TOWARDS A BALTIC SEA UNAFFECTED BY EUTROPHICATION

HELCOM Overview 2007

HELCOM Ministerial Meeting

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Cover photo by Nanna Rask, Fyn County

Note: This is a background document for the HELCOM Ministerial Meeting 2007 elaborated by the HELCOM Secretariat.

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:

- show how ecological objectives are used as basic assessment tools for evaluating whether the Baltic Sea has reached a good status with respect to eutrophication,

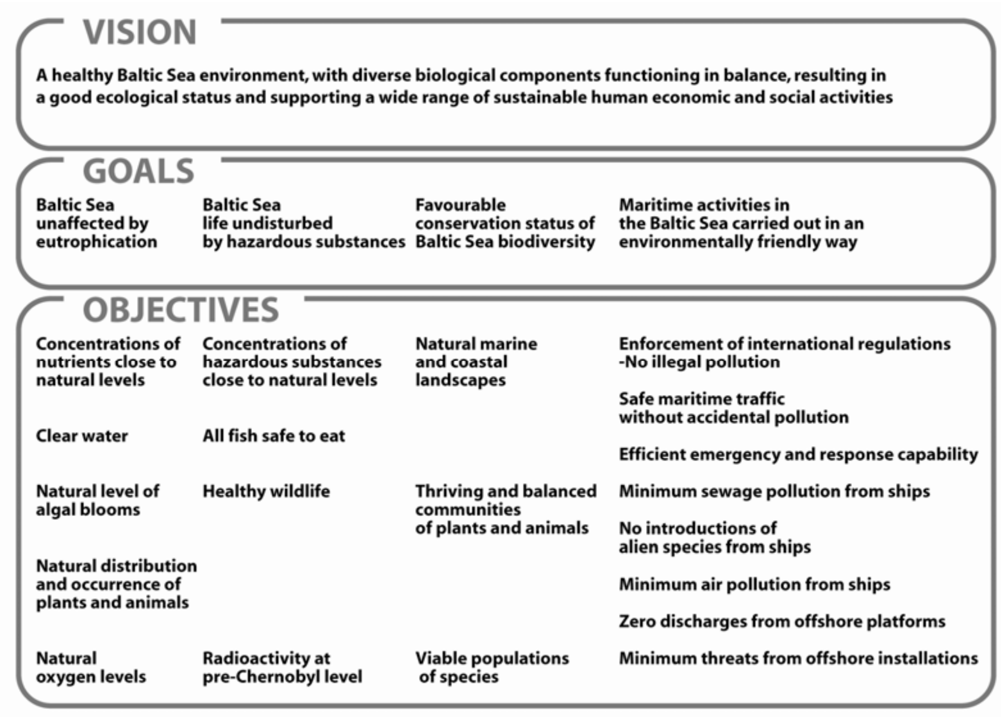
- present a set of scenarios for future nutrient inputs to the Baltic Sea and their consequent effects on the environment,

- present the definition of the needed nutrient reductions to the Baltic Sea in total and by sub-region as well as the allocation of load reductions to countries included in the HELCOM Baltic Sea Action Plan (BSAP) in order to reach good environmental status by using the Baltic NEST model, and

- outline the current state and trends in the marine environment, with respect to eutrophication, thus justifying the actions included in the HELCOM Baltic Sea Action Plan (BSAP).

A comprehensive, integrated HELCOM thematic assessment of eutrophication in various sub-basins of the Baltic Sea will be made by 2009.

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. It is a condition affecting aquatic ecosystems, where excess nutrient inputs lead to elevated nutrient concentrations. This in turn stimulates the growth of algae leading to imbalanced functioning of the system. This imbalance is seen as increase in production of organic matter, its sedimentation to the sea floor, and there, an increase in oxygen consumption. All this leads to oxygen depletion and recurrent internal loading of nutrients as well as 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:

1. Concentrations of nutrients close to natural levels
2. Clear water
3. Natural level of algal blooms
4. Natural distribution and occurrence of plants and animals
5. Natural oxygen levels

The agreed objectives will be measured by indicators. Since the clarity of seawater integrates many of the concrete effects of eutrophication *Secchi depth*[*)] has been chosen as the primary indicator.

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 in different sectors and parts of the Baltic Sea catchment area are ongoing and will continue to provide input for future developments in the Baltic Sea Action Plan.

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 have been compared with HELCOM target levels for the environmental indicator water clarity measured by *Secchi depth*. The results 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 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.

[*)] see the explanation on page 7

Due to less progress in the field of agriculture compared to point sources, such as municipalities and industry, and because it has been envisaged that agricultural production will grow following the EU enlargement, nutrient reduction efforts should 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 agricultural production is intensified throughout the Baltic Sea region without application of strict measures the inputs will increase substantially.

The results of the MARE scenarios also 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 from Estonia, Latvia, Lithuania and Poland as well as from 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. These measures will primarily reduce the loads of phosphorus. In order to reduce the loads of nitrogen, non-point sources, particularly within agriculture, have to be addressed.

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 the sea and should be addressed. According to scenarios, the deposition of nitrogen to the sea will not decrease even if existing targets for nitrogen under the UNECE Gothenburg Protocol and the EU NEC Directive are reached.

One of the aims of the Action Plan is to 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 ecological and 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 from the coast regulated by the EU WFD. The actions presented in the Action Plan are foreseen to implement the proposed EU Marine Strategy Directive.

The starting point for all actions under the HELCOM Baltic Sea Action Plan is the aim for good ecological and environmental status in the Baltic Sea marine environment. The Action Plan defines the provisional maximum allowable nutrient inputs to the Baltic Sea that can be allowed and still reach the good status as well as the nutrient reductions needed to reach the target levels for the indicator reflecting the ecological objective “Clear water”. Provisional maximum allowable inputs are given at the following levels:

- country;
- sub-basin; and
- entire Baltic Sea.

The Action Plan puts forward provisional country-wise reduction targets for both nitrogen and phosphorus, which must be reduced from the annual nutrient inputs to the Baltic Sea. The Contracting States are to develop national programmes by 2010 in order to reach the required reductions. With the responsibilities transferred to country level, each Contracting State will have enough flexibility to choose the most cost-effective measures needed to fulfil its reduction requirement and include them to their national programmes/River Basin Management Plans.

