Oil spills management

Background Paper

Linus Hasselström, Enveco Ltd (www.enveco.se)
Scott Cole, EnviroEconomics Sweden (www.eesweden.com)

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Preface

BalticSTERN (Systems Tools and Ecological-economic evaluation – a Research Network) is an international research network with partners in all countries around the Baltic Sea. The research focuses on costs and benefits of mitigating eutrophication and meeting environmental targets of the HELCOM Baltic Sea Action Plan. Case studies regarding fisheries management, oil spills and invasive species have also been made, as have long-term scenarios regarding the development of the Baltic Sea ecosystem.

The BalticSTERN Secretariat at the Stockholm Resilience Centre has the task to coordinate the network, communicate the results and to write a final report targeted at Governments, Parliaments and other decision makers. This report should also discuss the need for policy instruments and could be based also on results from other available and relevant research.

The final report "*The Baltic Sea – Our Common Treasure Economics of Saving the Sea*" was published in March 2013. This Background Paper *Oil spills management* is one of eight Background Papers, where methods and results from BalticSTERN research are described more in detail. In some of the papers the BalticSTERN case studies are discussed in a wider perspective based on other relevant research.

CONTENTS

List of Abbreviations

AIS	Automatic Identification System
APM	Associated Protection Measures
BRISK	Sub-regional risk of spill of oil and hazardous substances in the Baltic Sea
BSAP	Baltic Sea Action Plan
CBA	CostBbenefit Analysis
CBD	Convention on Biological Diversity
CFP	Common Fisheries Policy
COW	Crude Oil Washing
DPSIR	Drivers, Pressures, State (of the Environment), Impacts, Responses
ELD	Environmental Liability Directive
ESA	Ecosystem Services Approach
ETS	EU Emissions Trading System
FSC	Flag State Control
HEA	Habitat Equivalency Analysis
HELCOM	Helsinki Commission
HFE	Human Factor Errors
IMO	International Maritime Organization
PSC	Port State Control
PSSA	Particularly Sensitive Sea Area
REA	Resource Equivalency Analysis
TAC	Total Allowable Catch
TEV	Total Economic Value
WTP	Willingness To Pay
COLREG:	Convention on the International Regulations for Preventing Collisions at Sea
Espoo	Espoo Convention on the environmental impact of development activities
GES	Good Environmental Status
IOPC funds	The International Oil Pollution Compensation Funds
MSFD	Marine Strategy Framework Directive
Paris MoU	The Paris Memorandum of Understanding on Port State Control.
R&D	Research and Development
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-operation
STCW	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
SOLAS	International Convention for the Safety of Life at Sea

1. Introduction

This analysis considers the decision-making dilemma: How to better manage the risk of oil spill impacts on the marine environment? Oil spill risks should not be viewed in isolation, they should rather be seen as included in an overall management of the Baltic Sea environment, together with other pressures. This report highlights some of the future challenges suggested by the case study and provides policy guidance. It focuses on relevant oil spill management options. For example, what are the types of measures available? Which measures are most effective? What types of literature may provide insight into improved oil spill management? The report concludes with a number of recommendations addressing these questions.

The analysis relies on two frameworks.

First, the decision-making dilemma is put into the context of the DPSIR framework (Turner et al., 2010). In practical terms, this suggests that decision-makers first consider various ***drivers*** causing the problem – in this case economic growth, global trade, and high demand for oil. Second, these variables lead to various ***pressures*** on the marine environment, such as increased eutrophication, overfishing, chemical releases, alien invasive species, and oil spills. The focus here is on oil spills, which leads to altered ***states*** of the environment (e.g., elevated contaminants), and subsequent ***impacts*** on human welfare (e.g., reduced recreational opportunities). The final component of this framework is the most challenging – finding an effective and efficient ***response***[1], that is measures that can prevent or reduce adverse impacts on society that may result from marine oil spills. In order to implement these measures an institutional capacity is required, including policy instruments and environmental governance (see Section 1.3). The DPSIR framework is implicit and underlying to this analysis.

The second framework – which is more explicitly spelled out in Chapter 2 – is one that connects the altered *state* of the environment to the resulting *impact* on human welfare. Here we rely on an Ecosystem Services Approach (ESA) to valuation. The objective of this framework is to identify how environmental change affects society's well-being, which then motivates the policy response.

1.1. Scope of the Analysis

The scope of this report is somewhat limited. The purpose is not to assess the costs of specific measures aimed at oil spill risk (which may include opportunity costs on industry or public budgets), nor is it to make recommendations on which policy instruments or governance strategies would be socially profitable. Rather, the objective is to broadly outline the types of benefits

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[1] Note that response in the DPSIR framework and "oil spill response" are two different things, where oil spill response refers to post accident activities such as clean-up of spilled oil, usage of oil booms, protection of birds, etc., whereas response in the DPSIR framework is a much broader term. Throughout the report, we write response in italics when we refer to the term in the DPSIR framework and response in plain letters when we refer to post accident activities.

society may obtain if additional policy responses to the oil spill risk in the Baltic are undertaken. We refer to these benefits as *the values at stake*. Further, the report identifies potential oil spill measures – and the complementary policy instruments and governance strategies – that are available to decision-makers to address the oil spill risk. This policy analysis can help promote a broad and holistic view of oil spill risk management in the Baltic Sea.

1.2. Report structure

This introduction touches upon the key topics to be covered in this analysis, including:

- **Context**: What is the oil spill risk in the Baltic and how is this risk connected to key *drivers* and *pressures*?
- **Costs**: what are the *impacts* (costs) on society from oil spills?
- **Response**: What types of policy *responses* are available to address these costs in terms of measures, policy instruments and environmental governance?

1.2.1. Context: Oil spill risk and the Baltic Sea

The pressure on the marine environment in the Baltic Sea from oil spills comes primarily from the maritime sector, which includes tankers, non-tankers (cargo, passenger and fishing ships), port activities and energy-related activities (wind farms and cables).[2] IVL, Enveco and EES (forthcoming) studied anticipated future development of these drivers. That report concluds that the most significant and increasing risk was posed by *tankers* and *port activities*, and a stable (but non-decreasing) risk was posed by *non-tankers* (due to the shift in fuel towards liquid natural gas). The report notes that other drivers have the potential to lead to oil spills (e.g., pipelines, refineries, offshore wind facilities, motor boats for recreational use, aquaculture, etc), but that this risk was relatively minor. Therefore, we limit our study to those drivers with stable and increasing risk: *tankers*, *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. Between 3,500 and 5,000 ships operate in the Baltic Sea Region each month (HELCOM, 2009), which inevitably requires significant port activities. Figure 1 provides an overview of shipping traffic in the Baltic. Furthermore, the Baltic is particularly sensitive to chemical and oil releases due to its "enclosed" characteristics, its brackish water, and its fairly species-poor mixture of freshwater and marine species. It has been listed by the International Maritime Organization (IMO) as a Particularly Sensitive Sea Area (PSSA), needing special protection (Russian waters excluded).

[2] Air emissions from marine transportation is an increasing concern for Baltic States, in part because nitrogen deposition from these emissions contributes further to the Sea's eutrophication problems. However, this study focuses exclusively on oil spills.

