophic to a more eutrophic state (Österblom et al., 2007 and references therein).

> An ecosystem regime shift is an infrequent, large-scale reorganization, marking an abrupt transition between different states of a complex system, affecting ecosystem structure and function and occurring at multiple trophic levels (e.g. Scheffer & Carpenter 2003; Collie et al., 2004).

Increases of organic production (organic enrichment) can, in some cases, have positive consequences on flora and fauna, but generally it relates to undesirable effects, for example on phyto- and zoobenthic communities (i.e. communities of flora and fauna, living in or on the sea bed), and has also led to massive algal blooms, among those potentially harmful cyanobacteria and other toxin producers (Barnes & Mann, 1991; Kautsky, 1988, 1991). Figure 9.1 shows the effects of eutrophication and regime shifts in the Baltic Sea.

The increased pelagic primary production led to decreased water transparency, and a reduction of the biomass, depth and geographic distribution of macro vegetation such as bladder wrack (*Fucus vesiculosus*) (Kautsky et al., 1992). This shift, from perennial submerged vegetation to annual filamentous (i.e. threadlike) algae, has been proposed to represent a second regime shift (Jansson & Jansson, 2002). The reduction of macro algae in turn changed the composition of the associated fauna, as there for example was a decrease or loss of food and nursery areas, leading to a lowered diversity.

In the late 1980s, the Baltic Sea underwent yet another large ecological regime shift. In the Central Baltic Sea the food web structure changed from a cod- to a sprat-dominated state, induced by, among other things, overfishing, eutrophication and changes in climate leading to hydrographic changes (Österblom et al., 2007; Möllmann et al., 2008, 2009; Casini et al., 2008). See BG Paper *State of the Baltic Sea* for further information on regime shifts in food webs and effects on fish populations in the Baltic Sea.

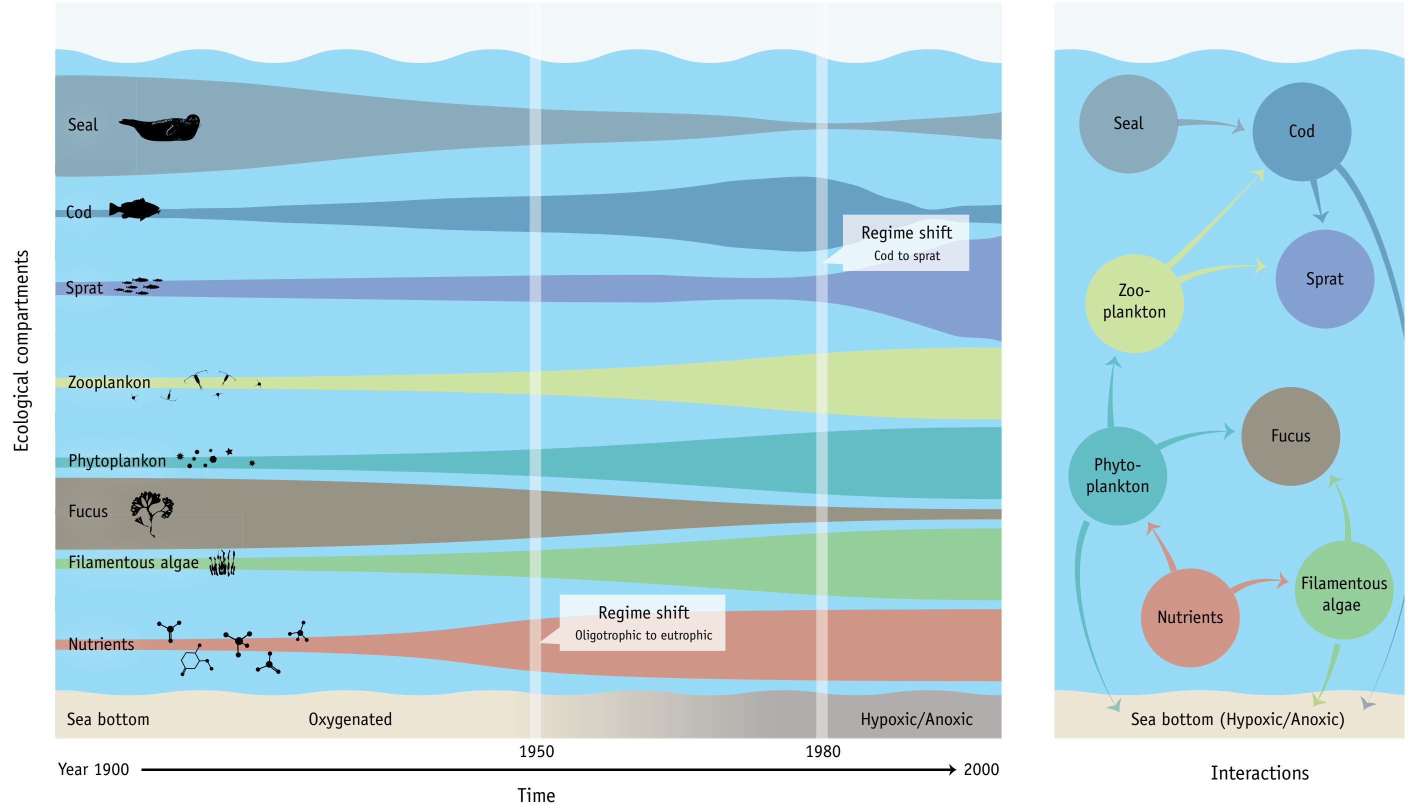


Figure 9.1. Changes in the Baltic Sea ecosystem during the 20th Century. The illustration shows changes in major ecological compartments and their interactions, as well as regime shifts in the Baltic Sea ecosystem. (Illustration by J. Lokrantz/Azote)

Ultimately, the organic matter sedimented to deeper waters, where bacteria and animals gradually degraded it – a process that consumed oxygen. The intermediate stagnation periods increased in both number and duration. These periods between inflows of saline water from the North Sea are characterized by decreasing salinity and oxygen content in the deep water and sometimes culminate in the formation of considerable hydrogen sulphide concentrations. Coupled with higher decomposition rates these processes led to decreased oxygen levels and increasing hypoxia, a state of deficient oxygen values, where long-term hypoxia corresponds to concentrations of oxygen below 2 ml l-1. Large areas of the Baltic Sea are now permanently anoxic, that is completely deployed of oxygen with formation of toxic hydrogen sulphide and negative effects on the ecosystem. (Elmgren, 1989, 2001; Green et al., 2000a; Kautsky & Kautsky, 2000; Rönnberg & Bonsdorff, 2004)

> Status of Baltic Sea hypoxia
> In the Baltic Proper, hypoxia covered approximately 3000 km² in 1906 and had by the 1930s increased to nearly 19 000 km². Since the 1950s, the size and extent of low oxygen regions have grown, reaching an area of 70 000 km² already in the 1970s – corresponding to an area larger than Lithuania. (Savchuk et al., 2008 and references therein) With hypoxia reaching the deep basins of the central Baltic Sea, loss of habitat and spawning areas for native flora and fauna, elimination of benthic animals and altered food chains are some of the consequences observed.

Reduction in nutrient loads during the past decades has led to an increase in water transparency in some parts of the Baltic (mainly the southern sea-basins), whereas the status in other parts is still deteriorating. In large parts of the Baltic Sea, the plankton abundance has increased. In the Baltic Proper, blue-green algal blooms seem to have become more abundant than before. In addition, fast-growing filamentous green or red algae, as well as reed, have expanded at the expense of bladder wrack and eelgrass. (Rönnberg & Bonsdorff, 2004; HELCOM, 2009a, 2010a)

9.3 Other environmental problems

In addition to the effects from eutrophication (described above and in BG Paper *State of the Baltic Sea*) overfishing (Chapter 6 and BG Paper *State of the Baltic Sea*), oil spills (Chapter 7 and BG Paper *State of the Baltic Sea*) and invasive species (Chapter 8 and BG Paper *State of the Baltic Sea*), a range of other environmental problems affects the Baltic Sea; such as hazardous substances and micro pollutants, marine litter, habitat loss, dredging, disposal of dredged material, as well as climate change. (See BG Paper *State of the Baltic Sea* for further information). The cumulative and synergistic effects of these problems in turn affect Baltic Sea biodiversity.

Pollution through hazardous substances constitutes a serious threat to the Baltic Sea environment. Contamination by for example persistent organic pollutants (POPs such as PCB, DDT and dioxins) and heavy metals (e.g. mercury, lead and cadmium) has had severe impacts on biodiversity, including populations of seals, eagles and guillemots.

Hazardous substances stem from point sources, land-based diffuse sources and atmospheric deposition; for example industry, agriculture, household consumer produces, traffic, shipping and energy production. In addition, after World War II, chemical munitions and chemical warfare agents were dumped and are now found throughout the Baltic Sea. Hazardous substances harm the flora and fauna mainly by affecting the immune and hormone systems, thus impairing general health and reproduction status. Due to bio-accumulating properties (i.e. accumulation of environmental chemicals in tissues of exposed organisms) they magnify through the food chain to species at higher trophic levels, and pose a threat also for humans who consume fish caught in the Baltic Sea. Their long residence times, in combination with the introduction of new substances, pose a grave threat for the state of the future Baltic Sea and health of future generations. (Bignert et al., 1998; HELCOM, 2009b, 2010a)

Marine litter is considered to be one of the major threats to oceans worldwide. Although the problems of marine litter in the Baltic Sea are not comprehensively studied, existing studies show that each cubic meter of water can contain hundreds of thousands of pieces of microscopic plastic particles, harming the marine environment in various ways. Marine litter can for example lead to entanglement of marine fauna such as seals, fish and seabirds. It can also cause physical injuries and famine through its food-resembling properties and contribute to transfer and movement of invasive species. In addition, marine litter on the coastline pose potential harm to flora and fauna, as well as causing damage to industry and reducing the aesthetic quality of coastal environments (Norén et al., 2009; HELCOM, 2007c; UNEP, 2005).

A serious concern when regarding the status of the Baltic Sea ecosystem is climate change, identified as one of the dominant drivers of ecosystem change globally. The response of the marine ecosystem during the last centuries, including those described above, has naturally been influenced also by changes in atmospheric forcing. During the 20th century, sea surface temperate increased by > 0.7 °C, to be compared with the global mean increase of 0.5 °C (BACC, 2008). Other effects of climate change include changes in salinity conditions, with decreasing salinity during the last two decades due to fluctuations in precipitation and temporal inflows of water through the Danish straits. Other variables, such as wind conditions, river run-off and coverage and thickness of the sea ice have also been affected, influencing the ecosystem in terms of for example nutrient loads, pressure on fauna and flora, and changes in food webs. (BACC, 2008; Meier et al., 2012) See BG Paper *State of the Baltic Sea* for further information regarding climate change and its consequences.

10. Scenarios for the Baltic Sea

Scenarios were a vital component in the BalticSTERN cost-benefit study. A number of scenarios for the Baltic Sea region exist. However, only a few of these have a time perspective and focus comparable to the BalticSTERN scenarios.

10.1 Future development of ecosystem services and benefits

Scenarios are important in order to understand how different possible future changes might affect the state of the Baltic Sea. The cost and benefits of reaching a good ecological status will depend on how the drivers behind the different problems evolve in the future.

The range of benefits we derive from the Baltic Sea have not been constant over time, which can be illustrated by, for example, the provisioning of food from the Sea. As described in Chapters 6 and 9, the amount of cod, herring, sprat and other species have, as a consequence of a combination of changes in pressures and drivers (e.g. fishing effort, oil spills, seal hunting) and natural dynamics of the ecosystem itself (e.g. changes in salinity and food-web dynamics) to a large extent varied over the past hundred years.

As pressures and drivers are not constant, the benefits obtained from ecosystem services cannot be taken for granted. Depending on a combination of how we decide to manage the Baltic Sea, and changes in drivers and pressures of limited control for the Baltic Sea countries (e.g. climate, world economy, global population), several different futures are possible. In order to address these different possible futures, and their consequences on the Baltic Sea ecosystem, scenarios need to be developed.

A scenario is a plausible description of how the future might develop, based on a coherent and internally consistent set of assumptions about the key relationships and driving forces (Nakicenovic et al., 2000).

Scenarios can be developed by using different kinds of models estimating the effect on the Baltic Sea for different kinds of input data regarding, for example, future agricultural production, fishing efforts and market prices. These, so called *quantitative* studies, provide numerical results based on modelling. An alternative approach is to describe possible scenarios in the form of narratives or visual symbols rather than numerical estimates, often referred to as *qualitative* studies or storylines. It is also possible to develop scenarios as a combination of both quantitative and qualitative studies, by combining modelling with storylines.

The purpose of developing scenarios can be varied, such as communication of complex information, bridging science and policy, raising public awareness, describing potential future states, or identifying future environmental problems.

Research projects addressing the environmental state of the Baltic Sea therefore usually includes the development of scenarios in order to describe how things might evolve in the future.

10.2 Survey of Baltic Sea related scenarios

Most of the scenarios developed within different Baltic Sea-related research projects are based on model calculations with a short time span. A majority of these have a focus on different aspects related to eutrophication.

One of the BalticSTERN secretariats' tasks has been to identify related programs and projects that could be relevant for the BalticSTERN project. Therefore, a survey was undertaken to create an overview of scenarios used within other research projects, of relevance for the Baltic Sea.

In the survey information regarding 15 Baltic Sea scenario studies were obtained. Most of the scenarios were quantitative scenarios in which a computer model is fed with input/driver data and a numerical, quantitative output is obtained in order to generate the relevant scenario information and explore future consequences of applied assumptions.

A major part of the research studies developed scenarios with a focus on either the effects of eutrophication (i.e. primary production, algae blooms, hypoxia) or the pressures and drivers behind it (i.e. land use, nutrient load, agricultural production). The length of time that the different studies address ranges from just a few months into the future until the end of the 21st century. Scenarios and predictions that cover the next five years or less, are technically not to be classified as scenarios as such, as they rather show trends. Despite the obvious connectedness of the topic area (where output of some studies could have been used as input to others), few references were made between the different studies. Furthermore, linking these scenarios with other regional or larger, global trends and storylines where made only by downscaling the climate scenarios from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) (IPCC, 2000).

One objective of the survey was to see whether scenarios developed by other projects support the scenarios used within BalticSTERN. About half of the studies of the survey include the Baltic Sea Action Plan (BSAP) nutrient reduction targets as a policy scenario. However, only the ECOSUPPORT project had a spatial and temporal scale in line with the BalticSTERN scenarios.

10.3 From global to regional scenarios

> The development of certain drivers affecting the state of the Baltic Sea are usually captured by global and regional storylines, which are based on narratives rather than numerical estimates in models. These qualitative storylines can be connected with the quantitative regional scenarios.

Global and regional storylines

The development of drivers, affecting the state of the Baltic Sea, is to a large extent dependent on global trends, which the Baltic Sea countries might have limited control over (e.g. climate change, global demand for fish and agricultural products, shipping). Future changes in the agricultural production, with regard to size as well as level of intensification, will have implications on the nutrient load to the Baltic Sea, and these changes are to a large extent driven by world market prices. Future climate changes will have indirect (e.g. through changed land use, water run off), as well as direct effects (e.g. water temperature increase) on the environmental state of the Baltic Sea. When developing scenarios for the Baltic Sea it is thus important to consider how these global drivers might evolve in the future.

In order to illustrate how global trends might impact the state of the Baltic Sea, two possible global storylines are described in this section.[1] In "*An overexploited world*" a rather pessimistic view of the future is depicted, with severe climate changes, increased population, and weak global institutions and environmental policies. A more optimistic view of the future is illustrated in "*A world in balance*", with a lower degree of climate change, stabilizing population, and strong global agreements and environmental policies.

When downscaled to the Baltic Sea region, both storylines imply an increase of agricultural production (especially in the eastern parts of the region), but to a less degree in the "*world in balance*" storyline. The increase is required in order to compensate for the increase in global demand, as well as a decreased agricultural production in other regions of the world caused by climate changes. However, the way the agricultural products are produced differ between the two storylines: with a large-scale, intensified and subsidized agricultural production in the "*overexploited world*" scenario, compared to the production in *"A world in balance"*, which is characterized by a diverse production, in which the farmed land produces additional ecosystem services besides crop yield production (e.g. biodiversity, nutrient purification and well-functioning habitats). Therefore, the nutrient load to the Baltic Sea is lower in the latter compared to the former storyline. The population in this region remains at about the same size as presently in both storylines. While fish biomass has decreased in the "*Overexploited world*", it has increased in *"A world in balance"* due to strong agreements regarding sustainable fishing polices in EU and amongst the Baltic Sea countries. These global scenarios and how they were downscaled to the Baltic Sea region are more thoroughly described in the BG Paper *Scenarios.*

In the WWF report "Counter currents: scenarios for the Baltic Sea towards 2030" (2012) four different regional story lines for the Baltic Sea region were developed by using the participative approach, in which stakeholders (representing businesses, academics, decision makers and NGO's) discussed the possible futures of the Baltic Sea during a workshop. See BG Paper *Scenarios* for a description of this report.

