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Baltic Sea nutrient reductions – What should we aim for?

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ABSTRACT

Nutrient load reductions are needed to improve the state of the Baltic Sea, but it is still under debate how they should be implemented. In this paper, we use data from an environmental valuation study conducted in all nine Baltic Sea states to investigate public preferences of relevance to three of the involved decision-dimensions: First, the roles of nitrogen versus phosphorus reductions causing different eutrophication effects; second, the role of time – the lag between actions to reduce nutrient loads and perceived improvements; and third; the spatial dimension and the roles of actions targeting the coastal and open sea environment and different sub-basins. Our findings indicate that respondents view and value the Baltic Sea environment as a whole, and are not focussed only on their local sea area, or a particular aspect of water quality. We argue that public preferences concerning these three perspectives should be one of the factors guiding marine policy. This requires considering the entire range of eutrophication effects, in coastal and open sea areas, and including long-term and short-term measures.

1. Introduction

Eutrophication of coastal marine areas and estuaries, in particular, is an increasing problem across the world (Nixon et al., 1996; Kroeze et al., 2014), mainly due to the human intensification of the global biogeochemical cycles of nitrogen (Erisman et al., 2013) and phosphorus (Elser and Bennet, 2011). Problems with nutrient enrichment have been reported in estuaries such as the Chesapeake Bay in the US (Murphy et al., 2011), the Mississippi and Changjiang estuaries (US and China) (Zhao et al., 2012) and the north-western Black Sea shelf in Europe (Capet et al., 2013).

Eutrophication, caused by nutrient enrichment, is the most pervasive and serious pollution problem also in the Baltic Sea (HELCOM, 2010), and has been high on political agendas during the last decades. Several initiatives have been taken to reduce nutrient loads to the Baltic, the most recent large-scale agreement being the HELCOM Baltic Sea Action Plan (BSAP; HELCOM, 2007, 2013), in which nutrient reduction targets were jointly negotiated by the nine coastal countries. Further, European Union directives such as the Water Framework Directive (WFD; European Parliament, 2000) and the Marine Strategy Framework Directive (MSFD; European Parliament, 2008) legally require the EU member states to take actions to achieve "Good Ecological (Environmental) Status (GES)" in coastal and marine waters. They also call for stakeholder involvement in the management decisions for implementation of the directives.

Much remains to be done to fulfil the ambitions of the EU directives and the BSAP. The load of nutrients to the sea needs to be substantially reduced in order to mitigate eutrophication effects. However, the term nutrient load reduction has several dimensions. In this paper, we discuss three of them: First, the roles of nitrogen versus phosphorus reductions causing different eutrophication effects; second, the role of time – the lag between the various actions to reduce nutrient loads and measurable improvements; and third; the spatial dimension and the roles of actions that target the coastal versus the open sea environment.

Eutrophication has a range of effects on the Baltic Sea ecosystem, such as increased water turbidity, increased blooms of cyanobacteria, deterioration of underwater sea-grass meadows, changes in fish species composition, and oxygen deficiency in bottom sediments. These effects are linked to marine ecosystem services such as the provision of seafood, recreational opportunities, and biodiversity. Ahtiainen et al. (2013) showed in a survey study that the Baltic Sea ecosystem services are very important to the citizens in the nine countries surrounding the Baltic Sea. For

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example, over 80 per cent of the respondents in the survey had visited the sea at least once to spend leisure time there.

Much of the debate on the importance of nitrogen versus phosphorus for eutrophication effects has concerned their influence on cyanobacterial blooms.[1] An increase in nitrogen availability can actually help reduce the cyanobacterial blooms by stimulating the growth of other phytoplankton competing with cyanobacteria for the limited supply of phosphorus (Elmgren and Larsson, 2001). Since nitrogen availability generally limits production of phytoplankton other than cyanobacteria in the Baltic Proper, and at least part of the time also in the Bothnian Sea and the Gulfs of Finland and Riga, increased nitrogen availability will increase phytoplankton biomass and hence water turbidity. This will, in turn, aggravate other symptoms of nutrient enrichment, such as changes in benthic fauna and vegetation, and the areal extent of oxygen-deficient sea bottoms.

It has been suggested that nitrogen-fixing cyanobacteria should be the primary concern when deciding on Baltic nutrient reduction management strategies, essentially ignoring other eutrophication effects (Schindler, 2012). From a policy perspective, these discussions are important. If the public preference is primarily for reducing the cyanobacterial blooms, it can be argued that well-directed management strategies should focus on this issue.

The purpose of this study is to investigate public preferences in the Baltic Sea states for reducing different eutrophication effects, to study distributional impacts of different management options, and to use the results to make policy recommendations.

The knowledge that nitrogen and phosphorus can cause different eutrophication effects, both in time and space, and that the citizens in the Baltic Sea countries may differ in their exposure and reaction to these effects, could lead the states to prioritize different management options. Any action to reduce the eutrophication level will cause distributional effects on the human population, both within and between countries. In general, the literature about distributional impacts of implementing new management plans for different environmental goods and services is limited. This is especially true with regard to non-market priced benefits of environmental goods and services, something that has been highlighted in previous studies (e.g. Håkansson et al., 2012). A number of valuation studies on environmental goods and services have been carried out in more than one country, but they have not focused on the distributional effects between the countries (Bateman et al., 2011).

This study is based on data from a large-scale contingent valuation (CV) survey performed in all nine Baltic Sea states in the fall of 2011, reported by Ahtiainen et al. (2014). The purpose of the study was to quantify public willingness to pay (WTP) for reducing eutrophication in the Baltic Sea according to the targets of the BSAP. We use previously unutilized data from the survey to assess public preferences for eutrophication management and possible distributional effects.

Our article is organized as follows: Section 2 provides an ecological background to the eutrophication effects and the three nutrient load reduction dimensions discussed in the paper, Section 3 presents the survey, the WTP question and the statistical methods used, Section 4 describes and discusses the results, and Section 5 draws conclusions.

2. Ecological background

The two major nutrients that influence plant growth in the Baltic Sea are nitrogen (N) and phosphorus (P). Phytoplankton are the dominant primary producers in the Baltic Sea and use approximately 16 atoms of N for each atom of P, or in terms of mass about 7.2 times more N than P (Redfield, 1958; Granéli et al., 1990). The annual inflow to the Baltic Sea from land and atmosphere have a ratio of N/P much greater than this (Elmgren and Larsson, 2001), yet when easily plant-available, inorganic forms of these nutrients are measured in the surface waters of the Baltic Sea proper in late winter, before the spring bloom, the N/P atom ratio is much lower than 16 (Granéli et al., 1990). The reason is that processes removing the nutrient from circulation are much more effective for N than for P. The result is that the spring bloom of phytoplankton ends when the available inorganic N has been exhausted, even though inorganic P is still available (Höglander et al., 2004).

This creates a situation where most phytoplankton is limited by a shortage of nitrogen, but nitrogen-fixing cyanobacteria are able to fill their nitrogen need by converting the abundant nitrogen gas dissolved in the water to biologically useful combined forms (the process of nitrogen fixation) (Granéli et al., 1990). This means that the main limiting nutrient for nitrogen-fixing cyanobacteria in the Baltic is phosphorus, even when other plant growth is nitrogen limited (Walve and Larsson, 2010). The growth of cyanobacteria is slow at first, but picks up speed as the water warms towards summer, and by early July a cyanobacterial bloom has normally developed. In warm and sunny weather, the blooms can accumulate at the surface and along the shores. They are toxic and stink when decomposing, and are therefore a menace to tourism and recreation. Through nitrogen-fixation, they also boost eutrophication by adding combined, plant-available nitrogen to a nitrogen-limited sea (Larsson et al., 2001).

