Marginal benefits of reducing nutrient loads to the Baltic Sea

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1. Introduction

Eutrophication is considered one of the most severe environmental problems in the Baltic Sea, also by the people living in its littoral countries (Ahtiainen et al 2014). Eutrophication is caused by an excessive amount of nutrients (nitrogen and phosphorus) in the sea, which results in increased primary production with changes in dominant fish species, algal blooming, decreased water clarity, and oxygen deficiency in sea bottoms. These changes affect the functioning of the water ecosystem and hamper recreation possibilities, decreasing human welfare.

Reducing eutrophication in the Baltic Sea is an international problem, as the coastline is shared by nine countries. Thus, the actions of one country affect the others. This is the case also with the benefits of eutrophication reduction – each country's benefits from its own actions depend on the actions of the other countries. In addition, benefits differ from one sea area to another because of different ecological characteristics and environmental conditions. Moreover, people value the sea areas unevenly and benefits are unevenly distributed between countries due to differences in income levels, cultural factors and the extent of recreational use of the sea. All these issues should be reflected in the assessment of the marginal benefits of reducing eutrophication.

Economically efficient management of eutrophication should find a balance between the costs and benefits of nutrient abatement. A good environmental state of the sea is not necessarily the most economically sound objective, if the costs of achieving the needed nutrient reductions are disproportionately high compared to the benefits. The costs (and marginal costs) of nutrient abatement measures have been examined in several recent studies (e.g. Helin et al 2008, Ahlvik et al 2014, Hyytiäinen et al 2014), but there are no up-to-date estimates of the marginal benefits of nutrient reduction. This report aims at filling this gap by presenting the marginal benefit estimates of reducing nitrogen and phosphorus loads to the Baltic Sea, that is, the benefits obtained by reducing one kilogram of the respective nutrient to some sea areas. The marginal benefits are country- and sea area-specific and depend on the assumed development in the state of the sea, i.e. the actions of other countries. The basis of the marginal benefit calculations are the basin level marine model (Ahlvik et al. 2014) and the benefit estimates from a valuation study conducted in the coastal states of the Baltic Sea (Ahtiainen et al. 2014).

The report is organized as follows. Section 2 describes the data and methods used in calculating the marginal benefits. Section 3 presents the marginal benefit estimates for each country and sea area. The final section discusses the results and their applicability.

2. Methods and data

2.1 Marine model

Nutrient dynamics in the Baltic Sea are estimated based on a sea basin level marine model that is reported in detail in Ahlvik et al (2014). The model takes into account the inflow of nitrogen and phosphorus from point and non-point sources, as well as the airborne deposition, movement of nutrients between sea areas and the most important biogeochemical processes of the sea. Time step of the model is one year. Calibration of the model parameters was carried out based on the period 1980-2000. Model validation, carried out for 2000-2008 data, revealed that the model was able to estimate nitrogen and phosphorus concentrations well. Furthermore, the model produced estimates that were consistent with other, more detailed, marine models, such as the Mare Nest-model that was used to calculate the targets of the HELCOM Baltic Sea Action Plan (HELCOM, 2007). The structure of the economic-ecological marine model is illustrated in Figure 1 and the division of the sea is shown in Figure 2.