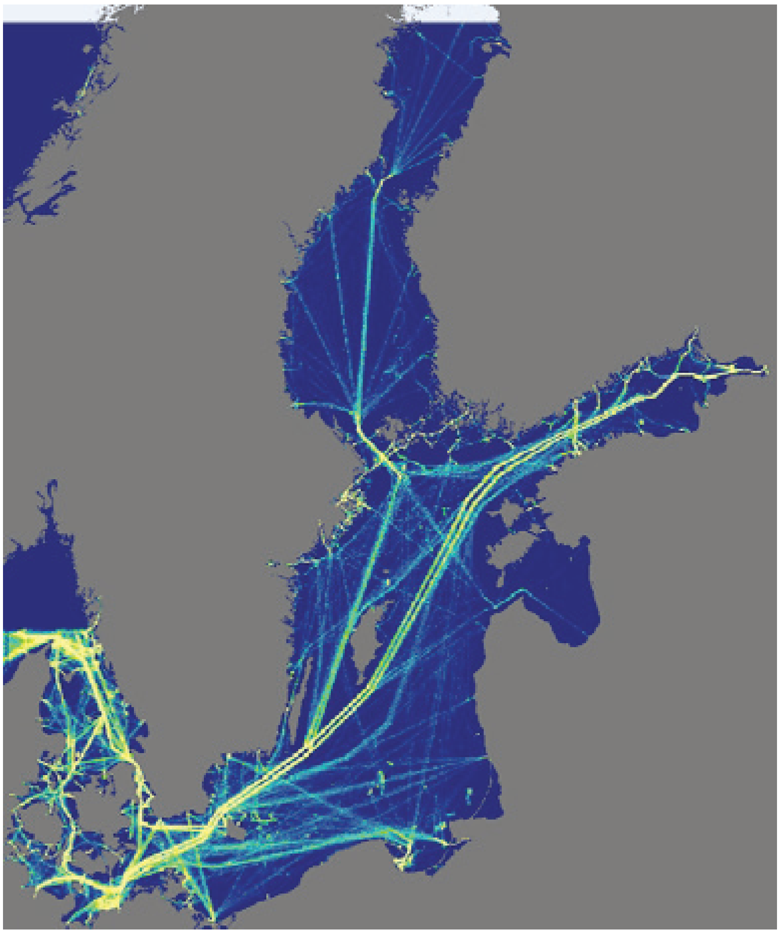

Figure 1. The density of ship traffic during one week in 2008, with the busiest routes in the Baltic highlighted in yellow (HELCOM, 2009). Note the clearly visible traffic separation lanes (e.g., north-south bound) which is an example of an Associated Protection Measure (APM) of the Baltic's Particularly Sensitive Sea Area (PSSA) designation.

According to the project sub-regional risk of spill of oil and hazardous substances in the Baltic Sea (BRISK)[3] the incidents can be divided into two[4] different categories of oil spills: *Operational spills* result from shipping and offshore extraction of oil (UNEP, 2011). They tend to be small, for example 91 per cent of operational spills from tankers involve less than 7 tons. This category includes intentional (and illegal) spills, such as washing of machine rooms and cleaning of tanks at sea. *Accidental spills* generally occur when vessels collide or come under distress, but may also occur from a blow-out of an offshore oil well or pipeline (UNEP, 2011). These tend to be larger spills, that is at least 88 per cent involve quantities in excess of 700 tons. The causes of accidental spills are frequently linked to human error, but may also include technical factors.

[3] The BRISK project was completed in 2012 and was financed by the EU. The purpose was to increase the preparedness of all Baltic Sea countries to respond to major spills of oil and hazardous substances from shipping.
[4] A third spill category is less relevant in the Baltic: Antagonistic spills, which are caused by e.g., terrorism.

Oil spill risk in the Baltic is becoming an increasing concern for managers due in part to the significant increase in shipping in the Baltic, which is easily congested given its relatively small size. Further, oil transport makes up a large percentage of this increase (see Figure 2).

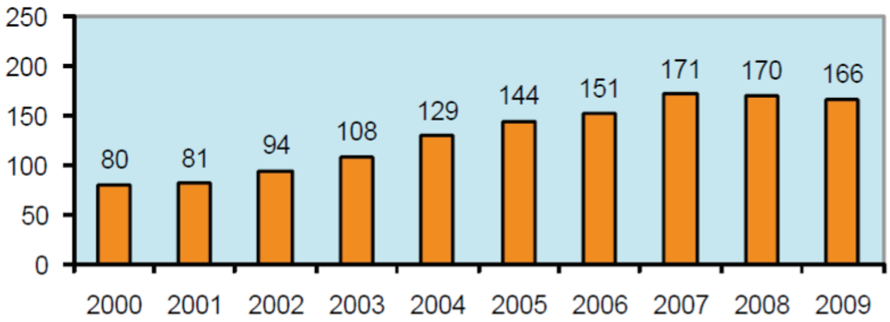

Figure 2. The amount of oil transported to and from the Baltic Sea, 2000-2009. Data source (HELCOM 2010)

A number of relevant variables may drive future oil spill risk from both shipping and port activities. The most relevant is continued **economic growth** which, despite a recent recession, is expected to continue over the long term. This in turn leads to increased **global trade**, with oil and oil products representing a large share of that future growth. Water-borne shipping represents the majority of global trade and significant and steep increases in cargo transportation further increases the risk of collisions. Further, **global oil demand** is expected to continue to increase, which will lead to increased exports, not the least from Russia through the Baltic Sea. General increases in regional economic growth will contribute to both trade and oil consumption.

1.2.2. The values at stake

How does this risk translate into actual impacts on social welfare? The DPSIR approach first identifies possible Impacts and then discusses how to value these impacts in terms of costs on society.

The impacts on society of an oil spill can be varied and extensive. The extent to which an oil spill results in negative effects on ecosystem function – and subsequently social welfare – is largely dependent on where and when the spill occurs, how much and what type of oil is spilled, and factors such as wind and weather. For example, a summer oil spill near popular beaches would likely have a larger impact on social welfare than a winter spill in the middle of the Baltic that is quickly contained. To better predict possible costs on society from future (unknown) oil spills, the spills can be classified into the following categories based on size (BRISK, 2011):

- Small spills (< 1 ton of oil)
- Medium spills (1–300 tons of oil)
- Large spills (300–5,000 tons of oil)
- Exceptional spills (5,000–150,000 tons of oil)

The costs for society of oil spills may include the following categories (Fejes et al., 2011):

- **Direct costs** may include the market value of oil spilled, damage to the oil tanker, clean up expenditures, repairs to infrastructure, etc. Expenditures that follow an oil spill may temporarily increase activity in local economies, but this should not be mistaken for a 'positive' consequence of an oil spill. These expenditures support activities that are unproductive for the economy compared to other public expenditures such as investments in education or health care or expanding a port. Thus, they represent an opportunity cost on society.
- **Market costs** may be imposed on consumers and producers who are dependent on natural resources as inputs to production (e.g., commercial fisheries, tourism). Producers suffer profit losses while consumers suffer welfare losses from increased prices or reduced quality or access to goods and services.
- **Non-market costs** are social welfare losses that are not visible in a market. These losses accrue when the public loses access to non-priced ecological resources (e.g., species) or the services they provide (e.g., habitat for wildlife, recreational opportunities, scenic vistas, etc). The lack of a market does not, however, indicate a lack of value. Various studies have concluded that the public values these types of resources and services and might have a willingness-to-pay (WTP) for their preservation. Analogously, damage to these resources or services impose a social cost (see e.g. World Bank, 2005).

Direct and market costs are less challenging to quantify relative to non-market costs, due to their linkages to visible market transactions. Section 2 discusses the Ecosystem Services Approach (ESA) for valuing the three cost categories using a Total Economic Value (TEV) framework.

1.2.3. Oil Spill Response: Measures, instruments, and governance

Although some costs on society from oil spills are not reflected in market prices they, nonetheless lead to a loss of valuable ecosystem services. Baltic Sea managers are interested in different responses in addressing or reducing the loss of these services.

We divide the "response" component of the DPSIR framework into three broad categories:

- **Measures** refer to a concrete action that has a direct impact on the environment (e.g., improving marine safety or spill response).
- **Policy instruments** refer to the policies that 'make the measures happen' (e.g., regulations or economic incentives).
- **Environmental Governance** refers to the overarching structure for collective environmental decision-making, in which environmental objectives are set, policy instruments are created, stakeholders are involved, and enforcement is provided. It can involve both state and non-state (profit and non-profit) actors and may be implemented on different levels (e.g., local, regional, national, European and global, see Rosenau, 2003).

In general, measures to address oil spill impacts vary and could be categorized into three broad categories (which are elaborated on in Section 3):

- **Measures targeted at Drivers** are measures that aim to reduce the driving forces behind oil spill risks, such as the demand for fossil fuels and the dependence on shipping.
- **Measures targeted at Pressures** focus directly on the goal of reducing the probability of a spill or improving the response once a spill has occurred.
- **Measures targeted at the State** of the environment are those that reduce the effect of an oil spill in the long-run, usually by improving the ecosystem's ability to recover from damage. In the absence of these measures the adverse impacts on ecosystem function and human welfare would be worse, following a given spill event.

The remainder of this analysis is structured as follows:

- Section 2 discusses the value associated with preventing oil spills, that is, the welfare gains to society from avoided environmental impacts.
- Section 3 identifies possible policy measures aimed at reducing oil spill risk and also discusses issues in selecting the most appropriate measures. As a basis for this discussion, we present a number of relevant studies that approach the issue from different perspectives.
- Section 4 provides our conclusions and recommendations for policy makers to improve management of the oil spill risk in the Baltic.

