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REPORT

The Costs of Meeting the Environmental Objectives for the Baltic Sea: A Review of the Literature

Katarina Elofsson

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Abstract The environmental targets of the recently agreed Baltic Sea Action Plan (BSAP) targets are likely associated with a considerable cost, which motivates a search for low-cost policies. The following review shows there is a substantial literature on cost-efficient nutrient reduction strategies, including suggestions regarding low-cost abatement, but actual policies at international and national scale tend to be considerably more expensive due to lack of instruments that ensure a cost-efficient allocation of abatement across countries and sectors. Economic research on the costs of reducing hazardous substances and oil spill damages in the Baltic Sea is not available, but lessons from the international literature suggest that resources could be used more efficiently if appropriate analysis is undertaken. Common to these pollution problems is the need to ensure that all countries in the region are provided with positive incentives to implement international agreements.

Keywords Baltic Sea Action Plan (BSAP) · Costs · Review · Eutrophication · Hazardous substances

Introduction

In 2007, the Helsinki Commission (HELCOM) launched the so called Baltic Sea Action Plan (BSAP), which outlines the steps necessary to restore good ecological status of the Baltic Sea's marine environment by 2021. The Baltic Sea Action Plan addresses all major environmental problems affecting the Baltic marine environment and defines four environmental objectives: a Baltic Sea unaffected by eutrophication, undisturbed by hazardous substances, with environmental friendly maritime activities, and with a favorable conservations status of Baltic Sea biodiversity (HELCOM 2007a). The targets imply that considerable efforts are called for. It is well known that large environmental improvements cannot be reached without costs to society and recognition of cost-efficient strategies is fundamental for decision makers who want to reach targets without wasting society's resources on unnecessarily expensive abatement programs.

The aim of this article is to identify the lessons to be drawn from the literature regarding cost-efficient strategies to improve the environmental situation in the Baltic Sea. The review shows there is a substantial literature on the costs of reducing eutrophication, but for hazardous substances and oil spills there is basically no research applied to the Baltic Sea. In these two latter cases, the relevant international economic literature is discussed instead.

The article is organized as follows: first, there is a brief introduction to the different environmental targets and the cost-efficiency concept, followed by an examination of the literature on cost-efficient strategies to reduce eutrophication, hazardous substances, and oil spill damages. The article ends with a discussion of the findings.

The BSAP Targets

Eutrophication

The Baltic Sea, see Fig. 1, is severely affected by pollution caused by human activity. Eutrophication of the sea's

K. Elofsson (✉)
Department of Economics, Swedish University of Agricultural Sciences, Box 7013, 750 07 Uppsala, Sweden
e-mail: katarina.elofsson@ekon.slu.se

Fig. 1 The Baltic Sea drainage basin. *Source*: GRID Arendal (http://www.grida.no/baltic/htmls/maps.htm)

ecosystem is known as a major problem (HELCOM 2007a) and has led to reduced water quality which has a negative impact on recreation, contributes to oxygen deficit in the deepwater and causes damage to biodiversity. The cause of eutrophication is the excessive nitrogen and phosphorus loads, coming mainly from land-based sources within the catchment area (HELCOM 2007a).

In order to address the eutrophication problem BSAP requires, e.g., concentrations of nutrients close to natural levels, clear water, a natural level of algal blooms, a natural distribution and occurrence of plants and animals, and natural oxygen levels. With assistance from researchers, quantitative targets for improved water transparency have been translated in operational targets for nitrogen and phosphorus load reductions to different marine basins. The basin load targets have been recalculated as targets for loads from each country to each basin, while requiring that reductions from a country should be proportional to its initial loads[1] (HELCOM 2007a).

[1] The initial loads are calculated as the average load 1997–2003, minus the reductions that would take place if all countries had fully implemented the Wastewater Directive or HELCOM Recommendation for municipal wastewater treatment.

