TOWARDS A BALTIC SEA UNAFFECTED BY EUTROPHICATION

Draft HELCOM Overview 2007

2nd Stakeholder Conference on
the HELCOM Baltic Sea Action Plan

Helsinki, Finland, 6 March 2007

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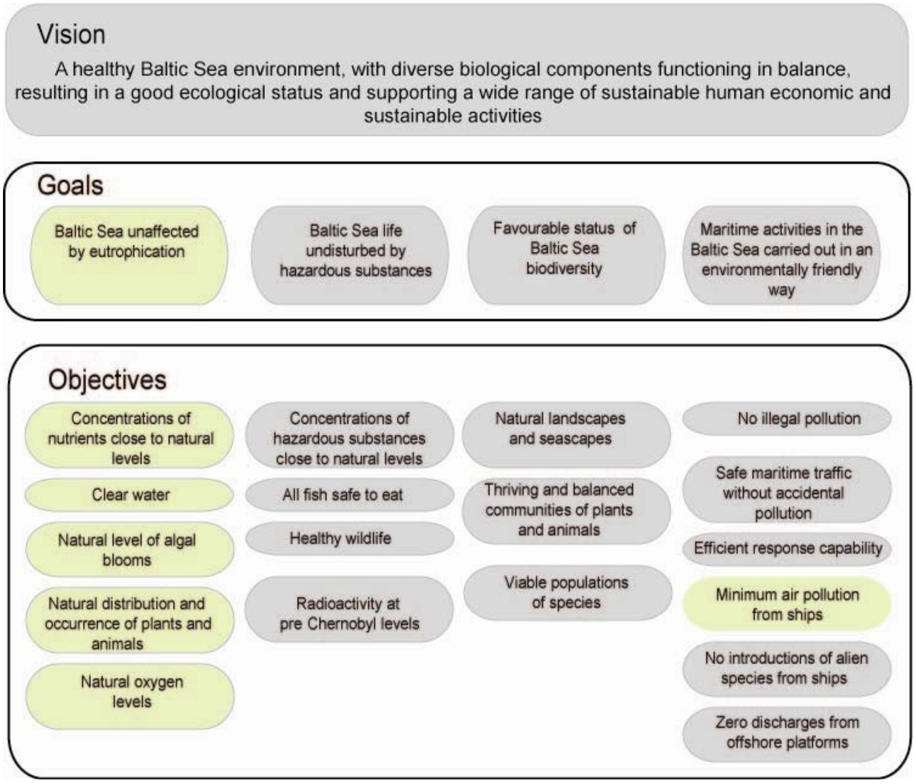
Cover photo by Nanna Rask, Fyn County

PREFACE

The aim of this concise overview is not to provide a comprehensive assessment on the status of eutrophication in the Baltic Sea, but rather to make a first attempt to outline an indicator-based assessment of scenarios for reducing eutrophication by:
- showing how ecological objectives can be used as basic assessment tools for evaluating whether the Baltic Sea has reached a good status with respect to eutrophication,
- presenting a set of scenarios for reducing nutrient inputs to the Baltic Sea and their consequent results if implemented, and
- stimulating discussion on the development of targets and indicators as well as actions for the HELCOM Baltic Sea Action Plan (BSAP).

For the implementation of the ecosystem approach, HELCOM has adopted a system of vision, strategic goals and ecological objectives. Eutrophication is one of the four thematic issues covered by the Baltic Sea Action Plan.



The HELCOM system of vision, strategic goals and ecological objectives

The specific **strategic goal** for eutrophication is to have a “Baltic Sea unaffected by eutrophication”. The **ecological objectives** related to this goal have been selected according on their understandability and the amount of data available. The objectives for eutrophication are: reaching concentrations of nutrients close to natural levels, having clear water, having natural levels of algal blooms, having a natural distribution and occurrence of plants and animals and natural oxygen levels. Due to the variable nature of the different sub-regions of the Baltic Sea, the targets to be reached determined according to local characteristics.

EXECUTIVE SUMMARY

Actions towards a Baltic Sea unaffected by eutrophication

Eutrophication is a major problem in the Baltic Sea. Since the 1900s, the Baltic Sea has changed from an oligotrophic clear-water sea into a eutrophic marine environment. Nitrogen and phosphorus are among the main growth limiting nutrients and as such do not pose any direct hazards to marine organisms. Eutrophication, however, is a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae which leads to imbalanced functioning of the system, such as:

- intense algal growth: excess of filamentous algae and phytoplankton blooms;
- production of excess organic matter;
- increase in oxygen consumption;
- oxygen depletion with recurrent internal loading of nutrients; and
- death of benthic organisms, including fish.

Excessive nitrogen and phosphorus loads coming from land-based sources are the main cause of the eutrophication of the Baltic Sea. About 75% of the nitrogen load and at least 95% of the phosphorus load enter the Baltic Sea via rivers or as direct waterborne discharges. About 25% of the nitrogen load comes as atmospheric deposition.

Goals and ecological objectives for eutrophication

The HELCOM goal related to eutrophication is to have the *Baltic Sea unaffected by eutrophication.* That goal is described by five ecological objectives:

A. Concentrations of nutrients close to natural levels

B. Clear water

C. Natural level of algal blooms

D. Natural distribution and occurrence of plants and animals

E. Natural oxygen levels

In order for the ecological objectives to be operational, indicators need to be identified. The indicators shall have set targets which, when reached, reflect a good ecological status.

The agreed objectives will be measured by the indicators presented below.

- Winter surface concentrations of nutrients reflecting objective A
- Summer Secchi depth reflecting objective B
- Chlorophyll *a* concentrations reflecting objective C
- Depth range of submerged vegetation reflecting objective D
- Area and length of seasonal oxygen depletion reflecting objective E

The clarity of seawater integrates many of the concrete effects of eutrophication and has been chosen as the primary ecological objective with summertime (June-September) Secchi Depth as indicator. The other indicators can be regarded as supportive indicators to give additional information on whether good ecological status has been achieved.

Proposed actions to reach targets

HELCOM assessments clearly show that problems with eutrophication persist in most of the sub-basins and that good environmental status has not been reached. Activities to identify further cost-effective nutrient reduction measures for the Baltic Sea Action Plan in the different sectors and parts of the Baltic Sea catchment area are ongoing.

At the moment HELCOM is working to assess the environmental impacts of various policies in the Baltic Sea region: the results of a number of policy scenarios produced by the MARE project are compared with HELCOM target levels for environmental indicators. The results will show how far existing EU legislation and programmes, as well as HELCOM recommendations, will bring us towards reaching the targets for eutrophication and Good Environmental Status. Accurate policy scenarios are difficult to develop, but even if not perfect the scenarios will provide guidance on the extent to which further measures are needed. This work combines pollution load models with environmental effect models in order to predict the environmental effects of various policies.

The preliminary results of the MARE scenarios show that:

- implementation of efficient waste water treatment from municipalities;
- increased connectivity to sewers; and
- introduction of phosphorus free detergents

have a great potential to further decrease nutrient inputs, especially in the new EU countries (Estonia, Latvia, Lithuania and Poland), Russia and Belarus. The implementation of existing regulations will reduce the inputs substantially, but going beyond and speeding up the agreed programmes would further improve the situation.

Due to less progress in the field of agriculture and because it has been envisaged that agricultural production will grow following the EU enlargement, nutrient reduction efforts should also particularly address the impact of agriculture. The reduction of nutrients from agriculture can be achieved through a combination of different measures that have to be applied according to the specific characteristics of the region (i.e. soil and watershed retention). The scenarios show a substantial reduction in nitrogen and phosphorus if balanced strategies optimising nutrient use and minimising nutrient fluxes from agricultural systems, such as animal feeding, handling of manure and crop cultivation are applied. The scenarios also show that if the agricultural production is intensified throughout the Baltic Sea region without application of strict measures the inputs will increase substantially.

The assessments also show that atmospheric nitrogen deposition to the Baltic Sea, including nitrogen coming from sources outside the catchment of HELCOM countries, makes up a large proportion of nitrogen input to sea which should be addressed. According to the scenarios the depositions of nitrogen to the sea will not decrease even if existing targets for nitrogen in the UNECE Gothenburg protocol and the EU NEC Directive are reached

First of all, the Action Plan should encourage and enhance full enforcement of already existing legislation. However, after current legislation has been fully implemented additional nutrient reductions are necessary to bring the Baltic Sea to a good environmental status. It should be noted that the needed actions go partly beyond those to reach good status according to the Water Framework Directive as the restoration of the whole Baltic Sea, including offshore waters, requires more drastic measures than those within the 1 nm limit regulated by the EU WFD. The actions presented in the action plan are estimated to comply with the aims in the field of nutrient reduction of the proposed EU Marine Strategy Directive.

The starting point for all actions under the HELCOM Baltic Sea Action Plan is the aim for good environmental status in the marine Baltic Sea ecosystem. The Plan will include the required nutrient reductions to reach the target levels of the indicators for the ecological objectives at the following levels:

- country;
- sub-region;
- for the entire Baltic Sea.

Also reduction targets should be established by country/sub region to the extent possible for the different sectors, at least for agriculture.

Based on calculations of required reductions in nutrient inputs, to reach the target levels, the establishment of a reduction quota system is considered. In the envisioned quota system each Contracting Party (country) will have a nutrient quota (in tonnes of P and N), which it will be required to reduce from its annual nutrient inputs to the Baltic Sea by a fixed year. With the responsibilities transferred to country level each Contracting Party will have the flexibility to choose the measures needed to fulfil its reduction quota and include them to their national programmes/River Basin Management Plans.

One idea for the distribution of costs is the consideration of the establishment of a sort of a simple trading mechanism for the reduction quotas among the HELCOM countries (in the spirit of the Kyoto process for greenhouse gases).

The Action Plan should also seek to encourage elaboration of bilateral and/or multilateral projects and programs to reduce nutrient inputs using the most cost-efficient measures. The national reduction quotas could be diminished not only by national means but also by international means on a sub-regional basis.

Based on the results of the scenarios, cost-efficiency analysis and evaluations of gaps in existing requirements at HELCOM, national and international level, the *ad hoc* Task Force for the development of the Baltic Sea Action Plan is currently considering various possible actions to be further selected and developed for the Ministerial Meeting in November 2007 for the following sectors:

- Waste waters: municipalities, scattered settlements and single family homes
- Agriculture
- Industry
- Transboundary air- and waterborne pollution

The Contracting Parties are also considering the identification of so called Hot Spots on a plant by plant basis, e.g., concerning big animal farms for pigs and hens, which should be addressed as first priority.

Taking into account that diffuse nutrient sources have a central role in determining the future state of the Baltic Sea environment, HELCOM Contracting Parties which are also EU Member Sates will give joint input to the forthcoming “health check” of the EU CAP stating the importance to marine environment concerning the content of, e.g., pillar II on the rural development programmes, cross compliance and subsidies to the farmers as well as to influence the revision of the targets for nitrogen in the UNECE Gothenburg protocol and the EU NEC Directive.

BALTIC SEA UNAFFECTED BY EUTROPHICATION

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B. Clear water

C. Natural level of algal blooms

D. Natural distribution and occurrence of plants and animals

E. Natural oxygen levels

The following tables give a general overview how the ecological status of the Baltic Sea unaffected by eutrophication has been assessed in this document.

The status is categorised using flounder smileys.


indicates a good status or a positive trend


an unsatisfactory status or a negative trend while


is neutral or no trend

refers to big gaps in information

For indicators that show a positive response to nutrient enrichment and eutrophication, the boundary between good and moderate ecological status has been defined as a 50% deviation from reference conditions, following the principles of the OSPAR Comprehensive Procedure. The reference conditions presented in the tables 1-3 are still under discussion and to be defined by HELCOM EUTRO-PRO. This assessment procedure will be developed to meet the requirements of the EU Water Framework Directive and the proposed EU Marine Strategy Directive.

Clear water

Clarity of seawater integrates certain effects of eutrophication, such as quantities of planktonic algae. The dramatic decrease in water clarity during the 20th century has awakened much of the public concern about the Baltic Sea environment and caused profound changes in the Baltic littoral communities. For instance Bladder wrack (*Fucus vesiculosus*) and eelgrass (*Zostera marina*) have become less common along many shorelines.

