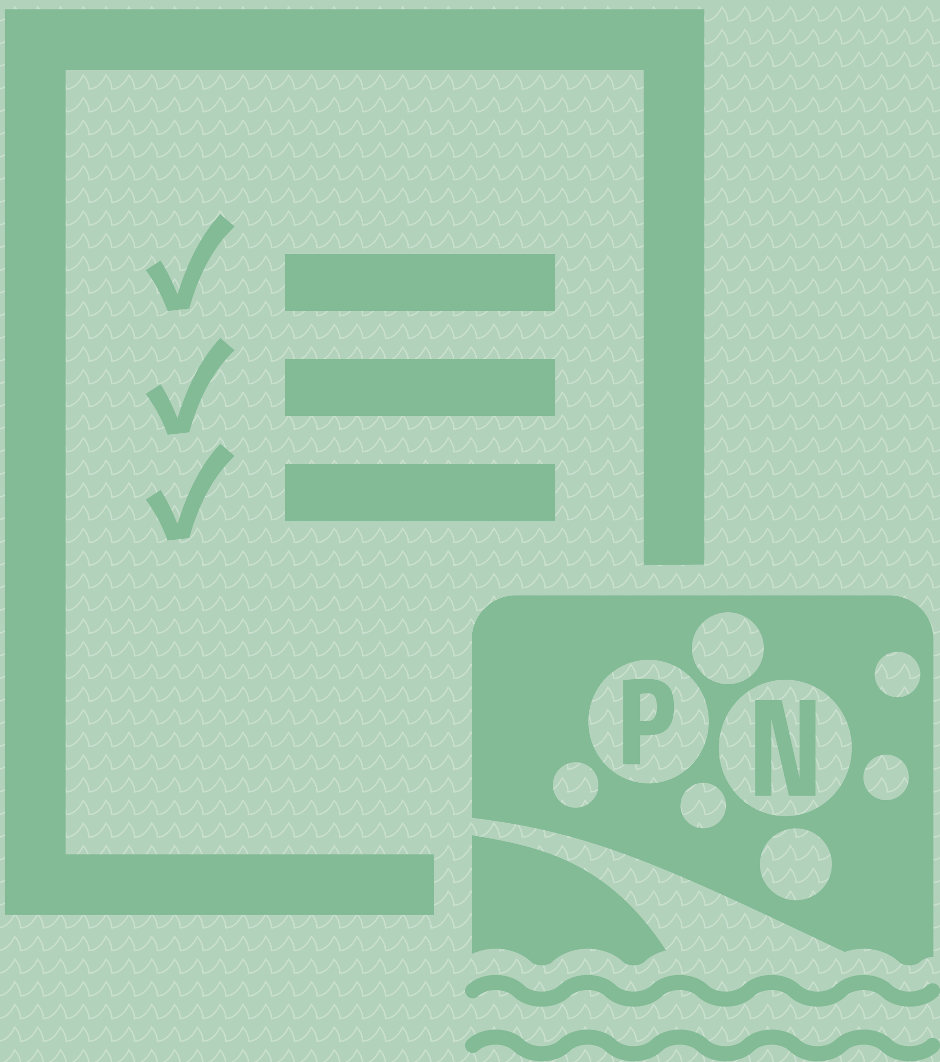
PLC-7

Baltic Marine Environment
Protection Commission

Assessment of sources of nutrient inputs to the Baltic Sea in 2017

Nutrients

BSEP n°187



helcom.fi

Published by:

Helsinki Commission – HELCOM
Katajanokanlaituri 6 B
00160 Helsinki, Finland

www.helcom.fi

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For bibliographic purposes this document should be cited as:
"Assessment of sources of nutrient inputs to the Baltic Sea in 2017. HELCOM (2022)"

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ISSN: 0357-2994

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1. Introduction and definitions

1.1. Background

Eutrophication caused by an excessive input of nutrients remains the major environment threat to the Baltic Sea according to the updated Baltic Sea Action Plan – BSAP 2021 (HELCOM, 2021a)

To reach good environmental status of the Baltic Sea Contracting Parties have agreed on a nutrient reduction scheme consisting of regional inputs targets: maximum allowable inputs (MAI) of nutrients, the maximum input of water and airborne total nitrogen and total phosphorus input to the Baltic Sea sub-basins. The BSAP 2021 updated net nutrient input ceiling (NIC) of water- and airborne nitrogen and phosphorus to achieve good status with respect to eutrophication for Baltic Sea sub-basins per country (HELCOM, 2021a). As the management objective of the BSAP with respect to eutrophication is to minimize inputs of nutrients from human activities, it is important to follow the importance of different nutrient input sources.

Nutrient inputs originate from natural sources and from human activities (anthropogenic sources) and enter the Baltic Sea via water and airborne inputs. The waterborne inputs are divided in riverine inputs and inputs from points sources discharging directly into the sea also called direct point sources or direct inputs.

Compilation of pollution load data for follow up of the implementation of the nutrient reduction scheme have been an integral part of the HELCOM assessment system since 1987. Periodical compilation of major sources and pathways of nitrogen and phosphorus have also been a part of the Pollution Load Compilations (PLC) since PLC-3 source assessment of 1995 data (HELCOM, 1998). The importance of sources was also assessed for 2000 data in the PLC-4 project (HELCOM, 2004), for 2006 data in the PLC-5 project (HELCOM 2011, 2012 and 2013), and 2014 data (2012 for Germany and Poland) in the PLC-6 project (HELCOM 2018 and Svendsen & Tornbjerg, 2019). The present report includes the results of assessing total nitrogen and total phosphorus input sources to the Baltic Sea in 2017 (for Poland 2018) and for the three main pathways: airborne, riverine, and direct.

1.2. Load- and source-oriented approaches

According to the PLC-guidelines (HELCOM, 2022) the assessment of sources – the source apportionment – is conducted with two approaches:

— Load-oriented approach
— Source-oriented approach

The objective of the load-oriented approach is to quantify sources of inputs to the sea from different inland point and diffuse sources of total nitrogen and total phosphorus actually entering the Baltic Sea via riverine, direct and airborne inputs (anthropogenic and natural background loads) taking into account the retention in inland surface waters. The load-oriented approach assesses the importance of the sources of nutrient inputs entering the Baltic Sea. PLC-3 until PLC-5 included only the load-oriented approach.

The objective of the source-oriented approach is to quantify total gross loads from point sources, diffuse sources, and natural background losses into inland surface waters within the whole Baltic Sea catchment area of total nitrogen and total phosphorus to get a comprehensive overview of the total loading originating in the Baltic Sea catchment area. Quantifying these nutrients inputs is important for assessing e.g., the effectiveness of pollution reduction measures and the extent of retention of pollutants in the catchment area. The source-oriented approach was exercised in a pilot study under the PLC-6 project (Svendsen & Tornbjerg, 2019).

1.3. Definitions

Table 1.1. provides an overview of the sources assessed in the report, how they can be aggregated, and the abbreviations used in the figures. Sources assessed with load-oriented approach have

Table 1.1. Overview on sources assessed by load-oriented approach (source with L in the end of abbreviation) and source-oriented approach (sources with and S in the end of the abbreviation) and the used abbreviation in the plots. For point sources it will be clearly indicated if it is inland points sources (called indirect point sources) or point sources discharging directly to the sea (direct point sources or direct inputs).

Source	Abbreviation	Comment
Agricultural load	AGL	
Atmospheric load	ATL	On inland surface waters
Aggregated diffuse load	DIL	Two or more diffuse sources load reported aggregated
Diffuse unknown load	DUL	Not specified diffuse loads
Managed forestry loads	MFL	
Natural background loads	NBL	
Load from scattered dwellings	SCL	
Load from storm waters	SWL	
Aquacultural loads	AQL	From inland fish farms (indirect loads) or marine aquaculture (direct loads)
Industrial loads	INL	From inland plants (indirect loads) or plant discharging directly to the sea (direct loads)
Municipal wastewater plant load	MWL	From inland plants (indirect loads) or plant discharging directly to the sea (direct loads)
Aggregated point source loads	PIL	Aggregation of load from two or more point sources (indirect or direct, respectively)
Transboundary loads	TRL	Load from upstream situated countries in a catchment
Diffuse other	DIF-other	Sum of load from two or more diffuse sources
Point source load	PSL	Sum of load from two or more point sources
Atmospheric deposition on the sea	ATM	
Agricultural sources	AGS	
Atmospheric sources	ATS	
Aggregated diffuse sources	DIS	Two or more diffuse sources reported aggregated
Managed forestry sources	MFS	
Natural background sources	NBS	
Scattered dwellings sources	SCS	In the catchment (inland sources)
Storm waters sources	SWS	In the catchment (inland sources)
Aquacultural sources	AQS	In the catchment (inland sources)
Industrial sources	INS	In the catchment (inland sources)
Municipal wastewater plant sources	MWS	In the catchment (inland sources)
Diffuse other sources	Diff-other	Sum of two or more diffuse sources
Point sources	PSS	Sum of two or more point sources

a “L” (L for load) included in the end of the abbreviation, and a “S” with the source-oriented approach (S for source).

Indirect sources cover sources discharging within the catchment, direct sources are sources discharging directly to the sea or at the coastline. The only direct sources are municipal wastewater treatment plants, industrial plants and marine aquaculture facilities.

We also quantify 3 main pathways of total nitrogen and total phosphorus inputs to the Baltic Sea:

— Riverine inputs – which are inputs entering the sea via big and small rivers including areas close to the coast.
— Direct inputs – points sources discharging directly into the sea. They can be located on land (at the coast) or in the sea (e.g. aquaculture plants).
— Atmospheric deposition – what is entering from the air (as dry or wet deposition) on the surface on the Baltic Sea.
— We are not including any inputs from shipping ballast waster or scrubbing, oil facilities etc.

1.4. Structure of report and how results are presented

Results of the load-oriented approach on 2017 input data (2018 for Poland) for total nitrogen and total phosphorus are presented in chapters 3 and 4, and of the source-oriented approach in chapter 5. Chapter 6 includes a comparison of the main pathways (load oriented approach) results since 1995 to evaluate any development in the importance of sources.

Chapter 2 – the extended summary - includes main results from the load-oriented approach by Baltic Sea sub-basins and by Country presented with some few tables, figures, and scaled pie charts on maps. Chapter 3 includes further results from the load-oriented approach shown by individual river catchment on maps. It also includes background information related to area specific runoff, land cover, agriculture land, retention, and population density per catchment in the Baltic Sea catchment area.

Table 1.2. Overview of Baltic Sea sub-basins and HELCOM countries and their abbreviations. In chapter 6 ARC are included in BOS, and SOU+WEB are merged as DS = Danish Straits.

Basin	Abbreviation	Country	Abbreviation
Archipelago	ARC	Denmark	DK
Baltic Proper	BAP	Estonia	EE
Bothnian Bay	BOB	Finland	FI
Bothnian Sea	BOS	Germany	GE
Gulf of Finland	GUF	Latvia	LV
Gulf of Riga	GUR	Lithuania	LT
Kattegat	KAT	Poland	PL
The Sound	SOU	Russia	RU
Western Baltic	WEB	Sweden	SE
Baltic Sea	BAS		

Chapter 7 includes conclusions of the source assessment and recommendations for the next source apportionment assessment.

The PLC guidelines (HELCOM, 2022) provides main principles on how to conduct the two source apportionment approaches. The specific methodology applied by the countries is in the applied methodology report of the PLC-7 project (HELCOM, 2021). Countries have the possibility to aggregate some of the sources e.g. the diffuse sources. Therefore, assessment results in chapters 3-5 are shown for both aggregated and individual sources. There are results for all 9 HELCOM countries with high source aggregation level, but information is missing for some countries and sub-basins regarding individual sources.

The results are shown for following combinations:

— The Baltic Sea.
— The nine Baltic Sea sub-basins (table 1.2).
— The nine Contracting Parties (table 1.2), and in cases of atmospheric nitrogen also for Baltic Sea shipping (BSS), North Sea shipping (NSS) and sum of other countries (countries besides HELCOM Countries).
— Combination of HELCOM countries and Baltic Sea sub-basins to which they have waterborne and/or atmospheric inputs (atmospheric only for total nitrogen).
— Monitored and unmonitored areas.

The results are show as:

— Maps with main sources to the Baltic Sea by sub-basins and by countries (in tonnes).
— Maps with area specific losses (kg/km^2) for each monitored river and for unmonitored areas country per basin.
— Pie charts showing the importance of the source in percentages and indicating the total input in tons in the header and the percentages of total input for both load and source-oriented approach.
— Box-Whisker plots for country per basin monitored rivers indicating the variation in relative importance (in percentages) of the sources assessed for both load and source-oriented approach.

Box-Whisker plots show the average, median, 25% and 75% percentile and the maximum and minimum values for asset of numbers, e.g., importance in percentages of the agricultural source for the 11 monitored catchment in the Swedish catchments area to Bothnian Sea.

As mentioned, we use different aggregation levels of sources. The following source aggregation levels are used for the load- and sources-oriented approach presented on Box-Whisker plots with results covering monitored catchments:

— Natural background losses, diffuse other and indirect point sources.
— Atmospheric deposition on inland waters, natural background losses, agricultural, diffuse other and indirect point sources.
— Atmospheric deposition on inland waters, natural background losses, agricultural, managed forestry, diffuse other, scattered dwellings (indirect) and storm water loads (indirect).
— Indirect municipal wastewater treatment plants, industrial plants, fish farms, scattered dwellings and storm water loads.

Source aggregation levels are used for the load- and sources-oriented approach presented as pie charts:

— Atmospheric deposition on the sea, riverine inputs, and direct point source input (load-oriented) – covering both riverine, direct, and atmospheric inputs to the sea (the main pathways).
— Atmospheric deposition on the sea, natural background load, diffuse other loads, and sum of direct and indirect point source load (load-oriented) – covering both riverine, direct, and atmospheric inputs to the sea.
— Natural background losses, diffuse other inputs, and indirect point source inputs (load- and source oriented) – covering monitored and unmonitored riverine inputs.
— Atmospheric inputs on inland surface waters, natural background losses, agricultural inputs, diffuse other inputs, and indirect point source inputs (load- and source-oriented) – covering monitored and unmonitored riverine inputs.
— Atmospheric inputs on inland surface waters, natural background inputs, agricultural inputs, managed forestry inputs, diffuse other inputs, scattered dwellings inputs and storm waters inputs (load- and source-oriented) – covering monitored and unmonitored riverine inputs.
— Indirect municipal wastewater treatment plant inputs, industrial inputs, fish farm inputs, scattered dwellings inputs and storm water inputs (load-and source-oriented) – covering monitored and unmonitored riverine inputs.
— Direct municipal wastewater treatment plant load, industrial load, and marine aquaculture load (load-oriented approach).
— Sum of indirect and direct municipal wastewater treatment plant inputs, sum of indirect and direct industrial inputs, sum of indirect and direct fish farm inputs, scattered dwellings inputs and storm water inputs – covering all human waste water inputs to the sea (riverine plus direct point sources).

Chapter 4 and 5 includes some selected examples with results presented as pie charts and Box-Whiskers plots. In the chapter 9 (annex) are information about where to find pie charts covering all countries, basins and country per basin, and country per basin Box-Whiskers plots. Chapter 9 also includes information on where to find data behind the assessment.

1.5. Comments on applied methodology and other conditions to consider

When comparing and evaluating source apportionment assessment results it is important to take account the following circumstances:

— Sources apportionment is assessed for one year – year 2017. Although one country – Poland – have reported 2018 data, while the remaining data, including on atmospheric deposition on the Baltic Sea are from 2017. While the importance importance of different sources will usually only change gradually in time, it is important to remember that source apportionment is performed on not weather normalized data, and therefore dry or wet weather conditions have an impact on the importance of different source categories. Overall, during a dry year, loads from diffuse sources (including losses from scattered dwellings and storm waters) are lower than in wet years. Loads from points sources (municipal wastewater treatment plants, industrial plants, and aquaculture) show less variability to weather conditions. Thus, we can expect that in catchments with dry conditions in 2017 the importance in percentages of diffuse sources is lower than in corresponding catchments with wet conditions. Table 1.3 summarizes flow and total inputs of total nitrogen and total phosphorus to the Baltic Sea sub-basins in 2017 compared with the corresponding average of 1995-2017. Flow is lower than average to Kattegat (17% lower than average) and to Bothnian Sea (10%), but higher than average particularly to Gulf of Riga (37%), but also to Baltic Proper and Danish Straits (13%) and to Gulf of Finland (8%) while it is close to the average to Bothnian Bay. To Kattegat the lower-than-average flow is valid from the Swedish part of the catchment as the flow from the Danish part of Kattegat catchment is higher than average. This is clearly indicated in figure 3.4 with a catchment map on deviations in the specific run-off (flow expressed as runoff per area unit) in 2017 from the average of 2005-2016).
— Poland discharges only to Baltic Proper, and for 2018 the flow to Baltic Proper was 15% lower than average of 1995-2018, therefore for Poland sources apportionment is assessed for a dry year which usually will imply that the share for the diffuse sources is lower than in a year with average flow
— Different methodologies applied for quantifying/estimating sources must be considered comparing importance of source from the countries. The relevant methodologies are summarized in table 4.1, with further details available in HELCOM, 2021c. One main issue concerns the fact that some countries are not estimating all sources, but aggregating two or more e.g., diffuse sources. Some countries estimate inputs from many of their point sources based on statistical information or by very simple modelling, while other countries monitor the losses from even several minor point sources. Estimated inputs of total nitrogen or total phosphorus from scattered dwellings and storm waters are also based on different levels of detailed statistics and models. The lower limit for quantifying and reporting inputs from wastewater treatment plants range from 30 PE (person equivalents) in e.g., Denmark up to 2,000 PE or bigger. Further, estimating natural background loads are not fully harmonized in PLC-7, both regarding the definition and methodology. Latvia only applies natural background losses for forested areas (then underestimating natural background losses and overestimating other diffuse sources), while other countries applied it for entire catchment maybe excluding fortified (urban) areas. Some countries quantify natural background losses from monitoring in small catchment with no or low human activity and impact (besides what is deposited via airborne deposition), other use only modelling. In modelling natural background loads some countries assume no human activity at all, leading to very low natural background loads and shares of total nutrient loads (as Germany). Agricultural loads are estimate using models, and in some cases as in the load oriented approach it is determined from total waterborne (monitored) inputs plus retention subtracting the other sources. Retention in inland surface waters (including retention due to flooding of river valleys) is important to take into account both in

the source- and the load-oriented approach, and countries used different methodologies/models to estimate the retention, and also different scales (small versus big rivers catchments). In the sources-oriented approach, it might be necessary to estimate retention not only in inland surface waters, but also in soils as for agricultural losses pending on the applied methodology/model.

— In the PLC-6 source apportionment Lithuania estimated their diffuse sources with the SWAT model as an average of 7 years (2007-2014), making their result less comparable with other countries, if we assume there have been changes in the importance of different sources.
— Denmark and southern part of Sweden catchment are characterized with rather small catchments and rivers. Even though Denmark monitors and reports source apportionment results from 171 rivers to HELCOM of the approx. 320 reported catchments by all contracting parties in PLC-7, a rather high proportion of the catchment remains as unmonitored areas (nearly 40 % for Denmark). Total nitrogen and total phosphorus inputs from unmonitored areas are based on model estimates, although some countries perform monitoring on (bigger) point sources in the unmonitored areas. Estimation of inputs from unmonitored areas ranges from simple area proportioning from upstream monitored catchments to use of more comprehensive modelling assessment (see table 1.4).

Table 1.3. Flow, waterborne total nitrogen and total phosphorus inputs to Baltic Sea sub-basins in 2017 as compared with average of 1995–2017. Archipelago Sea is included in Bothnian Sea (BOS) and The Sound and Western Baltic are merged as Danish Straits (DS).

	Catchment area	Basin sea area	Flow	Flow	TN waterborne	TN waterborne	TP waterborne	TP waterborne
			2017	1995-2017	2017	1995-2017	2017	1995-2017
	km^{-2}	km^{-2}	m^3 s^{-1}	m^3 s^{-1}	tonnes	tonnes	tonnes	tonnes
BOB	263,000	36,000	3,584	3,473	48,500	51,600	2,390	2,520
BOS	228,000	79,000	2,639	2,924	41,800	53,000	1,940	2,310
BAP	576,000	209,000	3,921	3,469	364,800	289,000	12,910	15,260
GUF	423,000	30,000	3,803	3,517	108,700	108,500	4,720	6,960
GUR	138,000	19,000	1,453	1,061	106,100	76,400	3,020	2,210
DS	27,000	21,000	256	227	39,600	39,900	1,560	1,530
KAT	87,000	24,000	900	1,086	46,500	54,600	1,380	1,510
BAS	**1,740,000**	**418,000**	**16,557**	**15,756**	**756,000**	**673,000**	**27,900**	**32,300**

Table 1.4. Summary of main characteristics of methods/models used for the PLC-7 source apportionment assessment by the countries. HELCOM (2021c) includes more detailed description of the applied methods and models.

	Flow/Load	Unmonitored areas	Source apportionment	Retention	Transboundary inputs
Denmark	Daily flow and daily concentration (linear interpolation). Chemical and hydrological stations are coinciding. All point sources >30 PE calculated based on monitoring flow and concentrations (sampling frequency depends on PE) Scattered dwelling: estimated based on statistic of number of scattered dwellings, type of wastewater collection/treatment and coefficient of annual TN and TP losses for category. Storm waters: losses relate to statistics and amount of rain Content of TP in 1 PE reduced gradually since 1990.	National model estimates flow, diffuse losses of TN and TP (including scattered dwelling). Modelled run off in 1*1 km grid are aggregate to 3351 catchments of 1.5 to 30 km^2 polygons, and modelled monthly diffuse losses are calculated on the 3351 catchments to estimated losses from the unmonitored areas. Diffuse losses for TN based on (soil type, % cultivation, degree of drainage, monthly 10*10 grid precipitation, air temperature nitrogen surplus) and TP (based on soil type, % cultivation, regional baseflow index BFI, monthly 10*10 km grid precipitation and % meadows) Point sources inputs (also monitored in unmonitored areas) added.	Load and source-oriented approach according to guidelines. Load oriented – agriculture estimate from loads. Minus other sources taking into account retention. Source oriented: Diffuse losses estimated with models (as for unmonitored areas). Atm. dep: calculated on inland surface waters based on monitored deposition on land (of TN and TP).	Calculated for all large lakes individually with a national model. Retention estimates for nearly 6,000 small ponds and lakes based on results from 16 monitored lakes), for streams wider than 2 m and for restored wetlands.	Not relevant for Denmark.
Estonia	Daily flow daily concentration (linear interpolation). Point sources quarterly reported flow and concentrations.	National model (EstModel) divides Estonia in three catchments and eight sub-basins. Average specific run-off per catchment based on monitored part of the catchment based on the simple coefficient-based model	Source oriented approach based on simple coefficients from the EstModel.	Retention in surface water is calculated using Michaelis-Menten equation approach (Michaelis & Menten, 1993). Retention on diffuse load is estimated as, where the value of the retention coefficient of the surface water is related to the estimated residence time of the nutrients in the waterbody. Retention on point sources are calculated by point source and by parameter (TN and TP) related to the time it takes for the point source loads to reach the monitoring station and the time the retention of the point source load attain half of the maximum value of the retention coefficient.	Narva River (border) assumed 1/3 of total load is Estonian.

Finland	Load: mean monthly concentration multiplied by mean monthly flow and summed up. Flow proportional sampling. Point sources monitored.	By extrapolation from monitored areas.	Load and source-oriented approach according to guidelines. Natural background inputs and diffuse load based on monitoring 45 catchments. SOILN-N for TN estimates and ICECREAM model for TP loads from agricultural land. These results are extrapolated for whole Finland with various models.	National statistical modelling with mass balance approach using incoming and outflowing load in a sub-catchment, and load from point sources, agriculture, forestry, scattered dwellings, natural leaching and atmospheric deposition of N on lakes. Retention is assumed negligible in unmonitored areas.	Based on monitored inputs of the rivers Torne and Vuoksi River and modelled nutrient inputs of the Seleznevka River.
Germany	Load: Daily flow and daily concentration (linear interpolation) or mean monthly flow and monthly concentration depending on the Federal State. Direct point sources based on continuous flow measurements and non-continuous concentration.	Annual reporting: Based on area proportion method based on the entire monitored area. PLC 7 – periodic reporting: Using the MoRE model to calculate pathway specific loads (coming from point and diffuse sources) and flow from unmonitored areas (summed up for the entire unmonitored area).	Source oriented approach using results of the empirical based emission MoRE model. Calculations are pathway oriented.	The MoRE model provides riverine retention based on the MONERIS retention coefficients for TN and TP (Behrendt & Opitz (1999)).	Based on agree proportions of total TN (3.7 %) and TP (8.5 %) load in Oder.
Latvia	Load: mean monthly concentration multiplied by mean monthly flow and summed up. Point source load quantified based on monitoring results.	By extrapolation from monitored areas.	Source oriented approach based on land-use and simple export coefficients.	Follows Behrendt & Opitz (1999) with retention coefficient for TN and TP depending on discharge, areas on surface waters in the catchment.	Monitored monthly concentrations and extrapolated discharges. Daugava loads divided between RU and BY taking into account catchments areas (guidelines).
Lithuania	Load: mean monthly concentration multiplied by mean monthly flow and summed up. Direct point source load monitored? Periodic reporting: Load and flow are modelled with SWAT model (set up for entire Lithuania).	Using areas proportion method using Minija River concentrations and flows. Periodic reporting: SWAT to model flow and load from unmonitored areas.	National model using average data 2007-2014. SWAT-model use environmental data, climate, point source discharge, agricultural activities etc.) – all sources simulated, but atmospheric deposition is monitored. Results re-scaled to mirror the reported annual, which were calculated from monitoring results.	Using SWAT model – calculate retention on all pollutants and sources – and include processes in river channels as sedimentation, resuspension, turn-over of nutrients, diffusion.	Modelling, but for Sventoji area proportion. The models do not cover catchment in other countries and are therefore not working very well. But, Belarussian based on monthly concentrations and daily flow monitored. Inputs through Matrosovka channel is calculated by flow proportional coefficient based on measured data in the channel. Also modelling transboundary inputs from Lithuania to Latvia.

Poland	Flow based on daily flow measurements. Nutrient concentration measured monthly. Load calculated as product of monthly flow and monthly concentration. Point sources- larger point sources need at least one measurement required – calculate load of the day and multiply with 365. For smaller WWTP (typical < 2000 PE) without monitoring 4.0 kg N/year per PE and 0.61 kg P/y per PE are used and assuming 65 % and 35 % reduction coefficients for TN and TP, respectively. Industries: Only data for plants in PRTR register. Used questionnaire to get information to several industrial plants. Information lacking rom several plants, load are underestimated. Scattered dwellings: TN and TP load 4.4 kg/n and 0.8 kg P per person, statistics on number of not connected person and coefficient of TN and TP entering surface waters according to HARP guidelines. Storm waters: Using HARP guidelines Using paved urban areas connected to combined sewer system, TN and specific TN and TP discharges from paved urban areas (14 kg N/ha and 1.2 kg TP/ha) Aquaculture sources: No fish feed data available. Use of standard units loads of 60 kg/N on fish and 9 kg/tons fish.	Use the area proportion methodology. The proportion between the unmonitored and monitored area of each river was used to calculate the load from unmonitored parts of river. The load from point sources located at unmonitored catchments was added to load in each catchment. For BAPLAND the load was extrapolated from 7 monitored rivers using the same proportion method.	Load-oriented approach: It is assumed that retention coefficient of nutrients from different sources are not equal. Sources have been divided in two groups: one group with the source discharging directly to surface waters (point sources and atmospheric deposition, the other group diffuse sources including scattered dwelling. overflows and natural background losses. Applying two scenarios. In scenario 1 retention coefficients for all sources in both groups, and scenario 2 all retention in group 1 is zero. Average of the two scenarios are used. Natural background losses: The losses are clearly separated from managed forestry and wastelands. 0.02 mg P/l is used for natural background concentration, while the nitrogen concentration depends on soil permeability from 0.15 mg N/l (highly permeable) to 0.60 mg N/l (poorly permeable) soils. For atmospheric deposition in natural background catchments a fixed literature value is applied (1.2 kg N/ha) Agricultural land: Monitoring in each catchment of nitrates and phosphates – monitored in a country wise groundwater and tile drainage water monitoring program (nitrate and phosphate) in mainly agricultural areas. Data only available for Vistula and Oder catchment. Flow from agricultural land: Load= average concentration time average flow multiplied by a correction factor to take into account other N and P compounds, and other correction done (se section 2.5 from Poland). For some minor catchment also used MONERIS modelling to estimate agricultural sources. Forestry and unmanaged land: Use of slope, permeability of soils, estimated N and P concentration in precipitation, flow weighted concentration from managed forestry.0,038 mg p/l was used for all soil types, while nitrogen concentration depends on soil permabilty from 0.31 mg N/l high permeable to 1.22 mg/l for poor permeability Direct atmospheric deposition: Based on monitoring from 22 monitoring stations TN and TP in precipitation and calculated for inland surface waters Scattered dwellings: Se column "Flow/load" Number of persons not connected to WWTP are estimated. It is assumed that 90 % of total N and P loads generated discharged from untreated areas is generated by people in such areas and using 4 kg N and 0.61 kg P per PE. The share of TN and TP reaching surface wasters are estimated by making an agricultural fertilizer balance. Urban surface run off and combined sewer overflow: Estimate some standard concentration in the flow from urban surface run off divided in some categories based om extensive US surveys. A tentative figure of 5 % of total N and P load discharged to combined sewers has been used for estimating combined sewer overflows. Source in monitored and unmonitored areas are estimated with exactly same methodology.	Retention coefficients in monitored rivers is calculated based on the mass-balance methodology. Retention in unmonitored part of a river catchment was calculated as proportional to the share of the unmonitored area of the entire catchment of that river catchment – but is only applied on the sources in the unmonitored part of a catchment	From Slovakia: Based on monitored concentration and flows received from Slovakia. From Ukraine: For on rivers based on monitored from other rivers based on the proportion af catchment I Ukraine and using a unit load From Belarus: More or less as from Ukraine. Czech Republic: Polish monitoring at the border covering 75 % of the catchment in Czech Republic. Remaining contribution from CZ are not quantified. Germany: Load from Germany estimated based on fixed ratios of Oder total loads (3.7 % TN and 8.5 % TP).