Based on the results of the scenarios, cost-efficiency analysis and evaluations of gaps in existing requirements at HELCOM, national and international level, it has been identified that there is a need to take actions both for point and diffuse sources in the following sectors:

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

Taking also into account that diffuse nutrient sources have a central role in determining the future state of the Baltic Sea environment, HELCOM countries which are also EU Member States will give joint input to the forthcoming Health Check of the EU Common Agricultural Policy stating the importance to marine environment concerning the content and the scope of, e.g., pillar II on the rural development programmes and cross compliance as well as to influence the revision of the targets for nitrogen in the UNECE Gothenburg Protocol and the EU NEC Directive.

The implementation of the Action Plan will also include the identification of so called Hot Spots on a plant by plant basis, e.g., concerning installations for the intensive rearing of poultry, pigs and cattle which should be addressed as first priority. There will also be more stringent requirements for agriculture concerning e.g. environmental permitting for animal farms and the application of nutrients in manure on the fields.

The Action Plan also encourages the elaboration of bilateral and/or multilateral projects and programmes to reduce nutrient inputs using the most cost-efficient measures, in particular for addressing transboundary nutrient inputs from non-HELCOM countries. The Action Plan suggests that such inputs should be jointly dealt with under a “common pool”, which can be diminished not only by national means but also by input from non-profit foundations and private companies providing funds on a voluntary basis.

BALTIC SEA UNAFFECTED BY EUTROPHICATION

Eutrophication is a major problem in the Baltic Sea. Since the 1800s, 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.

[*)] a depth at which a white disk that is lowered into the water is no longer visible

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 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 way to measure water clarity is Secchi depth. There exist Secchi depth measurements from the Baltic Sea from over a period of over 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 initial 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 Secchi depth (meters). Present conditions without need of improvement to reach the target levels are indicated with coloured cells.

Sub-basin	Secchi depth (Summertime) [meters]			Status
	Reference	Target	Present	
Bothnian Bay	7.5	Present	5.8	
Bothnian Sea	9.0	Present	7.0	
Gulf of Finland	8.0	>6.0	4.1	
Gulf of Riga	6.0	>4.5	3.4	
Kattegat	10.5	Present	8.5	
Baltic Proper	9.3	>7.0	6.3	

The waters in Bothnian Bay, Bothnian Sea and Kattegat are within 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 recreational purposes. The occurrence and intensity of cyanobacterial blooms in the Baltic Sea have increased since the 1960s 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 the abundances of other phytoplankton species have changed due to 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* have been selected as supporting indicators 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 levels should not exceed +50%. The initial 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 proven by an increase in area covered with laminated sediments, indicating dead, lifeless bottoms. It should be noted that many of the observed changes in oxygen levels, especially in the deeper bottoms, are due to natural variation but that geological records in laminated sediments also 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 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 (H_2S) in bottom waters 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.

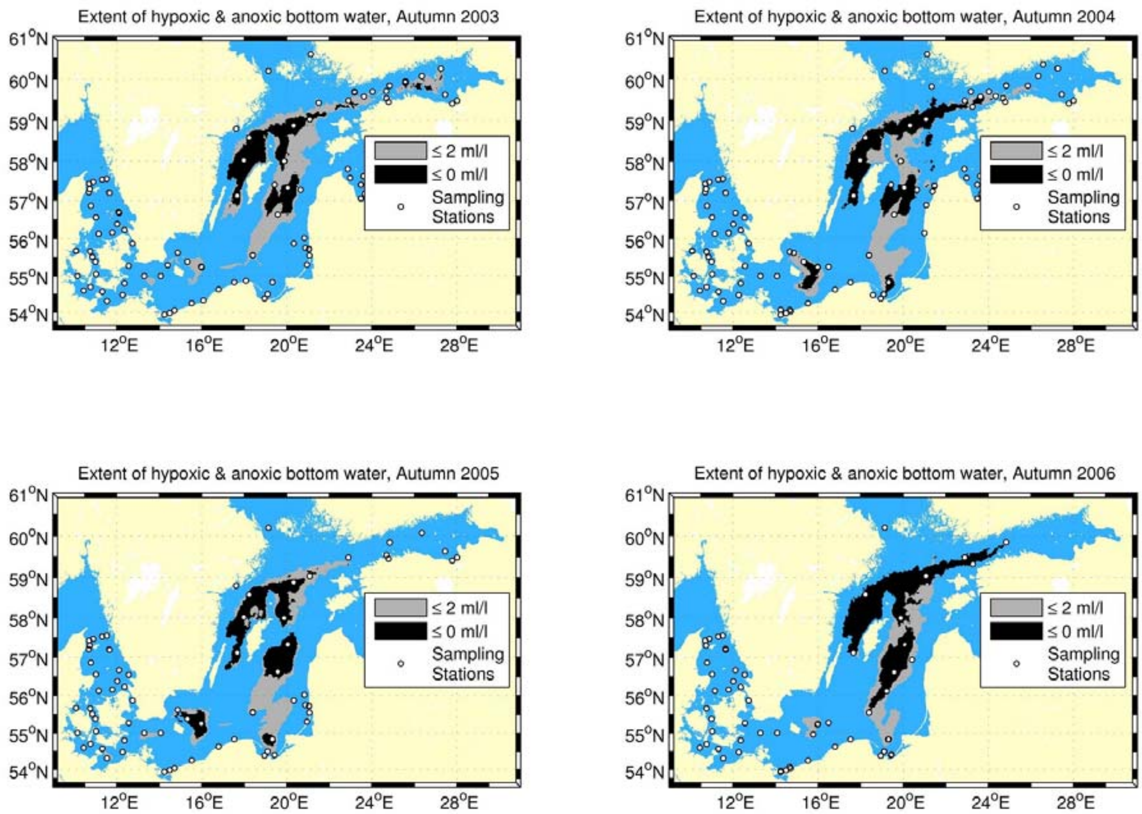


Figure 1. *Estimates of the extent of hypoxic (oxygen content less than 2 ml/l) and anoxic (oxygen content nil; often with presence of hydrogen sulphide) in autumn 2002 – 2006 (Axe 2007).*

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. Hydrogen sulphide now affects almost 10% of the East Gotland Basin and 17% of the West Gotland Basin and Northern Baltic Proper (by volume). In all these basins, around 40% of the water has oxygen levels below 1 ml/l. This is acutely toxic to benthic fauna, and the sea bottoms covered by this water can be considered dead (Axe 2007).