One of the means to measure water clarity is Secchi depth. There exist Secchi depth measurements from the Baltic Sea from over a period of one hundred years. Therefore, water clarity has been chosen as the primary ecological objective. The target level for Secchi depth has been agreed to be at maximum a -25% deviation from defined reference levels. The reference, target and present levels for summertime Secchi depth in the open sea of the different sub-regions are presented in **Table 1**.

Table 1. Reference conditions, targets and present values of summertime (June-September) Secchi depth (meters). Present conditions without need of improvement to reach the target levels are indicated with coloured cells.

Sub-basin	**Secchi depth (June-September) [meters]**			**Status**
	Reference	**Target**	**Present**	
Bothnian Bay	**7.5**	**>5.6**	**5.8**	
Bothnian Sea	**9.0**	**>6.8**	**7.0**	
Gulf of Finland	**8.0**	**>6.0**	**4.1**	
Gulf of Riga	**6.0**	**>4.5**	**3.4**	
Kattegat	**10.5**	**>7.9**	**8.5**	
Baltic Proper	**10**	**>7.5**	**6.3**	

The waters in Bothnian Bay, Bothnian Sea and Kattegat respect the HELCOM target for water clarity.

Natural levels of algal blooms

Algal blooms, mainly in the northern Baltic and in the Baltic Proper in the form of cyanobacteria, have closed beaches and caused frequent public concern about the future suitability of the Baltic Sea as a site for recreation purposes. The occurrence and intensity of cyanobacterial blooms in the Baltic Sea have increased since the 1960 according to sediment samples. Ecosystem effects of these blooms are likely to be important; especially the nitrogen-fixing activity of cyanobacteria contributes to the nutrient budget.

Also other phytoplankton species have changed in their abundances due to the increased nutrient levels. This has generated a general excess in photosynthetic production which the ecosystem is not able to process. The excess material sinks to the seabed where natural bacterial consumption uses up available oxygen.

Plankton spring blooms, *late-summer cyanobacterial blooms*, and *amount of harmful species* are proposed to be considered as indicators in defining natural levels of algal blooms. However, as these indicators are presently under development the summertime concentration of chlorophyll a (pigment used by plants and algae to carry out photosynthesis) is presented here as a measure of algae production intensity in the sea.

Target levels for the different sub-regions have been defined for summertime chlorophyll concentrations. As a pragmatic approach, the maximum acceptable deviation from reference level should not exceed +50 %. The reference, target and present levels for summertime chlorophyll a surface water concentrations in the open sea of the different sub-regions are presented in **Table 2**.

Table 2. Reference conditions, targets and present values of summer chlorophyll a concentration. Present conditions without need of improvement to reach the target levels are indicated with coloured cells.

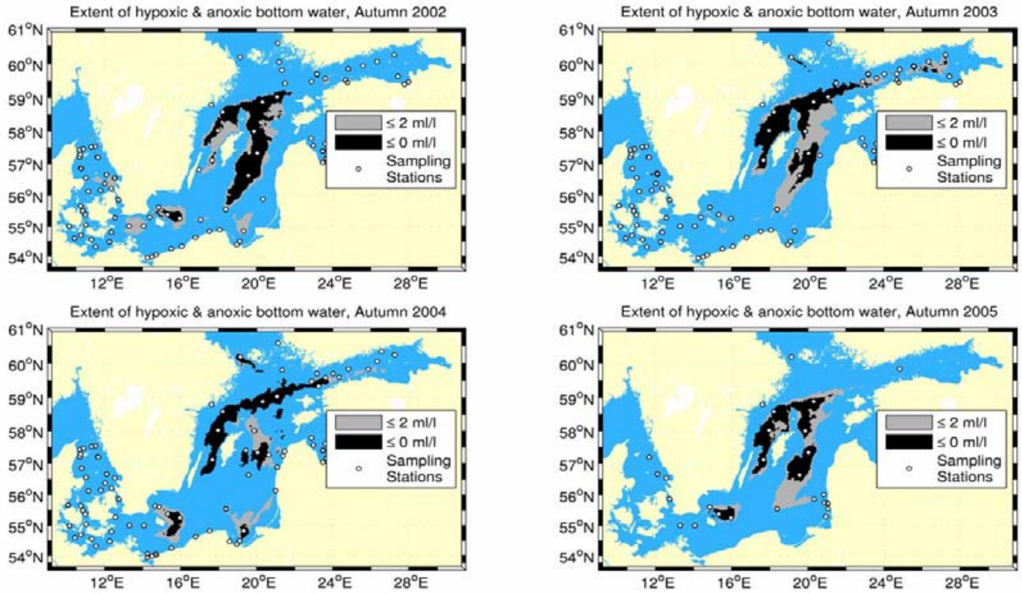
Sub-basin	**Chlorophyll-a (summer) [microgram/liter]**			**Status**
	Reference	**Target**	**Present**	
Bothnian Bay	**1.0**	**<1.5**	**1.8**	
Bothnian Sea	**1.0**	**<1.5**	**1.0**	
Gulf of Finland	**1.2**	**<1.8**	**4.9**	
Gulf of Riga	**1.1**	**<1.7**	**5.1**	
Kattegat	**1.3**	**<1.9**	**1.8**	
Baltic Proper	**1.0**	**<1.5**	**2.3**	

The waters in Kattegat and the Bothnian Sea respect the HELCOM targets for Natural levels of algal blooms.

Natural oxygen concentrations

Partly due to the increased input of organic matter the oxygen levels in most Baltic Sea deeper bottoms and also in the shallower coastal waters have decreased during the 20th century. This is evident as an increase in area covered with laminated sediments, indicating dead, lifeless bottoms. It should be noted that much of the observed changes in oxygen levels, especially in the deeper bottoms, are due to natural variation but the geological record in laminated sediments seem to indicate that present oxygen levels are below the range of natural variability. Anoxic conditions kill animals and plants directly but it also causes self-reinforcing of eutrophication by internal loading of especially phosphorus. During anoxia, organic matter, nutrients and also hazardous substances bound to sediments are released back to the water column causing intensified internal loading and circulation of toxic material.

Bottom water oxygen concentrations can, to some extent, be modelled and presented as area of bottoms with low oxygen levels (oxygen concentration <2 ml/l), anoxic bottoms (oxygen concentration 0 ml/l) or as occurrence of Hydrogen sulphide (H2S) in bottom water during autumn (exact month depending on latitude). *Bottom water oxygen* is proposed to be considered as an indicator for natural levels of natural oxygen concentrations (details to be determined). Target levels for the different sub-regions have to be defined separately.


Extent of hypoxic & anoxic bottom water, Autumn 2002

Extent of hypoxic & anoxic bottom water, Autumn 2003

Extent of hypoxic & anoxic bottom water, Autumn 2004

Extent of hypoxic & anoxic bottom water, Autumn 2005

Figure 1. *Estimates of the extent of hypoxic (oxygen content less than 2 ml/l) and anoxic (oxygen content nil; often with presence of hydrogen sulphide) in Autumn 2002 - 2005.*

In the western Baltic Proper, Danish Straits and Kattegat oxygen depletion is a seasonal phenomenon which occurs during autumn. The deepwater basins in the Baltic Proper however suffer severely from long-term oxygen depletion. The region least affected is the Gulf of Bothnia, where there is weak stratification and relatively little biological activity. The East Gotland Basin was the worst affected by hypoxia/anoxia, with between almost 40% of the total basin volume suffering reduced oxygen levels, and almost 30% having acute toxicity between 1998 and 2001. Anoxia affects almost 30% of the Northern Baltic Proper, and 5% of both the West Gotland Basin and the Gulf of Finland.

Natural levels of nutrients

Concentrations of nutrients in the Baltic Sea have increased in most sub-basins during the last century deviating today markedly from the natural levels. The nutrient concentrations are strongly affected by seasonality. During winter nitrogen and phosphorus concentrations are peaking as a result of remineralisation, vertical mixing of the water column and lack of phytoplankton activity. In spring phytoplankton bind the dissolved nutrients in the surface waters. In summer surplus of phosphorus promotes the blooms of nitrogen fixing cyanobacteria, also called blue-green algae. Internal loading from sediments and bacterial denitrification affects the cycles of phosphors and nitrogen, respectively.

Concentrations of nutrients in winter give the fuel for subsequent phytoplankton spring bloom and phosphorus to nitrogen ratio reflects to the cyanobacterial blooms. Therefore *dissolved nutrient concentrations during the winter time* as well as *N:P ratio* are proposed to be considered as suitable indicators for nutrients. Target values for different sub-regions have been defined for wintertime surface water nitrogen and phosphorus concentrations (50 % maximum acceptable deviation from reference level). The reference, target and present levels for wintertime surface water nitrogen and phosphorus concentrations in the open sea of the different sub-regions are presented in **Table 3**.

Table 3. Reference conditions, targets and present values of winter nitrogen (nitrite+nitrate in µM) and phosphorus (dissolved inorganic phoshorus, DIP in µM). Present conditions without need of improvement to reach the target levels are indicated with coloured cells.

Sub-basin	Nitrogen (winter surface nitrite+nitrate) [micromol/Litre]				Phoshorus (winter surface DIP) [micromol/Litre]			
	Reference	Target	Present	Status	Reference	Target	Present	Status
Bothnian Bay	**3.5**	**<5.3**	7.1	☹	**0.10**	**<0.15**	**0.04**	☺
Bothnian Sea	**2.0**	**<3.0**	**2.7**	☺	**0.20**	**<0.30**	**0.17**	☺
Gulf of Finland	**2.5**	**<3.8**	8.8	☹	**0.30**	**<0.45**	0.90	☹
Gulf of Riga	**4.0**	**<6.0**	11.2	☹	**0.13**	**<0.20**	0.85	☹
Kattegat	**4.5***	**<6.8***	8.3*	☹	**0.40**	**<0.60**	**0.59**	☺
Baltic Proper	**1.9**	**<2.9**	3.0	☹	**0.25**	**<0.38**	0.52	☹

The waters in the Bothnian Sea respect the HELCOM targets for both nitrogen and phosphorus concentration and the waters in Bothnian Bay and Kattegat respect the HELCOM targets for phosphorus.

Distribution of plants and animals

Many of the Baltic Sea communities, such as littoral perennial species, coastal fish stocks and zooplankton communities have experienced radical changes during the 20th century due to eutrophication.

Soft-sediment macrobenthic communities are central elements of Baltic Sea ecosystems and provide excellent indicators of environmental health. Most macrobenthic animals are relatively long lived (several years) and thus integrate changes and fluctuations in the environment over a longer period of time. Variations in species composition, abundance and biomass can be used to assess environmental disturbance.

Community structure of zoobenthos is proposed to be considered as an indicator for natural levels of distribution of animal and plants (details to be determined). Target values for the different sub-regions have to be defined separately.

PRESENT INPUTS OF NUTRIENTS TO THE BALTIC SEA

HELCOM monitoring programmes provide regular information on the water- and airborne inputs and sources of nutrients to the Baltic Sea and their trends.

Overview of nutrient inputs

Nutrients enter the Baltic Sea via rivers, through atmospheric deposition and in direct discharges from pollution sources located along the coastline. The riverine discharges originate both from point sources, such as industrial or municipal wastewater plants, and from diffuse sources, such as agriculture, scattered dwellings and atmospheric deposition within river basins. Natural background sources refer mainly to natural erosion and leakage from unmanaged areas that would occur irrespective of human activities (**Figure 2**).

Another cause for increased nutrient levels in the sea, especially in the case of phosphorus, is the “internal load”: Phosphorus reserves accumulated in the sediments of the sea bed are released back to the water under anoxic conditions. Neither this internal load, nor the amount of nitrogen fixed by cyanobacteria or blue-green algae, is considered in the overview of total loads to the Baltic Sea.