Russia	Load: mean monthly concentration multiplied by mean monthly flow and summed up. Direct point sources based on continuous monitoring (min 12 times per year).	Estimated using HYPE and FyrisNP model.	For big catchments using Institute of Limnological Loading Model. Model includes annual load, load from point sources, diffuse load from agriculture, diffuse emissions from land surface not affected by agriculture and atm. dep. HYPE og FyrisNP model used to assess source contribution in Leningrad region and smaller catchments in the watershed of Gulf of Finland. Point source load: state statistical data. Natural and anthropo genic load (excluding agriculture) specific concentrations in runoff from urban areas (scattered dwellings areas), natural background areas and mixed areas taking into area and runoff of each of these types. For small catchments load from scattered dwelling are estimated using a Swedish Environmental Protection Agency method. Atmospheric: TN zero, TP 3.2 kg/km^2. Agriculture diffuse loads: Formula 3 take into account N and P content I plough layer, organic and mineral fertilizer applied, field areas (per enterprise), coefficient related to uptake of organic and mineral fertilizer, nutrient outflow from plough layer, distance from agricultural areas to receiving surface waters, soil types, soil texture, land use structure, status of applying BAT. Background load: Take into account coefficient for mass exchange with atmosphere, % lake area and retention factor.	Follows Behrendt & Opitz (1999) method: See Russia formulas no. 5-6-7-8. Requires annual load from the catchment direct load to the lake, hydraulic load to the lake, lake percentage in the catchment, specific run-off.	Based on agree proportions used for PLC5.5.
Sweden	Daily flow and daily concentration (from linear interpolation of monthly concentrations). Point sources monitored loads. Smaller point sources estimated based on treatment methodology and number of person equivalents.	Main rivers (38) monitored to the mouths. Minor rivers and coastal areas are estimated with area-specific load estimated from similar rivers in the area.	Source oriented: TN and TP loads to lakes and rivers calculated for 39,600 sub-catchments. Several models used. Inputs from point sources and diffuse sources. Diffuse source estimated by land use area multiplied by specific runoff and concentration in runoff for the land use. Concentration for agricultural land calculated by the NLeCC – includes SOILNDB for N and ICECREAMDB for P (using fertilizer, atm. dep., crop yield, catch crops, buffer zones, agricultural practices, weather data, crop rotation, soil type, soil P, soil slope). Specific concentration for land use forest, wetlands, alpine and open land based on representative data based on monitoring campaigns. Storm water: runoff coefficients from statistics. Scattered dwellings: Number of population not connected, load per person, reductions efficiencies of applied techniques. Atm. dep. MATCH model (N) and monitoring (P). Load oriented approach Retention form SMED-HYPE in 39,600 sub-catchments. Calculated at river mouths using total loads from the annual reporting.	National models using SMED-HYPE model in the 39,600 sub-catchments. Take into account river and lake nutrient processes. SMED-HYPE is built upon HYPE – but use the land use leaching and local river retention.	Not reported in PLC-7. Load from Norwegian and Finnish catchments calculated from Corine Land Cover and land use not including anthropogenic land use sources.

Table 1.5. Monitored and total catchment area within the nine HELCOM countries, number of monitored rivers and unmonitored areas per country (upper part of the table) and per basin (lower part of the table) used for the source apportionment assessment on 2017 data (Poland 2018). The total Baltic Sea catchment area is about 1.74 million km2, of these 127,000 km2 being situation in upstream non-HELCOM countries. In the monitored catchment some countries have included upstream catchment area from other countries (Latvia, Lithuania, Sweden). See also table 1.3.

Country	Monitored catchment km²	Total catchment km²	Monitored rivers	Unmonitored areas	Total
Denmark	16,241	31,130	171	4	175
Estonia	34,800	45,400	18	3	21
Finland	264,404	301,250	29	4	33
Germany	24,155	29,090	25	2	27
Lithuania	64,262	65,200	8	1	9
Latvia	137,152	64,590	8	2	10
Poland	295,466	311,000	14	1	15
Russia	288,416	326,080	5	1	6
Sweden	371,654	442,700	38	5	43
Basin					
Bothnian Bay	257,922	262,300	22	2	24
Bothnian Sea	185,061	214,600	16	2	18
Archipelago	2,935	8,950	4	1	5
Baltic Proper	449,054	495,780	51	8	59
Gulf of Finland	377,030	422,880	24	3	27
Gulf of Riga	141,946	104,850	12	2	14
Western Baltic	12,447	22,280	90	2	92
Sound	1,126	4,620	15	2	17
Kattegat	68,406	79,640	81	2	83
Baltic Sea	**1,495,927**	**1,615,900**	**315**	**24**	**339**

Table 1.6. Number of monitored catchment country per basin in the nine HELCOM countries.

	BOB	BOS	ARC	BAP	GUF	GUR	WEB	SOU	KAT	Total
Denmark				9			73	14	75	171
Estonia					13	5				18
Finland	13	4	4		8					29
Germany				8			17			25
Lithuania				6		2				8
Latvia				3		5				8
Poland				14						14
Russia				1	4					5
Sweden	9	12		10				1	6	38
Total	22	16	4	51	24	12	90	15	81	315

1.6. Data used in the assessment

Contracting Parties have monitored and reported according to the PLC guidelines related to the periodic PLC reporting requirements (HELCOM, 2022 tables 1.1 and 1.2, chapter 13 and annex 3) for both the load- and source-oriented approach. In principle Contracting Parties should quantify and report total nitrogen and total phosphorus inputs from all individual point sources in the monitored part of the catchment to the nine Baltic Sea sub-basins, and all individual point sources discharging directly to sea. The point source categories are:

— Municipal waste water treatment plants
— Industrial plants
— Aquaculture plants

For unmonitored areas total nitrogen and total phosphorus inputs can be reported aggregated per point sources category per Baltic Sea basin.

Further, Contracting Parties should quantify and report total nitrogen and total phosphorus inputs from the following diffuse sources per monitored catchment individually, and aggregated per unmonitored area to each Baltic Sea sub-basin:

— Natural background loads
— Atmospheric input on inland surface waters
— Agriculture
— Forestry
— Scattered dwellings
— Storm waters

Some countries have aggregated some of the diffuse sources which results in some further diffuse source categories (see table 1.1).

Contracting Parties should also report inland surface water retention per monitored catchment and for unmonitored area.

Transboundary inputs via rivers from non-HELCOM countries are included as a separate diffuse source by Latvia and Lithuania. Sweden includes inputs from Norway as a part of the Swedish loads. There is a short summary in table 1.4 about how countries handle transboundary inputs.

Data on atmospheric deposition per country (including from Baltic Sea and North Sea shipping and from other countries not being HELCOM countries), per Baltic Sea basin, and per country by basin are modelled and provided by EMEP according to a contract with the HELCOM Secretariat.

The source apportionment data from 315 monitored rivers and 24 unmonitored areas reported cover the 1.74 million km^2 catchment areas to the Baltic Sea including transboundary inputs from approx. 127,000 km2 catchment area situated in upstream non-HELCOM countries (Belarus, Czech Republic, Norway, Slovakia, and Ukraine) (table 1.5).

1.7. Acknowledgments

Great thanks to the PLC-7 implementation group and data reporters and quality assurers from the Contracting Parties, PLC-7 periodic data manager, BNI and HELCOM Secretariat:

Denmark:
Lars M. Svendsen, DCE – Danish Centre for Environment and Energy, Aarhus University, Denmark
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Finland:
Antti Räike, Finnish Environment Institute (SYKE); Finland
Germany:
Julian Mönnich, German Environment Agency, Germany
Latvia:
Ilga Kokorite; Latvian Environment, Geology and Meteorology Center, Latvia
Lithuania:
Svajunas Plunge, Environmental Protection Agency, Lithuania
Poland:
Damian Bojanowski, State Water Holdings Polish Waters, Poland
Alicja Pecio, Institute of Soil Science and Plant Cultivation – State Research Institute, IUNG-PIB, Poland
Piotr Kwiatkowski, DHI, Poland
Russia:
Natalia Oblomkova, Institute for Engineering and Environmental Problems in Agricultural Production – branch of Federal State Budgetary Scientific Institution “Federal
Sweden:
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2. Extended Summary

2.1. Background and aims

Eutrophication caused by an excessive input of nutrients remains the major environment threat to the Baltic Sea according to the updated Baltic Sea Action Plan – 2021 BSAP (HELCOM, 2021a). Periodical assessment of major sources and pathways of nitrogen and phosphorus have been an integral part of the Pollution Load Compilations (PLC) since PLC-3 source assessment of 1995 data (HELCOM, 1998).

Assessment of sources are conducted with two different approaches:

— Load-oriented approach
— Source-oriented approach

The objective of the load-oriented approach is quantifying sources of inputs to the sea from different inland point and diffuse sources of nitrogen and phosphorus actually entering the Baltic Sea via riverine, direct and airborne pathways (anthropogenic and natural background loads) taking into account the retention in inland surface waters. The load-oriented approach assesses the importance of the sources of the nutrient inputs entering the Baltic Sea.

The objective of the source-oriented approach is quantifying total gross loads from point sources, diffuse sources, and natural background losses into inland surface waters within the whole Baltic Sea catchment area to an assessment of the total loading originating in the Baltic Sea catchment area. Quantifying these inputs is important for assessing e.g., the effectiveness of pollution reduction measures and the extent of retention of pollutants in the catchment area.

The main pathways of nitrogen and phosphorus inputs to the Baltic Sea are via rivers (riverine inputs), point sources discharging directly to the Baltic Sea (direct inputs), and via emissions to the air as deposition on the surface of the Baltic Sea (atmospheric deposition). The loads from point sources (municipal waste water treatment plants, industrial plants and aquacultural plants), and from diffuse sources (such as in natural background sources, and anthropogenic sources as agriculture, managed forestry, scattered dwellings, storm water etc.) are quantified. Definitions can be found in chapter 1.3.

Overall assessment results with focus on load-oriented findings are summarized in this chapter. They are based on monitoring and modelling results, and assessment of 315 riverine catchments, 24 unmonitored areas, and EMEP assessment of atmospheric total nitrogen deposition on the Baltic Sea in 2017 (although Polish waterborne data from 2018) – see chapters 1.5 and 1.6 for the methodology and data used in the assessment.

2.2. Content of report and reservations using assessment results

Results of the assessment are presented in chapters 3-5 and the annexes (chapter 9):

— Chapter 3: Sources of riverine total nitrogen and total phosphorus inputs to Baltic Sea sub-basins shown as area specific loads for each of the 315 monitored catchments, and for the unmonitored areas, for e.g., agricultural load, natural background loads, direct point source loads in 2017 etc. The chapter also includes background information on e.g., specific runoff in 2017, proportion of agricultural land, inland surface water retention, land cover etc.
— Chapter 4: Assessment results of the load-oriented approach in tonnes (tables and plots) and percentages per HELCOM countries and for the nine Baltic Sea sub-basins per pathways (riverine, direct inputs and atmospheric deposition), and per source at different aggregation level of the sources. Chapter 4 also provides examples on the variation of the proportions of sources for individual monitored rivers within country catchment to a Baltic Sea basin.
— Chapter 5: Same information as chapter 4 on sources, but for only for sources to inland waters using the source-oriented approach.

Chapter 1 includes a sub-chapter on applied methodologies, describing that even though PLC-7 is based on the until now by far most comprehensive and complete dataset there are some shortages, that must be taken into account when using and evaluating the results:

— One main challenge is the use of data from two years: eight contracting parties have reported 2017 data for the PLC-7 source apportionment assessment while Poland reported 2018, where the weather condition was rather extreme dry, and flow from Polish catchment was about 25% lower than average (1995-2017). Flow conditions were also rather extreme in part of the Baltic Sea catchment in 2017 for e.g., to Gulf of Riga (37% higher than average), Baltic Proper (12% higher) and Kattegat (16% lower than average) – see table 6.2 and figures 3.3 and 3.4.
— Countries have applied different methodologies, that not necessarily provide fully comparable results when quantifying sources as e.g., natural background loads, agricultural loads, load from scattered dwellings or storm waters.

— Some HELCOM countries have only provided sources on a rather aggregated level. Results are shown with different degree of aggregation level, where the most aggregated sources include alle countries and Baltic Sea sub-basins, while the most detailed level with up to 10 sources of total nitrogen and total phosphorus inputs to the Baltic Sea are shown for five countries and six of the nine Baltic Sea sub-basins, not including Baltic proper, Gulf of Finland and Guld of Riga.
— Inputs from upstream part of transboundary rivers are either not included in the downstream countries source apportionment or included in the category “other diffuse sources”, and thereby this category in some cases includes also inputs from point sources, natural background loads, atmospheric deposition on inland waters and anthropogenic diffuse sources.

Further weather and the resulting flow conditions have an impact on the proportion of point sources of total nitrogen and total phosphorus inputs into inland surface waters – and with a time lag to the sea. Generally, point sources discharge a certain amount per year independent of weather conditions, while there is for most diffuse sources a positive, but not linear relation between the flow and the load of nutrients. Overall, with annual flow higher than average we can expect that diffuse sources have a higher proportion of total inputs than in a year with a lower than average flow, where point sources will have higher shares of total inputs.

2.3. Main pathways of total nitrogen and total phosphorus to the Baltic Sea

Riverine inputs are the main pathways of total nitrogen (73%) and total phosphorus (88%) to the Baltic Sea in 2017 (table 2.1 and 2.2 and figure 2.1). Atmospheric deposition is the second most important pathway for both total nitrogen (24%) and total phosphorus (7%), and direct point sources representing the smallest pathway with 3% and 5%, respectively. Atmospheric deposition of total nitrogen is a very important pathway for two sub-basins: in the Archipelago it constitutes the most important pathway with a share of 48%, and to Western Baltic with 42% (second highest proportion for this basin). These sub-basins have rather large sea areas compared with the catchment area draining to the respective sub-basins. By country for total nitrogen the proportion from riverine pathway increases and atmospheric deposition decreases, as we then exclude atmospheric deposition from Baltic Sea and North Sea shipping and from non HELCOM countries (figure 2.2).

For phosphorus, direct point sources contribute as the second most important source with about 42% of total inputs to The Sound.

It should be noted that three sub-basins receive the main part of nutrient inputs to the Baltic Sea, the Baltic Proper nearly half of total inputs of total nitrogen and total phosphorus, and Gulf of Finland and Gulf of Riga about 15% each. These shares are to some extent impacted by the weather conditions in 2017 and 2018 for Polish data only (included in the Baltic Proper).

Table 2.1. Shares (in percentages) for main sources (pathways) of total nitrogen (TN, tonnes) to the Baltic Sea by basins in 2017 (Polish data from 2018). The rightmost column indicates the share of the total nitrogen inputs to the basin of the corresponding total nitrogen input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea.

TN Basin	Riverine %	PS_DIR %	ATM %	Total tonnes	Total of total (%)
Bothnian Bay	80.2	6.4	13.4	55,964	6.1
Bothnian Sea	60.7	6.5	32.9	52,499	5.7
Archipelago	44.7	7.7	47.6	12,826	1.4
Baltic Proper	67.9	1.3	30.8	399,394	43.2
Gulf of Finland	82.5	7.2	10.3	137,219	14.9
Gulf of Riga	93.0	0.3	6.7	139,332	15.1
Western Baltic	55.3	3.2	41.5	50,224	5.4
Sound	63.0	16.2	20.8	11,089	1.2
Kattegat	66.9	2.9	30.1	65,216	7.1
Baltic Sea	73.1	3.1	23.8	923,763	100

Table 2.2. Shares (in percentages) for main sources (pathways) of total phosphorus (TP, tonnes) to the Baltic Sea by basins in 2017 (Polish data from 2018) and total phosphorus inputs by basins in tonnes. For further explanation see caption to table 2.1.

TP Basin	Riverine %	PS_DIR %	ATM %	Total tonnes	Total of total (%)
Bothnian Bay	89.5	3.5	7.0	2,573	9.0
Bothnian Sea	69.6	9.0	21.4	1,695	6.0
Archipelago	86.7	8.5	4.8	642	2.3
Baltic Proper	90.0	1.6	8.4	12,424	43.7
Gulf of Finland	87.1	9.8	3.1	4,877	17.1
Gulf of Riga	96.1	1.2	2.7	3,432	12.1
Western Baltic	80.2	10.7	9.1	1,042	3.7
Sound	54.4	42.4	3.2	312	1.1
Kattegat	85.1	6.8	8.1	1,456	5.1
Baltic Sea	87.9	4.8	7.3	28,452	100

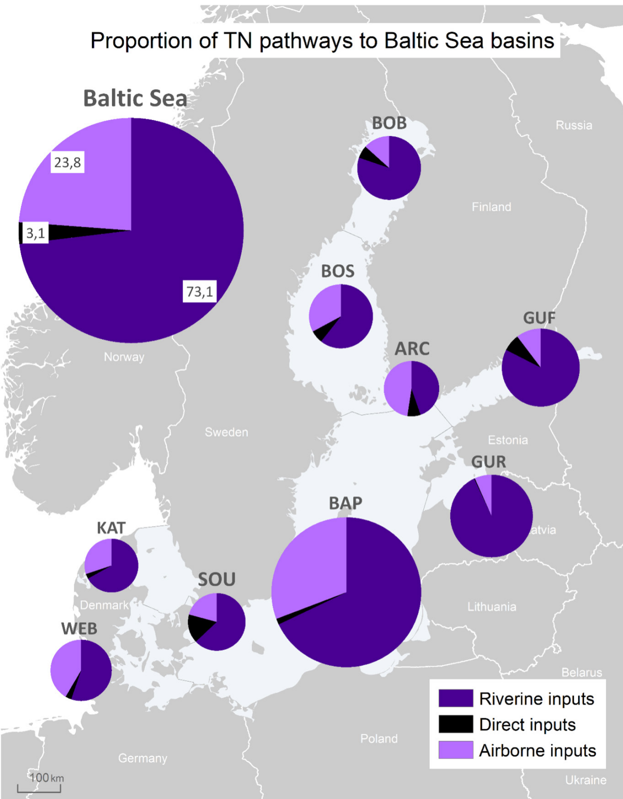


Figure 2.1. Share of total nitrogen inputs (TN in %) to the Baltic Sea sub-basins in 2017 for the main pathways in 2017 (load-oriented approach). Atmospheric deposition is regarding deposition on the sea surface of the sub-basins. Total inputs of nitrogen in tonnes to the sub-basins are shown in figure 2.3 and numbers are given in table 4.2 together with the percentages for all sub-basins.

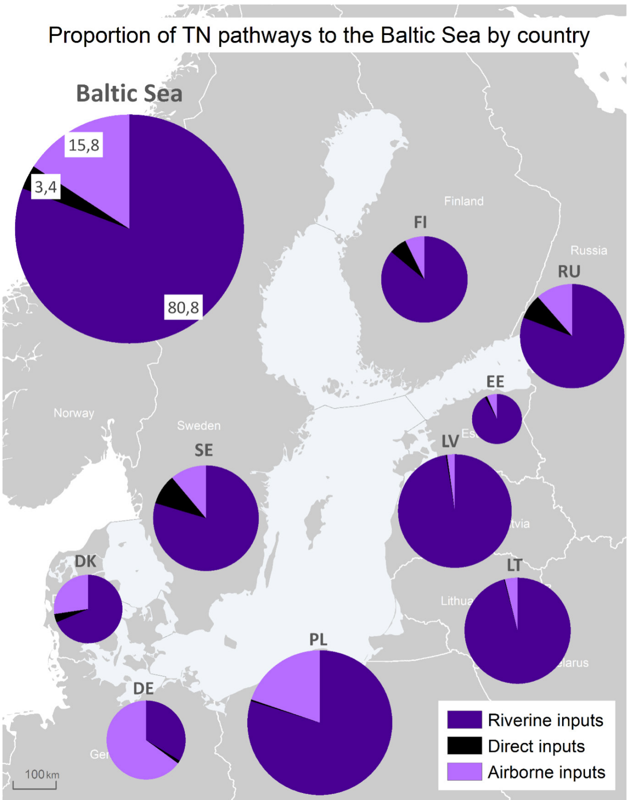


Figure 2.2. Share of total nitrogen inputs (TN in %) to the Baltic Sea by countries in 2017 (Poland 2018) for the main pathways (load-oriented approach). Atmospheric deposition is regarding deposition on the sea surface of the sub-basins. Compared with figure 2.1 atmospheric deposition from shipping on Baltic Sea and North Sea and from non HELCOM countries are not included in the pathway quantification increasing the importance of riverine input and accordingly decrease the proportion of atmospheric deposition. Total inputs of nitrogen by country are given in table 4.3 together with the percentages for all sub-basins.

2.4. Main sources of total nitrogen and total phosphorus to the Baltic Sea

Contribution by countries

Based on the total nitrogen and phosphorus inputs to the Baltic Sea the importance of inputs from HELCOM countries can be evaluated:

— The four biggest contributors of total nitrogen to the Baltic Sea in 2017 are Poland (17%, data from 2018), Latvia (13%, but that includes some transboundary inputs), Russia (12%) and Sweden (12%). Baltic Sea and North Sea shipping contribute with approx. 2.5% and total nitrogen inputs of other countries (both airborne and waterborne inputs) have a share of more than 7% (table 2.5).
— The four biggest contributors of total phosphorus to the Baltic Sea in 2017 are Poland (25%, data from 2018), Russia (14%), Finland (13%), and Latvia (12%, but that includes some transboundary inputs). Atmospheric deposition and some waterborne transboundary inputs from non HELCOM countries contributes with approx. 7% (table 2.6).

For inputs to individual sub-basins the shares from countries can be very high e.g., or Denmark and Sweden to the Sound for both total nitrogen and total phosphorus.

Main sources

It has been possible to divide inputs of total nitrogen and total phosphorus to all Baltic Sea sub-basins and from HELCOM countries in four source load categories (tables 2.3-2.6, figure 2.3-2.6):

— Natural background loads.
— Other diffuse sources which is the sum of loads from originating from agriculture, managed forestry, atmospheric deposition on inland waters, scattered dwellings, storm waters and for some countries the sum of upstream transboundary riverine inputs.
— Point sources which is the sum of loads from point sources discharging into inland surface waters (indirect point sources) reaching Baltic Sea via riverine loads and loads from point sources discharging directly into the sea (direct point sources). This category covers municipal waste water treatment plants, industrial plants (not connected to municipal waste water treatment plant) and aquaculture plants.
— Atmospheric deposition on the sea (for total nitrogen deposition is calculated by EMEP (e.g. Gauss et al, 2020) while for phosphorus is used a fixed area specific deposition of 5 kg P km^{-2} (HELCOM 2014)).

Diffuse other sources constitute the highest proportion of total nitrogen (nearly 50%) and total phosphorus (about 56%) inputs to the Baltic Sea. For total nitrogen, atmospheric deposition on the sea has the second highest share (24%) followed by natural background loads (20%) and point sources (9%). Natural background loads have the second highest share of total phosphorus inputs to the Baltic Sea (20%), followed by point sources (17%) and atmospheric deposition (7%).

For sub-basins the importance of the four sources is also shown in figures 2.3-2.4, clearly indicating that natural background loads have the highest proportions of total nitrogen and total phosphorus inputs in the northern and northeastern part of the Baltic Sea catchment (Bothnian Bay where it is the biggest source contributing 52% for both nitrogen and phosphorus, Bothnian Sea and Gulf of Finland), but also to Kattegat (the Swedish part of the catchment). Diffuse other sources have the highest proportion of total nitrogen and total phosphorus inputs in the southern and southwestern part of the Baltic Sea catchment as to Gulf of Riga (83%-84%), Baltic Proper, Western Baltic, The Sound and Kattegat. This source includes both agricultural loads, loads from scattered dwellings and storm waters and in some cases (as to Gulf of Riga) also transboundary inputs from upstream countries. Overall, it reflects higher agricultural activity and higher population density as compared with the northern and northeastern part of the Baltic Sea catchment area. The results are also shown by country (figures 2.5-2.6), reflecting the overall tendency in importance of sources described above.

For Denmark, Finland, Germany, Poland, and Sweden and for the sub-basins Bothnian Sea, Bothnian Bay, Archipelago, Western Baltic, The Sound and Kattegat it is possible to assess the inputs of total nitrogen and total phosphorus in 10 source categories (load from natural background loads, atmospheric deposition on inland surface waters, agriculture, managed forestry (included in agricultural load from Denmark and Germany), scattered dwellings, storm waters, municipal waste water treatment plants (both indirect and direct), industrial plants (indirect and direct) and aquaculture plants (direct and indirect) providing more specific information on the most important sources. From chapter 7 tables 7.1 and 7.2 the main findings are:

For total nitrogen:

— Natural background load is the biggest source of total nitrogen input to Bothnian Bay (52%) and Bothnian Sea (33%).
— Atmospheric deposition on the Sea has the highest share of inputs to Archipelago (48%) and is equally important as natural background loads to Bothnian Sea (33%) and agricultural loads to Western Baltic (42%).
— Agricultural loads have the highest shares of inputs to The Sound and Kattegat (approx. 35%) and is equally important as atmospheric deposition on the sea to Western Baltic (42%).
— Municipal waste water load constitutes approx. 18% of total nitrogen inputs to The Sound.
— Natural background load proportion is at least 20% of total input to the six sub-basins besides from Western Baltic (7%), and atmospheric deposition at least 13%.
— Of the remaining sources only municipal waste water treatment plants constitute in minimum 4% or more of total nitrogen inputs to the Baltic Sea.

For total phosphorus:

— Natural background load is the biggest source of total phosphorus input to Bothnian Bay (52%) and Western Baltic and has the same share as agricultural loads to Bothnian Sea (28%).
— Agricultural load has the highest proportion of inputs to Archipelago (67%), Western Baltic and Kattegat (both about 30%), and has the same share as natural background load to Bothnian Sea (28%).
— To the Sound municipal waste water is the most important source constituting 46% of total phosphorus load, and with storm waters as the second biggest source (25%) reflecting high population density as more than 75% of total phosphorus inputs is from waste water.
— Atmospheric deposition on the sea has and rather high share

of inputs to the Bothnian Sea (21%), but less than 10% for the other five sub-basins.
— Natural background losses and agricultural loads constitutes each at least 10% of the inputs to the six sub-basins.
— Storm waters (14%) and municipal waste water treatment plant loads (18%) are also an important total phosphorus input source to Western Baltic and Kattegat (together approx. 17%).
— Load from industrial plants constitutes usually less than 3% of total inputs, but it is 8% to Bothnian Bay reflecting the sparsely populated and extensively managed area.
— Loads from aquaculture constitute 7% of total inputs to Archipelago, otherwise less than 4%.
— The total loads from scattered dwellings are estimated to constitute 4% to 7%.

Both for total nitrogen and total phosphorus atmospheric deposition on inland surface waters and managed forestry each constitutes less than 3% of the corresponding total inputs to the six sub-basins.

Inputs from storm waters and scattered dwellings are quite uncertain and are also affected using different definitions. Some countries include waste water from settlements up to 2,000 person equivalents (PE) into scattered dwellings, while in other countries the threshold is a mere 30 PE.

In future source apportionments sources of atmospheric nitrogen depositions on the sea could be included, which would increase the shares from agriculture, but also introduce further sources such as transportation, combustion, and electric power generation.

Table 2.3. Shares (in percentages) for main sources of total nitrogen (tonnes) to the Baltic Sea by sub-basins in 2017 (Polish data from 2018). The rightmost column indicates the share of the total nitrogen inputs to the basin of the corresponding total nitrogen input to the Baltic Sea. NBL = natural background losses, diff-other = remaining diffuse sources entering Baltic Sea via rivers, PS = indirect and direct point sources (municipal waste water treatment plants, industrial plants and aquaculture plants), and ATM = atmospheric deposition on the Baltic Sea.

TN Basin	NBL %	Diff-other %	PS %	ATM %	Total tonnes	Total %
Bothnian Bay	52.1	23.2	11.4	13.4	55,964	6.1
Bothnian Sea	33.4	20.2	13.5	32.9	52,499	5.7
Archipelago	15.0	29.4	8.0	47.6	12,826	1.4
Baltic Proper	9.2	51.8	8.2	30.8	399,394	43.2
Gulf of Finland	35.5	38.9	15.2	10.3	137,219	14.9
Gulf of Riga	9.2	83.3	0.9	6.7	139,332	15.1
Western Baltic	6.9	45.3	6.2	41.5	50,224	5.4
Sound	20.4	39.5	19.2	20.8	11,089	1.2
Kattegat	24.0	39.6	6.3	30.1	65,216	7.1
Baltic Sea	**18.2**	**49.4**	**8.5**	**23.8**	**923,763**	**100**

Table 2.4. Shares (in percentages) for main sources of total phosphorus (tonnes) to the Baltic Sea by sub-basins in 2017 (Polish data from 2018). See caption for table 2.1 for further explanation.

TP Basin	NBL %	Diff-other %	PS %	ATM %	Total tonnes	Total %
Bothnian Bay	52.4	35.7	4.9	7.0	2,573	9.0
Bothnian Sea	28.4	37.8	12.4	21.4	1,695	6.0
Archipelago	10.8	75.6	8.8	4.8	642	2.3
Baltic Proper	8.7	62.1	20.8	8.4	12424	43.7
Gulf of Finland	33.1	42.5	21.3	3.1	4,877	17.1
Gulf of Riga	8.9	84.4	3.9	2.7	3,432	12.1
Western Baltic	16.9	51.3	22.6	9.1	1,042	3.7
Sound	10.4	39.6	46.8	3.2	312	1.1
Kattegat	35.5	43.6	12.8	8.1	1,456	5.1
Baltic Sea	**19.8**	**56.3**	**16.6**	**7.3**	**28,452**	**100**

Table 2.5. Shares (in percentages) for main sources of total nitrogen (tonnes) to the Baltic Sea by country and shipping in 2017 (Polish data from 2018). The column "Total %" indicates the share of the total nitrogen inputs from the country and from shipping (all sources) while the column "Total of CP's (%)" are the corresponding shares only for the nine HELCOM countries. NBL = natural background losses, diff-other = remaining diffuse sources entering Baltic Sea via rivers, PS = indirect and direct point sources (municipal waste water treatment plants, industrial plants and aquaculture plants), and ATM = atmospheric deposition on the Baltic Sea.

TN source/ Country	NBL %	Diff-other %	PS %	ATM %	Total tonnes	Total %	Total of CP's (%)
Denmark	13.6	53.2	5.9	27.4	57,836	6.3	6.9
Estonia	28.3	63.2	1.8	6.6	34,225	3.7	4.1
Finland	36.1	43.4	13.2	7.3	83,281	9.0	10.0
Germany	1.2	30.1	3.8	65.0	71,285	7.7	8.5
Lithuania	15.7	77.8	2.5	3.9	103,250	11.2	12.4
Latvia	4.8	92.1	0.9	2.2	116,517	12.6	13.9
Poland	4.6	61.4	14.2	19.8	156,838	17.0	18.8
Russia	37.1	34.0	17.4	11.4	106,197	11.5	12.7
Sweden	48.3	24.9	15.6	11.1	106,316	11.5	12.7
Baltic Sea shipping				100	13,020	1.4	
North Sea shipping				100	8,858	1.0	
Other Countries				100	66,140	7.2	
BAS	18.2	49.4	8.5	23.8	923,763		

Table 2.6. Shares (in percentages) for main sources of total phosphorus (tonnes) to the Baltic Sea by country and shipping in 2017 (Polish data from 2018). See caption for table 2.3 for further explanation.