Hazardous Substances

Hazardous substances damage the ecosystem through impaired health and harmed reproduction of animals and increased pollutant levels in fish for human consumption (HELCOM 2007b). Once released into the sea, hazardous substances can remain in the marine environment for long time and accumulate in marine organisms. BSAP expresses the strategic goal as a “Baltic Sea life undisturbed by hazardous substances” (HELCOM 2007b). The short-term operational target is a decreasing trend in concentrations for all substances, while the medium-term target is to reach EU maximum levels in muscle meat of fish for, e.g., mercury, cadmium, and dioxins. The long-term target is to reach near background concentrations for naturally occurring substances (e.g., mercury and cadmium) and to reach close to zero concentrations for man-made synthetic substances (e.g., tributyltin).

Oil Spills

The Baltic Sea is one of the most intensely trafficked marine areas in the world (HELCOM 2007c). This heavy traffic occurs in narrow straits and shallow waters, making the Baltic Sea a difficult area for navigation, with an increased risk of shipping incidents. Some of the environmental consequences of the extensive shipping are illegal and accidental discharge of oil. Oil spilled deliberately or during accidents may destroy important marine and coastal habitats (HELCOM 2007c). Among its targets for marine activities, BSAP therefore aims at zero illegal and accidental pollution of the sea.

The Cost-Efficiency Concept

In the environmental debate cost-efficiency is often called for (see e.g., EC 2008). Cost-efficiency implies that environmental targets are reached at minimum cost to society. This means, roughly, that the cheapest measures should be implemented first, followed by successively more expensive measures until the target is fulfilled.

Three steps are necessary in order to define a cost-effective allocation of measures. The first is to interpret the politically determined environmental target into a measurable target indicator if the original target is broadly defined. The second is to calculate costs of measures at the sources and the third to quantify the impact of measures on the target. Together, this information makes it possible to evaluate the costs of different measures in relation to the impact on the environmental target.

Eutrophication

Reducing Nutrient Loads at Least Cost

A handful of studies analyze the costs of nutrient reductions on Baltic-wide scale. The model structure applied is compared in Table 1.

The first large-scale study, by Gren et al. (1997), was published in 1997 and includes estimation of the costs for different reductions in the coastal loads of nitrogen and phosphorus. One major finding in the study is that a policy with uniform, proportional reduction targets for all countries around the Baltic Sea could imply four times larger costs than the cost-efficient solution when nutrients are reduced by 50%. It is shown that in spite of a cost-efficient strategy being beneficial to the region as a whole, many countries are likely to resist a cost-efficient distribution of the abatement burden. The reason is that countries with many low-cost abatement options will have higher costs with a cost-efficient agreement than under proportional reductions.

Proportional and cost-efficient allocations of the abatement will imply different spatial distributions of load reductions. As the Baltic Sea is heterogeneous this could have implications for the environmental effects. Based on the results in Gren et al. (1997),[2] Neumann and Schernewski (2005) compare the impact on the sea of the two policies and conclude that on the overall, differences between the strategies are small, but with cost-efficient reductions the environmental improvements in coastal regions in the southern part of the Baltic Sea will be larger.

Ollikainen and Honkatukia (2001) analyze the costs of reaching a 50% reduction of nitrogen and phosphorus loads to the Baltic Sea. In spite of the large difference in cost estimates between this study and the one by Gren et al. (1997) the qualitative results are rather similar, confirming that uniform, proportional reductions in all countries will imply unnecessarily high costs for meeting nutrient targets and that low-cost countries are unlikely to prefer a cost-efficient allocation of the abatement burden to a proportional one.

Schou et al. (2006) present a cost-efficiency model for the Baltic Sea drainage basin using more recent data compared to the above studies. The costs for nitrogen reductions are computed for a single reduction level.

HELCOM has initiated an analysis of the costs and effects of alternative policy scenarios suggested in the BSAP (COWI 2007). One scenario is, e.g., a combined strategy where the number of people connected to wastewater treatment is increased and the performance of the plants is improved in some countries, there is a 55% reduction in NO_x-emissions from shipping and agricultural land is reduced.