An exploration of the trends and uncertainties identified at the workshop enabled the development of a structure for describing the following four possible future scenarios for the Baltic Sea in 2030:

- *Clear waters ahead*: with small ecological footprints[2] in combination with strong and integrated governance this scenario clearly describes an optimistic future of the Baltic Sea in 2030. The implementation of policies aimed at restoring the Baltic Sea (e.g. BSAP, MSFD, CFP) has been successful and led to an improvement of its state.
- *Dangerous currents*: With large ecological footprints and strong and integrated governance this scenario describes a future Baltic Sea characterized by cooperation, but with a focus on short-term economic prosperity where the environmental problems are not prioritized by neither citizens nor governments.
- *Islands in the stream*: With small ecological footprints but fragmented and weak governance this scenario describes a future in which people and companies have taken action in order to improve the state of the Baltic Sea, while the governments have lost the will to cooperate and take actions.
- *Shipwrecked*: With large ecological footprints and fragmented and weak governance this scenario describes a pessimistic future, where the environmental decline of the Baltic Sea has accelerated due to the focus on short-term economic profits and lack of governmental cooperation and actions.

Qualitative scenarios, such as these storylines, are capable of describing a more holistic view of possible futures, but usually lack a more specific description (e.g. actual nutrient load in tonnes per year), which is the strength of the model-based quantitative scenarios.

Model-based quantitative scenarios

As shown in Section 10.2 there are few long-term model-based scenarios for the development of the Baltic Sea.

Long-term scenarios for the Baltic Sea including climate effects were developed within the BONUS-funded research project ECOSUPPORT (Meier et al., 2012). In that project several scenario simulations were made, however here only two examples will be presented, that is, a worst-case and a

[1] These two storylines are based on the storylines from the reports "Five scenarios for 2050: Conditions for agriculture and land use" by Öborn et al. (2011) and Agrimonde's "Scenarios and challenges for feeding the world in 2050" (2009). The names are directly taken from two of the scenarios in the former study.

2 Ecological footprints are an indicator that measures our impact on nature – the land and sea area required to produce goods and services that we consume and to deal with the waste products of our consumption.

best-case scenario simulating the effects until 2100. The worst-case, Business-As-Usual (BAU), scenario is very similar to the "*overexploited world*" storyline previously referred to. In this scenario BAU development was assumed for agriculture and cod fishing, in combination with climate change (emission scenario A1B (of IPCC), a scenario which projects an annual mean increase of around 2 degrees surface water in the central Baltic Sea by the end of 2100. In the model simulations of this scenario, the continuous increase of nutrient loads from the catchment caused a further enhancement of today's deep-water anoxic areas in association with substantial summer algal blooms. These symptoms of eutrophication, together with the higher cod fishing, project a future cod stock that is close to extinction.

In the best-case scenario an agriculture that reduces nutrient load emissions according to BSAP targets, as well as cod fishing following the EU cod recovery plan with a low fishing mortality, were assumed in combination with the same climate change (emission scenario A1B) as in the worst-case scenario. The reason behind using the same climate scenario is that the uncertainties in the global climate models are higher than the differences in the emission scenarios of IPCC (Meier et al., 2012). That is, an ensemble of climate models is needed as the output of a single climate model is not sufficient to predict the effect of future climate on the relevant aspects. This scenario is very similar to "*the world in balance*" scenario. In the model simulations the BSAP implementation reduced the nutrient loads from the catchment, and led to an improvement of present deep-water anoxic areas in association with summer algal blooms, which did not worsen. These improvements, together with the lower cod fishing, projected a cod stock, which is higher compared to present conditions, but constrained at the end of the century by the projected decrease in salinity affecting the cod recruitment success. Effects on phytoplankton and algal blooms as well as cod stocks of the two scenarios are illustrated in Figure 10.1.

Figure 10.1 illustrates that cod biomass would be close to extinction under a worst-case scenario with high levels of cod fishing and increasing nutrient loads according to the ECOSUPPORT Business-As Usual-projections. In contrast a best-case scenario with low cod fishing and fulfilment of the BSAP targets regarding nutrient loads would lead to an improvement of cod biomass compared to present conditions. Due to climate change causing decrease in salinity there is a downward tendency at the end of the century.

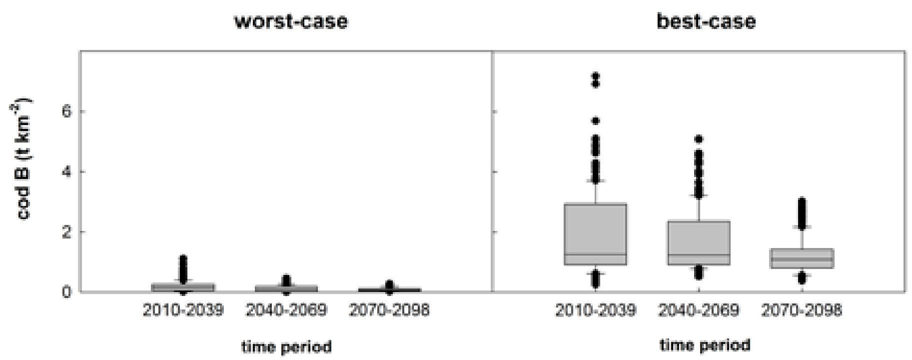


Figure 10.1. Future projections of cod biomasses under a worst-case and a best-case scenario for the time period 2010-2100. (Source: Unpublished results; Susa Niiranen, Stockholm Resilience Centre)

In Figure 10.2 the future development of phytoplankton according to ECOSUPPORT modeling is shown. In the worst-case scenario phytoplankton almost doubles, which substantially increases the risk of summer algal blooms. In the best case scenario the situation is neither worsening nor improving.

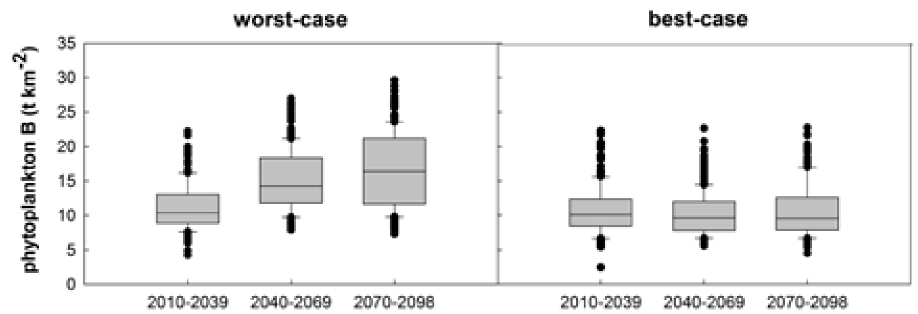


Figure 10.2. Future projections of phytoplanktion under a worst-case and a best-case scenario for the time period 2010-2100. (Source: Unpublished results; Susa Niiranen, Stockholm Resilience Centre)

Figure 10.3 illustrates the risks of regime shifts in the Baltic Sea food web in a worst-case and a best-case scenario. The Regime Shift Index (RSI) indicates a risk for more frequent regime shifts of a higher magnitude in the worst-case scenarios compared to the best-case scenario.

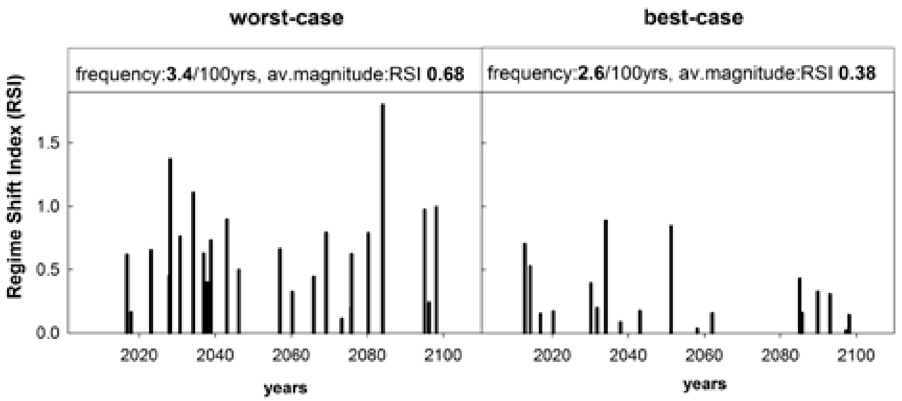


Figure 10.3. Risk for regime shifts in the Baltic Sea food web during the period 2010–2100 for a worst-case and a best-case scenarios respectively. (Source: Unpublished results; Susa Niiranen, Stockholm Resilience Centre)

10.4 Discussion

In the valuation study BalticSUN two future possible scenarios of the Baltic Sea anno 2050 were described to the respondents. First a so-called Business-As-Usual (BAU) scenario was described, in which no further actions were taken in order to reach the BSAP nutrient reduction targets. This scenario would lead to a deteriorating state of the Baltic Sea characterized by an increase in algae blooms and hypoxia. Secondly, a scenario in which the BSAP reduction targets were met was described, leading to an improvement of the state of the Baltic Sea in 2050 in terms of less algae blooms and hypoxia. The only difference between these two scenarios is whether the BSAP targets are reached or not. They can therefore be said to represent the same global storyline, a storyline likely in line with the optimistic storyline "*A world in balance*" described above, since no drastic increases of the nutrient load to the Baltic Sea is expected.

If a more pessimistic global storyline, such as the "*An overexploited world*" had been used in this study, costs as well as benefits of reaching the BSAP targets would be different. In a pessimistic storyline with increased and intensified agricultural production in the Baltic Sea region, the costs of reaching the BSAP targets would be higher as more measures would be required. However, the difference between the two scenarios (with and with out BSAP) illustrated in the valuation questionnaire of the BalticSUN survey, would be larger, implying that the benefits of implementing the BSAP would also likely be larger. An interesting area of future research would be to conduct a Cost-Benefit Analysis (CBA) under a more pessimistic scenario.

V. Discussion and conclusions

11. Management strategies

There is need for an ecosystem based, holistic and integrated management strategy with a common vision for a sustainable transformation of the Baltic Sea, which could safeguard ecosystem services and the benefits they provide to human societies. Flexible management is important since the actions required are likely to change over time due to changes of drivers and the dynamics of the ecosystem. The strategy should take into account effects of climate change and risks of surpassing thresholds causing regime shifts. The different environmental problems also require specific strategies and policy instruments based on the characteristics of the problem, drivers and pressures, as well as measures targeted.

According to a number of recent research studies (Gilek et al., 2011; Hassler et al., 2011; Renn et al., 2011; Österblom et al., 2010) there are three major problems identified in marine environmental governance: firstly; how to link the management of different natural resource uses and their environmental effects across sectors, secondly; how to more actively deal with ecological uncertainties and risks connected to human resource use, and thirdly; how to involve stakeholders in management, in particular on regional and transnational levels (Hammer & Gilek, 2012). Apart from these problems, the success of environmental governance will in the end depend on the political will to implement policy instruments.

These problems and possible ways to deal with them are to some extent addressed in this chapter after a recap of the challenges. Chapter 11.2 focuses on possible approaches to be used in managing the complexity and linkages between different environmental problems. Chapter 11.3 illustrates the presence of ecological uncertainties, with a focus on uncertainties regarding how the future evolves and how management strategies can be designed to deal with this aspect.

Management of the specific environmental problems is addressed in 11.4. The characteristics of the different environmental problems of the Baltic Sea are described together with a discussion regarding how they should be taken into consideration with regard to management. Existing hindrances and possibilities for a successful management of the Baltic Sea is discussed in 11.5 and need for future research is indicated in 11.6. Finally, conclusions are presented in 11.7.

11.1 Challenges (recap)

Any management strategy for the Baltic Sea must take into consideration possible future changes of the range of drivers affecting the state of the Sea including climate change.

The Baltic Sea has changed drastically during the last century due to successively higher pressures from human activities. Increasing nutrient loads have made the Sea shift from oligotrophic (nutrient poor) to eutrophic (nutrient rich). This has caused increased production of phytoplankton, which in turn has influenced the ecosystem functions in several ways. Potentially dangerous algal blooms have increased tenfold, as have sea bottoms with low or no oxygen and thereby poor conditions for fish spawning. Due to these changes and to overfishing the food web has undergone regime shifts from seal domination in the early 20th century to cod domination after the 1950s. An abrupt shift from cod to domination by sprat and herring occurred in the late 1980s. See Figure 9.1.

Sea traffic has increased and caused unintentional and intentional oil spills, as well as releases of other hazardous chemicals. Vessels bring alien species to the Sea and warmer sea temperature increases the possibilities for invasive species to survive. Increases in consumption, production and waste have lead to littering of the coasts and the Sea.

Through the HELCOM agreement (HELCOM, 2007a) on the Baltic Sea Action Plan (BSAP) the nine littoral countries have undertaken to reduce nutrient loads and are struggling to implement the plan. BalticSTERN research has shown that doing so will provide clear welfare benefits. BSAP also sets goals regarding biodiversity conservation, hazardous substances and shipping.

At the same time new challenges appear. Recent modelling shows that climate change will lead to a warmer and less saline Sea and that climate effects will be seen earlier than previously thought. Some scenarios for long-term development envisage significant increases of drivers such as agricultural production and traffic (sea and land transports).

Climate change is not taken into account in the scenarios developed within the Cost-Benefit Analysis (CBA) of the BalticSTERN as it was supposed to have little effect up to the year 2050, which was the time span of the scenarios. Furthermore, the Business-As-Usual (BAU) scenario of the CBA is based on a fairly marginal increase of drivers. Nevertheless, this scenario envisages a gloomy development for large parts of the Baltic Sea. As illustrated in the maps in Figure 11.1 (see also Chapter 2.1) only two of the basins – Bothnian Bay and Kattegat – would be in an acceptable state in 2050. The Baltic Proper would be in a really bad condition with very turbid water, blue-green algae blooms in large areas every summer and with constant oxygen shortages in sea bottoms in large areas. Underwater meadows would be almost lost and non-suitable for fish spawning. There would be almost no cod, fewer sprat and herring but lots of roach, carp and bream.

BAU 2050 **BSAP 2050**

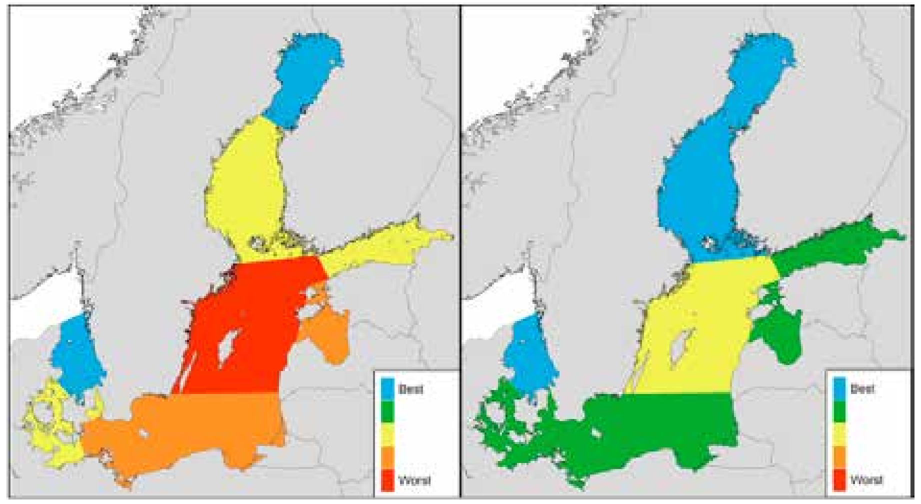


Figure 11.1. Maps showing the situation in the Baltic Sea 2050 in a BAU (11a) and a BSAP (11b) scenario respectively.

The modelling made within ECOSUPPORT (see Chapter 10) indicates that in a worst-case non-action scenario, with substantial increases of drivers and where climate change is accounted for, the consequences will be even more drastic. An even larger increase of nutrient loads, subsequent rise of algae blooms and cod populations close to extinction in the whole Baltic Sea may be the result. Risks for, maybe not yet fully understood, feedback mechanisms may enhance the risk of surpassing thresholds and may trigger the ecosystem into a situation that is even worse.

In Chapter 1 a table was presented (Table 1.1) indicating that outcome of measures has to be looked at assuming both a best-case and a worst-case scenario for development of drivers. It was also indicated that the Cost-Benefit-Analyses (CBA) of the BalticSTERN action and non-action scenarios would be based on a best-case scenario regarding the development of drivers. In Table 11.1 the results from the BalticSTERN CBA are presented. Subsequently Table 11.1 illustrates costs and benefits for action and non-action in a best-case scenario.

