Baltic Sea Environment Proceedings No. 141

Review of the Fifth Baltic Sea Pollution Load Compilation for the 2013 HELCOM Ministerial Meeting

Helsinki Commission

Baltic Marine Environment Protection Commission

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Content

Preface

Since the establishment of the Convention for the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) in 1974, the Commission for the Protection of the Marine Environment of the Baltic Sea Area (HELCOM) has been working to reduce the inputs of nutrients to the sea. Through coordinated monitoring, HELCOM has, since the mid-1980s, been compiling information on the magnitude and sources of nutrient inputs into the Baltic Sea. By regularly compiling and reporting input data, HELCOM is able to follow the progress towards reaching politically agreed goals. The first Baltic Sea Pollution Load Compilation (PLC-1) was published in 1987 and the latest (PLC-5) in 2011 (HELCOM, 2011).

In 2007, the HELCOM Baltic Sea Action Plan (BSAP 2007) was adopted by the Baltic Sea coastal countries and the European Community (HELCOM 2007). The BSAP has the overall objective of reaching a Baltic Sea in good environmental status by 2021 by addressing the issues of eutrophication, hazardous substances, biodiversity and maritime activities. The BSAP has estimated the maximum annual waterborne nutrient input to the Baltic Sea that can be allowed and still make it possible to reach good environmental status with regard to eutrophication, based on modeled calculations by the Baltic Nest Institute (BNI), Sweden. The BNI also estimated the necessary waterborne nutrient reductions at the sub-basin level. To reach these reduction targets, responsibility has been divided between the HELCOM countries through a nutrient reduction allocation scheme based on the polluter pays principle. The EU Water Framework Directive, WFD (2000/60/EC), and the EU Marine Strategy Framework Directive, MSFD (2008/56/EC), also require 'good ecological status' / 'good environmental status' of coastal and open sea areas in Europe, respectively. Reducing eutrophication and hence water- and airborne inputs of nutrients can only be done if the sources and magnitude of nutrient pollution are known. This is why HELCOM's pollution load compilation (PLC) data are of such great importance.

In BSAP 2007, it was acknowledged that the decided environmental and nutrient reduction targets for the Contracting Parties were provisional. Pursuing the adaptive management principles, it was agreed that all figures related to environmental status and maximum allowable inputs should be periodically reviewed. Revised maximum allowable inputs and new country-wise allocated reduction targets were adopted at the HELCOM Ministerial Meeting in October 2013 (HELCOM 2013a). Complete, consistent, updated and high quality water- and airborne input data are a pre-requisite for determining reduction schemes, for example, to make a fair share of the nutrient reductions between the Contracting Parties and to follow up progress upon fulfillment of the reduction requirements. It was for this reason that the PLC-5.5 project[1] was established. It has updated the PLC-5 report (HELCOM 2011 & HELCOM 2012) by updating, correcting, gap-filling and quality assuring the PLC data set[2], and by including water- and airborne data for 2009 and 2010. The PLC-5.5 data set, including estimates made by the project to fill in data gaps, has been approved by the HELCOM Contracting Parties for use in this Review of the PLC-5 for the 2013 HELCOM Ministerial Meeting, the PLC-5.5 report and for revised calculations of the BSAP maximum allowable nutrient inputs (MAI) and country-wise allocation of reduction targets (CART). The latest changes in the data set were made in July 2013.

This report was prepared as supporting material for the 2013 HELCOM Ministerial Meeting which was

1 Project for the review of the Fifth Baltic Sea Pollution Load Compilation for the 2013 HELCOM Ministerial Meeting (HELCOM PLC-5.5) – implemented during 2012-2013.

2 HELCOM 33/2012 noted the implications of missing data for HELCOM assessment purposes as well as the recalculation of maximum allowable nutrient inputs and country-wise nutrient reduction allocations and stressed that remaining gaps in data will be filled with estimates determined by the PLC-5.5 project group unless this missing data is provided by the Contracting Parties (paragraph 4.23, LD 41 Minutes of the Meeting).

held in Copenhagen, Denmark on 3 October 2013. It is a review and update of the Fifth Baltic Sea Pollution Load Compilation (HELCOM 2011 & 2012) covering water- and airborne inputs to the sea. The focus in this report is on time series; trends in inputs from 1994 to 2010; the comparison of normalized inputs during 2008-2010 compared with the corresponding inputs during the BSAP reference period (1997-2003); and the status of inputs in 2010. Source apportionment from the PLC-5 report (based on data from 2006) has not been updated as this will be covered by the next PLC assessment (PLC-6).

It should be noted that the figures presented are rounded (although not necessarily to the number of digits that corresponds to the level of accuracy) in order to avoid confusion when summing different numbers.

A PLC-5.5 report (HELCOM, in prep), although in general covering nutrient inputs during the same period as in this report, will include more detailed information as well as information about follow-up of progress toward reaching the revised nutrient reduction targets agreed on in the 2013 HELCOM Copenhagen Declaration.

1 Introduction

Table 1.1. Population (2006) and surface areas of the Baltic Sea catchment area and sub-regions as well as total water flow (2010).

Sub-region	Population (thousands)	Terrestrial surface area (km^2)	Marine surface area (km^2)	Water flow ($m^3 s^{-1}$)
Bothnian Bay	1,370	260,675	36,250	3,140
Bothnian Sea	2,250	220,765	65,400	2,850
Archipelago Sea	530	9,000	13,400	70
Gulf of Finland	12,320	413,100	30,000	4,070
Gulf of Riga	3,820	127,840	18,650	1,370
Baltic Proper	54,990	574,545	209,300	4,740
Western Baltic	3,600	22,740	18,650	200
The Sound	2940	4,625	2,300	40
The Kattegat	3,820	86,980	23,650	1,170
Total	**85,640**	**1,720,270**	**417,600**	**17,650**

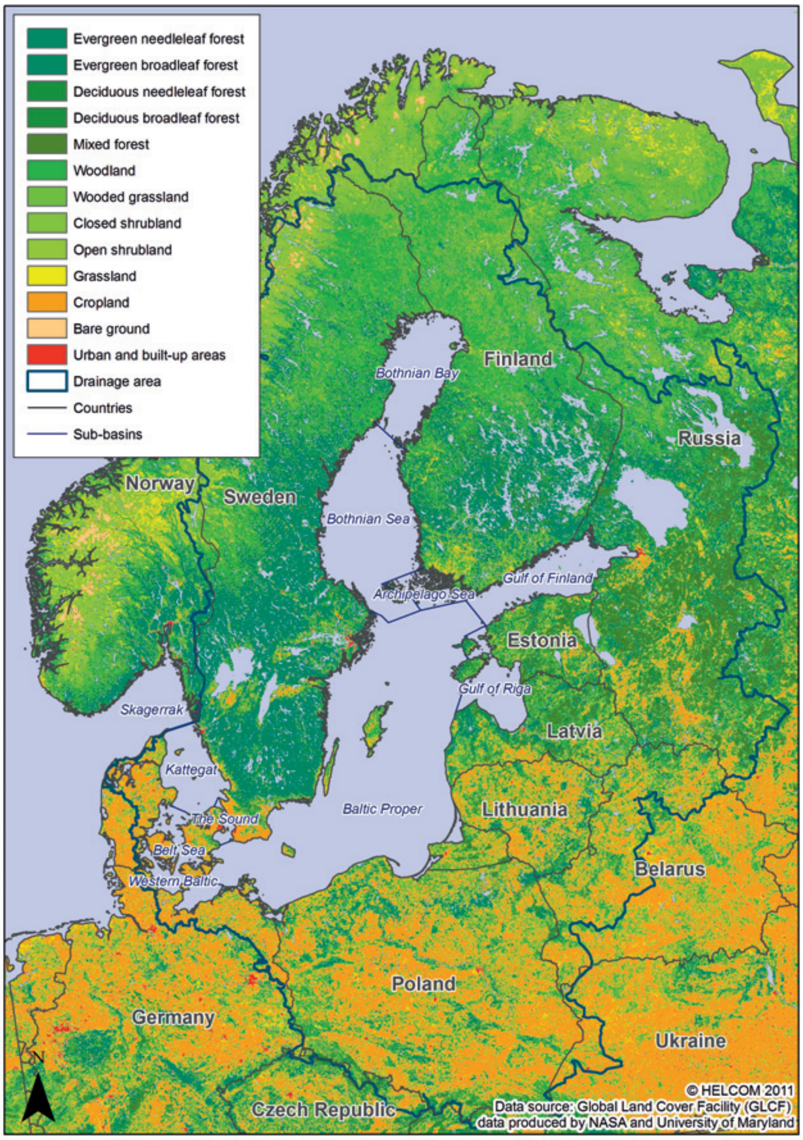


 Figure 1.1. Land cover, catchment area and sub-basins of the Baltic Sea.

Eutrophication is one of the main environmental problems facing the Baltic Sea. Since the early 1900s, the Baltic Sea has become increasingly eutrophied as a result of increasing inputs of the nutrients *nitrogen* and *phosphorus* from anthropogenic activities in the catchment area and at sea.

Nitrogen and phosphorus are the main growth limiting nutrients - high nutrient concentrations in the aquatic environment stimulate the growth of algae, which leads to an imbalanced functioning of the ecosystem. The intense algal growth is manifested as an excess of filamentous algae and phytoplankton blooms and generally a production of excess organic matter. At the end of summer, the algae die and are decomposed by oxygen consuming bacteria, resulting in oxygen depleted waters and consequently the death of benthic organisms, including fish.

The total Baltic Sea catchment area comprises approximately 1,720,000 km², of which nearly 93% is within the borders of the nine HELCOM countries[3] and 7% lies within the territories of five non-Contracting Parties[4]. **Figure 1.1** shows the main sub-basins of the Baltic Sea. Of these, the sub-basin catchment areas of the Baltic Proper and the Gulf of Finland are the largest covering 575,000 km² (33%) and 413,000 km² (24%), respectively; the Archipelago Sea has the smallest catchment area covering 9,000 km² (5%) of the total catchment area (**Table 1.1**). The Baltic Proper is the biggest marine sub-basin covering 50% of the Baltic Sea's 417,600 km² surface area. In most tables and figures in this report, the Archipelago Sea is included in the Bothnian Sea and the Western Baltic and the Sound are included with the Danish Straits.

Over 85 million (2006) people live within the Baltic Sea catchment area. Human populations as well as anthropogenic activities such as agriculture and industry contribute the majority of nutrient input to the Baltic Sea. For more information see the Fifth Baltic Sea Pollution Load Compilation (HELCOM 2011) and Updated Fifth Baltic Sea Pollution Load Compilation (HELCOM, in prep).

3 The Contracting Parties to the 1992 Helsinki Convention are Denmark, Estonia, the European Union, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden.

4 Belarus, Czech Republic, Norway, Slovakia and Ukraine.

1.1 Pathways and sources of nutrient inputs

The land-based nutrient inputs entering the Baltic Sea are either air- or waterborne (**Figure 1.2**). The main *pathways* of nutrient input to the Baltic Sea are:

- Riverine inputs of nutrients to the sea - nutrients entering inland surface waters within the Baltic Sea catchment area and transported by rivers to the sea.
- Point sources discharging directly to the sea.
- Direct atmospheric deposition on the Baltic Sea water surface.
- The influx of nutrients from North Sea and Skagerrak to the Baltic Sea (not included in this report).

The different *sources* for the inputs of nitrogen and phosphorus are from:

- Atmospheric emissions of airborne nitrogen compounds emitted mainly from traffic or combustion for heat and power generation, industrial processes, and from fertilizer applications, animal manure and husbandry.
- Point sources including inputs from municipalities, industries and fish farms both discharging into inland surface waters and directly into the Baltic Sea.
- Diffuse sources, mainly from agriculture, but also nutrient losses from *e.g.* managed forestry and rural areas. Losses from scattered dwellings and storm water overflows are also included under diffuse sources.
- Natural background sources, mainly natural erosion and leakage from unmanaged areas as well as the corresponding nutrient losses from *e.g.* agricultural and managed forested land that would occur irrespective of human activities.

Phosphorus enters the Baltic Sea mainly as waterborne input and to a lesser extent as atmospheric deposition. Based on monitoring information from the HELCOM countries compiled by the PLC-5.5 project, it is estimated that atmospheric deposition of phosphorus to the Baltic Sea in average is maximum 5 kg P km^{-2} or about 2,100 tonnes of phosphorus per year as compared to former estimates in the BSAP of 6,300 tonnes. This figure should be seen as a preliminary estimate based on results from land-based and coastal monitoring stations[5] (for more information see HELCOM PLC-5.5 report, in prep).

5 Document 3/2 HELCOM LOAD 5/2013 describes how the atmospheric deposition rate of 5 kg P km^{-2} has been derived.

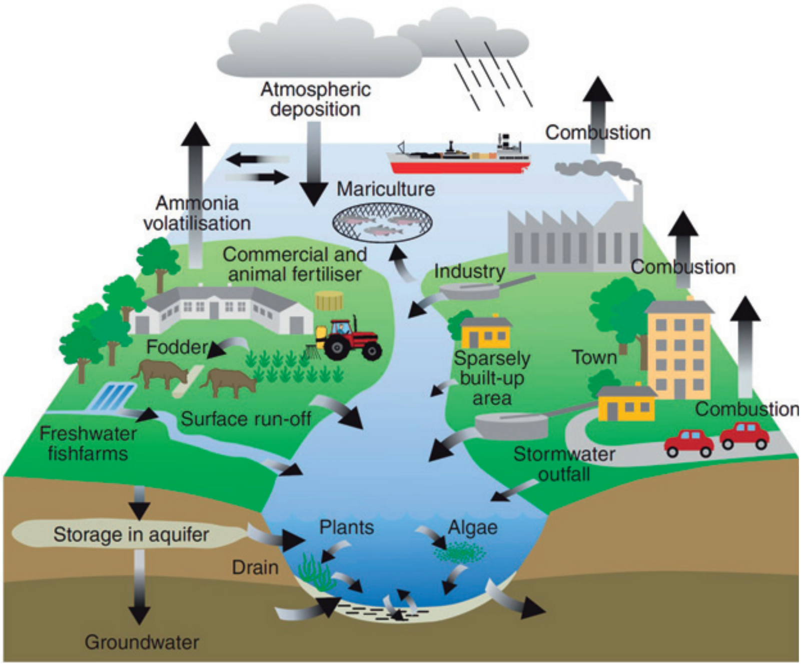


Figure 1.2. Different sources of nutrients to the sea and examples of nitrogen and phosphorus cycles. The flow related to ammonia volatilization shown in the figure applies only to nitrogen. In this report, also combustion and atmospheric deposition deal only with nitrogen. Emissions of phosphorus to the atmosphere by dust from soils are not shown in the figure (Source: Ærtebjerg et al. 2003).

A part of the nutrient input to the Baltic Sea originates from outside the HELCOM area. Distant sources contribute with a significant portion of atmospheric inputs of nitrogen. As indicated in **Figure 1.2**, nutrients enter inland waters by different pathways and are thereafter affected by a variety of processes in rivers and lakes. The amount of rainfall and the resulting water flow in rivers, as well as groundwater inflow to inland surface waters, are important controlling factors determining the actual amounts of nutrients entering the Baltic Sea. Biological, physical, morphological and chemical factors also retain and/or transform nutrients within river systems and surrounding river valleys before they enter the sea.

Another cause for increased nutrient levels in the sea, especially in the case of phosphorus, is the 'internal load' - phosphorus pools 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 this report.

Chapter 8 contains a list of definitions and abbreviations.

1.2 Data basis

The HELCOM countries annually report inputs from riverine and direct point sources to Baltic Sea sub-basins. Since the Fifth Pollution Load Compilation (HELCOM 2011) which included waterborne data from 1994 to 2008, data from 2009 and 2010 have been added. Most countries have updated or revised old PLC data covering the period 1994-2008 by providing missing data and/or correcting previously reported data. Further, the PLC-5.5 project, HELCOM LOAD[6] Core Group and BNI Sweden have made great efforts to fill in missing data and provide proposals for correcting of suspicious (HELCOM 2013b). By this, the most complete, consistent and quality assured PLC data set has been developed covering 1994-2010 waterborne inputs to the Baltic Sea. Filling in data gaps/missing data was considered necessary as no monitoring or modeling results were available or provided to HELCOM for some catchments. All changes, including filling in data gaps, have been discussed with the HELCOM countries; moreover, the PLC-5.5 data set has been approved by all the HELCOM Contracting Parties for use in the PLC-5.5 report and for revised calculations of the BSAP maximum allowable nutrient inputs (MAI) and the country-wise allocation of the reduction targets (CART). It should be noted, however, that Russia has not accepted to include the present Russian PLC-5.5 data in the PLC-database as official Russian data.

The most important data gaps and challenges that had to be solved to obtain a complete and consistent PLC-5.5 data set are summarized below (further details are given in HELCOM 2013b).

<u>Missing data:</u>

- Flow: e.g. all water flows from Latvia from 2009-2010 and unmonitored areas from 1994-2003 and 2007-2010. All Russian water flows from unmonitored areas and 16 small rivers.
- Nitrogen: e.g. all Latvian data from 2009-2010 and unmonitored areas from 1994-2003 and 2007-2010. Russia has reported nitrogen fractions for four rivers, but total nitrogen is missing from Pregolya and Seleznevka during 1994-2010, for Neva during 1994-1999 and 2006 and for Luga River during 1994-2000. Nitrogen data from unmonitored areas and 16 small rivers to the Gulf of Finland and to the Baltic Proper are missing.
- Phosphorus: e.g. all Latvian data from 2009-2010. Russia has reported dissolved phosphorus for four rivers, but total phosphorus is missing from Pregolya and Seleznevka during 1994-2010, and for Luga River during 1994-2000. Phosphorus data from unmonitored areas and 16 small rivers to the Gulf of Finland and to the Baltic Proper are missing.
- Some countries are missing data from direct waste water treatment plants and direct industry partly or fully for one or several years (water flow, nitrogen, phosphorus).

The following main challenges have been dealt with in order to complete the PLC-5.5 dataset (further details are given in HELCOM 2013b):

- Some countries only monitored and reported inorganic (dissolved) nutrient fractions for some years.
- Nemunas 1994: Nitrogen and phosphorus inputs were exceptionally high. Further, it has been clear that inputs from Matrosovka (a channel from the River Nemunas that enters from Lithuania into Kaliningrad region) were included into the total Nemunas inputs for some years and in other years excluded from it.
- There was no obvious explanation for very high inputs for some years in some rivers (the Odra and Vistula in Poland and the Neva in Russia).
- As mentioned above, total nitrogen and total phosphorus was missing for some or all years for the four monitored Russian rivers during 1994-2010, although total phosphorus was reported for Neva during all years. The reported total phosphorus input from Neva was for several years very high and reduced significantly by the LOAD Core Group and BNI based on additional information. For the four rivers, loads of inorganic, dissolved fractions were reported during 1994-2010, and total nitrogen and total phosphorus inputs estimated.
- Direct point source loads are included in unmonitored or coastal loads for some years; the reporting of direct point sources in many cases does not cover all point sources. Further, some countries sometimes include direct loads in unmonitored areas/coastal areas or even in monitored loads. This has not been solved completely,

6 Expert Group on follow-up of national progress towards reaching BSAP nutrient reduction targets (HELCOM LOAD)

which mainly affects the statistical analyses on trends on direct inputs from some countries to some Baltic Sea sub-basins, but does not affect total waterborne inputs.

Data on atmospheric inputs cover 1995-2010, where 1995-2008 data have been updated and recalculated compared with the PLC-5 Executive summary (HELCOM 2012). Emissions and monitored atmospheric deposition data are submitted by the countries to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP), which subsequently compiles and reports this information to HELCOM. To smooth the effects of changing weather conditions, riverine data have been flow normalized and the EMEP has developed a methodology and calculated normalized deposition data (HELCOM, in prep). Direct point source input to the Baltic Sea is not normalized as it is generally not affected by weather conditions. It is indicated in this report when the figures and tables are based on normalized data.