In a recent study by Gren (2008a), the BSAP targets are analyzed. The cost and benefits for (i) BSAP country targets and (ii) cost-efficient reductions of total nitrogen and phosphorus loads to coastal waters are compared. The latter target is shown to be the cheapest, as it allows measures to be located where loads can be reduced at least cost. It is estimated that achievement of the BSAP country targets will, at the minimum, cost 2,560 Million EUR/year. If this target was replaced by one requiring the same total reduction, but no restrictions were made on the location of measures and loads, the total minimum cost would be 1,620 Million EUR. Thus, introducing separate targets for different basins and countries could increase costs by the order of 60%.

Given that the BSAP abatement burden has been determined through negotiations, one might be tempted to assume that the extra cost it implies should at least give benefits in terms of a more "fair" distribution of the abatement burden. However, Gren (2008b) shows that if by "fairness" is meant either a more equal distribution of efforts per capita or a distribution of efforts that is determined by ability to pay, the opposite is likely to be the case, i.e., the BSAP abatement will be more unfair than a general cost-efficient abatement policy.

Comparison of Results in Baltic-Wide Studies

The Baltic-wide studies show considerable differences with regard to the number of measures included, spatial coverage, spatial disaggregation, and data used. Costs are calculated for different total load reductions. These factors all contribute to differences in the estimated total costs for a given load reduction. In the following, results are compared with regard to the costs for nitrogen load reductions, conclusions regarding low- and high-cost measures, and incentives for international cooperation.

In Fig. 2, the total minimum cost for nitrogen emission reductions are compared.[3] Costs for the combined policy analyzed in COWI (2007) are considerably higher than the cost-efficient solution which gives the same environmental

[2] Or, more precisely, a popular presentation of the results in (Gren 2000).

[3] Although all the included studies have been published in different years, the effect of the time of data collection is not easily established. From a theoretical viewpoint, the costs for abating a given additional quantity of nutrients should increase over time, if the cheapest abatement options are successively used up. However, there is no evidence that the cheapest measures are the ones that have actually been implemented first (see e.g., Elofsson and Gren 2004). Moreover, the capacity estimates of different measures used in the studies are rather qualified guesses than built on hard data, as such data cannot be found. Hence, one cannot expect to find that the chosen capacities in the studies decrease over time.

Table 1 Comparison of models that calculate Baltic-wide costs of nutrient reductions to coastal waters

	Gren et al. (1997)	Ollikainen and Honkatukia (2001)	Schou et al. (2006)	COWI (2007)	Gren (2008a)
Number of measures included	15	Measures included in HELCOM reports	10	16	14 for nitrogen and 7 for phosphorus
Sectors covered	Agriculture Wetlands Wastewater treatment Energy Transport	Measures included in HELCOM reports	Agriculture Wetlands Wastewater treatment Energy Transport	Agriculture Wetlands Wastewater treatment Phosphate-free detergents Rural households Energy Transport	Agriculture Wetlands Wastewater treatment Phosphate-free detergents Rural households Energy Transport
Nutrient transports from sources to the sea	Interdependencies between measures	Not included	No interdependencies	No interdependencies	Interdependencies between measures
Nitrogen target[a], reduction in total load to coastal waters	0–60%	50%	20%	12%	0–50%
Phosphorus target[b], reduction in total load to coastal waters	0–60%	50%	n.a.	33%	0–60%
Total cost per country reported	X	X	X	X	X
Marginal cost of total reduction reported	–	–	–	–	X

[a] Given that total N-loads to coastal waters are approximately 800,000 tons per year

[b] Given that total P-loads to coastal waters are approximately 37,000 tons per year