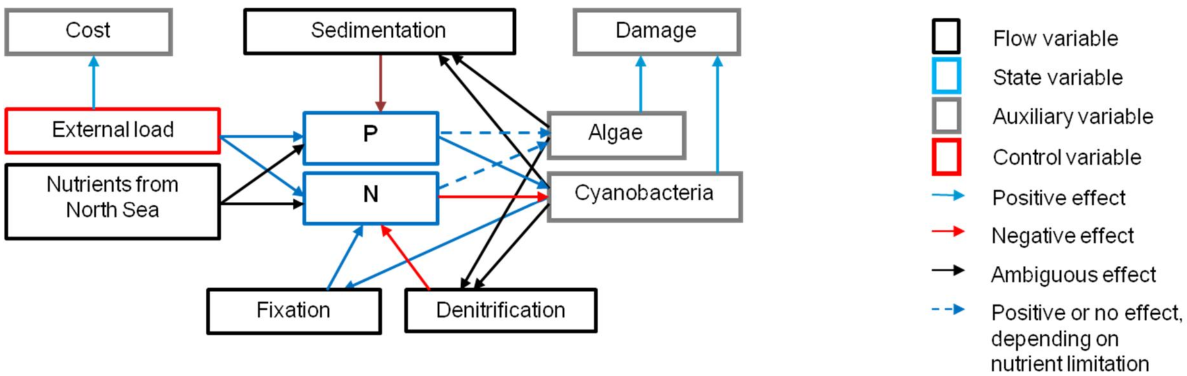

Figure 1. Structure of the economic-ecological marine model

The model considers stocks of nitrogen and phosphorus; N_t and P_t. Damages are caused by increased biomass of phytoplankton, which is divided into two categories: algae (A_t) and cyanobacteria (C_t). Algae include all phytoplankton species that cannot fix molecular nitrogen. After the algal spring bloom, cyanobacteria will use the excessive phosphorus and convert molecular nitrogen into ammonia by nitrogen fixation. Mathematically, the formation of these two types of phytoplankton can be written as

$$A_t = \begin{cases} \varphi_N N_t^j & \text{if } \varphi_N N_t \leq R\varphi_P P_t \\ R\varphi_P P_t^j & \text{otherwise} \end{cases} \tag{1}$$

$$C_t = R\varphi_P P_t^j - A_t^j \quad (2)$$

where φ_i is the bioavailable fraction of nutrient *i* and *R* is the Redfield ratio (7.22 for masses). The model depicts the dynamics of the nitrogen and phosphorus stocks (N_t and P_t) in each sea basin *j* based on the following transition equations:

$$N_{t+1}^j - N_t^j = n_t^j + \sum_{k=1}^7 \frac{N_t^k}{V^k} W_{k,j} - \frac{N_t^j}{V^j} \sum_{k=1}^7 W_{j,k} - D^j(Q_t^j) + C_t, \quad (3)$$

$$P_{t+1}^j - P_t^j = p_t^j + \sum_{k=1}^7 \frac{P_t^k}{V^k} W_{k,j} - \frac{P_t^j}{V^j} \sum_{k=1}^7 W_{j,k} - B^j(Q_t^j), \quad (4)$$

The first terms, n_t and p_t, depict the total nitrogen and phosphorus inputs. The second and third terms describe water exchange between the sea basins, so that $W_{j,k}$ is the amount of water from basin *j* to basin *k* and V^j is the volume of basin *j*. The fourth term depicts the two decay processes, denitrification $D(Q_t)$ and permanent burial of phosphorus $B(Q_t)$, which are functions of the carbon flux to the sediments that works as a proxy for oxygen deficiency. This can be written as $Q_t = A_t + \xi C_t$, where the smaller contribution of cyanobacteria is taken into account using the weight ξ. Denitrification and permanent burial are depicted as quadratic functions, so that oxygen deficiency (implied by too large values of Q_t) can harm the efficiency of these decay processes. The fifth term, nitrogen fixation by cyanobacteria C_t, adds another nutrient input to the system.