Waterborne transboundary inputs from other Contracting Parties and non-Contracting Parties are included in the inputs from the Contracting Party where these inputs enter the Baltic Sea. For example, the waterborne inputs to Gulf of Riga at the outlet of Daugava (in Latvia) include transboundary inputs from Russia and Belarus, and a minor contribution from Lithuania and Estonia; however, the inputs are included as part of the waterborne values from Latvia. The Lithuanian inputs to the Baltic Proper are based on the reported Lithuanian data and estimated inputs via the Matrosovka Canal, calculated by the PLC-5.5 Project. The estimated net transboundary waterborne inputs from non-Contracting and Contracting Parties, taking into account retention within surface waters, are included in **Tables 3.3a** and **3.3b**.

It should be noted that the figures presented are rounded (although not necessarily to the number of digits that corresponds to the level of accuracy) in order to avoid confusion when summing different numbers.

2 Long-term trends in emissions and inputs

2.1 Nitrogen and phosphorus inputs in the reference period 1997-2003

As mentioned in the Preface, the HELCOM Contracting Parties agreed - when adopting the HELCOM Baltic Sea Action Plan - to reduce their nutrient inputs so that good environmental status of the Baltic Sea can be achieved by 2021 (HELCOM 2007). The provisional reduction requirements were achieved by deducting maximum allowable nutrient inputs (MAI) to the Baltic Sea sub-basins from waterborne reference inputs and dividing the reduction requirement between the Contracting Parties according to specified allocation principles (see e.g. HELCOM 2013c). Inputs in the reference period 1997-2003 are given in **Table 2.1**. The reference input was defined as the average annual waterborne input in 1997-2003 based on the available PLC data set in 2007. Airborne nitrogen deposition was seen as a background input without any reduction targets in the BSAP 2007; the used average airborne nitrogen and phosphorus deposition in the reference period is also shown in **Table 2.1**. In the BSAP 2007, the MAI was approximately 602,000 tonnes of nitrogen and 21,000 tonnes of phosphorus waterborne inputs, respectively, leading to a reduction requirement on water inputs of 135,000 tonnes of nitrogen and 15,300 tonnes of phosphorus compared with the reference period.

The PLC data set has been updated (see **Chapter 1**) and the waterborne input in the reference period (1997-2003) has been flow normalized, resulting in a revised set of waterborne inputs for the reference period (**Table 2.2**). This data set has then been used for calculating the revised nutrient reduction scheme which was adopted by the 2013 HELCOM Copenhagen Ministerial Meeting (HELCOM 2013a). Also, nitrogen deposition has been recalculated and normalized for the reference period (**Table 2.2**). In the calculation of the revised MAI and new CART for the HELCOM Ministerial Meeting in 2013, contributions from Contracting Parties to atmospheric nitrogen deposition was taken into account when allocating the nitrogen reduction requirements between the HELCOM Contracting Parties. Further reduction is assumed on transboundary atmospheric nitrogen deposition originating from non-HELCOM sources and for waterborne nitrogen and phosphorus inputs from non-Contracting Parties (HELCOM 2013c). Only phosphorus deposition is considered as an input for which the sources are not identified and for which there is no expected reduction requirement.

The revised maximum allowable inputs calculated by BNI using the PLC-5.5 data set are 792,200 tonnes of nitrogen and 21,700 tonnes of phosphorus, leading to a reduction requirement of 118,100 tonnes of nitrogen and 15,200 tonnes of phosphorus compared to the inputs during the reference period 1997-2003 (HELCOM 2013a).

In order to evaluate the progress of countries in reaching their nutrient reduction targets and to assess the effectiveness of measures to reduce nutrient inputs, it is important to evaluate the long-term trends in emissions and inputs of nutrients. Thus, the development from 1994 to 2010 and

Table 2.1. BSAP 2007 waterborne, airborne and total inputs in the reference period (average of annual 1997-2003) according to BSAP 2007 (HELCOM, 2007).

Sub-basins/ inputs in tonnes	BSAP 2007 waterborne reference inputs		BSAP 2007 airborne input		BSAP 2007 total reference input	
	Total N	Total P	Total N	Total P	Total N	Total P
Bothnian Bay	51,436	2,585	8,820	550	60,256	3,135
Bothnian Sea	56,786	2,457	27,197	1,180	83,983	3,637
Baltic Proper	327,259	19,246	129,048	3,150	456,307	22,396
Gulf of Finland	112,680	6,860	12,828	450	125,508	1,136
Gulf of Riga	78,404	2,180	10,015	280	88,419	2,460
Danish Straits	45,893	1,409	23,711	350	69,604	1,759
Kattegat	64,257	1,573	20,364	310	84,621	1,883
Baltic Sea total	**736,714**	**36,310**	**231,983**	**6,270**	**968,698**	**42,580**

Table 2.2. **Waterborne, airborne and total inputs in the reference period (1997-2003) with a revised PLC-5.5 data set and revised atmospheric deposition, and the use of normalized input data as used for the calculation of the revised MAI and the new CART which were adopted by the HELCOM Ministerial Meeting in 2013. Note: The PLC-5.5 data set has been approved by HELCOM HOD 38/2012 for the development of the revised MAI, the new CART and the PLC-5.5 report; however, Russia has not accepted them as official data to be included in the PLC database. The data include transboundary inputs (waterborne and airborne) entering the Baltic Sea.**

Sub-basins/ inputs in tonnes	New reference waterborne inputs		New reference airborne inputs		New reference total input	
	Total N	Total P	Total N	Total P	Total N	Total P
Bothnian Bay	49,437	2,494	8,185	181	57,622	2,675
Bothnian Sea	54,605	2,379	24,767	394	79,372	2,773
Baltic Proper	297,679	17,274	126,243	1,046	423,921	18,320
Gulf of Finland	102,919	7,359	13,333	150	116,252	7,509
Gulf of Riga	78,373	2,235	10,045	93	88,417	2,328
Danish Straits	41,605	1,496	24,393	105	65,998	1,601
Kattegat	58,484	1,569	20,277	118	78,761	1,687
Baltic Sea total	**683,102**	**34,807**	**227,242**	**2,087**	**910,343**	**36,893**

a comparison between inputs during 2008-2010 (the most recent three-year average for a robust comparison) compared with the reference period (1997-2003) has been calculated and is summarized in this chapter.

The PLC-5.5 data set gives a lower waterborne input during the reference period than the PLC data used for BSAP 2007. This is due to both the correction of suspicious values and the use of flow normalized riverine inputs. In BSAP 2007, a rate of 15 kg phosphorus km^{-2} was used to calculate atmospheric deposition (**Table 2.1**), while 5 kg phosphorus km^{-2} has been used for the revised inputs during the reference period, based on new information from the Contracting Parties' monitoring data, **Table 2.2** (HELCOM, in prep.)

Some 25% of total nitrogen input during the reference period entered the Baltic Sea as atmospheric deposition while phosphorus deposition only constituted less than 6% of total phosphorus inputs.

2.2 Development in air emissions and atmospheric depositions of nitrogen

Data on atmospheric emissions and deposition of nitrogen on the Baltic Sea from HELCOM countries and other sources (non-HELCOM countries and shipping) are available from 1995. Emissions are compiled from the whole territory of the countries, but for Russia only a part of the territory is included. The area of the Russian territory was considerably extended in 2006, leading to higher emissions from Russia. Emissions from non-Contracting Parties also contribute significantly to nitrogen deposition on the Baltic Sea (see below). Annual emissions of total nitrogen from seven HELCOM countries have decreased from 1995-2010, (**Figure 2.1)**. According to the EMEP (EMEP 2012), emissions have decreased significantly since 1995. The largest reductions have been achieved by Denmark and Sweden, with 41% and 32% lower total nitrogen emissions to air in 2010 compared to 1995, respectively. Emissions from Estonia, Finland, Germany, Lithuania and Poland were 10-28% lower and the emissions from Latvia unchanged compared with 1995. Emissions from Russia increased with 28%, partly explained by the extension of the EMEP domain within the Russian territory which resulted in increased emissions after 2006 (Bartnicki 2012a). Also, some marked increases in emissions from Russia have been reported in 2007-2009. It should be pointed out, however, that the methodology of how emissions are calculated has changed between 1995 and 2010. Overall, the reduction of NO_x emissions was higher than the corresponding reduction in NH_x emissions from most HELCOM Contracting Parties.

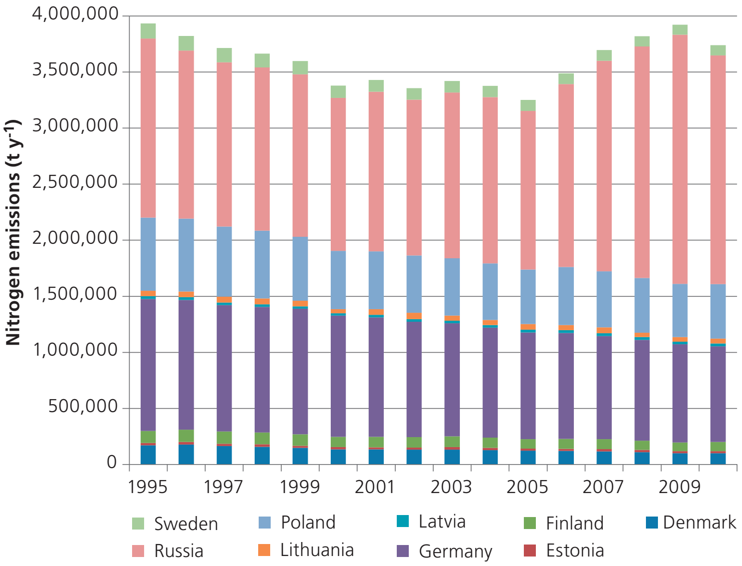


Figure 2.1. Annual atmospheric emissions of total nitrogen (tonnes per year) from individual HELCOM countries during 1995-2010. Note: the data cover emissions from the entire territories of the countries, except for Russia, where only emissions from the area covered by the EMEP domain are included. This area was significantly extended from 2006 resulting in a large increase of nitrogen emissions from Russia (Source: Bartnicki 2012a).

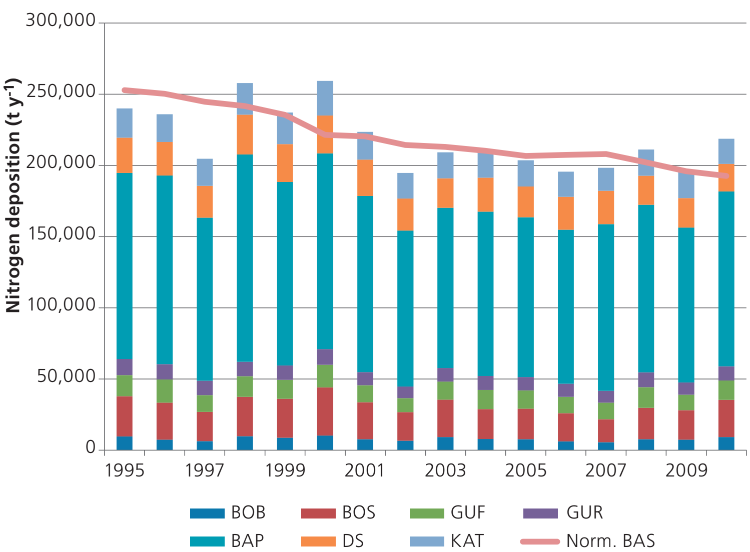


Figure 2.2. Annual actual atmospheric total nitrogen deposition (not normalized) on the Baltic Sea main sub-basins (bars) and annual normalized total nitrogen to the Baltic Sea (line) during 1995-2010 (tonnes nitrogen per year) (Source: Bartnicki 2012b).

In 2010, approximately 50% of nitrogen emissions were in oxidized form (NO_x), mainly resulting from combustion processes; the other 50% were in reduced form (NH_x), mainly ammonia from the agricultural sector. In Denmark, Latvia and Lithuania, NO_x only constituted about 40% of total nitrogen emissions but over 60% from Finland. In 1995, NO_x constituted an average 54% of the total emissions from the Contracting Parties and up to 73% from Finland. Emissions from shipping (NO_x) have been increasing since 2000 with growing shipping traffic - current estimates indicate a systematic annual increase of these emissions to be in the range of 2-3% (Bartnicki 2012a).

Deposition of total nitrogen is affected by climatic conditions and inter-annual variation of meteorological conditions, such as dominating wind direction, precipitation (intensity, frequency, distribution and type) and temperature. To evaluate to which extent decreased emissions have resulted in lower atmospheric deposition, the EMEP has for PLC work, in particular, introduced a procedure for the normalization of the annual deposition to the Baltic Sea during 1995-2010 to smooth the effect of inter-annual meteorological variation[7] (see HELCOM 2013c). **Figures 2.2** and **2.3** show the none-normalized (actual) atmospheric nitrogen deposition during 1995-2010 for the seven Baltic Sea sub-basins (**Figure 2.2**) and actual deposition on the Baltic Sea from the Contracting Parties and other sources (**Figure 2.3**) in the same period. A line has been included in both figures to show the normalized total nitrogen deposition to the Baltic Sea during 1995-2010. **Chapter 2.4** includes the results of the statistical analysis on the development in atmospheric nitrogen deposition, showing a significant decline in normalized depositions of total nitrogen for most Contracting Parties and the whole Baltic Sea. Nitrogen deposition to the Baltic Sea is reduced from approximately 240,000 tonnes in 1995 to some 193,000 tonnes of nitrogen in 2010 (Bartnicki 2012b). However, the actual atmospheric nitrogen deposition was rather high in 2010 (approximately 218,000 tonnes or 12% higher than in 2009) mainly related to rather high precipitation

7 For each year in this period, annual deposition is modeled 16 times by using the meteorological conditions for each year in the period and then taking an average of the 16 model runs (e.g. deposition for 1995 is calculated using meteorological conditions from 1995, 1996, 1997..., 2010, respectively, but using the same emission figures for each model run and then averaging the 16 estimates of the 1995 deposition to a normalized figure).

in that year over some parts of the Baltic Sea catchment area.

Russia has increased nitrogen emissions since 2006 as compared with 1995-2005 related to the previous mentioned inclusion of emissions from a larger part of Russia; however, as these sources are situated in distant areas east from the Baltic Sea, they have a small contribution to the nitrogen deposition to the sea. It should be noted that up to 40% of the deposition to the Baltic Sea originates from emissions outside the HELCOM countries ranging annually between 38-47% with the lowest shares in 2009 and 2010. Baltic Sea shipping amounted from 4-5% of total nitrogen deposition at the beginning of the period to 5-6% in later years.

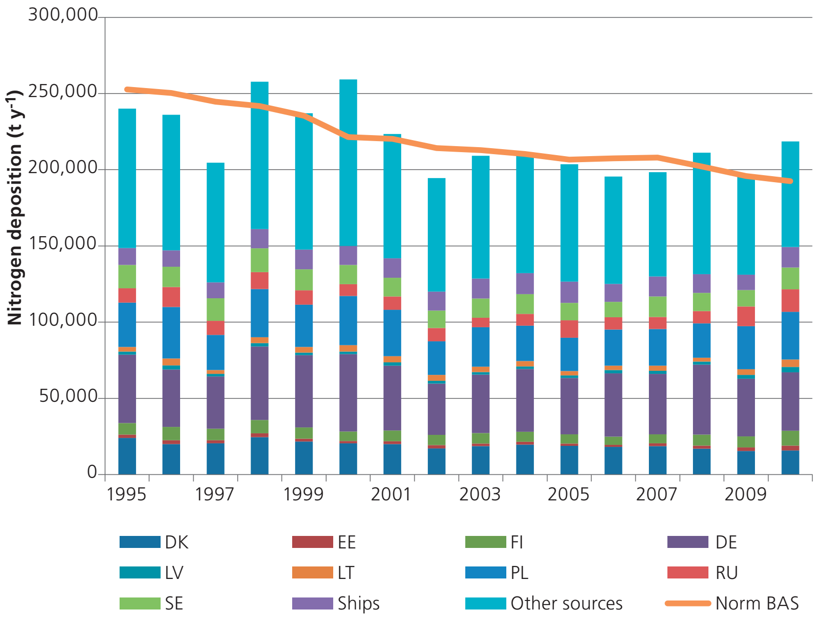


Figure 2.3. Annual actual atmospheric total nitrogen deposition from HELCOM Contracting Parties, Baltic Sea shipping (Ships) and other countries and sources (Other sources) on the Baltic Seas and annual normalized total nitrogen to the Baltic Sea (Norm BAS, line) during 1995-2010 (tonnes nitrogen per year).

2.3 Development in waterborne inputs of nutrients

Actual annual waterborne inputs (riverine and direct inputs) to the Baltic Sea of total nitrogen and total phosphorus by country (**Figures 2.4a** and **2.4b**) and by Baltic Sea sub-basin (**Figures 2.5a** and **2.5b**) show rather high annual variation making it difficult to compare inputs between years. When assessing trends in riverine and waterborne inputs into the Baltic Sea, the controlling influence of climatic conditions, mainly run-off, should be taken into account since there is a close correlation between run-off and nutrient inputs. During years with heavy precipitation and associated high run-off, more nitrogen and phosphorus are leached and eroded from cultivated areas, and most probably also from natural background areas, resulting in higher riverine nutrient inputs to the Baltic Sea than in dry years. Flow normalization of riverine input[8] data allows for a more correct evaluation of trends in the total waterborne inputs to the Baltic Sea as it, to some extent, can smooth out the annual variation caused by the weather conditions. The BNI carried out a flow normalization of annual total riverine inputs per country and per main Baltic Sea catchment sub-region. Subsequently, the Danish Centre for Environment and Energy (DCE), Aarhus University carried out trend analysis to evaluate whether there are any statistically significant decreases or increases in waterborne nitrogen and phosphorus inputs. Flow normalization of riverine inputs and trend analysis on normalized inputs is done with the methodology agreed upon by HELCOM LOAD (described in (Larsen & Svendsen, in prep.).

In **Figures 2.4a**, **2.4b**, the linear trend line on annual total flow normalized waterborne inputs of nitrogen is added to allow for visual inspection of trend in the time series of waterborne input. In Figures **2.5a** and **2.5b** the same is shown for phosphorus In **Chapter 2.4**, the statistical trend analyses are summarized. In cases where the trend is significant, the changes from 1994 to 2010 on the normalized waterborne inputs are given. It is quite clear that e.g. Denmark and total Baltic Sea have had significant decrease of waterborne inputs of nitrogen and phosphorus, as also confirmed by results of the statistical trend analysis in **Chapter 2.4**. The importance of weather conditions is rather clear when e.g. comparing the nitrogen and phosphorus waterborne inputs for most Contracting Parties in 2003 with the corresponding inputs in 1998. The high inputs from Poland in 2010 were due to two big flood events within one year (cf. **Figure 2.6**).