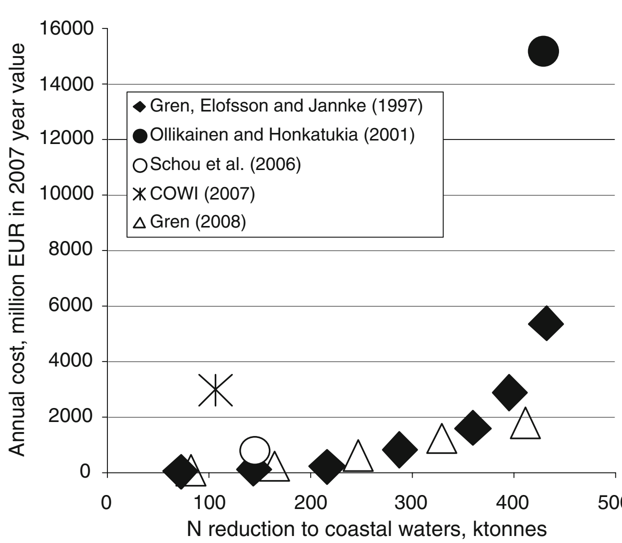

Fig. 2 Minimum total cost for different nitrogen reductions in Baltic-wide models. (Costs have been converted to EUR using average exchange rate 2007 according to the Swedish Riksbank. All data have been inflated to 2007 year value using the Swedish CPI)

effect in Gren et al. (1997) or Gren (2008a). One important reason is that the scenario in COWI (2007) is not a cost-efficient one, but the outcome of a limited set of more arbitrarily chosen combination of policy measures.[4] Also the study by Schou et al. (2006) yields higher costs than Gren et al. (1997) and Gren (2008a) for the comparable reduction level. One explanation for the difference is that the target in Schou et al. (2006) requires a fixed reduction for each marine basin. The study by Ollikainen and Honkatukia (2001) indicates much larger costs than Gren et al. (1997) and Gren (2008a) for the same reduction. The reason is that costs are estimated based on a small subset of measures, namely point source emission reductions, which are not representative for the larger supply of measures available.[5] The cost estimates in Gren (2008a) are slightly lower than in Gren et al. (1997), which is counterintuitive as policies undertaken in the time between the two studies could have implied higher costs for reducing the remaining emissions. However, the difference between the two studies might be explained by agricultural policy reform, which has altered the costs of some measures, differences in measure coverage and data. As can be seen in the figure,

[4] This completely outweighs the effect of inclusion of Ukraine and Belorussia in the COWI study, which could be expected to lead to lower total costs.

[5] Instead, most studies suggest many low-cost abatement options in the agricultural sector.

three of the studies give rather similar results with regard to the total costs of nitrogen reductions in spite of the variation in measure coverage and data. The differences toward the two remaining studies seem to have straightforward methodological explanations, clarified above.

The actual costs of abatement will be higher if policies are not cost-efficient. Elofsson and Gren (2004) compare Swedish nitrogen policies from 1995 until the early 2000's to results from a cost-efficiency model and show that costs for reductions undertaken are approximately three times higher than what would have been the case if the policy were cost-efficient. Correspondingly, with the same budget, reductions could have been at least twice as large. The national inefficiencies are explained by both the choice of measures and their geographical distribution. In particular, results suggest that measures in the Bothnian Bay drainage basin can be cost-efficient if the target is an improvement in the Baltic Proper, which contrasts with policy suggested by BSAP.

Comparing the conclusions regarding the relative costs of different measures, one finds that wetland construction, reductions in fertilizer use, improved manure management, catalytic cleaning of NO_x-emissions from ships and improved wastewater treatment is recommended in more than one study to reduce nitrogen loads. For phosphorus, the importance of reductions at wastewater treatment plants and the use of phosphate-free detergents is emphasized in the studies, see Table 2.

The decision to participate and enforce international agreements is taken by the individual national governments in the Baltic region. Several studies compare the incentives for countries to participate in international agreements. Gren et al. (1997) and Ollikainen and Honkatukia (2001) compare the incentives for countries to participate in a cost-efficient international agreement on nutrient reductions when the alternative is the proportional reductions. Gren (2008a) presents net benefits to different countries for a couple of scenarios where both nitrogen and phosphorus are reduced and Gren (2001) analyzes the benefits and costs from signing an international agreement when free-riding is an alternative. The results from these comparisons are collected in Table 3. The table suggests that Poland, Latvia, Lithuania, and Russia are countries that may not prefer a cost-efficient or cooperative solution unless other countries contribute to their abatement costs. Sweden and Finland seem to be the major winners from cost-efficient or optimal international cooperation. Thus, unless mechanisms are developed to ensure that all countries have incentives to sign and enforce international agreements there might be a risk that environmental targets for the sea are not met. It is interesting to note that the conclusions are robust in spite of the methodological differences, e.g., between Gren (2001) and the other studies.