2. The values at stake

Policy measures cost society money, which begs the question: what values or benefits can society expect from these measures? That is, given limited public resources, valuation of non-market resources helps society make trade-offs as in a Cost-Benefit Analysis (CBA). For example, managers may wish to compare the costs of measures aimed at preventing or responding to spills (e.g., requirements for double-hulled ships, regular training of spill response teams, etc.) to the benefits in terms of avoided losses to non-market ecosystem services. Proper valuation estimates provide important inputs to a CBA. However, valuation may also be useful in scaling environmental compensation. For example, an oil spill may reduce the flow of valuable ecosystem services from eelgrass beds or the possibility for sports fishing. The value of these types of losses may be used to inform the scale of compensatory damages paid to the public after the spill.

To highlight the values at stake we review the valuation literature related to marine ecosystem service benefits that may be lost in the event of an oil spill (for more detailed information see IVL, Enveco and EES, forthcoming). Garpe (2008) identify a number of ecosystem services that are potentially impacted by oil spills in the Baltic. These include:

- Biogeochemical cycling
- Diversity
- Habitat
- Resilience
- Scenery
- Science and education
- Inspiration
- Food
- Genetic resources
- Chemical resources
- Space and waterways
- Recreation
- The legacy of the sea

IVL, Enveco and EES (forthcoming) conclude that *scenery*, *recreation*, and *food* are three of the ecosystem services that are most likely to be impacted by an oil spill. However, the report warns that ecosystem effects from oil spills are hard to predict, suggesting that the exact type and quantity of lost values from a spill in the Baltic Sea is uncertain.[5] Nonetheless, we identify several studies below to help highlight the type and magnitude of values at stake.

Several studies have attempted to monetize the impacts from oil spills in the Baltic Sea and the results suggest that the values at stake may be significant. In the case of *direct costs* Forsman (2003, 2006 and 2007) identifies clean-up costs for three scenarios of crude oil spills in Sweden: 30,000 tons in the Stockholm Archipelago; 25,000 tons in Bohuslän on the Swedish west coast; and 30,000 tons in Southern Sweden. The estimated costs were approximately 50 million Euros, 20-30 million Euros, and 20 – 35 million

[5] BRISK (2011) developed probabilities for *large* and *exceptional* spills in the Baltic Sea with the former expected to occur once every 4 years and the latter expected every 26 years. Predicting future probabilities is complicated and many factors are involved. IVL, Enveco and EES (forthcoming) argue that the probability of *exceptional* spills is likely to increase in the future due to a predicted increase in tanker traffic. For *large* spills, however, they argue that the present probability is estimated to remain approximately constant due to a shift in fuels of non-tankers to liquid natural gas.

Euros, respectively. Further, the author estimates *market costs* of up to 17–160 million Euros for tourism and 5-65 million Euros for commercial fishing.

IVL, Enveco and EES (forthcoming) present an overview of available data to estimate oil spill costs and key knowledge gaps to be addressed (Table 1). A key conclusion is that international data on valuation studies are accessible but local valuation studies are few. This brings into focus the challenging questions of how and when international value estimates are transferrable to specific areas of the Baltic Sea, including the transfer of values from one Baltic Sea state to another.

Table 1. Cost categories that should be included in an assessment of expected costs from a *large* or *exceptional* oil spill. Available data and key knowledge gaps. Modified from IVL, Enveco and EES, forthcoming)

Cost category	Available data	Key knowledge gaps
Direct Costs		
Clean-up	E.g. case studies by Forsman (2003, 2006, 2007) Louriero *et al.* (2006)	Are Forsman's values valid also in other areas in the Baltic Sea? Are values from international studies valid for the Baltic Sea?
Financial costs	Relevant values and/or studies not yet identified	What can be said generally?
Market Costs		
Short-term profit losses to tourism	E.g. case studies by Forsman (2003, 2006, 2007) USBOEM 2011	Are Forsman's values valid also in other areas in the Baltic Sea? Are values from international studies valid for the Baltic Sea?
Long-term profit losses to tourism	Relevant values and/or studies not yet identified	What in general are the long-term ecological effects from an oil spill? How do these affect tourism?
Short-term profit losses to commercial fisheries	E.g. case studies by Forsman (2003, 2006, 2007) USBOEM 2011	Are Forsman's values valid also in other areas in the Baltic Sea? Are values from international studies valid for the Baltic Sea? Is methodology in USBOEM 2011 relevant to the Baltic Sea?
Long-term profit losses to commercial fisheries	Relevant values and/or studies not yet identified	What in general are the long-term ecological effects from an oil spill? How do these affect tourism?
Short-term and long-term losses of consumer surpluses	Estimate from Louriero et al. (2006) regarding losses in canning and fish processing sector.	Can estimates from Louriero et al. be used in order to say something general regarding effects to secon-dary markets (consumers in fisheries market) What general effects does a reduc-tion of the provision of tourism and fisheries have to end-consumers in the markets?
Non-market costs		
Short-term losses in recreational fishing	Estimates by Paulrud (2004) and Kinell *et al.* (2009) on the value of an additional fishing day.	How many fishing days are lost from an oil spill? How does the availability of substitute sites affect the number of lost days? What is the value of a fishing day at a substitute site?
Long-term losses in recreational fishing	Potentially: Estimates by Paulrud (2004) and Kinell et al. (2009) on the value of increased catch.	What are the long-term ecological effects from an oil spill? How do these affect recreational fishing?
Short-term losses in beachside recreation	Estimates by Söderqvist et al. (2010) and Enveco, DHI and Resurs (2012) regarding recreational activities.	What is the value of a recreational day in different parts of the Baltic Sea?
Long-term losses in beachside recreation	Relevant values and/or studies not yet identified	What are the long-term ecological effects from an oil spill? How do these effects affect beachside recreation?
Non-use values	Estimate by Ahtiainen (2007) on the WTP for reducing impacts of spills. Carson (et al., 2003; 1996) or Van Biervliet et al. (2006) HEA or REA-generated estimates of non-use values for intermediate goods	What are the use/non-use compo-nents of these kinds of estimates? Are these results valid for other parts of the Baltic Sea? Can we develop links from the inter-mediate goods valued by HEAREA and final services?
Total cost per expected oil spill = sum of Direct costs, Market costs and Non-market costs (paying attention to possible double-counting)		

At least one study in the Baltic has focused on the non-market costs associated with oil spills. An important concept in this regard is the TEV framework, which refers to the categories of value that are relevant in the non-market context: *use values*, *non-use values* or *passive values* (including existence values) (see BG Paper *Benefits of mitigating eutrophication* and Chapter 6 for an overview). One way of capturing all of these value categories is through a contingent valuation survey. Ahtiainen (2007) estimates the WTP among Finns for improved oil spill response capacity and finds that the total value to Finnish households may be 112 million Euro. Focusing specifically on use values, IVL, Enveco and EES (forthcoming) suggest that non-market impacts may be estimated by combining the value of a recreational day at Sea with estimates of the number of recreational days forgone from a spill. For example, the value of a recreational fishing day to a Swede has been estimated at 7–14 Euros. Using an estimate of losses in recreational fishing days from Forsman (2006) of 950,000 days, IVL, Enveco and EES (forthcoming) conclude that these estimates may imply a cost of up to 6-13 million Euros.

A significant international literature exists related to the valuation of actual or hypothetical oil spills. A few key studies from the literature addressing both use and non use values are summarized below.

- Carson et al. (2003) report on a study commissioned in response to the Exxon Valdez oil spill in Alaska (1989) where survey participants were asked their willingness to pay for a hypothetical program that would guide ships into the harbor, thus reducing the probability of an oil spill to zero. Their study found a total lost value of $2.8 billion based on multiplying the median household WTP ($48) by the number of English-speaking households in the US (recreational values were not included in this non-use estimate). A similar study by Carson et al. (1996) estimated households' value for a program designed to prevent various environmental injuries from an oil spill including mortality to birds, crabs, mussels and loss of shoreline habitat and salt water plants. The study found that the typical household in California was willing to pay approximately $76 (1995). Van Biervliet et al. (2006) estimate the loss of non-use values from hypothetical oil spill scenarios along the Belgian Coast. The study finds a potentially large welfare loss in the absence of a spill prevention program, ranging from 120 million Euro to 606 million Euro, depending on the size and the frequency of the oil spill scenario.
- Other studies have attempted to value certain ecosystem services separately, rather than trying to capture the total economic value. Liu et al. (2009) estimate the value of contingency plans to respond to oil spills in the Wadden Sea (along the German, Dutch and Danish coasts). The survey estimated individuals' values for several attributes that may be affected by a future spill. The study estimated a total WTP of German households to be 1.1 billion Euro for a response plan that could, for a given spill, increase the oil collection ratio and thus reduce the amount of surface water, beaches and birds that are oiled.