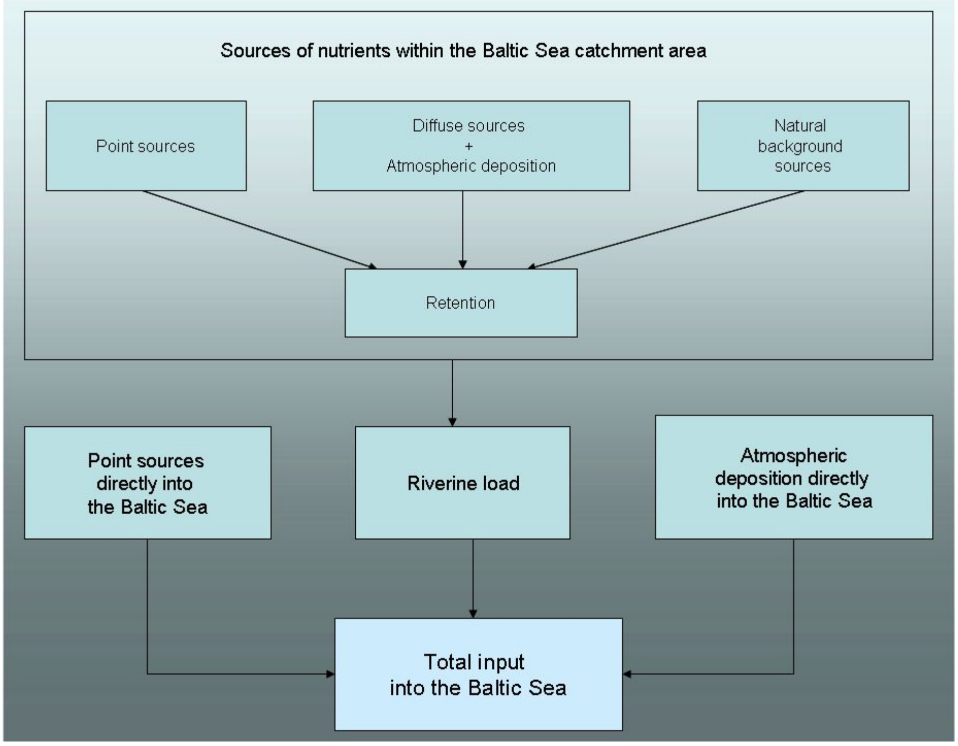


***Figure** 2. Sources of nutrients within the Baltic Sea catchment area.*

In 2000 the total inputs amounted to 1 009 700 tonnes of nitrogen and 34 500 tonnes of phosphorus (HELCOM 2004). About 75 % of the nitrogen entered the Baltic Sea as waterborne input and the rest as atmospheric deposition. Phosphorus enters to the Baltic Sea mainly as waterborne input. It is estimated that the airborne contribution is only 1-5 % of the total phosphorus input. An updated assessment on the inputs and sources will be made for 2006 (PLC-5).

Waterborne nutrient inputs

Diffuse losses (mainly from agriculture, forestry and scattered dwellings) contribute 58 % of the waterborne nitrogen and 49 % of phosphorus inputs to the Baltic Sea. Atmospheric deposition on inland waters is also a significant source of nitrogen. About 10 % of nitrogen and 25 % of phosphorus originates from point-sources (municipalities and industry). The proportions of natural background losses were 32 % of nitrogen and 26 % of phosphorus (**Figures 3** and **4**). **Figures 5** and **6** show the riverine loads of nitrogen and phosphorus to the Baltic Sea by a Contracting State.

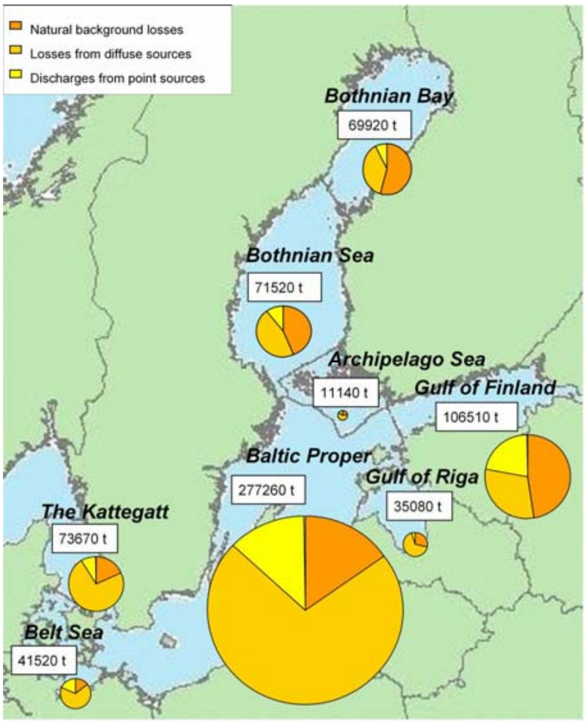


Figure 3. *Proportion of sources contributing to waterborne nitrogen input into the Baltic Sea sub-regions in 2000*[1] *(HELCOM 2004).*

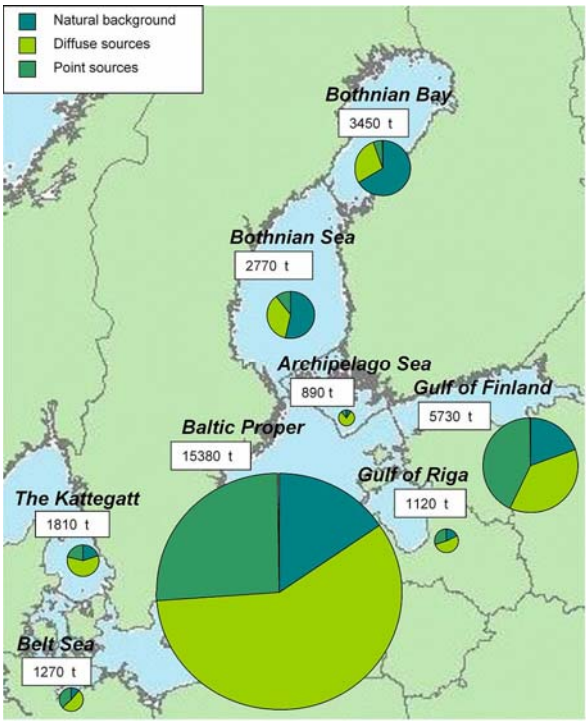


Figure 4. *Proportion of sources contributing to phosphorus inputs into the Baltic Sea sub-regions in 2000*[1] *(HELCOM 2004).*

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[1] The proportions of the different sources are based on available data from Contracting Parties, e.g. Russian data is incomplete and inputs from Latvia and Lithuania do not include transboundary pollution.

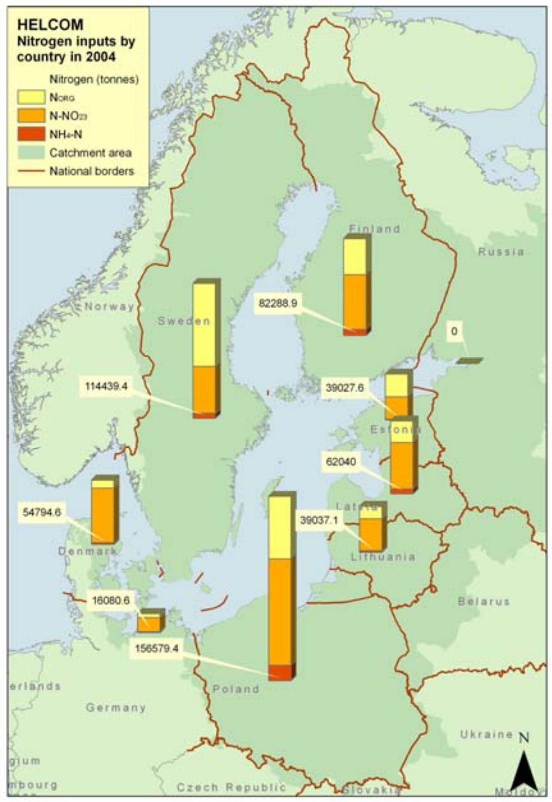


Figure 5. *Riverine load of nitrogen (in tonnes) to the Baltic Sea by HELCOM Country in year 2004 (HELCOM PLC-Group 2006). (No info available from Russia. Data from Latvia to be checked).*

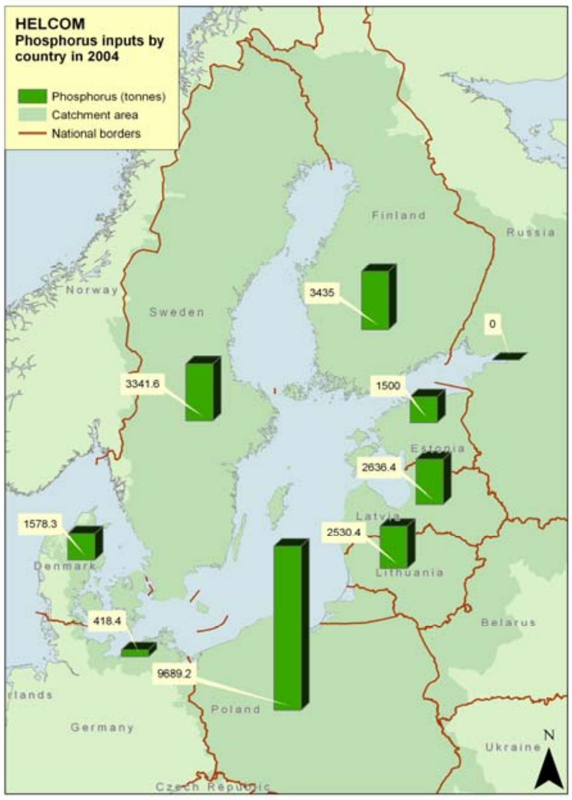
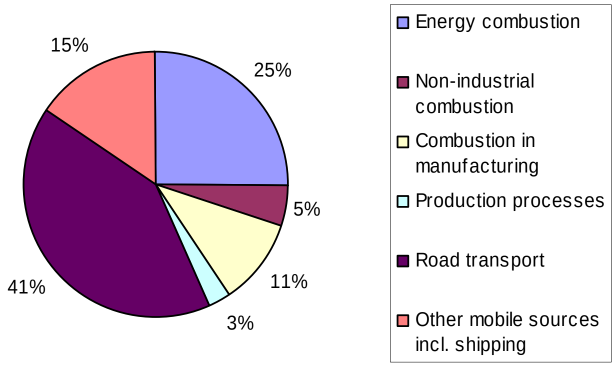


Figure 6. *Riverine load of phosphorus (in tonnes) to the Baltic Sea by HELCOM Country in year 2004 (HELCOM PLC-Group 2006). (No info available from Russia. Data from Latvia to be checked).*

Airborne nutrient inputs

Airborne nitrogen contributes significantly to the input of nutrients to the Baltic Sea: from the total nitrogen input to the Baltic around a quarter comes as atmospheric deposition. The estimated airborne contribution of phosphorus is only 1-5 % of the total phosphorus input.

Nitrogen compounds are emitted into the atmosphere as nitrogen oxides and ammonia. Road transportation, energy combustion and shipping are the main sources of nitrogen oxide emissions in the Baltic Sea region (**Figure 7**).



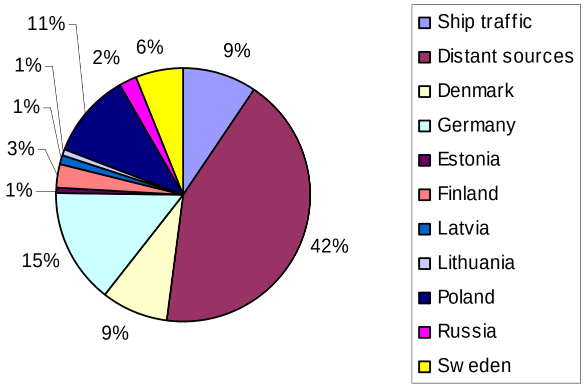


Figure 7. *Percentage of total emissions of nitrogen oxides (NOx) from different sectors in the HELCOM Contracting States (EMEP 2005).*

Figure 8. *Proportion of atmospheric deposition of nitrogen entering the Baltic Sea basin in 2003. The diagram shows that over 40 % of the total nitrogen input originates from sources outside the HELCOM Contracting area (EMEP 2005).*

In the case of ammonia, roughly 90 % of the emissions originate from agriculture. Agriculture is the most significant contributor of total airborne nitrogen, accounting for 43 % of the total air emissions of nitrogen from the HELCOM Contracting Parties. Consequently, the need to reduce emissions and discharges from agriculture has become increasingly important as this sector is also responsible for the majority of the waterborne nitrogen discharges into the Baltic Sea. Distant sources outside the Baltic Sea catchment area account for more than 40 % of the total airborne deposition of nitrogen (**Figure 8**).