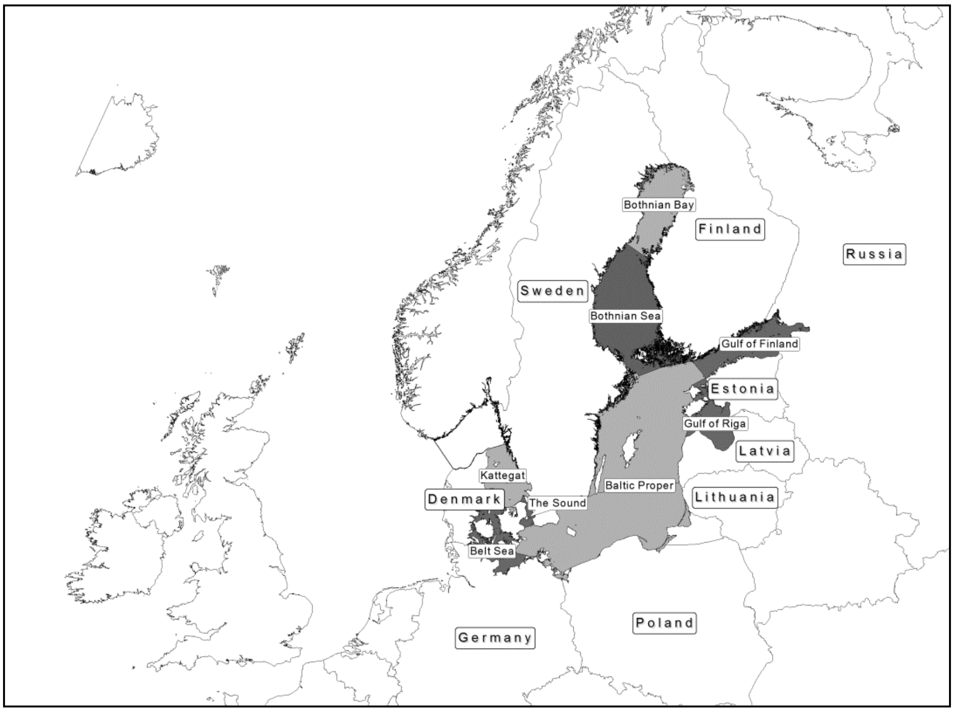

Figure 2. Baltic Sea catchment and the division of the sea into sea areas

2.2 Benefits of reduced eutrophication

The marginal benefit estimates are based on a contingent valuation study conducted in the nine coastal state of the Baltic Sea in 2011 (for details see Ahtiainen et al. 2013, 2014). Contingent valuation is a well-established method in environmental valuation (Carson and Hanemann 2005). It is one of the stated preference methods which are the only methods capable of capturing both use and non-use (passive use) values associated with environmental improvements. Non-use values are likely to be significant in the case of the Baltic Sea, which can be considered to be a unique environmental resource for the population living in the coastal countries.

Contingent valuation is based on carefully designed surveys that elicit people's willingness to pay (WTP) for a well-defined change in environmental conditions, in this case in the eutrophication status of the Baltic Sea. The willingness to pay represents the monetary benefits of the environmental change. In addition to specifying the baseline (typically current) status of the environment, the contingent valuation survey describes the target level which is achieved by implementing the policy that is being valued.

The benefits of reduced eutrophication were studied in 2011. The questionnaire was designed in international cooperation, and it was pre-tested with focus groups, cognitive interviews and pilot studies before implementing the final survey. Over 10500 people from the coastal countries responded to the identical survey, either in face-to-face interviews or via internet.

The change in eutrophication was portrayed to the respondents using verbal descriptions of the different levels of eutrophication and color maps that presented the level of eutrophication in each area of the Baltic Sea. The verbal descriptions presented five levels of eutrophication and described each of them in terms of water clarity, occurrence of algal blooms, fish species composition, condition of underwater meadows and lack of oxygen in deep sea bottoms. Each eutrophication level was associated with a color, and thus the eutrophication status could also be presented on maps to improve respondents' understanding (see Figure 3). Respondents were asked to state their willingness to pay (WTP) for two changes in eutrophication that differed in their scope: one corresponded to the nutrient reduction targets specified in the Baltic Sea Action Plan (HELCOM 2007) and the other to partial (50%) fulfillment of the targets.

The mean WTP was estimated based on country-wise ordinary least squares (OLS) regressions that explained the size of the willingness to pay with income, age, gender, education and distance to the Baltic Sea (see Ahtiainen et al. 2014 and Hyytiäinen et al. 2014 for details).