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. Nutrient concentrations are strongly affected by seasonality. During winter, nitrogen and phosphorus concentrations peak 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, a surplus of phosphorus promotes the blooms of nitrogen fixing cyanobacteria, also called blue-green algae. Internal loading from sediments and bacterial denitrification affect the cycles of phosphorus and nitrogen, respectively.

Concentrations of nutrients in winter provide fuel for the subsequent phytoplankton spring bloom and the phosphorus to nitrogen ratio affects cyanobacterial blooms. Therefore, *dissolved nutrient concentrations during the winter time* as well as *N:P ratio* have been selected as 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 phosphorus, 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 are within the HELCOM targets for both nitrogen and phosphorus concentration and the waters in Bothnian Bay and Kattegat are within the HELCOM targets for phosphorus.

Distribution of plants and animals

Many 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 are 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 has been selected 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. These internal sources are large and have been considered in the MARE NEST marine models.

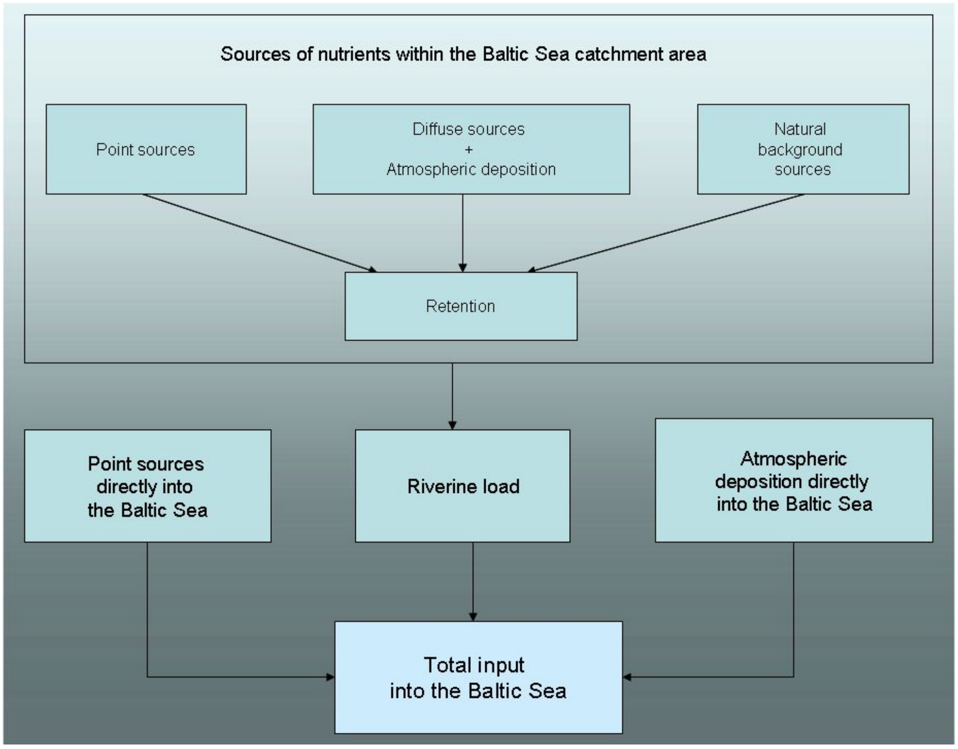


***Figure** 2. Sources of nutrients within the Baltic Sea catchment area.*

In 2005 the total inputs amounted to 787,000 tonnes of nitrogen and 28,600 tonnes of phosphorus (HELCOM PLC Group 2007 and Bartnicki 2007).[1] 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 waterborne loads of nitrogen and phosphorus to the Baltic Sea by HELCOM Contracting States.

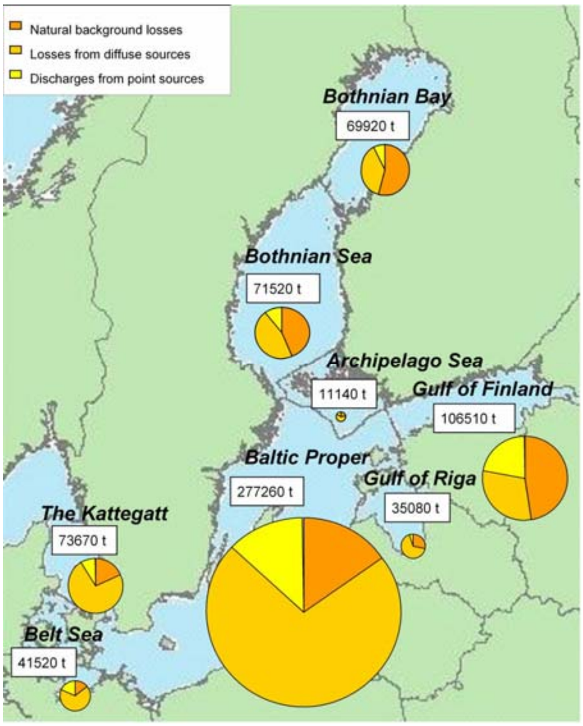


Figure 3. *Proportion of sources contributing to waterborne nitrogen input into the Baltic Sea sub-regions in 2000[2] (HELCOM 2004).*

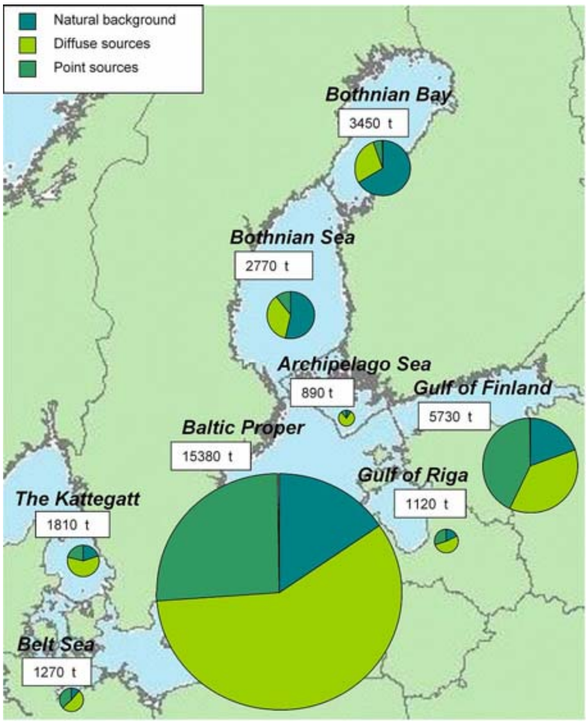


Figure 4. *Proportion of sources contributing to phosphorus inputs into the Baltic Sea sub-regions in 2000[1] (HELCOM 2004).*

[1] The waterborne input figures for 2005 lack some data from Russia
[2] 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.