Monetary valuation estimates generally require a number of assumptions and limitations, including a reliance on an anthropocentric view. However, keeping these limitations in mind, some general conclusions may be drawn from this section. First, there are significant values at stake associated with the flow of ecosystem services, which can be damaged completely or partially from future oil spills in the Baltic Sea. A failure to pay attention to these values may result in suboptimal management from an economic perspective. Measures are costly, but so is inaction. Finding a sound balance requires economic analyses. Second, the information need is high. New information is needed in several dimensions in order to support further monetization of ecosystem service impacts from future oil spills. The concept of ecosystem services provides a useful framework for assessing welfare impacts, and future research should further investigate the ecological impacts from oil spills and the preferences of Baltic Sea residents in preventing these impacts.

3. Potential oil spill responses

In this section, we argue that the management of oil spill risks in the Baltic requires a broad perspective. On the one hand, response could be directed at sources of risk to ecosystem services. For example, managers could reduce risk by reducing the probability of accidents or by improving the overall resilience of marine ecosystems, which then reduces the risk of ecological disturbance. However, implementing these measures is not always straightforward due to the complexities of the international shipping industry. Baltic Sea managers need to decide where to put their efforts: Should they focus on lobbying for new international agreements or should they seek other ways of accomplishing ecosystem protection? We argue that this depends on what measures are being discussed and what factors lay behind the need for these measures.

This section first identifies the overarching drivers to be considered when developing potential responses to oil spills. Second, we identify a general classification of responses that are directed at Drivers, Pressures, and the State of the environment, respectively. We describe examples of these responses and then consider recent literature on the topic from the Baltic Sea region.

3.1. Drivers

The starting point for identifying potential responses is identifying the *drivers* behind oil spill risk. Policy measures must consider the different factors leading to operational (including intentional) and accidental spills. Different drivers require different policy responses.

In order to account for various types of responses, we divide the drivers into two categories: underlying drivers and direct drivers:

- By **underlying drivers** we mean drivers such as economic growth, increased global trade and fossil fuel dependency, all leading to increased oil demand. Together with the global preference for relatively inexpensive sea-based transport, this will lead to the **continued growth of the maritime transport sector**, and a subsequent increase in oil spill risk.
- By **direct drivers** we mean drivers that directly imply a risk for oil spills. These are generated by the underlying drivers, for example:
  - **Tanker traffic** transporting large amounts of oil. The shallow Baltic Sea is challenging to navigate, which restricts certain size tankers. Nonetheless the average size of tankers is expected to grow, as is the total volume of oil – both of which increase the risk of spills.
  - **Non-tanker traffic** including cargo and passenger transport vessels, fishing vessels and cruise ships. These vessels carry large amounts of oil in their fuel tanks, and given increased global trade, non-tanker vessel traffic will continue to grow in the Baltic, leading to an increased risk of accidents. However, there is a trend in shipping towards replacing oil with natural gas. This would reduce the risk of accidental or operational oil spills from these vessels.
  - **Port activities** include the loading and unloading of cargo and oil products, which can lead to accidental spills.

3.2. Universe of possible measures

Given the drivers above, the universe of possible policy measures may fall into three general categories: Measures targeted at (1) *drivers*, (2) *pressures*, or (3) the *state* of the environment. For each of the measures, we provide examples of policy instruments that may support these measures and the overarching governance structure within which they may be carried out. We also provide some insights regarding the relevant implementation level (e.g., local, national, regional or international).

3.2.1. Measures targeted at Drivers

Measures directed at *drivers* focus on reducing the risk of oil spills by limiting the direct or underlying drivers themselves. For example, these measures could be in terms of:

- **Transition to natural gas fuel in shipping.** This reduces the risk for oil spills from sea-based transports. A policy instrument that could accomplish this might be creating economic incentives for this transition. However, managers should note that even natural gas poses an environmental risk in extraction and production. There are several environmental governance umbrellas that may directly or indirectly support this transition, such as the EU Emission Trading System (ETS), which aims to increase the cost of CO_2 emissions. This type of measure should be implemented on an international level, due to the international character of the shipping market. Further it requires significant investment in port infrastructure and should be viewed as a long-term measure.
- **Reduce fossil fuel demand**. The global fossil fuel demand is a key driver behind oil spill risk. Reducing this demand will reduce the demand for oil transport. Policy instruments may be information, which aims at changing the preferences of actors in society, or economic instruments such as fossil fuel taxes or subsidies on "green" fuels. Further, stimulating demand for green transports such as railroads might lead to a reduced fossil fuel demand. These measures may be implemented on the local, national, regional or international level.
- **Reduce transportation demand**. Reducing the demand for international transport would affect the number of ships at sea and thus reduce the risk of oil spills. One way of working towards this end could be through stimulating local production by various means. Environmental governance such as eco-labeling institutions and green infrastructure networks are examples of governance that can be used to pursue this reduction. Most common are national and regional initiatives in the Baltic Sea states. Increased use of pipelines may reduce the demand for sea-based transports, but they also pose a risk to the marine environment both from construction and operation.
- **Development of alternative energy sources**. An improved availability of alternative energy sources might result in a substitution from fossil fuels to more sustainable fuels. Stimulating research and development in this field may reduce the risk of oil spills via a reduction in tanker traffic. Political discussions are active in several Baltic Sea states. The EU Directive on

renewable energy (2009/28/EC) provides one relevant governance framework. These measures may be implemented on all levels, including locally, nationally, regionally and internationally. Stimulating private initiatives may also provide benefits in this regard.

These types of measures are likely to be of a long term character and should not replace more targeted measures. Note, however that these types of measures might create ancillary benefits. For example, many of these measures are consistent with climate policy targets.

The above measures are directed at underlying drivers. However, measures could also target direct drivers, such as reducing shipping or reducing tanker traffic. Currently, we find no policy instruments that have this aim and, given the environmental impacts from many alternative transport options, it might be that these measures are undesirable in the larger perspective.

3.2.2. Measures directed at Pressures

Measures directed at *pressures* focus directly on the goal of reducing oil spill probability or improving spill response, given existing traffic patterns. For example, these measures may include:

- **Limiting tanker traffic in sensitive areas.** If sensitive ecological areas are protected through limiting tanker traffic, the risk of oil spills in these areas is reduced. For example, policies that regulate waterways may be used as an instrument to achieve this measure, and IMO's classification of the Baltic Sea as a PSSA is an example of governance that may allow this kind of policy instrument. The implementation of these measures may be done on a national and regional level, but may require approval by the IMO.
- **Improved technical standards.** Requirements for double-hulled ships and separated ballast tanks would fall into this category. This reduces the risk for spills, or reduces the likely amount of oil that is spilled. Further, technical rules may require mandatory navigation equipment in certain areas. Policy instruments that stimulate these improvements are usually international regulations. Fejes et al. (2011) and Costanza et al. (2010) argue that stricter compensation requirements (i.e. liability) after an oil spill accident may increase the incentives for preventive action among the ship owners, such as improving technical standards. Further, port controls could be improved by creating better incentives for operators to follow existing regulations.
- **Improved spill response capacity.** Response capability is crucial for limiting impacts. For example, improving the training of staff responsible for clean-up or improving international collaboration may result in a more efficient response. Further, allocating resources to coastal communities to improve their capacity could be a way of limiting the impacts from a spill. An international governance umbrella that regulates response capacity is the IMO's International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC). However, the actual implementation needs to be done on a regional, national and local level and there may be room for improvement.

- **Safer navigation procedures.** For example, traffic separation requirements, regulations concerning navigation equipment and other operative procedures may result in a reduced risk for collision. The IMO Convention on the International Regulations for Preventing Collisions at Sea (COLREG) provides an example of international governance that addresses navigation procedures and in general, policy instruments in this field need to be internationally anchored. However, the monitoring and enforcement of existing regulations may be improved on a regional/national level.
- **Better trained crews.** Since a majority of the accidents at sea are caused by 'human factors', improved training, improved control of crew composition, and requirements for maximum duty time could be important policy instruments to reduce the probability of accidents. IMO regulations such as The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) are the main governance umbrellas. National policy instruments may be difficult to implement (see also the ILO Merchant Shipping Convention).
- **Increased usage of piloting in harbors.** Many passages in the Baltic are narrow and hard to navigate. The use of pilots could reduce the risk for accidents in these areas. In order to stimulate this use, operating requirements or subsidized piloting services in harbors may be used. These types of instruments may be implemented on a local/national level, but are often driven and affected by regional governance structures such as the Paris MoU and other international conventions.