ACHIEVED INPUT REDUCTIONS

HELCOM requirements in the Convention and Recommendations as well as international regulations, including EU and national legislation have resulted in stricter controls on industry, municipalities as well as diffuse sources such as agriculture.

Achieved reductions in waterborne discharges and input

The riverine load varies a lot from year to year mainly depending on the hydrological conditions. The overall reductions in waterborne discharges for both phosphorus and nitrogen in the Baltic Sea catchment area has been roughly 40 % in total since the late 1980's. The reduced discharges within the catchment have not yet resulted in a clear reduced trend in the riverine input to the Baltic Sea due to the timelag caused by nutrient retention in inland waters (HELCOM 25/2004, HELCOM PLC-Group 2005).

Point sources

The progress in reducing waterborne nutrient discharges from point sources such as municipal and industrial wastewater treatment plants has been good, with the 50 % reduction target for phosphorus achieved by almost all the HELCOM Countries already in 2000 (HELCOM 2004). Some 20 HELCOM Recommendations have been elaborated to reduce discharges from industrial plants. The Recommendations concerning new or reconstructed industrial plants are implemented by all of the Contracting States. A lot of activity in construction and modernisation of municipal waste water treatment plants has improved the implementation situation of the HELCOM Recommendations in this field in all Contracting States. Especially the new EU Member Countries have in recent years undertaken extensive modernisation plans for both municipal wastewater treatment plants and industries. Also the construction of new treatment plant in St. Petersburg is an encouraging step forward. There are still some problems to comply especially with the nitrogen limit values in some Contracting States.

Diffuse sources

The diffuse nutrient runoff consists mostly of discharges from agriculture, scattered settlements and forestry. It is difficult to separate these sources, but especially for phosphorus both the runoff from agriculture and scattered settlements are important. Reducing nutrient losses from these sources is much more complicated than curbing loads from point sources due to technical and socio-economic obstacles.

Annex III of the Convention regarding agriculture and requirements in Recommendation 24/3 have been implemented almost fully by the old EU Countries according to an assessment made for year 2000 (Percy-Smith et. al. 2003). Some of the requirements are implemented by the new EU Countries and Russia, and have been transposed into national legislation. However, the practical implementation of the required measures at farm level is very difficult to assess and has not so far resulted in significant reductions in losses from farmlands. There is, however, a considerable long time-lag before the effects of measures can be seen due, for instance, to the high usage of fertilisers in the 1970s and 1980s in many countries which have resulted in a long-term surplus of nutrients in the soil.

For scattered settlements there are only few specific regulations either in HELCOM or EU, but in some Contracting States national legislation has been recently adopted as the share of phosphorus discharges from scattered settlements is assessed to be higher compared to municipalities

Achieved reductions in airborne emissions and deposition

Since 1980 there has been a reduction of approximately 40 % in the levels of total nitrogen emissions to the air from the HELCOM Contracting Parties (HELCOM 2004, EMEP 2005). On the other hand, deposition levels have only declined roughly by 15 % during the same time period. This is partly due to the fact that the deposition of nitrogen into the Baltic Sea is highly dependent on meteorological conditions, which change from year to year (**Figure 9**). As a result, reductions in nitrogen emissions in the Baltic Sea region, and even elsewhere, do not necessarily lead to corresponding reductions in observed depositions to the Baltic Sea.

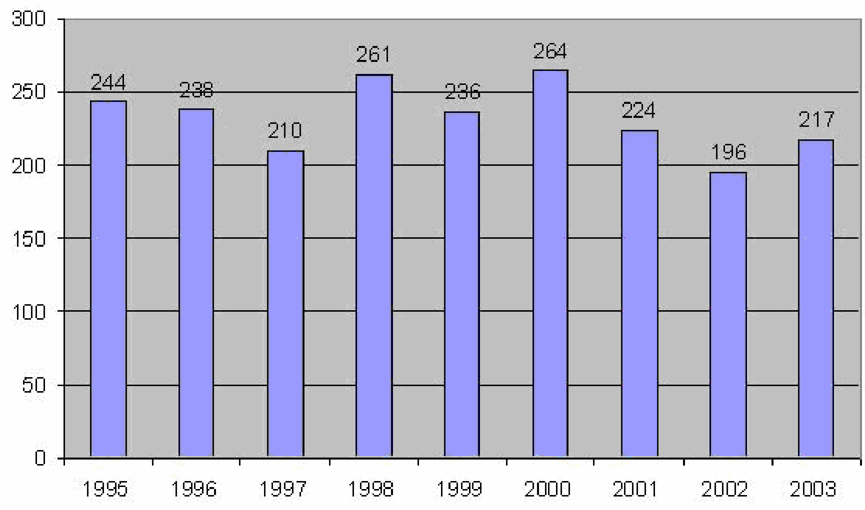


***Figure 9.** Atmospheric deposition of total (oxidised and reduced) nitrogen to six sub-basins of the Baltic Sea for the period 1995-2003. Units: kilotonnes N/year (Bartnicki 2005).*

Land-based air emissions are also quite well regulated at all levels and programmes for the reduction of emissions from the different sectors have been adopted in EU and the United Nations Economic Commission for Europe (UNECE). The Gothenburg protocol under the Framework Convention on Long-Range Transboundary Air Pollution (CLRTAP) of UNECE and the Directive 2001/81/EC of the European Parliament and of the Council on National Emission Ceilings for certain pollutants (NECs) are among the most important regulatory instruments at European level to reduce airborne pollutants. Taking into account that almost half of the nitrogen deposition on the Baltic Sea originates from outside the catchment these instruments are important when evaluating possible further developments and the adequacy of measures taken to reduce airborne nitrogen pollution.

The shipping sector is not regulated as extensively as land-based sources. Due to the lack of regulations and the increased maritime transport activity the emissions from shipping have not decreased.

FUTURE INPUT PROJECTIONS BASED ON PRESENT MANAGEMENT REGIME

Waterborne inputs

Further reductions in nutrient discharges from point sources are likely in some HELCOM Countries, thanks to the continued implementation of nitrogen and phosphorus removal measures required by HELCOM Recommendations, the EU Industrial Pollution and Prevention Control Directive, the EU Urban Waste Water Directive and supplementary national regulations. However, although the significance of point source pollution for the Baltic Sea as a whole is decreasing, the effects of pollution from industries and municipalities can still be observed, especially locally.

Also for agriculture it can be foreseen that the implementation of load reduction measures (e.g., Annex III of the Helsinki Convention, the EU Nitrate Directive and the Water Framework Directive) will support further reductions in nutrient inputs from agriculture. However, the possible intensification of agricultural activities in the new EU Countries and Russia might without further measures lead to an increase of nutrient inputs to the Baltic Sea.

Airborne inputs

Although reductions for nitrogen oxides have been achieved by 2003, the emission ceilings of the Gothenburg protocol to the UN/ECE CLRTAP and the EU NEC Directive for 2010 may be difficult to achieve for some of the Contracting States. This is mostly due to difficulties in decreasing traffic emissions. Other Contracting States have already reached the required emission levels.

HELCOM assessments also show that the total nitrogen depositions on the Baltic Sea will be higher in 2010 as in 2003 even with the fulfilment of the targets for nitrogen in the Gothenburg protocol to the UN/ECE Convention on Long-range Transboundary Air Pollution and the EU NEC Directive. The increase is mostly due to predicted increase in agricultural activities and shipping. The share of airborne nitrogen deposition originating from agriculture is, according to the scenarios, increasing due to expected growth in agricultural production.

Recent estimates (EEB, 2004) show that nitrogen oxides emissions from the international shipping traffic on the European seas increased by more than 28 % between 1990 and 2000. The emissions of NO_x from international shipping are expected to increase by two-thirds by the year 2020 even after the implementation of MARPOL Annex VI concerning air pollution by ships. According to this estimate, by 2020 emissions from international shipping throughout Europe will surpass emissions from all land-based sources in the 25 EU member states combined (Entec 2002).[2]

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[2] More information about maritime activities is available in the Thematic assessment on maritime activities.

REDUCTION SCENARIOS FOR FURTHER ACTIONS

HELCOM assessments clearly show that problems with eutrophication persist in most of the sub-basins and good environmental status has not been reached. Actions to identify further cost-effective nutrient reduction measures for the Baltic Sea Action Plan in the different sectors and parts of the Baltic Sea catchment area are ongoing.

At the moment HELCOM is working to assess the environmental impacts of various policies in the Baltic Sea region: the results of a number of policy scenarios are contrasted with HELCOM target levels for environmental indicators (chapter 1). The results will show how far existing EU legislation and programmes, and HELCOM recommendations, will bring us towards reaching the targets for eutrophication and Good Environmental Status. Accurate policy scenarios are difficult to develop but even if not perfect the scenarios will provide guidance to what extent further measures are needed. This work combines pollution load models with environmental effect models to be able to predict the environmental effects of various policies. The timelag between applied measures and observed environmental effects is an important aspect which has not been fully considered at this stage.

In addition HELCOM is carrying out an economic analysis on the costs of the scenarios for different sectors to reach the required reductions by country, sub-region and for the entire Baltic Sea. Based on this HELCOM is identifying most cost-effective solutions for further actions to be applied inside, and also outside the Baltic Sea catchment area to improve the status of the Baltic environment.

This section includes initial scenarios on the policy impacts using one specific model (MARE-NEST). The model results for the environmental parameters are average values of offshore waters in main basins. The model does not take explicitly into account coastal waters or exchange of waters between the offshore, and coastal waters. It also has to be borne in mind that results from all models of this kind are very much dependent on the quality and accuracy of the input data. The nutrient load data used in the model calculations is compiled from official data supplied to HELCOM, describing average annual loads for the period 1997-2003. The modelled scenarios also take into account that nutrients originate from countries that are not directly bordering the sea but are within the drainage basin, i.e. Belarus, the Czech Republic and Norway. Ukraine has also a part within the drainage basin but is not considered yet, due to lack of data.

The following scenarios assessed by the MARE project (http://www.mare.su.se/index.html) are presented:

- Improved sewage treatment scenario;
- Phosphorus free detergent scenario;
- Two agricultural scenarios:
    - Intensive agriculture in the whole Baltic Sea region;
    - Best possible practices;
- Combinations of the above scenarios.

Scenario 1: Improved sewage treatment

The levels of treatment describing the % of people connected to different sewage treatment in 2004, compiled from official EUROSTAT statistics and input from Contracting Parties and non-Contracting Parties, were used in the calculations (**Table 4**).

Table 4. Levels of sewage treatment in 2004 according to EUROSTAT and input from Contracting Parties (wwt refers to waste water treatment).

% Population connected to	BY	CZ	DE	DK	EE	FI	LIT	LAT	N	PO	RU	SE
Primary wwt	0	0	0	2	2.2	0	33	1.8	0	2.2	0	0
Secondary wwt	50	61	9	5.2	34.4	0	6	35.1	5.8	23.3	50	5.8
Tertiary wwt	0	0	85	81.4	33.6	80	18	33.1	85.8	33.5	0	85.8

The MARE improved sewage treatment scenario assumes that all countries will have sewage treatment as in Sweden 2004 (85.8% population with tertiary, and 5.8% population with secondary treatment). The exceptions are Sweden, Denmark, Finland, Norway and Germany where no changes are expected compared to 2004 levels.

This scenario reduces the overall nitrogen load by 5% and phosphorus loads by 33%. No reductions occur in the Bothnian Bay or Sea, the Danish Straits or Kattegat since direct loads to these basins originate only from the Nordic countries and Germany (Danish Straits). The largest reduction of both P and N load with improved sewage treatment comes from Poland (43%), followed by Russia (31%) and Belarus (16%).

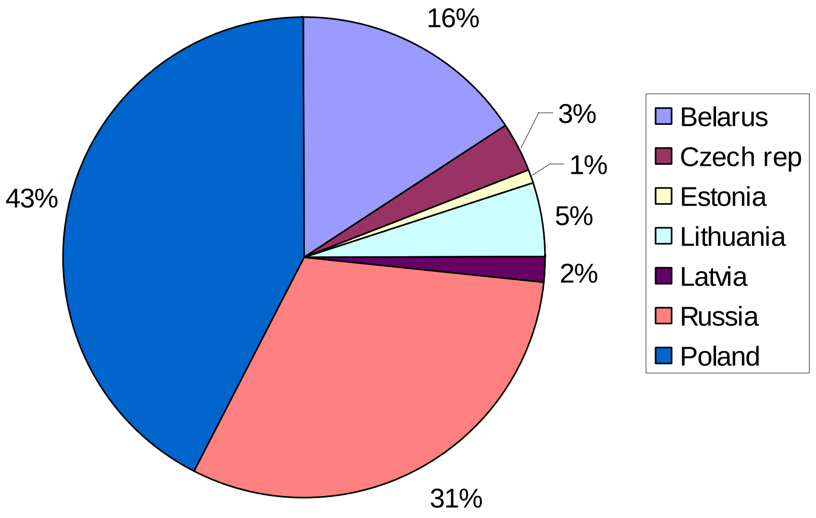

Figure 10. *The contribution by country to the total load reduction of nitrogen and phosphorus, if modern sewage treatment was implemented in these countries*.