The Links Between Policies Against Eutrophication and Other Policy Issues

Policies in several fields affect both the needs for emission reductions and the relative costs of different abatement options. The Common Agricultural Policy in the EU countries has for many decades provided incentives for intensive agricultural production, which has contributed to larger emissions of nutrients. The single-farm payment scheme introduced in 2003 implied that price-support to agricultural production was largely replaced by area-based flat-rate support to agricultural land. The reform is

Table 2 Comparison of results in Baltic-wide models

	Gren et al. (1997)	Ollikainen and Honkatukia (2001)	Schou et al. (2006)	COWI (2007)	Gren (2008a)
Nitrogen measures deemed cheap	Wetlands Agricultural measures Wastewater treatment	n.a.	NO_x-reductions in energy sector Reduced fertilizer use Wetlands Catchcrops	NO_x-red from shipping WWTPs in coastal urban areas Catchcrops, reduced fertilizer use Manure-storage facilities	NO_x-red from shipping Fertilizer reductions Wetlands
Nitrogen measures deemed expensive	n.a.	n.a.	Livestock reductions	NO_x-red if only purpose is eutrophication target	NO_x-red in energy and transport sector Private sewers
Phosphorus measures deemed cheap	Wastewater treatment Wetlands Agriculture	n.a.	n.a.	Wastewater treatment in coastal urban areas Phosphate-free detergents	Phosphate-free detergents Fertilizer reductions Wetlands
Phosphorus measures deemed expensive	n.a.	n.a.	n.a.	n.a.	n.a.

Table 3 Losers under a cost-effective or cooperative solution (losers are marked with X)

	Nitrogen			Phosphorus		Nitrogen and phosphorus
	Gren et al. (1997)	Ollikainen and Honkatukia (2001)	Gren (2001)	Gren et al. (1997)	Ollikainen and Honkatukia (2001)	Gren (2008a)
Sweden						
Denmark		X		X	X	
Germany				X		
Poland	X	X	X	X	X	X
Estonia	X		X			
Latvia	X	X	X	X		X
Lithuania	X	X	X	X	X	X
Russia	X		X	X	X	
Finland						

expected to lead to lower nutrient emissions on the larger scale (Nowicki et al. 2007; Schmid et al. 2007; Gaiser et al. 2007). One important reason is the expected reduction in livestock holdings (Schmid and Sinabell 2007; Oglethorpe 2005). At smaller scale, the impact of agricultural reform on nutrient emissions may vary in both direction and magnitude between different catchments depending on the changes in the localization of agricultural production (Gaiser et al. 2007; Lehtonen et al. 2007). If nutrient emissions to the Baltic Sea are reduced on the overall, this implies that the total abatement cost will fall.

Over time, some agricultural support has been shifted over from production to rural development programs. Under these programs, each country can develop agri-environmental policy programs given that the measures are co-funded from the national budget. However, Brady (2003) concludes that for southern Sweden, agri-environmental policies directed toward nitrogen emissions barely compensate for the increase in emissions caused by production-related support and shows that the cost-efficient strategy differs with or without production support.

Climate change and climate policy will affect cost-efficient abatement strategies for the Baltic Sea. It is expected that climate change will increase riverine outflow of nutrients to the Baltic Sea (Arheimer et al. 2005) and thereby increase the need for nutrient reductions. However, nutrient emissions depend also on the responses of policy makers and farmers to climate change (Abler et al. 2002). Climate policies directed toward CO_2-emissions will, e.g., as a by-product also reduce NO_x-emissions (Östblom 2007) and increased cultivation of energy crops on arable land might reduce nutrient emissions (Börjesson 1999). Both natural and policy-induced changes will thus have implications for the cost-efficient strategy.