Table 11.1. Costs and Benefits of Action and Non-action regarding mitigation of eutrophication in a time perspective of 2050, assuming best-case development of drivers.

Best – case scenario		
	Costs	**Benefits**
Action towards BSAP targets for nutrient loads	< 2 300-2 800 million Euros	> 3 800 million Euros
No further action	Only Bothnian Bay and Kattegat would be in a good condition. All other basins would be in an unacceptable condition. Baltic Proper would be worst off with very turbid water, blue-green algae blooms over large areas every summer, underwater meadows almost lost and unsuitable for fish spawning, almost no cod, fewer herring and sprat, constant oxygen shortage in large bottom areas and extinction of bottom animals. Loss of recreational and existence values > 3 800 million Euros annually	As the required measures under a best-case scenario are not implemented the costs of these are avoided (<2 300 – 2 800 million Euros annually)

The costs and benefits for action+ and non-action in a worst-case scenario, based on the outcome of ECOSUPPORT, is illustrated in Table 11.2.

Table 11.2. Costs and Benefits of Action and Non-action regarding mitigation of eutrophication in a time perspective of 2050, assuming worst-case development of drivers.

Worst – case scenario		
	Costs	**Benefits**
Action+	The required measures under a Worst-case scenario would be larger than in the Best-case scenario, implying larger costs	> 3 800 million Euros to infinite
No further action	Continuous increase of nutrient loads and subsequent increase of algae blooms in the whole Sea. Cod almost extinct and fewer sprat and herring. Adding a longer time perspective (2100) and non-action regarding additional environmental problems, there may be system collapses – and costs may be infinite	As the required measures under a Worst-case scenario are not implemented, the costs of these are avoided, costs that would be compared to in the Best-case scenario

Regardless of how the drivers will evolve in the future (i.e. worst-case or best-case), Tables 11.1 and 11.2 indicate that it is motivated to take further action aimed at improving the state of the Baltic Sea. As this report has illustrated, the environmental problems of the Baltic Sea are complex and interlinked, and there are uncertainties regarding future drivers and risks of regime shifts.

The implications of these preconditions when setting up management strategies will be discussed in the following.

11.2 Management of complex and interlinked systems

In managing complex and interlinked environmental problems an ecosystem and holistic approach is recommended. Furthermore, vertical and horizontal integration of different management strategies are important for a successful management.

Using the DPSIR (Drivers-Pressures-State-Impact-Response) framework as a starting point allows for an overview of the complexity of managing the Baltic Sea. Figure 11.2 illustrates how one can capture all the relevant parts of a specific environmental problem by identifying the Drivers and Pressures behind the State, as well as the Impact this State has on human welfare. This may lead to Responses (e.g. policy instruments) that create incentives for the sectors behind the Drivers to take actions that reduce Pressures. Response could also be targeting Pressures, State or even Impacts directly.

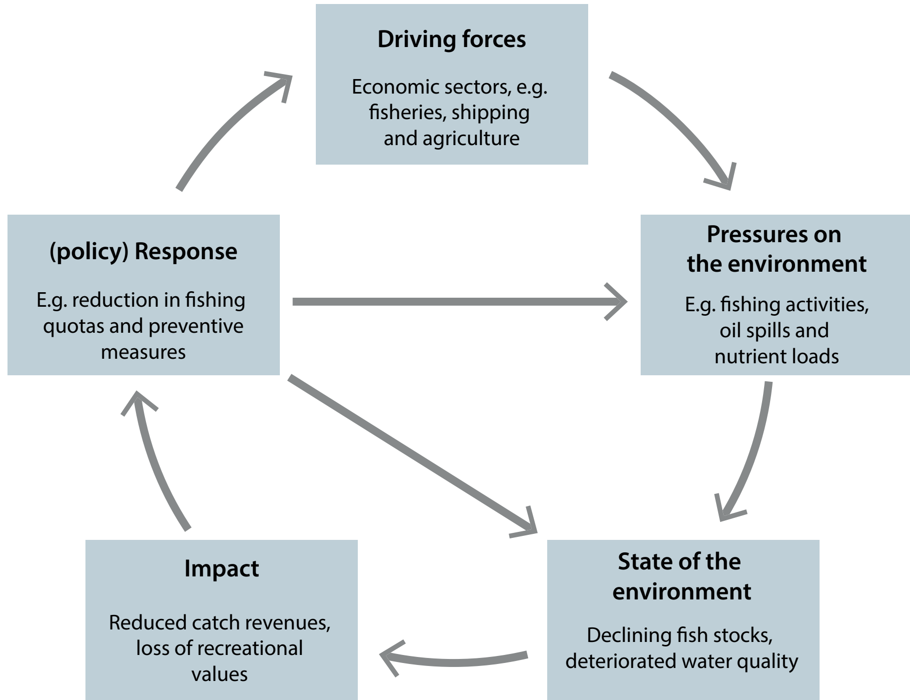


Figure 11.2. The DPSIR (Drivers-Pressures-State-Impact-Response) framework.

The Impact on welfare is mainly caused by how different ecosystem services provided by the Sea are affected by changes in State and how these services affect the benefits to humans. Most of the ecosystem services are linked, implying that in order to protect/improve one of these, the state of a number of others, so called intermediate services, also need to be addressed. For example, the provisioning of fish as an ecosystem service is dependent on primary production, food-web dynamics, habitats, nutrient buffering, regulation of environmental toxins, resilience and so on (see Figure 11.3).

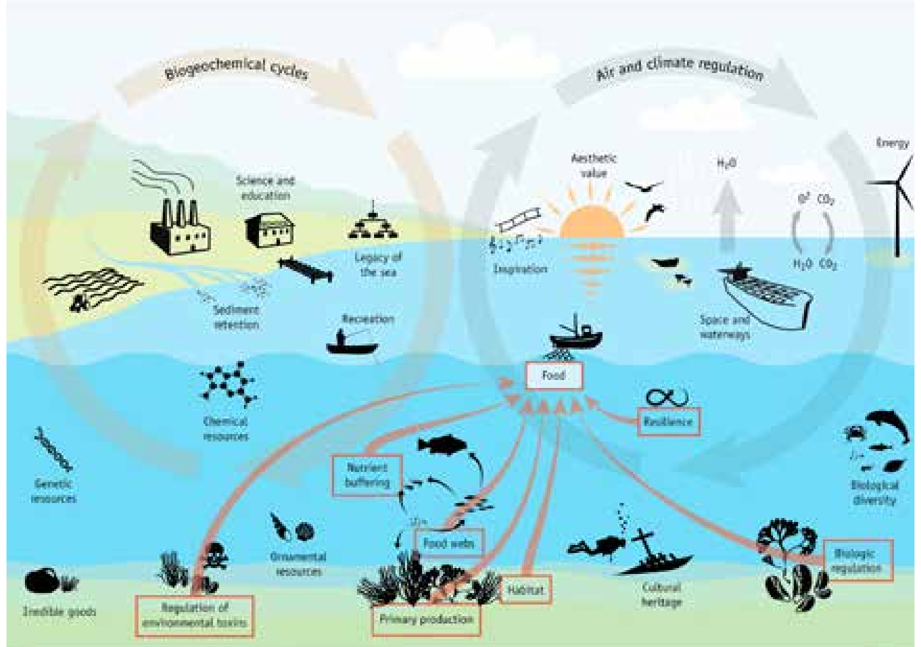


Figure 11.3. Intermediate ecosystem services (orange arrows) important for fish as food.

Therefore, any management of the fish stock need to, apart from focusing on the fishing effort, also consider the State of these services and the Drivers and Pressures affecting them. That is, the ecosystem should be the starting point of any management strategy.

Ecosystem approach

According to Borja et al. (2010) there is a trend in Europe towards more environmental-based governance of the Sea, where the focus is on reaching a certain environmental state (e.g. BSAP, MSFD, WFD).

EU's Marine Strategy Framework Directive (MSFD) states under article 1.3: "*Marine strategies shall apply an ecosystem-based approach to the management of human activities*". This requires an appropriate understanding of the marine ecosystems and the impact they have on human wellbeing. An ecosystem approach to management implies that the focus should be on considering the whole ecosystem and its dynamics and interactions, in contrast to traditional single resource/pollutant management. The aim is to maintain and protect functioning ecosystems capable of delivering ecosystem services for human wellbeing. It is, therefore, important to use the State of the ecosystem as a starting point for an ecosystem approach.

An ecosystem approach is especially relevant when assessing status and need for actions regarding the Baltic Sea, as this Sea is vulnerable due to its semi-enclosed character and brackish water with relatively few and interdependent species.

Figure 11.4 illustrates how the State of the ecosystem is affected by a variety of Pressures and Drivers. The different Pressures affecting the ecosystem State of the Baltic Sea are above all: nutrient load, fishing, oil spills, invasive species and hazardous substances. The figure illustrates that Drivers outside the boundary of the system, such as natural variability of for example climate, also have an effect on the State.

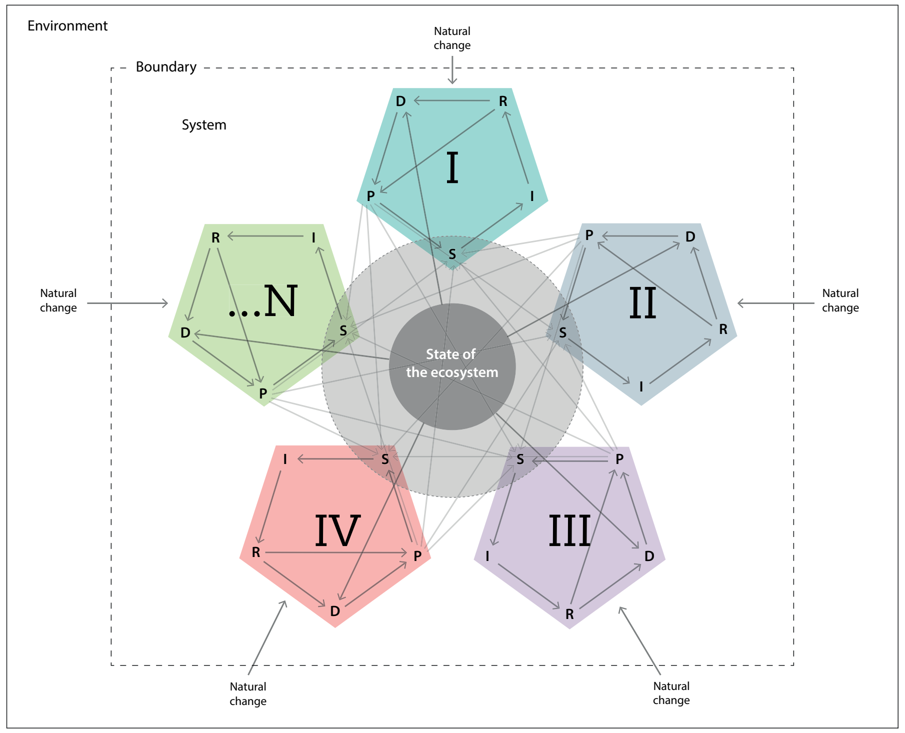


Figure 11.4. A nested DPSIR framework for the ecosystem approach. (Source: Atkins et al., 2011 modified by Mike Elliott and thereafter by the BalticSTERN)

There is a need to understand how effects of the different Pressures interact in the ecosystem and influences the State. Having decided on the ecosystem State aimed at, it is possible to determine necessary restrictions of Pressures such as nutrient loads, fishing effort, risk of oil spills and invasive species. In that way all environmental problems, as well as the interactions between them, are captured.

The management of these Pressures needs to be integrated, since the effect of one on the State might influence the effect of others.

Holistic approach

The ecosystem approach is a necessary base for a holistic approach. The former should be used to set up appropriate objectives (e.g. GES) for the state of the sea. The latter implies that all factors of the DPSIR framework and their linkages should be taken into consideration when managing the problems. This means that all the environmental problems and the pressures causing them need to be managed simultaneously, as illustrated in Figure 11.5. Each environmental problem needs to be addressed by a separate management strategy (R), but there is also a need to integrate these into a holistic management strategy. For example, the nutrient load causing eutrophication also affects the state of the fish stock, so any integrated management plan needs to take this double effect of eutrophication into consideration.

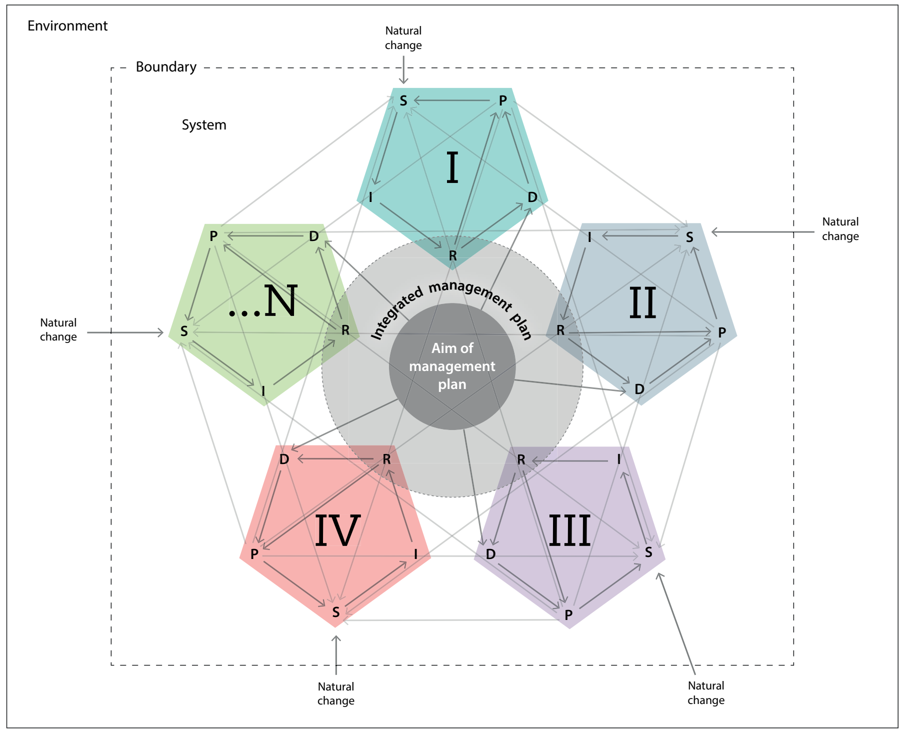


Figure 11.5. A nested DPSIR framework for the integrated management of the marine environment. (Source: Atkins et al., 2011 modified by Mike Elliott and thereafter by the BalticSTERN)

Horizontal and vertical integration

As illustrated in Figure 11.5, horizontal integration of strategies for different environmental problems is thus important for a successful management strategy. However, it might be even more important to integrate strategies from different policy areas. For example, policies and legislation targeting economic sectors, such as agriculture and fisheries, needs to be in accordance with polices and legislation aimed at improving the environmental state.

Vertical integration of different local, national, regional and international management strategies is important in order to obtain an efficient and transparent management. For example, actions on a local level against overfishing may be dependent on policies and legislation decided on a national, regional and international level, and vice versa. As emphasised by Hassler et al. (2011) national, regional (e.g. HELCOM) and EU levels of governance need to be closer coordinated in order to avoid inefficient overlaps and regulatory gaps.

11.3 Management strategies in an uncertain future

Management strategies must be adaptive in order to respond to possible future changes of drivers, growing evidence of external pressures, interactions and non-linear dynamics. Targets might need to be revised and policy instruments strengthened.

Any management strategy must be able to respond to future developments and new information. There are several possible ways in which future developments and new information can influence what has to be done in order to meet the environmental objectives, and thereby the possibility and cost of reaching these.

First, if there is reason to believe that one or several of the drivers targeted by the management strategy (e.g. agricultural production, shipping, fishing) will increase in the future, it will be important that the strategy is capable of handling such a possibility. This emphasizes the need for a management strategy, which, when confronted with changes in the drivers or new information (regarding e.g. the effect of a measure), can adapt in order to make sure that the environmental objectives are reached. For example, in order to not exceed the targeted nutrient load to the Baltic Sea, more measures might be required due to an increase in agricultural production. In order to take account of possible future pressures holistic scenarios as regards the development of significant drivers can be of help.

Second, management strategies must also be capable to deal with so called moving targets. The targets, and thereby measures, required for meeting the environmental objectives might change due to:

- Faster increase of external forces (e.g. climate change) than expected.
- Interactions that are not covered by the management strategy or yet not completely understood (e.g. eutrophication-invasive species)
- Feedback mechanisms that accelerate undesirable changes and the risk of regime shifts.