8 Flow normalization is only performed on riverine inputs, but not on the direct inputs from point sources as their discharges in general are independent on weather conditions. When mentioning flow normalized waterborne inputs it is the sum of flow normalized riverine inputs + actual direct inputs

Figure 2.4a. Actual annual total riverine + direct (waterborne) nitrogen inputs by Contracting Party to the Baltic Sea and the total inputs to the Baltic Sea. The trend for the flow normalized waterborne total nitrogen input is inserted as a line to indicate a possible trend (solid line = a statistically significant trend; dotted line = no statistically significant trend; see further explanations in **Chapter 2.4**). See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

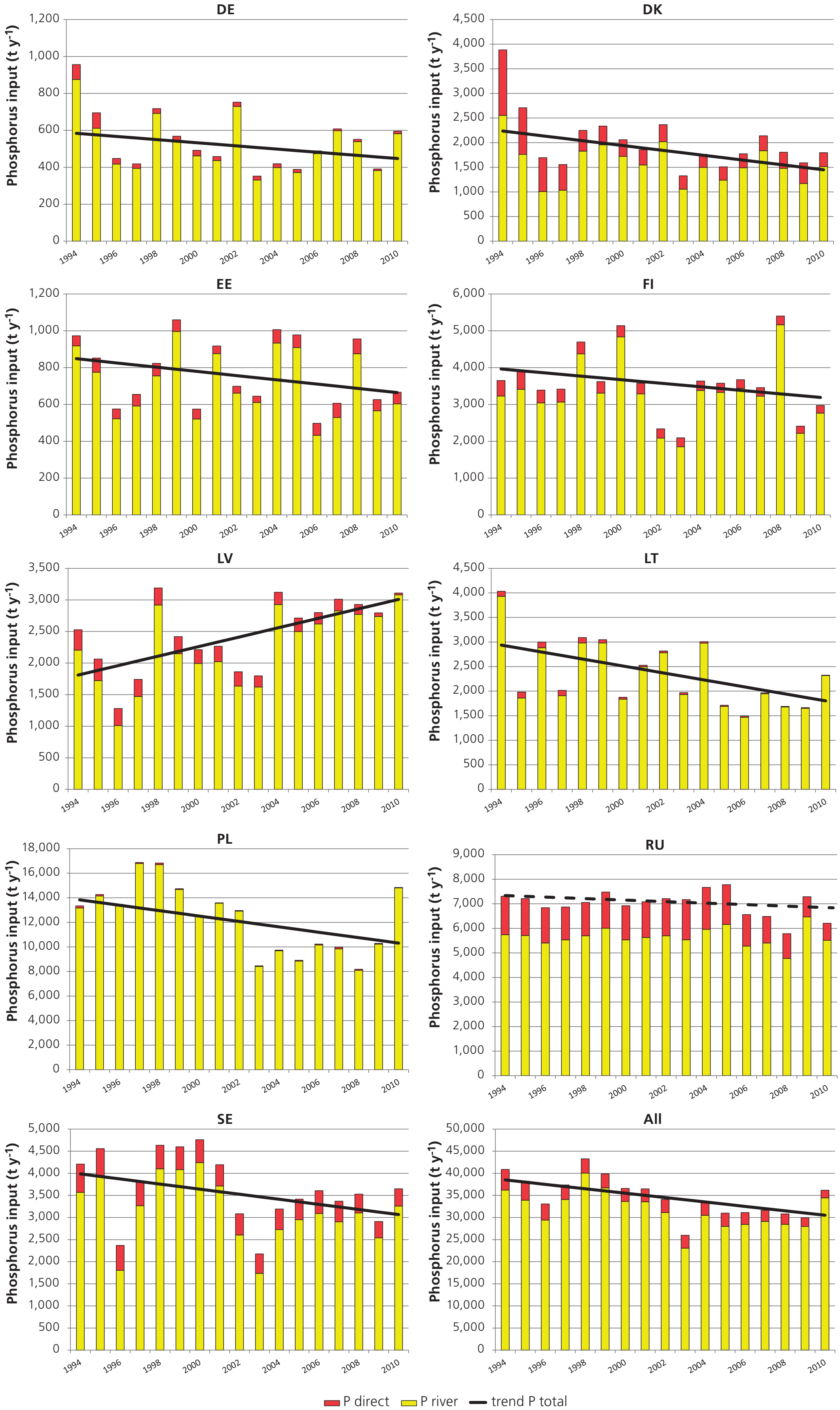


Figure 2.4b. Actual annual total riverine + direct phosphorus inputs by Contracting Party to the Baltic Sea and the total input to the Baltic Sea. The trend line for the flow normalized waterborne total phosphorus input is inserted as a line to indicate possible trend (solid line = a statistically significant trend; dotted line = no statistically significant trend; see further explanations in **Chapter 2.4**). See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

Figure 2.5a. Actual annual total riverine + direct nitrogen inputs to Baltic Sea sub-basin and total to the Baltic Sea. The trend line for the flow normalized waterborne total nitrogen input is inserted as a line to indicate possible trend (solid line = a statistically significant trend; dotted line = no statistically significant trend; see further explanations in **Chapter 2.4**). See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

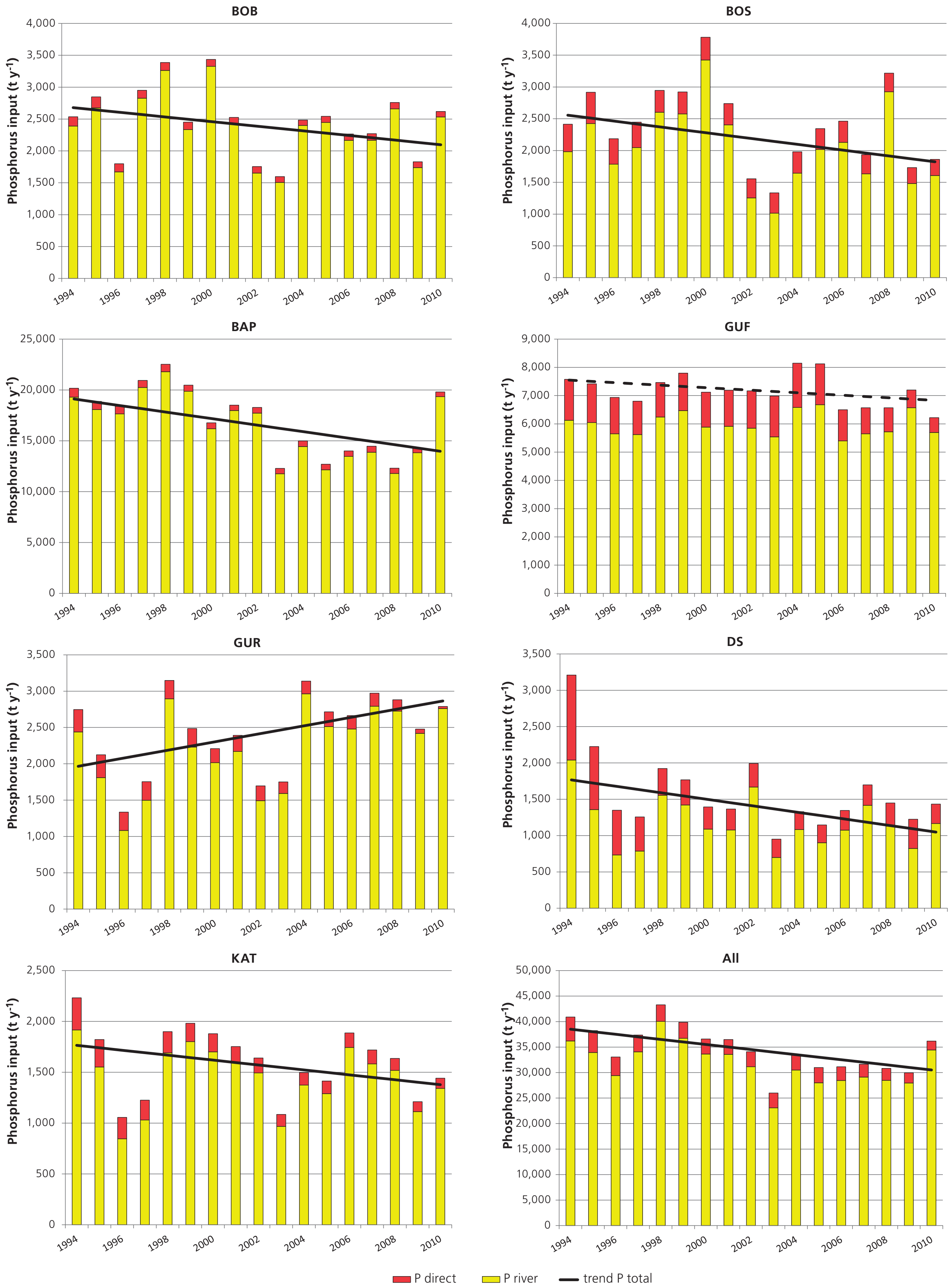


Figure 2.5b. Actual annual total riverine + direct phosphorus inputs to Baltic Sea sub-basin and the total input to the Baltic Sea. The trend line for the flow normalized waterborne total phosphorus input is inserted as a line to indicate possible trend (solid line = a statistically significant trend; dotted line = no statistically significant trend; see further explanations in **Chapter 2.4**). See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

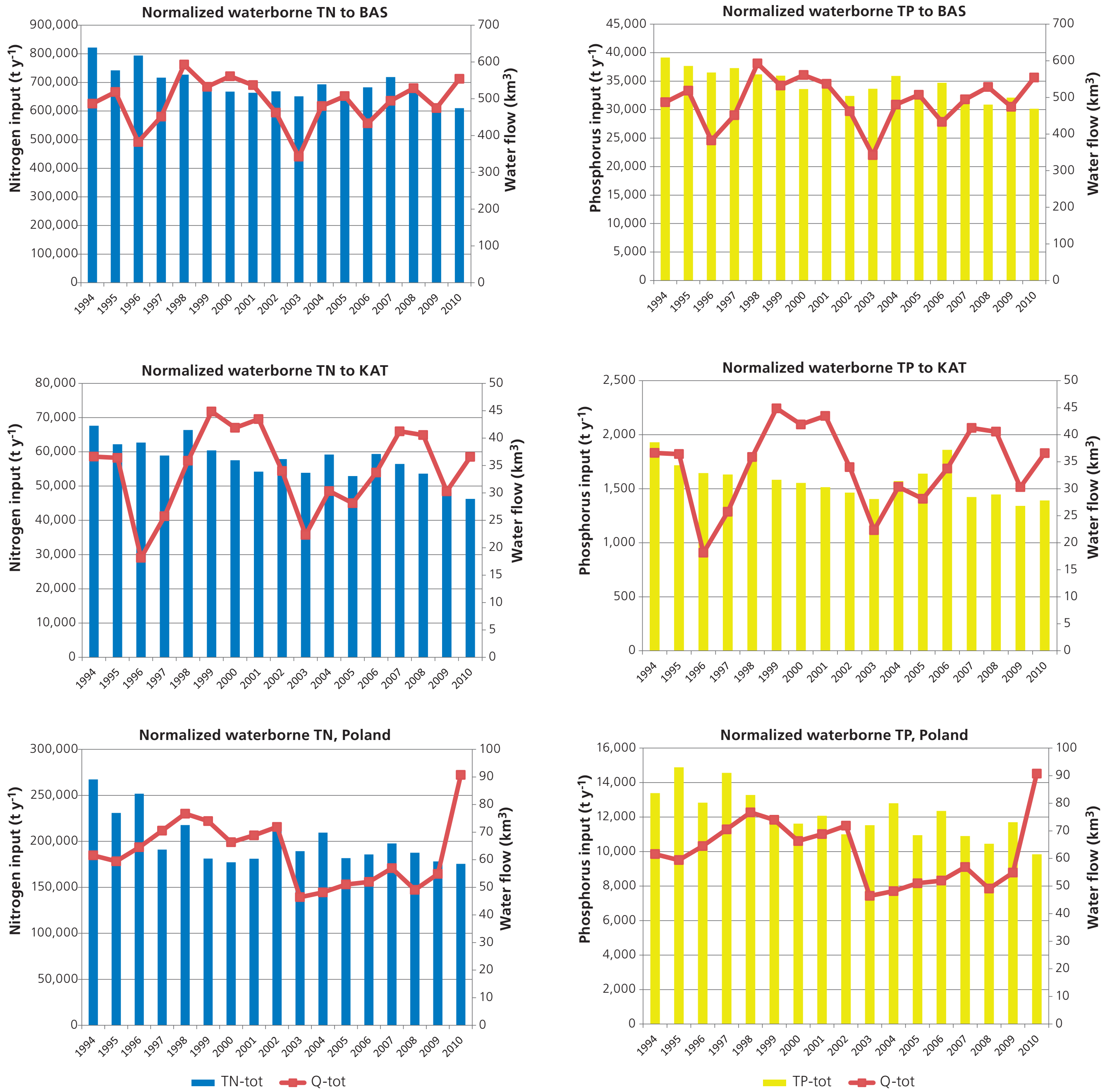


Figure 2.6. Flow normalized annual waterborne (riverine + direct) nitrogen and phosphorus inputs (left-axis, in tonnes per year) and water flow – Qtot (right y-axis, in km³) to the Baltic Sea (top), the Kattegat (middle) and from Poland (bottom). See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

As examples, flow normalized waterborne total nitrogen and phosphorus input to the Baltic Sea, Kattegat and from Poland are shown to illustrate the effect of flow normalization on waterborne inputs (**Figure 2.6**). Compared with **Figures 2.4** and **2.5**, it is quite obvious that flow normalization markedly smoothens out inter annual variation and therefore makes its easer to visually evaluate any trends in nutrient inputs to the Baltic Sea. Flow normalized waterborne inputs to all sub-basins by Contracting Party will be included in the PLC-5.5 report (HELCOM, in prep).

The proportion of direct inputs to the Baltic Sea constitutes only a small share of the total input to the Baltic Sea sub-basins (7% of total nitrogen and 11% of total phosphorus at the beginning of the period and 5% and 7%, respectively at the end of the period). Comparison between the Contracting Parties and between years for some of the given time series must be made with caution **(Figures 2.4** and **2.5).** The Contracting Parties have not compiled direct inputs in the same way and changes in methodology during the period 1994-2010 cannot be ruled out, e.g. including some point sources as a part of the riverine inputs some years and in the direct inputs in other years. Poland and Latvia are examples of countries that have a very low proportion of direct inputs of nitrogen and phosphorus (for both 0-1% only). **Chapter 4** provides further details on direct inputs and **Chapter 2.4** elaborates on the trends in direct inputs.

2.4 Trend analysis for water- and airborne inputs

A trend analysis study has been carried out by DCE, Aarhus University (Denmark), using Mann-Kendall methodology (Hirsch et al, 1982) on annual flow normalized riverine inputs (A); direct inputs (B); flow normalized waterborne inputs (C=A+B); normalized airborne inputs (D); and the total normalized inputs (E=C+D) of nitrogen and phosphorus for all relevant combinations of Contracting Parties and main sub-basins of the Baltic Sea. Where there is a significant trend, the annual changes were deducted with a Theil-Sen slope estimator (Hirsch et al., 1982) and the change from 1994 to 2010 was calculated (1995-2010 for airborne inputs). The methodology follows agreements by HELCOM LOAD (more information on trend analysis and determining the changes in input can be found in Larsen & Svendsen, in prep). The results of these statistical analyses for the Contracting Parties and main sub-basins are summarized in **Tables 2.3** to **2.6.** The graphs give the estimated slopes and percentage changes in inputs of nitrogen and phosphorus from 1994 to 2010 (for airborne input 1995-2010) for cases with a statistically significant trend with a confidence value less than 5%.[9] The figures in parentheses indicate results with confidence levels between 5-10%. No trend analyses were carried out on airborne phosphorus inputs as the same value (deposition rate) is used throughout the period 1995-2010.

9 The null hypothesis tested whether there is no linear trend in a data series. This means that if the test shows a low confidence (< 5%), the hypothesis is rejected and there is a high statistical certainty of a linear trend.

Normalized annual total nitrogen atmospheric deposition is reduced with statistical significance (confidence < 5%) for six Contracting Parties and from non-HELCOM EU countries (EU20), and other countries and sources (OC) (**Table 2.3**). The reduction to the Baltic Sea is 24% from 1995-2010 or more than 50,000 tonnes of nitrogen. Denmark has the highest relative reduction (40%), but also Finland, Germany, Poland, Sweden and the EU20 show marked reductions of between 23-34%. Atmospheric total nitrogen deposition from Russia and Baltic Sea shipping (SS) increased significantly, with 34% and 44% respectively, during the period.

Denmark, Germany, Poland and Sweden reduced their flow normalized total waterborne (riverine + direct) nitrogen input considerably (36%, 19%, 26% and 15%, respectively) from 1994 to 2010. These reductions are all statistically significant[10] as was the total input to the Baltic Sea (17%). Latvia and Lithuania also showed significant decreases but only with a confidence of between 5-10%; the Latvian data, however, must be interpreted with caution as the data from later years have been estimated due to the lack of reported data. The results from Lithuania are also influenced by very high flow normalized nitrogen inputs in 1994. Only Denmark (32%), Poland (26%) and Sweden (12%) show significant decreases with less than 5% confidence for flow normalized riverine inputs. Results of the trend analyses on direct inputs are included in **Chapter 4**. The total normalized nitrogen (waterborne + atmospheric) inputs to the Baltic Sea were significantly reduced with 16% from 1994 to 2010; Denmark (34%), Germany (23%), Poland (19%) and Sweden (15%) have also significantly reduced their combined airborne and waterborne inputs.

Flow normalized total phosphorus waterborne (riverine + direct) inputs were significantly reduced from all Contracting Parties and to the Baltic Sea (20%), except for Latvia where it increased significantly with 69%. As mentioned above, Latvian data are rather uncertain for 2008-2010 (**Table 2.4**). Denmark (34%), Lithuania (38%) and Poland (25%)

10 Changes in percentages have been calculated on normalized inputs as ((value 2010 – value 1994)/value 1994)*100% (for atmospheric input 1995 instead of 1994) when the statistical analysis indicated significant trend. The trends are statistically significant while the change in percentages should be interpreted as an estimated change from the beginning to the end the period 1994 (1995)-2010 on the normalized data series.

have the highest reductions in total flow normalized waterborne phosphorus inputs from 1994 to 2010. Reductions in direct phosphorus inputs play a rather important role for the reduction of total flow normalized waterborne phosphorus inputs to the Baltic Sea, as these are reduced with 49% compared with the 16% reduction on flow normalized riverine phosphorus inputs.

Table 2.3. Estimates of slope (annual change in tonnes per year) and percentage of change (calculated on normalized values as (((value 2010 – value 1994)/value 1994)) *100%) for the analyzed period of annual normalized airborne inputs, flow normalized riverine inputs, waterborne inputs (= direct + riverine inputs) and total normalized inputs of total nitrogen from the Contracting Parties and total inputs to the Baltic Sea (BAS) from 1994 to 2010 (airborne 1995 to 2010) based on a statistical trend analysis. Normalized airborne nitrogen deposition inputs from Baltic Sea shipping (SS), the EU20 (non-HELCOM EU countries including Croatia) and other sources such as other countries, North Sea shipping etc. (OC) are also included. Only the results where the trend is statistically significant (confidence < 5%) are shown (see footnotes 9 and 10); results are given in parentheses where the confidence is between 5-10%. See note to Table 2.2 regarding the preconditions on the PLC-5.5 data set.