TP source/ Country	NBL %	Diff-other %	PS %	ATM %	Total tonnes	Total %	Total of CP's (%)
Denmark	30.9	44.4	24.7	0.0	1,521	5.3	5.8
Estonia	34.6	61.1	4.3	0.0	757	2.7	2.9
Finland	28.3	64.7	7.0	0.0	3,721	13.1	14.1
Germany	10.6	69.6	19.8	0.0	889	3.1	3.4
Lithuania	15.1	76.4	8.5	0.0	2,571	9.0	9.8
Latvia	6.3	89.8	3.9	0.0	3,290	11.6	12.5
Poland	5.0	67.5	27.5	0.0	6,976	24.5	26.5
Russia	36.3	34.6	29.2	0.0	3,974	14.0	15.1
Sweden	51.2	31.9	16.9	0.0	2,664	9.4	10.1
Baltic Sea shipping						0.0	
North Sea shipping						0.0	
Other Countries				100	2,088	7.3	
BAS	19,8	56,3	16,6	7,3	28,452	100	

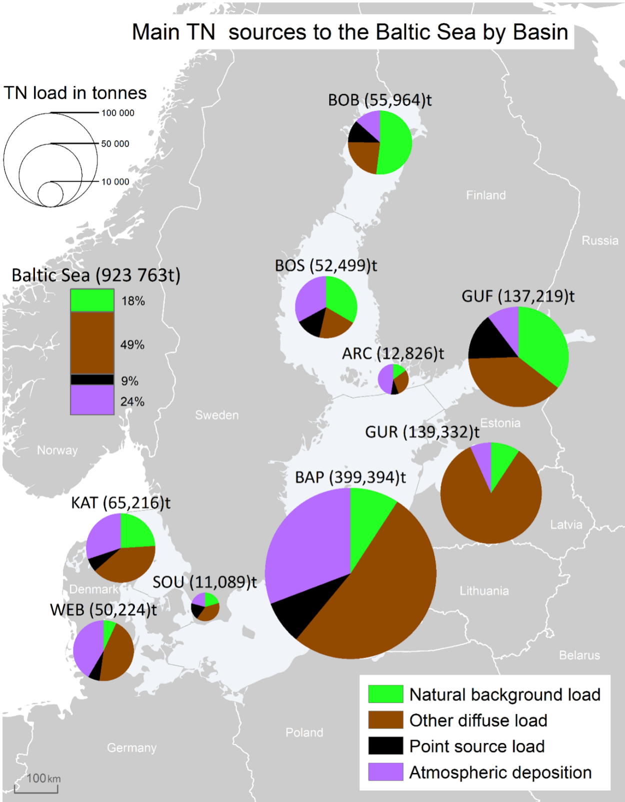


Figure 2.3. Main sources of total nitrogen (TN in tonnes) to the Baltic Sea sub-basins in 2017 (Polish data from 2018) with the load-oriented approach. Other diffuse loads include agricultural, managed forestry, scattered dwellings, storm waters and other diffuse sources loads. Point source load covers all municipal waste water treatments plants, industrial plants and aquaculture plants both discharging to inland surface waters or directly into the sea. Atmospheric deposition is on the sea surface of the basins. The circles are scaled allowing for direct comparison of the inputs.

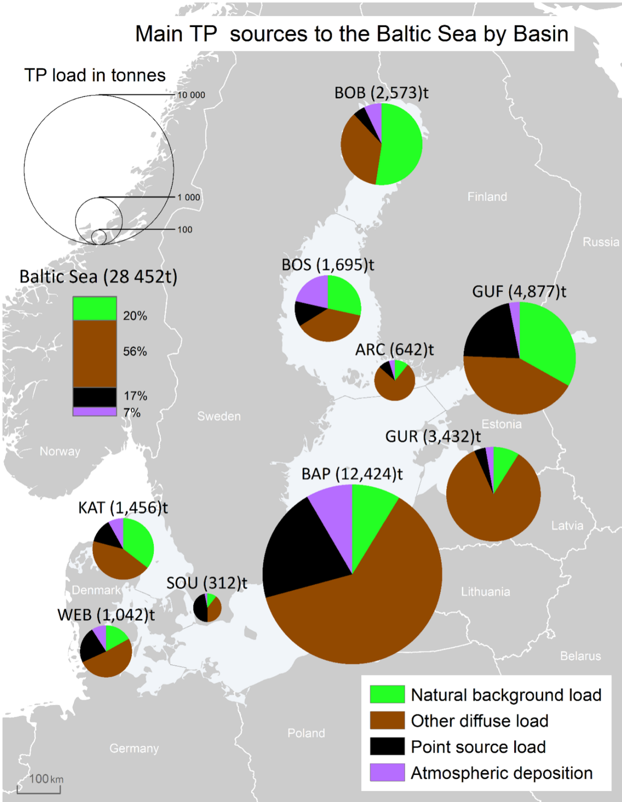


Figure 2.4. Main sources of total phosphorus (TP in tonnes) to the Baltic Sea sub-basins in 2017 (load-oriented approach). See further explanation in the caption to figure 2.3.

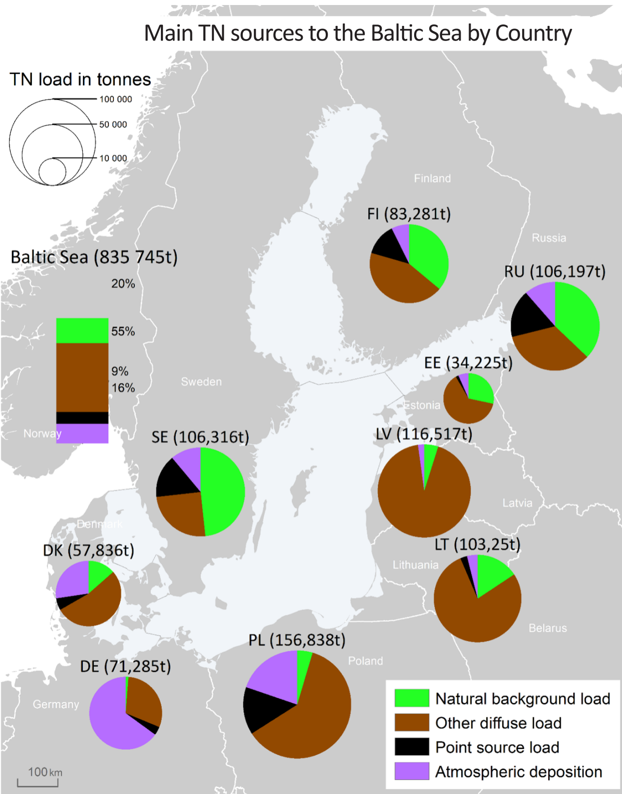


Figure 2.5. Main sources of total nitrogen (TN in tonnes) to the Baltic Sea by country in 2017 (Poland 2018) with load-oriented approach. Atmospheric deposition is on the sea surface of the sub-basins. The circles are scaled allowing for direct comparison of the inputs. Compared with figure 2.2 inputs for Baltic Sea shipping (13.020 tonnes N), North Sea shipping (8.858 tons N tonnes) and non HELCOM contries (66.140 tonnes) or altogether 88.018 tonnes N are not included.

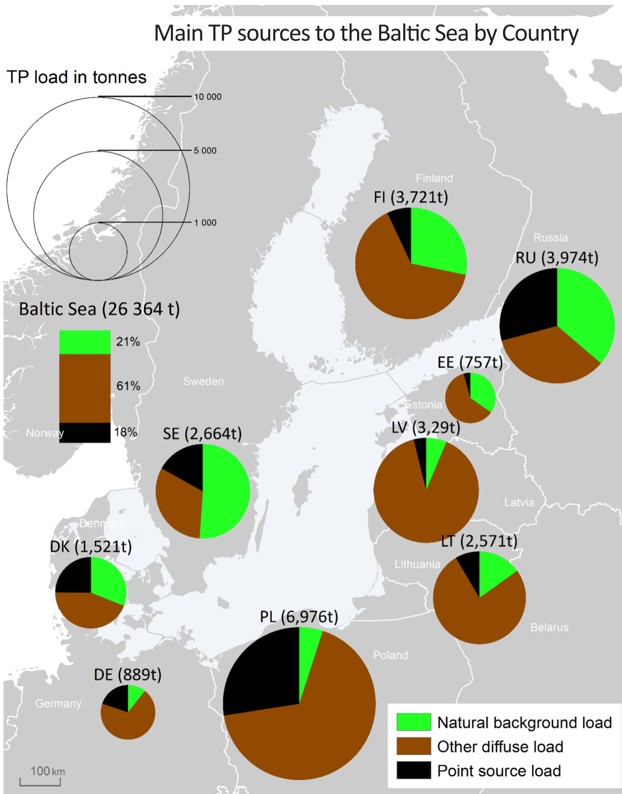


Figure 2.6. Main sources of total phosphorus (TP in tonnes) to the Baltic Sea by country in 2017 (Poland 2018) with load-oriented approach. Atmospheric deposition is on the sea surface of the sub-basins. The circles are scaled allowing for direct comparison of the inputs. Compared with figure 2.4 atmospheric phosphorus deposition (2,088 tonnes P) is not included as it is not possible to divide it between countries or other sources.

2.5. Main sources of riverine loads to the Baltic Sea

Riverine loads include the total nitrogen and total phosphorus inputs entering the sea via big and small rivers including from areas close to the coast, but without direct point source load that per definition discharges directly into the sea. Based on the reported data riverine loads from the whole Baltic Sea catchment area it is only possible to source apportion in:

— Natural background loads.
— Diffuse other loads (atmospheric deposition on inland surface waters, agriculture, managed forestry, scattered dwellings, storm waters, and for some countries transboundary inputs from upstream countries).
— Indirect point sources (point sources discharging into inland surface waters).

The results are in chapter 4.3, but some main findings are summarized below. For the Baltic Sea diffuse other sources constitute about 2/3 of riverine total nitrogen inputs, and natural background losses about 25%, while indirect point sources are a minor source (7%) – see figure 2.7. The corresponding shares for phosphorus are 64% for diffuse other loads, 23% natural background loads, and 13% indirect point sources. But there is rather big variation in importance of these sources between the sub-basins (tables 4.5) with higher importance of natural background loads in northern and northeastern part of the Baltic Sea catchment area e.g., Bothnian Bay with 65% of total nitrogen and 59% of total phosphorus riverine loads and high importance of diffuse other loads in the southern and southeastern part as e.g., Baltic Proper (76% of total nitrogen inputs and 69% of total phosphorus inputs) and Gulf of Riga (90% of total nitrogen and 88% of total phosphorus inputs). But for Gulf of Riga the high share of diffuse other loads also is affected by inclusion of transboundary inputs that include all kind of sources.

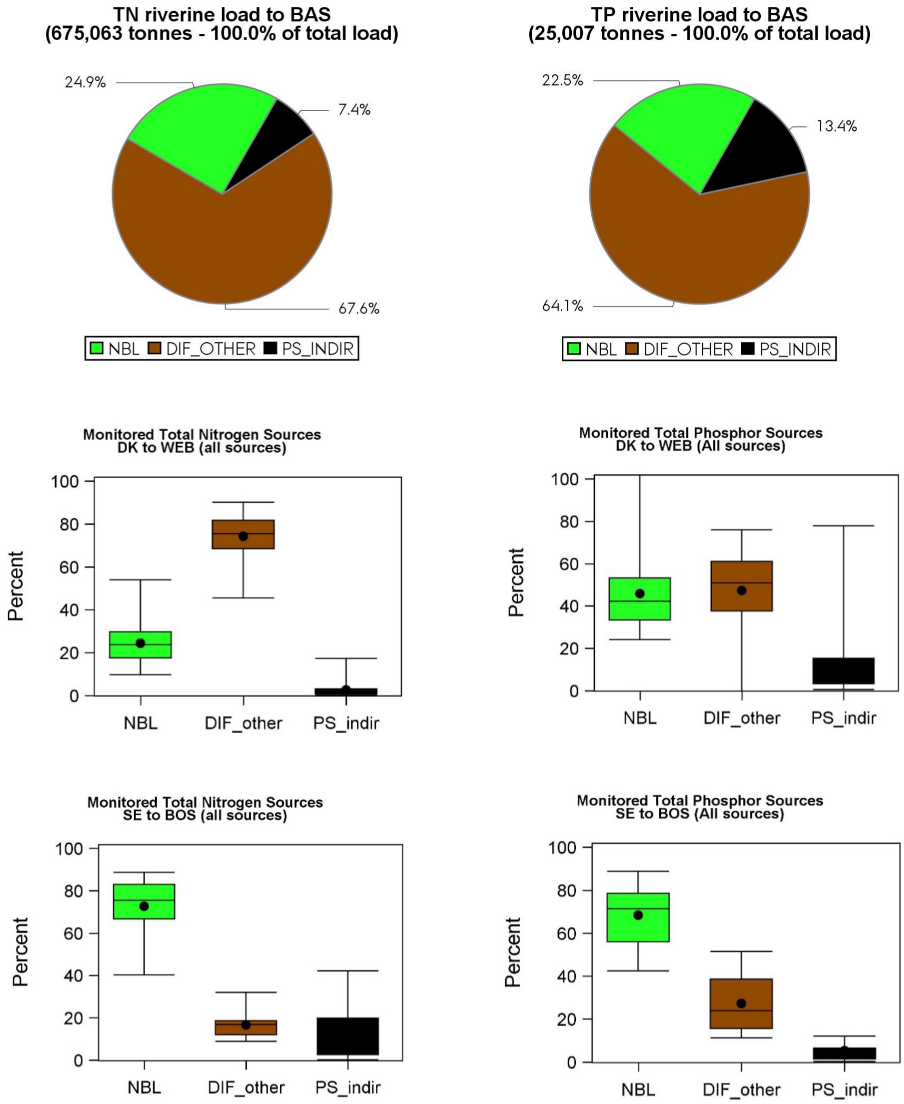


Figure 2.7. Two upper figures: Shares (%) for main sources of total riverine inputs: NBL = natural background load, Dif_other = diffuse loads inputs other than natural background loads and for some countries including transboundary inputs from upstream situated countries, PS_indir = point source load to inland surface waters (indirect point sources) of total nitrogen (left column) and total phosphorus (right column) to the Baltic Sea. In the two lower columns Box-Whisker plots of the share (percentages) for three sources of riverine inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers in Danish catchment to Western Baltic, and the Swedish catchment to Bothnian Sea. For reading a Box Whiskers plot see chapter 9.2.

Within the catchment to the sub-basins there are often high variation for the individual rivers of the importance of these sources, which is shown with some few examples in figures 2.7 presented as Box-Whisker plots (how to read these plots is explained in chapter 9.2). For the monitored Danish rivers in the catchment of the Western Baltic (73 monitored rivers) for total phosphorus diffuse other sources constitutes between 0% and more than 75% with an average of 47% (and median 50%), for natural background loads between 24% and 100% and for indirect point sources between 0% and 78%. The size of Danish river catchments to the Western Baltic are ranging from few km^2 to 750 km^2. Also for e.g., the 12 Swedish river catchments to the Bothnian Sea range in size from approx. 400 to 30.000 km^2, we find big variations in the importance of sources for the monitored rivers catchments.

Riverine inputs have been further divided in more diffuse and point sources for some countries in chapters 4.4-4.6, but some countries have aggregated the sources, and therefore it is not possible to make a more detailed source apportionment for the Baltic Sea. Figure 2.8 shows examples for five country by basins with the detailed source allocation of riverine load divided in:

— Atmospheric deposition on inland surface waters
— Natural background loads
— Agricultural loads
— Diffuse other sources (scattered dwelling, storm waters, managed forestry, and for some countries the diffuse sources not quantified and transboundary inputs from upstream countries)
— Indirect point sources.

There is a rather obvious gradient from north/northeast to the south/ southwest in the importance of natural background loads (highest share to the north) and for agriculture (highest shares to the south/southwest) on riverine inputs, although it is quite clear that Germany only includes very pristine conditions when estimating natural background loads. Agricultural loads and atmospheric inputs together cover from at least 70% of total nitrogen and more than 50% of total phosphorus riverine inputs to up to 90%. Atmospheric deposition of total nitrogen is quite important in the German catchment to Baltic Proper, and Finnish catchment to Gulf of Finland with 13% of total inputs with high shares where there are

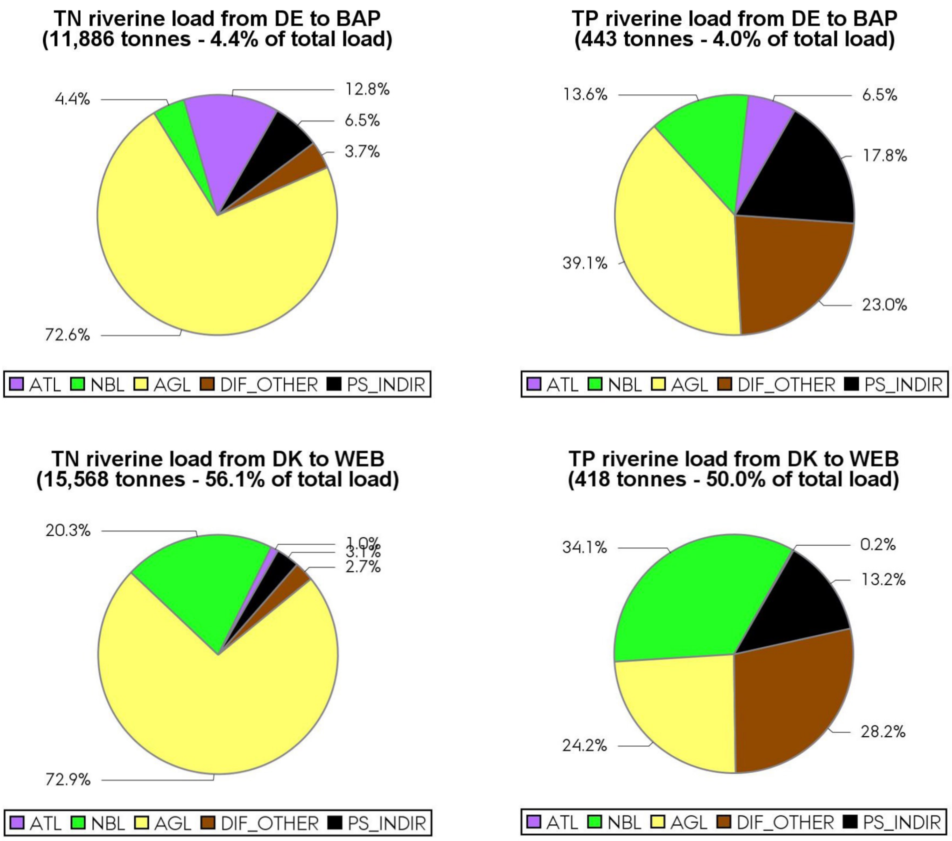


Figure 2.8. Shares (%) of total riverine inputs: ATL = Atmospheric deposition on inland surface waters, NBL = natural background load, AGL = agricultural load, Diff-other = scattered dwellings, storm waters and managed forestry for Finland, Poland and Sweden, PS_indir = point source load to inland surface waters (indirect point sources) of total nitrogen (left column) and total phosphorus (right column) to five countries by basins. The headings are indicating total riverine load from respective country to respective sub-basin (tonnes) and the percentages of total loads to that sub-basin. Data from 2017, but for Poland from 2018.

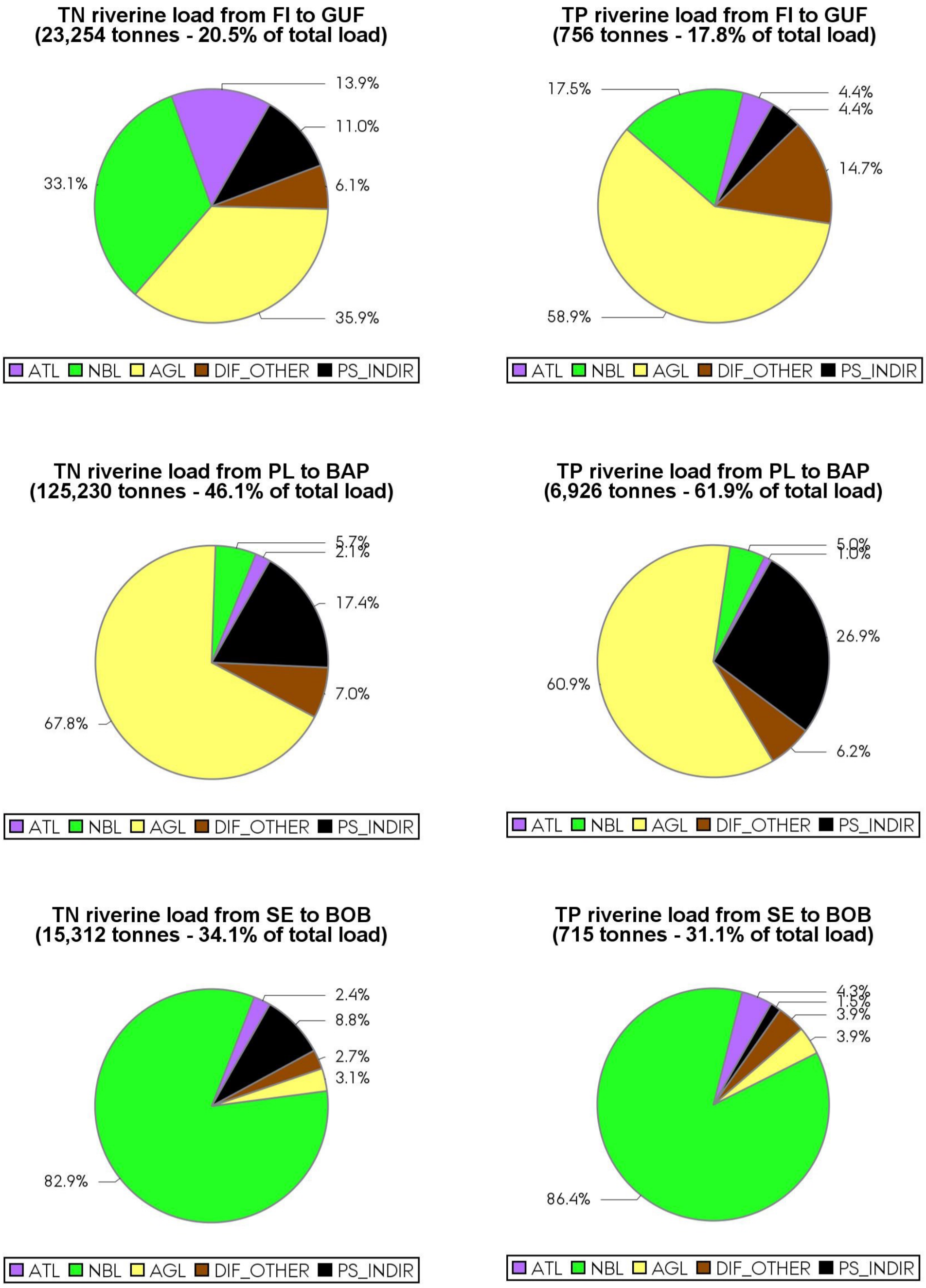


Figure 2.8. Continued. Shares (%) of total riverine inputs: ATL = Atmospheric deposition on inland surface waters, NBL = natural background load, AGL = agricultural load, Diff-other = scattered dwellings, storm waters and managed forestry for Finland, Poland and Sweden, PS_indir = point source load to inland surface waters (indirect point sources) of total nitrogen (left column) and total phosphorus (right column) to five countries by basins. The headings are indicating total riverine load from respective country to respective sub-basin (tonnes) and the percentages of total loads to that sub-basin. Data from 2017, but for Poland from 2018.

high percentages of lakes surface and/or high area specific nitrogen deposition due to high intensity of agriculture, combustion, or other nitrogen emissions sources. Indirect point sources are generally constituting more than 10% of riverine total nitrogen inputs to some sub-basins as e.g., for Finland to Gulf of Finland and Poland to Baltic Proper (17%, although 2018 was a dry year where importance of point sources is higher than in an average flow year). For total phosphorus indirect point sources are even more important constituting 27% of total Polish inputs to the Baltic Sea and 18% of total phosphorus inputs from Germany to Baltic Proper and 13% from Denmark to Western Baltic. All these are areas with high population density. The importance of high population density and urban areas is also indicated by high shares for diffuse other sources (up to 28%) from Germany to Baltic Proper, Denmark to Western Baltic and Finland to Gulf of Finland, which primarily covers waste water from storm waters and scattered dwellings (managed forestry are included in diffuse-other but constitute low shares of nitrogen and phosphorus inputs (less than 4%)).

2.6. Waste water sources

Five countries (Denmark, Finland, Germany, Poland, and Sweden) have reported data on the five source categories producing waste water allowing for evaluating which of these sources are the most important waste water sources of total nitrogen and total phosphorus to the Baltic Sea (indirect and direct inputs) see also chapter 4.6:

- Municipal waste water treatment plants (direct and indirect)
- Industrial plants (direct and indirect)
- Aquaculture plants (direct and indirect)
- Scattered dwellings (indirect)
- Storm waters (indirect)

The main results regarding sources of waste water are:

For nitrogen:

- Municipal waste water treatment plants are the main waste water source of nitrogen for the five countries, constituting from 58% (Poland) to 70% (Germany and Sweden) of total nitrogen waste water loads.
- The second most important waste water source is industrial plants for Finland (21%) and Sweden (17%), while it is storm waters for Denmark (15%) and Germany (22%) and scattered dwellings for Poland (19%). Industrial plants are also an important waste water total nitrogen source from Poland (16%).
- Scattered dwellings also have a considerable share from Finland (13%).
- Aquaculture share is 11% from Denmark but less than 4% for the other four countries.

For phosphorus:

- Municipal waste water treatment plants are the main waste water source of total phosphorus for four of the countries, constituting from 30% (Sweden) to 74% (Poland), but for Finland scattered dwellings is by far the most important waste water source of total phosphorus with a share of 53%, and with only 17% from municipal waste water treatment plants.
- Industrial plants are the second most important waste water source for Finland (19%) and Sweden (29%), while it is storm waters for Denmark (29%) and Germany (47%) and scattered dwellings for Poland (9%).
- Scattered dwellings also have a considerable share from Denmark (16%) and Sweden (21%) and some importance from Poland (9%).
- Storm waters is also a major waste water phosphorus source form Denmark with a share of 29%
- Aquaculture share is 11% from Finland and 8% for Denmark, and less than about 5% for the other three countries.

2.7. Inputs from direct point sources

Overall direct inputs of total nitrogen (3.1%) and total phosphorus (4.8%) only constitute a minor share of the corresponding inputs to the Baltic Sea in 2017, but it is an important anthropogenic source with potential for further reduction.

Assessing the three point source categories (municipal waste water treatment plants, industrial plants and aquaculture plants) for direct discharge of total nitrogen and total phosphorus to the Baltic Sea based on the load oriented approach we have the findings below based on table 4.12 for total nitrogen:

- Municipal waste water treatment plant inputs are by far the major source of direct inputs to all the Baltic Sea sub-basins and to the Baltic Sea (85%) followed by inputs from industrial plants (12%). Direct inputs from aquaculture constitutes only about 3% of total direct inputs of total nitrogen.
- Direct inputs from industrial plants are an important source to Bothnian Bay (38%) and Bothnian Sea (35%), for the remaining sub-basins it constitutes between 1 and 9%.
- Aquaculture is a significant source of direct inputs to Archipelago (41%) and Western Baltic (21%), for the remaining sub-basins it constitutes between 0 and 4%.
- Gulf of Finland receives 34% of total nitrogen inputs via direct inputs to the Baltic Sea followed by Baltic Proper (18%), and Bothnian Bay (13%).
- For all countries municipal waste water treatment plants are the main direct total nitrogen source, ranging from 65% (Finland) to more than 99% (Poland and Russia).
- Direct industrial total nitrogen shares are highest from Finland (27%) and Sweden (18%), but constitute only between less than 1% to 6% for the remaining countries.

- For the three countries reporting inputs of total nitrogen from marine aquaculture plants it constitutes 14% of total direct inputs from Denmark, 9% from Finland and 1% from Sweden.

And the main findings from for total phosphorus from table 4.13:

- Municipal waste water treatment plant inputs are the major source of direct total phosphorus inputs to the Baltic Sea (71%) followed by inputs from industrial plants (22%). Direct inputs from aquaculture constitutes only about 7% of total direct inputs of total phosphorus.
- Municipal waste water treatment plant inputs are the major source of direct inputs to six sub-basins except for Bothnian Bay and Bothnian Sea, where inputs from industrial plants are the most important sources with 79% of total direct phosphorus inputs to both basins, and Archipelago, where aquaculture plants are the most important source (81%).
- Direct inputs from industrial plants are important to Baltic Proper (27%) and Kattegat (14%), but for the remaining five sub-basins it constitutes between 1 and 5%.
- Aquaculture is the most important source of direct inputs of total phosphorus to Archipelago (81%) and important to Western Baltic (30%), and for the remaining sub-basins it constitutes between 0% and 9%.
- Gulf of Finland receives 35% of total phosphorus inputs via direct inputs to the Baltic Sea followed by Baltic Proper (15%), and Bothnian Sea (11%).
- For all countries besides Finland and Sweden municipal waste water treatment plants are the main total phosphorus direct source. It constitutes between 62% (Poland) and 98% (Russia). For Finland and Sweden, the shares are 32% and 44% respectively.
- Direct industrial total phosphorus inputs are the most import source from Finland (37%) and Sweden (53%), but also important from Poland (38%). For the remaining six countries it constitutes only between 2 and 6%.
- For the three countries reporting inputs of total phosphorus from marine aquaculture plants it constitutes 13% of total direct inputs from Denmark, 31% from Finland and 3% from Sweden.

3. Area specific losses and retention

Based on the load-oriented source apportionment we have calculated the area specific losses (amount of total nitrogen and total phosphorus transported per catchment unit area in kg/km$^{2)}$ for different sources and total riverine inputs to the Baltic Sea in 2017 (Poland for 2018). Results are presented on maps covering the Baltic Sea catchment, and information are provided for the 315 monitored river catchments and for 24 unmonitored catchment areas reported as a part of the PLC-7 source apportionment assessment covering the 1.74 million km^2 catchment to the Baltic Sea – see chapter 1.6. Further importance of direct sources (in tonnes per year) is indicated by scaled circles on maps for direct total nitrogen and total phosphorus inputs of municipal waste water treatment plants, industrial plants and aquaculture, respectively.

To provide information facilitating interpretation of the results, this chapter includes maps indicating monitored rivers and unmonitored areas, flow, deviation of flow in 2017 with the average flow 2005-2016, retention in surface waters, proportion of agricultural land and population density that are shown for each monitored river and monitored areas. There is also a land cover map included.

The structure of the chapter is:

— Monitored, unmonitored and transboundary areas (chapter 3.1).
— Runoff in 2017 and compared with average of 2005-2016 (chapter 3.2).
— Natural background losses of total nitrogen and total phosphorus (chapter 3.3).
— Diffuse other losses of total nitrogen and total phosphorus (chapter 3.4).
— Agricultural losses of total nitrogen and total phosphorus (chapter 3.5).
— Diffuse other losses of total nitrogen and total phosphorus (chapter 3.6).
— Total riverine total nitrogen and total phosphorus losses (chapter 3.7).
— Total nitrogen and total phosphorus retention (chapter 3.8).
— Total nitrogen and total phosphorus from direct point sources per category (chapter 3.9).
— Land covering the Baltic Sea catchment areas (chapter 3.10).
— Population density (chapter 3.11).

3.1. Monitored, unmonitored and transboundary areas

About 88-89% of the catchment to the Baltic Sea is covered by riverine monitoring stations (figure 3.1). It is mainly coastal areas, minor river catchment and areas influence by tides that are unmonitored. Only for the catchment to The Sound (24%), Archipelago (33%) and Western Baltic (56%) monitored areas constitutes less than 85 %. Even though Denmark monitors 171 rivers or more than 54% of all rivers monitored in the Baltic Sea catchment area in 2017 it only covers 52 % of the Danish catchment areas to the Baltic Sea.

Transboundary catchment areas are located both in upstream HELCOM countries and in non HELCOM countries (figure 3.2). About 127,000 km^2 of the total catchment area or more than 7% are situated in non HELCOM countries.

Figure 3.1. Monitored and unmonitored areas based in the Baltic Sea catchment.