Adding plant-available nitrogen to the water will normally increase the growth of plankton other than cyanobacteria, thereby increasing water turbidity and decreasing light penetration. Nitrogen addition will also hinder the growth of benthic vegetation, such as sea-grass meadows, through shading by the turbid water, and by microalgal overgrowth, stimulated by the nitrogen. Some of the new organic matter produced with the added nitrogen will sink to the bottom, where its decomposition will consume oxygen and increase areas of oxygen-deficient, "dead" bottoms (Elmgren, 1989). The sediment of such bottoms has a reduced capacity for retaining phosphorus (Blomqvist et al., 2004), which leaks out into the water, eventually increasing phosphorus concentrations in the surface water. But nitrogen addition also has effects that can be considered positive, since the extra production creates a potential for higher fish production (though not only of species of interest to sport and commercial fisheries) and counteracts the development of cyanobacterial blooms (Niemi, 1979). In general, salmonids are harmed when eutrophication reduces oxygen levels in the deep, cold coastal waters, and a similar effect is seen for cod in the open Baltic, while cyprinids with little commercial value increase with nutrient levels (Hansson, 1985). Addition of phosphorus to a nitrogen-limited sea will, as its primary effect, stimulate the growth of nitrogen-fixing cyanobacteria, but some of the nitrogen they fix will leak from their cells (Rolff et al., 2007; Ploug et al., 2011), creating indirectly also many of the effects of direct nitrogen addition.

Nitrogen and phosphorus differ not only in their primary effects, but also in the time perspective for load reductions. The water in the Baltic Sea exchanges only very slowly with the sea outside, on the order of 20–25 years for water and even longer for biologically retained nutrients. The P load comes to a considerable extent from sewage, and is currently being effectively reduced by more efficient sewage treatment, and by banning high-P household detergent formulations around the Baltic Sea. Phosphorus additions to the Baltic are mainly eliminated by sequestration in the sediments. In the Baltic Proper, where much of the sediment is oxygen-deficient, this is an inefficient sink, meaning that P already in the system is eliminated very slowly. Even if the load to the Baltic Sea can be effectively curtailed, it may therefore take the system a long time,

[1] We use the terms "cyanobacterial blooms" and "blue-green algal blooms" synonymously throughout the paper.

possibly many decades, to reach a new steady state with the reduced P load (Savchuk and Wulff, 2009).

Nitrogen dynamics are very different, with quite efficient removal of added combined, plant-available N through its microbial conversion back to N_2 gas, which each year removes N corresponding to most of the load. This takes place in the sediments as well as in oxygen-deficient deep waters, and becomes more effective when oxygen-deficiency is wide-spread. If most input of combined N to the Baltic could be stopped, N concentrations would fall rapidly. The problem is that it is very difficult to substantially reduce the *N* input (Löfgren et al., 1999).

Sewage is only a minor N source, but it is the easiest to reduce and measures have already been taken. The major anthropogenic N source is agriculture, where leakage can be reduced, by improved management and decreased use of fertilisers. Atmospheric deposition is also a considerable N source, which has been somewhat reduced in recent years with further reductions possible, but only at great cost. Finally, nitrogen fixation by cyanobacteria in the waters of the Baltic Sea is a major source that can probably only be reduced by lowering the availability of P in Baltic waters. Thus P inputs can be reduced rather drastically in a few years, given sufficient political will, but it will take a long time for the concentrations in the sea to fall. N inputs are more difficult to reduce markedly, but successful reduction would likely cause a rapid fall in the nutrient concentrations. It is also good to note that the marginal costs of nutrient abatement differ for N and P, and are not constant per unit. Rather, the abatement costs rise heavily after initial inexpensive steps have been taken (see e.g. Ahlvik et al., 2014).

Considering the spatial dimension, many coastal areas of the Baltic Sea are P-limited even if the sea outside is N-limited, due to large local inputs of nitrogen, either from rivers or from major sewage treatment plants. In such areas there can be a quick, very localized reduction of eutrophication through P input reduction, as shown in the 1970's in the Stockholm Archipelago (Brattberg, 1986), but at the price of greater export of nitrogen to outer, nitrogen-limited areas, and thus a larger area affected by eutrophication, albeit of a less intensive nature. When nitrogen removal is added, a further reduction of eutrophication can be achieved within a year or so (Savage and Elmgren, 2004).

3. Data and methods

3.1. Survey

The data for this study come from an environmental contingent valuation study[2] that was implemented in the fall 2011 in all Baltic Sea coastal states using identical questionnaires. The survey development followed the tailored design method (Dillman et al., 2009) with extensive pre-testing of the survey instrument. The surveys were executed using Internet panels in Denmark, Estonia, Finland, Germany and Sweden, and face-to-face interviews in Latvia, Lithuania and Russia. In Poland, both face-to-face interviews and an Internet panel were used. Face-to-face interviews were used in countries where it was evident that Internet panels could not provide a representative sample of the population.

The questionnaire consisted of six sections. The first described the Baltic Sea, the second posed questions about leisure time spent at the sea, and the third provided a description of, and questions regarding, eutrophication. For example, the respondents were asked to which extent they viewed various aspects of eutrophication as problems. The fourth section presented the valuation scenario and willingness to pay (WTP) question using the contingent valuation method. The fifth posed debriefing questions regarding response certainty and motivation for willingness to pay, including which aspects of eutrophication the respondents considered when stating their WTP. The final section included questions on the socio-economic background of the respondents. In this study, we focus on responses to questions on eutrophication effects, spatial considerations and willingness to pay and its motives.

Ecological modelling was used to generate the eutrophication scenarios presented to the respondents. The scenarios were based on simulations of the effects of reducing nutrient loads, using a basin-scale dynamic marine model (Ahlvik et al., 2014) and two, spatially more detailed, biogeochemical models of the Baltic Sea, the EIA-SYKE 3D model as presented by Virtanen et al. (1986); Koponen et al. (1992); Kiirikki et al. (2001, 2006); and the DMI-BSHcmod -Ecological Regional Ocean Model (ERGOM) as presented by Maar et al. (2011); Neumann (2000); Neumann et al. (2002); Neumann and Schernewski (2008). The models suggested that the full benefits of investments in nutrient abatement would only be realized after 40 years, and thus the year 2050 was selected as the base year for the valuation survey. The ecological models predicted water quality development in the Baltic Sea with high spatial detail, but the predictions were aggregated to the basin level to ensure their comprehensibility to the respondents of the valuation survey.

The presentation of eutrophication in the survey combined a verbal description with visual materials. The eutrophication status was shown to respondents in colour-coded maps, which depicted the eutrophication level in each sea basin in 2050 (Fig. 1). The colours and their associated level of eutrophication were verbally described before presenting the maps and the WTP question. In the verbal description, water quality was divided into five colour-coded levels, each described in terms of five eutrophication effects: water clarity, blue-green algal blooms, underwater meadows, fish species and oxygen conditions in deep sea bottoms (see Appendix A).

In the WTP elicitation stage the respondents were presented two future scenarios: the baseline (no additional measures to reduce eutrophication) and the policy scenario (eutrophication reduction corresponding to the Baltic Sea Action Plan targets), and asked to state their willingness to pay for obtaining the improved state of the sea instead of the baseline by year 2050.

3.2. Willingness to pay question

The willingness to pay was elicited in two steps: first the respondents were asked whether they would in principle be willing to pay for reducing eutrophication in the Baltic Sea (this type of question is referred to as a spike or in-the-market question). If the answer was *yes* or *don't know*, then the respondent was presented with the maps comparing the policy scenario with the baseline scenario, together with the WTP question.

The elicitation format was a payment card, constructed using the approach outlined in Rowe et al. (1996). The payment card was a 4 x 5 matrix,[3] with 18 positive bids, a zero bid and the option to choose *don't know*. Monetary amounts presented on the card were country-specific, chosen based on the results of the pilot studies. The WTP question was formulated as follows: “What is the most you would be willing to pay every year to reduce eutrophication in the Baltic Sea as shown in the maps? Please consider your disposable income carefully before answering the question.”

The payment was said to be collected as an earmarked special Baltic Sea tax from each individual and firm in all Baltic Sea

[2] The full version of the questionnaire in English is presented in Ahtiainen et al. (2012).

[3] The Russian payment card was a 4 x 4 matrix due to technical issues.