Regime shifts

Natural systems change constantly, even with minimal pressures from human activities. However, there is growing evidence that human activities are causing pressures to ecosystems that could lead to regime shifts, pushing the systems into a whole new state. There is still much to learn about recovery and options when thresholds have been surpassed.

Recent research shows that even if measures are taken to reverse a negative development of state (e.g. depletion of fish stock, increased primary production), it will probably take time for these to recover. Furthermore, as illustrated in Figure 11.6, one cannot be certain that the ecosystem (response variables) will fully recover (green curve), the recovery might be partial (orange curve) or in worst case it might not be possible to recover at all. Examples from different parts of the world show that ecosystems that have undergone regime shifts may not return to the original state even if pressures are reduced to the original level (Lotze et al., 2011). These examples often show patterns of only partial recovery.

One example with no recovery at all is the overfishing of cod (*Gadus morhua)* outside Newfoundland, which led to a collapse in the early 1990s. Despite a fishing moratorium no significant recovery has been seen up to date. (Hutchings & Reynolds, 2004)

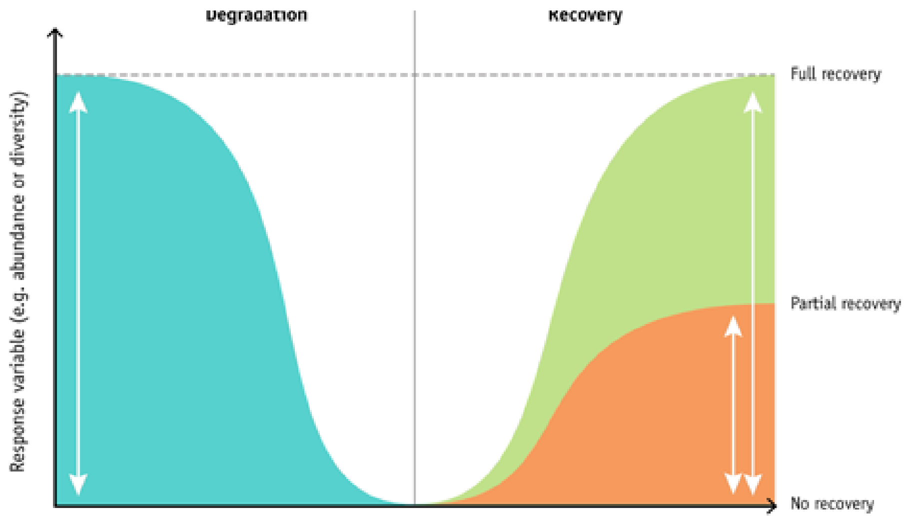
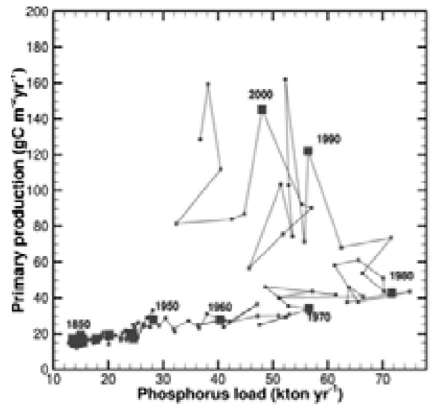


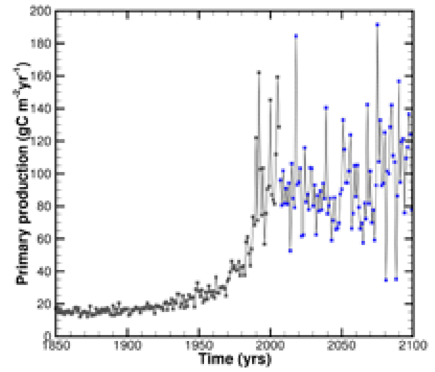
Figure 11.6. Recovery can be measured as the magnitude (arrows), rate (slope) and time of increase (or sometimes decrease) in a response variable, and compared to the magnitude, rate or time of previous depletion or degradation. Note that 'no recovery' could also consist of further decline or degradation.

As regards the Baltic Sea one could envisage that, for instance, the invasion of some new invasive species might be irreversible in that once they have established there are no ways to get ride of them. Also, changing conditions of the Sea, in combination with pressures such as overfishing, may lead to irreversible extinction of present species.

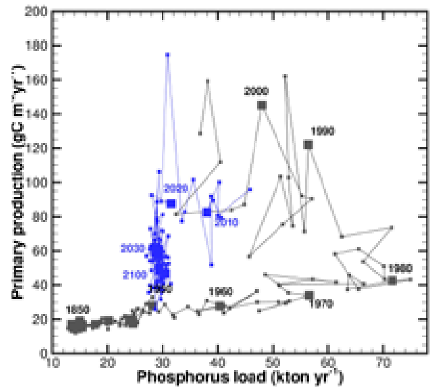
Modelling done at the Baltic Nest Institute indicates that eutrophication may be a problem for which it is difficult to reach a full recovery. Figure 11.7 illustrates the relation between phosphorus load and primary production (and thereby probability of algae blooms) in the Baltic Sea based on data from the period 1850–2006. It seems that in the 1980's a threshold may have been surpassed after which reductions of phosphorus loads did not lead to any reductions of primary production.



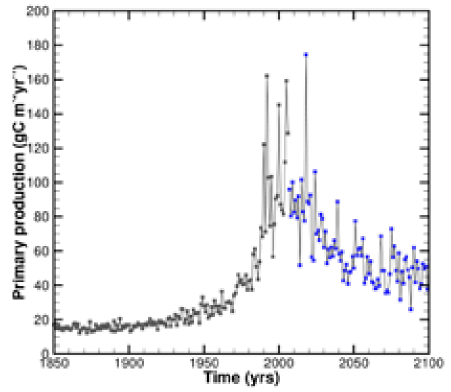
Figur 11.7



Figur 11.8



Figur 11.9



Figur 11.10

Figures 11.7–10. Relation between phosphorus load and primary production in the Baltic Sea based on data from the period 1850-2006 and modelling estimates 2007-2100. (Source: Unpublished figures, Bo Gustafsson, BNI (see also Gustafsson et al., 2012))

If phosphorus loads would remain at the same level as in 2006 primary production would develop as illustrated in Figure 11.8, where the blue line indicates predicted levels. As can be seen, there is not much of recovery as regards primary production up to 2100. However, if the phosphorus load is reduced somewhat more after 2006, a significant effect on primary production is predicted as illustrated in Figure 11.9 and 11.10. Although, compared to the 1950s there is still not full recovery. Figures 11.7-11.10, thus, illustrate a case of partial recovery, in that even though the phosphorus loads have been reduced to a level corresponding to the 1950's, the primary production is still higher compared to that time as illustrated in Figure 11.10. An interesting observation is that the figures indicate that there may be thresholds also regarding actions to reverse negative developments.

Since changes in the state have implications for the benefits derived, high welfare values may be at stake if there is a risk of regime shifts. It seems that this is the case regarding the benefits to human societies provided by the Baltic Sea. Furthermore, the dynamics of ecosystems can be slow. In connection to problems with long time spans between pressure and effects, such as is the case of eutrophication, invasive species, hazardous substances and to some extent oil spills, observations in the ecosystem as a basis for adaptive governance will not be satisfactory. Therefore, monitoring and developing models, which can help understand future effects of today's actions, are necessary tools for developing adaptive management strategies. It is therefore important with a science-policy dialogue.

The challenge for policy is to develop management strategies that can take into consideration the possibilities of regime shifts and threshold effects. That is, avoiding passing thresholds, but also understanding what is required once a regime shift has occurred and whether it is even possible to reverse such a shift and recover. In addition, management strategies must take into consideration that there might exist threshold points with regard to the effect of measures on state, as illustrated in figures 11.7–11.10. Even if a full recovery is not possible there may be ways to manage transformation so that welfare values are not lost.

Management challenges

A management strategy must be flexible for several reasons. First, a future increase of drivers might imply that more measures need to be implemented in order to reach the targets. Second, the ecological objectives might require a revision of the targets (e.g. allowable catches, maximum nutrient load) necessary to meet the objectives (e.g. good ecological status) due to change of external forces, ecosystem dynamics/interactions, possible feedback mechanisms and risk of regime shifts. This could imply that more measures are needed even if there is no increase of drivers.

Management strategies must be adaptive in that they include the possibility to revise the targets and the policy instruments towards the measures required to meet those targets.

In summary, a deeper sustainable management strategy, aimed at building the resilience required to cope and adapt to change, may be needed to respond to possible future increase of drivers, growing evidence of external pressures, interactions and non-linear dynamics.

11.4 Management of specific environmental problems

As a basis for an integrated management strategy there is need for specific management strategies towards the different environmental problems. These must to a large extent be guided by the characteristics of the problems, as well as the drivers causing them.

The different types of environmental problems of the Baltic Sea have been described to various degrees in this report. It is obvious that there is a connection between the problems, in that the effects of one (e.g. overfishing on fish biomass) influence the effects of others (e.g. eutrophication), making a holistic perspective necessary.

However, the drivers, pressures and the responses in form of governance structures related to the different problems differ. A main driver behind risks for oil spills and invasive species is shipping, which is mainly targeted by international governance, such as within the IMO (see Chapters 7 and 8). Eutrophication is the result of nutrient loads and atmospheric depositions from several different drivers, mainly within the catchment area of the Baltic Sea. Agriculture is a major source, but wastewater and traffic are also dominant drivers.

The type of specific management strategies that best addresses the environmental problems of the Baltic Sea must to a large extent be guided by the characteristics of the problems, as well as the drivers causing them. Management strategies that may be appropriate in addressing overfishing might not have the same success in addressing eutrophication, and vice versa.

Table 11.3 provides an overview of the different problems described in this report. First, the drivers and pressures of the different problems are specified, followed by their effects on the state and finally impact on benefits. Finally the main framework structures related to the problem in question is displayed.

Consumption patterns are indirect drivers behind all of the environmental problems of the Baltic Sea. Consumption of food, in terms of agricultural products and fish, is a driver behind eutrophication and overfishing, while consumption of oil and other commodities leads to oil spills, invasive species and hazardous substances. How the problem will evolve in the long run will therefore be affected also by changes in global and regional consumption patterns.

Important governing environmental frameworks addressing eutrophication are MSFD, WFD and BSAP, but CAP is also important for the development of this problem. EU's Common Fishery Policy (CFP) is the main framework governing fishery in the Baltic Sea. See BG Paper *Management frameworks* for a more detailed description of the different governing frameworks addressing the environmental problems of the Baltic Sea.

Table 11.3. DPSIR of the different environmental problems presented in this report.

	Eutrophication	Over fishing	Oil spills	Invasive species	Hazardous substances
Drivers	Consumption, Agricultural production, Wastewater, Industry, Shipping	Consumption, Fishing fleet	Consumption, Shipping, Port activities, Oil demand,	Consumption, Shipping, Aquaculture	Consumption, Waste & goods, Industry, Wastewater, Shipping
Pressures	Nutrient load, Atmospheric deposition, Climate	Fishing effort, Eutrophication, Hazardous substances, Climate	Intentional oil spills Accidental oil spills	Ballast water Climate	Releases of hazardous substances War chemicals Dump sites Invasive species
State	Turbid water, Algae blooms, Hypoxia, Secchi depth, clarity of water Underwater meadows, Fish spawning and fish stocks	Fish stock, Food-web, Eutrophication	Biodiversity Status of water	Biodiversity	Toxicity Impaired reproduction Food web
Impact	Recreation Fish landings Tourism	Fish landings Recreation	Recreation Fish landings	Fish landings Recreation	Health Fishing Recreation
Response:					
Target state	BSAP, MSFD,	MSFD	MSFD, BSAP	MSFD, BSAP	MSFD, BSAP
Target pressures	WFD, Nitrate directive, BSAP	CFP	IMO	IMO, CBD	
Target drivers	EUWWTD, IMO, CAP, UNFCCC	UNFCCC	IMO, MARPOL, UNFCCC	IMO MARPOL UNFCCC	REACH, CLRTAP, POP's convention

Most of the different governance structures under response in the table above provide a framework for actions and sometimes even policy instruments addressing the problems. However, it is in most cases (e.g. BSAP, MSFD, WFD) up to the individual country to determine and implement the type of policy instruments needed to generate the measures so that the objectives are reached. The success of any chosen management strategy will therefore depend on whether it includes policy instruments sharp enough to get the necessary measures implemented.

Important factors to consider when choosing policy instruments are target fulfilment, cost-effectiveness and dynamic cost-effectiveness, as well as other aspects such as distributional effects and uncertainties (see Goulder & Parry, 2008; Sterner & Coria, 2012). The compliance of any policy instrument is also important to take into consideration when choosing and designing policy instruments. In the following sections the importance of these different aspects is discussed for each of the specific environmental problems. Risks and uncertainties related to the different problems are discussed partly based on the work by Hassler et al. (2011) and Hammer & Gilek (2012). The characteristics of the environmental problems and the targeted sectors and measures are also important to take into consideration when choosing policy instrument. See BG Paper *Management frameworks* for a more detailed description.

Oil spills and invasive species

Target fulfilment and monitoring compliance are important with regard to oil spills. Monitoring and discussion on targets and strategies are needed as regards invasive species.

The problems of *oil spills* and *invasive species* are similar in that the risk of incidents with very large effects is not high at every given moment, but there is a considerable risk that at some point a large oil spill will occur or an aggressive invasive specie may succeed to establish, and the effects on state and impacts on welfare can in those cases be very high. A common denominator for these two problems is that the main driver, shipping, is regionally and globally mobile, which makes monitoring compliance complicated. Due to this, it is governed mainly by international regulations, such as IMO.

A strategy needs to consider both preventive and reactive measures, as well as the policy instruments needed to get such measures implemented. The two problems, however, differ regarding uncertainties and existing governance.

The risk for oil spills has been dealt with for a long time and there are even internationally overlapping regulations. The risk is well known and the consequences are also foreseeable, even if more knowledge may be needed regarding sensitivity in specific spatial areas. Monitoring and enforcing compliance must be a major part of any management strategy aimed at this problem. (Hassler et al., 2011)

With regard to invasive species, current knowledge is quite poor regarding both the probability of the intrusion of invasive species into the Baltic Sea and its consequences (Hassler et al., 2011). Due to the large uncertainties regarding consequences the focus should be on preventive measures. The International Ballast Water Convention coordinated by IMO is an important step for managing this problem.

As the main driver, shipping, is governed mainly by international regulation that are two main options for policy: 1) to influence this regulation, which could be done through for example alliances with concurring partners, and 2) to use the more restricted national (or local) room for manoeuvre, focusing on compliance and activities with national competence, such as port activities.

Overfishing

> Target fulfilment is more important than cost-effectiveness and dynamic efficiency criteria. Monitoring compliance and stakeholder involvement is crucial.

Fishing deals with management of a common renewable resource. *Overfishing* is the only environmental problem addressed in this report where the main sector causing the problem and the main sector affected is the same. It is, therefore, necessary, but maybe not sufficient, that management of the Baltic Sea fish stocks involves the stakeholders. As the understanding of the problem often appears to differ between researchers and fishermen, for example regarding the status and character of fish stocks, dialogues between sciences, policy and stakeholders seems to be important for this problem (Hassler et al., 2011).

As regards fishery, it is important to monitor the development of different fish species and that management is able to respond quickly to signs of reduction of stocks and changes in food web composition, for example, by changing total allowable catches quotas. Accurate data regarding status of fish stocks and fish landings are vital when setting targets within the EU Common Fishery Policy (CFP) as well as for regional dialogues. The case study FishSTERN (Swedish EPA, 2011) indicated that there might still be need for improvements regarding fish landing data (see Chapter 6).

Recent CFP management plans are reported to have had some positive effects, with cod stocks recovering in the Baltic Sea. As there still exist considerable overcapacity of the fishing fleet a stringent management is important. The case study FishSTERN indicated that a lower fishing effort would be positive for profits and employment as well as ecosystem health.

Monitoring compliance is crucial but complicated mainly due to the mobility of fishing vessels. In Chapter 6 it is suggested to use a twofold strategy, where compliance is strictly monitored for the fewer pelagic vessels, which stand for the main part of fish landings, while the many small coastal fishing vessels could be managed in a more self-organizing system.

There is a strong link between the state and value of the fish stock and other environmental problems of the Baltic Sea, such as eutrophication, oil spills, invasive species and hazardous substances. For example, even if successful management of the fishing effort would lead to a larger fish stock, the value of such a fish stock might be compromised by the accumulation of hazardous substances in the fish (e.g. dioxin and mercury), reducing its value for consumption.