3.2.3. Measures directed at the State of the environment

From an oil spill perspective, measures directed at the *state* of the environment reduce the effect of an oil spill in the long-run, usually by improving the ecosystem's ability to recover from an oil spill.[6] 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. These measures are often on-going policy instruments (e.g., MSFD or WFD) and are not considered oil spill measures *per se*, but they nonetheless provide benefits in terms of reduced welfare impacts from future oil spills. Finally, note that these measures also provide ancillary benefits in the event of other natural or man-made disasters, such as extreme weather, climate change or chemical spills. Examples may include (see e.g. Halpern et al., 2012):

- **Restoration of marine ecosystems** by private and public actors, repairing historic environmental damage (e.g., habitat restoration), thus improving ecological resilience. Such measures may be driven by policy instruments that require environmental compensation for damage resulting from infrastructure development or oil/chemical releases. The EU's Environmental

[6] We label these as *measures directed at the state of the environment* due to the oil spill focus in this report. However, one could argue that from another perspective – e.g., a eutrophication focus – these same measures could be labeled as *measures directed at drivers or pressures,* which in that case may be targeting growth in the agricultural sector (driver) or improved capacity in sewage treatment plants (pressure).

Liability Directive[7] (ELD) or the International Maritime Organisation (IMO) Oil Pollution Compensation Fund (IOPC Fund) provide governance mechanisms for these measures, which are implemented on the regional and international level, respectively.

- **Improved fishing regulations** address over-fishing and thus restore the marine ecological balance. The policy instruments may take the form of Total Allowable Catch (TAC) or the establishment of marine reserves that prohibit fishing. Governance initiatives, such as the EU's Common Fisheries Policy (CFP) or the Baltic Sea Action Plan (BSAP), tend to be implemented regionally or internationally between countries.
- **Sensitive urban development.** Measures that reduce non-point storm runoff or encourage compact urban development (rather than suburban sprawl) help to reduce the ecological footprint of human infrastructure, and ultimately improves water quality. These measures may be carried out through "green infrastructure" or "brownfields redevelopment" instruments and tend to be implemented on regional or local government levels.
- **Protection of biodiversity** helps to restore resilience in ecological systems and may be implemented through the establishment of environmental objectives that aim to maintain, or prevent the decline in, a certain level of biodiversity (policy instrument). The governance structure surrounding such initiatives may be, for example, the International Convention on Biological Diversity (CBD) or countries' own national initiatives.
- **Measures to remove pollutants** improve water quality and restore the ecological balance (e.g., blue mussels that consume contaminants or measures to improve oxygen levels in the sediment). These measures may be accomplished through instruments such as improved control and treatment of wastewater or expanded capacity of treatment plants. The governance structure may include national or regional (e.g., EU) legislation that establishes and enforces certain water quality standards.
- **Promoting coastal livelihoods** decreases the distance between citizens and nature and thus create an incentives for local residents to invest in a resource's protection (Ostrom, 2005). Human presence may facilitate oil spill response. Instruments that may accomplish this goal includes rural development assistance programs on the national or regional level, which support local fishing villages, maintain a cultural landscape, and ensure rural employment.

3.2.4. Summary: measures, instruments and governance

Table 2 provides an overview of the available categories of oil spill response. We divide the table rows into measures that address *Drivers* (both underlying and direct), *Pressures*, and the *State* of the environment. For each concrete measure we provide a link to an example of a policy instrument, governance framework, and implementation level. These examples are intended to be illustrative rather than exhaustive.

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[7] Note that the ELD explicitly exempts oil spills from compensatory requirements but covers other types of damage on land and water.

This analysis suggests that policy-makers should take a broad and holistic perspective in considering alternative oil spill responses. For example, conventional oil spill management aimed at reducing risks from *pressures* (e.g., operative requirements) could be complemented by approaches that are aimed at *drivers* (e.g., transition of fuel to liquefied natural gas) and/or the *state* of the environment (e.g., improving the resilience of the ecosystem). Future work should consider an optimal mix of policies across these three broad categories.

Table 2. Summary of available oil spill response categories: measures, instruments, environmental governance, and implementation level *

Examples of measures	Examples of policy instruments	Examples of environ-mental governance	Main implementation level
Measures aimed at underlying *drivers*			
Transition to natural gas fuel in shipping	Economic incentives to reduce use of fossil fuel, such as emis-sions trading or taxes	Institutions that implement the ETS or a CO_2 tax	International
Reduce fossil fuel demand	Information, forming of public's preferences, taxes	Institutions that implement the ETS or a CO_2 tax	All levels
Reduce transportation demand	Support for domestic and local markets, increased public transport	Eco-labeling institutions, Green infrastructure	National, Regional
Develop alternative energy sources	Supporting R&D of green energy sources	EU Directive on renewable energy (2009/28/EC)	All levels
Measures aimed at direct *drivers*			
Reduce shipping	(*No existing policy instruments aimed at this driver*)		
Reduce tanker traffic	(*No existing policy instruments aimed at this driver*)		
Measures aimed at *pressures*			
Limit tanker traffic in sensitive areas.	Establishment of protected areas	PSSAs under IMO	National, Regional
Improve technical standards	Requirements for double hulls, separa-ted ballast tanks, etc.	IMO - SOLAS 1974	International
Improve spill response capacity	Oil response training drills, training of personnel	IMO – OPRC 1989	National, Regional, local
Safer navigation procedures	Regulatory require-ments on navigation equipment, rules of the road, and operating procedures	IMO - COLREG 1972	International
Better trained crews	Regulatory require-ments for training and credentials	IMO - STCW 1978 ILO 1976	International
Increase usage of piloting in harbors	Requirements (unsub-sidized) or incentives (subsidies) for piloting services at local harbors	Paris MoU	National

Measures aimed at *state of the environment*			
Restore ecosystems	Environmental compensation requirements, efforts to reach GES	ELD, IOPC Funds, MSFD	National, Regional, International
Improve fishing regulations	Reduce fishing allowances, better enforcement of existing regulations (TAC), establishment of marine reserves	CFP (EU)	Regional, International
Environmentally-sensitive urban development	Incentives for compact urban growth, improved control of non-point pollution	Green infrastructure, Brownfields re-development, Espoo Convention	Local
Protect biodiversity	Fulfillment of environmental objectives on biodiversity	CBD	National, Regional, International
Measures to remove pollutants	Improved control and treatment of wastewater, expand capacity of treatment	BSAP	National, Regional
Promote coastal livelihoods	Government subsidies to fishing villages or to support tourism industry	Rural development assistance programs	National, Regional
See list of abbreviations at front of chapter			

3.3. Bibliography of oil spill studies in the Baltic Sea

In this section, we present a number of studies that discuss the management of oil spill risks in the Baltic Sea from various perspectives. The studies address oil spill response strategies, including values at stake, measures, instruments and governance. This is not an exhaustive list but provides an overview of present research. For each of the studies, we provide a summary and short information concerning method, geographic scope and the main management recommendations.

3.3.1. Hassler (2011)

Hassler, B. 2011. *Accidental versus operational oil spills from shipping in the Baltic Sea: Risk governance and management strategies*. Ambio 40: 170–178.

Main management recommendation: Increase the use of policy instruments that address actors' incentives to alter behavior.
Geographic scope: Whole Baltic Sea.
Method: Regime analysis / discussion based paper / literature overview.
Summary: The authors distinguish between two types of oil spills; accidental and intentional. The authors argue that accidental spills often cause dramatic local ecological and economic effects, whereas the effects from intentional spills are harder to assess but may create more harmful long run effects. The focus of the paper is to study how risks for each type of spill affect institutional responses in the Baltic Sea. A conclusion is that the institutional responses vary in a rational manner depending on which type of spill has driven their emergence.

For accidental spills, the main response has been requirements on vessel constructions and onboard safety installations. At a Baltic Sea level, further measures are traffic separation schemes and designation of protected areas. To improve remediation once a spill has occurred, the Baltic Sea states collaborate on coast guard training and have strategies to pool regional response capability.