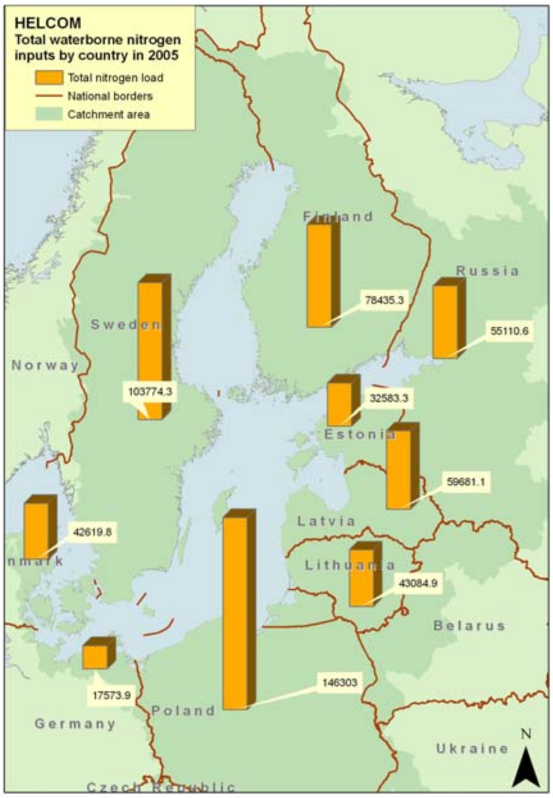


Figure 5. *Waterborne load of nitrogen (in tonnes) to the Baltic Sea by HELCOM Country in year 2005. (HELCOM PLC-Group 2007). (Russian data partly missing).*

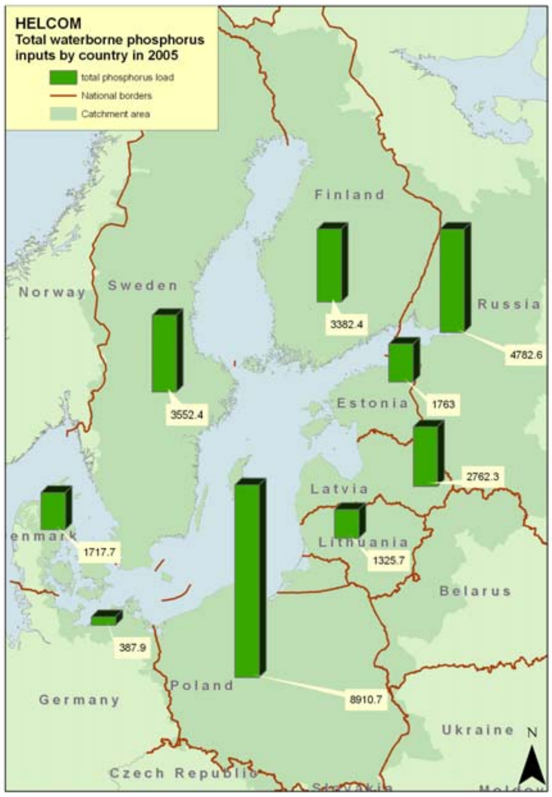


Figure 6. *Waterborne load of phosphorus (in tonnes) to the Baltic Sea by HELCOM Country in year 2005. The reported total waterborne phosphorus input was 28 600 tonnes in 2005. (HELCOM PLC-Group 2007). (Russian data partly missing).*

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**).

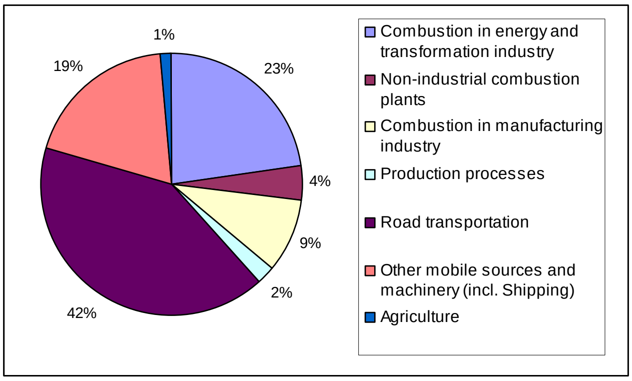


Figure 7. *Percentage of total emissions of nitrogen oxides (NOx) from different sectors in the HELCOM Contracting States in 2005 (EMEP 2007).*

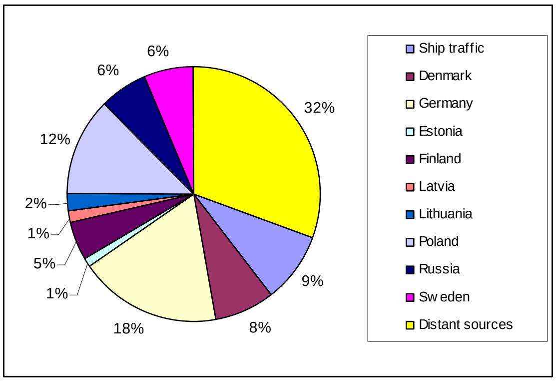


Figure 8. *Proportion of contribution by source to the atmospheric deposition of nitrogen entering the Baltic Sea basin in 2005. The diagram shows that over 30% of the total nitrogen input originates from sources outside the HELCOM area (EMEP 2007).*

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 States. 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 30% of the total airborne deposition of nitrogen (**Figure 8**).