Eutrophication

> Cost-effectiveness and dynamic cost-effectiveness criteria are important in mitigating eutrophication, but target fulfilment is also crucial.

Eutrophication is a complex problem as there are drivers in different economic sectors and many sources are diffuse in character. Wastewater treatment, agricultural production, industry and traffic are the main sources, and there exist a vast number of measures that could be used to reduce the nutrient load from these. The major part of the sources are located in the Baltic Sea region, making it possible to address them with regional management strategies.

As many of the possible measures are quite costly, and the costs vary much between different measures and also for the same measure at different locations, it is important to find cost-effective solutions and create strong incentives for the development/innovation of new measures. The risk of passing thresholds that could cause potentially irreversible regime shifts, however, also makes it important to achieve target fulfilment. While the nutrient loads from wastewater treatment can be expected to decrease in the future (mainly due to the implementation of EU's UWWTD), it is possible that the agricultural production in the region will increase. All this has to be taken into consideration by allowing for flexibility in the management strategy.

In the long run it is necessary with policy instruments that could lead to reduced inputs of phosphorous and nutrients to the system and that could create incentives for a circular system of nutrients. For example, a tax on the prime factor behind the problem, namely fertilizers, would give a signal to all users to reduce the use of this input. However, a tax would not guarantee target fulfilment and could, out of competition reasons, also perhaps not be high enough to achieve the needed reductions. Such a tax might therefore need to be complemented with other policy instruments. A nutrient credit trading or permit fee system, as suggested in NEFCO (2008) and Swedish EPA (2009b), might be a way to achieve both cost-effectiveness and target fulfilment, and could be worth testing on a smaller scale, for instance a catchment area. See further reasoning in Chapter 5. Such a combination of tax and nutrient credit trading or permit fee system might also create incentives towards an agricultural production characterised by resource efficiency and less nutrient leakage without compromising the production capacity.

Hazardous substances

> Target fulfilment and monitoring compliance are important for a strategy on hazardous substances. Measures that could cope with the problems upstream should be aimed for.

Release of *hazardous substances* could pose serious threats to the Baltic Sea ecosystem and will interact with other pressures influencing the Sea.

Through the Baltic Sea Action Plan (BSAP) the Baltic Sea countries have committed themselves to achieve a "*Baltic Sea with life undisturbed by hazardous substances*".

Loads and impacts of some hazardous substances have been reduced considerably during the past 20-30 years, but concentrations of some other substances have increased in the marine environment. Knowledge regarding is quite good regarding some hazardous substances while there is a significant lack of such knowledge for many existing and new substances. Furthermore, knowledge regarding the risks hazardous substances cause the Baltic Sea ecosystem, with its special conditions, is still inadequate. However, it is clear that the pollution caused by hazardous substances do pose risks to the Baltic Sea and impacts benefits to human societies negatively (e.g. through high content of harmful substances in fish).

There has been no study within BalticSTERN regarding hazardous substances. However, a recent research project, COHIBA (Control of hazardous substances in the Baltic Sea region) has studied sources and inputs of eleven hazardous substances or substance groups of the HELCOM Baltic Sea Action Plan (BSAP), which are not very well known. The project also developed recommendations for measures to reduce these substances. The overall objective of COHIBA was to support the implementation of the BSAP with regard to hazardous substances by developing joint actions to reach the goal. (Pitke et al., 2012)

According to COHIBA point sources remain relevant within the Baltic Sea region, but diffuse sources, including emissions during the service life of consumer articles, are becoming increasingly important. Atmospheric deposition seems to be important for the occurrence of several of the BSAP-substances in the Baltic Sea and in the Baltic Sea catchment area. Furthermore, atmospheric transport is an important pathway for several of the substances into the region. It is also, according to the project, important to find demolition techniques, which reduce emissions of hazardous substances in for example building materials. Combustion facilities for energy/heating (especially residential) and to some extent waste are important sources for which measures should be proposed in order to decrease emissions. The project also emphasizes the need to track upstream sources of emissions from wastewater treatment plants.

A conclusion from the COHIBA project is that there is no "one size fits all" management strategy. As a basis it is necessary that "core measures", such as those required according to the EU Urban Wastewater Treatment Directive (EU UWWTD) and the EU Directive on Integrated Pollution Prevention and Control (EU IPPC), are implemented. On top of these measures, and depending on local boundary conditions, an adapted set of combinations of measures must be found. This should be done in an iterative process starting with measures promising a big reduction at reasonable costs. The progress made and the selection of measures should be reviewed regularly.

The widespread content of hazardous substances in goods and their diffuse releases is a complex issue. There was a 57-fold increase in world production of chemicals during the second half of the 20th century and production still increases. Trade is global and control of risks therefore difficult. Humans and the environment are exposed to many substances simultaneously, and there is not sufficient knowledge of their effects. (KEMI, 2011)

An upstream strategy is necessary to cope with hazardous substances in consumer articles. Additional international regulations need to be considered for those substances, which reach the Baltic Sea Region via imported products or via long-range transport (Pitke et al., 2012). Most relevant within EU is the regulation on chemicals and their safe use, REACH (Registration, Evaluation, Authorization and Restriction of Chemicals Substances). Globally there are several conventions covering hazardous substances of priority, which need to be ratified by all HELCOM Contracting States. These are above all the Stockholm POPs (Persistent Organic Pollutants) Convention, the protocols on POPs and heavy metals under the Convention on Long Range Transboundary Air Pollution (UNECE-CLRTAP), the IMO Anti-fouling Convention, and the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.

Since there are uncertainties regarding both the hazard of individual substances and the risk they pose when released to the Sea, a precautionary approach is advisable in the management of hazardous substances. Such an approach is often recommended and is also suggested by Hassler et al. (2011). The authors' note, however, that while the precautionary principle is increasingly stipulated for coping with uncertainty, there is little agreement and guidelines on how this principle should be implemented in practice.

The widespread content of hazardous substances in goods and their diffuse releases are difficult to control and an upstream strategy is necessary. To really manage the problem it may be necessary to introduce more general criteria regarding non-acceptable properties of substances as practised to some extent for pesticides.

Targeting consumption patterns

Strategies and policy instruments targeting drivers and pressures in economic sectors may be complemented with policy instruments directed towards developing sustainable consumption patterns. For instance, as the consumption of meat is the driver behind livestock agriculture, causing the largest nutrient leakages; a tax on meat could be a plausible instrument. Exports and imports would however need to be considered, in order to judge possible effects on loads to the Baltic Sea. In addition, distributional effects may be important politically.

Targeting the State

Measures and policy instruments directed at State should be a parallel strategy. The effects of all the environmental problems described above also depend on the State of the Sea. The resilience of the ecosystem is of importance since it has implications for the consequences pressures have on the State. If resilience is low the Sea is more vulnerable and the effects may be worse compared to if there was a good capacity for natural mitigation and recovery from disturbances. According to the analyses on the ecosystem services made by the Swedish Environmental Protection Agency (Swedish EPA, 2008) Baltic Sea resilience is threatened. Measures to strengthen the resilience of the ecosystem and its ability to withstand pressures and to recover (after for instance oil spills) could therefore be recommended as a complementary and probably cost-effective way of reducing effects. This can be accomplished through for instance safeguarding important spawning areas. International studies have shown that biodiversity and redundancy is important for resilience (Folke et al., 2004; Carpenter & Cottingham, 1997; Walker, 1995).

Marine spatial planning may be a helpful tool in protecting and improving the State if practiced in a more holistic way compared to what seems to be standard today (see Chapter 6.3). A marine spatial zoning plan for the Baltic Sea could serve as a basis for setting up biodiversity/habitat protection sites, directing shipping routes away from sensitive areas, deciding on suitable areas for wind power etc.

Long-term models estimate warmer waters with lower salinity, and this will have effects on for example fish stocks, food webs and possibilities for invasive species to survive. To buffer and build resilience may prove even more important when taking a long-term and broader view.

To conclude, every environmental problem needs a specific management strategy. But, as discussed in 11.2 and 11.3 there is also need for an integrated management strategy capable of coping with the linkages between different environmental problems and evaluating the specific management strategies from a holistic point of view. For example, how will the management of eutrophication, hazardous substances, invasive species and oil spills influence the success of the management of fisheries? Such an integrated overview of the problems might reveal a need to re-evaluate and modify the specific management strategies. In retrospect, the problem of eutrophication might not have become as severe as it presently is, if the management of the Baltic Sea fish stocks had been more successful.

11.5 Preconditions for change

Although there are many preconditions for change at place, a number of obstacles still needs to be tackled.

Preconditions at place

Experiences from other environmental problems, such as ozone depletion, acidification and banning of certain hazardous substances, show that some preconditions often seem to be crucial for the ability to cope with the problems. Consensus about the problem, leadership and advocating actors, critical mass of public awareness and media attention as well as technical solutions, which economic sectors behind the problems can apply, seem to be important for action to take place. Political will and preparedness to decide on policy instruments sharp enough is in the end decisive for solving the problem. (SOU, 2007)

In order to safeguard the health of the Baltic Sea several problems have to be tackled simultaneously, which complicates the picture. Future climate change makes the task even more challenging as such changes will affect all of the problems presently encountered.

Regarding most of the environmental problems there is sufficient knowledge regarding drivers, pressures and their effect of the state of the Sea, as well as the connection between this state and human welfare. There are also frameworks and targets at place through, for example, MSFD, WFD, BSAP and CFP. Measures to cope with these problems have also been identified. The BalticSTERN surveys BalticSurvey and BalticSUN show that there is awareness of the problems and public support for actions to be taken.

There are many constellations engaged in improving the state of the Baltic Sea. HELCOM (Helsinki Commission) is the overarching body for political discussions and negotiations among all littoral states. Baltic Sea Regional Advisory Council (BS RAC) with stakeholder, government, NGO and scientific representation, as well as BaltFish, a body for collaboration among Fishery Ministries in Baltic Sea countries, are organisations for discussing fishery policies.

Other bodies are Council of the Baltic Sea States (CBSS) and Baltic Development Forum, which are both engaged in giving input to the EU Strategy for the Baltic Sea Region (EU SBSR). Coalition Clean Baltic is an umbrella organization for NGO's and Baltic Sea Action Group focuses on dialogues with business. Baltic Sea Forum is a private network organisation with members from business, politics and administration. VASAB (Vision and Strategies around the Baltic Sea) holds ministerial conferences on the spatial development of the Baltic Sea Region and has launched *Long Term Perspective for the Territorial Development of the Baltic Sea Region till 2030*. In Sweden, a number of coastal counties and municipalities have joined forces in the *Baltic Sea Initiative*, with the aim to cooperate and share experience regarding local actions to deal with the environmental problems of the Baltic Sea. There are thus several forums where scenarios and solutions for the future can be discussed among different stakeholders.

In summary many preconditions for actions to solve the problems are at place. There is

- sufficient scientific consensus regarding the problems and their origin,
- public awareness and support for action,
- political frameworks at place,
- political will expressed and
- measures identified.

So what more is required to reach the desired state of the Baltic Sea? There is obviously need for policy instruments that could give incentives to actors to implement necessary measures. So why are these policy instruments not in place? What are the hindrances? In the following section, these questions will be discussed.

Obstacles and options

Institutional weaknesses

The most adequate level for an integrated management plan with an ecosystem approach and a holistic perspective would be the regional level (i.e. the Baltic Sea region), where HELCOM is the obvious relevant overarching forum. At the regional level it is possible to simultaneously address all the environmental problems and evaluate their combined effects in the common ecosystem, the Baltic Sea. It is also possible to identify drivers and cost-effective solutions. And it would be possible to make scenarios for future development and integrate risks for surpassing thresholds and be trapped in perhaps irreversible regime shifts. This could be undertaken in an iterative science-policy dialogue over time involving also stakeholders. To some extent there are already such on-going processes within HELCOM. A recent study (Valman, 2013) indicates that there may still be work to be done for a thorough ecosystem approach to be applied within HELCOM. The study points to a need to better integrate ecosystem assessments with management.

The HELCOM BSAP addresses many of the main environmental problems of the Baltic Sea. For one of the most severe problems, eutrophication, there is also a well defined agreement on reductions of nutrient loads and a process for monitoring and revising targets, as well as a policy-science dialogue for the process (HELCOM, 2007b). The weakness, however, is that the agreement is not binding. It is up to each country to decide on policy instruments that could give incentives for the necessary measures. And there are no sanctions if this is not happening. This also implies that policy instruments embracing several countries, that could have the potential to create more cost-effective solutions, may not be considered.

The enlargement of EU, to also include as members Poland and the Baltic countries, changed the preconditions for binding legislations regarding the Baltic Sea. In those environmental problem areas where there exists specific EU legislation, such as the EU Wastewater Treatment Directive, this has made a big difference for reduction of pressures.

The EU framework Directives, MSFD and WFD, are of the necessary long-term, overarching character, setting targets for the status of the Waters and the Sea, respectively. They also demand that Member States shall develop programmes of measures. However, deciding on policy instruments to get those measures implemented will be the responsibility of each Member State, and these directives are thus of a less binding character. An obvious weakness is that EU Directives are not encompassing all Baltic Sea countries.

A way forward may also be to start such cooperation on a basin-wide level. For example, to reach a good status in the Gulf of Finland, the three states Russia, Finland and Estonia could cooperate in order to find common solutions. Such discussions could identify necessary measures regarding eutrophication, fishery and shipping, as well as policy instruments needed.

Distributional effect a hindrance

How the benefits and costs of improving the state of the Baltic Sea are distributed amongst different stakeholders (e.g. agriculture, shipping, industry, households) as well as different countries is of importance for the success of any management strategy. In the end, the distribution of the costs will depend on the type of policy instrument that is used to get the required measures implemented. For example, a tax on the polluting activities implies that it is the sectors that take the financial burden, while subsidising the required measures means that it is the taxpayers that take this burden (see BG Paper *Management frameworks*).

Resistance, awareness, financial situation and political priorities will differ among the nine countries. This might imply that implementation plans have different prospects of being realized in the respective countries. A solution to this, as regards eutrophication, might be to introduce some kind of trading system, which could also include possibilities of more cost-effective actions.

There is consensus about the main problems among scientists and within HELCOM, but maybe not consensus enough among all stakeholders. Due to asymmetric information there may be disagreement on certain aspects of the problem, for example, uncertainties regarding the effect and cost of measures or the state of the problem and its impact on human well-being.

Economic sectors that would need to invest in measures but do not enjoy the benefits, might have incentives to disagree both on the seriousness of the problem and as regards the actions required.

Science-policy-stakeholder dialogues are needed to clarify the different standpoints and the evidence for those. By involving stakeholders in the formulation of problems, targets and needed action, the knowledge base for and legitimacy of decisions and their implementation may be strengthened. Apart from stakeholders representing sectors that need to take measures, also groups whose benefits are at risk if no action is taken should be represented (e.g. by NGO's). The dialogues should be iterative and include not only environmentally governing bodies but also representatives from bodies governing the relevant economic sectors, such as Ministries of Agriculture, Fishery and Finance.

Compliance

Any management strategy should also consider the importance of compliance.

Even if policy instruments are in place, there is no guarantee for reaching the targets, as there might be non-compliance. Non-compliance of policy instruments is to a varying degree a problem for the different measures suggested. Non-compliance is mainly determined by the following three factors: 1) gain of non-compliance, 2) possibility of being detected, and 3) consequences of being detected.

It is possible that the gain of non-compliance is not that large, but if the possibility of detection is almost zero, non-compliance might still be the choice for the regulated actor. If the consequences (e.g. fines) of non-compliance are minor, non-compliance might still be the choice even if the possibility of being detected is high. The incentives for non-compliance related to policy instruments must therefore also be considered in any management strategy, as it will affect the probability as well as cost of reaching the targeted objective. The risk and implications of non-compliance must be considered for all policy instruments and environmental problems.

Short-term versus long-term perspectives

There is awareness of the environmental problems of the Baltic Sea among stakeholders and among the public, but there may still not be full awareness among most of the actors in all countries regarding long-term shifting base lines, nonlinearities, risk for collapse of important ecosystem services and the effects this may have on benefits.

It is therefore of importance that scenarios for the future development of drivers and pressures are developed. There is also a need to understand the combined and dynamic effects future pressures may have on the Baltic Sea ecosystem. Scenarios should be discussed openly to create awareness in civil society and among stakeholders as well as preparedness to respond politically.

In order to safeguard the health of the Baltic Sea, several problems have to be tackled simultaneously, which complicates the picture. Future climate change makes the task even more challenging as such changes will affect all of the problems presently encountered.

Experiments and new solutions

Some of the measures to reduce eutrophication included in the BalticSTERN Cost-Benefit Analysis are costly and might be hard to get fully implemented under present conditions. This could be the case for measures such as livestock reduction. If demand for meat is increasing in the region and globally, it may be very difficult to enforce such measures.