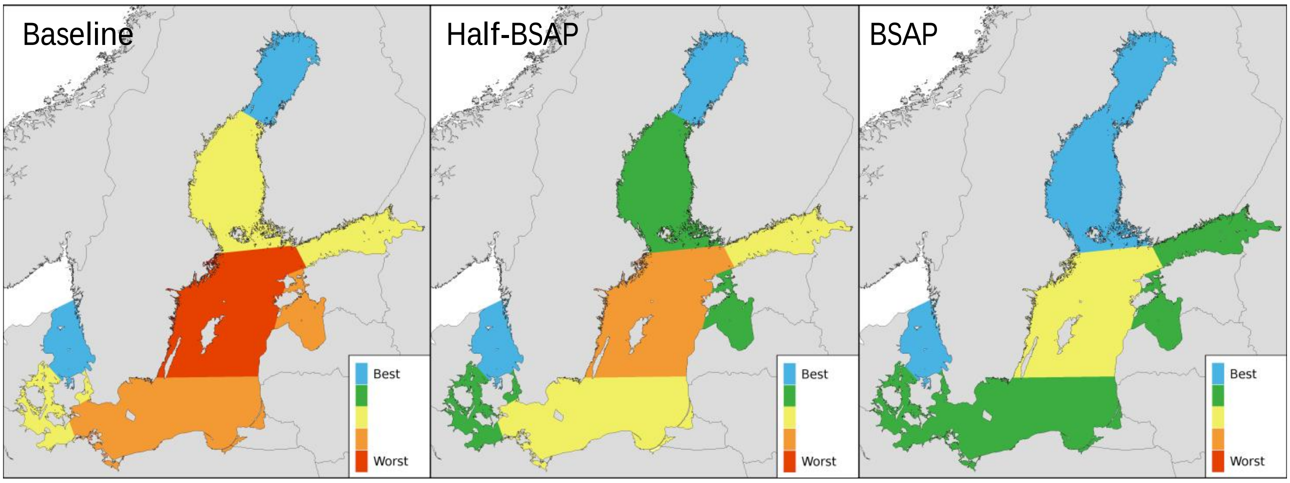

Figure 3. Level of eutrophication in the Baltic Sea for the baseline, partial (half-BSAP) and full (BSAP) fulfillment of the Baltic Sea Action Plan targets as presented in the survey. Blue color corresponds to the best water quality and red to the worst.

2.4 Estimation of marginal benefits

The information obtained from the contingent valuation survey is used to estimate the benefit functions, one for each sea basin and country. This is done based on the following steps. First, to obtain the aggregate national benefits, the estimated mean WTPs were multiplied by the amount of adult population. In all countries except Russia, samples were drawn from the entire geographical area of the country, justifying the aggregation of WTP to the full national adult populations[1]. Second, the aggregate national benefits were divided between sea basins based on the sea areas that the respondents stated they considered when expressing their WTP. Third, the benefits were divided between the two types of phytoplankton, algae and cyanobacteria, based on which effects of eutrophication (water turbidity, blue-green algal blooms, underwater meadows loss, fish species composition changes, lack of oxygen) the respondents considered when responding to the WTP question. Based on the survey results, a weight 61 % of was assigned to effects caused by algal biomass, and 39 % to effects caused by cyanobacteria.

Following Hyytiäinen et al (2014), the functional form of the benefit from reduced eutrophication for country *i* in sea area *j* is assumed to be

$$B_{i,j}\left(x_t^j\right) = \sum_{t=1}^{\infty} \sum_{l=1}^{2} \frac{\vartheta_l \alpha_{m,j}}{(1+r)^t} \left(1 - e^{-\beta_{m,j} x_t^j}\right) \tag{5}$$

[1] Following adult population sizes were used (in millions): Denmark: 3.6, Estonia: 1.0, Finland: 3.6, Germany: 68.3, Latvia: 1.7, Lithuania: 2.5, Poland: 24.6, Russia (Western Russia: Central, Southern, North-Western and Volga Federal Districts): 81.5 and Sweden: 7.6

where *m* denotes the country, *j* the sea area and *l* the type of phytoplankton, *r* is the rate of discount, $\alpha_{i,j}$, $\beta_{i,j}$ and ϑ_l are the country, sea area and phytoplankton-specific parameters and is the reduction in algal or cyanobacterial biomass. Discount rate of 3.5% is used throughout the report (HM Treasury 2003; Boardman et al. 2014). The benefit function is illustrated in Figure 4, where the black curve depicts the total benefits and blue lines depict marginal benefits. The total benefits increase as the nutrient abatement increases, and the total benefits are the largest in the BSAP scenario. However, the results imply decreasing marginal benefits: reductions in nutrient loads are more desirable if the initial state of the sea is poor.