Finally, marine nutrient reduction policies have implications for other environmental targets; reductions of NO_x-emissions can lead to improved air quality and thereby considerable health benefits (Krupnick et al. 2005; Samakovlis et al. 2005) and reduced nutrient loads to the sea may affect fish biomass (Thurow 1997) and hence the value of fish catches.

The Implications of Ecosystem Behavior for Cost-Efficient Nutrient Reductions

Policies addressing large-scale ecosystems need to take uncertainty into account. Coastal load variability will increase abatement costs if the policy maker dislikes uncertainty about target achievement and correlation between different variable processes can be of importance for the cost-efficient policy (Elofsson 2003; Byström et al. 2000).

Internationally agreed targets for the Baltic Sea are expressed in terms of load reductions to coastal waters, but marine research has shed light on the importance of nutrient transports between different basins in the Baltic Sea. Gren and Wulff (2004) apply input–output analysis to a marine transport model to compare policies that take into account either the immediate or the final impact on each basin in the Baltic Sea from changes in loads to any of the basins. Results show that for the Baltic Proper and the Gulf of Finland, costs would be overestimated if only the immediate effects were taken into account, as the effects are larger in the longer run due to biochemical processes in the sea. If marine transports are accounted for, there is a larger possibility that measures located at a long distance from the target basin can be included in the cost-efficient strategy.

So far, no Baltic-wide cost-efficiency model takes the role of time dynamics into account, but small-scale studies suggest that it can be cost-efficient to apply downstream measures more intensively in an earlier phase of the abatement (Hart 2002; Laukkanen and Huhtala 2007). Furthermore, the debate concerning whether action against nitrogen or phosphorus should be prioritized has been shown to have an economic aspect: a cost-efficient strategy would require that the choice of nutrient to focus on is jointly determined by costs of nutrient load reductions, the impact of nutrients on eutrophication and the stringency of the environmental target (Elofsson 2006).

Hazardous Substances

To calculate cost-efficient solutions for reductions in hazardous chemicals it is necessary to have information on transport pathways, persistence, decay, and bioaccumulation. Without this information, preventive and remedial measures cannot be compared with regard to the impact on the targets. In addition to this, it is necessary to have information on, e.g., regional and domestic production and consumption of hazardous substances. Information on these parameters is often not available (Selin and VanDeveer 2004).

Although systematic investigations of cost-efficient reductions of hazardous substances in the Baltic Sea have not been found, a review of the international economic literature might serve as a point of departure for future work in this field.

Estimation of Abatement Costs at the Sources/Site of Abatement

Much of the literature addresses the costs of reducing a single pollutant at different sources, e.g., mercury (Hylander and Goodsite 2006; Vandeven and McGinnis 2004; De Cerreño et al. 2002) or cadmium (Peirce et al. 2002).

For the Baltic Sea, a large set of hazardous substances is targeted by HELCOM and several of those are accumulated in sediments. Thus, multiple substances can be abated simultaneously through sediment removal. Studies on the costs of removal of contaminated sediments show that the costs for treatment of contaminated sediments depends on technology choice, the type of contaminants present, sediment thickness and volume, sediment type, distance from the site to the coast, water depth, and topography (Laugesen et al. 2001).

Tributyltin (TBT), which is used on ship hulls as an antifouling agent, is one of the hazardous substances targeted by HELCOM. TBT can be considered as an input in shipping activity. The substance is mainly spread via international maritime transports. It is persistent and bioaccumulating and reduces immune defense systems and changes the hormone balance. The International Maritime Organization (IMO) has banned the use of TBT for vessels below 25 m, but larger vessels may still sail in spite of being painted with TBT. This ban implies a restriction on input use, which can be expected to give rise to a cost. The economic implications of the TBT ban has been analyzed in a couple of studies where it is argued that the costs of a ban are large because the lower speed when the hull is fouled leads to delays and increased use of fossil fuels (Abbott et al. 2000). Moreover, several factors, such as increased emissions of CO_2 and sulfur (Abbott et al. 2000) and a larger risk for introduction of invasive species (Champ 2000), have not been accounted for when evaluating the costs of the ban.