	Airborne inputs		Riverine inputs		Waterborne inputs		Total nitrogen inputs	
	Estimated slope	Change since 1995	Estimated slope	Change since 1994	Estimated slope	Change since 1994	Estimated Slope	Change since 1994
	$t\,N\,y^{-1}$	%	$t\,N\,y^{-1}$	%	$t\,N\,y^{-1}$	%	$t\,N\,y^{-1}$	%
DE	-821	-25	-	-	-271	-19	-1,041	-23
DK	-649	-40	-1,064	-32	-1291	-36	-1,851	-35
EE	-15	-10	-	-	-	-	-	-
FI	-127	-23	-	-	-	-	-	-
LV	-	-	(-1,142)	(-22)	(-1,105)	(-21)	-	-
LT	-	-	(-1,263)	(-39)	(-1,309)	(-39)	-	-
PL	-599	-29	-3,525	-26	-3,550	-26	-3,128	-20
RU	212	44	-	-	-	-	-	-
SE	-313	-31	-872	-12	-1,163	-15	-1,422	-15
SS	230	34					230	34
EU20	-1,503	-34					-1,503	-34
OC	-296	-15					-296	-15
BAS	**-3,895**	**-24**	**-7,207**	**-16**	**-8,139**	**-17**	**-10,428**	**-16**

Table 2.4. Estimates of slope (annual change in tonnes per year) and percentage of change (see caption in Table 2.3) of the analyzed period of annual flow normalized riverine inputs, waterborne inputs (= riverine + direct inputs) and total normalized inputs of total phosphorus from the Contracting Parties and the total to the Baltic Sea (BAS) from 1994 to 2010 (airborne 1995 to 2010) from statistical trend analysis. As atmospheric phosphorus deposition is assumed constant during 1994-2010, the slope and change is zero and is thus not shown in the table (total deposition of phosphorus is nearly 2,100 tonnes). Only the results where the trend is statistically significant (confidence < 5%) are shown (see footnotes 9 and 10); the results where the confidence is between 5-10% are in parentheses. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

	Airborne inputs		Riverine inputs		Waterborne inputs		Total phosphorus inputs	
	Estimated slope	Change since 1995	Estimated slope	Change since 1994	Estimated Slope	Change since 1994	Estimated Slope	Change since 1994
	$t\,P\,y^{-1}$	%	$t\,P\,y^{-1}$	%	$t\,P\,y^{-1}$	%	$t\,P\,y^{-1}$	%
DE			(-5.5)	(-16)	-8.55	-23	-7.5	-20
DK			-23.2	-21	-49.2	-34	-41.8	-29
EE			-12.9	-26	(-11.5)	(-21)	-	-
FI			(-32)	(-15)	-48.2	-19	-45.1	-17
LV			85.6	100	74.9	69	86	75
LT			-63.4	-36	-71	-38	(-61)	(-33)
PL			-215	-24	-220	-25	-224	-24
RU			-	-	-	-	-	-
SE			-48.6	-22	-57.5	-23	-48.2	-18
BAS			**-354**	**-16**	**-499**	**-20**	**-476**	**-18**

Normalized total nitrogen atmospheric deposition decreased significantly to all seven Baltic Sea sub-basins (18-27%) from 1995 to 2010 (**Table 2.5**) and with 24% to the Baltic Sea. The Kattegat, the Danish Straits and the Baltic Proper also show a statistically significant decrease for both flow normalized riverine (21-29%) and waterborne (22-39%) nitrogen inputs from 1994 to 2010, while all sub-basins, except the Bothnian Sea and the Gulf of Riga, show a significant reduction in total normalized nitrogen inputs from 1994 to 2010.

For total normalized waterborne phosphorus inputs, significant decreases were calculated for the Bothnian Sea (28%), the Baltic Proper (26%), the Danish Straits (40%), and the Kattegat (22%). A significant decrease was also calculated for the Bothnian Bay (21%) but here the confidence level was between 5-10%. On the other hand, inputs increased with more than 50% to the Gulf of Riga (Latvia data are rather uncertain, especially for 2008-2010) and no significant trends were detected for the Gulf of Finland (**Table 2.6**.)

Table 2.5. Estimates of slope (annual change in tonnes per year) and percentage of change (calculated on normalized values as (((value 2010 – value 1994)/value 1994) *100%) for the analyzed period of annual normalized airborne inputs, flow normalized riverine inputs, waterborne inputs (= direct + riverine inputs) and total normalized inputs of total nitrogen by sub-basin and total inputs to the Baltic Sea (BAS) from 1994 to 2010 (airborne 1995 to 2010) based on a statistical trend analysis (see caption of Table 2.3). Only results where the trend is statistically significant (confidence < 5%) are shown (see footnotes 9 and 10); results where the confidence is between 5-10% are given in parentheses. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

	Airborne inputs		Riverine inputs		Waterborne inputs		Total nitrogen inputs	
	Estimated slope	Change since 1995	Estimated slope	Change since 1994	Estimated slope	Change since 1994	Estimated slope	Change since 1994
	t N y^{-1}	%	t N y^{-1}	%	t N y^{-1}	%	t N y^{-1}	%
BOB	-114	-20	-	-	-	-	-	-
BOS	-391	-22	-	-	-	-	-654	-12
BAP	-2206	-24	-4,256	-21	-4,655	-22	-6,077	-20
GUF	-177	-18	-	-	-	-	-516	-6
GUR	-160	-22	-	-	-	-	-	-
DS	-461	-26	-750	-29	-1,200	-39	-1,594	-32
KAT	-410	-27	-874	-22	-968	-23	-1,358	-23
BAS	**-3,895**	**-24**	**-7,207**	**-16**	**-8,139**	**-17**	**-10,428**	**-16**

Table 2.6. Estimates of slope (annual change in tonnes per year) and percentage of change (see caption in Table 2.3) of the analyzed period of annual flow normalized riverine inputs, waterborne inputs (= riverine + direct inputs) and total normalized inputs of total phosphorus by sub-basin and the total to the Baltic Sea (BAS) from 1994 to 2010 (airborne 1995 to 2010) from statistical trend analysis (see caption of Table 2.4). Only results where the trend is statistically significant (confidence < 5%) are shown (see footnotes 9 and 10); results where the confidence is between 5-10% are given in parentheses. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

	Airborne inputs		Riverine inputs		Waterborne inputs		Total phosphorus inputs	
	Estimated slope	Change since 1995	Estimated slope	Change since 1994	Estimated Slope	Change since 1994	Estimated slope	Change since 1994
	t P y^{-1}	%	t P y^{-1}	%	t P y^{-1}	%	t P y^{-1}	%
BOB			(-33)	(-21)	(-36,3)	(-21)	-	-
BOS			-35	-25	-45.8	-28	-47.1	-24
BAP			-297	-25	-321	-26	-331	-24
GUF			-	-	-	-	-	-
GUR			68.8	69	56.2	47	76.2	63
DS			-17.8	-23	-44.9	-40	-35.9	-30
KAT			-14.4	-15	-24.2	-22	-21.2	-17
BAS			**-354**	**-16**	**-499**	**-20**	**-476**	**-18**

Table 2.7 shows statistically significant changes in the total inputs of nitrogen and phosphorus from 1994 to 2010 for all relevant countries by sub-basin. The results of the trend test, slope estimator and changes from 1994 to 2010 for all country by sub-basin combinations are included in the PLC-5.5 report (HELCOM, in prep). Denmark, Germany (with exception of total phosphorus to the Baltic Proper) and Poland are the only Contracting Parties with significant reductions of total nitrogen and total phosphorus to all the main Baltic Sea sub-basins they have inputs to. Finland and Sweden have significant reductions of total nitrogen and phosphorus inputs to most sub-basins, but only partly to the Bothnian Bay and the Bothnian Sea; for Sweden, the reduction in total phosphorus inputs to the Kattegat is not significant. Latvia and Russia have either significant increases or no trends in total nitrogen and phosphorus inputs to Baltic Sea sub-basins; Lithuania has no trend in nitrogen and phosphorus inputs except for total phosphorus to the Baltic Proper. Overall, Denmark has the highest reduction in nitrogen and phosphorus input to different Baltic Sea sub-basins.

Atmospheric nitrogen deposition from Baltic Sea shipping has significantly increased to all sub-basins, but has significantly decreased from the EU20. For other countries (OC), there is a decrease to five sub-basins. There is an increase in deposition to the Kattegat and the Danish Straits, which partly might relate to higher deposition caused by North Sea shipping.

The average normalized total airborne plus waterborne inputs of total nitrogen and phosphorus during 2008-2010 are compared with the corresponding normalized reference inputs from **Table 2.2** and aggregated by country in **Table 2.8,** and by country and sub-basin in **Table 2.9** (total nitrogen) and **Table 2.10** (total phosphorus). The percentage of change since the reference period is calculated; however, it is not tested whether these

Table 2.7. Significant changes in total normalized nitrogen and phosphorus inputs (waterborne + atmospheric) to the Baltic Sea by country and by sub-basin from 1994 to 2010. For phosphorus, results are only given for cases when a country has waterborne inputs entering to a sub-basin. Only results where the trend is statistically significant (confidence < 5%) are shown (see footnotes 9 and 10); results where the confidence is between 5-10% are given in parentheses. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set. (SS = Baltic Sea shipping, EU20 = non-HELCOM EU countries including Croatia, OC = and other sources such as other countries, North Sea shipping etc., n.i. = no inputs from the Contracting Party to this sub-basin.)

	BOB		BOS		BAP		GUF		GUR		DS		KAT	
	N %	P %	N %	P %	N %	P%	N %	P %	N %	P %	N %	P %	N %	P %
DE	-29	n.i	-29	n.i.	-19	-	-29	n.i.	-29	n.i.	-26	-23	-26	n.i.
DK	-42	n.i	-42	n.i.	-40	-27	-42	n.i.	-42	n.i.	-38	-32	-29	-23
EE	-11	n.i	-11	n.i.	(-18)	-	-	-	-	-	-11	n.i.	-7.7	n.i.
FI	-	-18	-	(-19)	-32	n.i.	-20	-	-33	n.i.	-37	n.i.	-37	n.i.
LV	-	n.i.	-	n.i	-	88	-	n.i.	-	72	-	n.i.	-	n.i.
LT	-	n.i.	-	n.i.	-	(-33)	-	n.i.	-	n.i.	-	n.i.	-	n.i.
PL	-28	n.i.	-29	n.i.	-19	-24	-28	n.i	-29	n.i.	-27	n.i.	-28	n.i
RU	41	n.i	44	n.i.	10	-	-	-	44	n.i.	44	n.i.	43	n.i.
SE	-	-	-	-28	-19	-20	-37	n.i.	-39	n.i.	-38	-26	-18	-
SS	34		34		34		34		34		34		34	
EU20	-34		-33		-34		-33		-33		-33		-36	
OC	-21		-23		-16		-28		-24		10		8.8	

changes are statistically significant. The results can be used by the Contracting Parties to indicate how reductions of nutrient inputs to the Baltic Sea proceed; specific tests are currently being developed to statistically test for the fulfillment of BSAP nutrient reduction requirements (Larsen & Svendsen, in prep) and are expected to be included in the PLC-5.5 report against the CART approved by the 2013 HELCOM Ministerial Meeting (HELCOM, in prep). All Contracting Parties, except for Latvia and Russia, have lower normalized total nitrogen and phosphorus inputs (nitrogen and phosphorus inputs during 2008-2010) compared with the reference period. Latvia has a markedly higher total normalized phosphorus input; however, data from 2008-2010 are uncertain. Atmospheric deposition from Baltic Sea shipping increased with 15% (**Table 2.8**). For the Baltic Sea, the normalized total nitrogen and phosphorus inputs has decreased with approximately 10%, or with more than 80,000 tonnes of nitrogen and nearly 3,800 tonnes of phosphorus, respectively. More than 30,000 tonnes of the total nitrogen reduction is due to the reduction in the atmospheric deposition, of which 15,500 tonnes has been reduced by non-Contracting Parties (some 90% of this reduction is by the EU20 countries which are not HELCOM Contracting Parties). Inputs from Baltic Sea shipping have increased by more than 1,700 tonnes of nitrogen since the reference period to 2008-2010. It should be underlined that it has not been tested whether the changes are statistically significant and, for example for Finland, the decreases indicated in **Tables 2.8** to **2.10** might be due to that normalization does not adequately smooth all variations caused by weather conditions, especially in the catchments to the Bothnian Bay and Bothnian Sea.

The reduction in nitrogen inputs from the reference period to 2008-2010 (average during 2008-2010) is given separately for total normalized

Table 2.8. Percentage of change in the total normalized nitrogen and phosphorus inputs (waterborne + atmospheric) from the reference period (average of 1997-2003) to 2008-2010 (average) by country and for Baltic Sea shipping (SS); the EU20 countries that are not HELCOM Contracting Parties including Croatia (EU20); other non-HELCOM Contracting Parties and other sources contributing to atmospheric nitrogen deposition (other atm. sources); and atmospheric deposition of phosphorus (Atm. P dep.). See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Country (source)	New Reference total input 1997-2003 (tonnes)		Normalized input 2008-2010 (tonnes)		Change (%)	
	TN	TP	TN	TP	TN	TP
Denmark	70,490	1,928	56,538	1,745	-20	-10
Estonia	27,684	804	25,760	648	-7	-19
Finland	82,652	3,560	73,038	3,208	-12	-10
Germany	63,335	526	54,949	520	-13	-1
Latvia	77,959	2,227	79,960	2,811	3	26
Lithuania	46,335	2,635	41,546	1,834	-10	-30
Poland	220,606	12,310	204,637	10,666	-7	-13
Russia	93,598	7,178	95,518	6,310	2	-12
Sweden	130,279	3,639	113,891	3,315	-13	-9
Other atm. sources	28,009		26,360		-6	
Atm. P deposition		2,087		2,087		0
SS	11,868	0	13,592	0	15	-
EU20 atm. Dep.	57,528	0	43,618	0	-24	-
Baltic Sea total	**910,343**	**36,893**	**829,406**	**33,143**	**-9**	**-10**

inputs (**Table 2.9c**) and for atmospheric deposition (**Table 2.9e**).

Tables 2.9a-e and **Table 2.10a-c** summarize the calculations on the nitrogen and phosphorus input reductions between the reference period and the 2008-2010 period, given by country and by main Baltic Sea sub-basins. These tables provide detailed information on nutrient reductions and the data can be compared with the input ceilings for Contracting Parties and sub-basins which are calculated based on the MAI and CART which were agreed on by the 2013 HELCOM Ministerial Meeting. Overall the development in nitrogen and phosphorus inputs is rather comparable with the corresponding development from 1994 to 2010.

Table 2.9a. New reference level for total nitrogen air- and waterborne input (average normalized data 1997-2003) by country (source) and by sub-basin (tonnes nitrogen). SS = Baltic Sea shipping; EU20 = non-HELCOM EU countries including Croatia; OC = other non-HELCOM countries and other sources (e.g. North Sea shipping). See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Source/sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE	801	2,994	32,555	1,477	1,437	20,708	3,364	**63,336**
DK	226	854	10,046	376	374	28,587	30,027	**70,490**
EE	93	299	1,795	12,683	12,777	17	20	**27,685**
FI	34,389	27,978	1,993	17,903	250	60	79	**82,651**
LV	62	258	11,100	206	66,284	23	26	**77,959**
LT	108	464	44,920	294	437	51	61	**46,335**
PL	631	2,647	212,487	1,313	1,335	1,061	1,133	**220,607**
RU	696	1,465	14,831	75,754	510	164	178	**93,599**
SE	17,571	31,502	39,299	565	440	5,870	35,032	**130,278**
OC	1,090	3,793	15,278	2,166	1,572	1,958	2,152	**28,009**
SS	361	1,461	7,169	739	561	826	751	**11,868**
EU20	1,595	5,658	32,449	2,775	2,441	6,673	5,938	**57,528**
ALL	**57,622**	**79,372**	**423,921**	**116,252**	**88,417**	**65,998**	**78,761**	**910,344**

Table 2.9b. Changes in normalized total nitrogen air- and waterborne input from the reference period to the average of 2008-2010 in tonnes. SS = Baltic Sea shipping; EU20 = non-HELCOM EU countries including Croatia; OC = other non-HELCOM countries and other sources (e.g. North Sea shipping). See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Source/Sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE	-165	-616	-4,754	-304	-290	-1,673	-587	**-8,388**
DK	-67	-250	-2,493	-111	-109	-6,152	-4,771	**-13,951**
EE	-6	-17	-330	200	-1,768	-2	-1	**-1,925**
FI	-1,500	-4,697	-409	-2,921	-53	-15	-19	**-9,613**
LV	0	4	1,987	8	3	0	0	**2,001**
LT	-16	-71	-4,559	-45	-84	-7	-8	**-4,789**
PL	-75	-313	-15,017	-155	-161	-119	-130	**-15,970**
RU	316	660	1,746	-1,184	229	73	80	**1,919**
SE	-2,071	-1,770	-5,441	-118	-88	-1,083	-5,815	**-16,386**
OC	-107	-417	-941	-284	-164	134	131	**-1,649**
SS	53	212	1,041	107	81	120	109	**1,723**
EU20	-385	-1,337	-7,757	-650	-571	-1,694	-1,515	**-13,910**
ALL	**-4,023**	**-8,611**	**-36,928**	**-5,457**	**-2,974**	**-10,417**	**-12,528**	**-80,937**

Table 2.9c. Changes in **Table 2.9b** as percentage of values in **Table 2.9a**. SS = Baltic Sea shipping; EU20 = non-HELCOM EU countries including Croatia; OC = other non-HELCOM countries and other sources (e.g. North Sea shipping). See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

Source/Sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE	-21	-21	-15	-21	-20	-8	-17	**-13**
DK	-29	-29	-25	-30	-29	-22	-16	**-20**
EE	-7	-6	-18	2	-14	-10	-7	**-7**
FI	-4	-17	-21	-16	-21	-24	-24	**-12**
LV	1	2	18	4	0	-2	-1	**3**
LT	-14	-15	-10	-15	-19	-13	-13	**-10**
PL	-12	-12	-7	-12	-12	-11	-12	**-7**
RU	45	45	12	-2	45	45	45	**2**
SE	-12	-6	-14	-21	-20	-18	-17	**-13**
OC	-10	-11	-6	-13	-10	7	6	**-6**
SS	15	15	15	15	15	14	15	**15**
EU20	-24	-24	-24	-23	-23	-25	-26	**-24**
ALL	**-7**	**-11**	**-9**	**-5**	**-3**	**-16**	**-16**	**-9**

Table 2.9d. New reference level for total nitrogen deposition (average normalized data 1997-2003) by country (source) and by sub-basin (tonnes nitrogen). SS = Baltic Sea shipping; EU20 = non-HELCOM EU countries including Croatia; OC = other non-HELCOM countries and other sources (e.g. North Sea shipping). See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

Source/Sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE	801	2,994	25,708	1,477	1,437	7,865	3,364	**43,646**
DK	226	854	8,182	376	374	5,311	5,635	**20,956**
EE	93	299	661	680	247	17	20	**2,018**
FI	1,764	2,337	1,993	994	250	60	79	**7,476**
LV	62	258	967	206	441	23	26	**1,982**
LT	108	464	2,384	294	437	51	61	**3,799**
PL	631	2,647	19,655	1,313	1,335	1,061	1,133	**27,774**
RU	696	1,465	3,881	1,748	510	164	178	**8,643**
SE	758	2,537	7,916	565	440	384	941	**13,542**
OC	1,090	3,793	15,278	2,166	1,572	1,958	2,152	**28,009**
SS	361	1,461	7,169	739	561	826	751	**11,868**
EU20	1,595	5,658	32,449	2,775	2,441	6,673	5,938	**57,528**
ALL	**8,185**	**24,767**	**126,243**	**13,333**	**10,045**	**24,393**	**20,277**	**227,242**

Table 2.9e. Percentage change in the normalized total nitrogen deposition from the reference period to the average deposition of 2008-2010 in tonnes. SS = Baltic Sea shipping; EU20 = non-HELCOM EU countries including Croatia; OC = other non-HELCOM countries and other sources (e.g. North Sea shipping). See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

Source/Sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE	-21	-21	-18	-21	-20	-14	-17	**-17**
DK	-29	-29	-26	-30	-29	-23	-23	**-25**
EE	-7	-6	-6	-1	0	-10	-7	**-4**
FI	-9	-12	-21	-17	-21	-24	-24	**-15**
LV	1	2	5	4	13	-2	-1	**6**
LT	-14	-15	-19	-15	-19	-13	-13	**-18**
PL	-12	-12	-13	-12	-12	-11	-12	**-13**
RU	45	45	45	45	45	45	45	**45**
SE	-20	-19	-16	-21	-20	-18	-16	**-17**
OC	-10	-11	-6	-13	-10	7	6	**-6**
SS	15	15	15	15	15	14	15	**15**
EU20	-24	-24	-24	-23	-23	-25	-26	**-24**
ALL	**-9**	**-12**	**-14**	**-7**	**-11**	**-16**	**-17**	**-13**

Table 2.10a. New reference level for total of phosphorus air- and waterborne inputs (average normalized data 1997-2003) by country (source) and by sub-basin (tonnes nitrogen). OS: Other sources, such as atmospheric deposition, cannot be allocated to any specific country or source. See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

Source/Sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE	0	0	175	0	0	351	0	**525**
DK	0	0	59	0	0	1,040	829	**1,928**
EE	0	0	23	504	277	0	0	**804**
FI	1,668	1,255	0	637	0	0	0	**3,560**
LV	0	0	269	0	1,959	0	0	**2,228**
LT	0	0	2,635	0	0	0	0	**2,635**
PL	0	0	12,310	0	0	0	0	**12,310**
RU	0	0	960	6,218	0	0	0	**7,178**
SE	826	1,125	843	0	0	105	740	**3,639**
OS	181	394	1,046	150	93	105	118	**2,087**
ALL	**2,675**	**2,773**	**18,320**	**7,509**	**2,328**	**1,601**	**1,687**	**36,894**

Table 2.10b. Changes in the normalized total phosphorus air- and waterborne inputs from the reference period to the average of 2008-2010 in tonnes. OS: Other sources, such as atmospheric deposition, cannot be allocated to any specific country or source. See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

Source/Sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE	0	0	8	0	0	-14	0	**-5**
DK	0	0	-8	0	0	-72	-103	**-184**
EE	0	0	0	-99	-57	0	0	**-156**
FI	-184	-135	0	-32	0	0	0	**-352**
LV	0	0	145	0	438	0	0	**583**
LT	0	0	-801	0	0	0	0	**-801**
PL	0	0	-1,644	0	0	0	0	**-1,644**
RU	0	0	0	-868	0	0	0	**-868**
SE	76	-171	-135	0	0	-22	-72	**-324**
OS	0	0	0	0	0	0	0	**0**
ALL	**-108**	**-306**	**-2,435**	**-1,000**	**381**	**-108**	**-175**	**-3,751**

Table 2.10c. Changes in **Table 2.10b** as percentage of values in **Table 2.10a.** OS: Other sources, such as atmospheric deposition, cannot be allocated to any specific country or source. See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

Source/Sub-basin	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
DE			-5			-4		**-1**
DK			-14			-7	-12	**-10**
EE			0	-20	-20			**-19**
FI	-11	-11		-5				**-10**
LV			54		22			**26**
LT			-30					**-30**
PL			-13					**-13**
RU			0	-14				**-12**
SE	9	-15	-16			-21	-10	**-9**
OS	0	0	0	0	0	0	0	**0**
ALL	**-4**	**-11**	**-13**	**-13**	**16**	**-7**	**-10**	**-10**

3 Total nutrient inputs to the Baltic Sea in 2010

The annual nutrient inputs to the sea are often reported as total amounts by country and sub-basin. In addition to the total supply of nutrients to the sea, the environmental effects of the nutrients are also determined by their chemical form and the pathway of entering. Inorganic forms of nitrogen and phosphorus are normally readily available for algae, whereas organic nitrogen leached from coniferous forest areas, for example, is considered to have low direct bioavailability. Another aspect to consider is that considerable amounts of water-borne nutrients may be retained or transformed in coastal waters and thus not reach the open sea, as opposed to nitrogen deposited via the atmosphere.