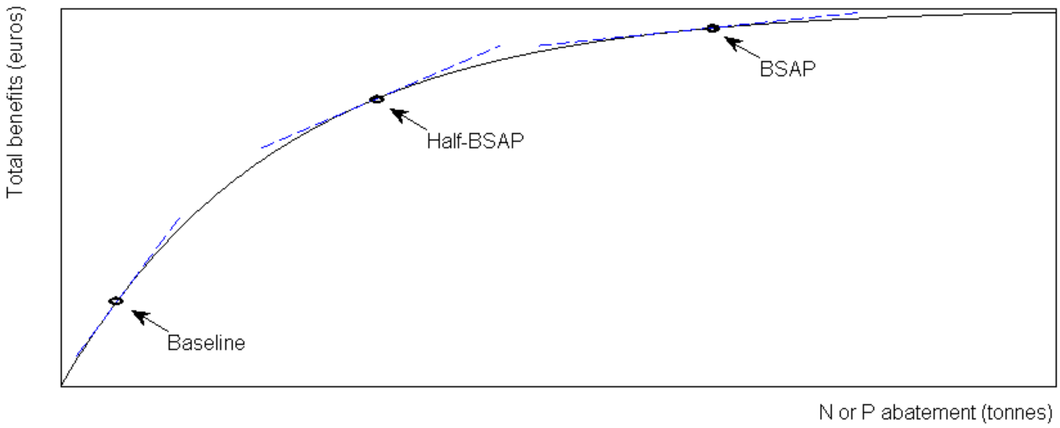

Figure 4. Illustration of the benefit function and the marginal benefits. Y axis depicts the total benefits in euros and X axis the total nutrient abatement in tonnes.

3. Results

Marginal benefits are defined as the estimate of the economic benefits associated with reducing one additional kilogram of nitrogen or phosphorus to one of the sea basins at the current time period (now). The benefits from the nutrient load reductions are derived in the course of several years, and therefore the marginal benefits have been expressed as net present values. Note that Table 1 presents the marginal benefit estimates in 2011 euros and Table 2 in 2014 euros. The estimates in Table 2 have been adjusted for inflation using country-specific consumer price indices from OECD (Russia) and Eurostat (all other countries).[2]

Estimates of marginal benefits depend strongly on the assumed development of the nutrient loads in the future. In this report, we focus on two alternative scenarios:

[2] Eurostat: HICP (harmonized indices of consumer prices), all items, annual data. OECD: Stat Extracts, Consumer Prices, all items, annual data.

(i) Baseline development: current level of water protection is maintained, but no additional abatement measures are implemented

(ii) Baltic Sea Action Plan development: all countries follow the nutrient reduction targets agreed on in the Baltic Sea Action Plan (HELCOM 2007) by 2016 and the state of the sea will develop accordingly

The marginal benefits of abatement in these two scenarios are different. If countries do not implement the BSAP and follow baseline development, the future state of the sea will be poor and consequently nutrient reductions today are very valuable. On the contrary, if all countries follow the BSAP, the sea will be in a good environmental state in the future and the reduction of one kilogram of nutrient today is much less valuable. In both cases the decreasing marginal benefits have been accounted for, so that the marginal benefits are first larger and when the state of the sea improves, they become smaller.

Table 1. Aggregated marginal benefits of reducing nitrogen and phosphorus loads to each sea basin (in 2011 euros / kg)

	Nitrogen		Phosphorus	
	Baseline development	Baltic Sea Action Plan development	Baseline development	Baltic Sea Action Plan development
Bothnian Bay	37.8	1.3	591.2	94.4
Bothnian Sea	45.3	1.6	612.9	73.0
Baltic Proper	37.6	1.7	498.0	61.0
Gulf of Finland	61.4	3.6	730.3	84.1
Gulf of Riga	80.9	3.9	993.4	89.7
Danish Straits	48.4	2.3	205.5	45.3
Kattegat	43.6	2.0	231.8	26.3

Table 2. Aggregated marginal benefits of reducing nitrogen and phosphorus loads to each sea basin (in 2014 euros / kg)

	Nitrogen		Phosphorus	
	Baseline development	Baltic Sea Action Plan development	Baseline development	Baltic Sea Action Plan development
Bothnian Bay	39.0	1.4	611.5	98.0
Bothnian Sea	46.8	1.7	634.3	75.9
Baltic Proper	38.9	1.8	515.8	63.5
Gulf of Finland	64.0	3.8	757.9	88.0
Gulf of Riga	83.7	4.0	1028.6	93.5
Danish Straits	50.0	2.4	212.4	47.0
Kattegat	44.9	2.0	239.4	27.3