Uncertainty and Time Dynamics

Analyzing the role of pollutant transports for the cost-effective abatement strategies against heavy metals in the river Dalälven catchment in Sweden, Baresel et al. (2006) conclude that down-stream measures such as wetlands are cost-effective if there is uncertainty about the distribution of emissions on different sources of origin. The intuitive explanation is that money spent on abatement at the sources runs the risk of targeting the wrong source.

The role of time dynamics and the persistent nature of hazardous substances are analyzed by Conrad and Olson (1992). They calculate strategies for reductions in the concentrations of a pesticide outside eastern Long Island. Dynamics of the pollutant is based on time series data on agricultural use of the substance and concentrations in the water, and the results show when and how much to abate in order to achieve a future environmental target for pesticide concentration in water.

Oil Spills

Under the BSAP target for environmental friendly maritime activities reductions in oil spills, accidental and deliberate, is one of the concrete aims. Economic analysis of oil spill cleanup costs or costs for preventive measures that reduce the probability of oil spills are not available for the Baltic Sea. However, there is a relatively large international literature in the field.

The damage from oil spills can be reduced through (i) reductions of the probability of an oil spill or (ii) oil spill clean ups after a spill has occurred. The probability of an accidental oil spill due to collisions and grounding can be reduced through broadening or deepening of transportation lanes, while changes in the localization of transportation lanes might reduce environmental damages from oil spills. Moreover, the probability of an oil spill could be reduced through enhanced control efforts, which reduce the incentives to spill oils deliberately. Once an oil spill has occurred, the cleanup is almost never complete. Therefore, if policies that prevent oil spills are compared to oil spill clean ups, it is necessary to take into account the expected environmental damage that may occur even after a cleanup operation.

Oil Spill Clean-up Costs

Estimations of the costs of oil spill cleanups show that they depend on the type of oils spilled, the method used, the size of the spill, the location, and the extent of shoreline pollution (Etkin 2000). In addition, the total costs of oil spill clean ups are likely to depend on enforcement efforts. One might expect that larger enforcement efforts should reduce the number of oils spills detected because of the deterrence effect. However, the number of oil spills detected could increase with increased surveillance if the larger number of detections outweigh the lower total number of oil spills (Epple and Visscher 1984). Using data from the US Coastguard, Cohen (1986) also shows that it matters who carries out the cleanup operation: polluter financed cleanups tend to be more costly than governmental cleanups, possibly because polluters have incentives to signal that cleanups are too costly compared to the benefits.

The Expected Clean-up Costs of Accidental and Illegal Oil Spills

The probability of an oil spill depends on, e.g., the amount of shipping, the amount of oil transported, enforcement efforts, and requirements for assisted navigation. These are factors that could be affected through policies. With knowledge about the link between these factors and their corresponding role for the risk for an oil spill, the resulting risk for an oil spill at different locations could be estimated. Bigano and Sheehan (2006) show how accidental oil spill probabilities can be calculated based on information about the probability of different events that contribute to the risk of an accident. Having calculated the risk of an accidental oil spill at some vulnerable sites in the Mediterranean, they are able to estimate expected clean-up costs for differently large oil spills at different locations.

Of importance for the ex ante expected costs of accidental oil spills are also the private economic incentives to avoid accidents. In the case of a casualty, there are private costs associated with damages to the ship, losses of revenue because the ship must be repaired, and costs for crew hurt or left without work. Thus, there are smaller private incentives to avoid accidents if a vessel and its cargo has low-private economic value (Cohen 1987).