ACHIEVED INPUT REDUCTIONS

The Helsinki Convention and HELCOM 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 1980s. Despite reduced discharges within the catchment area, no clear trend in reduced riverine inputs to the Baltic Sea has be observed 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 and Recommendations concerning new or reconstructed industrial plants have been implemented by all of the Contracting States. In all HELCOM countries, many municipal waste water treatment plants have been constructed and/or modernised, thus improving the implementation situation of the HELCOM Recommendations in this field. Especially the new EU Member countries have recently undertaken extensive modernisation plans for both municipal wastewater treatment plants and industries. Also the construction of a new treatment plant as well as introduction of chemical phosphorus removal in some existing plants in St. Petersburg, are encouraging steps forward. There are, however, still some compliance problems, especially with regard to nitrogen limit values, in some Contracting States.

Diffuse sources

Diffuse nutrient runoff originates mostly 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 Helsinki Convention, regarding agriculture, and requirements in Recommendation 24/3 have been implemented almost fully by Denmark, Germany, Finland and Sweden according to an assessment made for year 2000 (Percy-Smith et. al. 2003). Some of the requirements have been implemented by Estonia, Latvia, Lithuania, Poland 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 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 within HELCOM or EU, but in some Contracting States, relevant national legislation has recently been adopted as the share of phosphorus discharges from scattered settlements has been assessed to be higher than from municipalities.

Achieved reductions in airborne emissions and deposition

Since 1980 there has been a reduction of approximately 38% in the levels of total nitrogen emissions to the air from the HELCOM Contracting States (HELCOM 2004, EMEP 2007). On the other hand, deposition levels have only declined roughly by 33% 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.

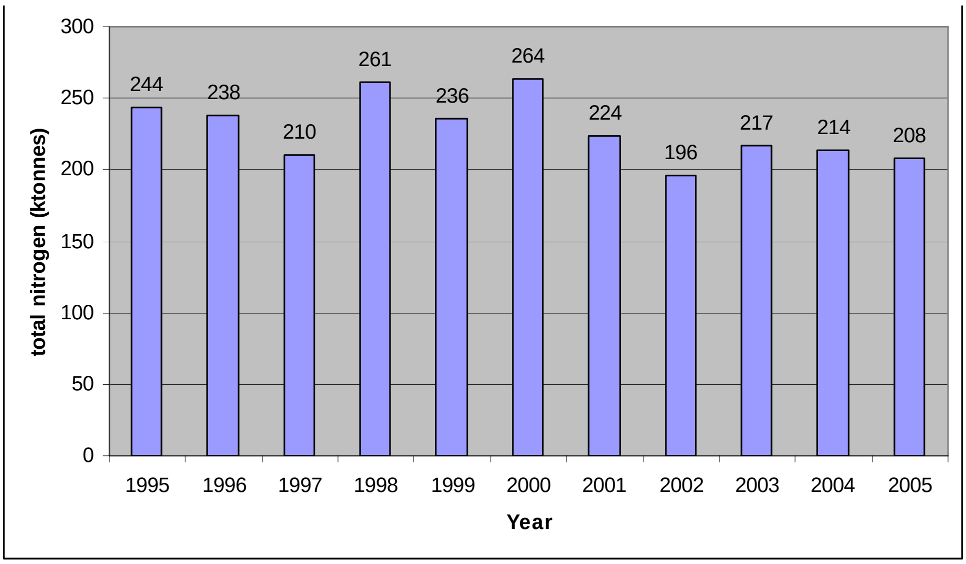


Figure 9. *Atmospheric deposition of total (oxidised and reduced) nitrogen to six sub-basins of the Baltic Sea for the period 1995-2005. Units: kilotonnes N/year (Bartnicki 2007b).*

Land-based air emissions are 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 area, 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 emissions from shipping are estimated to be increasing at an annual range of 2-3% (Bartnicki, 2007a).

FUTURE INPUT PROJECTIONS BASED ON PRESENT MANAGEMENT REGIME

Waterborne inputs

Further reductions in nutrient discharges from point sources will continue in the 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 in nitrogen oxides emissions have been achieved, the emission ceilings of the Gothenburg Protocol to the UNECE 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, however, already reached the required emission levels.

HELCOM assessments indicate that the total nitrogen depositions on the Baltic Sea in 2010 will be higher than in 2003, even with the fulfilment of the targets for nitrogen in the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution and the EU NEC Directive. The increase is mostly due to a 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 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).[3]

[3] 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 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 Sea environment.

This section includes initial scenarios on the policy impacts using specific modelling tools (MARE-NEST, see Wulff et al., 2007). 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, as initial conditions, are 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%).

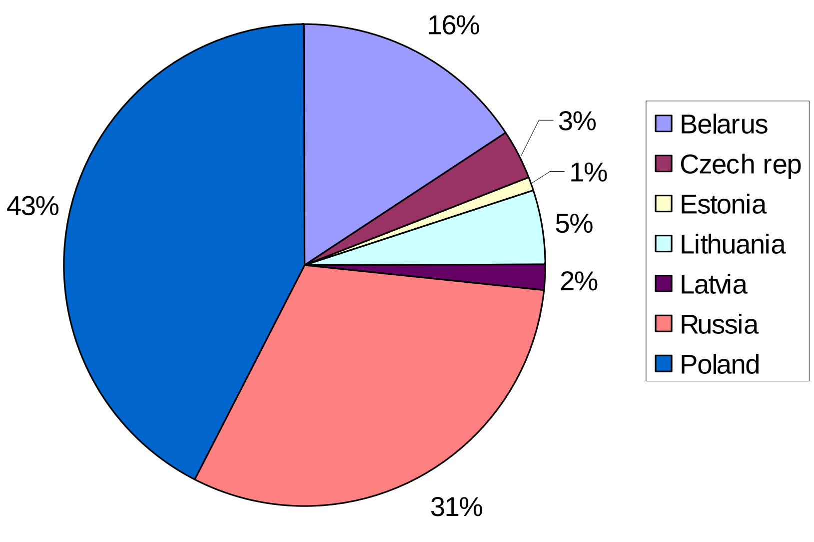


Figure 10. *The contribution by country to the total load reduction of nitrogen and phosphorus, if modern sewage treatment was implemented in these countries*.

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.