The *load reductions per capita* of this scenario vary greatly between the countries. The differences are related to nutrient retentions in the drainage basins and to differences between contemporary and projected degree of sewage treatment for the populations of the different countries. Poland is below the average for per capita load reduction potential while Russia and Belarus have the largest potential for load reductions per capita. However, as

Poland has a large population with almost half of the total population of the Baltic Sea drainage basin (Hannerz & Destouni, 2006), Polish inputs are of central importance.

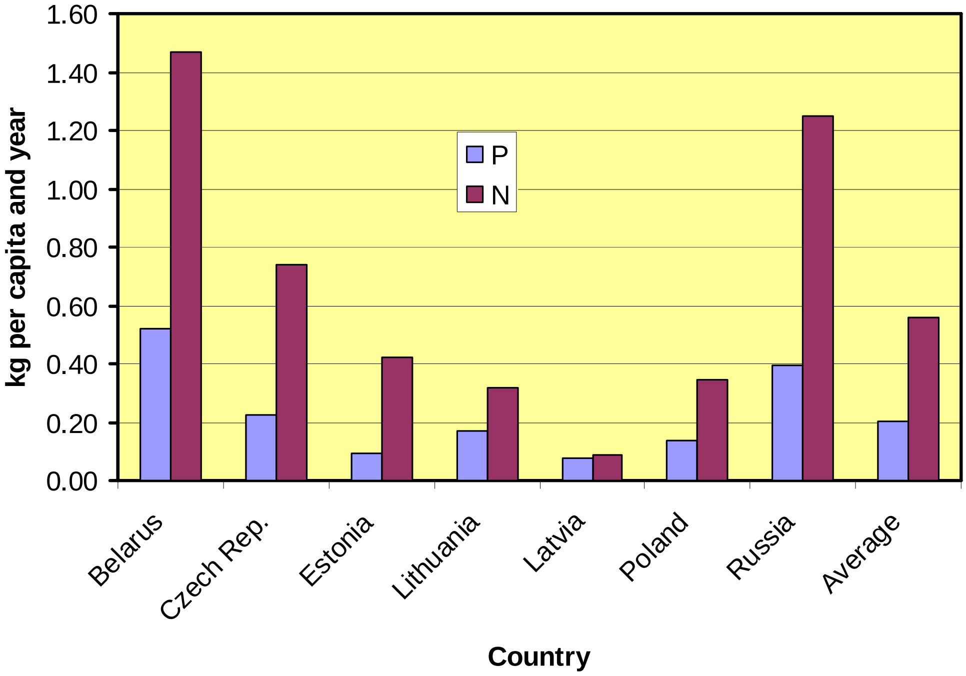

Figure 11. *The contributions by capita and country to the load reduction of N and P, if modern sewage treatment was implemented in these countries.*

The reductions of N and P loads with more efficient municipal sewage treatment in all countries give the effects shown in **Table 5** on the marine ecosystem, expressed in % of initial (2004) conditions. The results are presented as steady states, disregarding natural interannual variations. Thus, as a ‘rule of thumb’, changes within ± 10% would not be detected in field observations and be considered significant.

Table 5. Effects of the improved sewage treatment scenario (% change from initial conditions).

Basin	Load reductions (tons)		Nutrient concentrations,		Secchi depth	Primary production	Nitrogen fixation	Hypoxic area
	N	P	N	P				
Bothnian Bay	0%	0%	5%	0%	5%	-11%		
Bothnian Sea	0%	0%	4%	-20%	25%	-33%	-100%	
Baltic Proper	-6%	-40%	-3%	-25%	17%	-22%	-53%	-26%
Gulf of Finland	-11%	-49%	-4%	-38%	36%	-43%	-96%	
Gulf of Riga	-4%	-49%	5%	-36%	37%	-40%	-100%	
Danish Straits	0%	0%	-2%	-25%	17%	-12%		
Kattegat	0%	0%	-1%	-14%	1%	-5%		

Summary

Improved wastewater treatment scenario

If all countries in the Baltic Sea drainage basin would improve their sewage treatment to Swedish 2004 levels (85.8% population with tertiary, and 5.8% population with secondary treatment), with the exceptions of Sweden, Denmark, Finland, Norway and Germany where no changes are expected, it would result in:

- This scenario reduces the overall nitrogen load by 5% and phosphorus loads by 33%, which is approximately 34 300 tonnes of nitrogen and 12 400 tonnes of phosphorus
- All basins are affected, even those where there are no direct reduction of loads from the surrounding drainage basins, because the advective inflows from other basins are reduced.
- Atmospheric dinitrogen fixation, which can be considered as a proxy for the intensity of cyanobacterial blooms, are virtually eliminated in all the basins, except in the Baltic proper.
- The blooms in the Baltic proper will be halved and the extension of hypoxic areas will be reduced with 26% from 42,000 km^2, but the effect on water transparency will be limited (+17%).
- Changes in the Gulf of Finland and Riga will be more pronounced, in addition to the elimination of cyanobacterial blooms, with improved water transparency and reduced primary productivity. The Gulf of Riga will switch from being limited by N to P, which is also reflected in an increase in concentrations of unutilized N.
- The smallest effects are seen in the northernmost Bothnian Bay. The conditions in the nitrogen limited Danish Straits and Kattegat are not affected significantly since this scenario primary reduce P loads.
- Overall the largest effects can be seen in the Baltic proper and in the Gulf of Finland and Riga.

Scenario 2: Phosphorus free detergents

Phosphorus contributions from the use of phosphates in detergents are largely dependent on use patterns, marketing conditions and the adoption on specific conditions on the use of phosphates in detergents either through regulatory or voluntary agreements. It is likely that these numbers will vary between countries. Considering the great uncertainty and range in these estimates, two scenarios were chosen, where P emissions are reduced by 0.6 and by 0.2 kg per person and year, respectively in order to cover maximum and minimum effects, due to a ban of detergents containing P. The total P load reductions to the different basins are shown in the Annex to this document, Table 5.

The overall reduction of phosphorus loads would range from about 3,000 to 9,000 tons, from the lower to the higher estimate of phosphorus content in detergents.

The effects on the marine ecosystem, if P detergents contain 0.2 kg P person^{-1} yr^{-1}, would be very limited and not detectable in the sea, except that cyanobacterial blooms would be reduced in the Gulf of Riga and in the Gulf of Finland. The reduction in the Bothnian Sea (-70%) would be from an already very low level. The effects on the marine ecosystem if P detergents contain 0.6 kg P person^{-1} yr^{-1} are more substantial. The results are shown in the box and in detail in the Annex to this document, Table 6.

Summary: Scenario with P-free detergents (maximum effect)

If use of Phosphorus detergents would stop completely and assuming that this would reduce inputs with 0.6kg P person^{-1} yr^{-1}, it would result in:

- 24 % total reduction of phosphorus inputs to the Baltic Sea, which is approximately 9000 tonnes.
- Substantial reduction in primary production and cyanobacterial blooms in the Bothnian Sea, and in the Gulfs of Finland and Riga.
- For the Baltic proper there will be on a reduction in the extension of hypoxic bottoms and a substantial reduction in cyanobacterial blooms but the decrease in productivity is less pronounced than in the Gulfs.
- Any effects on environmental quality in the Danish straits and Kattegat will not be seen in these nitrogen limited basins.

Scenario 3: Improved sewage treatment *and* P free detergents

In this scenario the effect of improving sewage treatments are combined with the use of P-free detergents (assuming that this means a reduction of 0.6 kg P person^{-1} yr^{-1}).

The combined effect gives a total phosphorus load reduction which is less than the sum of each measure. This is because most people are now already connected to sewage treatment with highly efficient phosphorus removal in this scenario. The effects on the marine ecosystem are shown in the Annex to this document, Tables 10 and 11.

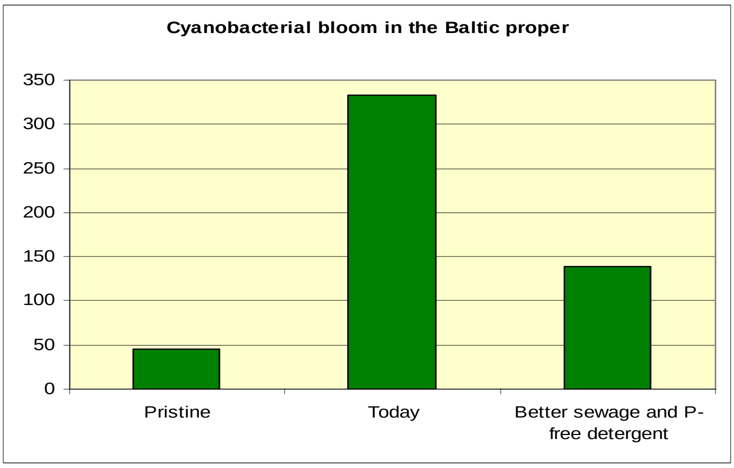

Figure 12. Effects of the combined scenario on cyanobacterial blooms in the Baltic Proper.

Summary: Combined scenario with improved sewage treatment and Phosphorus free detergents

If use of Phosphorus detergents would stop completely (assuming that this would reduce inputs with 0.6kg P person^{-1} yr^{-1})

AND

if all countries in the Baltic Sea drainage basin would improve their municipal sewage treatment to Swedish 2004 levels, with the exceptions of Sweden, Denmark, Finland, Norway and Germany where no changes are expected, it would result in:

- 41 % reduction of phosphorus and 5 % reduction of nitrogen inputs to the Baltic Sea which is approximately 34300 tonnes of nitrogen and 15500 tonnes of phosphorus.
- Primary production will be halved in the Gulf of Riga and Finland, and with a quarter in the Baltic proper compared to year 2004. Detectable reductions would be seen in the Bothnian Sean and Baltic proper as well.
- The extension of hypoxic bottom areas will be reduced by 30%.
- Improved water transparency (Secchi depth) will be detected in all basins except in the Bothnian Bay and Kattegat.

Scenario 4: Business as usual in Agriculture

During the last century, agricultural practices have change dramatically. New technologies, crops, animal breeding and, particularly, the introduction of artificial fertilizers, have increased productivity enormously. At the same time, consumer preferences have changed dramatically towards a large proportion of meat in human consumption. These changes have been most pronounced in the western countries but similar changes are now occurring in the new EU member states, as well as in Russia and Belarus. Higher living standards and EU agricultural subsidies are driving this development.

In this scenario it is assumed that all countries around the Baltic will develop their agriculture to the same state as in Denmark, the country that is leading in terms of agricultural development. More specifically, according to this scenario each country will have the same number of milk cow and other cattle's, sows and slaughter pigs per agricultural areas as in Denmark. Moreover, the productivity, in term of meat and milk per animal will increase to Danish levels, which also means that nutrient excretion per unit animal will increase.

In this 'pessimistic' scenario we will also assume that sewage treatment will remain at the 2004 levels and no further restriction in the use of P in detergents will be implemented.

This scenario results in a massive increase in loads; doubled phosphorus inputs to the Baltic proper and a 70% increase in nitrogen loads, with even higher relative increases for the Gulf of Riga. The contributions of additional nutrient loads for each country are dependent on the differences between the current states of animal productivity in agriculture and that of Denmark, and of the total area of agricultural land in each country's drainage basin to the Baltic.