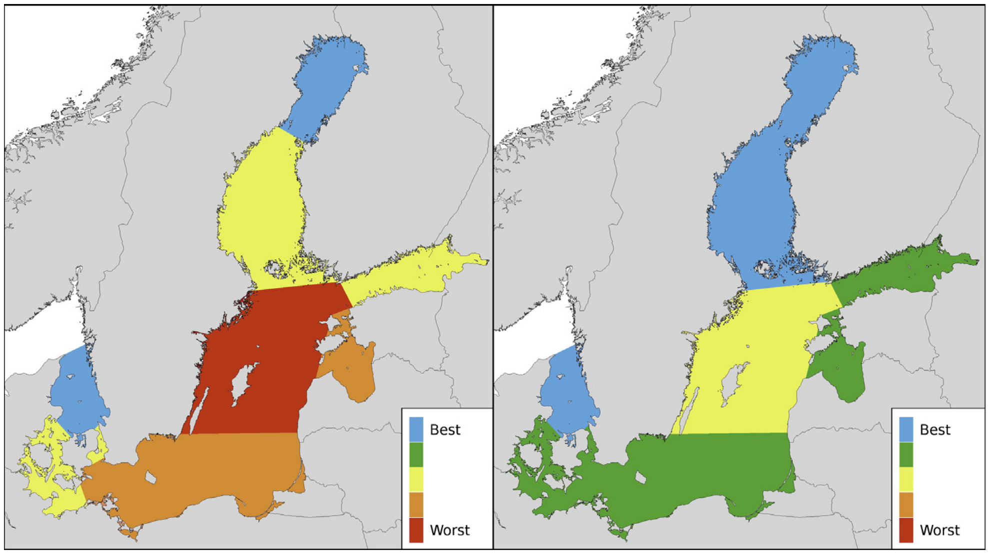

Fig. 1. Maps of the baseline scenario (left map) versus the BSAP scenario (right map) in 2050 as presented in the survey.

countries. Previous study results indicated that ear-marked payments were, in general, preferred by the citizens of the nine Baltic Sea countries in funding actions concerning the sea (Söderqvist et al., 2010), and the tax was deemed both credible and acceptable based on pre-testing using focus groups and in-depth interviews. The respondents were also asked to note that – if they agreed to pay – they would have to pay every year for an infinite period and this would therefore leave less money to spend on other things. Further, the respondents were reminded that the proposed actions would affect only eutrophication and that they could have substitutes for Baltic Sea recreation (see e.g. Bateman et al., 2002).

3.3. Statistical analysis

Statistical analyses were used to test for significant differences in respondent perceptions of eutrophication effects and the spatial extent of the public's concern, and to analyse the determinants of willingness to pay.

Perceptions of eutrophication effects were analysed based on responses to a survey item measuring how problematic the different effects were considered, given on a five-point Likert scale from “not at all a problem” to “a very big problem”. To test for differences in respondents' perceptions within countries, we used the Friedman test (Friedman, 1937, 1940), followed by separate Wilcoxon Signed-Rank tests with the Bonferroni correction for each pairwise combination of effects as the post-hoc analysis (Conover, 1971, 1980). The Friedman test is the non-parametric alternative to the repeated-measures analysis of variance, and it is used to detect differences between treatments (in this case, different effects of eutrophication) when the dependent variable is ordinal.

We used the non-parametric Cochran's Q test for related samples (Conover, 1999; Sheskin, 2004) to test for differences in which effects of eutrophication were considered when answering the WTP question within countries. Cochran's Q provides a method of testing for differences between three of more matched sets of frequencies when responses are binary (0/1). McNemar's test with the Bonferroni correction was used in the post-hoc analysis to test the differences between paired frequencies (McNemar 1947).

To examine the spatial extent of respondents' concern – the whole sea or a specific part of the sea – we used pairwise Pearson's χ^2-tests to analyse if responses between the nine countries were statistically different. The other spatial aspect of WTP, i.e. open-sea areas versus coastal areas, was tested for general differences across the countries using the non-parametric Kruskal–Wallis test (Kruskal and Wallis, 1952) that relaxes normality assumptions. As the Kruskal–Wallis test only identifies that there is a difference, rather than where the differences lie, we used the Siegel-Castellan post-hoc analysis (Siegel and Castellan, 1988) to further analyze which countries gave similar responses.

Binary logit regression and ordinary least squares (OLS) regression models were estimated to model the determinants of willingness to pay (Greene, 2007). The binary logit model was used to explain the probability of being willing to pay, while the OLS regression analyzed the factors that influence the size of the WTP. The analysis was split into two models as it is likely that the data generating process for zeros in the population is different for the two choices – the factors that explain the probability of being willing to pay may have different effects when explaining the size of the WTP.

4. Results

4.1. Descriptive statistics

In total, 10564 interviews were conducted in the nine countries. The smallest country-specific sample was 505 (Estonia) and the largest 2029 (Poland). As shown in Table 1, the response rate was generally lower (lowest in Germany, 32%) in countries where an internet survey was used, rather than face-to-face interviews (highest in Russia, 69%).

Table 1 also presents selected socio-demographic data for the sample: mean age, percentage of women among the respondents, mean household size, mean monthly net income and the percentage of respondents who have a high level of education.

The samples collected in each country exhibited similar properties in terms of representativeness. Generally, respondents had larger households, lower income and higher education levels than the relevant national population. The results are based on the total sample for all countries, i.e. protest responses[4] or other suchlike were not removed.

[4] Protest responses refer to the situation where respondents do not report a true value for the good in question. They typically appear as protest zeros, when people who actually value the environmental good state that they are not willing to pay for it. There is no general agreement on how to treat protests (Jorgensen et al., 1999).

Table 1
Socio-demographic data for the survey samples by country. Corresponding figures for the population in parenthesis where applicable.

Country	Sample size	Response rate (%)	Mean age	Gender (% female)	Household size	Higher education (%)	Mean monthly net income (in 2011 €)[a]
Denmark	1061	38.2	50 (46)	43 (50)	2.2 (2.1)	48 (25)	2275 (2385)
Estonia	505	42.1	38 (44)	50 (53)	2.9 (2.2)	55 (31)	583 (542)
Finland	1645	39.4	51 (45)	49 (51)	2.3 (2.1)	32 (29)	1890 (2031)
Germany	1495	32.5	42 (43)	50 (51)	2.5 (2.1)	39 (25)	1641 (1827)
Latvia	701	45.0	44 (45)	55 (53)	2.8 (2.5)	25 (23)	311 (428)
Lithuania	617	60.5	43 (42)	49 (54)	2.8 (2.5)	22 (24)	205 (387)
Poland	2029	n/a (36)[b]	39 (39)	50 (51)	3.3 (2.6)	32 (18)	495 (492)
Russia	1508	69.3	44 (39)	55 (54)	3.0 (2.6)	44 (23)	338 (462)
Sweden	1003	34.0	54 (41)	54 (50)	2.2 (2.0)	50 (33)	1858 (2024)

Sources of population statistics: Statistics Denmark 2011, Statistics Estonia 2011, Statistics Finland 2010, Statistisches Bundesamt 2010 (Germany), Population Census 2011 (Latvia), Statistics Lithuania 2011, Polish Central Statistical Office 2010, Rosstat 2010 (Russia), Statistics Sweden 2010.
[a] n/a for face-to-face interviews, 36% for internet panel.
[b] Source of population income: Eurostat 2013a, except Russia: Rosstat 2010.

4.2. Motives for willingness to pay

The shares of respondents who were willing to pay for reducing eutrophication are shown in Table 2. The differing shares between countries could reflect, for example, the differences in income levels and geographical factors. Smallest proportions of respondents willing to pay were found in Russia, Latvia and Lithuania, i.e. in countries which also had the lowest mean income according to Table 1. The proportion of respondents willing to pay was largest in Sweden and Finland, both high-income countries with long coastlines. It is worth noting that altogether, over half of the respondents were willing to pay something for reducing eutrophication in the Baltic Sea.

Those respondents who were willing to contribute to the protection of the Baltic Sea were requested to state their main motive for being willing to pay (Table 3).[5] Interestingly, almost a third of the respondents stated that the main reason was that "The existence of healthy marine ecosystems and plants and animals is important". Another third chose the response option "Future generations will be able to enjoy the water quality improvements". This is a strong indicator of non-use (or passive use) values, which are not directly related to the individual's own use of the Baltic Sea. Further, from a temporal perspective, this also indicates that people are willing to contribute to investments that have an effect in the long run, not only to measures that improve the state of the sea in the near future.

4.3. Perceptions of eutrophication effects

Perceptions of eutrophication effects were analysed based on responses to survey items measuring how problematic the different effects were seen[6] and which of them the respondent considered in answering the WTP question.[7] Respondents were first given a description of the five effects, i.e. water turbidity, blue-green algal blooms, underwater meadows loss, fish species composition change and lack of oxygen in deep sea bottoms, and then asked whether they considered them problematic. Responses were given on a five-point Likert scale from "not at all a problem" to "a very big problem".