The total marginal benefits for each sea area, summed over all the littoral countries, are shown in Table 1 and the country-specific values are presented in Appendix A, Tables A1 and A2 (2011) and Tables A3 and A4 (2014). The marginal benefit estimates are generally larger for phosphorus than for nitrogen, because their different contribution in phytoplankton production (equations 1-2) and nutrient dynamics (equations 3-4). When evaluating public projects, countries should take into account the total societal benefits of eutrophication reduction (shown in Table 1). If countries only considered the benefits for their own citizens, their behavior would be non-cooperative, and many projects that would be socially desirable would not be carried out, because they would not be beneficial from the perspective of a single country. This would result in a tragedy of the commons and the loss of welfare (Ahlvik and Pavlova 2013).

The estimates presented in Table 1 can be used as they are for nutrient load reductions that take place today. If the nutrient load reductions occur in future years, the marginal benefits should be discounted to present values to enable comparisons if the costs have been expressed in present values.

4. Discussion

The marginal benefits of nutrient abatement hinge strongly on three aspects. First, the marginal benefits depend strongly on the sea basin where the nutrient reduction is carried out. The effect of nutrient abatement on marginal benefits depends on:

- (i) the weight respondents assign on each sea basin in the survey
- (ii) location of the basin, for instance, nutrient abatement to basins close to the North Sea have a smaller effect because nutrients flow out the Baltic Sea quickly, and
- (iii) depth of the basin.

Second, marginal benefits depend strongly on the nutrient under consideration. The marginal benefits of nitrogen and phosphorus abatement depend on:

- (i) the weight people assign on the effects caused by algae and cyanobacteria in the survey
- (ii) effects of nutrients on the two types of phytoplankton, depending on whether N or P is the limiting nutrient, and
- (iii) nutrient dynamics in the sea.

Note that phosphorus abatement also decreases nitrogen input via decreased cyanobacterial biomasses and reduced nitrogen fixation. Nitrogen abatement can have a positive effect on phosphorus inputs, if reduced algal biomass increases oxygen levels in the bottom and makes the phosphorus burial processes more efficient. Results in Table 1 show that marginal benefits of phosphorus reduction are larger, even if these numbers are weighted by the Redfield ratio. Third, marginal benefits hinge on the scenario for future development of nutrient loads. In the case of baseline development, nutrient reductions are essential, and respectively, marginal benefits are large. In contrast, if nutrient loads are reduced according to the Baltic Sea Action Plan, the sea will be in a good environmental state in the future and additional nutrient reductions are much less vital. The marginal benefits represent always the benefits of reducing nutrient loads by one additional kilogram (additional to the nutrient load reductions specified in the scenario, i.e. baseline or BSAP). Marginal benefits are larger when the state of the sea is poorer, and when the state follows the baseline development. It is also worth noting that, in any case, the total benefits increase as the nutrient abatement increases and the state of the sea improves.

The marginal benefits are the highest for the Gulf of Finland and the Gulf of Riga. First, they are both very eutrophic sea areas, and nutrient abatement is much needed. Second, especially the Gulf of Riga is very shallow, and nutrient reductions have a large effect there. Third, there are large cities in coasts of the Gulf of Finland and Gulf of Riga and, consequently, people are aware and concerned about their states. Fourth, both gulfs are far from the North Sea, and therefore nutrient abatement has effects on other parts of the sea, for instance the Baltic Proper. On the contrary, the marginal benefits are the lowest for the Bothnian Bay and the Baltic Proper. The Bothnian Bay is located in the sparsely populated Northern Baltic Sea, and it is at present in a good state (see Figure 3). Consequently, nutrient reductions are less valuable there. The Baltic Proper, on the other hand, is the deepest sea area, and nutrient abatement will have less effect on primary production that only takes place in the uppermost layer of the sea.

The results of this report should be interpreted in light of the caveats related to the models. First, the model assumes that each sea area is homogeneous. This is, the model does not take into account movement of nutrients within the sea basins, and consequently it does not take into account where in the sea area the nutrient reductions take place. Possible local effects of nutrient reductions, e.g. in nearby coasts and estuaries, are not included, as the sea areas are treated as a whole. Second, the benefit function neglects any benefits gained from improved water quality in inland waters. Consequently, the marginal benefits are likely to be underestimated.