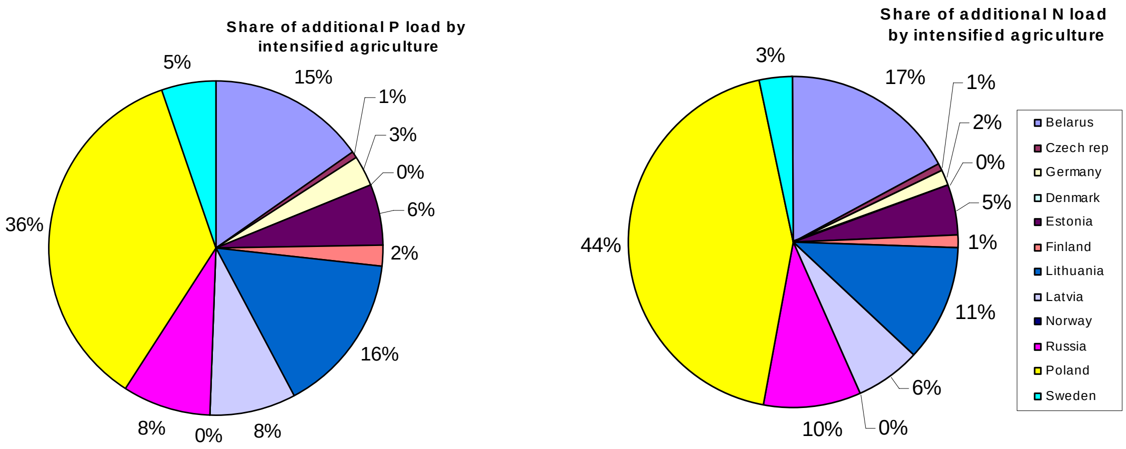

Figure 13. *The % contribution by country to increased nutrient loads if all counties intensified agriculture to Danish levels.*

Increased input of nutrients by country, expressed as tons yr^{-1} to each basin, caused by intensified agriculture for P and N are presented in Annex to this document, Table 14.

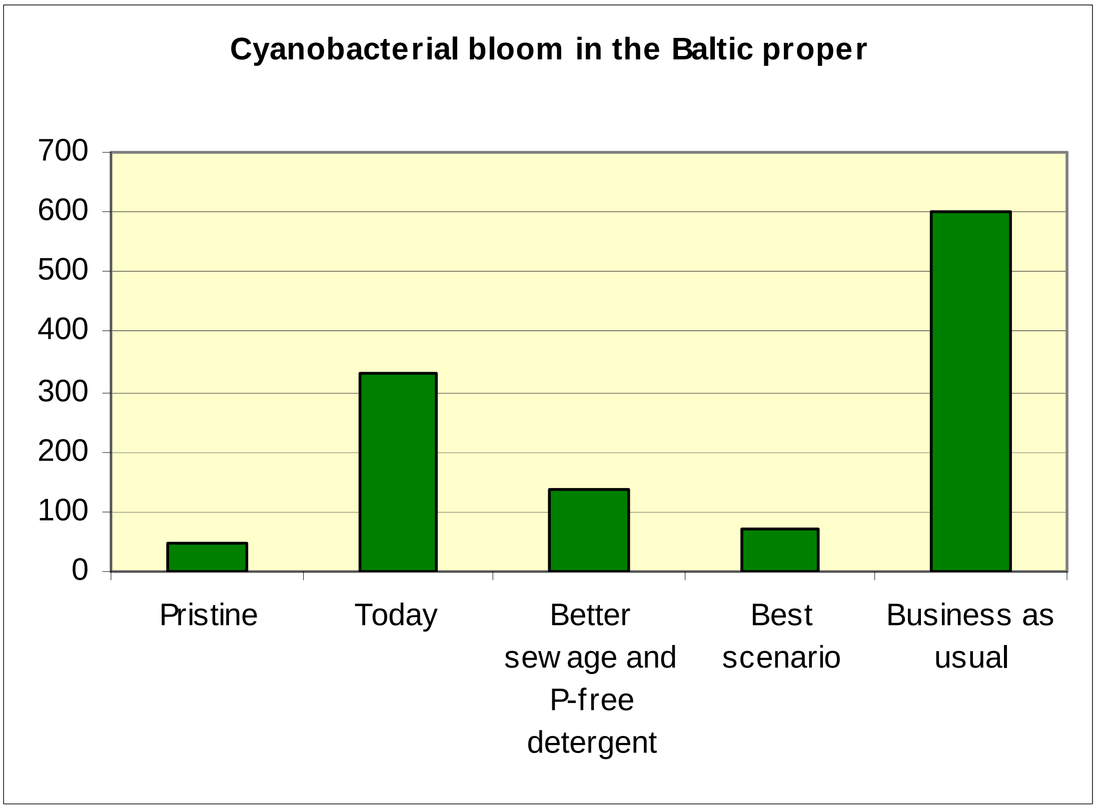

Figure 14. *Effect on cyanobacterial blooms of the different scenarios.*

***Summary:* Assuming business as usual in agriculture**

If all countries around the Baltic would have the same number of animals per agricultural area and same level of production in meat of milk cow and other cattle, sows and slaughter pigs as Denmark, it would result in:

- 48 % and 43 % increase of nitrogen and phosphorus loads, respectively, in total to the Baltic Sea which is approximately 340000 tonnes of nitrogen and 16000 tonnes of phosphorus.
- The total hypoxic bottom areas will increase from about 42,400 to almost 64,000 km^2!
- Nitrogen fixation that today is small in the Bothnia Sea will increase 2.5 times and undoubtedly cause environmental damage obvious to humans.
- The Gulf of Riga will have drastically reduced water transparency, doubled primary production and cyanobacterial blooms. Even the Danish Straits will see clear deteriorations of the environmental conditions.
- Only the Bothnian Bay and Kattegat will be relatively unaffected, compared to the present situation in this scenario.

Scenario 5: Best possible agricultural practices

A variety of measures are available for reducing the loads from agriculture, including balanced strategies for animal feeding, for housing, handling and spreading of manure, as well as for crop cultivation. Current practices of concentrating animals in different regions from where animal feed is produced, and supplementing animal fodder with a large proportion in imported food contribute to excess nutrient leakage which can be minimised through planning and policy measures.

However, the effects of such agricultural practices to nutrient loads to the Baltic vary to a great extent between different regions due to variations in soil properties, climate and hydrology. The current version of the drainage basins model included in NEST cannot model these differences in detail, due to lack of data. Therefore this scenario should be seen as a rough expert judgment on the magnitude of combined net effects to nutrient loads, if all such possible agriculture measures were implemented.

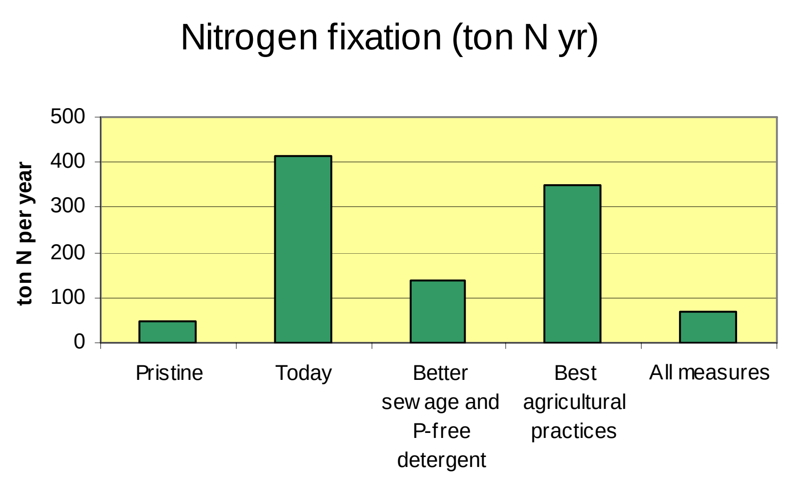

***Figure 15.** Effects on nitrogen fixation of the various scenarios*

Summary:Bbest possible agricultural practice

If balanced strategies optimising nutrient use in, and minimising nutrient fluxes in or out of agricultural systems; including 1) animal feeding 2) housing, handling and spreading of manure, as well as for 3) crop cultivation would be implemented, it would result in:

- The net P load would be eliminated and that the N load would be halved (47%). The effects on current total loads, varies from a few % to the northern basins with a small proportion of cultivated land to almost a third of the N load and almost half of the P load to the Danish Straits.
- The reduction expressed as tonnes is approximately 150000 tonnes of nitrogen and 21000 tonnes of phosphorus
- There will be a substantial reduction in water transparency (Secchi depth) in the Baltic proper, Gulf of Riga and Danish straits in this scenario.
- The effects on primary production and cyanobacterial blooms (nitrogen fixation) are small.

Scenario 6: Best case scenario combining all possible actions

The combined effects of improved sewage treatment, P-free detergent and best possible agricultural practices results in an overall reduction of almost 150,000 tons of nitrogen and about 21,000 tons of phosphorus, corresponding to a reduction to 21% and 56 % respectively of the loads for 2004.

Primary production and nitrogen fixation levels in the Baltic proper are substantially reduced, approaching pristine conditions' at the turn of the last century, see Savchuk et al (2007). In the following section, these measures are compared to the pristine (reference) and target levels set up by the HELCOM EUTRO project.

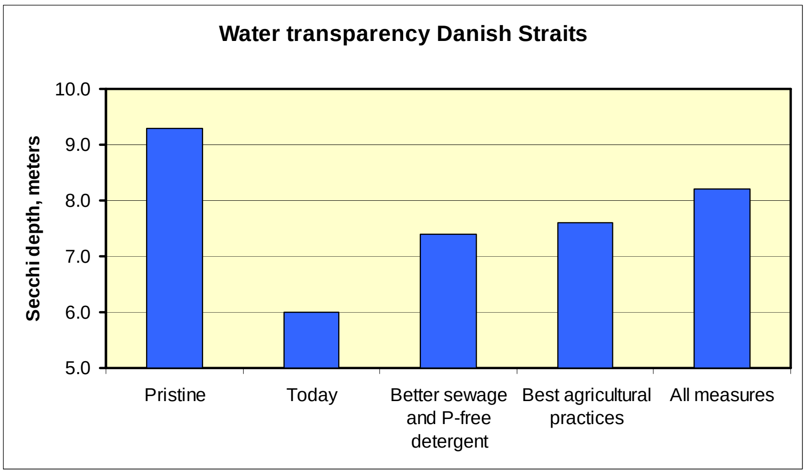

Figure 16. *Effect of the various measures on water transparency in the Danish straits.*

The effects on the marine ecosystems, expressed as % of the 2004 scenario are presented in **Figure 16.**

Table 6. The effect of the combined scenarios on the Baltic Sea marine environment.

Sub-basin	**TotN conc**	**TotP conc**	**Secchi depth**	**Primary production**	**Nitrogen fixation**	**Hypoxic area**
Bothnian Bay	2%	0%	11%	-20%		
Bothnian Sea	-4%	-40%	41%	-55%	-100%	
Baltic Proper	-19%	-50%	50%	-37%	-83%	-57%
Gulf of Finland	-13%	-50%	62%	-63%	-100%	
Gulf of Riga	-7%	-55%	73%	-65%	-100%	
Danish Straits	-17%	-38%	37%	-21%		
Kattegat	-8%	-14%	14%	-10%		

Conclusions on the scenarios

Naturally, the scenario calculations have many uncertainties still embedded. Improvement in data describing nutrient inputs and retentions in the various drainage basins and countries are needed as well as improvements in the models of the marine basins. A better understanding on how changes in land use and agricultural practices will affect loads to the sea is urgently needed. Conflicting data exist on the quantitative importance of using P-free detergents makes it difficult to judge the importance of this measure.

However, in spite of these uncertainties, it is clear that considerable reductions of nutrient inputs to the Baltic, particularly of phosphorus, can be reached if efficient modern municipal sewage treatments are implemented in the entire drainage basin. Improving agricultural practices will further reduce the phosphorus load but also cause a substantial reduction of nitrogen loads. The combined effects on the marine ecosystems are considerable and will most likely reach and surpass target levels for Secchi depths in all basins. However, the good future of the Baltic Sea is by no way guaranteed if the current rapid development of agriculture continues, as show in the ‘business as usual’ scenario. The current scenarios despite being the result of only one model provide a basis for initial assessment of the adopted measures to be further developed. Further, as stated above the long time-lag before the effects of measures taken to reduce loads to the sea are visible as well as the response in the Baltic Sea including the internal loading has to be taken into account when assessing the needed reductions.