The authors argue that there are three ways to reduce accidental oil spills: Flag State Control (FSC), Port State Control (PSC), and Human Factor Errors (HFE). For FSC, a problem is that not all flag states have the same safety standards, causing a "flags of convenience" problem. For PSC, the authors conclude that more port inspections need to be performed and that regional differences are too high. For HFE, the authors conclude that about 50 per cent of the vessel accidents in the Baltic Sea are due to human errors.

For intentional spills, the most common causes are cleaning of tanks at sea, flushing of machine rooms and similar actions. Several measures can be taken to reduce these spills: Crude Oil Washing (COW), which requires the cleaning of tanks at port (where the relevant facilities are in place); Load on Top procedures, where the hot water used for cleaning is allowed to separate from the oil contents during voyage and only the relatively clean water can then be released; and HELCOMs No-Special-Fee system, which allows cost-free tank cleaning at port. Further, the coast guard surveillance is an important aspect. The authors however point to two difficulties: a) convincing polluting vessels to clean in port and b) reducing the number of undetected spills that are likely to occur where/when surveillance is less effective. They also discuss the difficulties associated with enforcing regulations and taking legal action against polluters. Identification of the polluter is one of the main obstacles.

The authors divide marine governance into four 'empirical areas'

- Precaution/vessel design (e.g. double hulls, protected areas and traffic separation)
- Monitoring (e.g. surface, aerial and satellite surveillance, Port state control)
- Enforcement (e.g. FSC, No-Special-Fee system and coast guard patrols)
- Remedial action (e.g. pooling of equipment in case of large spills and joint exercises to combat oil pollution).

Hassler further use a spatial division of governance:

- Global (e.g. IMO, ILO)
- Regional (e.g. EU, HELCOM)
- Local (including sub national actors such as municipalities and port authorities)

For accidental oil spills, a conclusion is that the existing governance is mainly global and national, and focused on precaution/vessel design. For intentional spills, regional measures such as the No-Special-Fee system are the main governing forces, and national/global measures are less pronounced. The authors argue that the marginal cost of washing tanks in port is not zero –

ships lose valuable voyage time in the port – which underscores the importance of designing policies with a full understanding of the incentive structure facing operators.

3.3.2. Ihaksi et al. (2011)

Ihaksi, T., Kokkonen, T., Helle, I., Jolma, A., Lecklin, T., 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

Main management recommendation: Decision-making tools are needed to prioritize the use of oil combating equipment in the event of an oil spill. An index-based tool that is easily accessible to non-ecologists is a promising way forward to effectively safeguard areas of high conservation value.
Geographic Scope: Gulf of Finland.
Method: Index-based, using map application developed for spatial prioritization of oil combating with oil booms.
Summary: The authors argue that the areas typically identified by sensitivity maps are too large to be safeguarded with available oil combating equipment. New methods for prioritization of areas are needed that are able to pinpoint particularly important species and populations within these areas. Further, the decision making on spatial allocation of oil combating capacity is heavily constrained by time, resources and knowledge available in the event of an oil spill. New prioritization tools need to be user-friendly and comprehensible for non-ecologists.

The paper develops an index-based method that can be used to prioritize the spatial location of oil booms in the event of an oil spill. Previous sensitivity maps have failed to consider the recoverability of species following an oil spill. The authors argue that populations of common species can recover well in the long term (ten years) but if the population pattern is clustered the population may be harmed even from a small spill. They also argue that certain populations of rare species might show a slow and uncertain recovery if they are already under pressure from other human activities.

The index is based on (1) the degree of exposure and mortality due to an oil spill, (2) the recovery potential after the spill, (3) the relative conservation value compared to other species or populations, and (4) the technical possibility to safeguard the population with oil booms. Species to be included in the index are selected based on four criteria: (1) the species is vulnerable to oil spills in the Gulf of Finland, (2), the species possesses conservation value, (3) the national population of the species is dependent on the coastal habitat, and (4) it is possible to predict the location of the species during the accident in order to use oil booms effectively.

669 populations representing approximately 120 threatened or near threatened species were included in the analyses, including vascular plants, algae, lichens, invertebrates, fish, birds and mammals. During the study it was found that all populations of some insect species could be wiped out as a

result of a single oil spill accident in the Gulf of Finland. This may cause severe effects to biodiversity. The authors recommend future use of the method and suggest that it be scaled up for use in other parts of the Baltic.

Note: A complementary approach to using this model is available in Kokkonen et al. (2010).

3.3.3. Lecklin et al. (2011)

Lecklin, T., Ryömä, R., 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.

Main management recommendation: Further research on the impacts of oil exposure on different groups of organisms is needed to guide management decisions.
Geographic Scope: Gulf of Finland.
Method: Bayesian Network simulation.
Summary: The paper presents a model for analyzing the acute and long-term impacts from an oil spill to selected functional groups of organisms in the Gulf of Finland. Existing knowledge is rather imprecise concerning ecological effects of an oil spill, in particular the varying spill impact depending on location. For the Gulf of Finland, no *ex post* information exists because the area has thus far been spared from large scale oil spills.

The model is run for two scenarios: the most probable and the worst case accident in the Gulf of Finland. In the most probable scenario, a tanker carrying between 10 000 and 35 000 tons of heavy oil runs aground in coastal waters during spring. In the worst case scenario, a tanker carrying 150 000 tons of heavy oil collides with another vessel in the open sea during spring. The impacts on biota are modeled using six subnetworks of organisms: terrestrial plants, macrophytes, littoral macrofauna, fish, birds and mammals. Further, five variables are assessed: *acute impact* (estimated fate of adult individuals directly after oil exposure), *impact on offspring* (decrease in number of offspring after exposure to oil), *recolonization* (estimated rate at which the group of organisms recolonize exposed areas), *reproduction* (estimated average reproduction rate of the group of organisms), and *recovery* (the state of the group of organisms ten years after the oil spill).

The most probable scenario results in only minor long term effects, however effects to populations of auks may still be evident ten years after the accident. For the worst case scenario, long term impacts are more likely, especially to auks and ducks. The authors argue that these results should be cautiously used since the model contains many uncertainties. They argue for the continued use of similar models and the need for ecological data and more precise projections of marine oil transport patterns as a tool for informing decision makers about ecologically sensitive areas at risk.

Note: The paper also presents a thorough literature overview on existing information concerning ecological impacts from oil spills.

3.3.4. Hyytiäinen & Huhtala (2011)

Hyytiäinen, K. & Huhtala, A., 2011. *Combating eutrophication in coastal areas at risk for oil spills.* Annals of Operations Research, April 2011.

Main management recommendation: Improving management of coastal areas requires analyses that simultaneously tackle all important environmental threats.
Geographic Scope: Gulf of Finland.
Method: Monte Carlo simulation.
Summary: The paper studies the social profitability of nutrient abatement measures in the Gulf of Finland under the exogenous risk of oil spills. The authors use a model that integrates loads of nutrients from agriculture, nutrient dynamics in the sea basins, oil spill risk and recreational value of the Sea.

The Gulf of Finland is eutrophied and measures to reduce the effluents of nutrients to the Sea are costly. However, reducing eutrophication provides benefits, not the least in terms of recreational values. The costs of measures have been studied in several previous occasions and the authors use available cost data. Regarding benefits, the paper is based on estimates by Vesterinen et al. (2010). The study investigates how the profitability of unilateral (Finnish) or joint (Finnish, Estonian and Russian) nutrient abatement measures are affected when the risk for major oil spill events are present in the model. The underlying assumption is that an oil spill would lower the recreational value of the coastline, thus undermining the benefits created by nutrient abatement.

In the model, the development of nutrient concentrations is described as a stochastic processes in which the nutrient concentration in the current period, together with the net input of nutrients to the area, determines the concentration in the next period. For oil spills, the model is based on (1) the annual probability of large-scale damage from a spill, (2) variability in the magnitude as measured by change in recreational value, and (3) expected duration of the damage. The model further consists of four components: Nutrient stock dynamics, stochastic loads of nutrients, the cost of (agricultural) nutrient abatement measures and the benefits of nutrient abatement to the Finnish citizens. The last component also includes the probability and consequences of major oil spills.

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 at least for Finland. Generally, the models indicate that even a low risk of oil spills may reduce the expected net present value of nutrient abatement significantly.

The authors emphasize that the recreational losses from an oil spill, as well as the gains in recreational values from reduced eutrophication, represent only a proportion of the total cost-benefit picture; inclusion of other values are required to improve the basis for decision-making.