The total nutrient input to the Baltic Sea can vary significantly depending on whether it is a wet or dry year. For example, 2010 was a very wet year in the southern part of the Baltic Sea catchment and the actual (not normalized) nutrient input figures presented in the PLC-5.5 report are therefore very high for some countries. Further, actual atmospheric deposition was also rather high in 2010. In this chapter, the status of actual nutrient inputs in 2010 is summarized with further details included in the PLC-5.5 report (HELCOM, in prep).

In 2010, the total water- and airborne inputs of nitrogen and phosphorus to the Baltic Sea were

Tables 3.1a and 3.1b. Water flow as well as actual (non-normalized) waterborne and airborne inputs of phosphorus and nitrogen to the Baltic Sea in 2010 by a) country and b) sub-basin. EU20 = non-HELCOM EU countries, including Croatia; 'other atm. Sources' and 'atmospheric phosphorus sources' = other countries and sources contributing to atmospheric deposition on the Baltic Sea. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Table 3.1a

Country	Flow	Nitrogen (t)			Phosphorus (t)		
	m³/s	Waterborne	Airborne	Total	Waterborne	Airborne	Total
Denmark	313	40,881	15,914	56,795	1,797		1,797
Estonia	452	25,362	3,180	28,542	667		667
Finland	2,326	62,255	9,722	71,977	2,973		2,973
Germany	128	24,145	38,327	62,472	596		596
Latvia	1,369	81,539	3,457	84,996	3,109		3,109
Lithuania	790	55,980	4,969	60,949	2,326		2,326
Poland	2,880	270,287	31,278	301,565	14,845		14,845
Russia	3,577	93,186	14,813	107,999	6,208		6,208
Sweden	5,863	104,702	14,207	118,909	3,649		3,649
Baltic Shipping			13,523	13,523			
EU20			39,987	39,987			
Other atm. sources			29,227	29,227			
Atm. P sources						2,087	2,087
Total	**17,698**	**758,337**	**218,604**	**976,941**	**36,168**	**2,087**	**38,255**

Table 3.1b

Country	Flow	Nitrogen (t)			Phosphorus (t)		
	m³/s	Waterborne	Airborne	Total	Waterborne	Airborne	Total
Bothnian Bay	3,136	43,267	9,140	52,407	2,618	181	2,799
Bothnian Sea	2,926	46,247	26,143	72,390	1,861	394	2,255
Gulf of Finland	4,068	108,347	13,600	121,947	6,220	150	6,370
Gulf of Riga	1,372	78,602	9,973	88,575	2,790	93	2,883
Baltic Proper	4,784	395,568	122,843	518,411	19,806	1,046	20,852
Danish Straits	238	38,110	19,341	57,451	1433	105	1,538
Kattegat	1,173	48,197	17,564	65,761	1,442	118	1,560
Total	**17,698**	**758,337**	**218,604**	**976,941**	**36,168**	**2,087**	**38,255**

977,000 tonnes of nitrogen and 38,300 tonnes of phosphorus, respectively (**Tables 3.1a** and **3.1b**). Atmospheric nitrogen deposition amounted to 218,600 tonnes, or 22% of the total nitrogen input. Atmospheric phosphorus deposition, which is assumed to be the same every year, constituted 5% of the total phosphorus input to the Baltic Sea (**Table 3.1a**). To take into account the influence of weather conditions, the flow normalized waterborne and normalized airborne inputs to the Baltic Sea has also been calculated (**Tables 3.2a** and **3.2b**). The total normalized nitrogen and phosphorus inputs in 2010 were considerably lower than the actual inputs (802,000 tonnes of nitrogen (18% lower) and 32,200 tonnes of phosphorus (16% lower)). The normalized nitrogen atmospheric deposition was 193,000 tonnes nitrogen or 24% of the total nitrogen input to the Baltic Sea. Normalized total nitrogen inputs, especially from Poland, Lithuania and Russia, is considerably lower than the actual total inputs, while they are higher for Finland. See also note to **Table 2.2** regarding the preconditions on the PLC-5.5 data set.

Table 3.2a and 3.2b. Flow normalized waterborne and normalized airborne inputs of phosphorus and nitrogen to the Baltic Sea in 2010 by a) country and b) sub-basin. EU20 = non-HELCOM EU countries (including Croatia); 'other atm. sources' and 'atmospheric phosphorus sources' = other countries and sources contributing to atmospheric deposition on the Baltic Sea. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Table 3.2a

Country	Flow	Nitrogen (t)			Phosphorus (t)		
	m^3/s	Waterborne	Airborne	Total	Waterborne	Airborne	Total
Denmark	313	38,095	15,334	53,429	1,706		1,706
Estonia	452	22,491	1,993	24,484	612		612
Finland	2,326	67,213	6,411	73,624	3,297		3,297
Germany	128	21,991	35,090	57,081	564		564
Latvia	1,369	67,315	2,165	69,480	2,548		2,548
Lithuania	790	38,428	3,233	41,661	2,015		2,015
Poland	2,880	175,475	24,396	199,871	9,842		9,842
Russia	3,577	81,182	11,491	92,673	6,050		6,050
Sweden	5,863	97,713	11,330	109,043	3,527		3,527
Baltic Shipping			13,840	13,840			
EU20			42,046	42,046			
Other atm. sources			25,226	25,226			
Atm. P sources						2,087	2,087
Total	**17,698**	**609,903**	**192,555**	**802,458**	**30,161**	**2,087**	**32,248**

Table 3.2b

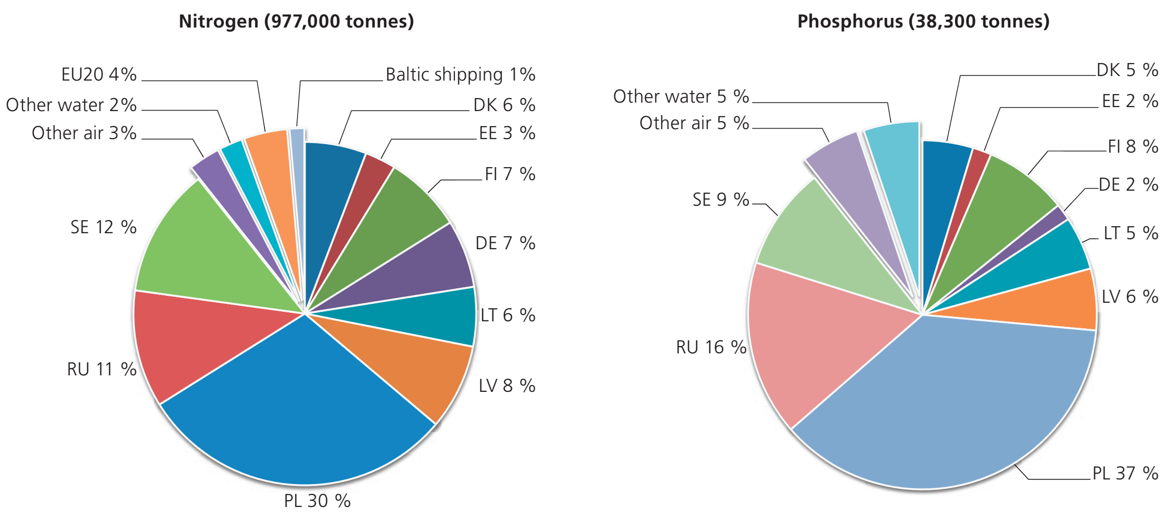
Country	Flow	Nitrogen (t)			Phosphorus (t)		
	m^3/s	Waterborne	Airborne	Total	Waterborne	Airborne	Total
Bothnian Bay	3,136	44,582	7,258	51,840	2,748	181	2,929
Bothnian Sea	2,926	48,635	21,347	69,982	2,045	394	2, 439
Gulf of Finland	4,068	95,536	12,015	107,551	6,114	150	6,264
Gulf of Riga	1,372	66,240	8,691	74,931	2,303	93	2,396
Baltic Proper	4,784	271,695	106,589	378,284	14,190	1,046	15,236
Danish Straits	238	36,955	20,091	57,046	1,369	105	1,474
Kattegat	1,173	46,260	16,564	62,824	1,392	118	1,510
Total	**17,698**	**609,903**	**192,555**	**802,458**	**30,161**	**2,087**	**32,301**

The contributions of the HELCOM Contracting Parties to the actual total inputs of nitrogen and phosphorus to the Baltic Sea in 2010 are given in **Figure 3.1**. For total water and airborne inputs of nitrogen to the Baltic Sea in 2010, the greatest contributors were Poland (30%), Sweden (12%) and Russia (11%). For phosphorus, Poland is the greatest contributor with 37%, followed by Russia (16%) and Sweden (9%). The shares are markedly affected by the unusually high amount of precipitation in the Polish catchment in 2010, which gives Poland a high proportion of total actual inputs in 2010. Calculated as normalized inputs, Poland's contribution of nitrogen and phosphorus to the Baltic Sea is 24% and 30%, respectively. Transboundary atmospheric nitrogen deposition inputs from non-Contracting Parties (EU20 and other atmospheric sources) and from Baltic Sea shipping constituted more than 8% of the total nitrogen inputs to the Baltic Sea in 2010 (**Figure 3.1).**

The Baltic Sea also receives transboundary waterborne nitrogen and phosphorus inputs originating from five non-HELCOM countries: Belarus, Czech Republic, Norway, Slovakia and Ukraine. In 2010, these inputs constituted 2% of total nitrogen and 5% of phosphorus inputs to the Baltic Sea; for some basins, they play a greater role such as for phosphorus inputs to the Gulf of Riga. In most tables and figures in the report, the waterborne transboundary input entering the Baltic Sea is included in the waterborne inputs from the receiving Contracting Parties. Transboundary inputs from other HELCOM Contracting Parties entering the Baltic Sea - as from Lithuania to Latvia and Russia, Poland to Russia, Germany to Poland, and Finland to Russia - are also included in the riverine inputs of the downstream Contracting Parties unless otherwise indicated. Two rivers, the Torne and Narva are border rivers where the inputs to the Baltic Sea have been divided according to agreed proportions between the bordering countries. For the Odra, which is a border river between Poland and Germany at its outlet and also receives riverine inputs from the Czech Republic, the total inputs are included as the waterborne input from Poland.

In **Tables 3.3a** and **3.3b**, the waterborne transboundary net nitrogen and phosphorus inputs from non-Contracting Parties (**Table 3.3a**) and from Contracting Parties as given (**Table 3.3b**) as compiled by BNI (Gustavsson & Mörth, in prep) and additional information is included in the HELCOM PLC-5.5 report (HELCOM, in prep). The largest amounts of transboundary waterborne nutrient inputs to the Baltic Sea originate from Belarus and drain via Latvia and Lithuania.

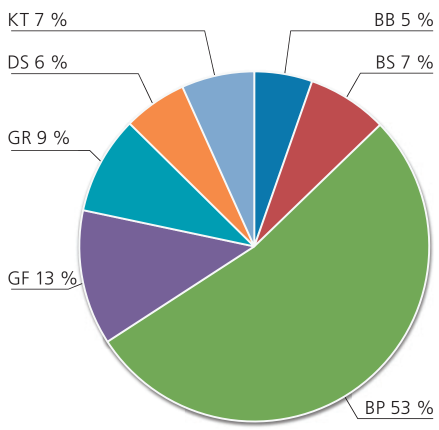
In total, more than 10% of the total nitrogen and more than 5% of the total phosphorus inputs

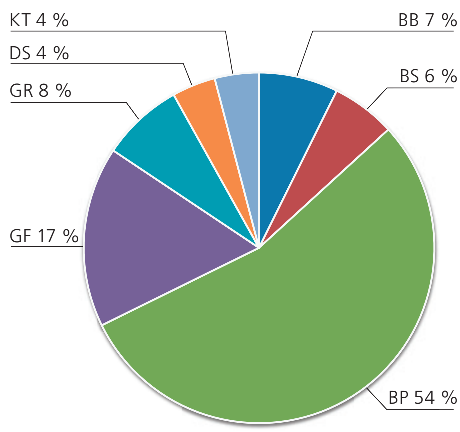


Figures 3.1a and 3.1b. Total actual water- and airborne inputs of nitrogen and phosphorus to the Baltic Sea in 2010 by HELCOM Contracting Parties and other sources. Atmospheric nitrogen deposition is divided into Baltic shipping, EU20 (the 20 non-HELCOM EU countries including Croatia) and 'other air' - which for nitrogen is other non-HELCOM countries and other distant sources (such as North Sea shipping) and for phosphorus all atmospheric sources. 'Other water' is transboundary waterborne inputs from non-HELCOM Contracting Parties entering the Baltic Sea (see Table 3.3a). See also note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

to the Baltic Sea originate from distant sources outside HELCOM countries; for phosphorus, however, it is not possible to divide atmospheric deposition on different sources as no emission sources have been quantified (**Figure 3.1**).

Of the Baltic Sea sub-basins, the Baltic Proper received by far the greatest proportion of nutrient inputs in 2010 (**Figure 3.2**). More than 50% of both total nitrogen and phosphorus inputs to the Baltic Sea enter the Baltic Proper. The second highest amount enters the Gulf of Finland (13% of total nitrogen and 17% of total phosphorus), while the remaining seven sub-basins receive between 4-9% of the total inputs of nitrogen and phosphorus per sub-basin.





Figures 3.2a and 3.2b. Total actual water- and airborne inputs of nitrogen and phosphorus to the Baltic Sea by sub-basin in 2010. See note to Table 2.2 regarding the preconditions on the PLC-5.5 data set.

Table 3.3a. Transboundary riverine inputs from non-HELCOM countries in the Baltic Sea catchment area (in tonnes per year) used in the CART calculations. The retention coefficient is from Table 9.4 in Gustafsson and Mörth (in prep). All data are averaged 1997-2003 except for the Belarusian data which are averaged 2004-2011. Input at the border is multiplied with the retention coefficient to estimated net waterborne input to the Baltic Sea. 'Share of inputs to the sub-basin' expresses in percentages how large a proportion of the total waterborne input to a sub-basin originates from the non-Contracting Party during the reference period.

From	Via	To	Border		Retention		To Baltic		Share of input to the sub-basin	
			TN (t)	TP (t)	TN (t)	TP (t)	TN (t)	TP (t)	TN (%)	TP (%)
Czech	Poland	BAP	5,700	410	0.4	0.28	3,420	295	1.1	1.7
Belarus	Lithuania	BAP	13,600	914	0.54	0.53	6,256	430	2.1	2.5
Ukraine	Poland	BAP	4,124	127	0.4	0.28	2,474	91	0.8	0.5
Belarus	Poland	BAP	5,071	331	0.4	0.28	3,043	238	1.0	1.4
Total		**BAP**					**15,193**	**1,055**	**5.1**	**6.1**
Belarus	Latvia	GUR	8,532	1,360	0.27	0.32	**6,228**	**925**	**7.9**	**41.4**

Table 3.3b. **Transboundary riverine inputs between HELCOM Contracting Parties (in tonnes per year) in the reference period. The input at the border is multiplied with the retention coefficient to estimate net waterborne transboundary inputs to the Baltic Sea. See also note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.**

From	Via	To	Border		Retention		To Baltic	
			TN (t)	TP (t)	TN (t)	TP (t)	TN (t)	TP (t)
Lithuania	Latvia	BAP	5,516	158	0.39	0.58	3,365	66
Poland	Russia	BAP	4,400	320	0.30	0.37	3,080	202
Germany	Poland	BAP					2,337	101
Total		**BAP**					**8,782**	**369**
Lithuania	Latvia	GUR	7,185	282	0.27	0.32	5,245	192
Russia	Latvia	GUR	4,256	734	0.54	0.71	1,957	215
Total		**GUR**					**7.202**	**407**
Finland	Russia	GUF			0.48	0.82	5,353	49

In 2010, the Baltic Proper received a much higher proportion of total nitrogen and phosphorus inputs (53% and 55%, respectively) than the share of the catchment area to this sub basin (33%) of the total Baltic Sea catchment area (**Table 3.4**). This is partly explained by exceptionally high run-off and high nutrient inputs, for example from Poland caused by floods (for normalized 2010 data, the share of nitrogen and phosphorus inputs to the Baltic Proper was 47%). The Danish Straits is the sub-basin that received the highest proportion of nitrogen and phosphorus compared with its share of the total Baltic Sea catchment. This reflects the high population density and human activity in both the sub-catchment of the Danish Straits and the Baltic Proper. On the other hand, the Bothnian Bay and the Bothnia Sea received a low share of total inputs to the Baltic Sea compared to their proportion of the total catchment area, which also corresponds with the low population density and low agricultural activity in these catchment areas. Comparing shares of inputs with shares of the Baltic Sea sub-basin marine surface areas suggests high inputs for the Gulf of Riga and low inputs for the Bothnian Sea (**Table 3.4**).

To provide further details on the actual waterborne inputs in 2010, the specific water flow (in l s^{-1} km^{-2}) and area-specific input of waterborne nitrogen and phosphorus in kg km^{-2} per catchment area have been elaborated by BNI and are shown by major sub-catchment and by Contracting Party in **Figures 3.3a**, **3.3b** and **3.3c**, respectively. Information on area-specific nutrient inputs, expressed as kg km^{-2}, makes it possible to directly compare nutrient inputs from different sub-regions and countries around the Baltic Sea, irrespective of the catchment size.