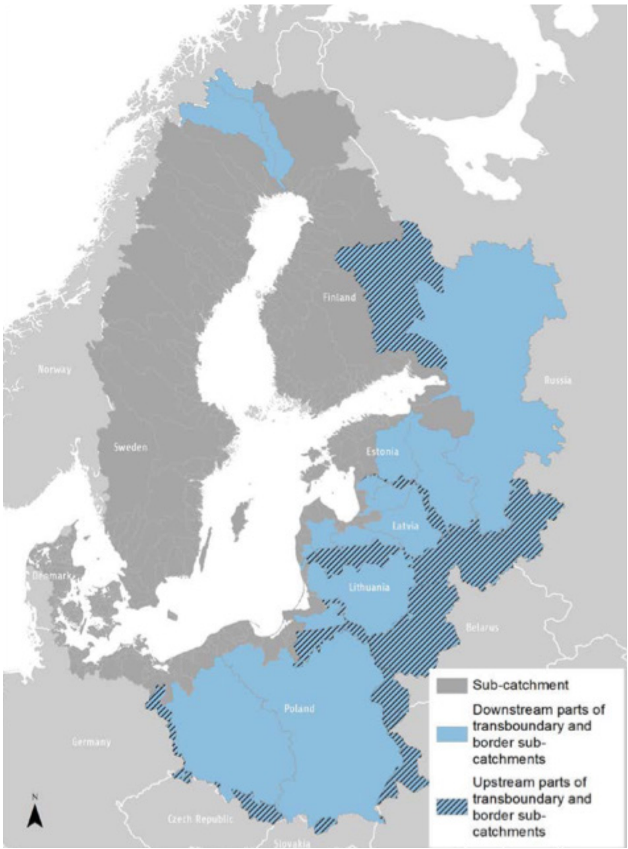


Figure 3.2. Transboundary and border rivers in the Baltic Sea catchment area.

3.2. Runoff in 2017, and compared with average of 2005–2016

Specific runoff is flow (in liter per second) calculated per area unit catchment area (km^2) allowing direct comparison of flow for catchment of different size. In general, in 2017 the specific runoff was low from main part of Poland, eastern part of German catchment, southeastern Sweden and rather high in the catchment to Kattegat, central and north Sweden and northern Finland and some minor catchments to the Gulf of Finland (in Finland) to the Baltic Sea and Gulf of Riga (figure 3.3). To have a possibility to evaluate 2017 compared with the average specific runoff we compared 2017 with the average of 2005-2016 (figure 3.4), revealing where flow in 2017 was particularly high or low. The flow was 10% or more higher from main part of the three Baltic countries, area around St. Petersburg, and up to 10% higher for parts of Estonia, southern Sweden, Denmark, southern Finland and for some river catchments in central and northern Sweden and a catchment in central Finland.

The specific runoff was 10% or more lower from western part of Poland, main part of Denmark, main part of central and southern part of Sweden and some catchments in western parts of Finland, and between 0-10% lower than average for main part of Finland, Russia, the Vistula catchment and several catchments in northern Sweden and parts of southern Sweden.

Poland reported total nitrogen and total phosphorus data from 2018 where flow was 23% lower than average of 1995-2016.

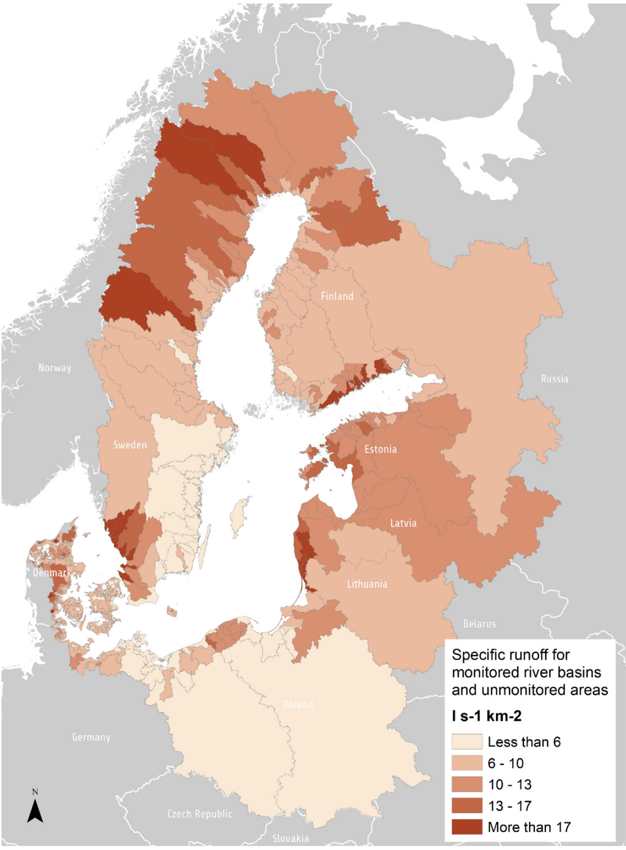


Figure 3.3. Specific runoff (flow, L s^{-1} km^{-2}) for monitored and unmonitored areas in 2017 in the Baltic Sea catchment.

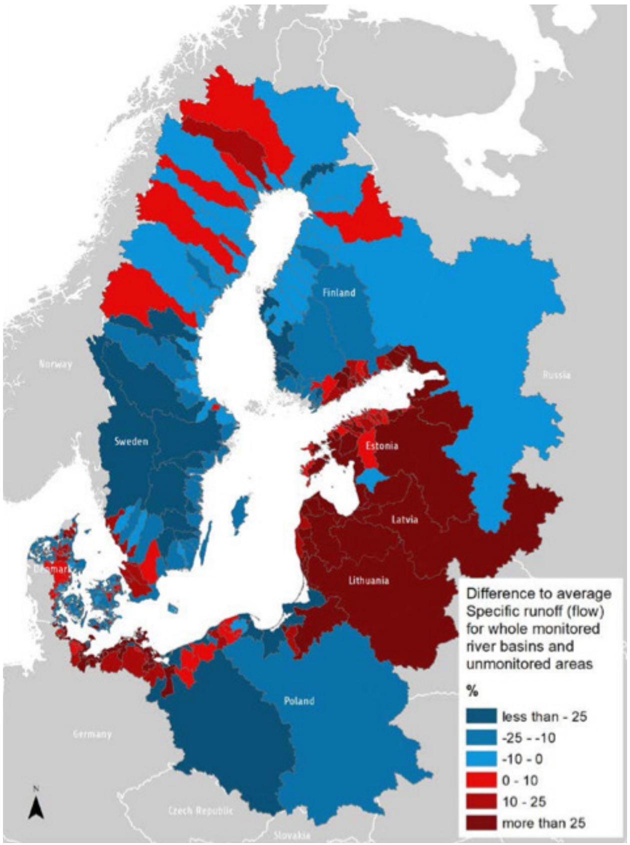


Figure 3.4. Difference of specific runoff (flow, L s^{-1} km^{-2}) for monitored and unmonitored areas in 2017 from average specific runoff in 2005–2016 in the Baltic Sea catchment.

3.3. Natural background loads of total nitrogen and total phosphorus

The area specific natural background loads are highest from Denmark, southern Sweden, coastal areas from Sweden to Baltic Proper, Lithuania, and parts of Estonia, and lowest from Germany, Poland (but data are from 2018), Latvia and some few catchments in Sweden (figure 3.5). For phosphorus the highest natural background loads are from most Danish catchments south-western Sweden, a catchment in Lithuania, some coastal areas to Gulf of Finland and one catchment in northern Sweden (figure 3.6). The lowest natural background phosphorus losses are form Germany, Poland (data form 2018), most of Russian catchment, eastern part of Finland and northern part of Finland and Sweden.

Contracting Parties use different approaches estimating natural background loads. Some countries use monitoring results from minor natural catchments with no or low human impact, other countries different modelling approaches (see table 1.4), so results from different countries are not fully comparable, but the natural background loads reflect to some degree the specific runoff pattern seen in figure 3.5 where high specific flow also result in rather high natural background loads.

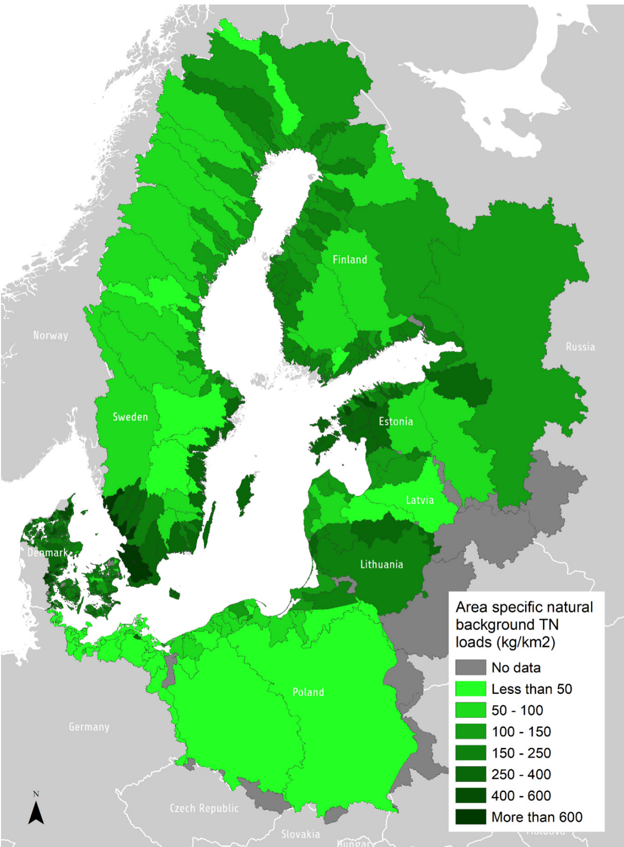


Figure 3.5. Area specific natural background loads of total nitrogen (TN in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

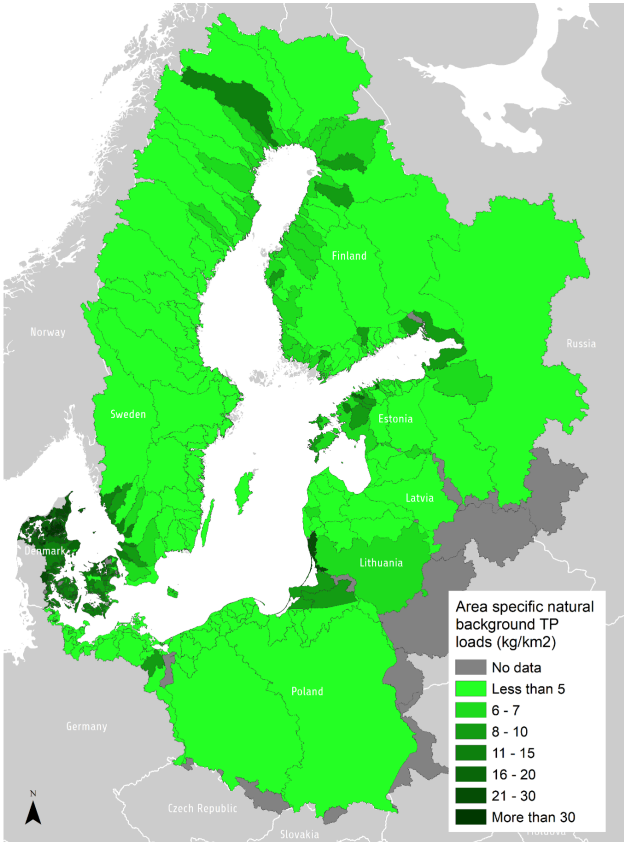


Figure 3.6. Area specific natural background loads of total phosphorus (TP in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

3.4. Diffuse sources load of total nitrogen and total phosphorus

Diffuse total nitrogen and total phosphorus loads shown in figures 3.7 and 3.8 include both natural background loads and anthropogenic diffuse sources loads from agriculture, managed forestry, scattered dwellings, storm waters etc. It is usually estimated as the riverine loads minus indirect point source loads. Highest diffuse loads of total nitrogen are from Danish, German, southwestern Swedish, some Lithuanian and a few Estonian catchments to the Baltic Sea, the lowest diffuse loads from northern and central parts of Finland, non-coastal parts of Russian and central and northern Sweden catchments to the Baltic Sea. The pattern for high diffuse total phosphorus loads is overall as for total nitrogen, but there are also high losses from some coastal areas in Finland. The lowest diffuse total phosphorus loads are from non-coastal catchments from central and northern Sweden and parts of central Finland.

It should be noted that retention in surface waters can play an important role reducing loads from catchments to the sea, particularly for catchments situated with some distance from the sea. Patterns of surface water retention are presented in chapter 3.8.

In chapters 3.5 and 3.6 total nitrogen and total phosphorus loads from agriculture and other diffuse anthropogenic sources are shown, respectively.

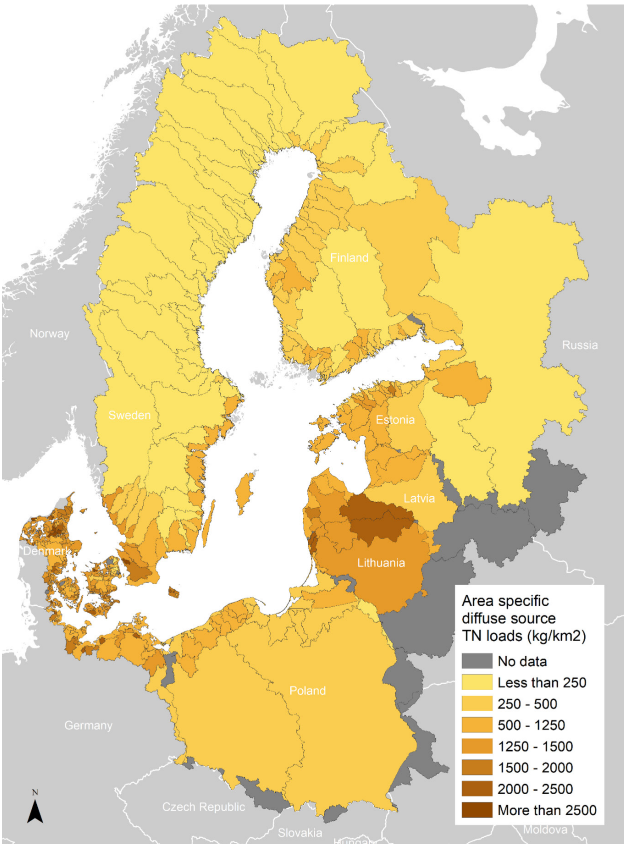


Figure 3.7. Area specific diffuse sources loads of total nitrogen (TN in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment. Diffuse sources include natural background losses.

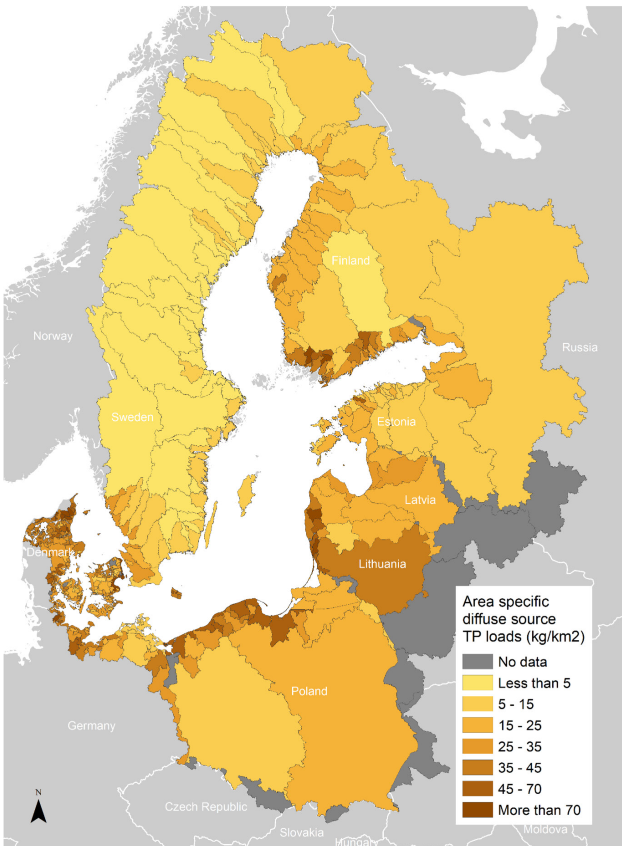


Figure 3.8. Area specific diffuse sources loads of total phosphorus (TP in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment. Diffuse sources include natural background losses.

3.5. Agricultural loads of total nitrogen and total phosphorus

Agriculture is one of main diffuse sources of total nitrogen and total phosphorus riverine inputs to the Baltic Sea for many catchments (see chapter 4.4). Highest agricultural loads are closely related to the proportion of agricultural land (figure 3.9), farming intensity and the weather and flow conditions. The patterns of high and low area specific diffuse total nitrogen loads seen in figure 3.7 are overall reflected in the corresponding map for agricultural area specific total nitrogen losses in figure 3.10. It should be noted that e.g., Latvia has not assessed agricultural sources separately and therefore it is shown as no data in figures 3.10 and 3.11. For total phosphorus (figure 3.11) coastal areas of Poland and some catchments in southern Finland also have high area specific phosphorus loads despite low specific flow from Poland in 2018.

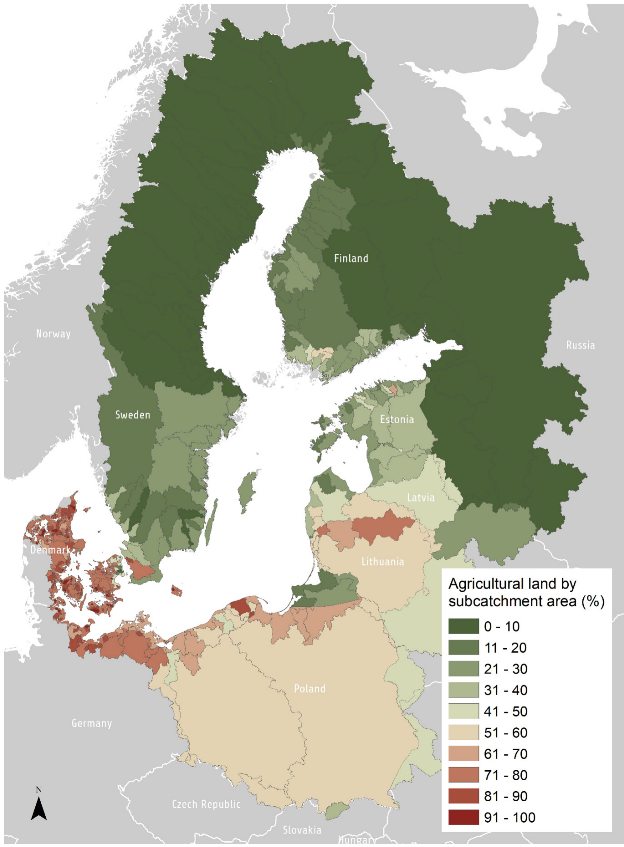


Figure 3.9. Proportion of agricultural land area (%) by sub-catchments in the Baltic Sea catchment. Source: Corine 2012. Russia: NASA Global Land Cover Facility (GLCF).

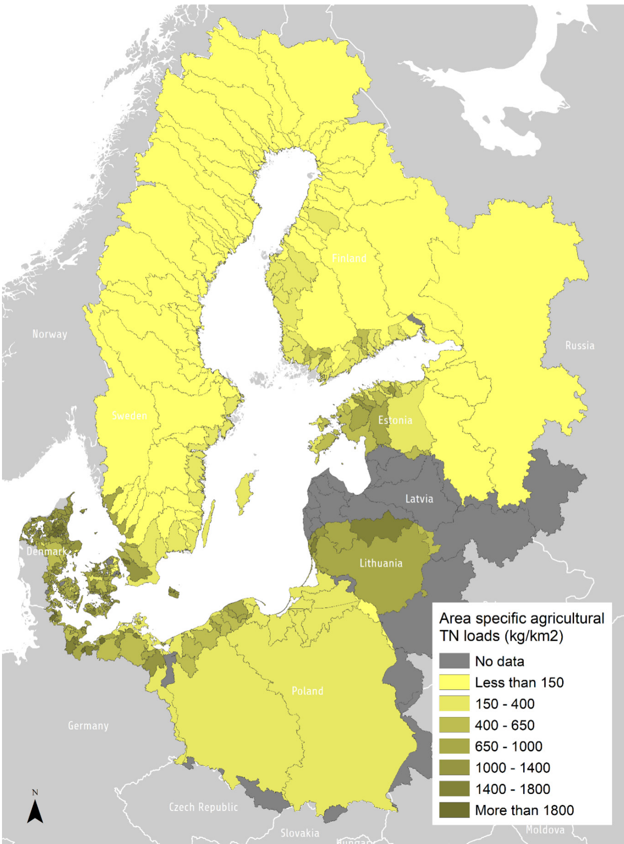


Figure 3.10. Area specific agricultural loads of total nitrogen (TN in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

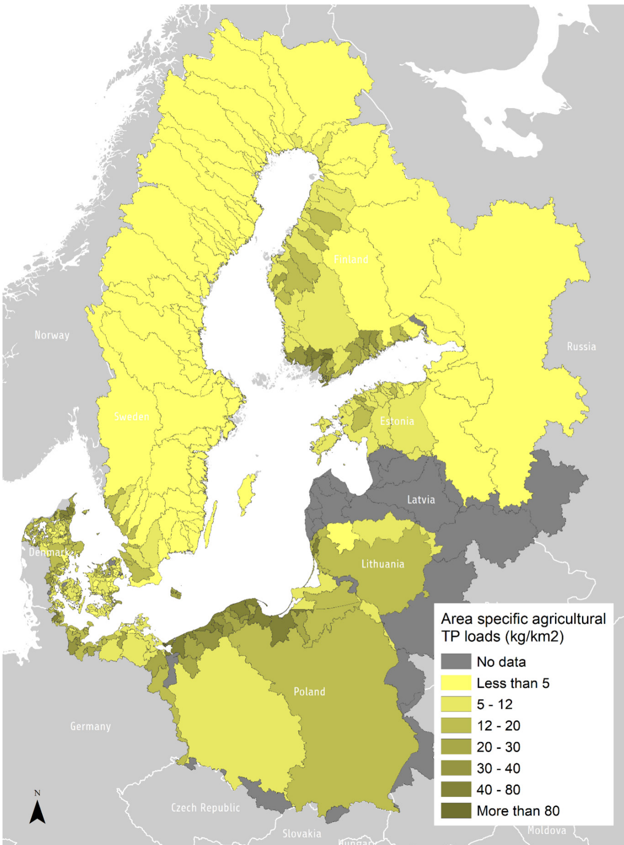


Figure 3.11. Area specific agricultural loads of total phosphorus (TP in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

3.6. Diffuse other loads of total nitrogen and total phosphorus

Diffuse other loads of total nitrogen and total phosphorus include loads from scattered dwellings, storm waters and for some countries also loads from managed forestry but exclude natural background loads and agricultural loads. For Latvia it includes agricultural loads as Latvia has not quantified these sources separately. That is the reason for very high area specific total nitrogen loads from Latvia (figure 3.12). As shown in chapter 4.5 managed forestry overall only constitutes up to 1.5 to 3.5% of diffuse source loads in Sweden and Finland, respectively but in some catchments the share is higher. Denmark, Germany, Latvia, Lithuania, and Russia include managed forestry in the agricultural loads.

For total phosphorus the area specific other diffuse loads are for many catchments probably dominated by loads from scattered dwellings and therefore related to the number of inhabitants in areas with high number of scattered dwellings/minor towns without municipal wastewater treatment plants as seen in the southern, southwestern part of the Baltic Sea catchment area, and around Gulf of Finland and coastal catchments in Sweden to Baltic Proper (figure 3.13). For total nitrogen there are also rather high area specific loads from other diffuse sources from Russian catchments areas.

It should be noted there is rather high uncertainty from some countries quantifying other diffuse sources, and that some countries have included transboundary inputs in this source category.

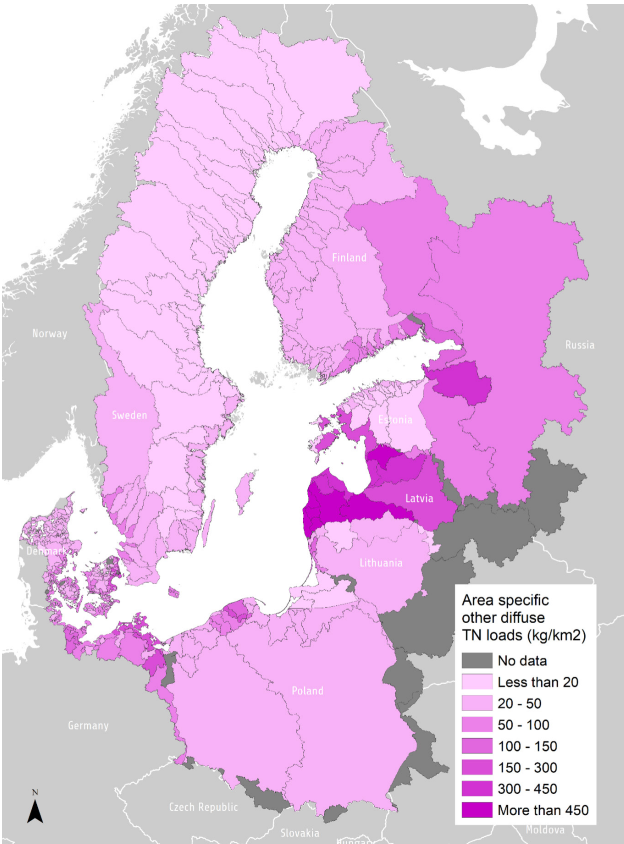


Figure 3.12. Area specific diffuse other sources loads of total nitrogen (TN in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment. Other diffuse sources include losses from forrestry, scattered dwellings, storm water effluents and other diffuse sources besides natural background and agricultural losses.

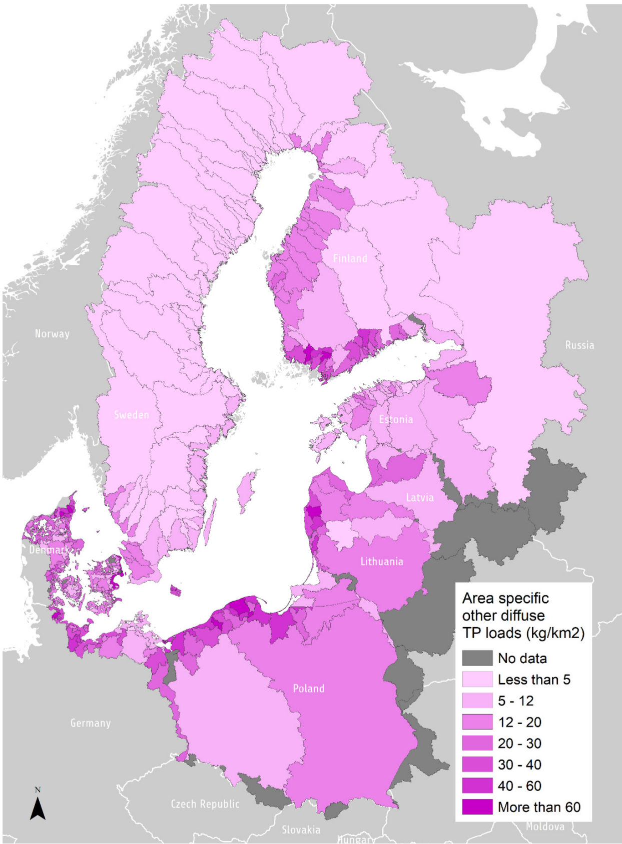


Figure 3.13. Area specific diffuse other sources loads of total phosphorus (TP in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment. Other diffuse sources include losses from forrestry, scattered dwellings, storm water effluents and other diffuse sources besides natural background and agricultural losses.

3.7. Riverine total nitrogen and total phosphorus loads

Riverine loads include diffuse and inland point sources loads of total nitrogen and total phosphorus (but not the direct point sources discharging into the sea). As diffuse sources are the main sources of riverine total nitrogen inputs (more than 88% - see table 4.6) to all sub-basins of the Baltic Sea the area specific riverine losses in figure 3.14 have a pattern very close to the area specific diffuse losses of total nitrogen seen in figure 3.7. For total phosphorus, the diffuse sources constitute more than 88% except for Baltic Proper (79%), Western Baltic (85%) and Gulf of Finland (87%) – see table 4.7. Thus the pattern of area specific riverine total phosphorus losses (figure 3.15) is very close to the corresponding for diffuse sources losses (figure 3.8).

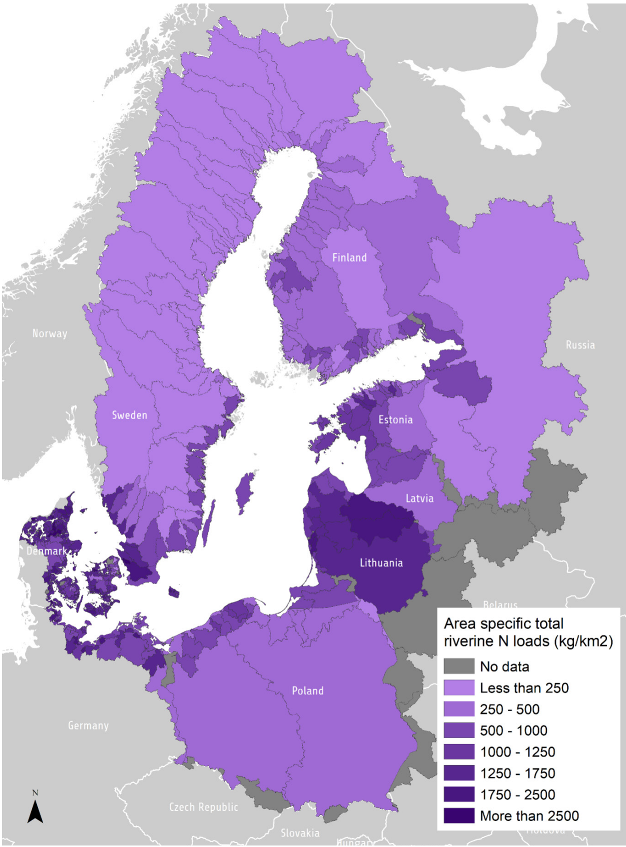


Figure 3.14. Area specific riverine loads of total nitrogen (TN in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

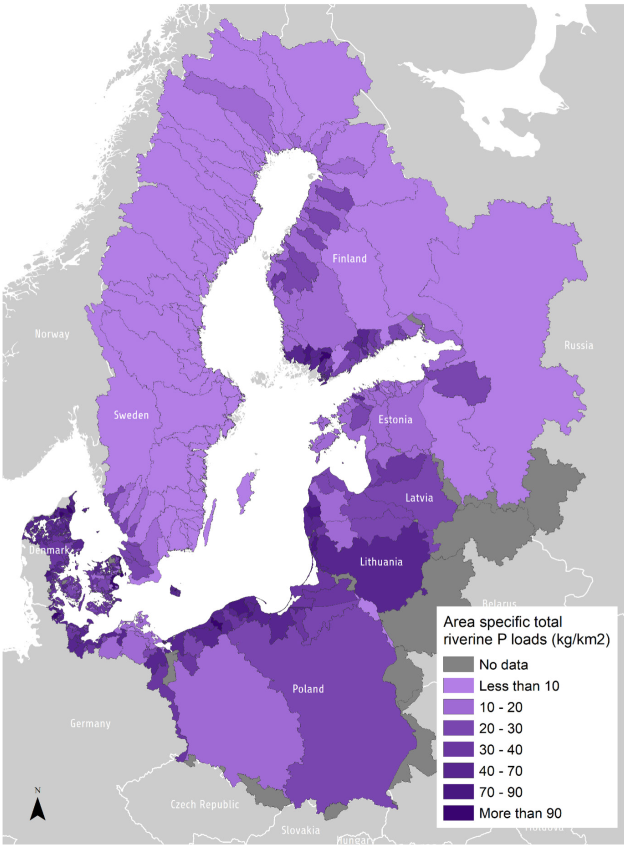


Figure 3.15. Area specific riverine loads of total phosphorus (TP in kg km^{-2}) in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

3.8. Total nitrogen and total phosphorus retention

When nitrogen and phosphorus enter inland surface waters from point and diffuse sources a proportion are retained in the rivers, riparian zones, or river valleys temporarily or more permanently due to biological, chemical and physical processes. The annual net retention of total nitrogen and total phosphorus in inland waters for the monitored rivers and unmonitored catchments in inland surface waters have been estimated/modelled and the results are presented in figures 3.18 and 3.19, respectively. The retention is in percentages, and 20% indicates that 20% of e.g., nitrogen inputs entering the catchment are retained in the inland surface waters that respective year.