The expected costs of illegal oil spills can be reduced through enhanced enforcement efforts. Cost-efficiency consideration requires that the most efficient enforcement activities are used. In this spirit, Cohen (1987) compares the impact of different types of enforcement efforts, such as, e.g., actual monitoring of oil transfer operations, random port patrolling, and vessel inspections, on the amounts of oil spilled and concludes that the two former have a larger deterring impact. Hence, a better effect might be achieved through a reallocation of enforcement efforts towards more efficient activities.

The Expected Environmental Damage Cost of Oil Spills

The expected environmental damage costs of oil spills matters to the choice between preventive and remedial action against oil spills and to the choice of strategy once an oil spill has taken place. Although not including economic estimates of the environmental damage cost, e.g., Aps et al. (2007) point to the need to account for uncertainties, e.g., regarding the transports and fate of a given oil spill and the threat it poses to different habitats and populations, and how expected damages jointly depends on multiple uncertain factors.

Discussion

This article aims at providing an overview of the literature regarding cost-efficient strategies to improve the environmental conditions in the Baltic Sea. There are several limitations to the review. The most important is perhaps that it does not include the costs of policy implementation, although the choice and mix of environmental policy instruments can have significant implications for the total costs of meeting environmental targets. Moreover, measures to restore fish stocks or manage alien species are not included.

The review shows that several studies have analyzed the total minimum costs of reducing nutrient loads to coastal waters under static and deterministic conditions. These studies provide an indication of the annual total cost of meeting the BSAP nutrient reduction targets although the spatial restrictions on abatement implied by the BSAP targets will lead to higher costs compared to these studies, where such spatial restrictions are mostly absent. In addition, several studies show that a cost-efficient international allocation of the abatement burden cannot be achieved unless some countries are compensated for their efforts. The large total costs of meeting the BSAP nutrient targets imply that cost-efficient international policy instruments such as, e.g., tradable nutrient emission permits are called for. It is well-known that such problems could be addressed through the choice of initial allocation of tradable emission permits. Actual policies at both national and international level tend to be more expensive compared to the cost-efficient strategies. This suggests that additional efforts to develop national policy instruments that ensure a cost-efficient coordination across sectors are called for. There is also a need to further analyze the role of agricultural policy and climate change and policy for the future need for nutrient abatement and the relative costs of different abatement options. Research on the marine ecosystem has shown that it is characterized by long response times, uncertainty and nutrient interaction with regard to environmental damage. Although some economic studies have developed models that take such effects into account, those are mostly applied on small-scale. Further research in this field, including joint analysis of both uncertainty and time dynamics seems necessary to obtain a better understanding of cost-efficient policy making under more realistic conditions.

To address pollution by hazardous substances, the Baltic Sea Action Plan prescribes a number of general preventive measures, such as bans and substitution in production. Remedial measures are not mentioned although they have cost advantages, e.g., through simultaneously addressing multiple pollutants and through the immediate impact on the recipient.

The majority of international applied studies regarding hazardous substances are source-oriented and thus, one cannot draw conclusions about cost-efficient strategies to meet particular conditions in a recipient. To improve the knowledge in this field, it seems necessary to undertake cross-disciplinary research at smaller scale with an aim to integrate models of pollutant fate into economic models. Cross-disciplinary research in this field could also address issues such as, e.g., the relative costs and effects of meeting the targets for different substances and the relative merits of various abatement measures with regard to meeting the targets for specific pollutants.

Considerable efforts have already been undertaken to control oil spill damages in the Baltic Sea, but research on cost-efficient strategies is not available. The international literature in the field shows that these issues can be analyzed in a probabilistic framework. For example, this could imply analysis of oil spill probabilities and how they depend on enforcement activity and the design of transportation routes. Better understanding of the costs for oil spill cleanups in the Baltic Sea and Skagerrak would require an in-depth analysis of the determinants of costs. Further analysis of expected damage cost is necessary to understand the consequences of different policies. A cost-efficient strategy would require an integration of different alternative measure issues into a coherent framework, where both preventive and remedial measures are analyzed together with the damage costs of oil spills.

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Author Biography

Katarina Elofsson is assistant professor at the Swedish University of Agricultural Sciences. Her research is focused on management of water quality and of invasive species.