Appendix A

Table A1. Marginal benefits of nitrogen reduction per country (in 2011 euros/ kg)

Baseline development							
	BB	BS	BP	GoF	GoR	DS	KT
Sweden	12.82	15.38	11.30	17.41	25.50	9.45	13.28
Finland	2.34	2.81	1.66	4.32	3.79	1.03	1.44
Russia	1.62	1.95	1.90	7.56	4.61	1.03	1.36
Estonia	0.13	0.16	0.14	0.47	0.62	0.08	0.11
Latvia	0.05	0.06	0.06	0.09	0.53	0.03	0.04
Lithuania	0.12	0.14	0.14	0.18	0.28	0.07	0.09
Poland	1.98	2.38	2.56	3.13	4.34	1.14	1.49
Germany	14.49	17.39	15.60	21.93	31.82	24.16	14.53
Denmark	4.20	5.04	4.23	6.36	9.39	11.41	11.23
Total	37.76	45.32	37.59	61.44	80.87	48.40	43.58
Baltic Sea Action Plan development							
	BB	BS	BP	GoF	GoR	DS	KT
Sweden	0.21	0.27	0.27	0.55	0.69	0.27	0.43
Finland	0.03	0.03	0.07	0.29	0.21	0.06	0.09
Russia	0.08	0.10	0.12	0.56	0.28	0.07	0.10
Estonia	0.00	0.01	0.01	0.03	0.03	0.00	0.01
Latvia	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Lithuania	0.00	0.01	0.01	0.01	0.01	0.00	0.00
Poland	0.05	0.06	0.08	0.11	0.13	0.04	0.05
Germany	0.94	1.16	1.15	2.02	2.52	1.84	1.26
Denmark	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Total	1.32	1.63	1.70	3.58	3.90	2.31	1.95

* BB Bothnian Bay, BS: Bothnian Sea, BP: Baltic Proper, GoF: Gulf of Finland, GoR: Gulf of Riga, DS: Danish Straits, KT: Kattegat, See the map in Figure 2 for the sea areas,

Table A2. Marginal benefits of phosphorus reduction per country (in 2011 euros/ kg)

Baseline development

	BB	BS	BP	GoF	GoR	DS	KT
Sweden	211.44	197.11	152.00	217.64	308.58	49.65	69.03
Finland	64.95	38.77	26.99	43.45	49.93	6.83	8.91
Russia	25.91	32.10	29.32	58.47	57.45	7.14	8.97
Estonia	2.56	2.58	2.27	4.09	6.18	0.55	0.71
Latvia	0.77	1.03	0.95	1.28	4.34	0.23	0.29
Lithuania	1.55	1.94	1.64	2.32	3.37	0.43	0.56
Poland	30.16	34.45	29.45	41.19	55.85	7.48	9.46
Germany	195.34	235.83	197.51	280.04	392.28	92.54	84.04
Denmark	58.56	69.03	57.87	81.78	115.39	40.60	49.78
Total	591.24	612.85	497.99	730.28	993.36	205.45	231.75

Baltic Sea Action Plan development

	BB	BS	BP	GoF	GoR	DS	KT
Sweden	34.15	15.83	10.47	13.56	15.42	4.36	4.32
Finland	27.27	9.50	4.92	7.20	6.38	1.29	1.46
Russia	4.03	4.50	4.39	9.50	6.58	1.33	1.42
Estonia	0.56	0.32	0.27	0.51	0.51	0.08	0.09
Latvia	0.02	0.04	0.04	0.05	0.12	0.01	0.01
Lithuania	0.09	0.15	0.14	0.19	0.22	0.04	0.05
Poland	3.72	2.31	1.97	2.54	2.88	0.60	0.65
Germany	24.47	40.24	38.70	50.48	57.51	37.46	18.20
Denmark	0.06	0.09	0.08	0.11	0.13	0.11	0.07
Total	94.38	72.98	60.98	84.13	89.75	45.28	26.27

* BB = Bothnian Bay, BS= Bothnian Sea, BP = Baltic Proper, GoF=Gulf of Finland, GoR=Gulf of Riga, DS=Danish Straits, KT=Kattegat, See the map in Figure 2 for the sea areas,