Table 3.4 The proportion of total water- and airborne nitrogen and phosphorus inputs in 2010 to Baltic Sea sub-basins of the total input to the Baltic Sea, the proportion of the main sub-basin catchment area of the total Baltic Sea catchment area and the proportion of the sub-basin's marine surface area of the total Baltic Sea surface area. See also note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Country	Total input	Total input	Catchment area	Marine area
	N (%)	P (%)	%	%
Bothnian Bay	5.4	7.3	15.1	8.7
Bothnian Sea	7.4	5.9	13.4	18.9
Gulf of Finland	12.5	16.7	24.0	7.2
Gulf of Riga	9.1	7.5	7.4	4.5
Baltic Proper	53.1	54.5	33.4	50.2
Danish Straits	5.9	4.0	1.6	5.0
Kattegat	6.7	4.1	5.1	5.7
Total	**100**	**100**	**100**	**100**

Specific run-off (water flow) is highest from the mountainous part of Sweden, northern Sweden and Finland (up to 16 l s^{-1} km^{-2}), and lowest in the southeastern part of the Baltic Sea catchment with 4-6 l s^{-1} km^{-2}. The area-specific losses of nitrogen and phosphorus show a different pattern. There is a rather clear southwest to northeast gradient with the highest area-specific waterborne input from catchments in Denmark, Germany and Poland, and with the lowest area-specific nitrogen loss in northern Sweden. The range is from 100 to more than 1,500 kg nitrogen km^{-2}. There are also areas in southern Finland and parts of the Baltic States with rather high area-specific nitrogen losses. High losses often reflect intensive agriculture and land-use, especially in catchments with a relatively

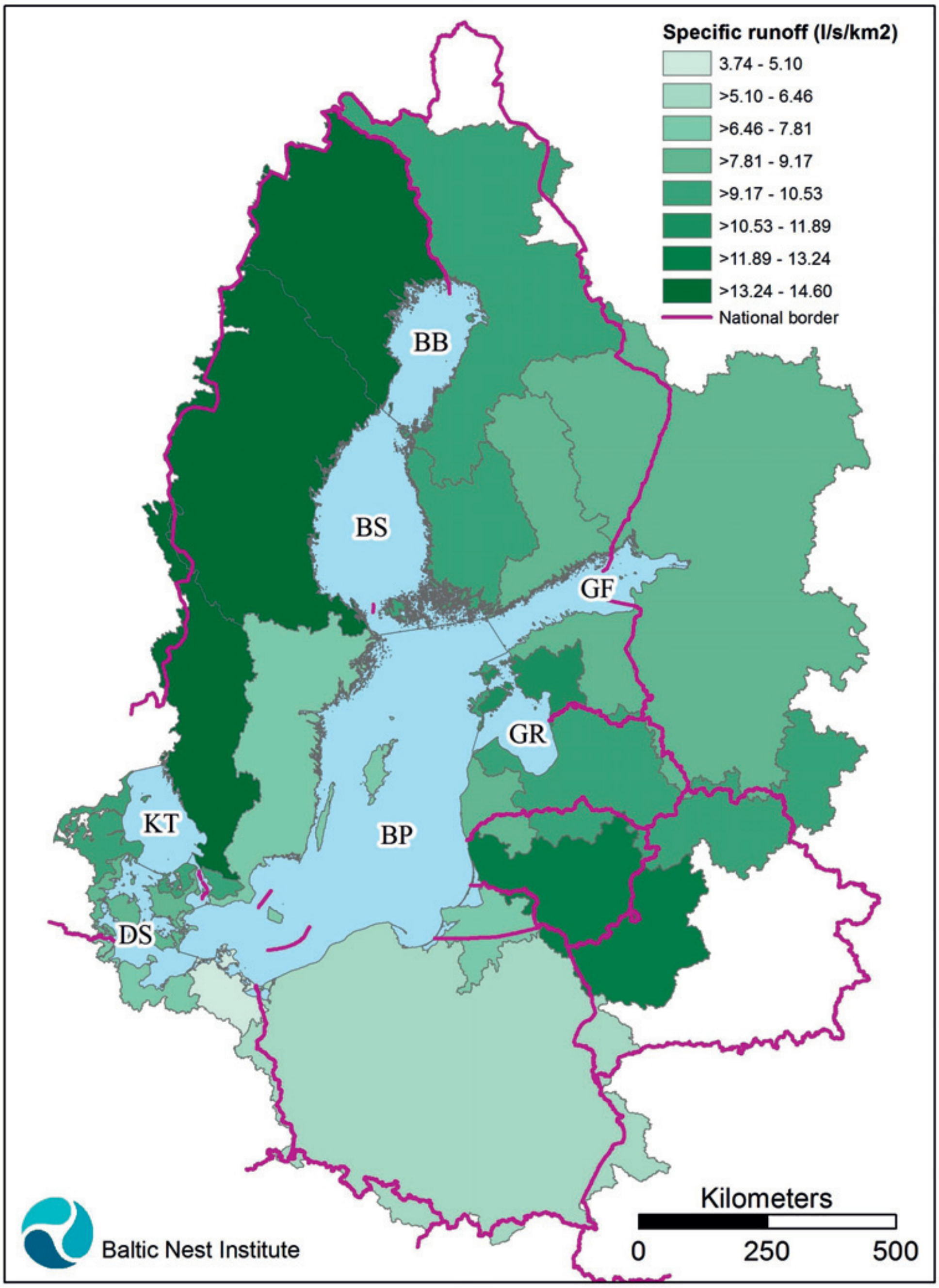


Figure 3.3a. Area-specific run-off (water flow, l s^{-1} km^{-2}) in 2010 calculated per main sub-catchment and per country. See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

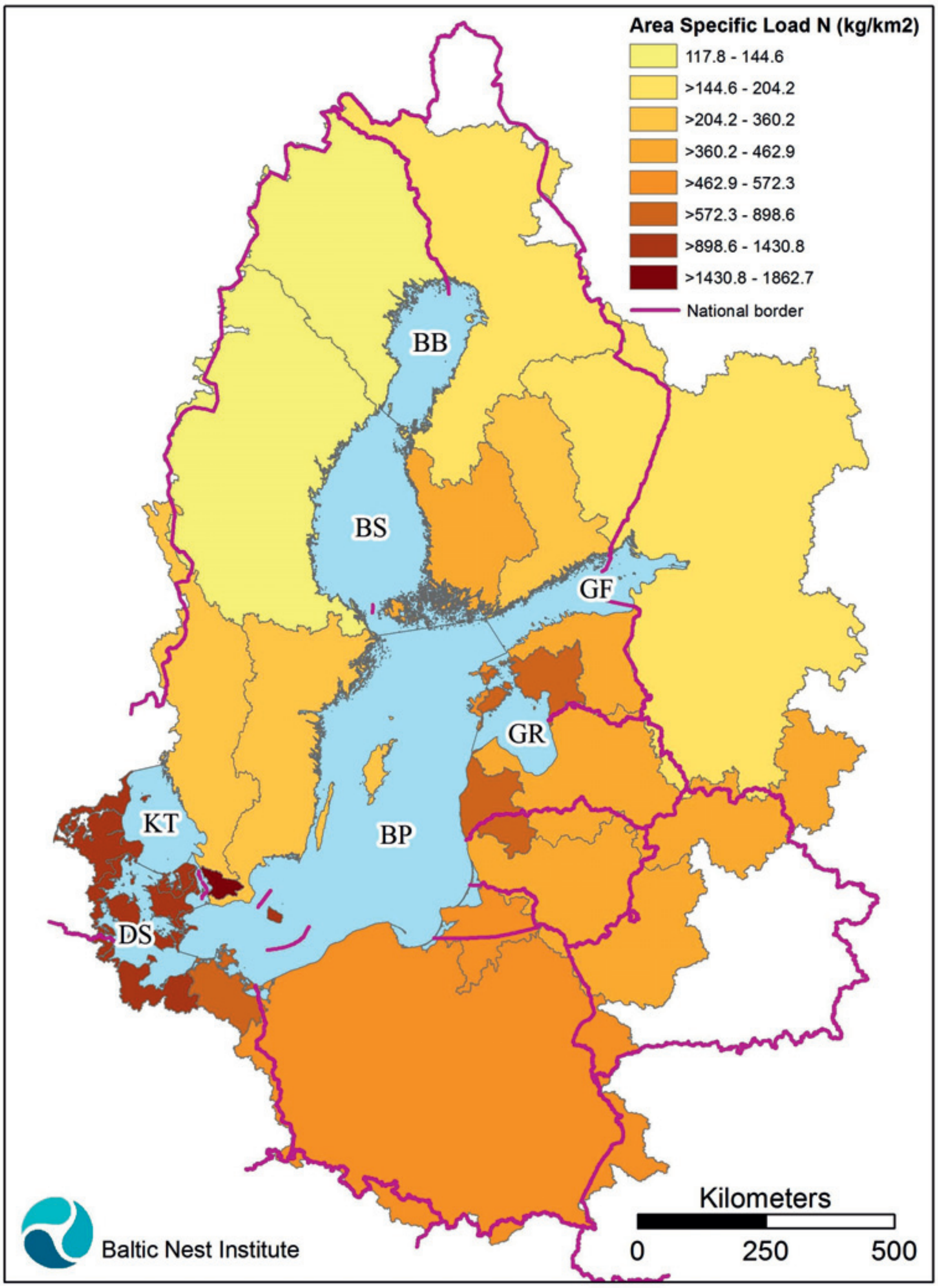


Figure 3.3b. Area-specific riverine nitrogen inputs (kg km^{-2}) in 2010 calculated per main sub-catchment and per country. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

low proportion of wetlands and lakes. The overall pattern for area-specific phosphorus losses is similar to that of nitrogen, with the highest losses in Denmark, Germany and Poland, but also rather high losses from southern Finland and parts of the Baltic States. As with nitrogen, this is related to intensive farming, but is also linked to high population densities with higher inputs of wastewater and the efficiency level in treatment of wastewater; it also reflects soil types and natural phosphorus contents in soils. Area-specific phosphorus inputs range from about 5 to more than 60 kg P per km^2.

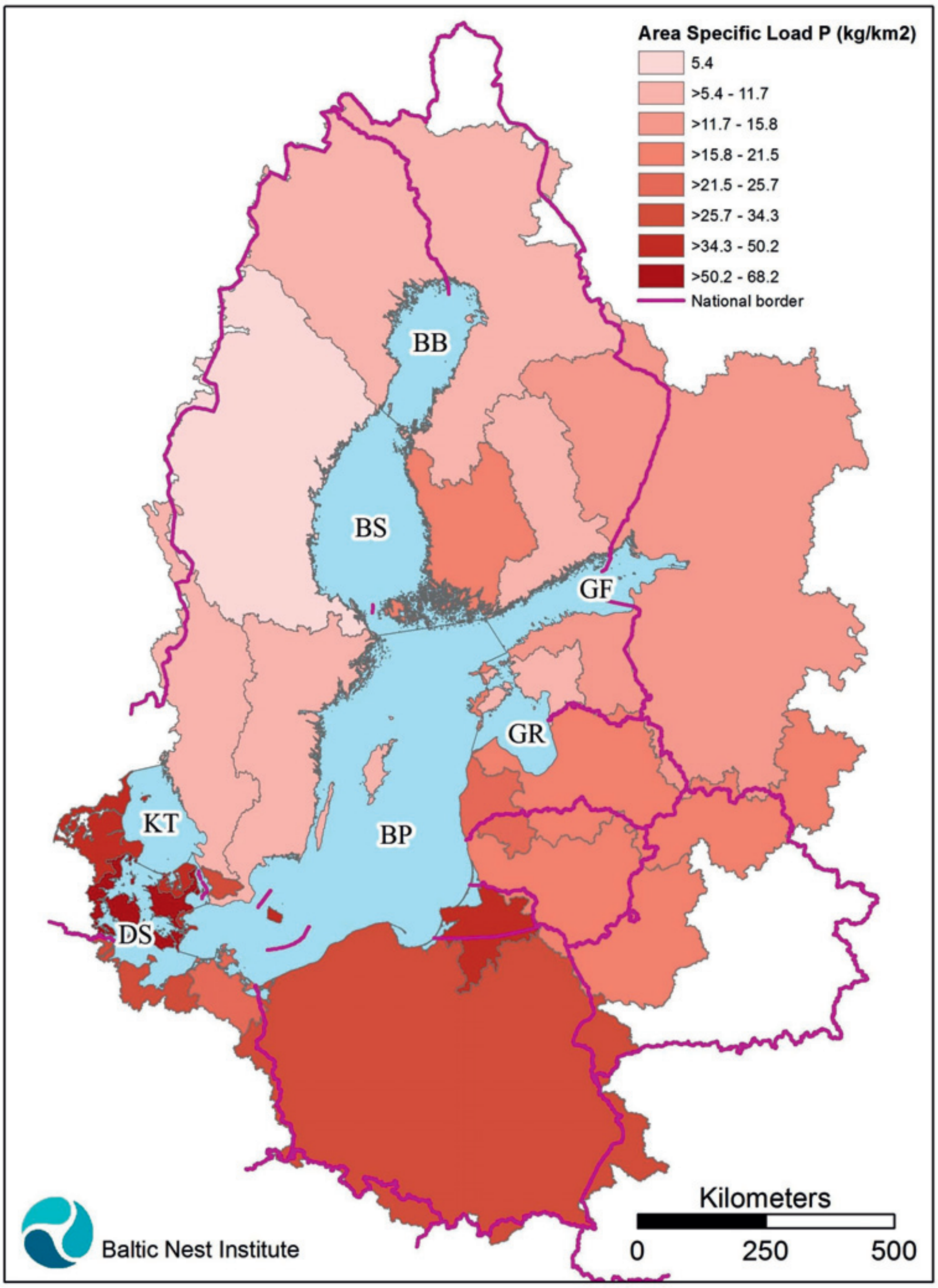


Figure 3.3c. Area-specific riverine phosphorus inputs (kg km^{-2}) in 2010 calculated per main sub-catchment and per country. See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

4 Nutrient sources in 2010

HELCOM countries report their total waterborne inputs of nitrogen and phosphorus from rivers, unmonitored and coastal areas as well as point sources discharging directly to the Baltic Sea on an annual basis. They also report emissions of nitrogen compounds to air to the Convention on Long-Range Transboundary Air Pollution (LRTAP) as an input for the EMEP calculations of nitrogen deposition to the Baltic Sea. The quantified source apportionment of waterborne inputs of nutrients was last assessed using 2006 data for the PLC-5 report (HELCOM 2011); the next source inventory and assessment will be part of the PLC-6 project and mainly based on 2014 data. Since the sources of atmospherically deposited nitrogen are described in the annual report by EMEP to HELCOM (EMEP 2012), only few examples of sources are shown in this chapter.

The contributions of actual waterborne and airborne inputs from HELCOM countries, Baltic Sea shipping and distant sources to the Baltic Sea in 2010 are presented in **Figure 4.1**.

4.1 Sources of airborne inputs in 2010

Nitrogen compounds are emitted into the atmosphere as nitrogen oxides (NO_x) and ammonia (NH_3). Oxidized nitrogen (NO_x) constitutes, in most years, the largest share of the total nitrogen deposited via the atmosphere to the Baltic Sea, up to around 55% on an annual basis. Combustion processes related to shipping, road transportation and energy combustion are the main sources of nitrogen oxide emissions in the Baltic Sea region, while agriculture

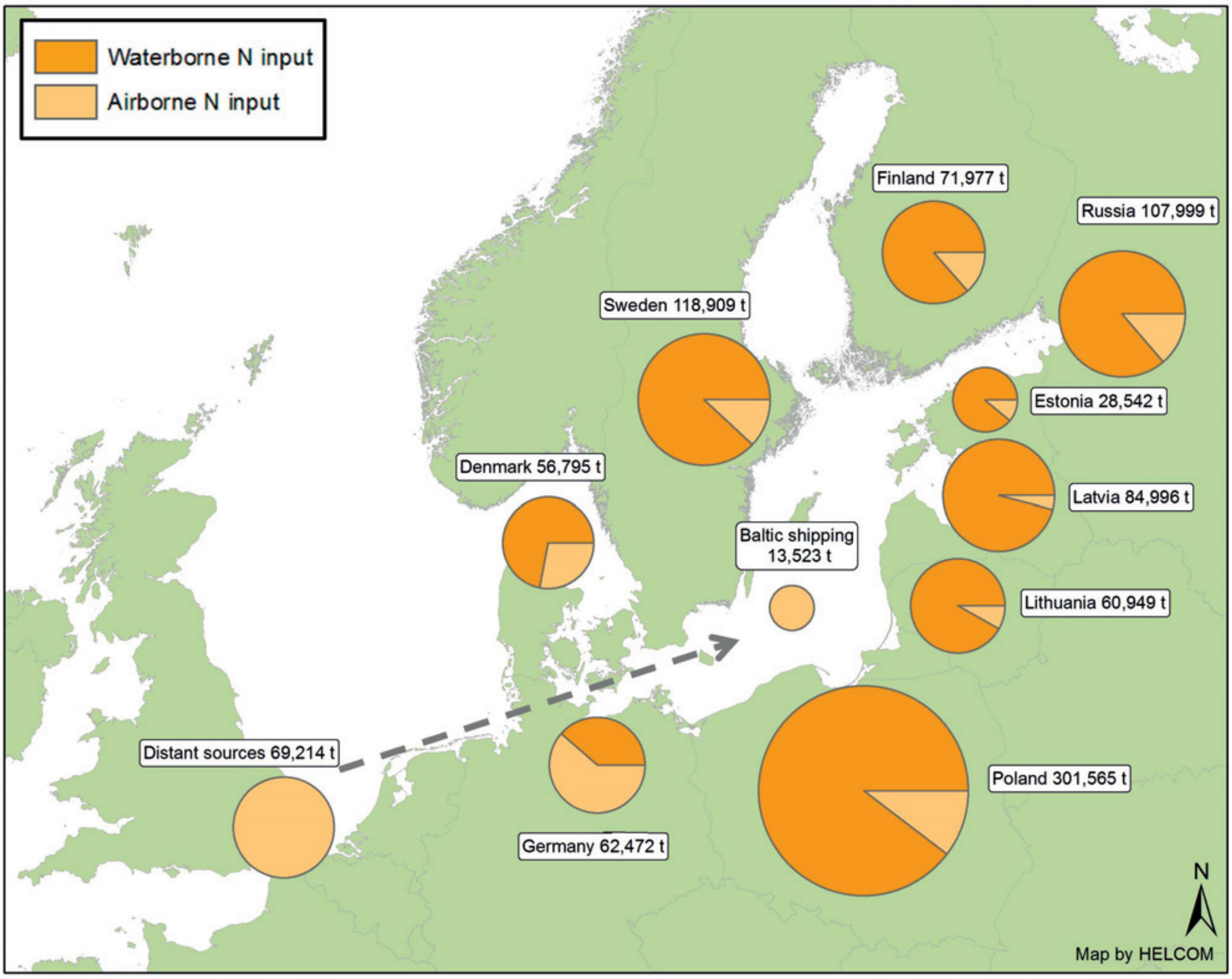


Figure 4.1. Total actual inputs of water- and airborne nitrogen (in tonnes) from HELCOM countries, Baltic Sea shipping and distant sources to the Baltic Sea in 2010. See note to **Table 2.2** regarding the pre-conditions on the PLC-5.5 data set.

generally contributes with 85-95% of the emitted ammonia (Bartnicki & Valiyaveetil 2009). While a major part of emitted nitrogen oxides are transported over long distances before being deposited, ammonium is deposited closer to the emission source.

In 2010, 218,600 tonnes of total nitrogen was deposited to the Baltic Sea via the atmosphere, of which 62% originated from HELCOM countries (including from areas in these countries – such as Germany and Russia - which are not part of the catchment area that drain to the Baltic Sea); 6% from Baltic Sea shipping (SS); 18% from the 20 EU countries which are not HELCOM Contracting Parties; and 13% from other countries and distant sources outside the Baltic Sea region (**Figure 4.2**). Germany (18%) and Poland (14%) are the two HELCOM Contracting Parties with the highest shares of the total atmospheric nitrogen input to the Baltic Sea. There is a southwest to northeast gradient in deposition, with the highest deposition in the southern and western parts of the Baltic Sea due to dominant wind systems and the location of the main emission sources.