According to the Friedman test, there was a statistically significant difference in how problematic the respondents perceived the different effects of eutrophication in each country (see Appendix B). Pairwise comparisons in the post-hoc analysis indicated that water turbidity was considered less problematic than the other effects in all countries. In addition, lack of oxygen and change in fish species composition were typically seen as more problematic than the other effects, especially in Germany, Latvia, Lithuania, Russia and Sweden. In Finland, blue-green algal blooms and lack of oxygen were considered most problematic.

The lower importance of water turbidity compared to the other effects is somewhat surprising, as it is one of the most visible effects of eutrophication. Sight depth (Secchi depth, Preisendorfer, 1986) or water turbidity has been used as a eutrophication indicator in several previous valuation studies in the Baltic Sea area (e.g. Atkins and Burdon, 2006; Sandström, 1996; Soutukorva, 2001; Söderqvist and Scharin, 2000), as it is easy to measure and communicate to people. However, although increased water turbidity is a nuisance, it does not prevent recreation.

In summary, all effects of eutrophication were not deemed equally problematic, but the differences between the effects were in most cases small. In addition, the most important effect varied between countries (see Appendix B for country-wise results). Fig. 2 shows the perceptions of the respondents in total (all countries summed). The aggregate results also suggest that water turbidity was seen as less problematic and fish species change and lack of oxygen as somewhat more problematic than blue-green algal blooms and underwater meadow loss.

After the WTP question, the respondents were asked which effects of eutrophication (one or many) they had in mind when answering how much they were willing to pay. This question was, in other words, only addressed to those who were willing to pay.

According to the Cochran's Q test results, there was an overall statistically significant difference in considering the eutrophication effects in each country (see Appendix C). In general, blue-green algal blooms were chosen often and underwater meadows rarely in all countries. Pairwise comparisons with the McNemar test indicated that countries also differed with respect to the eutrophication effects that were considered.[8] Cyanobacterial blooms seemed most important in Finland and Poland, water turbidity in Lithuania and Russia, lack of oxygen in Denmark and fish species in Sweden. In Latvia and Estonia, respondents ranked several effects of eutrophication as about equally important. As general patterns common to all countries could not be found, the results suggest that all effects of eutrophication are important on the Baltic-wide level (see Appendix C). On the aggregate level, the results showed that blue-green algal blooms and fish species composition change were

[5] The question read: "What was the most important reason for you to be willing to pay for reducing eutrophication in the Baltic Sea?"

[6] Respondents were asked the following: "To what extent do you personally view the following effects of eutrophication in the Baltic Sea as problems or not?"

[7] Respondents were asked the following: "Which of the effects of eutrophication did you have in mind when answering how much you were willing to pay?"

[8] McNemar test results are available from the authors on request.

Table 2
Shares of respondents willing to pay per country.

Country	Share willing to pay for BSAP (%)	N
Denmark	55	1061
Estonia	58	505
Finland	63	1645
Germany	56	1495
Latvia	50	701
Lithuania	55	617
Poland	56	2029
Russia	32	1508
Sweden	75	1003
Overall average	55	10564

Table 3
Most important reasons for being willing to pay.

Response option	Frequency	Share of respondents (%)
I have used the Baltic Sea for nature experiences and recreation	460	8
I plan to use the Baltic Sea for nature experiences and recreation in the future	567	10
The existence of healthy marine ecosystems and plants and animals is important	1800	31
Other people in my generation are able to enjoy the water quality improvements	211	4
Future generations will be able to enjoy the water quality improvements	1682	29
You can do a lot for environmental protection with a small contribution	914	16
Other reason	220	4
Don't know[a]	11	0
Sum	5865	100.00

[a] The don't know option was only available in the Danish questionnaire.

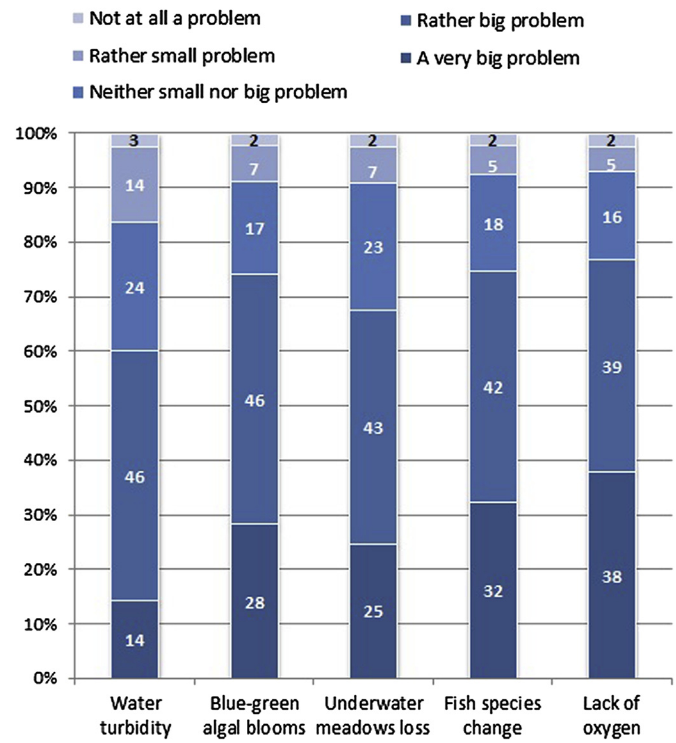

Fig. 2. Percentage shares of respondents' perceptions of the eutrophication effects (country-wise results available in Appendix B).

chosen most often (Table 4). However, as previously noted, the country-wise differences were quite large.

It is somewhat surprising that the eutrophication effects seen as most problematic did not, in some cases, correspond with the effects the respondents took into consideration in the WTP question. Cyanobacterial blooms were chosen most often but they were not seen as the most problematic, while lack of oxygen was not taken into consideration when stating the WTP as often although it was seen as one of the most problematic effects. A question thus rises if this result is due to differing samples (all respondents versus only those who are willing to pay). However, the previous findings of how problematic the respondents perceived the different effects of eutrophication in each country hold even if we consider only those who were willing to pay. A possible explanation for the dissimilarities could be the different context of the survey questions: respondents could have interpreted the first question (how problematic the effects are) as being on a general level, while the responses to the second question (which effects the respondent had in mind) in the WTP elicitation stage could be based on the more tangible effects.

4.4. Spatial considerations

In the survey, the respondents were asked to state their WTP for the whole Baltic Sea for a change in open-sea conditions. However, we understood that respondents might place greater emphasis on some sub-regions of the Baltic Sea, and also take coastal areas into consideration in their WTP response. The Baltic Sea covers a large geographical area and people may care more about their immediate surroundings than areas further away. To examine these issues, debriefing questions were presented after the WTP question. The first question examined whether the respondents had considered the whole Baltic Sea or some specific area of the Baltic Sea,[9] and the second to what extent they had considered open-sea versus coastal areas when stating their WTP[10].

In the question on the spatial extent of the WTP across the sea basins, more than one half of the respondents who were willing to pay had considered the whole Baltic Sea when stating their WTP. However, Pearson's χ^2-test showed statistically significant differences between countries. Fig. 3 presents the share of respondents being willing to pay for reduced eutrophication in the whole Baltic Sea (instead of some specific area of the Baltic Sea). The lines above the bars imply non-significant (p-value of difference >10%) test results for difference between the countries. Sweden alone was different from all countries with the highest proportion of people willing to pay for the whole sea, followed by Germans, Danes, Finns and Lithuanians who expressed statistically similar preferences. A likely explanation of why Swedes were the most interested in improving the condition of the entire Baltic Sea is that Sweden has the longest coastline, extending from the Bothnian Bay in the north to Kattegat in the south.

In turn, Latvians, Russians, Poles and Estonians were more often willing to pay for an improvement in a specific area of the Baltic Sea than respondents in other countries. It is unsurprising that Russians and Latvians preferred their contributions to go more towards specific areas, as these two countries are adjacent to the most

[9] The question read: "Did you consider the whole Baltic Sea or a certain area of the Baltic Sea when answering how much you were willing to pay?". The respondents who did not consider the entire sea were then asked to specify: "Which area(s) of the Baltic Sea did you have in mind when answering how much you were willing to pay? You may choose one or several areas."

[10] Respondents were asked the following: "To what extent did you consider open sea and coastal areas when answering how much you were willing to pay?"

Table 4
Shares of respondents considering the particular effects of eutrophication (country-wise results in Appendix C).