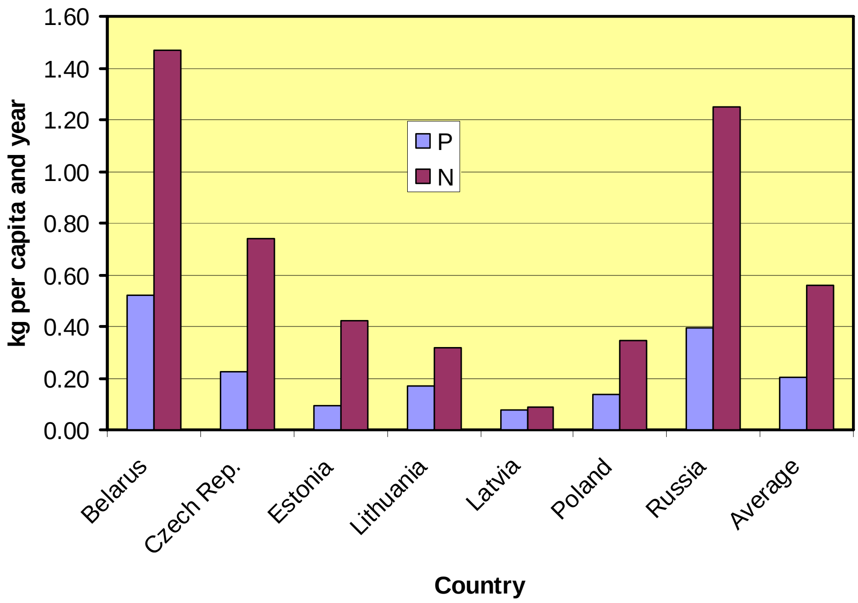


Figure 11. *The contributions by capita and country to the load reduction of N and P, if modern sewage treatment was implemented in these countries to the levels of treatment in the Nordic countries.*

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 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.

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* Phosphorus 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.

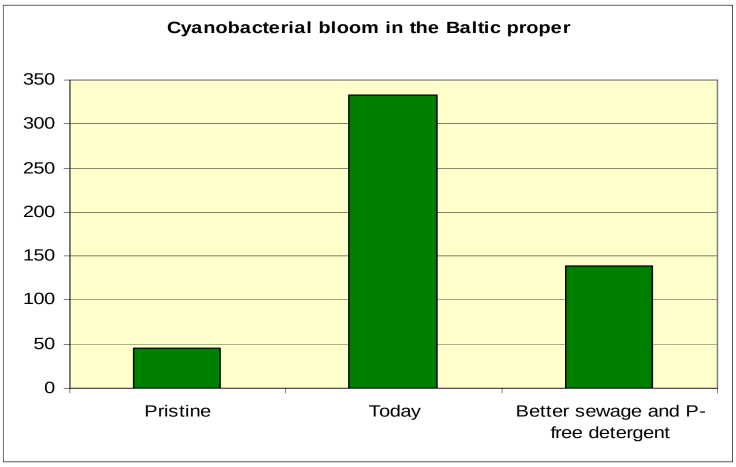


Figure 12. *Effects of the combined scenario on cyanobacterial blooms in the Baltic Proper. Pristine conditions are obtained with loads calculated for a century ago (Savchuk et al., 2007).*

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 34,300 tonnes of nitrogen and 15,500 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 (see Humborg et al., 2007) 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 cows and other cattle, 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.

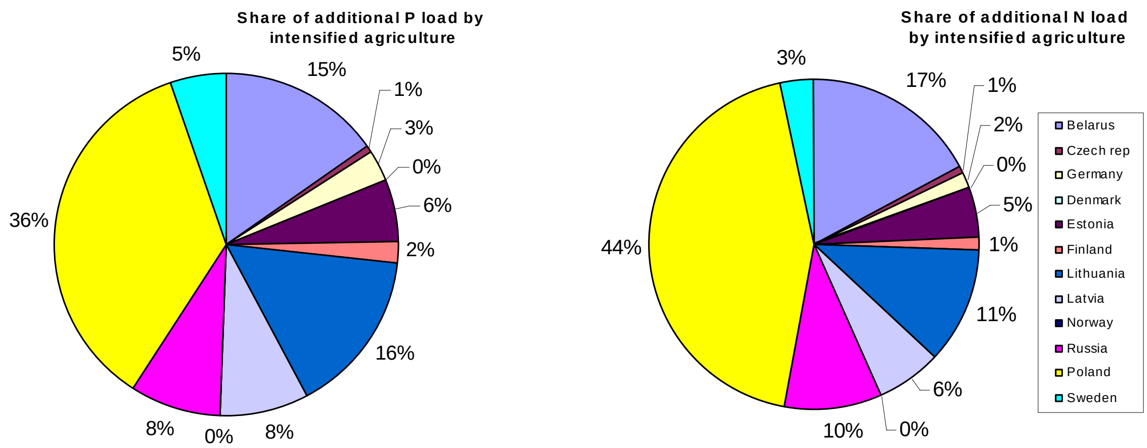


Figure 13. *The % contribution by country to increased nutrient loads if all counties intensified agriculture to Danish levels.*