An assessment of the top twenty main contributors to the atmospheric deposition of total nitrogen to the Baltic Sea shows that Germany followed by Poland are the greatest contributors, followed by Denmark, Russia and Sweden (**Figure 4.3)**. The United Kingdom and France, countries outside the HELCOM area, were the ninth and tenth largest contributors of total atmospheric nitrogen deposited onto the Baltic Sea, while Baltic Sea shipping was sixth and North Sea shipping eighth.

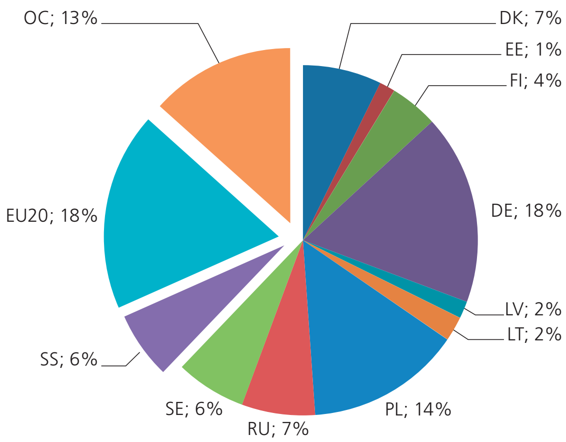


Figure 4.2. The relative share of different sources of actual atmospheric total nitrogen deposition to the Baltic Sea in 2010.

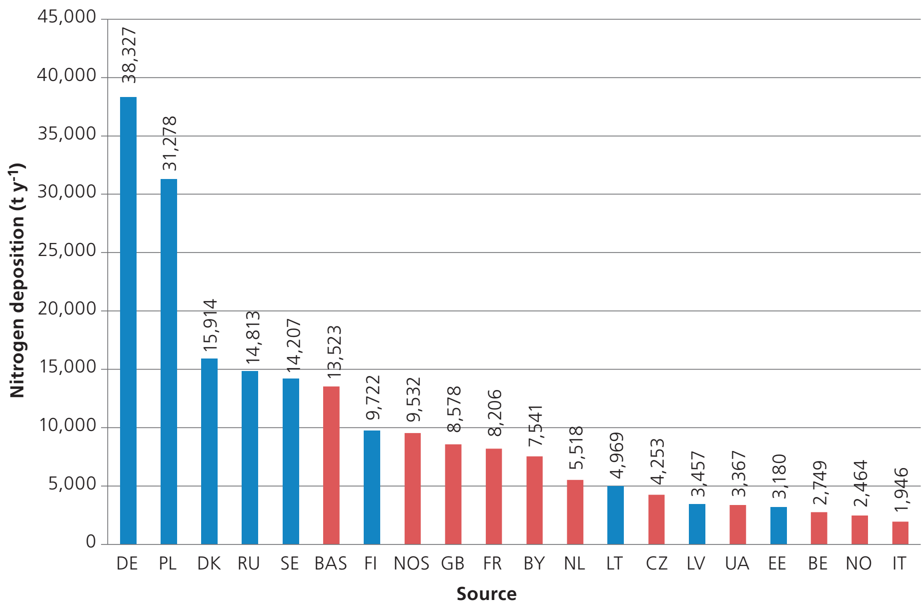


Figure 4.3. Top twenty biggest contributors of atmospheric total nitrogen deposition (in tonnes) to the Baltic Sea in 2010. Non-HELCOM countries or sources outside HELCOM area are in red. BAS = Baltic Sea shipping; BE = Belgium; BY = Belarus; NOS = North Sea shipping; UA = Ukraine.

4.2 Sources of waterborne inputs in 2010

The sources of waterborne nutrient inputs were last assessed using 2006 data in the PLC-5 report (HELCOM 2011 and HELCOM 2012). Information on inputs from point sources discharging directly into the Baltic Sea is, however, available for 1994-2010 and presented below. The Contracting Parties report three categories of direct sources: municipal wastewater treatment plants, industrial direct inputs and marine fish farms or fish farms located along the coast, which discharge directly to the Baltic Sea. One major challenge has been that some countries have changed their methodology on direct discharges during 1994-2010 by including, for example, at least some direct discharging point sources in unmonitored areas or even monitored rivers, or assigning point sources in unmonitored and coastal areas as direct sources. For this reason, comparisons between countries and years must be done with care even though the data set has been improved also for direct inputs. The most robust estimation of the direct sources is the aggregated input at the Baltic Sea level (**Figure 4.4**).

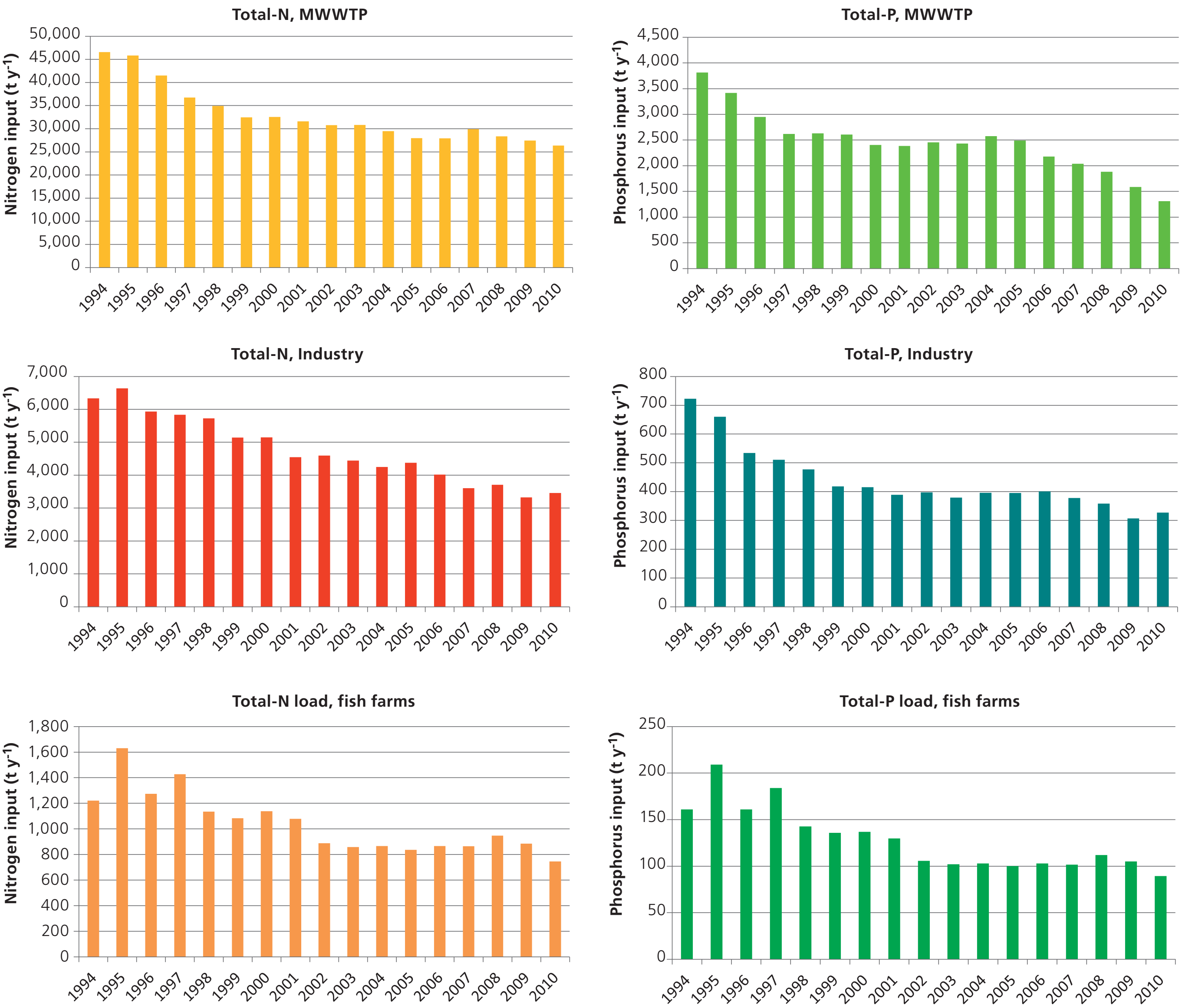


Figure 4.4. Annual direct inputs of total nitrogen and total phosphorus (in tonnes per year) to the Baltic Sea from municipal wastewater treatment plants, MWWTP (top), industrial plants (middle) and fish farms (bottom) discharging directly to the sea during 1994-2010. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

In 2010, total direct inputs of nitrogen constituted between 5-10% of the total actual waterborne nitrogen inputs in Denmark, Finland, Russia and Sweden, but only from 0.3% to less than 2.3% in Germany, Latvia, Lithuania and Poland. Corresponding shares for phosphorus were between 7% and nearly 16% for Denmark, Estonia, Finland, Russia and Sweden, but only 0.2-2.3% for Germany, Latvia, Lithuania and Poland. The shares from Latvia, Lithuania and Poland seem very low, even though riverine flow was very high from Poland in 2010.

Direct discharges of nitrogen and phosphorus from coastal municipal wastewater treatment plants (MWWTP), industries and fish farms into the Baltic Sea (**Figure 4.4**) are generally independent of variations in precipitation, although some municipal wastewater treatment plants may allow untreated overflows during heavy stormwater events. For all these sources, there is an overall statistically significant decrease for both nitrogen and phosphorus inputs to the Baltic Sea from 1994 to 2010. There is generally a marked decrease from 1994 to about year 2000. Further, there is a decrease for MWWTPs (phosphorus) and for industries from 2005 to 2010. For fish farms, reductions are seen until 2000 and then no major changes in the total input to the Baltic Sea can be noted (see **Figure 4.4**). For fish farms, this might be a combined result of improved feed usage and better cleaning on fish farms despite current higher production and higher feed consumption.

All Contracting Parties, except Estonia and Poland, have a statistically significant decrease in total direct point source inputs for phosphorus, and all countries, except Estonia and Latvia, have a statistically significant decrease in total direct point source inputs for nitrogen. Latvia shows a significant increase in direct nitrogen inputs, but the data are rather uncertain (**Table 4.1a**). Chapter 2.4 describes statistical trend analysis in more detail.

The direct point source inputs of nitrogen and phosphorus to the Baltic Sea have decreased markedly by 43% and 63%, respectively, from 1994 to 2010. Some Contracting Parties have reduced much more, such as Denmark and Germany as well as Lithuania for phosphorus. The real decrease might be higher for some countries mainly due to some methodology changes at the beginning of the period and because direct point sources have on some occasions been included in the riverine inputs by some Contracting Parties. It should also be noted that municipal nitrogen and phosphorus inputs from the Nordic Contracting Parties decreased significantly already before the 1988 HELCOM Ministerial Declaration (HELCOM 1988) was agreed upon due to measures taken already during the 1970s and 1980s, and also because reductions in some countries took place from 1990-1993. Trend estimates are based on an assumption of a linear trend which is not always fulfilled and thus might affect the estimated changes in direct inputs from 1994 to 2010.

Tables 4.1a and 4.1b. Results of the Mann-Kendall test for significant trends on direct nitrogen and phosphorus inputs to the Baltic Sea (sum of inputs from municipal wastewater treatment plants, industries and fish farms discharging directly to the sea) by country (Table 4.1a) and by sub-basin (Table 4.1b). Estimated annual change (with a Theil-Sen slope estimator) in tonnes per year and estimated percentage of change in inputs from 1994 to 2010 where the trend is significant (confidence < 5%) (see footnotes 9 and 10). The results where the confidence level is between 5-10% are given in parentheses. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Table 4.1a

	Direct point sources			
	Estimated slope	Change since 1994	Estimated slope	Change since 1994
	t N y^{-1}	%	t P y^{-1}	%
DE	-173	-85	-1.68	-83
DK	-140	-72	-22.1	-79
EE	-	-	-	-
FI	-337	-48	-11.7	-51
LV	30.4	38	-13.1	-90
LT	-44.6	-77	-6.51	-91
PL	(-30)	(-44)	-	
RU	-177	-23	(-35)	(-56)
SE	-345	-37	-13.5	-39
BAS	**-1,163**	**-43**	**-125**	**-63**

Table 4.1 b

	Direct point sources			
	Estimated slope	Change since 1994	Estimated slope	Change since 1994
	t N y^{-1}	%	t P y^{-1}	%
BOB	-49.4	-24	-3.51	-42
BOS	-87.2	-16	-10.1	-41
BAP	-253	-47	-19.6	-41
GUF	-369	-36	-36	-63
GUR	40.6	63	-12.5	-90
DS	-335	-75	-18.3	-77
KAT	-112	-49	-9.69	-68
BAS	**-1,163**	**-43**	**-125**	**-63**

5 Discussion and Conclusions

The PLC-5.5 data is the most complete and consistent data set on nitrogen and phosphorus inputs to the Baltic Sea to date and includes both waterborne (1994-2010) and airborne (1995-2010) inputs. The data set still has some shortcomings despite the fact that the old PLC data (1994-2008) have been updated and completed compared with the PLC-5 report (HELCOM 2011). The PLC-5.5 Core Project Group, BNI and the PLC data manager have filled in data gaps and missing data as well as corrected some obviously incorrect data. For 2009 and 2010, it has been necessary to estimate all Latvian data based on an assessment of older data since no data seem to be available from Latvia. Moreover, some Russian data (Kaliningrad region and unmonitored parts of the Leningrad region) have been estimated as described in **Chapter 1.2.** Russia has accepted to use this adjusted PLC-5.5 data set both for this review of the PLC-5 report for the 2013 HELCOM Ministerial Meeting, the PLC-5.5 report and for the revisions of MAI and the new CART, but has stressed that the Russian PLC-5.5 data should not be included into the PLC database as official data.

It should be noted that the figures presented are rounded (although not necessarily to the number of digits that corresponds to the level of accuracy) in order to avoid confusion when summing different numbers.

Based on normalized data – where the annual variations in inputs due to run-off are smoothened – the total inputs via rivers, direct inputs and atmospheric deposition in the mid-1990s were approximately 1,050,000 tonnes of nitrogen and 40,000 tonnes of phosphorus. Atmospheric deposition constituted approximately 250,000 tonnes of nitrogen (24%) and 2,100 tonnes of phosphorus (5%). The average total normalized inputs during 2008-2010 - the latest years for which the total inputs to the Baltic Sea have been assessed - were approximately 829,000 tonnes of nitrogen and 33,100 tonnes of phosphorus, with 197,000 tonnes of the nitrogen inputs from atmospheric deposition (24%). The atmospheric deposition of phosphorus remains at 2,100 tonnes as it is calculated using the same deposition rate (5 kg P km^{-2}) for all years. This indicates that the measures taken before and after 1994 to improve wastewater treatment, reduce emissions to air from combustion processes and losses from diffuse sources (agriculture and forestry) have reduced the input to the Baltic Sea by more than 200,000 tonnes of nitrogen and about 7,000 tonnes of phosphorus since the middle of the 1990s.

To assess the validity of the calculated changes in nitrogen and phosphorus inputs, statistical analyses have been carried out on the normalized input time series from 1994 to 2010 to test for trends (decrease or increase). These analyses show that the total inputs (air- and waterborne) of nitrogen and phosphorus to the Baltic Sea have significantly decreased with 16% and 18%, respectively from 1994 to 2010 (**Tables 2.3** and **2.4**). Denmark (35% for nitrogen and 29% for phosphorus), Germany (23% for nitrogen, 20% for phosphorus), Poland (20% for nitrogen, 24% for phosphorus) and Sweden (15% for nitrogen and 18% for phosphorus) have significantly reduced both their total nitrogen and phosphorus inputs to the Baltic Sea. Further, both Finland (17%) and Lithuania (33%) reduced their total phosphorus inputs, although the statistical confidence for Lithuania is less than 10%. Total phosphorus inputs from Latvia increased significantly (75%), but the data are rather uncertain, especially at the beginning and end of the period. The EU20 (the EU countries that are not HELCOM Contracting Parties) and other non-HELCOM countries and sources, besides Baltic Sea shipping, have also significantly reduced their nitrogen inputs (atmospheric deposition) to the Baltic Sea, with 34% and 15% respectively, while deposition from Baltic Sea shipping significantly increased with 34%.

There are significant reductions in total inputs of nitrogen and phosphorus to the Bothnian Sea (12% for nitrogen, 24% for phosphorus), the Baltic Proper (20% for nitrogen, 24% for phosphorus), the Danish Straits (32% for nitrogen, 30% for phosphorus) and the Kattegat (23% for nitrogen, 17% for phosphorus). Further, total nitrogen inputs decreased significantly to the Gulf of Finland (6%) but increased significantly for total phosphorus inputs to the Gulf of Riga (63%) (cf. **Tables 2.5** and **2.6**).

The total atmospheric deposition of nitrogen to the Baltic Sea decreased significantly (24%); for individual countries significant reductions are noted for Denmark (40%), Estonia (10%), Finland (23%), Germany (25%), Poland (29%) and Sweden (31%)

(cf. **Table 2.3**). A significant increase in atmospheric deposition of nitrogen from Russia (44%) is noted; however this is due to the inclusion of emissions from a bigger area of the country since 2006.

With regard to waterborne nitrogen inputs to the Baltic Sea (riverine + direct inputs from point sources), only Denmark (36%), Poland (26%), Germany (19%) and Sweden (15%) have significant reductions with a high statistical confidence (> 5%); Latvia and Lithuania also have a decrease, but with a confidence of < 10% (cf. **Table 2.3**). The total waterborne inputs of phosphorus have been reduced by 19-38% from all countries except Russia and Latvia; from Latvia it increased significantly with nearly 70% (cf. **Table 2.4**).

Inputs of nitrogen and phosphorus from direct sources (point sources discharging directly to the Baltic Sea) to the Baltic Sea have significantly decreased from 1994 to 2010 with 43% and 63%, respectively (cf. **Table 4.1a**). All countries have significantly (confidence < 5%) reduced their direct nitrogen and phosphorus losses, except Estonia, Poland and Russia whose reductions were not statistically significant. Russia, although had significant reduction in direct nitrogen inputs. Further, direct inputs of nitrogen increased by 38% from Latvia. The overall reduction in nitrogen and phosphorus inputs is certain, even though the results of the trend analysis for some countries are uncertain due to changed methodology for defining direct point sources. The methodology for estimating changes from 1994 to 2010 assumes a linear development in direct inputs which is not always fulfilled; to this end, a revised methodology should be implemented for these estimates in future.

Nitrogen and phosphorus inputs for all HELCOM countries and main sub-basins have been tested for trends and significant changes from 1994 to 2010 - the results follow the trends given above for individual countries (cf. **Table 2.7**). As an example, Denmark has significantly reduced total nitrogen and phosphorus inputs to all sub-basins to which Denmark supplies nitrogen and phosphorus. Sweden, which has inputs to five sub-basins, has significantly reduced total inputs of nitrogen and phosphorus to the Baltic Sea while there are no significant reductions to the Bothnian Bay or of total phosphorus to the Kattegat. Some Contracting Parties (such as Denmark, Finland and Sweden) took many measures in the 1970s, 1980s and early 1990s and reduced especially nitrogen and phosphorus losses to surfaces from municipal wastewater (and also diffuse losses) before 1994 when the PLC assessment period begins. They have also since 1994 implemented further measures to reduce inputs. Poland, the Baltic States and Russia implemented advanced wastewater treatment later, the effects of which are mainly reflected in reduced inputs from these countries after the reference period 1997-2003. It should also be noted that many measures taken to reduce diffuse losses to inland surface waters, will take several years before they result in reduced nutrient inputs to both coastal and open waters of the Baltic Sea. Moreover, in some catchments, retention in soils, groundwater and inland surface waters are so high that it can require a factor of 5-10 times higher reductions to obtain a given absolute reduction to the Baltic Sea.