3.3.5. Helle et al. (2011)

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: 182–192

Main management recommendation: Bayesian network models are useful for analyses of oil spill management. Efficiency of oil combating is highly dependent on environmental conditions. Additional measures to reduce the risk of oil spills are needed.
Geographic Scope: Gulf of Finland.
Method: Probabilistic Bayesian network model.
Summary: The paper presents a Bayesian network model that evaluates the effectiveness of three options for oil combating in the Gulf of Finland: (1) mechanical recovery offshore, (2) dispersants, and (3) oil deflection booms inshore. The effectiveness of these combating options is evaluated based on the expected impacts to six species: (1) the grey seal, (2) the common eider, (3) the blue mussel, (4) the Baltic herring, (5) the prickly saltworth, and (6) the scarab beetle. The first two species are mobile, living in contact with both the littoral zone and the water surface. Species (3) and (4) represent subsurface organisms, and species (5) and (6) represent terrestrial onshore species.

The model considers an accident during the spring resulting in a spill of 25 000 – 50 000 tons of medium crude oil, a realistic worst-case scenario. In the model, the efficiency of mechanical recovery offshore appears to be heavily dependent on wave height (i.e., higher waves lead to less recovery). The efficiency of dispersants seems to be low – the authors argue that this is mainly due to the inefficiency of the dispersants in low salinity conditions like the Gulf of Finland. For oil deflection booms inshore, the effects on species are also small, but this may be related to insufficient investment in combating equipment. The effectiveness of oil deflection booms is highly dependent on the placement of the booms.

The authors conclude that the decrease in the population sizes in the scenario would be greatest for the common eider and the least for the Baltic herring. However, they emphasize that the prickly saltworth and the scarab beetle are threatened species and deserve particular attention. Even minor reductions in these populations may lead to severe consequences. The model suggests that oil combating in the Gulf of Finland should rely on mechanical recovery and inshore protection instead of chemical combating. However, the effectiveness of these measures is hard to predict and highly dependent on the prevailing environmental conditions, such as wind and wave height. Consequently, even large investments in response capacity are likely to be insufficient for the protection of some species, which underscores the importance of measures that reduce the probability of accidents occurring.

3.3.6. Other inaccessible studies

A number of studies were not accessible for this analysis but are highly relevant and should be considered in future analyses.

- There were a number of studies from other Baltic Sea states related to the Initial Assessment under the MSFD that considered oil spills and that we suspect contains valuable information. However, these studies were in native languages rather than English and it was beyond the scope of this study to translate them. These include:
  - Estonia provides statistics of ship accidents in the Baltic Sea and the potential environmental and economic damages from future oil spill accidents in the Baltic Sea (Aljona Karlõševa, email correspondence).
  - Latvia provides (1) a characterisation of the expected development of marine shipping until 2020 by main cargo types, including oil products – general trends for the Baltic Sea and for the Latvian shipping/ports; (2) an assessment of the expected frequency and size of oil spills through 2020; and (3) an assessment of the expected environmental impact and damage of these spills. The damage assessment is based on combining the impact and the environmental sensitivity (Kristine Pakalniete, email correspondence).
  - Lithuania provides a list of oil spills for the last 15 years, the volume spilled and the damage in monetary terms (Daiva Semeniene, email correspondence).
- Several research papers within the project Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland (IBAM) are not releasable by the authors at this time. When these studies are complete they will likely prove to be valuable. These include:
  - Helle, I., Vanhatalo, J., Rahikainen, M., Hoviniemi, K., Tuomi, L., Hänninen, M., Uusitalo,L., Altartouri, A., Mäntyniemi, S., Pitkänen, H., Jolma, A. & Kuikka, S. Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland, the Baltic Sea – How is it done? Manuscript.
  - Kuikka, S., Helle, I., Rahikainen, M. & Mäntyniemi, S. The impacts of alternative aims and management actions on the foreseen risks under several environmental stress factors – environmental policy analysis for the Gulf of Finland. Manuscript.
  - Rahikainen, M. et al. Probabilistic integrative analysis of risks of eutrophication and oil spills – case study on the Gulf of Finland herring fishery. Manuscript.

4. Conclusions

This section suggests there is room for improvement of the management of oil spill risks in the Baltic and makes a number of recommendations.

4.1. Need for improvement

Enveco, EESweden and IVL (2012) concluded that the existing policy response for the oil spill pressure in the Baltic is inadequate:[8]

We suggest that despite the fairly aggressive policy response to oil spills, additional requirements may be needed to reach GES given the continued and drastic increase in oil transport through the Baltic and NE Atlantic, particularly for port activities. (Section 6.1.2)

In particular, the report suggests that future policies focus on addressing threats from tankers, non-tankers, and port activities (see Table 6.3 in that report) and notes that "*.the risk for oil spills is expected to increase dramatically [in the Baltic] under 'business as usual', both until 2020 and until 2050.*" To support this conclusion the study points to several reports and analyses that suggest an increase in maritime transport and traffic in general, oil transportation in particular, and oil demand. The study concludes that despite the fact that tanker-related spills has decreased only slightly in recent years, the significant increase in shipping activity combined with the fairly small and congested sea lanes in the Baltic suggests that oil spill risk overall is expected to increase (for details see IVL, Enveco and EES, forthcoming).

Section 2 of this report, along with a large number of previous studies, provides evidence that an inadequate response may be costly since many important ecosystem services are at risk. In the next subsection, we provide recommendations aimed at improving future management.

4.2. Recommendations

In this section, we provide recommendations for the future management of oil spill risks in the Baltic Sea.

Do not underestimate what individual countries in the Baltic Sea region can do. 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 these existing measures (e.g., rigorous harbor police controls, enforcing penalties for non-compliance, satellite surveillance, etc) may provide significant benefits to society in terms of avoiding future ecosystem service losses. In some cases, individual countries (or regional blocks

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[8] This effectiveness analysis was admittedly crude and did not specifically consider factors that may determine the effectiveness of policies on the regulated community (e.g., type of approach (incentive-based vs. command and control), type of framework (guidelines/action plans, legally-binding, voluntary frameworks, etc.), driving forces, etc.

of countries) may also influence the development of certain regulations through international political action. Further, measures that improve port routines and response preparedness are driven locally. Hassler (2008) argues that the dominance of international conventions does not preclude incentives for individual countries to take unilateral actions to improve environmental outcomes. The study suggests that Sweden is a pro-active country in regards to oil spill prevention and has induced other countries to improve their implementation of international agreements through so-called "side payments" that finance regulatory implementation. The study notes that individual actions by both Sweden and Finland helped pave the way for the classification of the Baltic Sea as a PSSA. Further, Sweden's actions were decisive in developing HELCOM's Automatic Identification System (AIS) which makes it possible to identify the movements of international vessels at sea.

Continue to seek international collaboration. Despite the important role that individual countries play, international collaboration is critical for achieving successful oil spill response. This includes both immediate on-site clean up and response, as well as the development of improved manuals and procedures for operators related to ports of refuge. Collaboration is particularly important given the need to communicate clearly across heterogeneous states with different languages, regulatory customs, levels of enforcement, and inherent incentives (e.g., oil producing versus non-oil producing countries). Failure to cooperate will lead directly to an increase in the social costs of oil spills identified above.

Improve existing measures targeted at *pressures*. Measures targeted at *pressures* are the 'conventional' measures against oil spills and have a long track record, dating to the early 1970s in response to several high profile oil spill cases. Despite this long track record, there is room for improvement including the following[9]:

- *Compensation and restoration requirements.* International conventions have weak provisions for environmental restoration and repair (compensation) following an oil spill. Besides improving ecological resources and ensuring equity for victims, such requirements also encourage tanker operators to internalize future costs by taking additional spill prevention measures today. However, this raises the question of what implementation levels are suitable – for example, can an individual country pursue more stringent compensation requirements than its neighboring countries, and what are the limitations in terms of intervention with existing international conventions? Issues like this remain to be investigated.
- *Precision in oil combating.* Several of the papers summarized in Section 3.3 conclude that the success of oil spill response in terms of ecosystem protection is highly dependent on the allocation of existing combating resources and prevailing environmental factors such as weather and wind directions. Key issues to address when designing such measures are (1)

[9] See e.g. Enveco, EES, IVL (2012) Section 6.4.5, and Hassler, 2011.

which species and populations need particular attention? (2) where are these populations located? (3) which ecosystem services are of greatest value to protect? and (4) which measures are most suitable for protecting these valued services and populations? The literature reviewed in Section 3.3 provides guidance through the use of simulation models and scenarios, but also underscores the need for ecological data that underly the models. When an oil spill occurs, time is a scarce resource and managers need detailed, science-based, user-friendly guidance on how best to allocate oil combating resources.