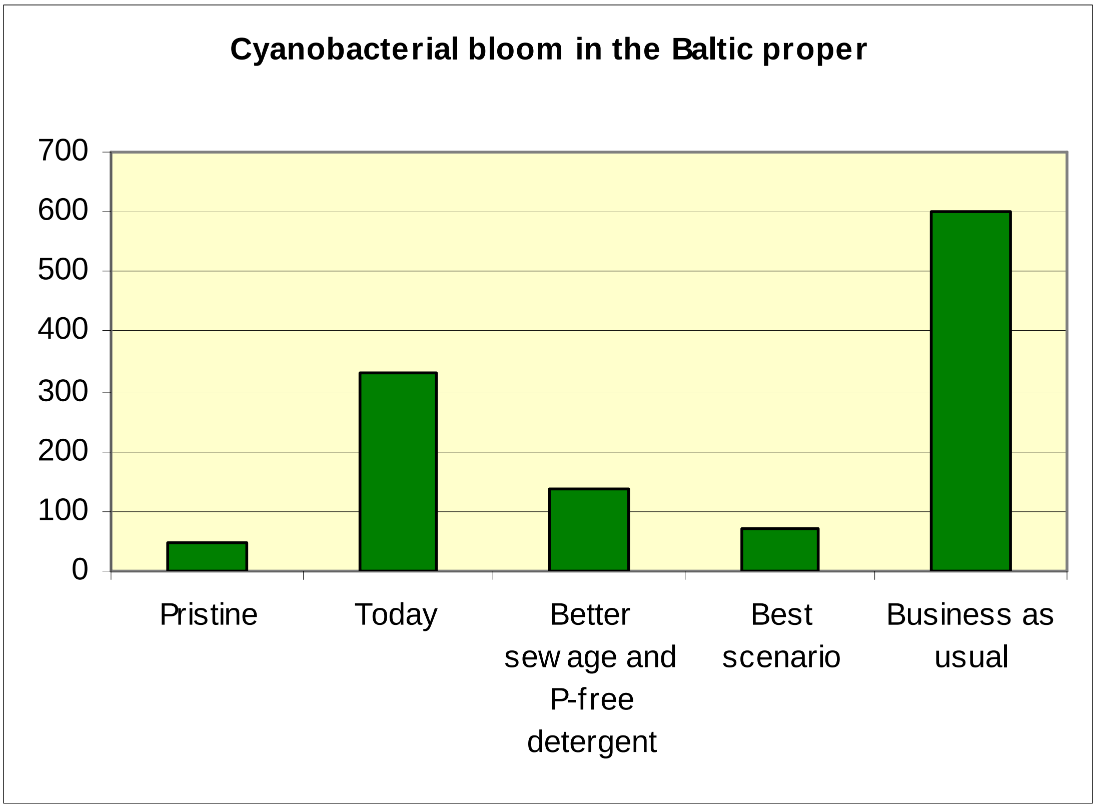


Figure 14. *Effect of the different scenarios on cyanobacterial blooms in the Baltic Proper.*

***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 cows 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 340,000 tonnes of nitrogen and 16,000 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.

Summary: Best 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 116,000 tonnes of nitrogen and 5,600 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.

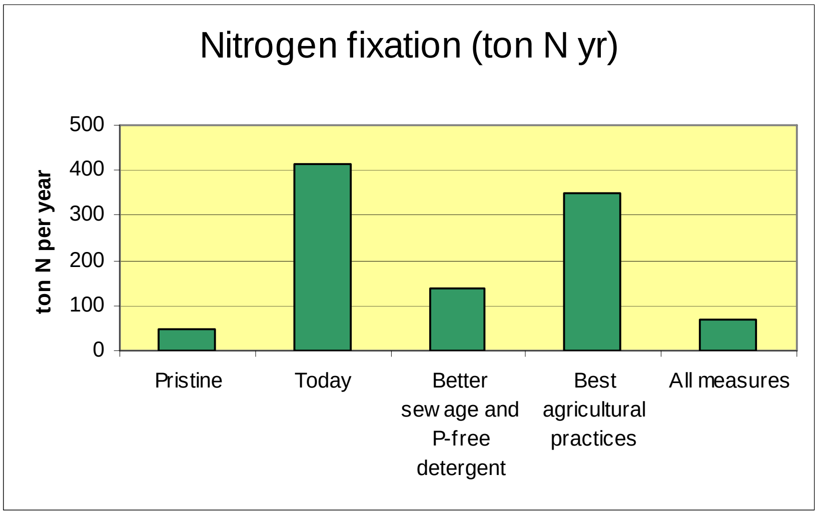


***Figure 15.** Effects on nitrogen fixation of the various scenarios.*

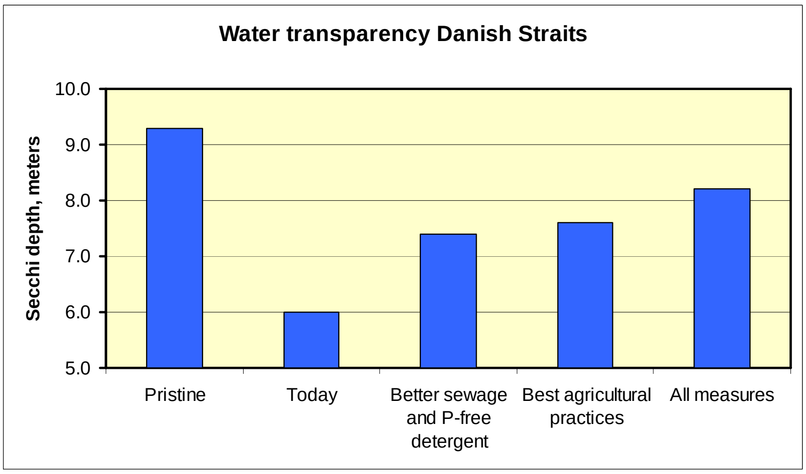


***Figure 16.** Effect of the various measures on water transparency in the Danish straits.*

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, 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) 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.

AN APPROACH TO SETTING COUNTRY-WISE NUTRIENT REDUCTION ALLOCATIONS TO REACH GOOD ECOLOGICAL STATUS OF THE BALTIC SEA

An approach to setting country-wise nutrient reduction allocations for reaching good ecological status has been developed under the umbrella of HELCOM with the aim of providing input to the HELCOM Baltic Sea Action Plan. The approach is based on HELCOM's ecological objectives and takes into account the complex interactions that control the Baltic Sea ecosystem. It implements the Ecosystem Approach and the Baltic NEST model was used to calculate the nutrient load reductions needed to the reach targets for Secchi depths (for a more detailed description see Document 2.1/2 of the 22nd Meeting of the Heads of Delegation of HELCOM (HELCOM HOD 22/2007)).

The proposed country-wise nutrient reduction allocations to reach the eutrophication targets for good ecological status of the Baltic Sea have been calculated on a sub-basin and country level. The proposed plan includes the allocation of transboundary pollution from upstream countries such as Belarus to a common pool to be addressed by joint initiatives.

The approach used takes into account not only the reduction of nutrient loads that result in a good ecological status of the marine environment in the Baltic Sea as a whole and in its sub-basins, but also aims to be fair and acceptable to all HELCOM Contracting Parties. The approach also takes into account water protection measures that have already been taken by the countries and allows flexibility in terms of future measures to be taken to reach the reduction targets.