Eutrophication effect	Percentage (%)
Water turbidity ($n = 6148$)	54
Cyanobacterial blooms ($n = 6128$)	68
Loss of underwater meadows ($n = 5944$)	40
Fish species composition change ($n = 6031$)	59
Lack of oxygen in deep sea bottom areas ($n = 5913$)	51

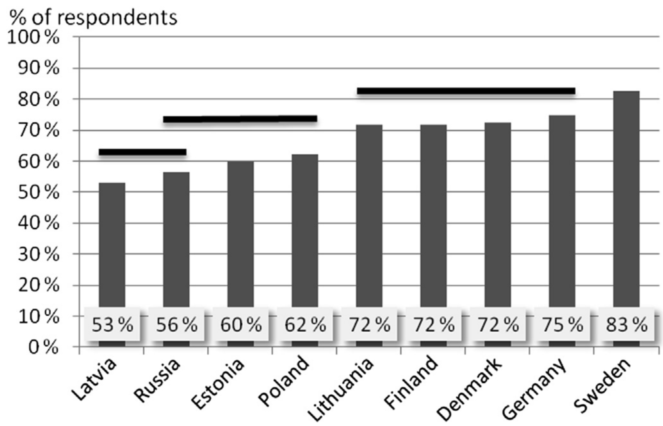

Fig. 3. Shares of respondents being willing to pay for reduced eutrophication in the whole Baltic Sea.

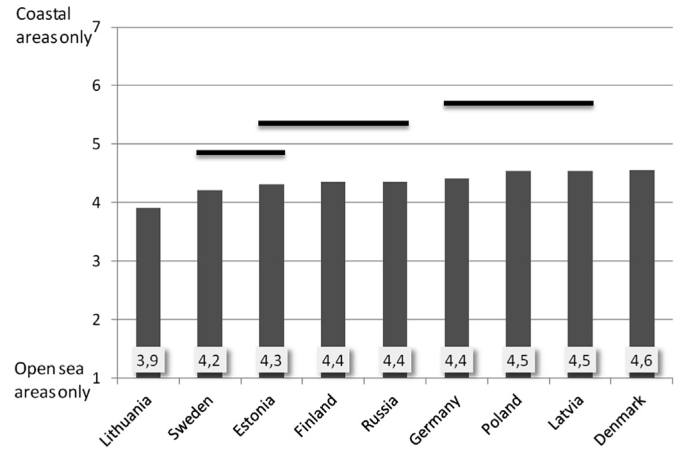

Fig. 4. Emphasis of open-sea versus coastal areas, mean values.

eutrophied waters with relatively short coastlines. Yet, the majority of the respondents directed their WTP towards the whole Baltic Sea showing that improving the state of the entire sea area is important and that large non-use values are likely to be attributed to the sea.

The second question on open-sea versus coastal areas was presented on a scale from 1 (open-sea areas only) to 7 (coastal areas only).[11] The results showed that, on average, respondents thought slightly more about the coastal areas than open-sea areas, with the exception of Lithuanian respondents. The Kruskal–Wallis test indicated that responses across countries differed significantly, even though the absolute differences in the average responses were small as shown in Fig. 4. Post-hoc Kruskal–Wallis tests found groupings of similar countries. Bars in Fig. 4 indicate p-value of difference less than 10%. There is no intuitive reason for the country groupings, however. Germany, Poland and Denmark border the southern Baltic Sea, where the waters are warmer for a longer period in the summer, thus providing better water recreation opportunities than in the north, which could lead to a larger share of use values attributed to the sea in these areas. On the other hand, Lithuania is also in the south, which does not support this reasoning.

Combining the findings of Figs. 3 and 4, it seems that Swedes thought more often of the entire Baltic Sea and open sea areas, while Latvians were at the opposite end with more emphasis on some specific parts of the Baltic Sea and coastal areas. These two countries differ both with respect to income levels and geographical location and scope, which may explain these differences.

4.5. *WTP functions*

To gain additional insights into perceptions of eutrophication, we examined whether the different eutrophication effects influenced the probability of being willing to pay (logit model) and the size of the WTP (ordinary least squares regression). The descriptive statistics for the variables included in the logit and OLS models can be found in Appendix D Tables D1 and D2.

When respondents report their maximum willingness to pay using a payment card, the actual maximum WTP figure will lie somewhere between the marked amount of money and the next largest sum of money in the payment card. We assumed that the mid-point of the interval represents the WTP (e.g. Håkansson, 2008).[12]

In the logit model, we included the socio-demographic variables presented in Table 1, and binary variables indicating whether the respondent stated the different eutrophication effects to be problematic or not.[13] In the OLS model, we included the socio-demographic variables as well as binary variables indicating which eutrophication effects the respondents had in mind when stating their WTP. Further, we added one new variable in the estimation, namely *WTP for the whole Baltic Sea*. The variable represents a willingness to pay for the whole Baltic Sea instead of specific sub-basins and was described in depth in the previous section.

Table 5 presents the logit model results, showing that those respondents in Denmark, Finland, and Latvia who considered cyanobacterial blooms as problematic in the Baltic Sea were more likely to be willing to pay. On the other hand, considering underwater meadows as problematic raised the probability of being willing to pay in Germany, Poland and Russia. Those finding fish community composition change as a problem were more likely to be willing to pay in Denmark and Sweden. A respondent who considered a lack of oxygen in the deep sea bottoms to be problematic was more likely to be willing to pay in Finland, Germany and Sweden. A surprising result was that those considering water turbidity important were not more likely to be willing to pay in any country. In general, concern for one or two effects of eutrophication influenced the probability of being willing to pay in one country. In addition, the effects that influenced the probability varied between countries.

Table 6 presents the results from the OLS model explaining the size of the WTP. Those respondents who reported a positive WTP were requested to state the eutrophication effects (one or more) they had in mind when answering. For this sub-population, it is

[11] Except for Denmark where a scale of 1–10 was used. That scale has been re-scaled to 1–7 to be comparable with other countries.

[12] The willingness to pay figures were adjusted to Euros using purchasing power parity (PPP) conversion rates, based on PPP data from Eurostat and OECD (Russia).

[13] The dummy was given the value 1 if the respondent had stated that the specific eutrophication effect was a 'rather big problem' or a 'very big problem', and 0 otherwise.

Table 5
The results of the logit models, coefficient estimates and standard errors.

Dependent variable: Probability of being willing to pay									
Variable	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
Water turbidity problematic, *binary*	0.019	−0.302	0.181	−0.212	0.254	0.395	−0.04	−0.097	−0.056
	0.171	0.234	0.133	0.138	0.197	0.253	0.147	0.172	0.177
Blue-green algal blooms problematic, *binary*	0.423*	0.332	0.401**	0.192	0.411*	−0.201	0.166	0.151	−0.056
	0.24	0.293	0.158	0.195	0.223	0.247	0.182	0.179	0.311
Underwater meadows loss problematic, *binary*	0.137	0.268	0.166	0.532***	0.279	0.262	0.599***	0.326*	0.112
	0.246	0.287	0.152	0.185	0.219	0.3	0.17	0.198	0.253
Fish species composition problematic, *binary*	0.535**	0.315	−0.012	0.045	0.052	0.484	0.073	−0.125	0.803**
	0.228	0.333	0.156	0.186	0.245	0.337	0.178	0.221	0.316
Lack of oxygen problematic, *binary*	0.363	0.132	0.417**	0.788***	−0.042	0.196	−0.048	0.284	0.815**
	0.285	0.344	0.166	0.258	0.248	0.37	0.197	0.219	0.349
Monthly income, 1000 (EUR 2011), *continuous*	0.081	0.262	0.105*	0.022	1.861***	2.757***	1.382***	1.139***	0.204*
	0.073	0.269	0.061	0.071	0.448	0.941	0.204	0.365	0.119
Age, *continuous*	−0.002	−0.019**	−0.003	−0.009**	−0.006	−0.020***	−0.006	−0.006*	0.001
	0.005	0.008	0.004	0.004	0.005	0.007	0.005	0.004	0.005
Female, *binary*	0.094	0.106	0.352***	0.106	−0.03	0.068	0.274**	0.193	0.276*
	0.149	0.213	0.111	0.13	0.166	0.189	0.115	0.121	0.158
Size of household, *continuous*	0.039	0.08	−0.099**	−0.016	0.004	0.059	0.014	−0.019	0.076
	0.069	0.085	0.045	0.05	0.069	0.087	0.043	0.05	0.076
University education, *binary*	0.051	0.232	0.553***	0.620***	−0.001	0.288	0.601***	0.108	0.191
	0.148	0.21	0.124	0.133	0.21	0.241	0.13	0.121	0.154
Constant	−1.120***	−0.149	−0.37	−0.808***	−0.806**	−0.479	−1.058***	−1.328***	−1.204**
	0.408	0.521	0.271	0.311	0.408	0.535	0.3	.311	0.472
N	918	439	1645	1176	647	522	1484	1403	985
Pseudo R^2	0.057	0.033	0.054	0.048	0.054	0.083	0.075	0.021	0.045
Log likelihood	−594	−289	−1025	−763	−424	−328	−939	−860	−534
Akaike Information Criteria	1211	601	2072	1549	870	678	1901	1742	1090