Comparison of the average normalized inputs of total nitrogen and phosphorus during 2008-2010 with the similar total input during the BSAP reference period (1997-2003) show a decrease from all HELCOM Contracting Parties except for Latvia (nitrogen and phosphorus), Germany (phosphorus and Russia (nitrogen) (cf. **Table 2.8**). The reduction of total nitrogen and phosphorus inputs to the Baltic Sea was 9% and 10%, respectively, corresponding to more than 80,000 tonnes of nitrogen and nearly 3,800 tonnes of phosphorus. The reduction was higher for some Contracting Parties such as Denmark (nitrogen), Estonia (phosphorus), Finland (nitrogen), Germany (nitrogen), Lithuania (phosphorus), Poland (nitrogen and phosphorus), Russia (phosphorus) and Sweden (nitrogen). The EU20 and other non-HELCOM countries reduced atmospheric deposition of nitrogen with 24% (14,000 tonnes) and 6% (1,600 tonnes) respectively, while Baltic Sea Shipping increased with 15% (approximately 1,800 tonnes). It should be underlined that the changes have not been tested for statistical significance and that, for example for Finland, the decrease might be due to that normalization of inputs has not adequately smoothened all variations imposed by weather, especially for inputs entering the Bothnian Bay and Bothnian Sea.

Regarding inputs from countries to the different sub-basins, changes in total inputs of nitrogen from the reference period to 2008-2010 indicate reductions to all sub-basins from all countries except for Estonia, Latvia and Russia (see **Table 2.9e**). One reason for this is that atmospheric deposition from all HELCOM Contracting Parties to all sub-basins has been reduced, except from Latvia and Russia. For phosphorus, it is not possible to assign deposited amounts to different countries as sources are not quantified, and inputs of phosphorus from countries to different sub-basins are only calculated if a country has waterborne inputs to a sub-basin. These inputs have been reduced since the reference period (not tested if it is significant) by Denmark, Finland, Germany, Lithuania and Poland to all sub-basins that they have waterborne inputs to (see **Table 2.10c**). Sweden has reduced waterborne phosphorus inputs to all sub-basins, except to the Bothnian Bay, and Estonia to the Gulf of Finland and Gulf of Riga.

In this report, the reductions calculated on total normalized nitrogen and phosphorus are not compared with the BSAP 2007 provisional country allocated reduction targets (CART) or the new CART adopted by the HELCOM Ministerial Meeting in October 2013. However, to facilitate future evaluation on progress in fulfilling the nutrient reduction requirements for the Baltic Sea, the reduction in normalized total nitrogen and phosphorus inputs from the reference period (1997-2003) to 2008-2010 is compared with the expected required reductions based on the scientifically developed maximum allowable inputs (MAI) adopted by the 2013 HELCOM Copenhagen Ministerial Meeting (HELCOM 2013a) (see **Table 5.1**). For the Baltic Proper, more than 35% of the required reduction of nitrogen seems to have been obtained in 2008-2010; however, this includes the reduction in nitrogen deposition from the EU20 and other non-HELCOM countries. For phosphorus inputs to the Baltic Proper, while more than 20% of the required reduction has been obtained, this also includes reductions in transboundary waterborne inputs from non-HELCOM-countries. The nutrient reductions to the Gulf of Finland from the reference period (2008-2010) constitute more than 35% and 25% of the potential reduction requirement of nitrogen and phosphorus, respectively. For the Kattegat, the reductions obtained by 2008-2010 were higher than the potential required reduction based on the revised MAI; however, part of these are caused by reduced atmospheric emissions from the EU20 and other non-HELCOM countries. Phosphorus inputs to the Gulf of Riga have increased with nearly 400 tonnes, even though there is a potential reduction need of more than 300 tonnes. As a part of the PLC-6 project, a statistical test has been developed to determine the fulfillment of the reduction targets – it will be implemented based on the revised MAI and new CART adopted by the 2013 HELCOM Ministerial Meeting.

The actual (not normalized) total nutrient input to the Baltic Sea in 2010 was 977,000 tonnes of nitrogen and 38,300 tonnes of phosphorus, respectively. Of this, nearly 219,000 tonnes of nitrogen (22%) entered the Baltic Sea as atmospheric deposition, the remaining 758,000 tonnes entered as waterborne nitrogen inputs. Atmospheric deposi-

Table 5.1. Updated total average inputs of nitrogen and phosphorus during the reference period 1997-2003; the required reduction of total nitrogen and phosphorus inputs based on the maximum allowable inputs presented and discussed at the meeting of HELCOM HOD 43/2013 in September 2013; and the calculated reductions obtained in 2008-2010 since the reference period. See note to Table 2.2 regarding the pre-conditions on the PLC-5.5 data set.

Sub-basins/ inputs in tonnes	New reference total input		Required reduction with MAI from June 2013		Reductions since reference period	
	Total N	Total P	Total N	Total P	Total N	Total P
Bothnian Bay	57,622	2,675	0	0	4,023	108
Bothnian Sea	79,372	2,773	0	0	8,611	306
Baltic Proper	423,921	18,320	98,921	10,960	36,928	2,435
Gulf of Finland	116,252	7,509	14,452	3,909	5,457	1,000
Gulf of Riga	88,417	2,328	0	308	2,974	-381
Danish Straits	65,998	1,601	0	0	10,417	108
Kattegat	78,761	1,687	4,761	0	12,528	175
Baltic Sea total	**910,343**	**36,893**	**118,134**	**15,177**	**80,937**	**3,751**

tion of phosphorus has been calculated by a fixed deposition rate and amounted to nearly 2,100 tonnes of phosphorus (5%). The Baltic Proper, which has one third of the Baltic Sea catchment area and covers 50% of the Baltic Sea surface area, received 53% of total nitrogen and 55% of total phosphorus input, followed by the Gulf of Finland (13% of total nitrogen and 17% of total phosphorus inputs, but with 24% of the catchment area) (**Table 3.4**). The main countries contributing to nitrogen inputs were Poland (30%), Sweden (12%), and Russia (11%) (**Figure 3.1a**). The largest inputs of phosphorus originated from Poland (37%), Russia (16%) and Sweden (9%) (**Figure 3.1b**). In 2010, high precipitation occurred over southern and some eastern parts of the Baltic Sea catchment area, leading to very high run-off and nutrient inputs from Poland. The normalized total inputs in 2010 were also considerably lower than the actual total inputs: they amounted to 802,000 tonnes of nitrogen and 32,200 tonnes of phosphorous (**Tables 3.2a** and **3.2b**).

The area-specific input of nitrogen into the Baltic Sea was typically highest in sub-regions with intensive agricultural activity and high population densities such as the Danish Straits, the Kattegat and the western part of Baltic Proper with 900-1,900 kg N km^{-2} (**Figure 3.3b**). Overall, specific inputs are highest in the southwestern and southern catchments of the Baltic Sea and lowest in the northern part, for example 100-200 kg N km^{-2} to the Bothnian Bay and the Bothnian Sea. Parts of southern Finland and the Baltic States also have net inputs over 600 kg N km^{-2}. For phosphorus, the highest area-specific losses were found in catchment areas with high population densities, many industries and high agricultural activity, which are more or less the same catchments as for nitrogen (**Figure 3.3c**). The highest specific losses found in the southern and western parts of the catchment amounted to 50-60 kg P km^{-2}. The lowest area-specific losses were from the Swedish sub-catchment to the Bothnian Sea with 5-10 kg P km^{-2}. Furthermore, geology, climate, wastewater treatment efficiency, the frequency of surface run-off and snow/ice cover have an impact on area-specific inputs of nutrients.

The PLC-5.5 assessment does not include a source inventory. The latest source apportionment was based on 2006 data and is documented in the PLC-5 report (HELCOM 2011 and HELCOM 2012). The next source inventory will be based on 2014 data and assessed in the PLC-6 report, which is expected in 2017. It is, however, possible to make an overall assessment for some of the inputs sources in 2010. Approximately 55% of the air emissions of nitrogen are NO_x, which overall originate from combustion processes such as energy consumption, transport sector, and industrial processes. The remaining 45% are NH_x emissions where the main source is ammonia from agriculture. Atmospheric deposition constituted 22% of the actual total nitrogen supply to the Baltic Sea in 2010. The top three contributors to atmospheric nitrogen deposition in 2010 were Germany (18%), Poland (14%) and Denmark (7%); however, the EU20 contributed with 18%, other non-HELCOM countries and sources more than 13% and Baltic Sea shipping 6%, meaning that approximately 38% of the nitrogen deposition on the Baltic Sea arrives from emissions outside the HELCOM countries (**Figure 4.2**). Of the top ten contributors to the nitrogen deposition on the Baltic Sea, four are non-Contracting Parties (Baltic Sea shipping, North Sea shipping, the United Kingdom and France) (**Figure 4.3**). It is not possible to allocate phosphorus deposition to sources.

Net transboundary waterborne nitrogen and phosphorus inputs to the Baltic Sea from non-Contracting Parties (Czech, Belarus, Ukraine and Slovakia), taking into account retention within catchments, are only important for some rivers entering the Baltic Proper and the Gulf of Riga (**Table 3.3a**). In total, 5% of waterborne nitrogen and 6% of total phosphorus that enters Baltic Proper originates from non-Contracting Parties. The corresponding figures to the Gulf of Riga for waterborne inputs are 8% nitrogen and 41% phosphorus, respectively.

The waterborne inputs to the Baltic Proper, the Gulf of Riga and the Gulf of Finland include net transboundary inputs from other Contracting Parties. These have been quantified as a basis for discussions on burden-sharing of reduction requirements for sub-basins (**Table 3.3b**). The net transboundary inputs from HELCOM countries amounted to approximately 8,800 tonnes nitrogen and 370 tonnes phosphorus to Baltic Proper, 7,200 tonnes nitrogen and 410 tonnes phosphorus to the Gulf of Riga and 5,400 tonnes nitrogen and

50 tonnes phosphorus to the Gulf of Finland. Only for the Gulf of Riga these inputs constitute 10% or more of the total inputs to the sub-basin.

The PLC-5 report (HELCOM 2011 and HELCOM 2012) identified various limitations in the PLC water data. The most important of these have been addressed - significant data gaps and missing data from some areas in the reported data, as well as data that were evaluated as not being valid. Incomplete and inconsistent data makes trend analysis, the evaluation of input sources and the fulfillment of the reduction targets more complicated and uncertain. The PLC-5 report also identified several issues to be addressed in order to improve the situation concerning the PLC data, most notably improved guidance on sampling, quantification and statistical methodologies, standardized analytical methods, and regular intercalibration and bilateral cooperation. While many of these initiatives have been taken into account in the PLC-6 project, it has not been possible to apply them to already collected data. However, the validation of data, filling in data gaps/missing data, correcting suspicious data and the statistical methods are based on standardized methodologies that will be included in the revised PLC guidelines, which are being elaborated by the PLC-6 project. Moreover, intercalibration has been conducted in 2013 and the results will to be used in the PLC-6 project.

6 Acknowledgements

The information presented in this report includes the main results to be presented in the HELCOM PLC-5.5 report (HELCOM, in prep). Data used include new data provided by the HELCOM Contracting Parties from 2008-2010, updates and corrections to old PLC data; new data provide by the Cooperative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP); and the Baltic Next Institute Stockholm (BNI). This Review of the PLC-5 report was prepared to serve as supporting information for the HELCOM Ministerial Meeting which was held in Copenhagen, Denmark, on 3 October 2013.

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7 References

Bartnicki, J. and Valiyaveetil, S. (2009). Estimation of atmospheric nitrogen deposition to the Baltic Sea in the periods 1997-2003 and 2000-2006. Summary Report for HELCOM. Meteorological Synthesizing Centre-West (MSC-W) of EMEP.

Bartnicki, J. (2012a). Nitrogen emissions to the air in the Baltic Sea area. HELCOM Baltic Sea Environment Fact Sheets 2012.

Bartnicki, J. (2012b). Atmospheric nitrogen depositions to the Baltic Sea during 1995-2009. HELCOM Baltic Sea Environment Fact Sheets 2012.

EMEP (2012). Atmospheric Supply of Nitrogen, Lead, Cadmium, Mercury and Dioxines/ Furanes to the Baltic Sea in 2010.

European Commission (2000). Directive 2000/60/ EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive, WFD).

European Commission (2008). Directive 2008/56/ EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive, MSFD).

Gustafsson, B.G and Mörth, C.M. (in prep.). Revision of the Maximum Allowable Inputs and CountryAllocation Scheme of the Baltic Sea Action Plan V. 3 with contributions from the BNI team: Bärbel Müller-Karulis, Erik Gustafsson, Bonghi Hong, Christoph Humborg, Steve Lyon, Marmar Nekoro, Miguel Rodriguez-Medina, Oleg Savchuk, Erik Smedberg, Alexander Sokolov, Dennis Swaney, and Fredrik Wulff. Baltic Nest Institute, Stockholm University.

HELCOM (1988). Declaration on the Protection of the Environment of the Baltic Sea. Adopted on 15 February 1988.

HELCOM (2007). Baltic Sea Action Plan. HELCOM Ministerial Meeting. Adopted in Krakow, Poland on 15 November 2007.

HELCOM (2011). Fifth Baltic Sea Pollution Load Compilation. Baltic Sea Environment Proceedings No. 128.

HELCOM (2012). Fifth Baltic Sea Pollution Load Compilation – An Executive Summary. Baltic Sea Environment Proceedings No. 128A.

HELCOM (2013a). HELCOM Copenhagen Ministerial Declaration. Taking further action to implement the Baltic Sea Action Plan – Reaching good environmental status for a healthy Baltic Sea. 3 October 2013, Copenhagen, Denmark. Adopted on 3 October 2013.

HELCOM (2013b). How a complete PLC-5.5 water data set was obtained. Documentation prepared by the HELCOM PLC-5.5 project group. Available via the HELCOM PLC-5.5 project page on the HELCOM website: http://www.helcom.fi/helcom-at-work/projects/plc-5-5/.

HELCOM (2013c). Popular summary report on the development of revised maximum allowable inputs (MAI) and new country allocated reduction targets (CART) of the Baltic Sea Action Plan. Supporting document of the 2013 HELCOM Copenhagen Ministerial Meeting.

HELCOM (in prep). Updated Fifth Baltic Sea Pollution Load Compilation (PLC-5.5). Baltic Sea Environmental Proceedings xxx.

Hirsch, R.M. and Slack, J.R. and Smith, R.A. (1982). Techniques of trend analysis for monthly water quality data. Water Resources Research, 18, 107-121.

Larsen, S.E. and Svendsen, L.M. (in prep). Statistical aspects in relation to Baltic Sea Pollution Load Compilation (task 1 under HELCOM PLC-6). Department of Bioscience and DCE - Danish Centre for Environment and Energy, Aarhus University.

Ærtebjerg, G., Andersen, J.H. & Hansen, O.S. (eds.) (2003). Nutrients and Eutrophication in Danish Marine Waters. A Challenge for Science and Management. National Environmental Research Institute. 126 pp.

8 List of definitions and abbreviations

Airborne	Nutrients carried or distributed by air.
Anthropogenic	Caused by human activities.
Atmospheric deposition	Airborne nutrients or other chemical substances originating from emissions to the air and deposited from the air on the surface (land and water surfaces).
BAP	Baltic Proper
BAS	The entire Baltic Sea (as a sum of the Baltic Sea sub-basins). See the definition of sub-basins.
Border river	A river that has its outlet to the Baltic Sea at the border between two countries. For these rivers, the inputs to the Baltic Sea are divided between the countries in relation to each country's share of the total input.
BNI	Baltic Nest Institute, Stockholm University, Sweden.
BOB	Bothnian Bay
BOS	Bothnian Sea
BSAP	Baltic Sea Action Plan
Catchment area	The area of land bounded by watersheds draining into a body of water (river, basin, reservoir, sea).
Contracting Parties	Signatories of the Helsinki Convention (Denmark, Estonia, European Commission, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden).
Country-Allocated Reduction Targets (CART)	Country-wise requirements to reduce waterborne and airborne nutrient inputs (in tonnes per year) to reach the maximum allowable nutrient input levels in accordance to the Baltic Sea Action Plan.
DCE	Danish for the Environment and Energy, Aarhus University, Denmark.
DE	Germany
Diffuse sources	Sources without distinct points of emission, e.g. agricultural and forest land, natural background sources, scattered dwellings, atmospheric deposition (mainly in rural areas).
DIN and DIP	Dissolved inorganic nitrogen and dissolved inorganic phosphorus compounds.
Direct Sources	Point sources discharging directly to coastal or transitional waters.
DK	Denmark
DS	Danish Straits
EE	Estonia
EMEP	Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe.
Eutrophication	Condition in an aquatic ecosystem where increased nutrient concentrations stimulate excessive primary production, which leads to an imbalanced function of the ecosystem.

FI	Finland
Flow normalization	A statistical method that adjusts a data time series by removing the influence of variations imposed by river flow, e.g. to facilitate assessment of development in, e.g. nitrogen or phosphorus inputs.
GUF	Gulf of Finland
GUR	Gulf of Riga
Input ceiling	The allowable amount of nitrogen and phosphorus inputs per country and sub-basin. It is calculated by subtracting the CART from the inputs of nitrogen and phosphorus during the reference period of the BSAP (1997-2003).
KAT	Kattegat
HELCOM LOAD	HELCOM Expert Group on follow-up of national progress towards reaching BSAP nutrient reduction targets.
LT	Lithuania
LV	Latvia
Maximum Allowable Input (MAI)	The maximum annual amount of a substance that a Baltic Sea sub-basin may receive and still fulfill HELCOM's ecological objectives for a Baltic Sea unaffected by eutrophication.
Monitored areas	The catchment area upstream the river monitored point. The chemical monitoring decides the monitored area in cases where the locations of chemical and hydrological monitoring stations do not coincide.
Monitoring stations	Stations where hydrographic and/or chemical parameters are monitored.
MSFD	EU Marine Strategy Framework Directive
MWWTP	Municipal wastewater treatment plant
Non-Contracting Parties	Countries that are not partners to the Helsinki Convention 1992, but that have an indirect effect on the Baltic Sea by contributing with inputs of nutrients or other substances via water and/or air.
PL	Poland
PLC	Pollution Load Compilation
Point sources	Municipalities, industries and fish farms that discharge (defined by location of the outlet) into monitored areas, unmonitored areas or directly to the sea (coastal or transitional waters).
Reference period	1997-2003
Reference input	The average normalized water + airborne inputs of nitrogen and phosphorus during 1997-2003 used to calculate the CART and input ceilings.
Retention	The amount of a substance lost/retained during transport in soil and/or water including groundwater from the source to a recipient water body. Often, retention is only related to inland surface waters in these guidelines.

Riverine inputs	The amount of a substance carried to the maritime area by a watercourse (natural or man-made) per unit of time.
RU	Russia
Statistically significant	In statistics, a result is called 'statistically significant' if it is unlikely to have occurred by chance. The degree of significance is expressed by the probability, P. P< 0.05 means that the probability for a result to occur by chance is less than 5%.
Sub-basins	Sub-division units of the Baltic Sea: the Kattegat (KAT); the Belt Sea (BES); the Western Baltic (WEB); the Danish Straits (DS) which include the Belt Sea (BES) and Western Baltic (WEB); the Baltic Proper (BAP); the Gulf of Riga (GUR); the Gulf of Finland (GUF); the Archipelago Sea (ARC); the Bothnian Sea (BOS); and the Bothnian Bay (BOB). The whole Baltic Sea is abbreviated BAS.
SE	Sweden
Transboundary input	Transport of an amount of a substance (via air or water) across a country border.
TN and TP	Total nitrogen and total phosphorus which includes all fractions of nitrogen and phosphorus.
Unmonitored area	Any sub-catchment(s) located downstream of the (riverine) chemical monitoring point within the catchment and further all unmonitored catchments. It also includes the coastal areas that have been used in former versions of the guidelines.
Waterborne	Substances carried or distributed by water.

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