About scenario calculations in relation to HELCOM environmental targets

For Secchi depths, the HELCOM EUTRO team has calculated reference Secchi depths and set target levels, based on a 25% increase from reference (pristine) conditions for all basins. For the Baltic proper, mean values of levels found for northern, western and south eastern sub regions are used. The values are compared to the Secchi depth found for the combined scenario (Scenario 3 page x) where improved waste water treatment is combined with a ban of P containing detergents plus the best possible agricultural scenario.

Secchi (m)	**HELCOM EUTRO**			**BNI**		
Sub-basin	**Reference**	**Target**	**Present**	**Pristine**	**Scenario**	**Present**
Bothnia Bay	7.5	5.6	5.8	8.5	7.0	6.2
Bothnian Sea	9.0	6.8	7.0	9.7	9.0	6.4
Gulf of Finland	8.0	6.0	4.1	7.0	7.3	4.6
Baltic Proper	9.3	7.0	6.3	10.0	9.0	7.4
Gulf of Riga	6.0	4.5	3.4	5.5	5.2	3.3
Kattegat	10.5	7.9	8.5	10.2	8.9	8.5

In this comparison, it is important to note that the HELCOM EUTRO values are based on summer (June-Aug) measurements while the NEST models calculate annual means for the resulting parameters. The HELCOM EUTRO target levels are *equal or lower* than obtained from NEST using nutrient loads resulting from the scenario 3, combining efficient sewage treatment with Phosphorus-free detergents. This means that the reductions in loads estimated in the scenarios 1-5 are likely to be slightly *lower* than in reality. However, the differences in HELCOM EUTRO and those obtained with the NEST model are relatively small (< 17%) for present levels of load. Following, the error in the load reduction estimates are estimated to be relatively small and it is still seems reasonable to consider that the combining efficient sewage treatment with Phosphorus-free detergents, resulting in an overall reduction of ca. 150,000 of nitrogen and 21,000 tons of Phosphorus will reach the target levels set by HELCOM EUTRO.

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ANNEX: MARE SCENARIO CALCULATIONS

Models in the scenarios

The scenario analyses provided by Fredrik Wulff and the MARE team have been made with Baltic Nest, an Internet based decision support system (http://www.mare.su.se). Data behind these calculations are primarily from official sources within HELCOM and EU.

Documentation of data and on the model used is available from this web-site as well, such as:

- The marine model is a coupled physical-biogeochemical 8 basin model presented in: Oleg Savchuk. Simple As Necessary Long-Term large-Scale simulation model of the nitrogen and phosphorus biogeochemical cycles in the Baltic Sea. Technical report, version 2, June 2005. http://www.mare.su.se/nest/docs/SANBalTS_QAv2.pdf
- The Watershed model , MCSIM, is presented in: Lars Rahm, Christoph Humborg, Stefan Löfgren, Carl-Magnus Mörth and Erik Smedberg. MCSIM Documentation. Technical report, 2005. http://www.mare.su.se/nest/docs/DOC_MCSIM_1_00_R050515.pdf

LOAD DATA USED FOR THE MARE MODELS

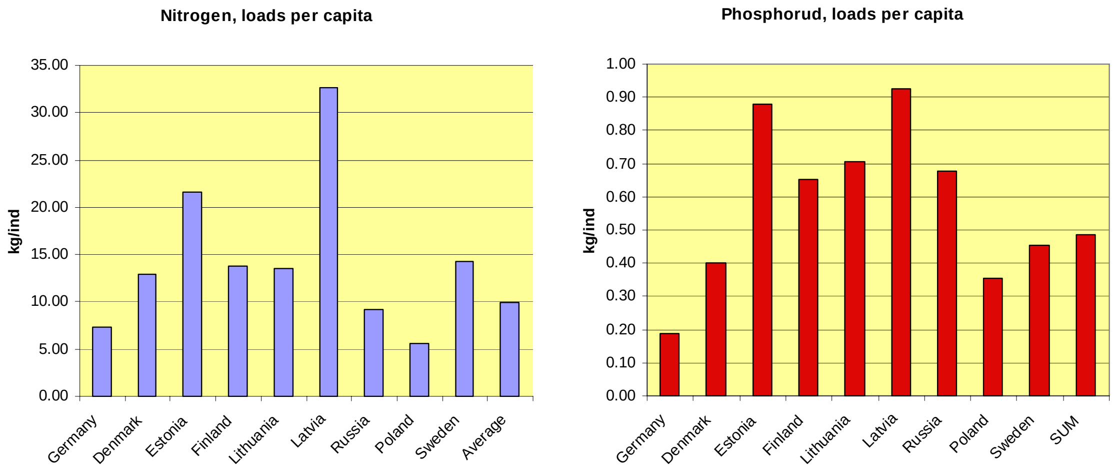

Figure 1. Load per capita of nitrogen and phosphorus to the Baltic Sea, averaged for 1997-2003

Table 1. Levels of sewage treatment in 2004

% Population connected to	BE	CZ	D	DK	ES	FI	LIT	LAT	N	PO	RU	SE
Primary wwt	0	0	0	2	2.2	0	33	1.8	0	2.2	0	0
Secondary wwt	50	61	9	5.2	34.4	0	6	35.1	5.8	23.3	50	5.8
Tertiary wwt	0	0	85	81.4	33.6	80	18	33.1	85.8	33.5	0	85.8

Improved sewage treatment scenarios

Table 2. Initial conditions in the Baltic Sea for 2004

Basin	**Nutrient concentrations, µmol**		**Secchi depth (meters)**	**Primary production (g C m^2 yr^{-1})**	**Nitrogen fixation (tons N yr^{-1})**	**Hypoxic area (km^2)**
	N	**P**				
Bothnian Bay	21.5	0.2	6.3	27	0	
Bothnian Sea	20.0	0.5	6.4	133	14	
Baltic Proper	22.3	0.8	6.0	189	413	42,391
Gulf of Finland	25.6	0.8	4.5	141	26	
Gulf of Riga	35.4	1.1	3.0	240	9	
Danish Straits	22.2	0.8	6.0	195	9	
Kattegat	18.7	0.7	7.8	213	6	

Table 3. Load reductions for phosphorus and nitrogen, from levels calculated for 2004, if modern sewage treatment was implemented.

Sub-basin	**Belarus**	**Czech Republic**	**Estonia**	**Lithuania**	**Latvia**	**Russia**	**Poland**	**SUM**	**%**
P reductions (tons)									
Bothnian Bay	0	0	0	0	0	0	0	0	0%
Bothnian Sea	0	0	0	0	0	0	0	0	0%
Baltic Proper	-1,447	-391	-2	-570	-17	-290	-5,292	-8,009	64%
Gulf of Finland	-7	0	-114	0	-7	-3,108	0	-3,236	26%
Gulf of Riga	-523	0	-17	-46	-162	-431	0	-1,179	9%
Danish Straits	0	0	0	0	0	0	0	0	0%
Kattegat	0	0	0	0	0	0	0	0	0%
SUM	-1,977	-391	-133	-615	-187	-3,829	-5,292	-12,424	100%
%	16%	3%	1%	5%	2%	31%	43%	100%	
N reductions (tons)									
Bothnian Bay	0	0	0	0	0	0	0	-10	0%
Bothnian Sea	0	0	0	0	0	0	0	0	0%
Baltic Proper	-4,184	-1,293	-4	-1,097	2	-1,050	-13,338	-20,963	62%
Gulf of Finland	-17	0	-585	0	-8	-9,947	0	-10,557	30%
Gulf of Riga	-1,374	0	-15	-54	-197	-1,131	0	-2,770	8%
Danish Straits	0	0	0	0	0	0	0	0	0%
Kattegat	0	0	0	0	0	0	0	0	0%
SUM	-5,574	-1,293	-604	-1,151	-203	-12,138	-13,338	-34,300	100%
%	16%	4%	0%	3%	1%	36%	39%	100%	

Table 4. Reductions of N and P loads with more efficient municipal sewage treatment in all countries give the following effects on the marine ecosystem, expressed in % of initial (2004) conditions. Results are presented as steady states, disregarding natural interannual variations. Thus, as a 'rule of thumb', changes within ± 10% would not be detected in field observations and be considered significant. (Units: % change from initial conditions)

Sub-basin	**Load reductions (tons)**		**Nutrient concentrations,**		**Secchi depth**	**Primary production**	**Nitrogen fixation**	**Hypoxic area**
	N	**P**	**N**	**P**				
Bothnian Bay	0%	0%	5%	0%	5%	-11%		
Bothnian Sea	0%	0%	4%	-20%	25%	-33%	-100%	
Baltic Proper	-6%	-40%	-3%	-25%	17%	-22%	-53%	-26%
Gulf of Finland	-11%	-49%	-4%	-38%	36%	-43%	-96%	
Gulf of Riga	-4%	-49%	5%	-36%	37%	-40%	-100%	
Danish Straits	0%	0%	-2%	-25%	17%	-12%		
Kattegat	0%	0%	-1%	-14%	1%	-5%		

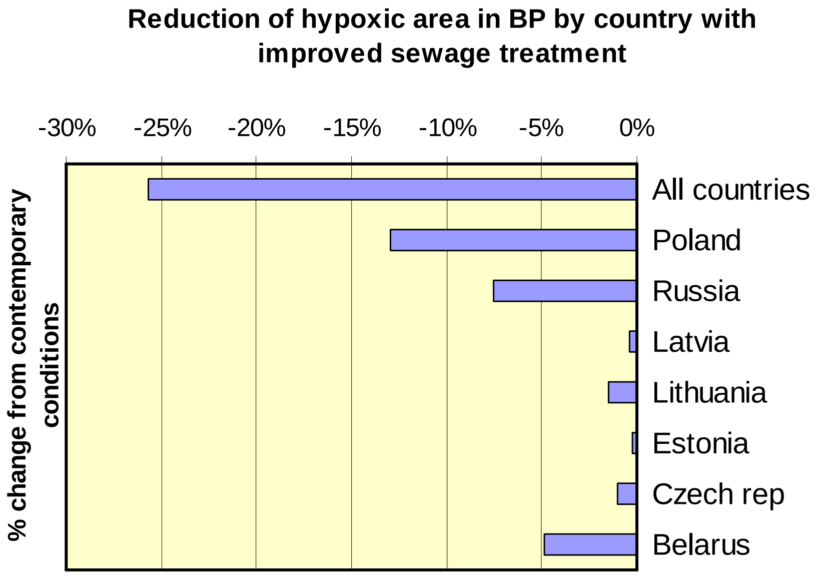

Figure 2. Reductions generated by improved sewage treatment, individually for each country and if all countries have jointly implemented these measures.

Using P free detergents scenario

Table 5. Maximum and minimum effects by using P-free detergents (by 0.6 and by 0.2 kg per person and year).

Sub-basin	MAX	MIN
Bothnian Bay	-3%	-1%
Bothnian Sea	-5%	-2%
Baltic Proper	-28%	-10%
Gulf of Finland	-32%	-12%
Gulf of Riga	-31%	-11%
Danish Straits	-16%	-6%
Kattegat	-8%	-3%
SUM	-24%	-9%

Table 6. The load reductions, expressed in tons, for each country into each basin, assuming that P-free detergents reduce the load with 0.2 kg per year are according to the model.

P	BE	CZ	DK	EST	FI	LIT	LAT	N	RU	PO	SE	SUM	%
BB	0	0	0	0	-29	0	0	0	0	0	-4	-33	1%
BS	0	0	0	0	-28	0	0	0	0	0	-14	-43	1%
BP	-294	-80	-1	-1	0	-182	-7	0	-59	-1,326	-51	-2,000	62%
GF	-1	0	0	-27	-103	0	-2	0	-623	0	0	-757	23%
GR	-106	0	0	-5	0	-19	-46	0	-87	0	0	-263	8%
DS	0	0	-93	0	0	0	0	0	0	0	-3	-96	3%
KT	0	0	-10	0	0	0	0	-2	0	0	-34	-47	1%
SUM	-401	-80	-104	-33	-160	-202	-55	-3	-769	-1,326	-106	-3,238	100%
%	12%	2%	3%	1%	5%	6%	2%	0%	24%	41%	3%	100%	

Table 7. The load reductions, expressed in tons, for each country into each basin, assuming that P-free detergents reduce the load with 0.6 kg per year are according to the model.