Statistical significance, *p*-values: * <10%, ** <5%, *** <1%.

interesting to examine whether the same eutrophication effects that affected the tendency to be willing to pay also explained the size of the WTP. The OLS models on the size of the WTP have a relatively poor fit, as the adjusted R^2 figures range from 0.026 in the German model to 0.22 in the Russian model. Thus, the eutrophication effects generally have quite small explanatory power for the size of the willingness to pay. However, the results do suggest that the size of the WTP is somewhat affected by multiple eutrophication effects and that their relative importance for the size of the WTP varies among countries.

Respondents thinking about fish species composition change had statistically significantly higher WTP in Denmark, Estonia, Finland and Lithuania. Perhaps surprisingly, water turbidity had mostly no statistically significant effect on the WTP, except in Latvia

Table 6
The results of the OLS model depicting the size of WTP, coefficient value and standard error.

Dependent variable: midpoint of the WTP interval									
Variable	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
Water turbidity a reason for WTP, *binary*	−0.015	0.198	0.085	−0.015	0.317**	−0.106	−0.031	−0.700*	−0.128
	0.119	0.154	0.065	0.079	0.147	0.163	0.075	0.391	0.088
Blue-green algal blooms a reason for WTP, *binary*	0.154	−0.121	0.101	−0.082	0.369**	−0.141	0.138*	1.297***	−0.090
	0.117	0.175	0.073	0.081	0.152	0.158	0.081	0.373	0.088
Underwater meadows loss a reason for WTP, *binary*	−0.036	−0.036	0.128	0.229***	0.178	−0.252	0.203**	0.086	0.125
	0.130	0.173	0.082	0.084	0.231	0.179	0.092	0.397	0.098
Fish species composition a reason for WTP, *binary*	0.391***	0.405**	0.204***	0.028	−0.028	0.357**	0.100	0.629	0.062
	0.116	0.166	0.067	0.080	0.160	0.175	0.078	0.388	0.088
Lack of oxygen a reason for WTP, *binary*	0.209*	0.102	0.096	0.023	0.035	0.088	0.023	−0.736**	0.309***
	0.121	0.169	0.067	0.082	0.206	0.168	0.090	0.373	0.087
WTP for whole Baltic Sea, *binary*	0.240**	−0.266*	0.056	0.091	0.388***	−0.023	−0.018	0.380	−0.020
	0.113	0.145	0.069	0.088	0.137	0.150	0.076	0.245	0.099
Monthly income, 1000 (EUR 2011), continuous	0.212***	0.441***	0.250***	0.074*	0.493	1.152*	0.314***	1.700**	0.275***
	0.055	0.165	0.036	0.043	0.358	0.629	0.101	0.722	0.060
Age, *continuous*	0.008**	0.011*	−0.003	0.006**	−0.010**	−0.020***	0.007*	−0.016**	0.001
	0.004	0.006	0.002	0.003	0.004	0.005	0.003	0.007	0.003
Female, *binary*	−0.066	−0.095	−0.065	−0.017	−0.112	0.054	−0.115	−0.282	−0.413***
	0.108	0.150	0.065	0.077	0.136	0.129	0.075	0.234	0.078
Size of household, *continuous*	0.057	−0.01	−0.004	0.013	0.081	0.015	−0.010	0.082	0.018
	0.049	0.061	0.027	0.030	0.054	0.057	0.029	0.113	0.038
University education, *binary*	0.049	−0.173	0.157**	0.101	0.077	0.001	0.293***	0.621**	0.201***
	0.110	0.146	0.068	0.079	0.166	0.148	0.077	0.240	0.077
Constant	2.301***	2.158***	3.248***	2.837***	0.761**	2.434***	1.510***	1.030	3.770***
	0.322	0.392	0.176	0.184	0.352	0.355	0.201	0.678	0.250
N	496	250	1023	693	312	266	826	155	724
Adjusted R^2	0.086	0.065	0.098	0.026	0.098	0.081	0.060	0.225	0.120
Log likelihood	−753	−370	−1420	−953	−485	−377	−1172	−265	−1023
Akaike Information Criteria	1529	763	2864	1930	995	778	2368	553	2070

Statistical significance. *p*-values: * <10%. ** <5%. *** <1%.

where the effect was significantly positive and Russia where the effect was weakly negative. In the latter two countries, however, respondents considering cyanobacterial blooms were willing to contribute significantly more than respondents thinking of other eutrophication issues. In other countries, blue-green algal blooms had no significant effect. Respondents thinking about underwater meadows had significantly higher WTP than others in Germany and Poland. Finally, concern about the lack of oxygen in the deep sea bottoms had a significant and increasing effect on WTP in Denmark and Sweden and a negative effect in Russia.

It is not straightforward to compare these results to the results from other valuation studies of eutrophication effects from the Baltic Sea region. The reason is that the definitions of water quality and eutrophication effects differ substantially between studies. For example, Eggert and Olsson (2009) defined water quality in terms of days per year where the bathing water quality fails to meet EU standards. In Östberg et al. (2012) the water quality attribute was holistic, including vegetation, water clarity and algal mat coverage. Also, most studies have presented no results on how the respondents rank different eutrophication effects (e.g. Atkins and Burdon, 2006; Bateman et al., 2011). An exception to this is Kosenius (2010), who estimated Finns' willingness to pay for different attributes of eutrophication reduction in the Gulf of Finland using the choice experiment method. The findings indicated that water clarity was most important, followed by blue-green algal blooms, fish species composition and bladder wrack. However, these results apply only to the Finnish population and a sub-region of the Baltic Sea. The only previous Baltic-wide study, reported in e.g. Söderqvist (1996), Gren et al. (1997), Turner et al. (1999) and Markowska and Zylicz (1999), did not report results on the public preferences for different eutrophication effects.

5. Discussion and conclusions

This paper investigated public preferences for three policy-relevant dimensions of nutrient reductions in the Baltic Sea: first, nitrogen versus phosphorus; second, the role of time; and third, the spatial dimension.

The results indicate that, in general, respondents care about the Baltic Sea. For example, most respondents are willing to make a monetary contribution to improve the Baltic Sea environment. Importantly, the respondents seem to appreciate the Baltic Sea environment in a holistic way – that is: they tend to care about eutrophication in general instead of focusing on a particular effect of eutrophication, and find improvement in the entire area of the Baltic Sea important rather than considering only their local environment.

In general, all effects of eutrophication are not seen as equally problematic in all countries, and the effect of primary concern differs among countries but the differences are mostly small. A similar result is found concerning which eutrophication effect the respondents primarily considered when stating their willingness to pay. There is an overall statistically significant difference among eutrophication effects for all countries summed. However, as general patterns common to all countries could not be found the results suggest that all effects of eutrophication are important on the Baltic-wide level. Finally, the WTP models also show similar results – the most influential eutrophication effect for the probability of being willing to pay and the size of the WTP differs among countries.

An additional indication that the respondents think holistically about the Baltic Sea environment is that more than half of the respondents willing to pay allocate their WTP-figure to the whole Baltic Sea rather than to a specific area. This also suggests that large non-use values are attributed to the sea. The non-use component of the value associated with the Baltic Sea is further supported by the respondents considering the coastal environment and the open sea approximately equally when responding to the willingness to pay question, and that the motives for being willing to pay are mainly related to the existence of a healthy marine ecosystem and the opportunities of future generations to enjoy the sea.