There is therefore a need to explore possible other ways of reducing nutrient loads. There exists a number of measures, which might be of low cost, that were not included in the CBA analyses, and that could be included when there is better knowledge about their effects, capacity and cost functions.

Testing and evaluation of new agricultural practices and abatement technologies are thus important. Their prospects regarding both agricultural yields and potential for nutrient load reductions should be looked at. This could be done on a small geographical scale.

The strategy may include different ways to test also new policy instruments. For instance a cap-and-trade system regarding nutrient loads could be tested on a local level and if successful, thereafter broadened to cover a whole basin's catchment area, for example the drainage areas of the three countries affecting the Gulf of Finland.

There is an ongoing discussion on what could be sustainable agricultural solutions in a world of growing food demand, prospects of peak phosphorous and increasing pressures on ecosystems. Solutions that could lead to reduced inflow of nutrients to the system and recycling of nutrients are needed.

Incentives for innovative solutions will of course be desirable also for other environmental problems than eutrophication. Innovations and solutions regarding fishing gears might be important to avoid unwanted catch and thereby discards. With regard to hazardous substances the development of less hazardous substitutes will be important.

Lifestyles

There is also a discussion about the sustainability of today's lifestyles and consumption patterns. Western lifestyles with increase of meat in the diets have both negative health effects and severe environmental consequences, especially if copied by large parts of the growing population on Earth. Western consumption is also linked to the shipping of goods in the Baltic Sea, with implications for risk of oil spills and invasive species. The problem of hazardous substances is also closely linked to the production and consumption of goods

in the region.

Strategies and policy instruments targeting drivers and pressures in economic sectors may be complemented with policy instruments directed towards developing sustainable consumption patterns. For instance, as the consumption of meat is the driver behind livestock agriculture, causing nutrient leakages, a tax on meat could be a plausible instrument. Exports and imports would, however, need to be considered, in order to judge possible effects on loads to the Baltic Sea. In addition, distributional effects may be important.

In summary, even if many preconditions for action seem to be at place there may still be lack of adequate institutional competence, need for a deeper consensus between all crucial actors, less costly solutions and strengthened political will and ability in all countries. To overcome these obstacles there may be need for new thinking also regarding policy instruments and present lifestyles.

11.6 Future research

There is a need to further develop and use different models to estimate what the long run effects on the Baltic Sea from different drivers and pressures might be. Furthermore, connecting the model-based quantitative scenarios with regional and global qualitative storylines would provide the opportunity to develop more policy relevant scenarios.

More research needs to be carried out regarding the appropriate policy instruments and other aspects of marine management strategies for the Baltic Sea. An evaluation of the existing policy instruments in the Baltic Countries would provide a good starting point for determining the need for new policy instruments. Research regarding different incentives of compliance for the different problems would provide important input to either the strengthening of existing policy instruments or the implementation of new policy instruments.

The linkages between different environmental problems of the Baltic Sea need to be better understood for an integrated management strategy.

Research on the linkages between ecosystem services and human welfare is of importance for developing an integrated management plan based on the ecosystem approach. The different benefits derived from the Baltic Sea must be identified and quantified. Other ways of monetary evaluation of these benefits, than the ones used in this report, is also an area for future research.

11.7 Conclusion

BalticSTERN studies show that there are high values at stake if the Baltic Sea Action Plan (BSAP) does not succeed. Every second person living in the Baltic Sea countries has experienced the effects of eutrophication, mainly in the form of water turbidity and algal blooms. Many are worried, not only about eutrophication, but also regarding other environmental problems, such as overfishing, oil spills and hazardous substances, litter and invasive species. A majority is willing to pay for achieving a healthier Sea.

It is also shown that the BSAP targets are possible to reach, even with the limited number of measures included in this study. It is further clear that this would generate welfare benefits of 1 000–1 500 Euros annually.

BalticSTERN scenarios indicate that if no further measures are implemented most of the Baltic Sea basins would be in a degraded state in 2050. The Baltic Proper would be in a really bad condition with very turbid water, blue-green algae blooms in large areas every summer and with constant oxygen shortages in sea bottoms in large areas. Underwater meadows would be almost lost and non-suitable for fish spawning. The cod stock would be close to extinction, sprat and herring would decrease but there would be lots of roach, carp and bream.

Furthermore, there is reason to believe that the situation could become even worse in a non-action scenario. Drivers and pressures may increase more than presumed and climate effects are predicted to cause warmer and less saline waters. The combined effects may trigger the ecosystem passed thresholds and into new states. Experience shows that such regime shifts may be difficult to reverse. As there may be non-linearities and not yet completely understood feed-back mechanisms in the system there is even risk for collapse of parts of the ecosystem.

This emphasizes the need for an ***ecosystem approach***, which should also be open for new information regarding ecosystem dynamics and the potential need to revise targets. The functions, dynamics and linkages of the marine ecosystem should determine the necessary targets for safeguarding the ecosystem services it provides.

Given the inter-linkages of environmental problems there is need for ***a holistic management strategy*** that could simultaneously deal with all problems affecting the ecosystem services. Furthermore, a robust management strategy also needs to be able to respond to future changes of drivers as well as the possibility of moving targets.

It is therefore important that the management is ***adaptive*** by, for example, implementing policy instruments that can be easily adjusted with respect to changes in drivers, pressures, and state. Monitoring the state and using models to estimate long run effects of actions taken will enhance the possibilities of successful management. For this, a continuous science-policy dialogue is vital.

For a successful management of the Baltic Sea it is also important to understand the main obstacles and reasons for not being able to cope with the problems and to find ways to tackle these. For instance, horizontal and vertical integration of different management frameworks will be required in order to avoid giving contradictory signals to actors.

A holistic, integrated regional strategy based on the ecosystem approach must be developed in cooperation between the Baltic Sea countries. HELCOM may be the institution most appropriate and their report HOLAS (HELCOM, 2010a) could be regarded as a first step in developing such a strategy. A way forward may also be to start such cooperation on a basin-wide level. For example, to reach a good status in the Gulf of Finland, the three states Russia, Finland, and Estonia could cooperate.

In the end it is the policy instruments of the management strategy that will be decisive for the state of the Baltic Sea and for the ecosystem services and benefits the Sea provides to human societies. The coming years will be crucial. According to the MSFD, plans for actions should be decided and reported by 2015, and the BSAP is to be revised with regard to country-specific targets at the HELCOM Ministerial Meeting autumn 2013.

Combating climate change will be of utmost importance also for the state of the Baltic Sea. To cope with long-term challenges significant structural changes will be needed in the energy sector, and may also be necessary as regards consumption patterns and agricultural production, for example, reducing the inputs to the nutrient cycle by a change in the way agricultural products are produced and transported.

To conclude there is need for an ecosystem based, holistic and integrated management strategy with a common vision for a sustainable transformation of the Baltic Sea, which could safeguard ecosystem services and the benefits they provide to human societies. Flexible management is important since the action required is likely to change over time due to the dynamics of the ecosystem as well as of the drivers.

REFERENCES

Agrimonde. 2009. Scenarios and Challenges for Feeding the World in 2050. *Summary Report*

Ahlvik, L., Pitkänen, H., Ekholm, P. and Hyytiäinen, K. 2012. *An econoic-ecological modeling framework to evaluate the impacts of nutrient abatement measures in the Baltic Sea*. 27+ p. [Manuscript, submitted]

Ahtiainen, H. 2007. *The willingness to pay for reducing the harm from future oil spills in the Gulf of Finland – an application of the contingent valuation method*. Discussion Papers 18. Environmental Economics. Department of Economics and Management, University of Helsinki.

Ahtiainen, H., Hasselström, L., Artell, J., Angeli, D., Czajkowski, M., Meyerhoff, J., Alemu, M., Dahlbo, K., Fleming-Lehtinen, V., Hasler, B., Hyytiäinen, K., Karlõseva, A., Khaleeva, Y., Maar, M., Martinsen, L., Nõmmann, T., Oskolokaite, I., Pakalniete, K., Semeniene, D., Smart, J., and Söderqvist, T. 2012. *Benefits of meeting the Baltic Sea nutrient reduction targets – Combining ecological modelling and contingent valuation in the nine littoral state*s, MTT Discussion Papers 1, 2012

Ahtiainen, H., Artell, J., Czajkowski, M., Hasler, B., Hasselström, L., Hyytiäinen, K., Meyerhoff, J., Smart, J.C. R., Söderqvist, T., Zimmer, K., Khaleeva, J., Rastrigina, O. and Tuhkanen, H. 2013. Public preferences regarding use and condition of the Baltic Sea-An international comparison informing marine policy. *Marine Policy*, http://dx.doi.org/10.1016/j.marpol.2013.01.011

Atkins, J., 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* 62: 215-226

BACC Author Team. 2008. *Assessment of Climate Change for the Baltic Sea Basin* (BACC), Regional Climate Studies. Springer Verlag, Heidelberg.

Baltic Sea Alien Species Database. 2012. http://www.corpi.ku.lt/nemo/

Barnes, R.S.K., and Mann, K.H., 1991. *Fundamentals of aquatic ecology*. Blackwell Sciences Ltd., Oxford, 270 pp.

Bignert, A., Olsson, M., Persson, W., Jensen, S., Zakrisson, S., Litz, N.K., Eriksson, U., Hagberg, L., Alsberg. T. 1998. Temporal trends of organochlorines in northern europe, 1967–1995. Relation to global fractionation, leakage from sediments and international measures. *Environmental Pollution* 99: 177–198.

Borja, A., Elliott, M., Carstensen, J., Heiskanen, A.-S., van de Bund, W. 2010. Marine Management – Towards an Integrated Implementation of the European Marine Strategy Framework and the Water Framework Directives. *Marine Pollution Bulletin* 60: 2175-2186

Brady, M. 2003. The relative cost-efficiency of arable nitrogen management in Sweden. *Ecological Economics* 47:53-70.

Carpenter, S. R., and K. L. Cottingham. 1997. Resilience and restoration of lakes. *Conservation Ecology* 1(2) Available on the Internet. URL: http://www.consecol.org/vol1/iss1/art2

Casini, M., Lövgren, J., Hjelm, J., Cardinale, M., Molinero, J.C., and Kornilovs, G. 2008. *Multilevel trophic cascades in a heavily exploited open marine ecosystem*. Proceeding of the Royal Society B 275 (1644): 1793–1801.

CFCA. 2010. *Annual Report of CFCA 2010*. Vigo.

Collie, J. S., Richardson, K., Steele, J. H. 2004. Regime shifts: can ecological theory illuminate the mechanisms? *Prog Oceanogr.* 60: 281–302.

COWI. 2007. *Economic analysis of the BSAP with focus on eutrophication*. Final report. April 2007.

Einarsson, P. 2012. Policy interventions for ecological recycling agriculture: available options for governments in the Baltic Sea Region. COMREC Studies in Environment and Development No. 5. BERAS Implementation Reports No. 1.

Elmgren, R. 1989. Man´s impact on the ecosystems of the Baltic Sea: energy flows today and at the turn of the century. *AMBIO* 18: 326-332.

Elmgren, R. 2001. Understanding human impact on the Baltic ecosystem: changing Views in recent decades. *AMBIO* 30: 222-231

Elofsson, K. 1999. *Cost-effective reductions in the agricultural load of nitrogen to the Baltic Sea*. In M. Boman et al. (eds.) Topics in Environmental Economics. Kluwer Academic Publishers.

Elofsson, K. 2003. Cost-effective Reductions of Stochastic Agricultural Loads to the Baltic Sea. *Ecological Economics* 47(1):13—31.

Enveco Environmental Economics Consultancy, DHI Sweden AB and Resurs AB. 2012. Marine tourism and recreation in Sweden: A study for the Economic and Social Analysis of the Initial Assessment of the Marine Strategy Framework Directive. SwAM Report 2012:2. Swedish Agency for Marine and Water Management, Göteborg.

European Commission. 2007. *Evaluation Report of Catch registration in Baltic Sea countries 2005-2006*.

European Commission. 2012. *REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on Member States' efforts during 2010 to achieve a sustainable balance between fishing capacity and fishing opportunities*. COM (2012) 368 final.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., Holling, C.S. 2004. Regime shifts, resilience and biodiversity in ecosystem management. *Annual review of Ecology, Evolution and Systematics* 35(1): 557 -581

Forsman B. 2003. Socioekonomiska effekter av större oljepåslag. Förstudie med scenario. [Socioeconomic consequences of major oil spill accidents – Preliminary study including scenario]. SSPA Rapport nr 2003: 3294-1. Räddningsverket, Karlstad.

Forsman B. 2006. Socioekonomiska effekter av större oljepåslag – scenariostudier för Halland, Skåne, Blekinge och Kalmar Län [Socioeconomic consequences of major oil spill accidents – scenario studies for the provinces of Halland, Skåne, Blekinge and the county of Kalmar]. SSPA Rapport nr 2006: 4238-1. Räddningsverket, Karlstad.

Forsman B. 2007. Socioekonomiska effekter av större oljepåslag – scenarios-

studie för Stockholmsregionen [Socioeconomic consequences of major oil spill accidents – scenario study for the Stockholm region]. SSPA Rapport nr 2007: 4478. Räddningsverket, Karlstad.
Fish, R., Burgess, J., Chilvers, J., Footitt, A., and Turner, K. 2011. Participatory and Deliberative Techniques to support the monetary and non-monetary valuation of ecosystem services: an introductory guide. (Defra Project Code: NR0124). Department for Environment, Food and Rural Affairs: London. Available at: www.defra.gov.uk.
Fisher, B., Turner, R.K., Zylstra, M., Brouwer, R., De Groot, R., Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirkby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu, D., Balmford, A., 2008. Ecosystem Services and Economic theory: Integration for policy-relevant research. *Ecological Applications* 18 (8): 2050-2067.
Fisher, B., Turner, R.K., Morling, P. 2009. Defining and classifying ecosystem services for decision-making. *Ecological Economics* 68: 643-653.
Gilek, M., Lundberg, C., Renn, O., Wolowicz, M., Linke, S., Jönsson, A-M., Hassler, B., Boström, M., Karlsson, M., Hammer, M., Udovyk, O., Söderström, S., Linke, S., Bonsdorff, E., Grönholm, S., Haahti, B-M., Joas, M., Kern, K., Dreyer, M., Sellke, P., Zgrundo, A., Smolarz, K. and Lemke, P. 2011. Environmental Risk Governance of the Baltic Sea. Deliverable 12 within the RISKGOV project.
Goulder, L.H., and Parry, W.H. 2008. Instrument choice in environmental policy, *Review of Environmental Economics and Policy* 2(2): 152—174.
Gren, I-M. 1993. Alternative nitrogen reduction policies in the Mälar region, Sweden. *Ecological Economics* 7:159-172.
Gren, I-M. and Zylicz, T. 1993. *Costs of the Baltic Sea Clean-Up: Will Wetlands Reconcile Efficiency with Biodiversity?* Beijer Discussion Paper Series, No. 24, Beijer International Institute of Ecological Economics, The Royal Swedish academy of Sciences, Stockholm.
Gren, I-M., Elofsson K., and Jannke, P. 1997. Cost-effective Nutrient Reductions to the Baltic Sea. *Environmental and Resource Economics* 10: 341-362.
Gren, I-M., Turner, K., Wulff, F. 2000a. *Managing a Sea – The ecological economics of the Baltic*. Earthscan, Publications Ltd., London.
Gren, I-M., Destouni, G and Scharin, H. 2000b. Cost effective management of stochastic coastal water pollution. *Environmental Modelling and Assessment* 5: 192-203.
Gren, I-M. 2001. International versus national actions against nitrogen pollution of the Baltic Sea. *Environmental and Resource Economics* 20: 41-59.
Gren, I-M. 2008. Adaption and mitigation strategies for controlling stochastic water pollution: an application to the Baltic Sea. *Ecological Economics* 66:337-347.
Gustafsson, B. G., Schenk, F., Blenckner, T., Eilola, K., Meier, H. E. M., Müller-Karulis, B., Neumann, T., Ruoho-Airola, T., Savchuk, O.P., and Zorita, E. 2012. Reconstructing the Development of Baltic Sea Eutrophication 1850–2006. *AMBIO* 41(6), 534-548. doi:10.1007/s13280-012-0318-x