Long distance to the sea and, high proportion surface area of lakes, big deep lakes in the catchment and big rivers usually will increase retention.

Retention of total nitrogen in 2017 (for Poland 2018) is from less than 5% in catchments in Lithuania and some small catchments in most countries (typically rather coastal located catchments), to more than 40 % in several catchments is eastern part of Finland, western part of Russia, central parts of Sweden and in some catchments in Latvia, Germany, and Denmark.

Retention of total phosphorus is from less than 2.5% in mainly some smaller catchments in Finland, and Denmark, to more than 40 % in some big catchments in e.g., central Sweden, western Poland, eastern Finland, and parts of Latvia.

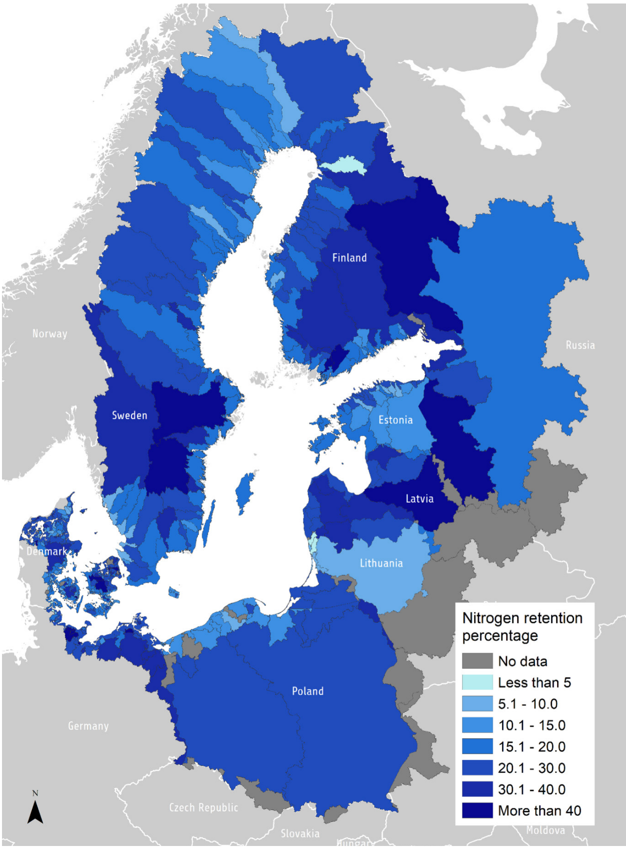


Figure 3.16. Total nitrogen retention (in %) in inland surface waters in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

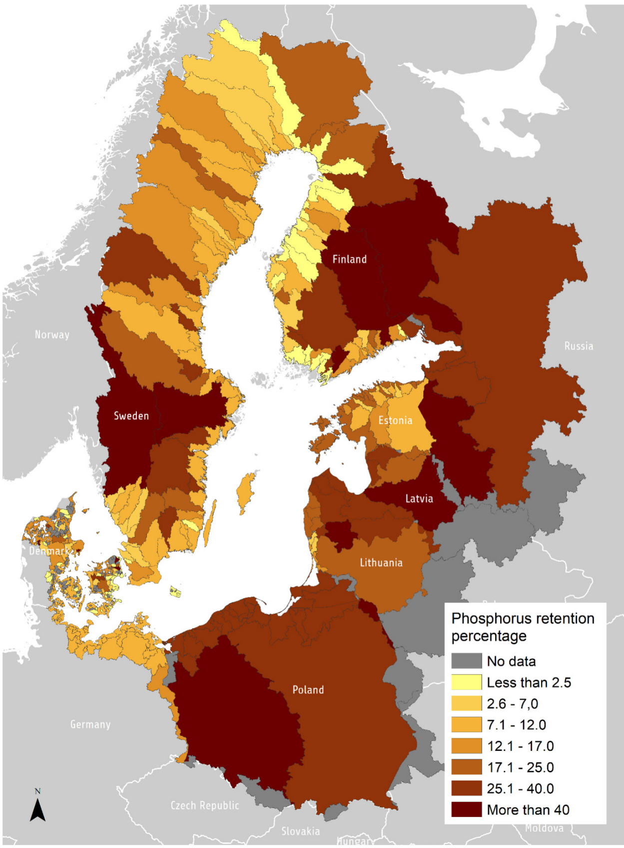


Figure 3.17. Total phosphorus retention (in %) in inland surface waters in 2017 (for Polish rivers in 2018) in the Baltic Sea cathment.

3.9. Total nitrogen and total phosphorus load from direct point sources (per category)

Total nitrogen and total phosphorus load from individual point sources discharging directly to the Baltic Sea are shown for aquaculture plants (figure 3.18 and 3.19), industrial plants (figure 3.20 and 3.21), and municipal waste water treatment plants (figure 3.22 and 3.23) using dot size to present the loads.

Only Denmark, Finland, and Sweden have reported loads from marine aquaculture plants, and not all countries have these facilities. The marine aquaculture plants are located primarily in Archipelago, Western Baltic, and Bothnian Sea, but they are also present in Bothnian Bay, Gulf of Finland, and very few in the Sound and Baltic Proper.

There are loads of total nitrogen and total phosphorus from industrial plants and municipal waste water treatment plants discharging directly to the sea to all sub-basins of the Baltic Sea. No data are shown from Russia as they as data are not reported by plants due to national legislation. For industrial plants, there are particularly many rather big total nitrogen and total phosphorus emitters located around Bothnian Bay and Bothnian Sea, and some few big ones around Baltic Proper and Gulf of Finland. There are many minor inputs from direct industrial plants to Kattegat, Western Baltic, and Swedish part of Baltic Proper. Estonia, Latvia, Lithuania, and Poland have reported very few direct emitting industrial plants. Much industrial waste waters are collected to municipal waste water treatment plants, and in some countries only few industry plants are located at the coast.

There are a few very big direct discharging municipal waste water treatment plants of total nitrogen and total phosphorus to the Baltic Sea, situated in big cities as St. Petersburg, Gothenburg, Helsinki, Stockholm, Malmö, Copenhagen, Umeå, and Oulu. There are several municipal waste water treatment plants discharging less than 100 tons total nitrogen and 5 tons total phosphorus in 2017 (2018 for Poland) at the Danish Estonian, Finnish, German and Swedish coastline to the Baltic Sea, but rather few from Latvia, Lithuania and Poland. Number of plants is related to both population density (towns) in coastal areas and if there are very big cities with few but big municipal waste water treatment plants, and if plants are emitting into rivers close to the coast as for Poland, or directly into the sea as for many counties.

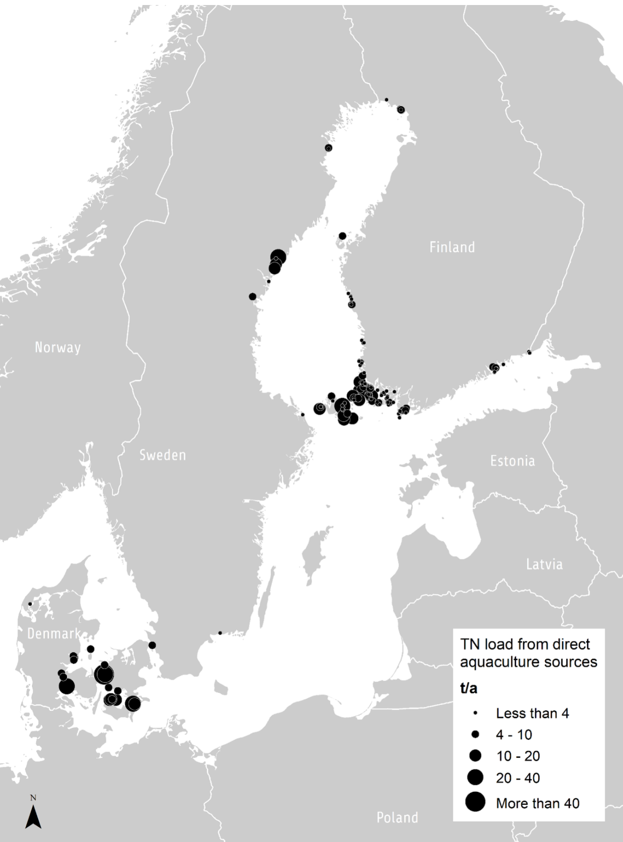


Figure 3.18. Total nitrogen inputs (TN in tonnes per year) from aquaculture plants discharging directly into the sea in 2017 (Poland 2018).

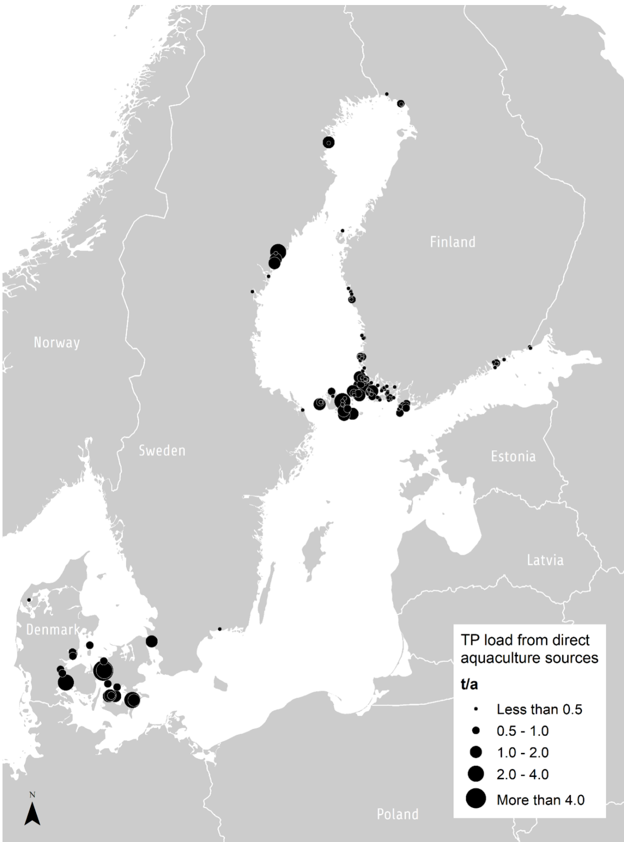


Figure 3.19. Total phosphorus inputs (TP on tonnes per year) from aquaculture plants discharging directly into the sea in 2017 (Poland 2018).

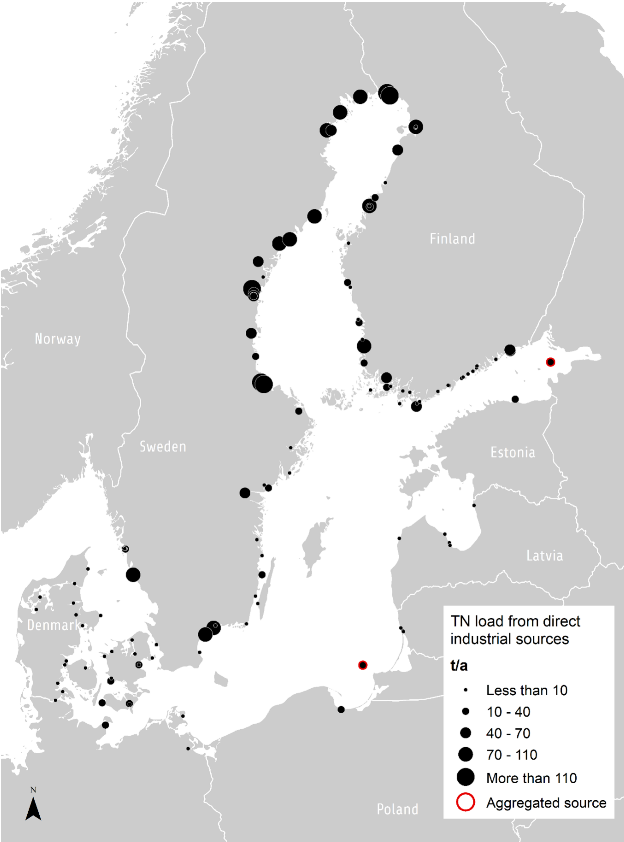


Figure 3.20 Total nitrogen inputs (TN in tonnes per year) from industrial plants discharging directly into the sea in 2017 (Poland 2018).

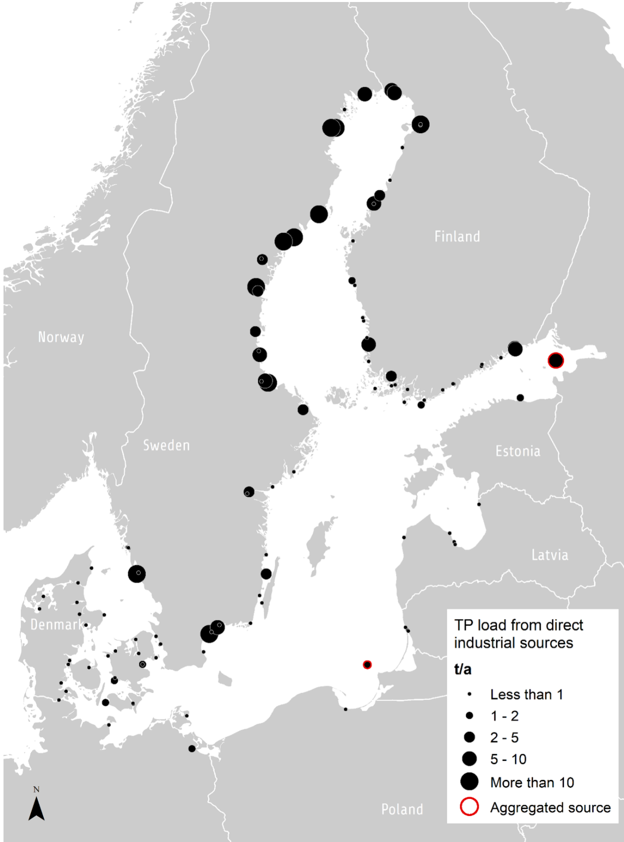


Figure 3.21 Total phosphorus inputs (TP in tonnes per year) from industrial plants discharging directly into the sea in 2017 (Poland 2018).

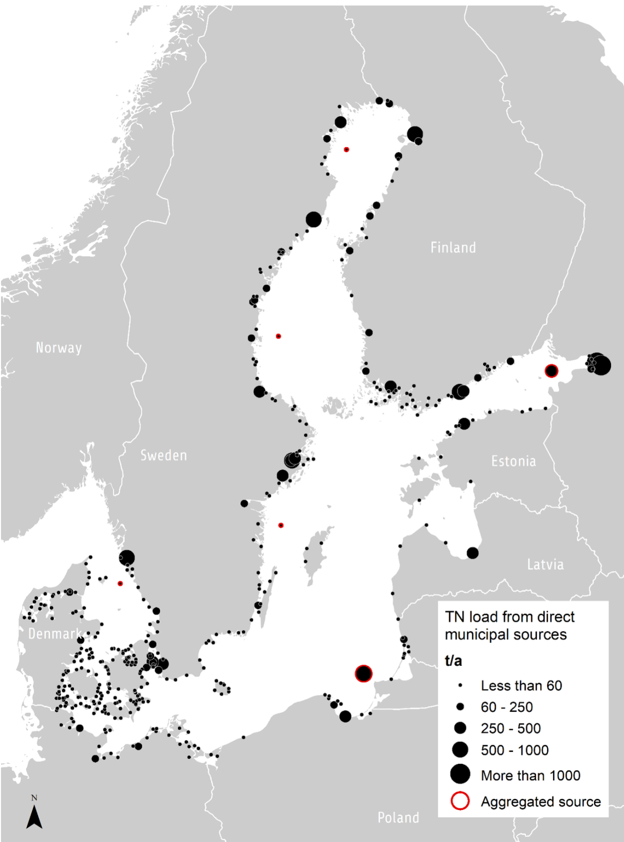


Figure 3.22 Total nitrogen inputs (TN in tonnes per year) from municipal waste water treatment plants discharging directly into the sea in 2017 (Poland 2018).

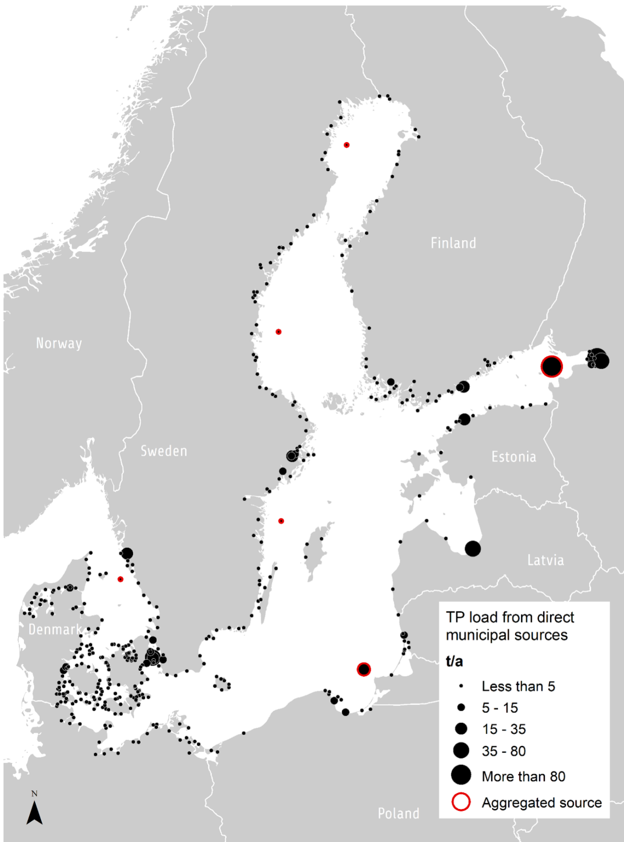


Figure 3.23 Total phosphorus inputs (TP in tonnes per year) from municipal waste water treatment plants discharging directly into the sea in 2017 (Poland 2018).

3.10. Land cover in the Baltic Sea catchment area

The land cover indicates where cultivated and managed land and forests are concentrated. It is rather obvious that the farmland is situated primarily in Denmark, Germany, main parts of Poland, Lithuania, parts of Latvia and Estonia, southern Finland, and southern Sweden (figures 3.24).

Forest covers the main parts of Sweden, Finland, and Russia, but is also important in bigger parts of the Baltic states and parts of Poland.

Cultivated and managed areas constitute in average 48 % of the catchment area to the Baltic Sea, and more than approx. 60 % of the catchment area in Denmark, Germany, Lithuania, and Poland (table 3.1). The proportion of forest is in average 28 % of the Baltic Sea catchment area, and higher than 50% in Finland, Russia, Sweden, and transboundary parts of Belarus.

Permanent water bodies and urban and built-up areas constitute in average only 6 and 3%, respectively of the Baltic Sea catchment area, but have markedly higher shares for some countries/to some sub-basins. The category "other" includes herbaceous vegetation and wetlands in mountains, bare rock, snow and ice cover.

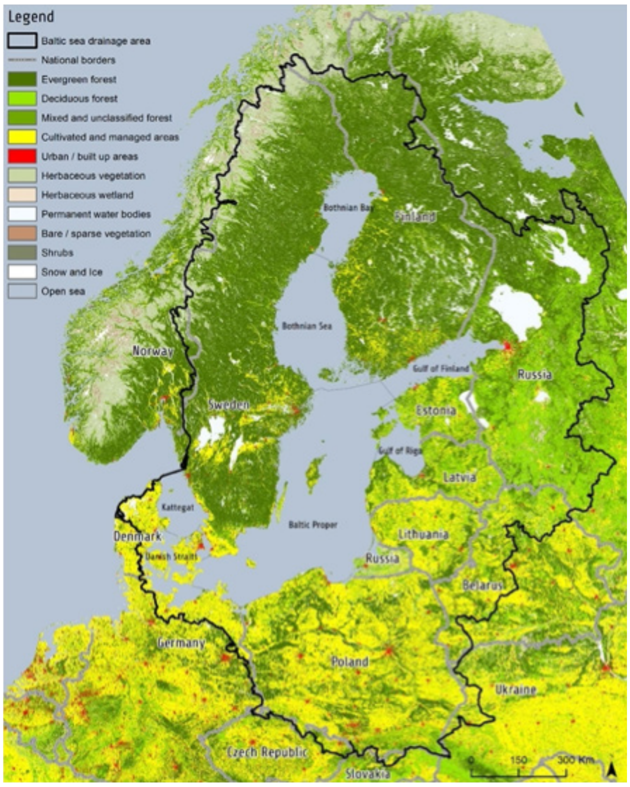


Figure 3.24. Land cover in the Baltic Sea catchment area. (Source: The Copernicus Land Service 2015 (https://land.copernicus.eu/global/).

Table 3.1. Land cover and land use of the Baltic Sea catchment by countries (%). Source Corine land Cover 2018 (https://land.copernicus.eu/pan-european/corine-land-cover/clc2018); For Belarus, Russia, and Ukraine Source Copernicus Global Land Services 2015 (https://land.copernicus.eu/global/).

	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden	Belarus	Czech Republic	Norway	Slovakia	Ukraine	Average
Year of data	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2015**	**2018**	**2015**	**2018**	**2018**	**2018**	**2015**	**2018**
Cultivated and managed areas	74	32	9	70	40	59	59	4	9	39	50	1	37	45	48
Forest	9	47	64	20	38	30	31	77	59	54	34	37	45	42	28
Permanent water bodies	1	5	9	2	2	2	2	12	8	1	1	7	0	1	6
Urban / built-up areas	7	2	1	5	2	3	6	1	1	1	9	0	4	3	3
Other	8	15	16	3	19	6	3	7	23	5	7	54	15	10	15

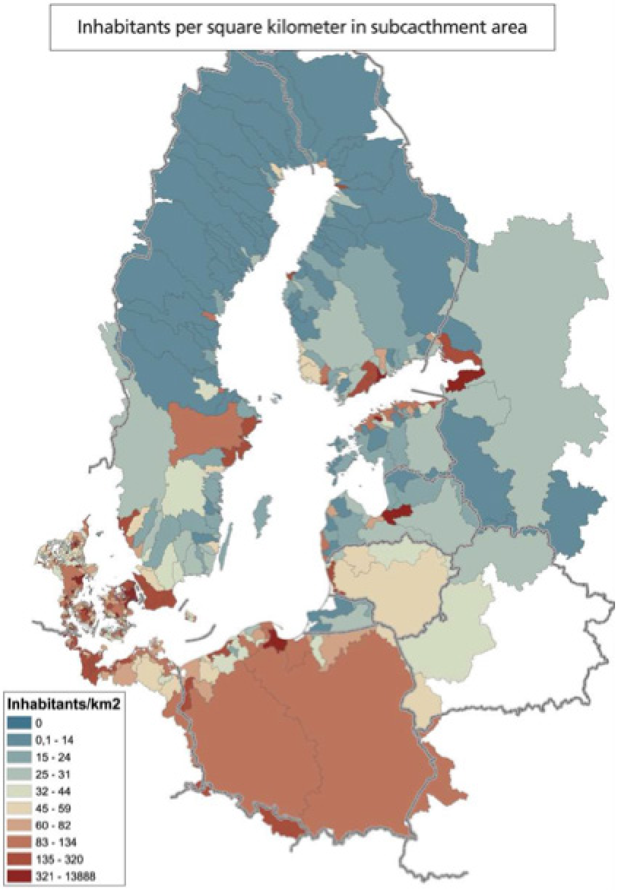


Figure 3.25. Population density (approx. in 2017) in the Baltic Sea catchment.

3.11. Population density

The population density is generally high in the Danish, German, Czech Republic, Slovakia, Ukraine, and Polish parts of the catchment to the Baltic Sea, around Gothenburg and Stockholm area and parts of coastal catchment to Gulf of Finland (figure 3.25 and table 2). It is generally low for central and Northern parts of Sweden and Finland, and mains part of Estonian, Latvian, and Russian catchment.

Table 3.2. Population and population density in HELCOM countries and in non HELCOM countries, for the part of the countries being riverine catchment to the Baltic Sea. From HELCOM, 2021b.

Basin/ Country	Baltic Sea catchment area (km^{-2})	Total population in catchment area (in 1000)	Population density in catchment (person km^{-2})
Denmark	31,130	5,150	165
Estonia	45,400	1,315	29
Finland	301,250	5,480	18
Germany	29,100	2,735	94
Latvia	64,590	1,940	30
Lithuania	65,200	2,930	45
Poland	311,000	38,400	123
Russia	326,080	10,300	32
Sweden	442,700	10,035	23
Total HELCOM countries	**1,616,450**	**78,285**	**559**
Non HELCOM countries			
Belarus	91,200	1,420	16
Czech Republic	7,150	1,145	160
Norway	13,350	20	1
Slovakia	1,960	180	92
Ukraine	13,100	1,230	94
Total non HELCOM countries	126,760	3,995	363
Total Baltic Sea catchment area	**1,743,210**	**82,280**	**922**

4. Load-oriented approach

This chapter includes results from the load-oriented source assessment. Some results are also presented in chapter 2 and 3 (on maps). The results are shown with different aggregation level of sources, starting with the most aggregated level in chapter 4.1 and with most detailed source information in sub-chapters 4.6 and 4.7:

- Riverine inputs, direct inputs, and atmospheric inputs on the sea (chapter 4.1).
- Natural background load, sum of other diffuse sources, sum of point sources (sum of indirect and direct), and atmospheric deposition on the sea (chapter 4.2).
- Natural background load, sum of other diffuse sources, and indirect point sources (chapter 4.3).
- Atmospheric deposition on surface waters, natural background load, agricultural load, sum of other diffuse sources, and indirect point sources (chapter 4.4).
- Inland diffuse sources load: atmospheric deposition on surface waters, natural background load, agricultural load, managed forestry, sum of other diffuse sources, scattered dwelling load, and storm water loads (chapter 4.5).
- Inland waste water loads: municipal waste water treatment plants loads, industrial loads, aquacultural plants loads, scattered dwelling load, and storm water (chapter 4.6).
- Direct point sources load: municipal treatment plant loads, industrial loads, and aquacultural plants loads (chapter 4.7).

The sub-chapters include examples with pie charts showing shares (in percentages) of sources by country, by basin and country by basin. Further there are Box-Whisker plots country by basin showing shares of sources (in percentages) for individual monitored rivers within the respective catchment to the basin. In chapter 9.2 it is explained how to interpret a Box-Whisker plot.

Only in chapters 3.1 and 4.2 are shown all pie charts per country and per basin, otherwise only selected plots and charts are shown, but in chapter 9 (annexes) it is explained where all (more than 1,400) the plots and charts per basin, per country and country per basin are available.

Some tables with data behind the pie charts are included in this chapter.

Overview of abbreviation are in table 1.1.

4.1. Riverine inputs, direct inputs, and atmospheric inputs on the sea

All countries (supplied by EMEP regarding atmospheric deposition) have reported data allowing to divide total nitrogen and total phosphorus inputs in three main pathways: riverine, direct inputs and atmospheric inputs to the Baltic Sea by basin, by country, and country by basin. The results are shown in table 4.1 (total nitrogen) and 4.2 (total phosphorus) by basin, and correspondingly in table 4.3 and 4.4 by country. The tables show the share of the sources of the inputs to basin (table 4.1 and 4.3) and from the country (table 4.2 and 4.4), and the total inputs are indicated in tons, and further how much the total to a basin or country constitutes of the total input to the Baltic Sea.

To visualize the scaling in inputs via the three pathways in tables 4.1. and 4.2 scaled pie charts are shown in figures 2.1 (total nitrogen by basin) and 2.2 (total nitrogen by country). Baltic Proper receives more than 40% of all total nitrogen inputs to the Baltic Sea, Gulf of Finland and Gulf of Riga about 15 % each, while the remaining 6 basins each receive from approx. 1 % (The Sound and Archipelago) to 5-7% (remaining four basins). Catchment to the Baltic Proper constitutes approx. 33 % of the Baltic Sea catchment and 50% of the Baltic Sea surface area (table 1.3). Riverine total nitrogen inputs are the most important total nitrogen pathway to the Baltic Sea (average 73%) ranging from 45% (Archipelago) to 93% (Gulf of Riga). Atmospheric total nitrogen deposition is the second most important pathway, in average 24%, ranging from less than 7% (Gulf of Riga) to nearly 48% (Archipelago), mostly reflecting the relation between catchment areas draining to the basin and basin sea-surface area. Direct point source loads constitute in average 3% of total nitrogen inputs to the Baltic Sea, ranging from less than 1% (Gulf of Riga) to about 16% (The Sound), for The Sound due to high population density (figure 3.25).

Nearly 44% of total phosphorus inputs to the Baltic Sea enters Baltic Proper. Gulf of Finland (17%) and Gulf of Riga (12%) receive the second and third highest proportion of total phosphorus inputs. The Sound (1%) and Archipelago (2%) receive the smallest amounts of the inputs, while the remaining 5 basins receive each between 4% and 9%. Riverine pathway is even more important for total inputs of phosphorous, in average 88% of total inputs to the Baltic Sea, ranging from only 54% to The Sound (due to high share of direct point source phosphorus inputs) to 96% (Gulf of Riga). Atmospheric total phosphorus inputs are the second most important pathway, in average 7% of total phosphorus inputs to the Baltic Sea, ranging from less than 3% (Gulf of Riga) to 21% (Bothnian Sea). Atmospheric inputs of phosphorus are calculated with a constant deposition rate for the entire Baltic Sea (5 kg P km^{-2}), and therefore sub-basins with relatively high proportion of sea-surface area compared with catchment areas have a tendency for higher atmospheric shares. Direct point sources inputs constitute in average less than 5% of total phosphorus inputs to the Baltic Sea, ranging from 1-2% (Gulf of Riga and Baltic Proper) to more than 42% (The Sound), reflecting both impact of high population density and industrial activity as well as the importance of other sources (agriculture affecting the importance of riverine inputs), or relatively big sea-surface areas leading to higher shares of atmospheric deposition.

Figures 4.1 and 4.2 include the pie charts showing the results in tables 4.1 and 4.2.

Table 4.1. Shares (in percentages) for main pathways of total nitrogen (TN in tonnes) to the Baltic Sea by sub-basin in 2017 (Polish data from 2018). The right-most column indicates the share of the total nitrogen inputs to the basin of the corresponding total nitrogen input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea.

TN - Basin	Riverine %	PS_DIR %	ATM %	Total tonnes	Total of total (%)
Bothnian Bay	80.2	6.4	13.4	55,964	6.1
Bothnian Sea	60.7	6.5	32.9	52,499	5.7
Archipelago	44.7	7.7	47.6	12,826	1.4
Baltic Proper	67.9	1.3	30.8	399,394	43.2
Gulf of Finland	82.5	7.2	10.3	137,219	14.9
Gulf of Riga	93.0	0.3	6.7	139,332	15.1
Western Baltic	55.3	3.2	41.5	50,224	5.4
Sound	63.0	16.2	20.8	11,089	1.2
Kattegat	66.9	2.9	30.1	65,216	7.1
Baltic Sea	73.1	3.1	23.8	923,763	100

Table 4.2. Shares (in percentages) for main pathways of total phosphorus (TP in tonnes) to the Baltic Sea by sub-basin in 2017 (Polish data from 2018) and total phosphorus inputs by sub-basins in tonnes. For further explanation see caption to table 4.1.