These findings have bearings on policy. For example, there are potential goal conflicts between the Water Framework Directive (WFD)—with water quality targets for coastal areas – and the MSFD – with water quality targets for the open sea. Our findings suggest that the citizens in the Baltic Sea littoral countries value improvements in coastal areas and the open sea about equally. This means that measures that improve the coastal environment at the cost of that of the open sea, or vice versa, need careful evaluation to ensure that they actually improve societal well-being. The arguments made by Schindler (2012), that policy should focus mainly on eliminating cyanobacterial blooms, do not match the public's preferences. Since both nitrogen and phosphorus reductions are required to achieve improvements in all our five investigated eutrophication effects, both nitrogen and phosphorus reductions are required to fulfil the public's preferences.

Moreover, that most of the respondents tend to care for the whole Baltic Sea implies that the citizens in the littoral countries can be expected to be willing to make a monetary contribution not only to finance measures in their own part of the sea, but also to finance measures in other countries. Since a cost-efficient allocation of nutrient abatement measures is politically difficult, this is a promising result. For example, a cap and trade system for nitrogen has been on the agenda in recent years (e.g. Swedish EPA, 2009; 2012). Such a system could reallocate nutrient reductions between countries. Had the respondents only cared for their own, local part of the Baltic Sea, one would expect resistance to such a policy instrument. Importantly, such a system would need to take both the coastal and open sea environment into account, and comply with both the WFD and the MSFD.

Concerning time, one aspect of our data is important. The improvements in our eutrophication reduction scenario would be reached fully by 2050 – a distant time horizon. In fact, many of the respondents stated that one of the reasons for being willing to pay was that future generations should be able to enjoy the water quality improvement. This suggests that the respondents are willing to pay to finance long-term measures, not only those with quick pay-off.

Better understanding of public perceptions and the benefits of nutrient load reductions can aid in forming international agreements that are both economically efficient and equitable. In addition to the benefits, also the distribution of the costs between countries needs to be considered to design cost-effective and fair policies.

Welfare maximization should be a factor when allocating limited resources for combating marine eutrophication, along with legal considerations, such as international agreements and the polluter-pays principle. This means that mitigation measures should target those effects on ecosystem services that the public values the most. Our results indicate that this requires taking the whole range of eutrophication effects into account, both in coastal and open sea areas, and including also measures that improve the state of the sea in the long run.

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Appendix A. The effects of eutrophication on water quality in open sea areas as presented in the survey

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

Appendix B. Test statistics and significance levels on perceptions of eutrophication effects

Table B1 presents the results of the Friedman test (Friedman, 1937, 1940) of whether there were differences within countries in how problematic respondents perceived the different effects of eutrophication (water turbidity, blue-green algal blooms, underwater meadows loss, fish species composition change and lack of oxygen in deep sea bottoms). The response scale was five-point (1 = not at all a problem, 2 = rather small problem, 3 = neither small nor big problem, 4 = rather big problem, 5 = a very big problem). The results indicate significant differences in all countries.

Table B1
Test statistics and significance levels (Friedman test).

Country	Observations	χ^2 (4)	Significance level
Denmark	1061	789.2	0.000
Estonia	505	216.4	0.000
Finland	1645	788.5	0.000
Germany	1447	1155.7	0.000
Latvia	700	317.0	0.000
Lithuania	617	370.6	0.000
Poland	2025	420.0	0.000
Russia	1470	328.8	0.000
Sweden	1003	1051.3	0.000

Table B2 shows how problematic respondents considered the effects of eutrophication in different countries.

Table B2
Extent to which respondents felt that the effects of eutrophication are a problem (%).

Denmark (n = 1061)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	2.5	11.5	32.7	42.2	11.1
Blue-green algae	1.1	4.3	21.8	49.1	23.7
Underwater meadows loss	1.5	4.1	25.1	44.5	24.9
Fish species composition change	1.8	4.2	25.4	42.0	26.6
Lack of oxygen in deep sea areas	1.5	3.3	17.9	35.4	41.8
Estonia (n = 505)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	1.4	12.5	25.7	50.9	9.5
Blue-green algae	0.8	5.7	13.9	52.5	27.1
Underwater meadows loss	1.4	5.7	19.0	48.7	25.1
Fish species composition change	1.6	3.8	14.7	46.9	33.1
Lack of oxygen in deep sea areas	1.6	4.0	17.0	44.2	33.3
Finland (n = 1645)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	3.8	15.7	23.6	46.0	10.9
	3.2	8.0	14.0	41.5	33.3

Table B2 (*continued*)

Denmark (n = 1061)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Blue-green algae					
Underwater meadows loss	4.7	11.1	30.1	38.1	16.0
Fish species composition change	3.3	9.3	20.7	44.5	22.1
Lack of oxygen in deep sea areas	4.1	8.1	19.8	36.7	31.2
Germany (n = 1471)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	0.9	18.5	22.9	47.1	10.5
Blue-green algae	0.8	4.2	12.8	58.7	23.5
Underwater meadows loss	0.7	4.4	16.0	51.3	27.6
Fish species composition change	1.1	3.4	14.7	46.7	33.9
Lack of oxygen in deep sea areas	0.9	2.0	7.7	44.2	45.2
Latvia (n = 701)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	3.4	19.5	28.8	39.1	9.1
Blue-green algae	3.3	12.1	24.7	40.8	19.1
Underwater meadows loss	2.6	11.7	34.0	34.7	17.1
Fish species composition change	2.1	0.0	21.8	39.4	29.7
Lack of oxygen in deep sea areas	2.4	7.0	25.3	35.6	29.7
Lithuania (n = 617)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	1.6	15.7	21.4	50.2	11.0
Blue-green algae	1.8	13.1	28.7	44.9	11.5
Underwater meadows loss	1.1	7.6	21.1	49.6	20.7
Fish species composition change	1.6	6.5	18.0	46.2	27.7
Lack of oxygen in deep sea areas	1.0	5.5	15.4	48.6	29.5
Poland (n = 2025)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	3.8	10.1	15.8	52.1	18.2
Blue-green algae	3.8	5.2	12.0	46.1	32.9
Underwater meadows loss	3.7	4.7	21.3	43.6	26.6

(continued on next page)

Table B2 (*continued*)

Denmark ($n = 1061$)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Fish species composition change	3.6	4.6	15.3	42.8	33.6
Lack of oxygen in deep sea areas	4.0	3.8	15.2	40.5	36.4
Russia ($n = 1475$)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	1.7	11.9	29.5	37.3	19.5
Blue-green algae	2.0	9.5	27.0	39.7	21.8
Underwater meadows loss	2.1	8.9	28.4	38.3	22.3
Fish species composition change	2.0	6.8	20.5	38.5	32.3
Lack of oxygen in deep sea areas	2.3	7.1	23.3	38.8	28.5
Sweden ($n = 1003$)	Not at all a problem (%)	Rather small problem (%)	Neither small nor big problem (%)	Rather big problem (%)	A very big problem (%)
Water turbidity	1.4	11.4	20.2	47.3	19.7
Blue-green algae	0.8	2.2	6.7	41.2	49.2
Underwater meadows loss	1.2	2.3	13.7	40.8	42.1
Fish species composition change	0.9	1.3	7.5	35.2	55.1
Lack of oxygen in deep sea areas	1.0	0.9	6.0	23.8	63.8

Appendix C. Consideration of different effects of eutrophication when stating the willingness to pay

Results of the Cochran's Q test (Conover, 1999) indicate significant differences within countries in consideration of eutrophication effects when stating the willingness to pay (Table B2). There were five effects to choose from: water turbidity, blue-green algal blooms, underwater meadows loss, fish species composition changes and lack of oxygen in deep sea bottom areas, and the respondent could choose one or several effects.

Table C1
Test statistics and significance levels (Cochran's Q test).

Country	Observations	χ^2 (4)	Significance level
Denmark	732	255.3	0.000
Estonia	288	101.4	0.000
Finland	1031	511.9	0.000
Germany	970	170.1	0.000
Latvia	331	174.3	0.000
Lithuania	342	68.9	0.000
Poland	1385	589.5	0.000
Russia	266	82.1	0.000
Sweden	830	329.2	0.000

Table C2 presents the shares of respondents considering the distinct effects of eutrophication when stating their WTP by country.

Table C2
Shares of respondents considering the distinct effects of eutrophication.