Table A3. Marginal benefits of nitrogen reduction per country (in 2014 euros/ kg)

Baseline development							
	BB	BS	BP	GoF	GoR	DS	KT
Sweden	13.00	15.59	11.46	17.65	25.85	9.58	13.46
Finland	2.47	2.96	1.75	4.56	4.00	1.09	1.52
Russia	1.82	2.19	2.13	8.48	5.17	1.16	1.53
Estonia	0.14	0.17	0.15	0.51	0.67	0.09	0.12
Latvia	0.05	0.06	0.06	0.09	0.54	0.03	0.04
Lithuania	0.13	0.15	0.15	0.19	0.29	0.07	0.09
Poland	2.07	2.49	2.68	3.27	4.54	1.19	1.56
Germany	15.04	18.05	16.19	22.76	33.02	25.07	15.08
Denmark	4.32	5.18	4.35	6.54	9.65	11.73	11.55
Total	39.02	46.84	38.91	64.04	83.73	50.01	44.94
Baltic Sea Action Plan development							
	BB	BS	BP	GoF	GoR	DS	KT
Sweden	0.21	0.27	0.27	0.56	0.70	0.27	0.44
Finland	0.03	0.03	0.07	0.31	0.22	0.06	0.09
Russia	0.09	0.11	0.13	0.63	0.31	0.08	0.11
Estonia	0.00	0.01	0.01	0.03	0.03	0.00	0.01
Latvia	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Lithuania	0.00	0.01	0.01	0.01	0.01	0.00	0.00
Poland	0.05	0.06	0.08	0.11	0.14	0.04	0.05
Germany	0.98	1.20	1.19	2.10	2.62	1.91	1.31
Denmark	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Total	1.36	1.71	1.78	3.76	4.05	2.38	2.02

* BB Bothnian Bay, BS: Bothnian Sea, BP: Baltic Proper, GoF: Gulf of Finland, GoR: Gulf of Riga, DS: Danish Straits, KT: Kattegat, See the map in Figure 2 for the sea areas,

Table A4. Marginal benefits of phosphorus reduction per country (in 2014 euros/ kg)

Baseline development							
	BB	BS	BP	GoF	GoR	DS	KT
Sweden	214.36	199.83	154.10	220.64	312.84	50.34	69.98
Finland	68.49	40.88	28.46	45.82	52.65	7.20	9.40
Russia	29.07	36.01	32.89	65.59	64.45	8.01	10.06
Estonia	2.75	2.78	2.44	4.40	6.65	0.59	0.76
Latvia	0.79	1.05	0.97	1.31	4.44	0.24	0.30
Lithuania	1.62	2.02	1.71	2.42	3.52	0.45	0.58
Poland	31.52	36.00	30.77	43.04	58.36	7.82	9.89
Germany	202.72	244.75	204.98	290.63	407.11	96.04	87.22
Denmark	60.21	70.97	59.50	84.08	118.63	41.74	51.18
Total	611.52	634.29	515.82	757.93	1028.65	212.42	239.37
Baltic Sea Action Plan development							
	BB	BS	BP	GoF	GoR	DS	KT
Sweden	34.62	16.05	10.61	13.75	15.63	4.42	4.38
Finland	28.76	10.02	5.19	7.59	6.73	1.36	1.54
Russia	4.52	5.05	4.92	10.66	7.38	1.49	1.59
Estonia	0.60	0.34	0.29	0.55	0.55	0.09	0.10
Latvia	0.02	0.04	0.04	0.05	0.12	0.01	0.01
Lithuania	0.09	0.16	0.15	0.20	0.23	0.04	0.05
Poland	3.89	2.41	2.06	2.65	3.01	0.63	0.68
Germany	25.40	41.76	40.16	52.39	59.68	38.88	18.89
Denmark	0.06	0.09	0.08	0.11	0.13	0.11	0.07
Total	97.96	75.92	63.51	87.95	93.47	47.03	27.31

* BB = Bothnian Bay, BS= Bothnian Sea, BP = Baltic Proper, GoF=Gulf of Finland, GoR=Gulf of Riga, DS=Danish Straits, KT=Kattegat, See the map in Figure 2 for the sea areas,

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