TP - Basin	Riverine %	PS_DIR %	ATM %	Total tonnes	Total of total (%)
Bothnian Bay	89.5	3.5	7.0	2,573	9.0
Bothnian Sea	69.6	9.0	21.4	1,695	6.0
Archipelago	86.7	8.5	4.8	642	2.3
Baltic Proper	90.0	1.6	8.4	12,424	43.7
Gulf of Finland	87.1	9.8	3.1	4,877	17.1
Gulf of Riga	96.1	1.2	2.7	3,432	12.1
Western Baltic	80.2	10.7	9.1	1,042	3.7
Sound	54.4	42.4	3.2	312	1.1
Kattegat	85.1	6.8	8.1	1,456	5.1
Baltic Sea	87.9	4.8	7.3	28,452	100

The shares for main pathways (riverine, direct inputs and atmospheric deposition on the sea) to the Baltic Sea by country of total nitrogen and total phosphorus are shown in tables 4.3 and 4.4, respectively, and in figure 4.2 The tables also include information on the total inputs shares by country of total input to the Baltic Sea. Main findings for total nitrogen from table 4.3:

— Poland (17%), Latvia (13%), Russia (13%) and Sweden (13%) are the biggest contributors of total nitrogen to the Baltic Sea, while Estonia (3.7%) and Denmark (6.3%) are the smallest. These shares reflect to some extent which countries have the biggest shares of the catchment areas (including upstream transboundary catchment as for Latvia), but also where there are intensive agriculture activities and high population density as in Denmark with 1.8% of the catchment area and 6.3% of the population in Baltic Sea catchment area (table 3.2).
— Total nitrogen inputs from other countries and from shipping constitutes 10% of total nitrogen inputs to the Baltic Sea.
— Riverine inputs constitute in average 73% of total nitrogen inputs to the Baltic Sea, ranging from 34% (Germany) up to more than 97% (Latvia). For Germany the catchment area to Baltic Sea is less than 30,000 km_2 while the entire territory of Germany contributes to the atmospheric nitrogen inputs on the Balti Sea.
— Atmospheric inputs constitute in average nearly 24 % of the inputs ranging from about 2% (Latvia) to 65% (Germany). Shipping on the Baltic Sea and North Sea contribute only with atmospheric deposition, while some other non HELCOM countries in fact also contribute with riverine inputs, but that is included in the riverine inputs from the nine countries
— Direct inputs of total nitrogen amount to about 3% in average of total nitrogen inputs to the Baltic Sea, ranging from less than 0.5 % (Lithuania, Latvia, Poland) to 9.3 % (Sweden). This reflects the situation that in some countries many major cities and industrial activities are located at the coast, in other countries many big cities are situated inland, and that some countries have significant amount of marine aquaculture.

Main findings for total phosphorus from table 4.4:

— Poland (25%), Russia (14%) and Finland (13%) are the biggest contributors of total phosphorus to the Baltic Sea, while Estonia (2.7%) and Germany (3.7%) are the smallest.
— Total phosphorus inputs from other sources constitutes 7.3% of total phosphorus inputs. That is also the share of atmospheric deposition of phosphorus. It is not possible to allocate the sources of phosphorus deposition, and the atmospheric phosphorus deposition is calculated with a fix rate of 5 kg P km^{-2} on the Baltic Sea. Upstream transboundary inputs are included in HELCOM countries riverine inputs.
— Direct inputs of total phosphorus constitute less than 5% in average of total phosphorus inputs to the Baltic Sea, ranging from less than 1.0 % (Lithuania, Poland) to more than 16% (Denmark). Low direct share of phosphorus inputs reflects that in some countries major part of the population and the industry are situated with some distance to the coastal area, so waste water discharges to rivers.

Table 4.3. Shares (in percentages) for main pathways of total nitrogen (TN in tonnes) to the Baltic Sea by countries, shipping, and other sources in 2017 (Polish data from 2018). The column "Total %" indicates the share of the total nitrogen inputs from the country and from shipping (all sources) while the column "Total of CP's (%)" is the corresponding shares only for the nine HELCOM countries. Riverine nitrogen inputs from non HELCOM countries are included in downstream HELCOM countries riverine inputs. For further explanation see caption to table 4.1.

TN - Country/source	Riverine %	PS_DIR %	ATM %	Total tonnes	Total of total (%)	Total of CP's (%)
Denmark	68.6	4.0	27.4	57,836	6.3	6.9
Estonia	91.9	1.5	6.6	34,225	3.7	4.1
Finland	86.0	6.7	7.3	83,281	9.0	10.0
Germany	33.8	1.3	65.0	71,285	7.7	8.5
Lithuania	95.9	0.2	3.9	103,250	11.2	12.4
Latvia	97.4	0.4	2.2	116,517	12.6	13.9
Poland	79.8	0.4	19.8	156,838	17.0	18.8
Russia	80.8	7.8	11.4	106,197	11.5	12.7
Sweden	79.6	9.3	11.1	106,316	11.5	12.7
Baltic Sea shipping			100	13,020	1.4	
North Sea Shipping			100	8,858	1.0	
Other countries			100	66,140	7.2	
Baltic Sea	73,1	3,1	23,8	923,763	100	

Table 4.4. Shares (in percentages) for main pathways of total phosphorus (TP in tonnes) to the Baltic Sea by countries, shipping, and other sources in 2017 (Polish data from 2018). The column "Total %" indicates the share of the total nitrogen inputs from the country and from shipping (all sources) while the column "Total of CP's (%)" are the corresponding shares only for the nine HELCOM countries. Riverine phosphorus inputs from non HELCOM countries are included in downstream HELCOM countries riverine inputs. Further explanation in caption to table 4.1.

TP - Country/source	Riverine %	PS_DIR %	ATM %	Total tonnes	Total of total (%)	Total of CP's (%)
Denmark	83.5	16.5	0.0	1,521	5.3	5.8
Estonia	96.3	3.7	0.0	757	2.7	2.9
Finland	95.2	4.8	0.0	3,721	13.1	14.1
Germany	96.8	3.2	0.0	889	3.1	3.4
Lithuania	99.5	0.5	0.0	2,571	9.0	9.8
Latvia	98.7	1.3	0.0	3,290	11.6	12.5
Poland	99.3	0.7	0.0	6,976	24.5	26.5
Russia	89.6	10.4	0.0	3,974	14.0	15.1
Sweden	86.7	13.3	0.0	2,664	9.4	10.1
Baltic Sea shipping					0.0	
North Sea Shipping					0.0	
Other countries			100	2,088	7.3	
Baltic Sea	87.9	4.8	7.3	28,452	100	

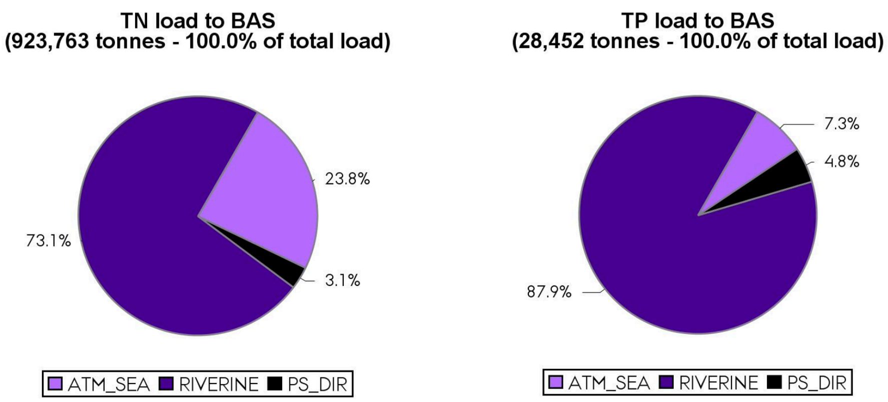


Figure 4.1. Shares (in percentages) for main pathways of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea by sub-basin in 2017 (Polish data from 2018). Total input to the basin (in tonnes) is indicated in the header as is the share (in percentages) of this input of the total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea. Data behind figure 4.1 is in tables 4.1 and 4.2.

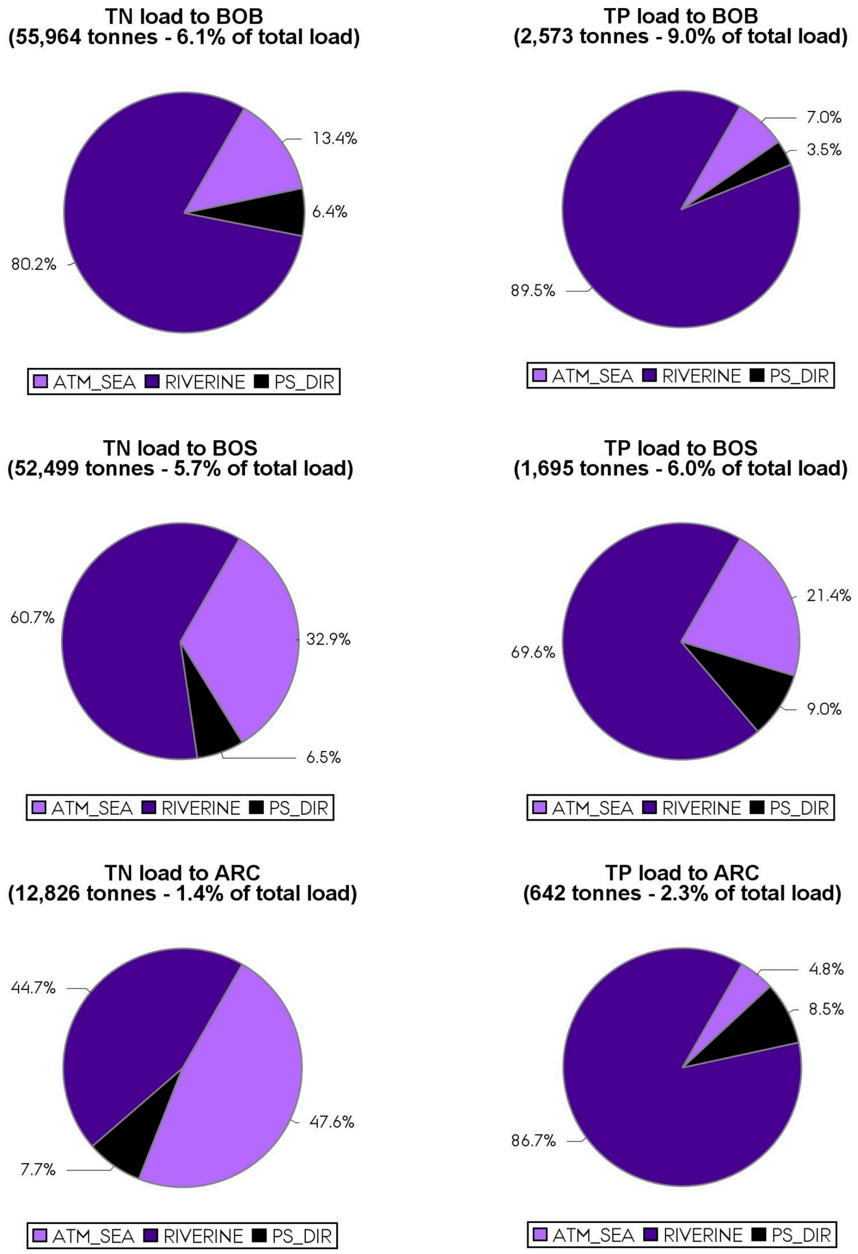


Figure 4.1. Continued. Shares (in percentages) for main pathways of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea by sub-basin in 2017 (Polish data from 2018). Total input to the basin (in tonnes) is indicated in the header as is the share (in percentages) of this input of the total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea. Data behind figure 4.1 is in tables 4.1 and 4.2.

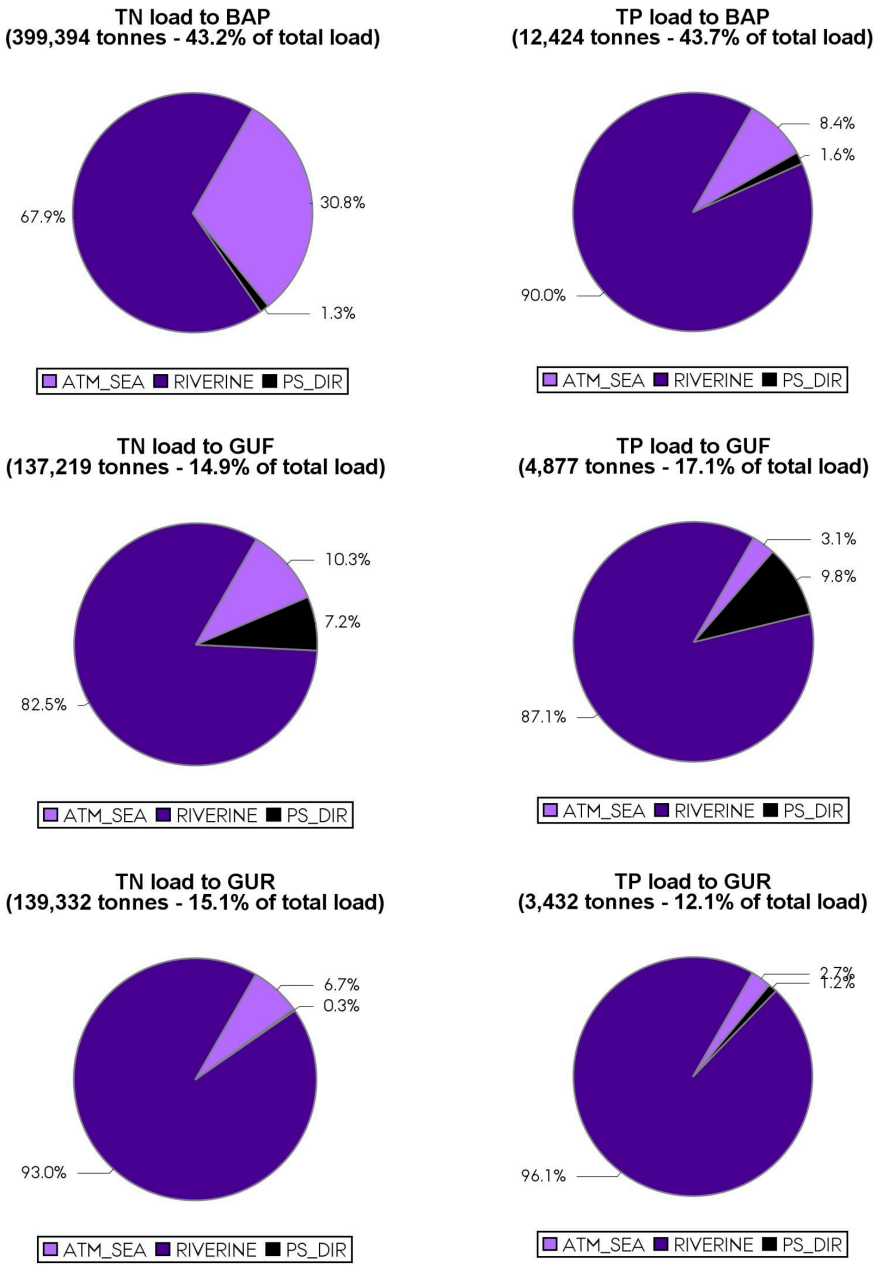


Figure 4.1. Continued. Shares (in percentages) for main pathways of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea by sub-basin in 2017 (Polish data from 2018). Total input to the basin (in tonnes) is indicated in the header as is the share (in percentages) of this input of the total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea. Data behind figure 4.1 is in tables 4.1 and 4.2.

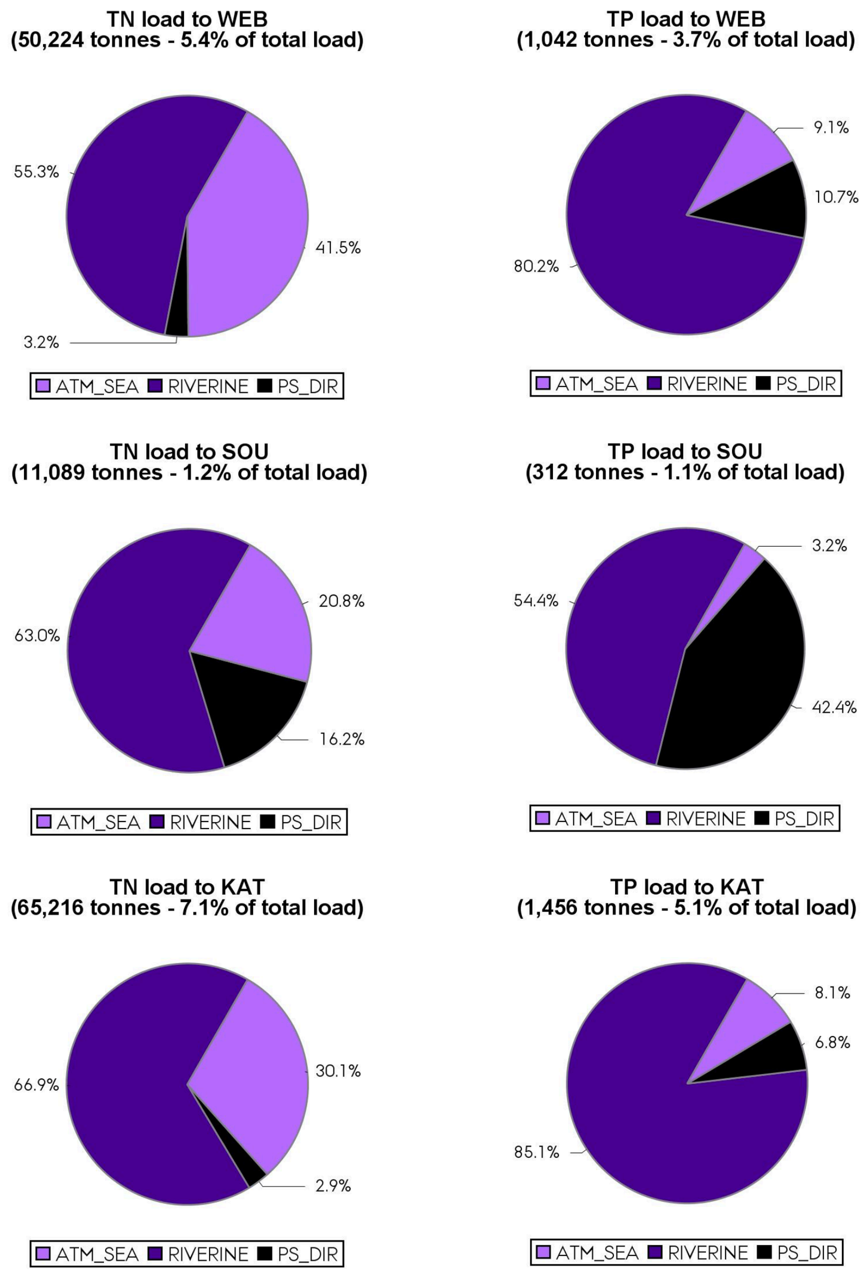


Figure 4.1. Continued. Shares (in percentages) for main pathways of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea by sub-basin in 2017 (Polish data from 2018). Total input to the basin (in tonnes) is indicated in the header as is the share (in percentages) of this input of the total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea. Data behind figure 4.1 is in tables 4.1 and 4.2.

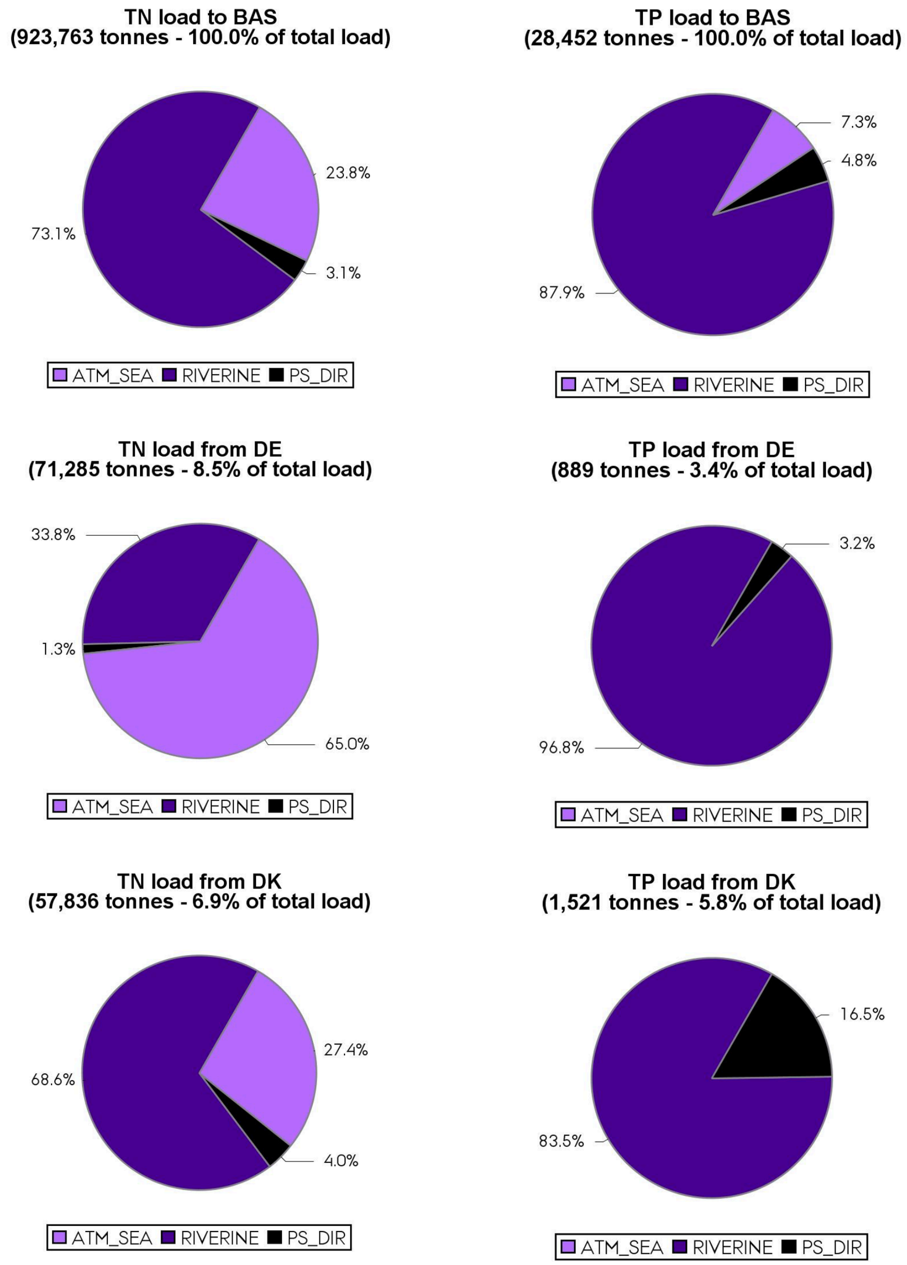


Figure 4.2. Shares (in percentages) for main pathways of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea by HELCOM countries in 2017 (Polish data from 2018). Total inputs from a country (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea is zero, as it cannot be allocated by country. Data behind figure 4.2 is in tables 4.3 and 4.4.

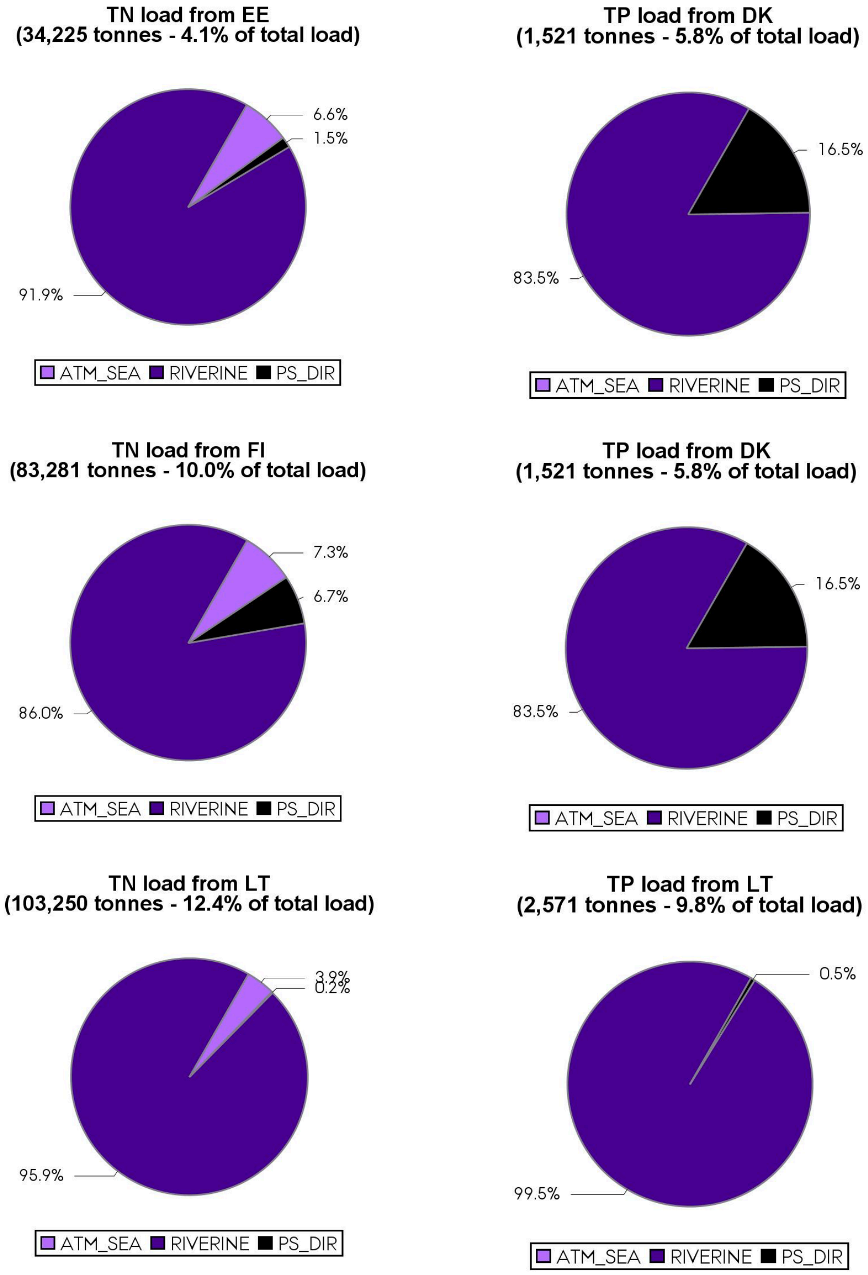


Figure 4.2. Continued. Shares (in percentages) for main pathways of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea by HELCOM countries in 2017 (Polish data from 2018). Total inputs from a country (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea is zero, as it cannot be allocated by country. Data behind figure 4.2 is in tables 4.3 and 4.4.

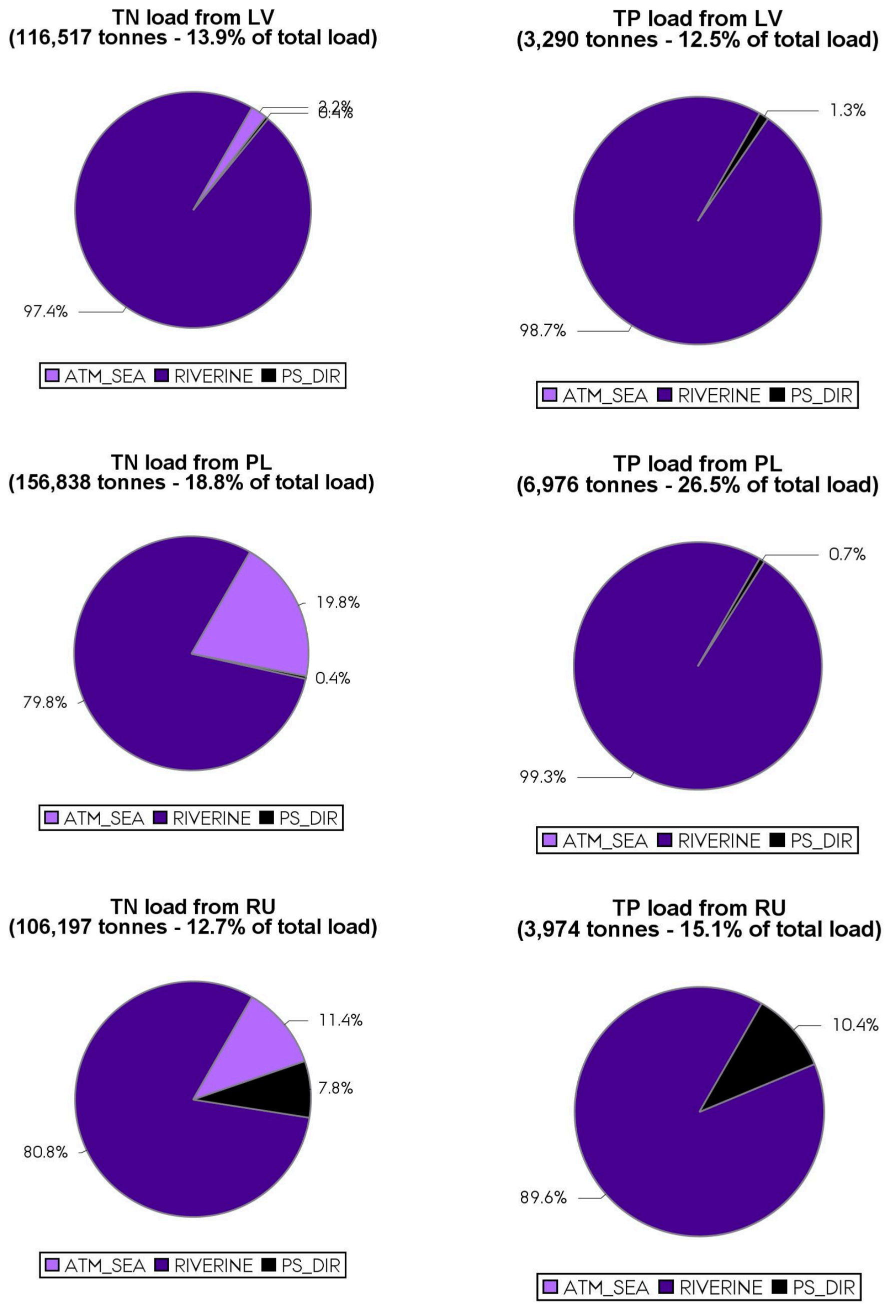


Figure 4.2. Continued. Shares (in percentages) for main pathways of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea by HELCOM countries in 2017 (Polish data from 2018). Total inputs from a country (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea is zero, as it cannot be allocated by country. Data behind figure 4.2 is in tables 4.3 and 4.4.

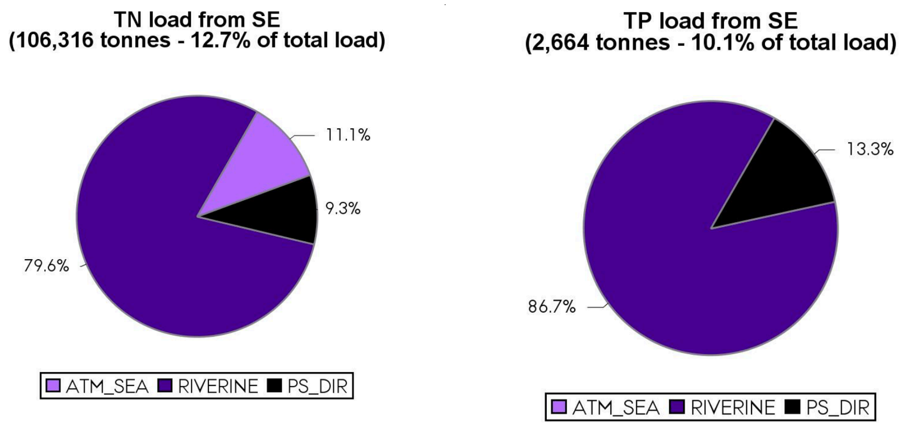


Figure 4.2. Continued. Shares (in percentages) for main pathways of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea by HELCOM countries in 2017 (Polish data from 2018). Total inputs from a country (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Riverine = inputs discharged via rivers to the sea, PS-DIR = inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly to the sea, ATM: atmospheric deposition on the Baltic Sea is zero, as it cannot be allocated by country. Data behind figure 4.2 is in tables 4.3 and 4.4.