Denmark ($n = 583$)	Percentage (%)
Water turbidity	35.3
Blue-green algal blooms	60.0
Underwater meadows loss	43.6
Fish species composition change	53.0
Lack of oxygen in deep sea bottom areas	68.4
Estonia ($n = 288$)	Percentage (%)
Water turbidity	58.0
Blue-green algal blooms	77.4
Underwater meadows loss	53.1
Fish species composition change	71.5
Lack of oxygen in deep sea bottom areas	47.2
Finland ($n = 1031$)	Percentage (%)
Water turbidity	51.6
Blue-green algal blooms	74.8
Underwater meadows loss	29.4
Fish species composition change	54.4
Lack of oxygen in deep sea bottom areas	49.3
Germany ($n = 844$)	Percentage (%)
Water turbidity	45.1
Blue-green algal blooms	60.1
Underwater meadows loss	44.2
Fish species composition change	64.3
Lack of oxygen in deep sea bottom areas	64.0
Latvia ($n = 331$)	Percentage (%)
Water turbidity	66.0
Blue-green algal blooms	66.0
Underwater meadows loss	31.7
Fish species composition change	53.4
Lack of oxygen in deep sea bottom areas	36.9
Lithuania ($n = 340$)	Percentage (%)
Water turbidity	76.2
Blue-green algal blooms	67.9
Underwater meadows loss	59.1
Fish species composition change	68.5
Lack of oxygen in deep sea bottom areas	54.7
Poland ($n = 1107$)	Percentage (%)
Water turbidity	64.0
Blue-green algal blooms	72.5
Underwater meadows loss	40.6
Fish species composition change	55.9
Lack of oxygen in deep sea bottom areas	40.5
Russia ($n = 489$)	Percentage (%)
Water turbidity	76.3
Blue-green algal blooms	68.9
Underwater meadows loss	34.6
Fish species composition change	52.8
Lack of oxygen in deep sea bottom areas	30.7
Sweden ($n = 756$)	Percentage (%)
Water turbidity	38.6
Blue-green algal blooms	66.5
Underwater meadows loss	41.4
Fish species composition change	67.6
Lack of oxygen in deep sea bottom areas	61.1

Appendix DDescriptive statistics for the variables included in the WTP models

Table D1
Descriptive statistics for the variables included in the logit model (means and standard deviations in parenthesis).

	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
Willing to pay, *binary*	0.554 (0.497)	0.574 (0.495)	0.630 (0.483)	0.573 (0.495)	0.509 (0.500)	0.561 (0.497)	0.567 (0.496)	0.319 (0.466)	0.745 (0.436)
Water turbidity problematic, *binary*	0.541 (0.499)	0.610 (0.488)	0.569 (0.495)	0.580 (0.494)	0.495 (0.500)	0.607 (0.489)	0.704 (0.457)	0.564 (0.4969)	0.674 (0.469)
Blue-green algal blooms problematic, *binary*	0.744 (0.437)	0.800 (0.401)	0.748 (0.434)	0.826 (0.380)	0.607 (0.489)	0.579 (0.494)	0.785 (0.411)	0.612 (0.4889)	0.905 (0.294)
Underwater meadows loss problematic, *binary*	0.707 (0.455)	0.729 (0.445)	0.541 (0.498)	0.792 (0.406)	0.522 (0.500)	0.711 (0.454)	0.700 (0.458)	0.607 (0.4899)	0.829 (0.376)
Fish species composition problematic, *binary*	0.700 (0.458)	0.804 (0.397)	0.666 (0.472)	0.808 (0.394)	0.689 (0.463)	0.751 (0.433)	0.757 (0.429)	0.704 (0.4579	0.905 (0.294)
Lack of oxygen problematic, *binary*	0.790 (0.408)	0.772 (0.420)	0.680 (0.467)	0.896 (0.305)	0.652 (0.477)	0.789 (0.408)	0.767 (0.423)	0.672 (0.4709	0.922 (0.269)
Monthly net income, 1000 (EUR 2011), *continuous*	2.274 (1.041)	0.583 (0.413)	1.890 (0.967)	1.639 (0.982)	0.311 (0.205)	0.205 (0.109)	0.494 (0.342)	0.337 (0.170)	1.858 (0.6779)
Age of the respondent, *continuous*	49.710 (14.067)	39.025 (12.771)	50.651 (14.091)	42.011 (14.810)	44.145 (16.256)	44.697 (15.795)	39.547 (11.431)	44.591 (16.710)	53.547 (16.409)
Female, *binary*	0.422 (0.494)	0.499 (0.501)	0.485 (0.500)	0.478 (0.500)	0.549 (0.498)	0.487 (0.500)	0.495 (0.500)	0.554 (0.497)	0.533 (0.499)
Size of household, *continuous*	2.232 (1.077)	2.872 (1.191)	2.263 (1.200)	2.486 (1.250)	2.813 (1.269)	2.707 (1.244)	3.313 (1.310)	2.979 (1.195)	2.200 (1.109)
University education, *binary*	0.483 (0.500)	0.547 (0.498)	0.324 (0.468)	0.412 (0.492)	0.241 (0.428)	0.247 (0.432)	0.318 (0.466)	0.440 (0.497)	0.504 (0.500)
N	918	439	1645	1176	647	522	1484	1403	985

Table D2
Descriptive statistics for the variables included in the OLS model (means and standard deviations in parenthesis).

	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
Log WTP (midpoint of the WTP interval in the payment card)	3.886 (1.169)	2.842 (1.125)	3.940 (1.027)	3.419 (0.979)	1.388 (1.231)	1.862 (1.066)	2.186 (1.039)	1.944 (1.578)	4.432 (1.069)
Water turbidity a reason for WTP, *binary*	0.357 (0.480)	0.592 (0.492)	0.515 (0.500)	0.452 (0.498)	0.651 (0.478)	0.774 (0.419)	0.640 (0.480)	0.826 (0.381)	0.385 (0.487)
Blue-green algal blooms a reason for WTP, *binary*	0.599 (0.491)	0.780 (0.415)	0.747 (0.435)	0.612 (0.488)	0.663 (0.473)	0.695 (0.461)	0.724 (0.447)	0.729 (0.446)	0.657 (0.475)
Underwater meadows loss a reason for WTP, *binary*	0.442 (0.497)	0.528 (0.500)	0.294 (0.456)	0.444 (0.497)	0.321 (0.467)	0.620 (0.486)	0.400 (0.490)	0.619 (0.487)	0.412 (0.492)
Fish species composition a reason for WTP, *binary*	0.522 (0.500)	0.716 (0.452)	0.543 (0.498)	0.645 (0.479)	0.529 (0.500)	0.703 (0.458)	0.558 (0.497)	0.729 (0.446)	0.670 (0.471)
Lack of oxygen a reason for WTP, *binary*	0.700 (0.459)	0.472 (0.500)	0.495 (0.500)	0.644 (0.479)	0.362 (0.481)	0.560 (0.497)	0.413 (0.493)	0.632 (0.484)	0.606 (0.489)
WTP for the whole Baltic Sea, *binary*	0.700 (0.459)	0.600 (0.491)	0.717 (0.451)	0.758 (0.429)	0.535 (0.500)	0.714 (0.453)	0.648 (0.478)	0.632 (0.484)	0.819 (0.385)

(*continued on next page*)

Table D2 (*continued*)

	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
Monthly net income, 1000 (EUR 2011), *continuous*	2.295 (1.022)	0.601 (0.455)	1.926 (0.956)	1.670 (0.993)	0.356 (0.209)	0.224 (0.111)	0.559 (0.373)	0.354 (0.169)	1.873 (0.672)
Age of the respondent, *continuous*	49.704 (14.062)	37.984 (13.004)	50.750 (14.522)	41.872 (15.060)	43.420 (15.646)	42.530 (15.668)	39.447 (11.134)	44.161 (16.251)	53.699 (16.380)
Female, *binary*	0.438 (0.497)	0.516 (0.501)	0.519 (0.500)	0.511 (0.500)	0.542 (0.499)	0.485 (0.501)	0.519 (0.500)	0.574 (0.496)	0.547 (0.498)
Size of household, *continuous*	2.258 (1.106)	2.932 (1.182)	2.211 (1.159)	2.483 (1.265)	2.840 (1.298)	2.820 (1.258)	3.306 (1.251)	2.884 (1.075)	2.222 (1.108)
University education, *binary*	0.492 (0.500)	0.576 (0.495)	0.368 (0.482)	0.472 (0.500)	0.272 (0.446)	0.305 (0.461)	0.407 (0.492)	0.439 (0.498)	0.517 (0.500)
N	496	250	1023	693	312	266	826	155	724

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