P	BE	CZ	DK	EST	FI	LIT	LAT	N	RU	PO	SE	SUM	%
BB	0	0	0	0	-80	0	0	0	0	0	-11	-92	1%
BS	0	0	0	0	-79	0	0	-1	0	0	-40	-120	1%
BP	-823	-225	-3	-2	0	-510	-19	0	-164	-3,712	-142	-5,600	62%
GF	-4	0	0	-76	-288	0	-6	0	-1,746	0	0	-2,120	23%
GR	-295	0	0	-15	0	-54	-129	0	-243	0	0	-737	8%
DS	0	0	-260	0	0	0	0	0	0	0	-9	-269	3%
KT	0	0	-29	0	0	0	0	-6	0	0	-95	-131	1%
SUM	-1,122	-225	-292	-93	-448	-564	-154	-7	-2,153	-3,712	-297	-9,067	100%
%	12%	2%	3%	1%	5%	6%	2%	0%	24%	41%	3%	100%	

Table 8. The effects on the marine ecosystem, expressed as % change from the default 2004 conditions if P detergents contain 0.2 kg P person^{-1} yr^{-1}.

Sub-basin	TotN conc.	TotP conc.	Secchi depth	Primary production	Nitrogen fixation	Hypoxic area
Bothnian Bay	0%	0%	2%	-4%		
Bothnian Sea	0%	0%	5%	-7%	-70%	
Baltic Proper	0%	0%	0%	-6%	-14%	-7%
Gulf of Finland	0%	0%	7%	-10%	-28%	
Gulf of Riga	0%	-9%	7%	-7%	-39%	
Danish Straits	0%	0%	2%	-3%		
Kattegat	0%	0%	0%	-1%		

Table 9. The effects on the marine ecosystem if P detergents contain 0.6 kg P person^{-1} yr^{-1}.

Sub-basin	TotN	TotP	Secchi depth	Primary production	Nitrogen fixation	Hypoxic area
Bothnian Bay	3%	0%	5%	-10%		
Bothnian Sea	2%	-20%	13%	-23%	-100%	
Baltic Proper	-2%	-13%	12%	-15%	-39%	-18%
Gulf of Finland	-2%	-25%	22%	-28%	-79%	
Gulf of Riga	-2%	-27%	20%	-19%	-100%	
Danish Straits	-1%	-13%	10%	-9%		
Kattegat	-1%	-14%	-12%	-4%		

Improved sewage treatment and P free detergents combined scenario

Table 10. The overall combined effects on nutrient loads to the basins of improving sewage treatments and with the use of P-free detergents (assuming that this means a reduction of 0.6 kg P person^{-1} yr^{-1}).

Sub-basin	Reduction in tons yr^{-1}		% of initial load	
	Tot N	Tot P	Tot N	Tot P
Bothnian Bay	0	-96	0%	-4%
Bothnian Sea	0	-120	0%	-5%
Baltic Proper	-20,963	-9,742	-6%	-48%
Gulf of Finland	-10,557	-3,793	-11%	-58%
Gulf of Riga	-2,770	-1,347	-4%	-56%
Danish Straits	0	-269	0%	-16%
Kattegat	0	-131	0%	-8%
SUM	-34,290	-15,498	-5%	-41%

Table 11. The effects on the marine ecosystem of the combined scenario of improved sewage treatment and with the use of P-free detergents (assuming that this means a reduction of 0.6 kg P person^{-1} yr^{-1}).

% difference: WWT/Initial	TotN conc	TotP conc	Secchi depth	Primary production	Nitrogen fixation	Hypoxic area
Bothnian Bay	7%	0%	6%	-15%		
Bothnian Sea	7%	-20%	25%	-42%		
Baltic Proper	-3%	-38%	33%	-26%	-66%	-30%
Gulf of Finland	-2%	-38%	44%	-52%	-100%	
Gulf of Riga	10%	-45%	43%	-50%	-100%	
Danish Straits	-2%	-25%	23%	-14%	-70%	
Kattegat	-1%	-14%	1%	-6%		

Agricultural scenarios

Table 12. The overall effects on nutrient loads to the basins assuming that all countries around the Baltic will develop their agriculture to the same state as in Denmark, the country that is leading in terms of agricultural development. In this 'pessimistic' scenario it is also assumed that sewage treatment will remain at the 2004 levels and no further restriction in the use of P in detergents will be implemented.

Sub-basin	Increase in tons yr^{-1}		% of initial load	
	Tot N	Tot P	Tot N	Tot P
Bothnian Bay	1,118	117	2%	4%
Bothnian Sea	2,376	138	5%	6%
Baltic Proper	238,314	10,460	70%	52%
Gulf of Finland	37,882	1,901	40%	29%
Gulf of Riga	55,304	2,933	82%	122%
Danish Straits	2,394	214	6%	13%
Kattegat	3,543	312	5%	18%
SUM	340,932	16,074	48%	43%

Table 13. The overall effects on the marine system of the "business as usual scenario for agriculture.

% difference WWT/Initial	TotN conc.	TotP conc.	Secchi depth	Primary production	Nitrogen fixation	Hypoxic area
Bothnian Bay	0%	0%	-6%	15%		
Bothnian Sea	6%	20%	-16%	36%	248%	
Baltic Proper	8%	38%	-17%	43%	45%	51%
Gulf of Finland	9%	25%	-13%	53%	30%	
Gulf of Riga	22%	64%	-27%	110%	109%	
Danish Straits	5%	25%	-7%	24%	51%	
Kattegat	2%	14%	-4%	10%		

Table 14. Increased input of nutrients by country, expressed as tons yr^{-1} to each basin, caused by intensified agriculture for P and N.

Sub-basin	BE	CZ	D	EST	FI	LIT	LAT	N	RU	PO	SE	SUM
Phosphorus												
BB	0	0	0	0	103	0	0	0	0	0	14	117
BS	0	0	0	0	58	0	0	2	0	0	78	138
BP	1,476	117	275	37	0	2,004	240	0	148	5,736	428	10,461
GF	16	0	0	629	158	0	91	0	1,007	0	0	1,901
GR	957	0	0	259	0	499	1,007	0	211	0	0	2,933
DS	0	0	190	0	0	0	0	0	0	0	23	214
KT	0	0	0	0	0	0	0	18	0	0	294	312
SUM	2,449	117	465	925	318	2,504	1,339	21	1,366	5,736	836	16,076
%	15%	1%	3%	6%	2%	16%	8%	0%	8%	36%	5%	100%
Nitrogen												
BB	0	0	0	0	1,004	0	0	0	0	0	106	1,110
BS	0	0	0	0	1,190	0	0	52	0	0	1,135	2,376
BP	36,078	2840	3,203	567	0	31,229	4,053	0	4,340	149,761	6,212	238,283
GF	333	0	0	11,112	1,917	0	1,336	0	23,183	0	0	37,881
GR	22,273	0	0	4,650	0	7,600	15,893	0	4,887	0	0	55,301
DS	0	0	1,996	0	0	0	0	0	0	0	397	2,393
KT	0	0	0	0	0	0	0	208	0	0	3,334	3,542
SUM	58,684	2,839	5,199	16,329	4,105	38,825	21,278	255	32,406	149,756	11,182	340,859
%	17%	1%	2%	5%	1%	11%	6%	0%	10%	44%	3%	100%

Best possible agricultural practices scenario

Table 15. The overall effects on nutrient loads to the basins according to Best practice scenario for agriculture.

Sub-basin	Total area, km^2	% cultivated	Reduction, %	
			N	P
Bothnian Bay	26,362,519	4%	-2%	-4%
Bothnian Sea	22,637,213	5%	-2%	-4%
Baltic Proper	57,153,463	57%	-21%	-17%
Gulf of Finland	43,110,463	20%	-8%	-6%
Gulf of Riga	13,378,794	51%	-22%	-20%
Danish Straits	2,883,425	79%	-33%	-44%
Kattegat	7,934,431	22%	-10%	-19%

Table 16. Effects on the marine ecosystems of the best practice scenario for agriculture

% difference WWT/Initial	TotN conc.	TotP conc.	Secchi depth	Primary production	Nitrogen fixation	Hypoxic area
Bothnian Bay	-7%	0%	5%	-6%		
Bothnian Sea	-14%	0%	9%	-12%	-62%	
Baltic Proper	-16%	-13%	33%	-12%	-15%	-14%
Gulf of Finland	-13%	0%	7%	-12%	-16%	
Gulf of Riga	-19%	-18%	37%	-17%	-24%	
Danish Straits	-14%	-13%	27%	-8%		
Kattegat	-7%	0%	12%	-4%		

A combination of all scenarios – best case

Table 17. The combined effects on nutrient inputs of improved sewage treatment, P-free detergent and best possible agricultural practices.

Sub-basins	Reduction in tons yr^{-1}		Reduction, %	
	N	P	N	P
Bothnian Bay	-950	-198	-2%	-7%
Bothnian Sea	-1,138	-224	-2%	-9%
Baltic Proper	-93,878	-13,238	-27%	-65%
Gulf of Finland	-17,871	-4,159	-19%	-64%
Gulf of Riga	-17,683	-1,823	-26%	-76%
Danish Straits	-12,237	-993	-33%	-61%
Kattegat	-6,599	-458	-10%	-26%
SUM	-150,356	-21,093	-21%	-56%

Table 18. The effects on the marine ecosystems, of the combined scenarios on nutrient inputs of improved sewage treatment, P-free detergent and best possible agricultural practices.

Sub-basins	TotN conc	TotP conc	Secchi depth	Primary production	Nitrogen fixation	Hypoxic area
Bothnian Bay	2%	0%	11%	-20%		
Bothnian Sea	-4%	-40%	41%	-55%	-100%	
Baltic Proper	-19%	-50%	50%	-37%	-83%	-57%
Gulf of Finland	-13%	-50%	62%	-63%	-100%	
Gulf of Riga	-7%	-55%	73%	-65%	-100%	
Danish Straits	-17%	-38%	37%	-21%		
Kattegat	-8%	-14%	14%	-10%		

Scenario calculations in relation to HELCOM environmental targets

Table 19. For Secchi depths, the HELCOM EUTRO team has calculated reference Secchi depths and set target levels, based on a 25% increase from reference (pristine) conditions for all basins. (Units: Secchi depth in meters)

Sub-basin	HELCOM EUTRO			BNI		
	Reference	Target	Present	Pristine	Scenario	Present
Bothnia Bay	7.5	5.6	5.8	8.5	7.0	6.2
Bothnian Sea	9.0	6.8	7.0	9.7	9.0	6.4
Gulf of Finland	8.0	6.0	4.1	7.0	7.3	4.6
Baltic Proper	9.3	7.0	6.3	10.0	9.0	7.4
Gulf of Riga	6.0	4.5	3.4	5.5	5.2	3.3
Kattegat	10.5	7.9	8.5	10.2	8.9	8.5

Table 20. The reference, targets (+ 50% of reference values) and contemporary wintertime surface DIN concentrations were also set by HELCOM EUTRO. They are here compared with the NEST combined scenario. (Units: DIN [μmol])

Sub-basin	HELCOM EUTRO			NEST		
	Reference	Target	Present	Pristine	Scenario	Present
Bothnia Bay	3.50	5.25	7.10	5.15	12.5	7.04
Bothnian Sea	2.00	3.00	2.71	4.29	6.87	3.23
Gulf of Finland	2.50	3.75	8.80	4.97	7.11	5.59
Baltic Proper	2.17	3.25	3.10	2.87	2.83	2.47
Gulf of Riga	4.00	6.00	11.20	6.43	13.4	6.96
Kattegat	4.50	6.75	8.26	4.09	4.20	4.59

Table 21. Reference, targets (+ 50% of reference values) and contemporary wintertime surface DIP concentrations were also set by HELCOM EUTRO. They are here compared with the NEST combined scenario. (Units: DIP [μmol])

Sub-basin	HELCOM EUTRO			NEST		
	Reference	Target	Present	Pristine	Scenario	Present
Bothnia Bay	0.10	0.15	0.04	0.06	0.06	0.05
Bothnian Sea	0.20	0.30	0.17	0.20	0.20	0.25
Gulf of Finland	0.30	0.45	0.90	0.34	0.31	0.52
Baltic Proper	0.25	0.38	0.52	0.24	0.25	0.50
Gulf of Riga	0.13	0.20	0.85	0.35	0.31	0.49
Kattegat	0.40	0.60	0.59	0.33	0.30	0.37