We have also assessed the main pathways on a country to sub-basin scale and some few examples are shown in figure 4.3. In chapter 9, Annex 9 is described where to find all pie plots by basin, by country and country by basin for the three main pathways: riverine, direct point sources and atmospheric deposition on the sea.

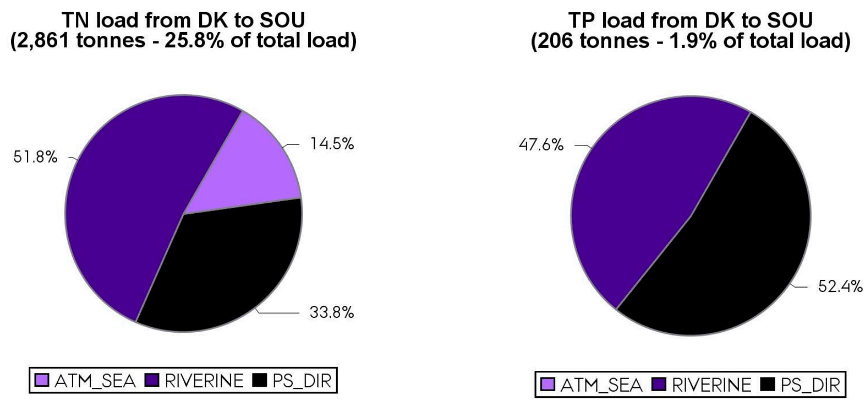


Figure 4.3. Shares (in percentages) for main pathways (PS-DIR = input for direct point sources and ATM-SEA = atmospheric deposition om the sea) of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea from Denmark to the Sound, Estonia to Gulf of Finland and Sweden to Baltic Proper in 2017. Total inputs from a country (in tonnes) to the sub-basin are indicated in the header as is the share (in percentages) of this input of the total input to the basin. Atmospheric phosphorus deposition is zero, as it cannot be allocated between countries.

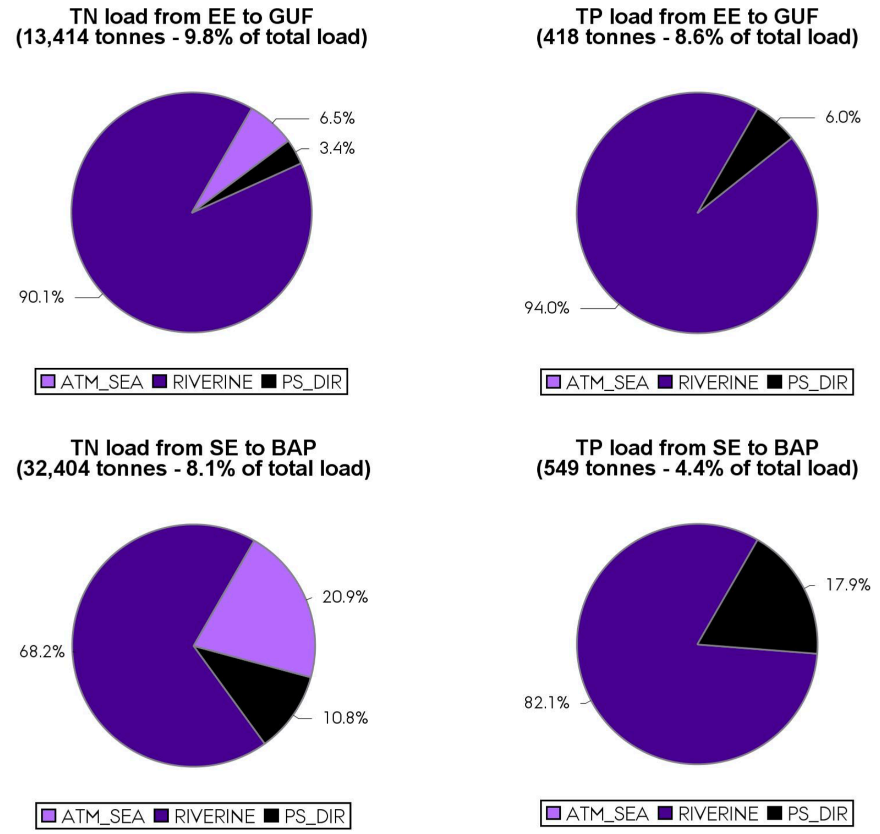


Figure 4.3. Shares (in percentages) for main pathways (PS-DIR = input for direct point sources and ATM-SEA = atmospheric deposition om the sea) of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea from Denmark to the Sound, Estonia to Gulf of Finland and Sweden to Baltic Proper in 2017. Total inputs from a country (in tonnes) to the sub-basin are indicated in the header as is the share (in percentages) of this input of the total input to the basin. Atmospheric phosphorus deposition is zero, as it cannot be allocated between countries.

4.2. Natural background load, sum of other diffuse sources, sum of point sources (sum of indirect and direct), and atmospheric deposition on the sea

In this sub-chapter we divide the total inputs to the Baltic Sea from chapter 4.1 in four main sources:

- Natural background loads (NBL).
- Load from other diffuse sources (DIF-other) covering agriculture, forestry, transboundary inputs, scattered dwellings, and storm waters.
- Load from point sources discharging within the catchment (indirect) and directly to the sea (direct) (PS_Total)
- Atmospheric deposition on the sea (ATM_SEA)

The results per sub-basin are summarized in tables 2.3 and 2.4 and per country in tables 2.5 and 2.6. Further scaled pie charts on maps for this source apportionment are show per basin in figure 2.3 and 2.4 and per country in figure 2.5 and 2.5 for total nitrogen and total phosphorus, respectively.

As described in chapter 1.5 countries are not using exactly same methods/methodology assessing some of the sources. Particularly for the quantification of natural background loads there are some marked differences as some countries are modelling this source, while other are monitoring in river catchments with a minor anthropogenic impact. In the modeling it is possible to set criteria assuming nearly 100% pristine (not at all affected by human activity) conditions determining natural background loads as Germany has done resulting in some very low shares of natural background loads. Therefore, the different criteria used by countries in the PLC-7 assessment don't provides fully comparable results. Further, Latvia for example only applies natural background loads on forested areas, while Denmark applies it for all not fortified part of the catchment.

It should be considered that flow was markedly higher than average from the Baltic Countries, Denmark, Germany, Southern Sweden, Southern Finland in 2017 which will lead to rather high diffuse losses and make shares from diffuse sources higher and from point sources lower. For particularly western part of Poland (2018), Southern half of Sweden besides the very southern parts and for southwestern part of Finland flow was markedly lower than average in 2017, which will relatively increase importance of point source inputs.

Main findings for total nitrogen (table 2.3 and figure 4.4.):

— Other diffuse sources consisting of sources such as agriculture, managed forestry, scattered dwellings, storm waters and for some countries transboundary upstream inputs from non-HELCOM countries are in average the biggest source (49%) of total nitrogen inputs to Baltic Sea basins. Atmospheric deposition is in average the second biggest source (24%) follow by natural background loads (18%) and inputs from indirect and direct point sources (9%).
— Other diffuse sources have the highest shares of total inputs for all basins beside the three most northern situated (Bothnia Sea, Bothnian Bay and Archipelago). The highest share is for Gulf of Riga (83%) which includes considerable amounts of transboundary nitrogen inputs from upstream situated countries, and Baltic Proper (52%). For the remaining 7 sub-basins the shares are between 20 and 40% of total nitrogen inputs to the basin.
— Natural background loads are the most import total nitrogen source to Bothnian Bay (52%) and to Bothnian Sea (33%), due to low intensity of agriculture and low population density. For Bothnian Sea also the relative high sea area compared with the catchment area makes atmospheric deposition rather important (33%). For the same reason atmospheric deposition is the most important source to Archipelago with 48% of total nitrogen inputs. Natural background loads have a very low share to Gulf of Riga (9%) and to Western Baltic (7%). For Gulf of Riga, because Latvia only assumes natural background loads from forested land, and to Western Baltic, because Germany is modelling assuming completely pristine criteria, there are very low natural background loads and shares of the respective total nitrogen inputs.
— Inputs from point sources (indirect plus direct) are less important source besides to Gulf of Finland where the share with 15% is higher than atmospheric deposition, but size of sea area for Gulf of Finland is only 1/14 compared with the catchment area to Gulf of Finland (table 1.4). The highest share of inputs from point sources is to The Sound (19%). The very high share of other diffuse sources to the Gulf of Riga is one main reason for the very low share (less than 1%) from point sources to that basin, but also rather low population density in the catchment explains this result (figure 3.25).

Main findings for total phosphorus (table 2.4 and figure 4.4.):

— Other diffuse sources (see above under nitrogen) are in average the biggest source (56%) for total phosphorus to Baltic Sea sub-basins (table 2.4) and figures 4.4. Natural background loads are in average the second biggest source (20%) followed by inputs from indirect and direct point sources (17%) and atmospheric deposition (7%).
— Other diffuse sources have the highest shares of total inputs for seven basins, only for Bothnian Sea and The Sound it is the second biggest source. The highest share is for Gulf of Riga (84%) as it includes considerable amounts of transboundary phosphorus inputs from upstream situated countries, and for Archipelago (76%). For the remaining 7 sub-basins the shares are between 36 and 62% of total phosphorus inputs to the basin.
— Natural background loads are the most import total phosphorus source to Bothnian Bay (52%), because of low intensity of agriculture and low population density. For Archipelago, Baltic Proper, Gulf of Riga and The Sound natural background loads constitute only 9 to 11% of total phosphorus inputs to these sub-basins, for the remaining basins the share is between 17 and 36%.
— For Bothnian Sea, where the size of the sea area is as much as 1/3 compared with the catchment area, atmospheric deposition is rather important (21%). For the other basins the shares are between 3% (Gulf of Finland) and 9% (Western Baltic).
— Input from point sources (indirect plus direct) are the most important source to the Sound (47%) due to very high population density and much industrial activity. Further to Baltic Proper (21%) and Gulf of Finland (21%) the importance of inputs from point sources are rather high, also reflecting rather high population density and industrial activity in the catchments. For the remaining sub-basins inputs from point sources constitutes only between 4% (Gulf of Riga) and 13% (Kattegat) of total phosphorus inputs.

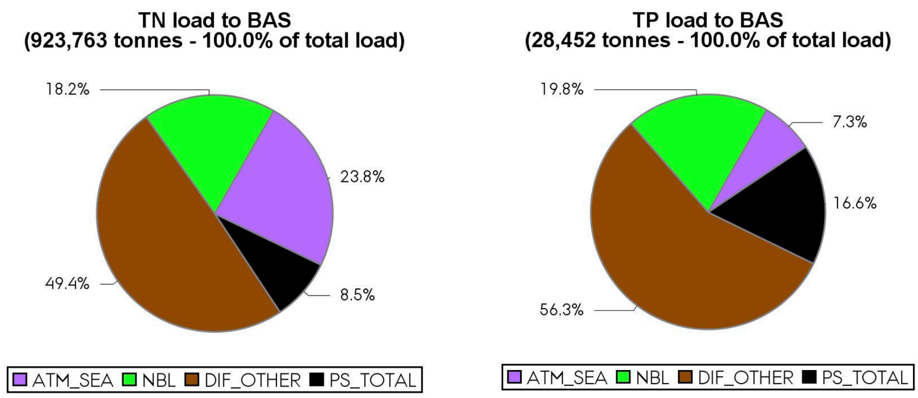


Figure 4.4. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background losses and for some countries including upstream transboundary inputs (DIF-other), and indirect and direct point sources (PS_TOTAL) of total nitrogen (TN - left column) and total phosphorus (TP - right column) to the Baltic Sea by basins in 2017 (Polish data from 2018). Total inputs to the basin (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.4 is in tables 2.3 and 2.4.

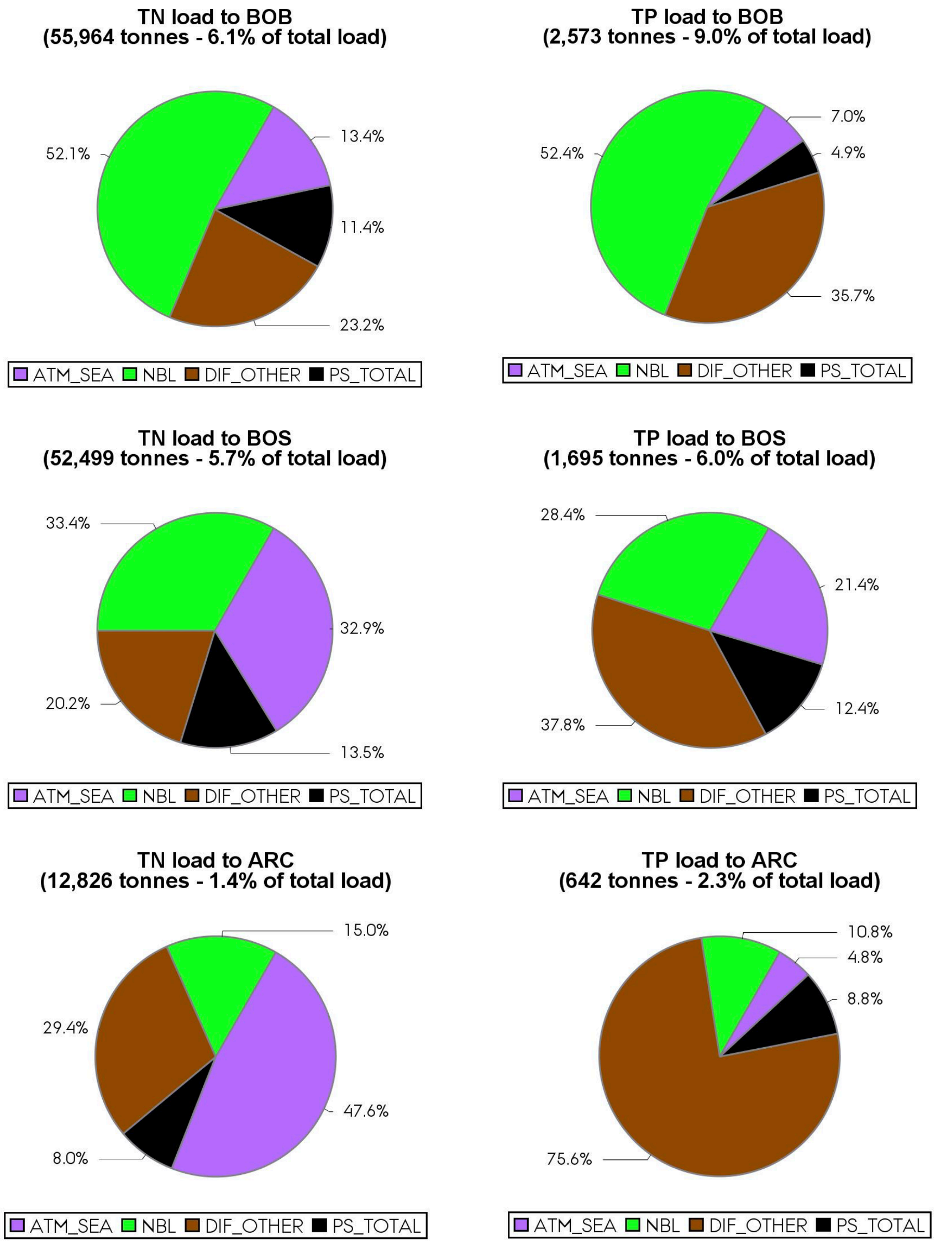


Figure 4.4. Continued. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background losses and for some countries including upstream transboundary inputs (DIF-other), and indirect and direct point sources (PS_TOTAL) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea by basins in 2017 (Polish data from 2018). Total inputs to the basin (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.4 is in tables 2.3 and 2.4.

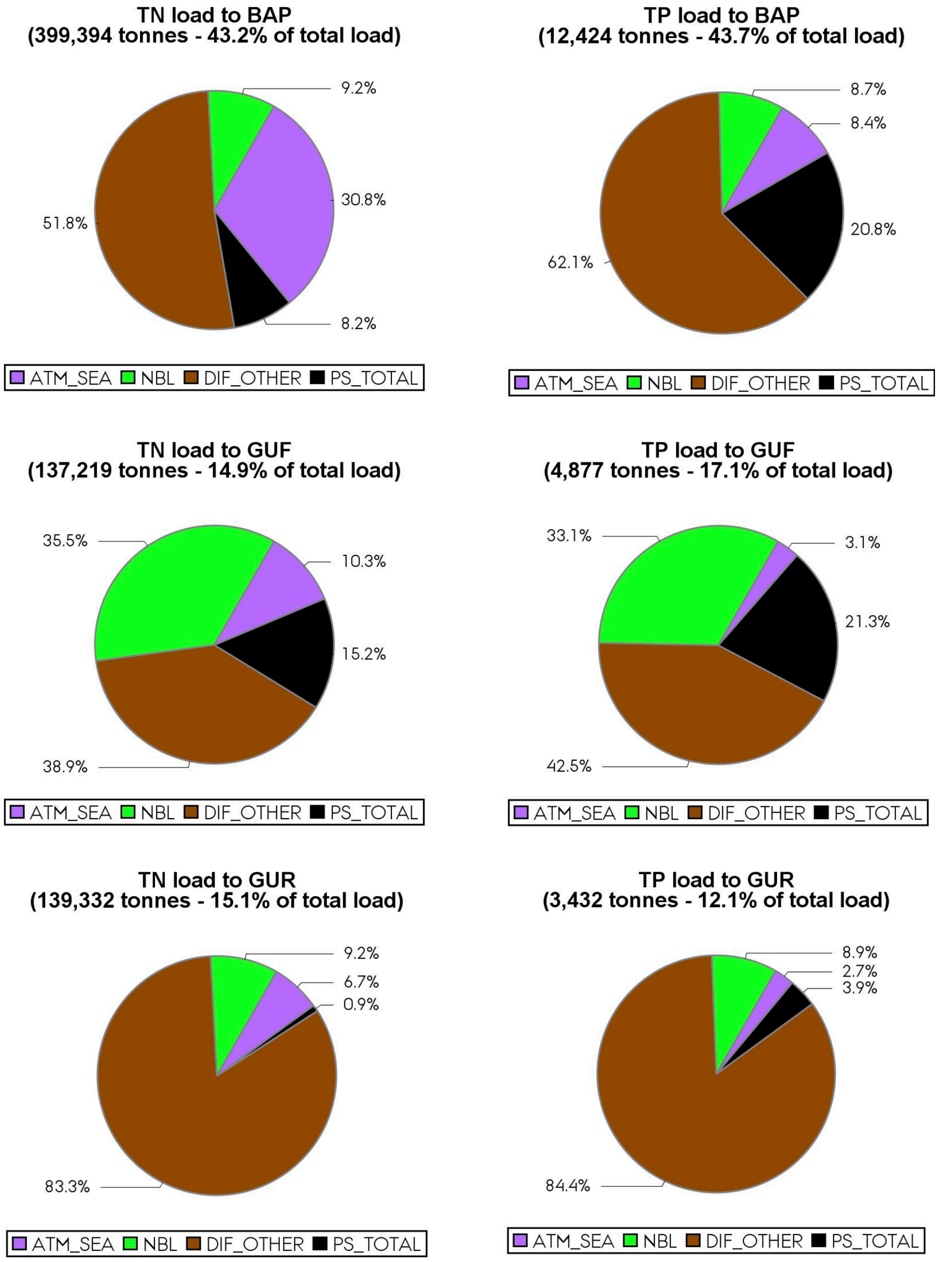


Figure 4.4. Continued. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background losses and for some countries including upstream transboundary inputs (DIF-other), and indirect and direct point sources (PS_TOTAL) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea by basins in 2017 (Polish data from 2018). Total inputs to the basin (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.4 is in tables 2.3 and 2.4.

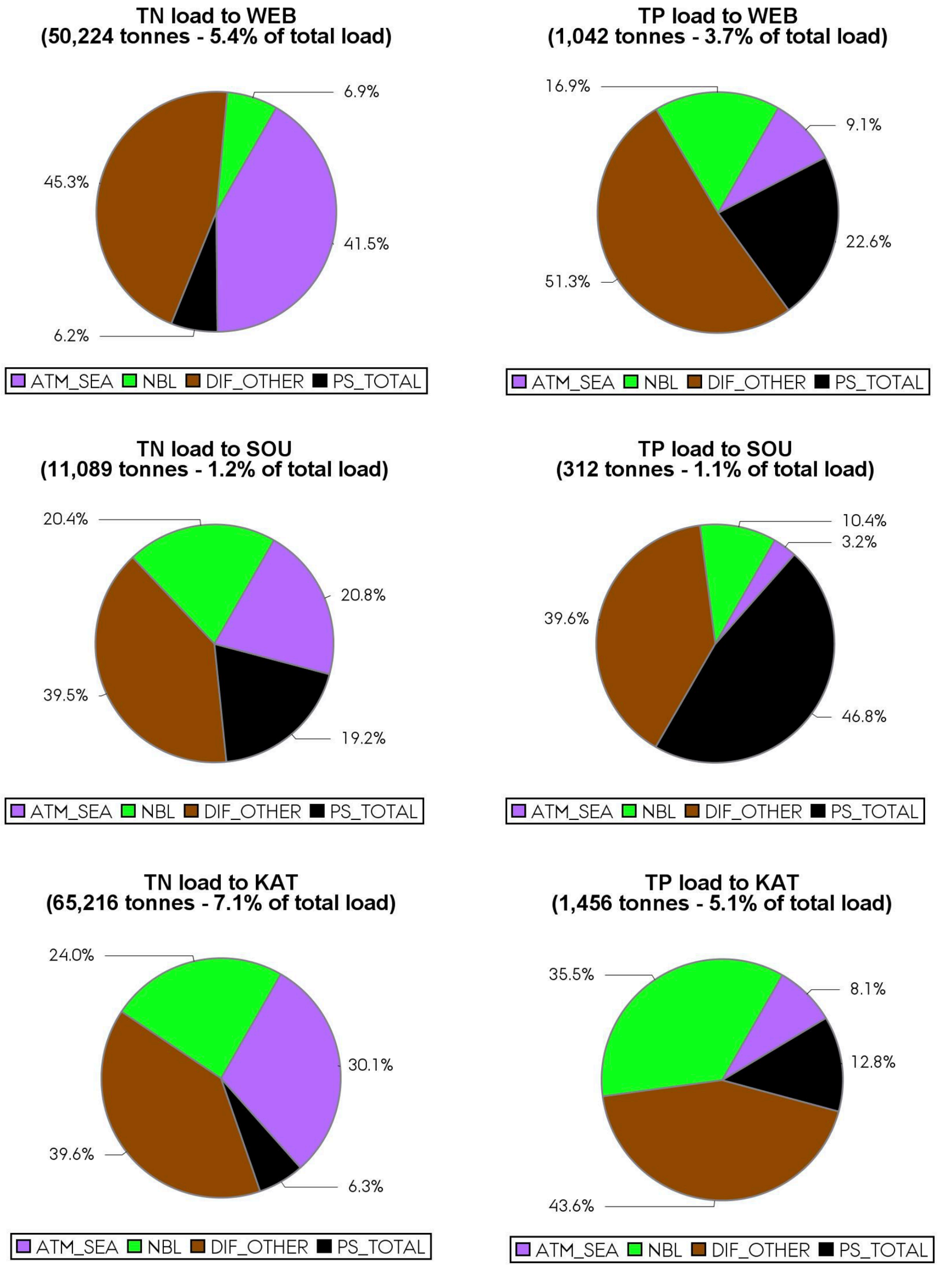


Figure 4.4. Continued. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background losses and for some countries including upstream transboundary inputs (DIF-other), and indirect and direct point sources (PS_TOTAL) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea by basins in 2017 (Polish data from 2018). Total inputs to the basin (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.4 is in tables 2.3 and 2.4.

Main findings for total nitrogen by countries (table 2.3 and figure 4.5):

- Diffuse other sources are the most importance source for six countries constituting between 43 and 92 % of total nitrogen inputs to the Baltic Sea. Only for Russia (37%) and Sweden (48%) natural background loads are the most important source, and for Germany it is atmospheric deposition with a share of 65% (due to Germany's big catchment area for emission of nitrogen ending up as atmospheric nitrogen deposition on the Baltic Sea).
- Natural background loads from Finland have also a considerable share (36%) of total nitrogen inputs to the Baltic Sea.
- Atmospheric nitrogen deposition on the Baltic Sea is the most import source for Germany (65%), but also important for Denmark (27%) and Poland (20%) reflecting also that these countries are situated south and southwest to the Baltic Sea (and the dominating wind direction is from southwest/west), have rather large areas with intensive agriculture and Germany has a big catchment area for emission of nitrogen. Russia has a big catchment area but due to dominant wind direction being westerly importance of atmospheric deposition is only about 11%. Shipping and non-HELCOM countries contribute with nearly 10 % of total nitrogen inputs to the Baltic Sea
- Shares of total nitrogen inputs from point sources are between 13 and 17% from Finland, Poland, Russia, and Sweden, and less than 6% for the remaining countries.

Main findings for total phosphorus by countries (table 2.4 and figure 4.5):

- Atmospheric phosphorus deposition constitutes more than 7% of total phosphorus inputs to the Baltic Sea but we cannot allocate it by countries (sources of atmospheric deposition are not quantified).
- Diffuse other sources are the most important source for seven countries constituting between 44 and 90 % of total phosphorus inputs to the Baltic Sea. Only for Russia (36%) and Sweden (51%) natural background loads are the most important source.
- Natural background load has also a considerable share for Denmark (31%), Estonia (35%) and Finland (28%), but is very low for Poland (5%), Latvia (6%) and Germany (11%). The reasons for Latvia and Germany are explained under total nitrogen, and for Poland it can be related to very dry (low flow) conditions in 2018.
- Shares of total phosphorus inputs from point sources are high – between 20-29% - for Denmark, Germany, Poland, and Russia, and very low for both Estonia and Latvia (about 4%) – see also under total nitrogen for an explanation of the reasons.

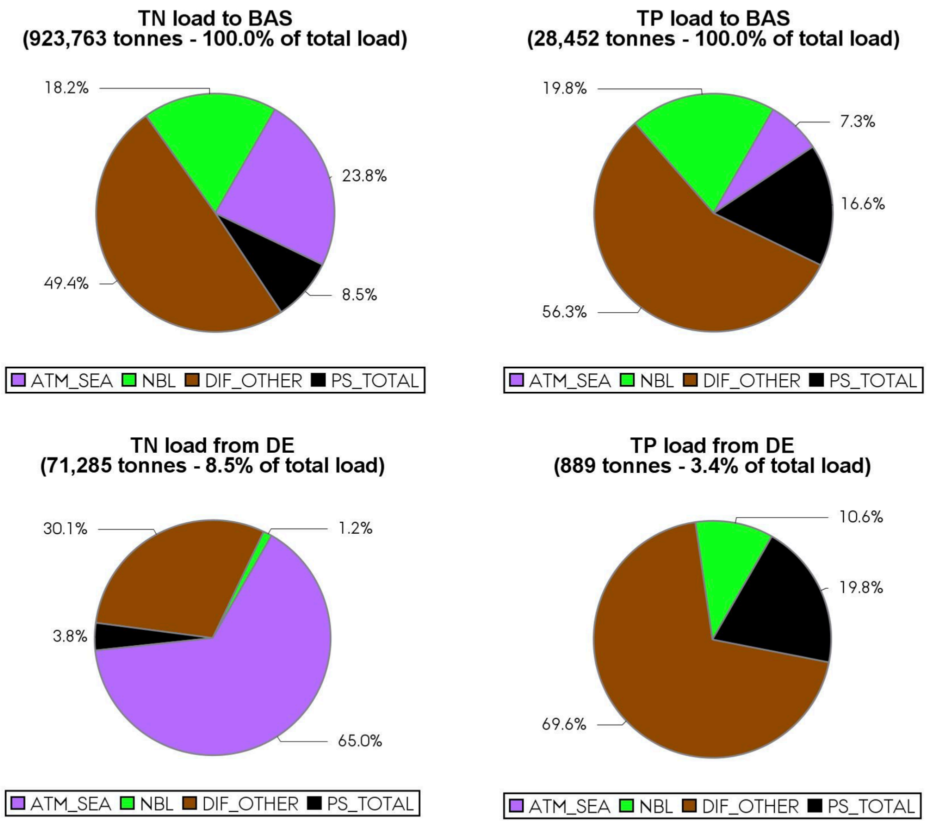


Figure 4.5. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background loads including upstream transboundary inputs (DIF-other) for some countries, and indirect and direct point sources (PS-TOTAL) of total nitrogen (TN - left column) and total phosphorus (TP -right column) to the Baltic Sea by countries in 2017 (Polish data from 2018). Total inputs by countries (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.5 is in tables 2.5 and 2.6.

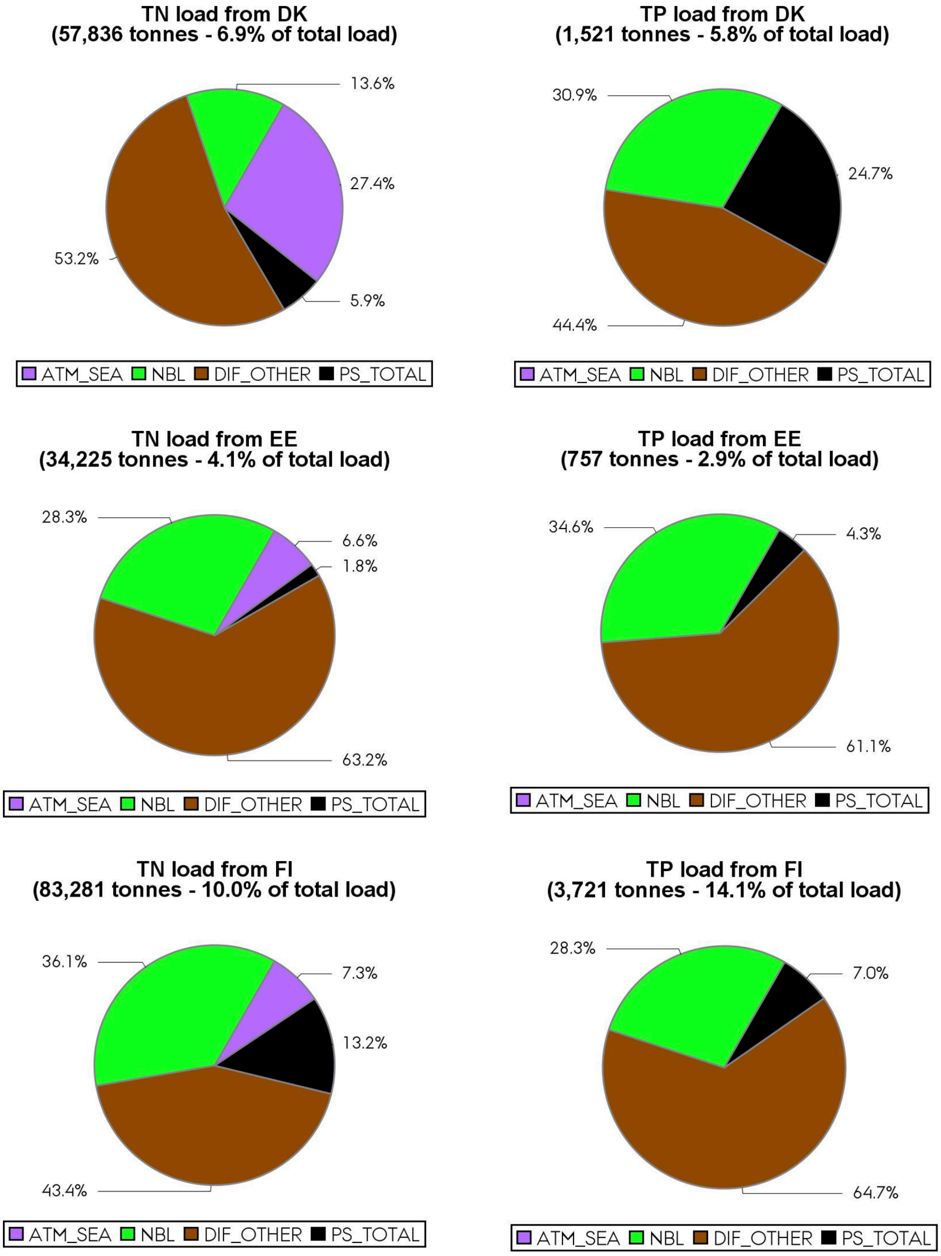


Figure 4.5. Continued. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background loads including upstream trans-boundary inputs (DIF-other) for some countries, and indirect and direct point sources (PS-TOTAL) of total nitrogen (TN - left column) and total phosphorus (TP -right column) to the Baltic Sea by countries in 2017 (Polish data from 2018). Total inputs by countries (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.5 is in tables 2.5 and 2.6.