Hammer, M. and Gilek, M. 2012. *Towards improved environmental risk governance of the Baltic Sea.* Deliverable 11 within the RISKGOV project.
Hasler, B., Smart, J.C.R., and Fonnesbech-Wulff, A. 2012. *Deliverable 8.1. RECOCA. Structure of BALTCOST drainage basin scale abatement cost minimization model for nutrient reductions in the Baltic Sea Region*.
Hassler, B. 2011. Accidental versus operational oil spills from shipping in the Baltic Sea – Risk governance and management strategies. *AMBIO* 40(2): 170-178
Hassler, B., Boström, M., Grönholm, S. and Kern, K. 2011. Environmental risk governance in the Baltic Sea – A comparison among five key areas. Deliverable 8 within the RISKGOV project. (www.sh.se/riskgov)
Hautakangas, S., and Ollikainen, M. 2011 *Making the Baltic Sea Action Plan workable: A nutrient trading scheme.* In Governing the blue-green Baltic Sea: Societal challenges of marine eutrophication prevention. Eds. Pihlajamäki, M., & Tynkkynen, P. FIIA REPORT 31
HELCOM. 2004. *The Fourth Baltic Sea Pollution Load Compilation (PLC-4).* Baltic Sea Environmental Proceedings NO. 93.
HELCOM. 2007a. *HELCOM Baltic Sea Action Plan*. HELCOM ministerial meeting Krakow, Poland, 15 November 2007, available at http://www.helcom.fi/stc/ files/BSAP/BSAP_Final.pdf, accessed on 4 May 2011
HELCOM. 2007b. *Towards a Baltic Sea unaffected by eutrophication*. HELCOM overview, 2007, Ministerial Meeting, Krakow, Poland, 15 November 2007. 35 pp
HELCOM. 2007c. *Assessment of the Marine Litter problem in the Baltic region and priorities for response.*
HELCOM. 2009a. *Eutrophication in the Baltic Sea – An integrated thematic assessment of the effects of nutrient enrichment and eutrophication in the Baltic Sea region*. Baltic Sea Environmental Proceedings No. 115B.
HELCOM. 2009b. *Biodiversity in the Baltic Sea – An integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea*. Baltic Sea Environmental Proceedings No. 116B.
HELCOM. 2009c. Reinforcing oil spill response capacity in the Baltic Sea. http://www.helcom.fi/stc/files/Publications/OtherPublications/Reinforcing_OilSpill_Resp_Capacity.pdf
HELCOM. 2010a. *Ecosystem Health of the Baltic Sea 2003-2007: HELCOM Initial Holistic Assessment*, Baltic Sea Environmental Proceedings 122.
HELCOM. 2010b. Maritime Activities in the Baltic Sea – An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea Region. Baltic Sea Environmental Proceedings No. 123
HELCOM. 2011. Fifth Baltic Sea Pollution Load Compilation (PLC-5). Baltic Sea Environment Proceedings No. 128.
Helle, I., Vanhatalo, J., Rahikainen, M., Mäntyniemi, S. and Kuikka, S. 2012. Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland, the Baltic Sea - How to do it? *ICES CM 2012/I:04*, 17-21 September 2012, Bergen, Norway.

Huhtala, A., Ahtiainen, H., Ekholm, P., Fleming-Lehtinen, V., Heikkilä, J., Heiskanen, A-S, Helin, J., Helle, I., Hyytiäinen, K., Hällfors, H., Iho, A., Koikkalainen, K., Kuikka, S., Lehtiniemi, M., Mannio, J., Mehtonen, J., Miettinen, A., Mäntyniemi, S., Peltonen, H., Pouta, E., Pylkkö, M., Salmiovirta, M., Verta, M., Vesterinen, J., Viitasalo, M., Viitasalo-Frösen, S. and Väisänen, S. 2009. *The economics of the state of the Baltic Sea -Pre-study assessing the feasibility of a cost-benefit analysis of protecting the Baltic Sea ecosystem*. Publication of The Advisory Board for Sectoral Research 2:2009.

Hutchings, J.A. and Reynolds, J.D. 2004. Marine fish population collapses: consequences for recovery and extinction risk. *BioScience* 54: 297-309

Hyytiäinen, K., and Huhtala, A. 2011. Combating eutrophication in coastal areas at risk for oil spills. forthcoming in *Annals of Operations Research,* DOI 10.1007/s10479-011-0879-2, available online.

Hyytiäinen, K., Lehtiniemi, M., Niemi, J.K., and Tikka, K. 2012. *An optimization framework for management of aquatic invasive species risk: the case of potential Asian clam (*Corbicula Fluminea*) invasion in thermal pollution areas of the Northern Baltic Sea*. European Association of Environmental and Resource Economists, 19th Annual Conference, 27 – 30 June 2012 http://www.webmeets.com/EAERE/2012/Prog/viewpaper.asp?pid=896

Ihaksi, T., Kokkonen, T., Helle, I., Jolma, A., Lecklin, T., and Kuikka, S. 2011. Combining Conservation Value, Vulnerability, and Effectiveness of Mitigation Actions in Spatial Conservation Decisions: An application to Coastal Oil Spill Combating. *Environmental Management* 47: 802-813

ICES. 2012. Cod in Subdivisions 25-32. ICES, Copenhagen, Available at: http://www.ices.dk/committe/acom/comwork/report/asp/advice.asp?titlesearch=&Region=30&Species=-1&Period=316&submit1=Submit+Query&mode=2 (January 2012)

IPCC. 2000. *Special Report on Emission Scenarios.* Cambridge University Press.

Jansson, A-M. and Kautsky, N. 1977. *Quantitative survey of hard bottom communities in a Baltic an: Biology of benthic Organisms*. 11th European Symposium of Marine Biology, Galway, 359 -366. Pergamon Press, Oxford.

Jansson, B-O. and Jansson, A-M. 2002. *The Baltic Sea: reversibly unstable or irreversibly stable?* In: Gunderson, L.H., Pritchard, L.P. (Eds.), Resilience and Behaviour of Large-Scale Ecosystems: 71–108. Island Press, Washington DC.

Kautsky, H. 1988. *Factors structuring phytobenthic communities in the Baltic Sea*. Doctoral thesis at the University of Stockholm, Dept. of Zoology.

Kautsky, H. 1991. Influence of eutrophication on the distribution of phytobenthic plants and animals. *International Review of Hydrobiology* 76 (3):423-432

Kautsky H., Kautsky L., Kautsky N., Kautsky U., and Lindblad C. 1992. Studies on the Fucus vesiculosus community in the Baltic Sea. *Acta Phytogeographica Suecicia* 78: 33–48.

Kautsky, L. and Kautsky N. 2000. *The Baltic Sea, including Bothnian Sea and Bothnian Bay*. Chapter 8 in Seas l Evaluation, Edited by C.R.C. Sheppard, Elsevier.

KEMI Rapport nr 3, 2011, *Kemikalier i varor. Strategier och styrmedel för att minska riskerna med farliga ämnen i vardagen (In Swedish).*

Larsson, U., Elmgren, R. and Wulff, F. 1985. Eutrophication and the Baltic Sea: Causes and consequences. *AMBIO* 14:9-14.

Lecklin, T., Ryömä, R., and Kuikka, S. 2011. A Bayesian network for analysing biological acute and long-term impacts of an oil spill in the Gulf of Finland. *Marine Pollution Bulletin* 62: 2822-2835.

Lotze, H. K., Coll, M., Magera, A.M., Waird-Page, C., and Airoldi, L. 2011. Recovery of marine animal populations and ecosystems. *Trends in Ecology and Evolution* 26(11): 595-605.

Mahon, R., McConney, P. and Roy, R. N. 2008. Governing fisheries as complex adaptive systems. *Marine Policy* 32:104 –112.

Meier, M.H.E., Andersson, H.C., Arheimer, B., Blenckner, T., Chubarenko, B., Donnelly, C., Eilola, K., Gustafsson, B.G., Hansson, A., Havenhand, J., Höglund, A., Kuznetsov, I., MacKenzie, B.R., Müller-Karulis, B., Neumann, T., Niiranen, S., Piwowarczyk, J., Raudsepp, U., Reckermann, M., Ruoho-Airola, T., Savchuk, O.P., Schenk, F., Schimanke, S., Väli, G., Weslawski, J-M and Zorita, E. 2012. Comparing reconstructed past variations and future projections of the Baltic Sea ecosystem—first results from multi-model ensemble simulations, *Environmental Research Letters* 7 (3)

Möllmann, C., Muller-Karulis, B., Kornilovs, G., and St John M. A. 2008. Effects of climate and overfishing on zooplankton dynamics and ecosystem structure: regime shifts, trophic cascade, and feedback loops in a simple ecosystem. *ICES Journal of Marine Science* 65(3): 302-310.

Möllmann, C, Diekmann, R, Müller-Karulis, B, Kornilovs, G, Plikshs, M, and Axe, P. 2009. Reorganization of a large marine ecosystem due to atmospheric and anthropogenic pressure: a discontinuous regime shift in the Central Baltic Sea. *Global Change Biology* 15:1377–1393.

Nakicenovic, N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Gruebler, et al., 2000: Special Report on Emissions Scenarios, Working Group III of the Intergovernmental Panel on Climate Change, IPCC, Cambridge University Press, Cambridge, UK, 595 pp.

NEFCO. 2008. Frame*work for a nutrient quota and credits' trading system for the contracting parties of HELCOM in order to reduce eutrophication of the Baltic Sea*.

Norén, F., Ekendahl, S. Johansson, U. 2009. *Mikroskopiska antropogena partiklar i svenska hav*. N-research report. HELCOM MONAS 12/2009. Document 7/7.

Norkko, J., Reed, D. C., Timmermann, K., Norkko, A., Gustafsson, B. G.,

Bonsdorff, E., Slomp, C. P., Carstensen, J. and Conley, D. J. 2012. A welcome can of worms? Hypoxia mitigation by an invasive species. *Global Change Biology* 18: 422–434.
Ojaveer, H., Jaanus, A., MacKenzie, B.R., Martin, G., Olenin, S., Radziejewska, T., Telesh, I., Zettler, M.I., and Zaiko, A. 2010. Status of Biodiversity in the Baltic Sea. PlosOne 5(9).
Olenin, S, Elliott, M, Bysveen, I, Culverhouse, P, Daunys, D, Dubelaar, GBJ, Gollasch, S, Goulletquer, P, Jelmert, A, Kantor, Y, Mézeth, KB, Minchin, D, Occhipinti-Ambrogi, A, Olenina, I., and Vandekerkhove, J. 2011. Recommendations on methods for the detection and control of biological pollution in marine coastal waters. *Marine Pollution Bulletin* 62(12): 2598-2604.
Ollikainen, M. and Honkatukia, J. 2001. Towards efficient pollution control in the Baltic Sea: an anatomy of current failure with suggestions for change. *AMBIO* 30: 245-253.
Pitke, A., Nakari,T, Schultz, E., Munne, P., Brorström-Lundén, E., Andersson, H., Mathan, C., Marscheider-Weidemann, F., Kirit Sild, K., Durkin, M. (Eds) 2012. *How to control and manage hazardous substances in the Baltic Sea region? Final summary report of the COHIBA project*
Pascual, M., Borja, A., Franco, J., Burdon, D., Atkins, J.P. and Elliott, M. 2012. What are the costs and benefits of biodiversity recovery in a highly polluted estuary? *Water Research* 46: 205-217.
Renn, O, Klinke, A and van Asselt, M. 2011. Coping with complexity, uncertainty and ambiguity in risk governance: a synthesis. *AMBIO* 40: 231-246.
Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society* 14(2): 32.
Rönnberg, C., and Bonsdorff, E. 2004. Baltic Sea eutrophication: area-specific ecological consequences. *Hydrobiologica* 51: 227-241,
Savchuk, P.O., Wulff, F., Hille, S., Humborg, C., and Pollehne, F. 2008. The Baltic Sea a century ago — a reconstruction from model simulations, verified by observations. *Journal of Marine Systems* 74: 485 –494.
Scheffer, M., and Carpenter, S.R. 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. *TRENDS in Ecology and Evolution* 18: 648 –56.
Schou, J.S., Neye, S.T., Lundhede, T., Martinsen, L., and Hasler, B. 2006. *Modeling Cost-Efficient Reductions of Nutrient Loads to the Baltic Sea*, National Environmental Research Institute. NERI Technical report 592, NERI, Copenhagen.
Steffen, W., Sanderson. A., Tyson, P. D., Jäger, J., Matson, P.A., Moore III, B.; Oldfield, F., Richardson, K., Schellnhuber, H.J., Turner II, B.L. and Wasson, R.J. 2004. *Global Change and the Earth System: A Planet Under Pressure*. Springer Verlag, Berlin Heidelberg New York.
Stern, N. 2006. *Stern Review on The Economics of Climate Change. Executive Summary.* HM Treasury, London
Sterner, T., and Coria J. 2012. *Policy Instruments for Environmental and Natural Resource Management*, RFF Press, Washington, DC
Swedish EPA. 2008. *Ecosystem services provided by the Baltic Sea and Skagerrak*. Naturvårdsverket, Report 5873.
Swedish EPA. 2009a. *What's in the sea for me? - Ecosystem Services Provided by the Baltic Sea and Skagerrak*. Naturvårdsverket Report 5872.
Swedish EPA. 2009b. *Proposal for a permit fee system for Nitrogen and phosphorus*. Naturvårdsverket, Report 5968
Swedish EPA. 2010a. *BalticSurvey – a study in the Baltic Sea countries of public attitudes and use of the sea*. Summary of main results. Naturvårdsverket, Report 6382.
Swedish EPA. 2010b. *BalticSurvey – a study in the Baltic Sea countries of public attitudes and use of the sea*. Report on basic findings. Naturvårdsverket, Report 6348.
Swedish EPA. 2011. *FishSTERN: A first attempt at an ecological-economic evaluation of fishery management scenarios in the Baltic Sea region.* Naturvårdsverket, Report 6428.
Swedish EPA. 2012. *Miljöpolitiska styrmedel och industrins konkurrenskraft (Environmental policy instruments and the competiveness of the industry.)* In Swedish with English summary, Naturvårdsverket, Report 6506.
SOU 2007. Tillväxt och miljö i globalt perspektiv (Growth and environement in a global prespective). (In Swedish) *Miljövårdsberedningens promemoria* (*Swedish Environmental Advisory Council Paper)*, 2007:1, ISSN 1653.2570.
Söderqvist, T. 2008. *BalticSTERN Baltic Systems Tool for Ecological economic evaluation: a Refined Nest-model.* A proposal for an international research and development program
Telesh, I.V., Schubert, H., and Skarlato, S.O. 2011. Revisiting Remane's concept: evidence for high plankton diversity and a protistan species maximum in the horohalinicum of the Baltic Sea, *Marine Ecology Progress Series* 421: 1–11.
Turner, R. K., D. Hadley, T. Luisetti, V. W. Y. Lam and W. W. L. Cheung. 2010. *An Introduction to Socio-economic Assessment within a Marine Strategy Framework*. DEFRA.
UNEP 2005. *Marine Litter. An analytical overview*. Report of UNEP Regional Seas Coordinating Office, the Secretariat of the Mediterranean Action Plan (MAP), the Secretariat of the Basel Convention, the Coordination Office of the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) of UNEP.
UN. 2012. Report of the United Nations Conference on Sustainable Development. Rio de Janeiro, Brazil, 20-22 June, 2012
United Nations Secretary-General's High-Level Panel on Global Sustainabili

ty. 2012. *Resilient people, resilient planet: A future worth choosing*, Overview. New York: United Nations.
US EPA. 2009. Valuing the Protection of Ecological Systems and Services: A Report of the EPA Science Advisory Board. EPA-SAB-09-012. May (www.epa.gov/sab)
Valman, M. 2013. Institutional stability and change in the Baltic Sea: 30 years of issues, crisis and solutions. *Marine Policy* 38: 54-64
Walker B. 1995. Conserving biological diversity through ecosystem resilience. *Conservation Biology* 9: 747–52.
Wulff, F., Savchuk, O.P., Sokolov, A.V., Humborg, C., and Mörth., C.M. 2007. Management options and effects on a marine ecosystem: Assessing the future of the Baltic. *AMBIO* 36: 243–249.
WWF. 2012. *Counter currents: scenarios for the Baltic Sea towards 2030*.
Zillén, L., Conley, D.J., Andrén, T., Andrén, E., and Björck, S. 2008. Past occurrences of hypoxia. *Earth-Science Reviews 91*, Issues 1–4: 77–92
Öborn, I., Magnusson, U., Bengtsson, J., Vrede, K., Fahlbeck, E., Steen Jensen, E., Westin, C., Jansson, T., Hedenus, F., Lindholm-Schulz, H., Stenström, M., Jansson, B., and Rydhmer, L. 2011. *Five Scenarios for 2050 – Conditions for Agriculture and Land Use*. Uppsala, Swedish University of Agricultural Sciences.
Österblom, H., Hansson, S., Larsson, U., Hjerne, O., Wulff, F., Elmgren, R. and Folke, C. 2007. Human induced trophic cascades and ecological regime shifts in the Baltic Sea. *Ecosystems* 10: 877– 889.
Österblom, H., Gårdmark A., Bergström, L., Muller-Karulis, B., Folke, C., Lindegren, M., Casini, M., Olsson, P., Diekmann Blenckner, T., Humborg, C., and Möllmann, C. 2010. Making the ecosystem approach operational—Can regime shifts in ecological and governance systems facilitate the transition? *Marine Policy* 34:1290-1299.