- *Monitoring and enforcement of intentional spills.* Surveillance of intentional spills is a complex issue that requires consideration of operators' incentives. Differences between the ambitions of individual countries may lead a 'rational' operator to plan the washing out of tanks and machine rooms where the probability of detection (and/or subsequent liability) is low. This underscores the importance of regional cooperation to protect the Baltic Sea as a whole, while also allowing national measures to protect countries' own coastlines.
- *Maritime safety and human error.* Reducing the probability of accidents is a key factor in protecting ecosystems and ecosystem services from oil spills given an expected increase in shipping over the next decades. Several measures aimed at safety can be taken, but the complex web of international regulations implies difficult challenges for Baltic Sea managers. Hassler (2011) points to the importance of enforcing port state control regulations on the local level. Further, he argues that overall, the policy instruments aimed at improved maritime safety need to better consider the incentives of operators, so that they actually take the desired measures. Literature related to game theory modeling (Cohen, 1987) suggests that the strongest incentives for firms are those that are based on fines for inadequate precautionary measures, that is, policies aimed at reducing the probability of accidents occurring tend to be more effective than policies that address the aftermath of an actual accident such as improved response time, more stringent compensation requirements, higher punitive fines etc.

Hassler (2011) suggests that human error is a common cause of accidents although there is little consensus in the literature regarding the influence of this cause. If human errors are a major safety risk, research has to be directed to lowering the probability for fatal errors. Humans make mistakes by nature, which means technological and procedural systems should improve built-in redundancy. A first step is to analyze the most common types of human errors in the Baltic Sea. The second step is to acknowledge that these types of human error occur (For example, HELCOM (2007) note that human error was responsible for 32% of all shipping accidents in the Baltic in 2007, which represented the most common cause). The third – and perhaps most difficult – step is to find ways to adapt the system to be able to allow these errors without fatal accidents happening. In the end, even 'technical' errors may be due to systems that are inadequate to deal with the natural shortcomings of humans. For example, faulty navigation equipment can be avoided by improving procedures for technical control or better training of technical staff. A concrete step might be to improve reports of the causes of near-accidents or accidents without major consequences, in order to learn more about the human factor errors.

Rely also on the potential of measures targeted at *Drivers* and the Environmental *States*. Although measures directed at *pressures* are critical to an oil spill management regime (see suggested improvements above) the existing international conventions might have already "picked much of the low-hanging fruit", that is, we may require newer and more creative ways of avoiding adverse impacts on social welfare from oil spills. While measures directed at *pressures* play an important role in avoiding oil spills or reducing ecological impacts when they occur, they are limited by society's own ingenuity and response capability. They do little to bolster or strengthen the affected environment itself. Further, additional measures aimed at *pressures* may risk being duplicative. For example, double-hull ship requirements are requested under various international and regional regulations, and there is tremendous 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 are clearer for the regulated community, as are the consequences of failing to implement them. Knudsen and Hassler (2011) recognize the problem of redundancy, which they refer to as "regulatory overload." They suggest that rather than adding new regulations, the IMO should consider the weaknesses of "the implementation machinery on the local levels" (p. 206), which is particularly vulnerable when it comes to implementing regulations that require active compliance and monitoring by a nation state. The authors suggest the introduction of fines and penalties for rule-breaking behavior by industry, and also suggest that the inconsistency in inspection procedures across countries be addressed by requiring all inspection personnel to be trained and employed by the IMO itself (but still funded by local states, as is the case today).

Our analysis suggests that measures aimed at *drivers* (e.g., reducing fossil fuel demand) and environmental *states* (e.g. reducing overfishing) have historically received little attention in the literature. We provided examples of studies that emphasize the importance of these somewhat non-conventional and indirect perspectives on oil spill management. Measures targeted at *drivers*, such as reducing fossil fuel demand or supporting alternative energy sources should not replace other measures. We argue instead that the benefits of reducing oil spill risks should also be included in the cost-benefit calculations of these measures. The debate on fossil fuels is (justifiably) about climate impacts, but for the Baltic Sea states there is an additional dimension to the benefits: reducing fossil fuel dependency also reduces the risk of oil spills.

There has been much debate concerning whether individual states have anything to gain from being a "first mover", that is, being more ambitious than other countries in the reduction of carbon dioxide emissions. Inevitably, the costs are allocated to a single state while the benefits are widely distributed. Our analysis suggests that there may also be a more local benefit. This type of benefit may be small in the overall context but may be worth considering when assessing the benefits of oil spill measures. The expected increase in Baltic Sea shipping suggests that oil spill management consider several dimensions simultaneously.

Concerning measures targeted at the *state* of the environment, the motivation for acknowledging these as a response to oil spill risk is that despite society's best efforts, the risk of oil spills will remain non-zero, which means insurance against inevitable damage may provide an attractive complement to other measures. This parallels the "mitigation vs. adaptation" debate in climate change. Just as society must be able to adapt to for example changing sea levels from climate change, we must also be able to adapt to the possibility of increased oil spills in the future by being able to build resilience into our ecological defenses. For example, the final report of the IBAM project (IBAM, 2011) suggests that reducing overfishing may be a cost-efficient alternative to large investments in response capacity in order to protect weak fish populations.

These measures also provide several ancillary environmental benefits, which is an important argument for this approach. For example, efforts to improve resilience of ecosystems underscore the importance of taking a larger ecosystem services approach to environmental management. Such an approach assumes that the entire system is unhealthy as a result of several activities (eutrophication, overfishing, oil spills, etc) and that improved management of the system as a whole requires measures with multiple benefits.

There are, however, some inevitable limitations to these measures. Improving the state of the Baltic Sea is a long term challenge that requires active participation from all Baltic Sea countries. These measures should complement rather than replace the measures aimed at *drivers* and *pressures*. The focus should first and foremost be on preventing oil spills or improving response capacity when they occur, but when the costs of doing so become prohibitive, then investment in "resilience-building measures" may be warranted. This recommendation is based on a relatively narrow oil spill management perspective. However, from a larger Baltic Sea perspective – that is, one that considers the plethora of problems facing Baltic Sea managers – it may be rational to undertake resilience measures *in parallel* with spill prevention or improved response measures, rather than to undertake them in a hierarchal fashion that focuses primarily on direct measures and secondarily on indirect resilience measures. We argue that Baltic Sea management requires not only responses to individual environmental pressures, such as eutrophication, oil spills, overfishing, invasive species, hazardous substances, etc., but also overarching governance and holistic expertise. Researchers and Baltic Sea managers should consider the concept of 'an optimal mix' of policy instruments that are both broad – which creates resilience of the system – and narrow – which targets specific risk sources such as oil spills.

Improve knowledge concerning ecological and economic impacts from oil spills. Section 1.2.2 suggests that non-market costs of oil spills are more challenging to measure than direct or indirect costs. The literature review underscores the demand for more information concerning the ecological impacts of oil spills. Improving this knowledge is crucial for future management. For example, the safeguarding of threatened species against oil spill risks requires more knowledge concerning how these species behave, where they are located and how best to protect them. Further, Section 2 and 3 highlight various studies that indicate that oil spills can be costly for society if too little is done to prevent them. However, assessing the social profitability of specific measures, a reasonable scale of measures, or choosing between types of measures requires new valuation estimates. Without such estimates, it is difficult to prioritize among available management options. An Ecosystem Services Approach (ESA) to management, as advocated by the MSFD, requires knowledge of which ecosystem services are the most valuable. This is particularly relevant in the discussion of response capacity in ecologically sensitive areas. The ESA would also require that spatial analyses be performed concerning particularly valuable areas, which deserve special attention in management. 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 could prove valuable when conducting socioeconomic analyses.

Further, there is a need for more economic data concerning the value of Baltic Sea ecosystem services and the costs and benefits of specific measures to address oil spill risk. We suggest the use of databases 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 costs. This can lead to inadequate policy appraisal or weak liability procedures against polluters.

Finally, we suggest that nationally produced reports that may be relevant for other Baltic Sea states be produced in English in order for this information to become internationally available. It is costly for this type of information to be hidden, given the large data demands across countries (Knudsen and Hassler (2011) note that IMO implementation challenges are frequently linked to language/communication problems).

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