Needed nutrient reductions in total and by sub-region

Successive model runs were carried out reducing P and N loads to the different Baltic Sea sub-basins until an agreement with the environmental targets were reached. First, the loads to the Baltic proper were reduced, then to the Gulf of Finland and the Gulf Riga and finally to the Danish straits and Kattegat. No reductions were needed to the Bothnian Bay and Bothnian Sea since the targets were already reached by reduced advective northward flows of nutrients when the targets were met in the Baltic proper.

Table 7. Loads of total nitrogen and phosphorus (tons year-1) to the Baltic Sea sub-basins (riverine and coastal point sources), averaged for 1997-2003 (from official data reported to HELCOM) and the reductions needed to reach the environmental targets as well as maximum allowable inputs.

Sub-basin	**Load 1997-2003**		**Needed reduction**		**Maximum allowable inputs**	
	Nitrogen	**Phosphorus**	**Nitrogen**	**Phosphorus**	**Nitrogen**	**Phosphorus**
Bothnian Bay	51,436	2,585	0	0	51,436	2,585
Bothnian Sea	56,786	2,457	0	0	56,786	2,457
Baltic Proper	327,259	19,246	94,000	12,500	233,259	6,746
Gulf of Finland	112,680	6,860	6,000	2,000	106,680	4,860
Gulf of Riga	78,404	2,180	0	750	78,403	1,430
Danish Straits	45,893	1,409	15,000	0	30,893	1,409
Kattegat	64,257	1,573	20,000	0	44,257	1,573
Total	736,714	36,310	135,000	15,250	601,713	21,060

Allocation of load reductions to countries

The proposed approach suggests the use of a two-step procedure, where the starting point is the needed reduction to reach good marine environment in each sub-basin.

1) The quantity of load reductions achievable by improved sewage treatment from 2004 levels up to the existing HELCOM Recommendation/EU UWWT Directive levels by each Contracting State is calculated (nitrogen reduction to 70% and phosphorus to 80% for cities above 10,000 inhabitants. For cities below 10,000 and 2,000 inhabitants it is assumed that secondary treatment levels are applied, i.e. 35% for nitrogen and 35% for phosphorus).

2) In the second step, the remaining load reduction, after improved sewage treatment has been implemented, is allocated among the sub-basin HELCOM Contracting States according to their proportion of the present load to that sub-basin (subtracted with the improvement of sewage treatment).

Actual wastewater treatment levels in 2004 of the coastal countries as well as possible and potential measures to further reduce loads were considered in the model. This leaves the HELCOM countries flexibility to choose their preferred water protection measures. Furthermore, the approach acknowledges measures already implemented and going, beyond the HELCOM Recommendations' levels, and gives countries credit for them. At the same time this allocation approach is based on a simplistic approach that can be easily verified.

Table 8. Total land based loads, averaged for 1997-2003 reported to by the countries to HELCOM and the allocated reductions for each country. Loads to sub basins where no reduction is needed are excluded here (see Table7). The common pool corresponds to the WWT load reductions from Belarus.

Sub-basin	**Loads in sub basins with a reduction need (97-03)**		**Country reduction allocations**	
	Phosphorus	**Nitrogen**	**Phosphorus**	**Nitrogen**
Germany	534	20,848	242	5,621
Denmark	51	57,501	16	17,207
Estonia	1,261	19,054	222	896
Finland[4]	578	15,852	146	1,199
Lithuania	1,336	45,109	881	11,746
Latvia	1,613	10,447	300	2,561
Russia	6,683	89,386	2,500	6,967
Poland	13,717	215,350	8,755	62,395
Sweden	860	72,762	291	20,780
Common pool (Belarus)	1,662	3,779	1,662	3,779
Total	**28,293**	**550,088**	**15,014**	**133,152**

Transboundary and atmospheric loads

The proposed country-wise nutrient reduction allocations approach calculates contributions from transboundary loads from the upstream countries (non-Contracting Parties). It has been suggested that a common pool should be established where the transboundary loads would be allocated and that reduction needs allocated to the common pool should be reached by initiating joint activities in the upstream countries e.g. by utilising EU neighbourhood policy and funding.

The proposal focuses on waterborne nutrient inputs and atmospheric and natural background loads have been estimated to be constant. Measures for reducing airborne nitrogen from shipping are considered in the Maritime segment of the Baltic Sea Action Plan.

[4] Finland will in addition address nutrient reduction needs in the Archipelago Sea according to national plans

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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

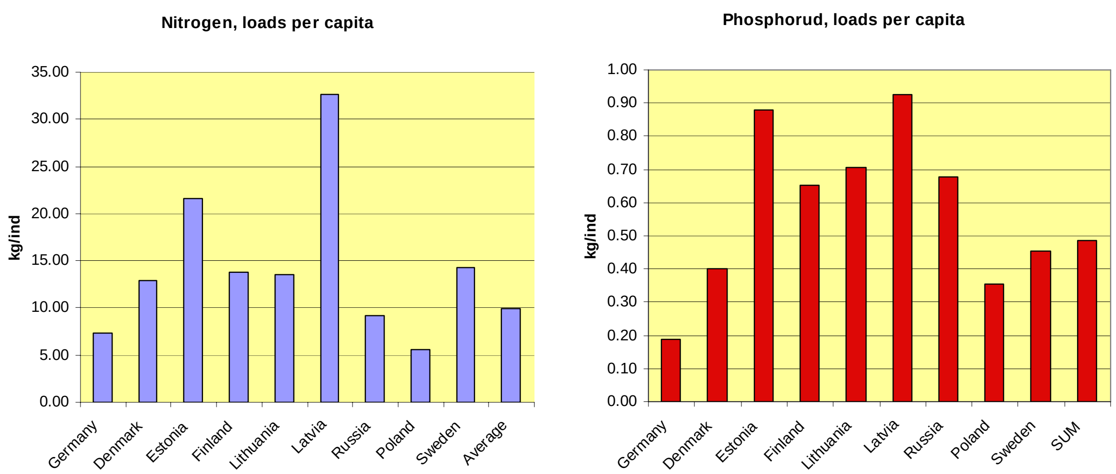

Figure 1. *Load per capita of nitrogen and phosphorus to the Baltic Sea, averaged for 1997-2003. Transboundary riverine loads are not allocated to the source country but to the country where the rivers enters the sea.*

Table 1. 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 2. Load reductions for phosphorus and nitrogen, from levels calculated for 2004, if modern sewage treatment according to the EU WWT Directive 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%	