APPENDIX A. BalticSTERN Research Network

BalticSURVEY

- Tore Söderqvist, Enveco Environmental Economics Consultancy Ltd. (Enveco Miljöekonomi AB), Sweden
- Heini Ahtiainen, MTT Agrifood Research, Finland
- Janne Artell, MTT Agrifood Research, Finland
- Mikolaj Czajkowski, Warsaw Ecological Economics Center, University of Warsaw, Poland
- Berit Hasler, National Environmental Research Institute, University of Aarhus, Denmark
- Linus Hasselström, Enveco Environmental Economics Consultancy Ltd. (Enveco Miljöekonomi AB), Sweden
- Anni Huhtala, MTT Agrifood Research, Finland
- Marianne Källstrøm, National Environmental Research Institute, University of Aarhus, Denmark
- Yulia Khaleeva, Centre for Economic and Financial Research at New Economic School, Russia
- Louise Martinsen, National Environmental Research Institute, University of Aarhus, Denmark
- Jürgen Meyerhoff, Institute of Landscape Architecture and Environemtnal Planning, Berlin Institute of Technology, Germany
- Tea Nõmmann, Stockholm Environment Institute Tallinn Centre, Estonian Institute of Sustainable Development, Estonia
- Ieva Oskolokaite, Center for Environmental Policy, Lithuania
- Olga Rastrigina, Baltic International Centre for Economic Policy Studies, Latvia
- Daiva Semeniene, Center for Environmental Policy, Lithuania
- Åsa Soutukorva, Enveco Environmental Economics Consultancy Ltd. (Enveco Miljöekonomi AB), Sweden
- Heidi Tuhkanen, Stockholm Environment Institute Tallinn Centre, Estonian Institute of Sustainable Development, Estonia
- Alf Vanags, Baltic International Centre for Economic Policy Studies, Latvia
- Natalia Volchkova, Centre for Economic and Financial Research at New Economic School, Russia

FishSTERN

- Thorsten Blenckner, Baltic Nest Institute Sweden
- Ralf Döring, Johann Heinrich von Thünen (vTI), Bundesforschungsinstitut, Hamburg Germany
- Michael Ebeling vTI, Hamburg, Germany
- Jesper Andersen, Institute of Food and Resource Economics (FOI), Univ. of Copenhagen, Denmark
- Tore Gustavsson, Swedish Board of Fisheries, Sweden
- Emma Sernland, Swedish Board of Fisheries, Sweden

- Tore Gustavsson, Swedish Board of Fisheries, Sweden
- Emma Sernland, Swedish Board of Fisheries, Sweden
- Jarno Virtanen, Finish Game and Fisheries Institute, Finland
- Markus Vetemaa, Estonian Marine Institute, Estonia
- Janek Lees, Estonian Marine Institute, Estonia
- Arina Motova, Lithuanian Institute for Agrarian Economics, Lithuania
- Emil Kuzebski Sea Fisheries Institute, Poland
- Ayoe Hoff, Institute of Food and Resource Economics (FOI), Univ. of Copenhagen, Denmark
- Maciej Tomczak National Institute of Aquatic Resources, Technical University of Denmark, Denmark
- Jonas Kjellstrand, UCC, Sweden

BalticSUN

- Heini Ahtiainen, Economic Research, MTT Agrifood Research, Finland
- Linus Hasselström, Enveco Environmental Economics Consultancy Ltd. (Enveco Miljöekonomi AB), Sweden
- Janne Artell, MTT Agrifood Research, Finland
- Daija Angeli, Society of Biology, United Kingdom
- Mikolaj Czajkowski, Warsaw Ecological Economics Center, University of Warsaw, Poland
- Jürgen Meyerhoff, Institute of Landscape Architecture and Environemtnal Planning, Berlin Institute of Technology, Germany
- Alemu Mohammed Hussen, Department of Environmental Science, Aarhus University, Denmark
- Kim Dahlbo, Marine Research Centre, Finnish Environmental Institute SYKE, Finland
- Vivi Fleming-Lehtinen, Marine Research Centre, Finnish Environmental Institute SYKE, Finland
- Berit Hasler, Department of Environmental Science, Aarhus University, Denmark
- Kari Hyytiäinen, Economic Research, MTT Agrifood Research, Finland
- Aljona Karlõševa, Stockholm Environment Institute Tallinn Centre, Estonia
- Yulia Khaleeva, Centre for Economic and Financial Research at New Economic School, Russia
- Marie Maar, Department of Environmental Science, Aarhus University, Denmark
- Louise Martinsen, Department of Environmental Science, Aarhus University, Denmark
- Tea Nõmmann, Stockholm Environment Institute Tallinn Centre, Estonia
- Ieva Oskolokaite, Centre for Environmental Policy, Lithuania
- Kristine Pakalniete, AKTiiVS Ltd., Latvia
- Daiva Semeniena, Centre for Environmental Policy, Lithuania
- James Smart, Department of Environmental Science, Aarhus University, Denmark and Griffith University, Australia
- Tore Söderqvist, Enveco Environmental Economics Consultancy Ltd. (Enveco Miljöekonomi AB), Sweden

APPENDIX B. BalticSTERN Publications

Ahlvik, L. & Hyytiäinen, K., 2012. *Dynamic modelling framework for analyzing cost-effective nutrient abatement in the Baltic Sea*. (Article in preparation)

Ahlvik, L. & Pavlova, Y., 2012. *A strategic analysis of eutrophication abatement in the Baltic Sea*. (Submitted manuscript)

Ahlvik, L., Pitkänen, H., Ekholm, P. & Hyytiäinen, K., 2012. *An economic-ecological modeling framework to evaluate the impacts of nutrient abatement measures in the Baltic Sea*. 27 p. (Submitted manuscript)

Ahtiainen, H., 2012. *The value of reducing eutrophication in European marine areas — A Bayesian meta-analysis*. Ecological Economics 83:1-10.

Ahtiainen, H., Artell, J., Czajkowski, M., Hasler, B., Hasselström, L., Hyytiäinen, K., Meyerhoff, J., Smart, J., Söderqvist, T., Zimmer, K., Khaleeva, J., Rastrigina, O., and Tuhkanen, H., 2013. *Public preferences regarding use and condition of the Baltic Sea – an international comparison informing marine policy*. Marine Policy 42:20-30

Ahtiainen, H., Hasselström, L., Artell, J., Angeli, D., Czajkowski, M., Meyerhoff, J., Alemu, M., Dahlbo, K., Fleming-Lehtinen, V., Hasler, B., Hyytiäinen, K., Karloseva, A., Khaleeva, Y., Maar, M., Martinsen, L., Nommann, T., Oskolokaite, I., Pakalniete, K., Semeniene, D., Smart, J. & Söderqvist, T., 2012. *Benefits of meeting the Baltic Sea nutrient reduction targets–Combining ecological modelling and contingent valuation in the nine littoral states*. MTT Discussion Papers 1/2012.

Ahtiainen, H., Artell, J., Blyh, K., Ericsdotter, S., Hasselström, L., Hasler, B., Hyytiäinen, K., Rockström, J., & Söderqvist, T., 2012. *Invånarna runt Östersjön villiga betala för bättre havsmiljö*. Svenska Dagbladet, 2/7 2012. Opinion.

Ahtiainen, H., Artell, J., Helin, J., Huhtala, A., Hyytiäinen, K., Koikkalainen, K., 2010. *Miten vertailla Itämeren suojelun kustannuksia ja hyötyjä?* In: Bäck Saara, Ollikainen Markku, Bonsdorf Erik, Eriksson Annukka, Hallanaro, Eeva-Liisa, Kuikka Sakari, Viitasalo Markku ja Walls Mari (eds.). Itämeren tulevaisuus. Gaudeamus.

Blyh, K., Ericsdotter, S., Nekoro, M., Scharin, H., Hasselström, L. & Söderqvist, T., 2012. *Värdet av en frisk Östersjö (The Value of a healthy Baltic Se*a). Havet 2012, ISSN: 1654-6741, ISBN: 978-91-980646-1-2.

Dahlbo, K., Tuomi, L., Pitkänen, H., Inkala, A., Maar, M., Ahlvik, L., Fleming-Lehtinen, V., Ahtiainen, H. & Heiskanen, A-S., 2012. *Scenarios of nutrient reduction impacts for communicating on eutrophication of the Baltic Sea*. (Article in preparation).

Hasler, B, Smart, JCR, Fonnesbech-Wulff, A, Andersen, HE, Thodsen, H, Blicher-Mathiesen, G, Smedberg, E, Göke, C, Czajkowski, M, Was, A, Elofsson, K, Humborg, C & Wulff, F., 2013. *Regional cost-effectiveness in transboundary water quality management for the Baltic Sea* (submitted)

Hasler B., Smart JCR, Fonnesbech-Wulff A., 2013. (in press): *BALTCOST - cost minimisation model for the Baltic Se*a. A documentation report. DCE technical report, Aarhus University.

Helle, I., Lecklin, T., Jolma, A. & Kuikka S., 2011. *Modeling the effectiveness of oil combating from an ecological perspective–A Bayesian network for the Gulf of Finland; the Baltic Sea*. Journal of Hazardous Materials 185(1):182-192.

Helle, I. & Kuikka, S., 2010. *Itämeren öljykuljetusten riskipeli. Teoksessa: Itämeren tulevaisuus (Risky game of oil transports in the Baltic sea).* Toim. S. Bäck, M. Ollikainen, E. Bonsdorf, A. Eriksson, E. Hallanaro, S. Kuikka, M. Viitasalo, M. Walls. Gaudeamus 2010. 350 pp.

Helle, I., Kuikka, S. & Luoma, E., 2012. *Öljyonnettomuuksia kannattaa ehkäistä (It pays to prevent oil accidents)*. Helsingin Sanomat. Vieraskynä 1.10.2012.

Helle, I., Vanhatalo, J., Rahikainen, M., Mäntyniemi, S. & Kuikka, S., 2012. *Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland, the Baltic Sea – How to do it*? ICES C.M./I:04.

Hyytiäinen, K. 2013. *Does it pay to combat eutrophication in the Baltic Sea*? Baltic Rim Economies 1/2013. http://www3.tse.fi/EN/units/specialunits/pei/economicmonitoring/bre/Pages/default.aspx

Hyytiäinen, K. & Huhtala, A., 2012. *Combating eutrophication in coastal areas at risk for oil spill*. Annals of Operations Research. (Forthcoming).

Hyytiäinen, K. & Lehtiniemi, M., 2012. *Vieraslajien riski koskettaa voimaloitakin (The risk of invasive species concerns also power plants).* Helsingin Sanomat 27.5.2012. Yliökirjoitus.

Hyytiäinen, K. ja Ollikainen, M. (eds.), 2012. *Taloudellinen näkökulma Itämeren suojeluun*. Ympäristöministeriön raportteja 22/2012. Edita Prima Oy. (*Economic aspects of Baltic Sea Protection*, Final report of the PROBAPS project intended for Finnish audience)

Hyytiäinen, K., Lehtiniemi, M., Niemi, J.K. & Tikka, K., 2012. *An optimization framework for management of aquatic invasive species risk: the case of potential Asian clam (*Corbicula fluminea*) invasion in thermal pollution areas of the Northern Baltic Sea.* European Association of Environmental and Resource Economists, 19th Annual Conference, 27 – 30 June 2012.

Hyytiäinen, K., Lehtiniemi. M., Niemi, J. & Tikka, K., 2012. *An Optimization Framework for Addressing Aquatic Invasive Species*. (Submitted manuscript)

Juntunen, T., Ahtiainen, H. & Mäntyniemi, S., 2012. *A Bayesian approach to address statistical errors and uncertainties in single binary choice contingent valuation*. (Submitted manuscript).

Lehikoinen, A., Luoma, E., Mäntyniemi, S. & Kuikka, S., 2012. *Optimizing the Recovery Efficiency of Finnish Oil Combating Vessels in the Gulf of Finland Using Bayesian Networks*. (Submitted manuscript).

Leppänen, J.-M., Rantajärvi, E., Bruun, J.-E. & Salojärvi, J. (toim.), 2012. *Suomen merenhoitosuunnitelman valmisteluun kuuluva meriympäristön nykytilan arvio (Initial assessment related to the implementation of Marine Strategy framework Directive in Finland).* Osa F. Sosioekonominen analyysi.

Luoma, E., Helle, I. & Kuikka, S., *Incorporating the maritime transport risk analysis: cost – benefit model of the oil spill mitigation and impacts*. (Article in preparation).

Nekoro, M. & Ericsdotter, S., 2012. *Havet viktigt för Östersjöbor (The Sea important for residents around the Baltic Sea).* HavsUtsikt 1/2012. ISSN: 1104-0513

Pavlova, Y. & de Zeeuw A., 2013. *Asymmetries in International Environmental Agreements*. Environmental and Development Economics 18(1):51-68.

Söderqvist, T., Ahtiainen, H., Artell, J., Czajkowski, M., Hasler, B., Hasselström, L., Huhtala, A., Källstrom, M., Khaleeva, J., Martinsen, L., Meyerhoff, J., Nommann, T., Oskolokaite, I., Rastrigina, O., Semeniene, D., Soutukorva, A., Tuhkanen, H., Vanags, A. & Volchkova, N., 2010. *Baltic Survey–A survey study in the Baltic Sea countries on people´s attitudes and use of the sea- Report on basic findings*. Swedish Environmental Protection Agency Report Series. Report 6348.

Söderqvist, T., Ahtiainen, H., Artell, J., Czajkowski, M., Hasler, B., Hasselström, L., Huhtala, A., Källstrom, M., Khaleeva, J., Martinsen, L., Meyerhoff, J., Nommann, T., Oskolokaite, I., Rastrigina, O., Semeniene, D., Soutukorva, A., Tuhkanen, H., Vanags, A. & Volchkova, N., 2010. *BalticSurvey–A study in the Baltic Sea countries of public attitudes and use of the sea–Summary of main results*. Swedish Environmental Protection Agency Report Series. Report 6382

Tuomi, L., Myrberg, K. & Lehmann, A., 2012. *The performance of the parameterisations of vertical turbulence in the 3D modelling of hydrodynamics in the Baltic Sea*. Continental Shelf Research 2012; 50-51: 64-79. http://dx.doi.org/10.1016/j.csr.2012.08.007

.

APPENDIX C.
BalticSTERN Stakeholder Seminar

On October 4th 2012 BalticSTERN organized a stakeholder seminar at Stockholm Resilience Centre to present and receive input on preliminary results from research within the Baltic STERN network. In total 43 representatives from 27 organizations participated in the seminar.

Presentations were made regarding BalticSTERN cost-benefit analyses of mitigation of eutrophication, case studies on fishery and oil spills, future scenarios for the Baltic Sea and management strategies. In connection to each presentation there were group discussions and comments in plenary. Special group discussions were organized to discuss possible measures, policy instruments and management strategies.

Organisations represented:

- Baltic Compass
- Baltic Nest Institute
- Baltic Sea Action Group
- Baltic Sea States Council
- BONUS Secretariat (EEiG)
- Coalition Clean Baltic
- Enveco Environmental Economics Consultancy Ltd
- DG Environment, European Commission
- Federation of Swedish Farmers
- Finnish Ministry for the Environment
- Finnish Environmental Protection Agency
- HELCOM Secretariat
- Lithuanian Environmental Protection Agency
- MTT Agrifood Research Finland
- Polish Environmental Protection Agency
- Polish Marine Fisheries Research Institute
- Secretariat of the Swedish All-Party Committee on Environmental Objectives
- Stockholm Resilience Centre
- Swedish Agency for Marine and Water Management
- Swedish Board of Agriculture
- Swedish Institute
- Swedish Ministry for Rural Affairs
- Swedish Ministry for the Environment
- Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas),
- The Fisheries Secretariat
- University of Warsaw
- WWF, Sweden

BalticSTERN Secretariat
Stockholm Resilience Centre
Stockholm University
SE-106 91 Stockholm, Sweden

www.stockholmresilience.org/balticstern

Havs- och vattenmyndigheten
Box 119 30, SE-404 39 Göteborg
Gullbergs Strandgata 15, 411 04 Göteborg

www.havochvatten.se
Telefon växel: 010-698 60 00
Havs- och vattenmyndigheten har även
lokalkontor i Kungshamn, Göteborg,
Simrishamn och Karlskrona.