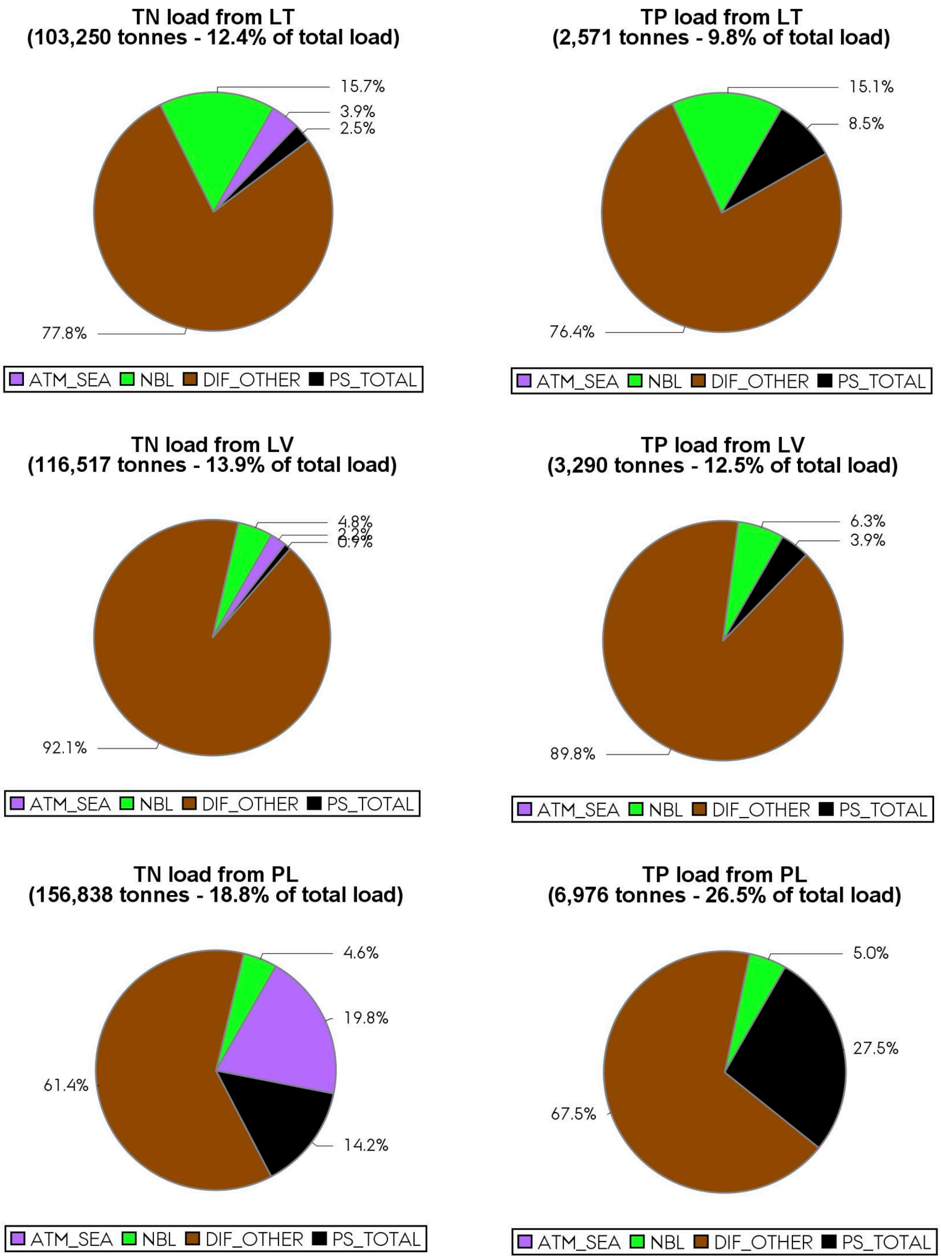


Figure 4.5. Continued. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background loads including upstream trans-boundary inputs (DIF-other) for some countries, and indirect and direct point sources (PS-TOTAL) of total nitrogen (TN - left column) and total phosphorus (TP -right column) to the Baltic Sea by countries in 2017 (Polish data from 2018). Total inputs by countries (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.5 is in tables 2.5 and 2.6.

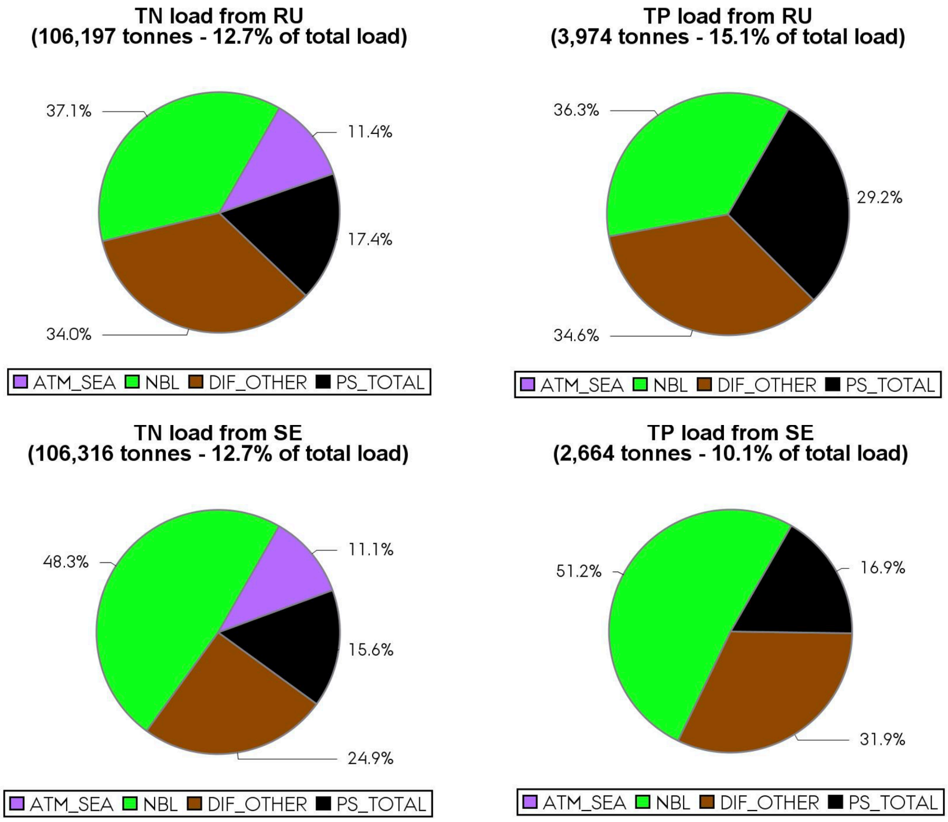


Figure 4.5. Continued. Shares (in percentages) for 4 main sources categories: atmospheric deposition on the sea (ATM-SEA); natural background loads (NBL); load from other diffuse sources than natural background loads including upstream trans-boundary inputs (DIF-other) for some countries, and indirect and direct point sources (PS-TOTAL) of total nitrogen (TN – left column) and total phosphorus (TP –right column) to the Baltic Sea by countries in 2017 (Polish data from 2018). Total inputs by countries (in tonnes) are indicated in the header as is the share (in percentages) of this input of the corresponding total input to the Baltic Sea. Data behind figure 4.5 is in tables 2.5 and 2.6.

We have also assessed the four main sources on a country to sub-basin scale, some few examples are shown in figure 4.6. In chapter 9 (Annex 10) it is described where to find all pie plots by basin, by country and country by basin for the four main sources to the sea.

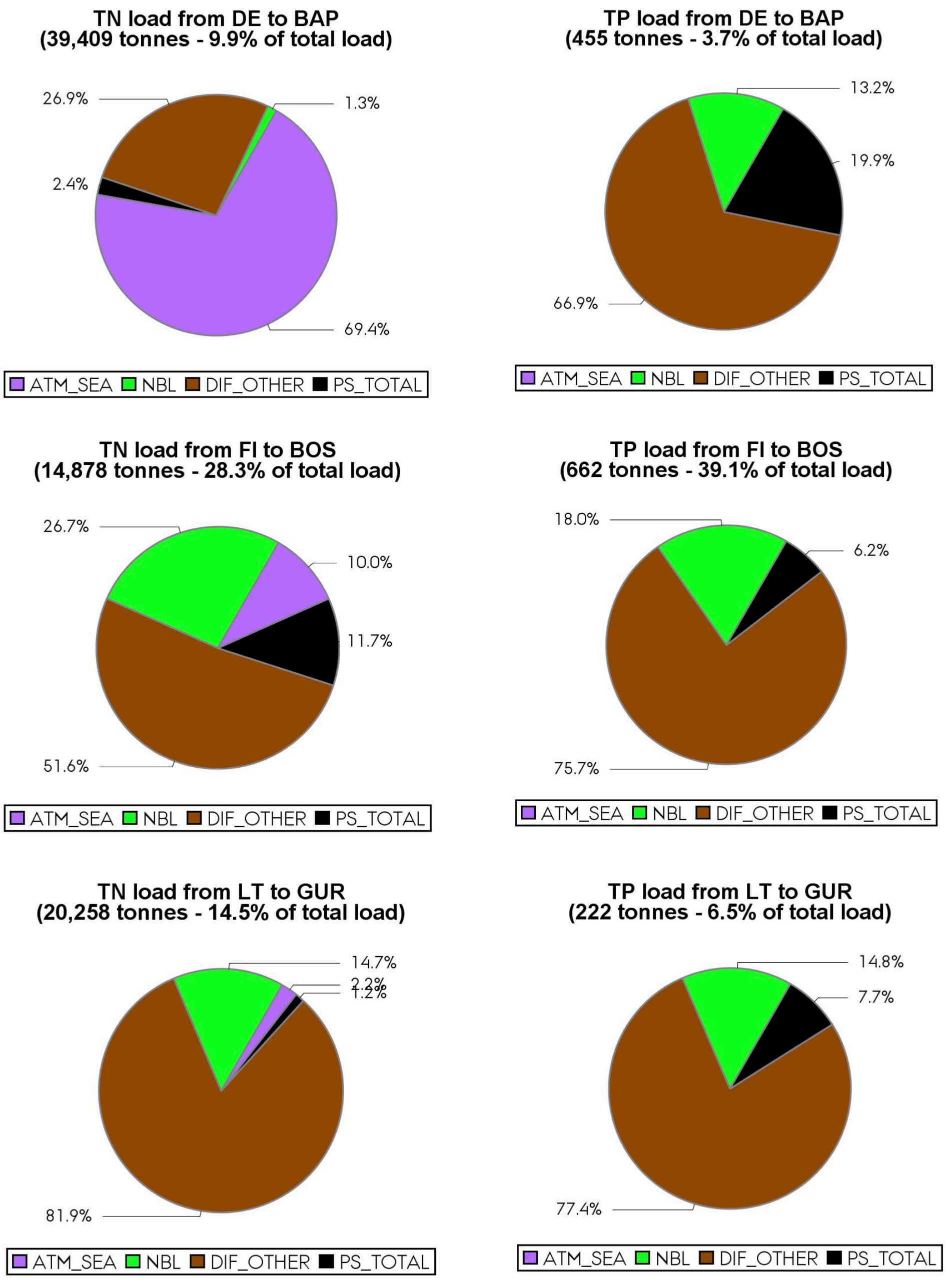


Figure 4.6. Shares (in percentages) for four main sources: ATM-SEA = atmospheric deposition om the sea; NBL = natural background loads, Dif_other = other diffuse sources, and PS-Total = inputs from indirect and direct point sources of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea from Germany for Baltic Proper, Finland to Bothnian Sea and Lithuania to Gulf of Riga in 2017. Total inputs from a country (in tonnes) to the sub-basin are indicated in the header as is the share (in percentages) of this input of the total inputs to the sub-basin. Atmospheric phosphorus deposition is zero, as it cannot be allocated between countries.

4.3. Riverine inputs divided in natural background loads, load from other diffuse sources, and indirect point sources loads

In this sub-chapter we assess sources of riverine total nitrogen and total phosphorus inputs by sub-basin, by country, country by basin and for all monitored river catchments with the load-oriented approach for three sources categories that all countries were able to provide:

- Natural background load (NBL)
- Sum of load from all other diffuse sources (Dif-other)
- Point sources discharging into inland waters, also called indirect point source (PS_indir)

In chapter 9 (Annex 3) it is described where to find all pie charts by basin, by country and country by basin, and some few examples of country by basin are shown in figure 4.7. Data behind by basin and by country is in tables 4.5.

Main findings for total nitrogen and total phosphorus (table 4.5 and figure 4.7):

- Diffuse other sources are the most important total riverine nitrogen source to the Baltic Sea (68%) followed by natural background load (25%) and indirect point sources (7%). The corresponding shares for total phosphorus are diffuse other sources 64%, natural background loads 23% and indirect point sources 13%.
- Diffuse other sources are the most important nitrogen riverine source (shares between 47 to 90%) to seven sub-basins, only to Bothnian Bay and Bothnian Sea (with shares ranging between 29 and 33%) natural background loads are the most important source, with 55-65% of riverine total nitrogen load. For phosphorus, diffuse other sources are the most important source to eight basins (shares between 51 to 88%). Only to Bothnian Bay natural background load is the biggest source (59%) of total riverine phosphorus inputs.
- Natural background loads constitute more than 30% of total riverine nitrogen inputs to all sub-basins except Baltic Proper, Gulf of Riga (lowest share: 10%) and Western Baltic, and for total phosphorus also to Archipelago, and the Sound, with Gulf of Riga with lowest share (9%).
- The share of indirect point sources of total nitrogen riverine inputs is less than 10% except to Bothnian Bay (12%) and Baltic Proper (10%). For total phosphorus Baltic Proper (21%), Gulf of Finland (13%) and Western Baltic (15%) have the highest share of indirect point source load of riverine input – which are also the most populated areas of the catchment to the Baltic Sea.
- For the countries the importance of sources described above are overall the same. Northern and eastern part of the Baltic Sea catchment area have high shares of natural background loads, and to the south and south-west diffuse other loads are the most important source of riverine total nitrogen and total phosphorus inputs.
- Figure 4.7 illustrates the variability of the three sources of riverine nitrogen and phosphorus loads between basins and countries.

Table 4.5. Shares (in percentages) for main sources of riverine inputs total nitrogen (TN) and total phosphorus (TP) in tonnes to the Baltic Sea by basin (upper part of the table) and by country (lower part of the table) in 2017 (Polish data from 2018). The columns "Total %" indicates the share of the total nitrogen and total phosphorus inputs, respectively of inputs to the basin or from the country of the corresponding total inputs to the Baltic Sea. NBL = natural background loads, Dif-other = other diffuse loads inputs than natural background and Point sour. = point source loads to inland surface waters (indirect point sources).

Basin/ Country	TN Indir NBL %	TN Indir Dif-other %	TN Indir Point sour. %	TN Indir Total tons	TN Total of total TN %	TP Indir NBL %	TP Indir Dif-other %	TP Indir Point sour. %	TP Indir Total tons	TP Total of total TP %
Bothnian Bay	64.9	28.9	6.2	44,901	6.7	58.6	39.9	1.5	2,302	9.2
Bothnian Sea	55.1	33.3	11.6	31,847	4.7	40.8	54.3	4.9	1,179	4.7
Archipelago	33.5	65.9	0.6	5,732	0.8	12.5	87.2	0.3	557	2.2
Baltic Proper	13.5	76.2	10.3	271,355	40.2	9.7	69.0	21.3	11,180	44.7
Gulf of Finland	43.1	47.2	9.7	113,215	16.8	38.0	48.8	13.2	4,249	17.0
Gulf of Riga	9.9	89.5	0.6	129,617	19.2	9.3	87.9	2.8	3,297	13.2
Western Baltic	12.5	82.0	5.5	27,753	4.1	21.1	64.0	14.9	836	3.3
Sound	32.4	62.7	4.8	6,985	1.0	19.1	72.7	8.2	170	0.7
Kattegat	35.8	59.1	5.1	43,657	6.5	41.7	51.3	7.0	1,239	5.0
Denmark	19.8	77.5	2.7	39,679	5.9	37.0	53.1	9.9	1,271	5.1
Estonia	30.8	68.8	0.4	31,460	4.7	35.9	63.4	0.6	729	2.9
Finland	41.9	50.5	7.6	71,651	10.6	29.7	67.9	2.4	3,543	14.2
Germany	3.5	89.0	7.5	24,071	3.6	10.9	71.9	17.2	861	3.4
Lithuania	16.4	81.2	2.4	99,025	14.7	15.2	76.8	8.0	2,557	10.2
Latvia	4.9	94.6	0.5	113,524	16.8	6.4	91.0	2.6	3,248	13.0
Poland	5.7	76.9	17.4	125,230	18.6	5.0	68.0	26.9	6,926	27.7
Russia	46.0	42.1	11.9	85,777	12.7	40.5	38.6	21.0	3,562	14.2
Sweden	60.7	31.3	8.0	84,646	12.5	59.0	36.8	4.1	2,310	9.2
Baltic Sea	**24.9**	**67.6**	**7.4**	**675,063**	**100**	**22.5**	**64.1**	**13.4**	**25,007**	**100**

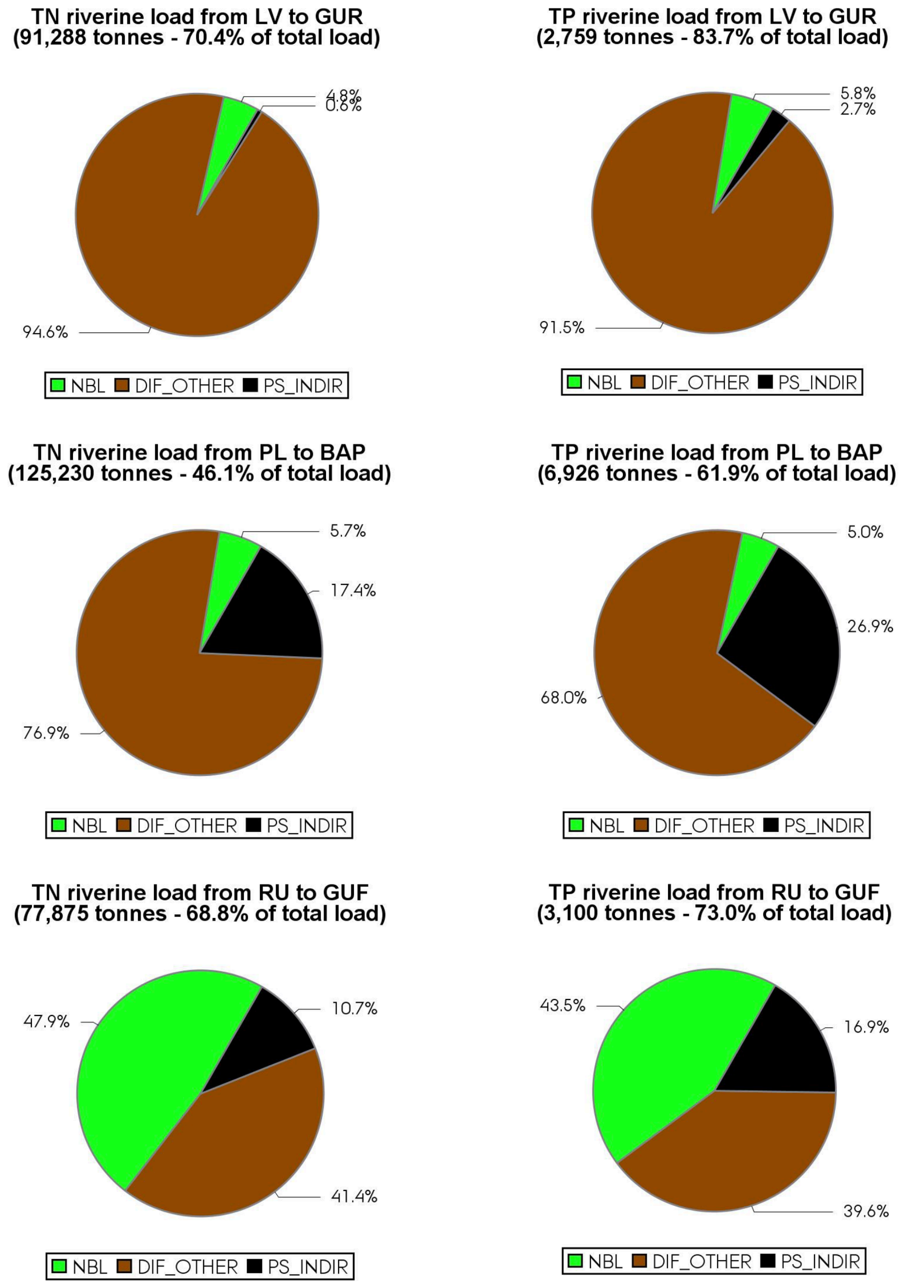


Figure 4.7. Shares (in percentages) for main sources of riverine inputs: NBL = natural background load, Diff-other = other diffuse loads inputs than natural background and PS_indir = load from inland point sources (indirect point sources) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea from Latvia to Gulf of Riga, Poland to Baltic Proper and Russia to Gulf of Finland in 2017 (Poland 2018). Total inputs from a country (in tonnes) to a basin are indicated in the header as is the share (in percentages) of this input of the total input to the basin.

Load oriented approach is applied on all monitored rivers and to illustrate the variation in the importance of the three sources for total nitrogen and total phosphorus inputs to inland waters within catchments to Baltic Sea sub-catchments. The results are presented as Box-Whisker plots and in chapter 9 (annex 1) is explained where to find all Box-Whisker plot. Some examples are in figure 4.8. It is explained in chapter 9.2 how to interpret a Box-Whisker plot but e.g., for Denmark to Western Baltic in 73 monitored rivers (tables 1.6) the share of natural background loads (NBL) of total nitrogen ranges from minimum of nearly 10% to maximum of 54

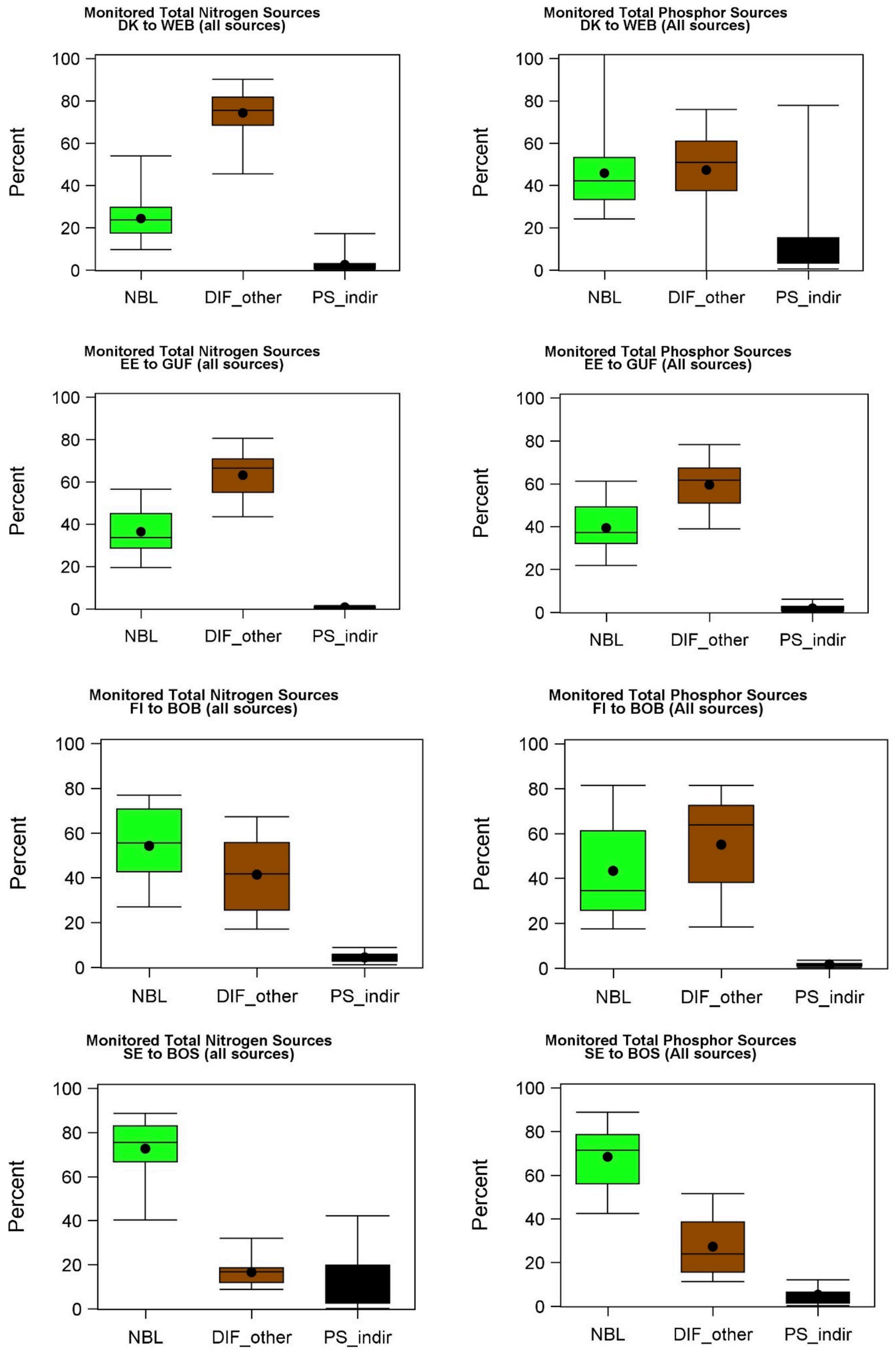


Figure 4.8. Box-Whisker plots of the share (percentages) for three sources of riverine inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers in Danish catchment to Western Baltic, Estonian catchment to Gulf of Finland, Finnish catchment to Bothnian Bay and Swedish catchment to Bothnian Sea in 2017. The sources are: NBL = natural background loads, Diff-other = other diffuse loads inputs than natural background and PS_indir = load from inland point sources surface waters (indirect point sources). See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

%, the median and average for the 73 rivers are 23.7% and 24.4%, respectively and the 25 % percental is 17.5% and the 75 % percentile is 29.7%, and for phosphorus the variation is even higher. Average and median indicates the overall importance of the source in a catchment while maximum, minimum values together with the 25% and 75% percentile indicates the variation in the share of a source in a catchment.

4.4. Atmospheric deposition on inland surface waters, natural background load, agricultural load, sum of other diffuse sources, and indirect point sources

In this sub-chapter we assess sources of riverine total nitrogen and total phosphorus inputs by sub-basin, by country, country by basin and for all monitored rivers catchment with the load-oriented approach for up to five sources categories:

— Atmospheric deposition on inland surface water (ATL)
— Natural background load (NBL)
— Agricultural load (AGL)
— Sum of load from other diffuse sources (Dif-other)
— Point sources discharging into inland waters, also called indirect source (PS_indr)

While "Dif_other" in sub-chapter 4.3 included all diffuse sources except natural background loads in this chapter load from atmospheric deposition on inland surface waters, and from agriculture are estimated separately by most countries. For many countries "Diff-other" in this sub-chapter is load from scattered dwellings and storm waters, but e.g. Sweden and Finland include managed forestry in this category and Latvia and Lithuania include transboundary inputs from upstream countries. Latvia, Lithuania, and Russia have not estimated ATL separately, it is included in Dif-other. Latvia has not quantified agricultural inputs separately, and this source is included in Latvia Dif_other sources. Therefore, it is not possible to estimate the shares of the sources on the Baltic Sea level.

In chapter 9 (annex 12) it is explained where all pie charts by basin, by country and country by basin are available, and some few examples of country by basin are shown in figure 4.9. Data behind by sub-basin and by country is in tables 4.6 (total nitrogen and) and 4.7 (total phosphorus).

Table 4.6. Shares (in percentages) for sources of riverine inputs total nitrogen (TN in tonnes) to the Baltic Sea by basin (upper part of the table) and by country (lower part of the table) in 2017 (Polish data from 2018). The columns "Total %" indicates the share of the total nitrogen inputs to the basin or from the country of the corresponding total inputs to the Baltic Sea. ATL = atmospheric deposition on inland surface waters, NBL = natural background load, AGL= agricultural load, Dif-other = other diffuse loads inputs than natural background load, Point sourc. = point source load to inland surface waters (indirect point sources).

Basin/ Country	TN Indir ATL %	TN Indir NBL %	TN Indir AGL %	TN Indir Dif-other %	TN Indir Point sour. %	TN Indir Total tons	TN Total of total %
Bothnian Bay	4.1	64.9	20.1	4.7	6.2	44,901	6.7
Bothnian Sea	4.5	55.1	23.7	5.1	11.6	31,847	4.7
Archipelago	1.0	33.5	59.0	5.8	0.6	5,732	0.8
Baltic Proper	1.7	13.5	54.5	20.0	10.3	271,355	40.2
Gulf of Finland	3.2	43.1	19.3	24.7	9.7	113,215	16.8
Gulf of Riga	1.9	9.9	18.6	69.0	0.6	129,617	19.2
Western Baltic	2.2	12.5	76.6	3.2	5.5	27,753	4.1
The Sound	0.6	32.4	57.0	5.1	4.8	6,985	1.0
Kattegat	5.0	35.8	51.3	2.8	5.1	43,657	6.5
Denmark	1.0	19.8	73.9	2.6	2.7	39,679	5.9
Estonia	9.3	30.8	58.9	0.5	0.4	31,460	4.7
Finland	7.4	41.9	37.3	5.7	7.6	71,651	10.6
Germany	8.2	3.5	77.0	3.8	7.5	24,071	3.6
Lithuania	0.0	16.4	54.8	26.4	2.4	99,025	14.7
Latvia	0.0	4.9	0.0	94.6	0.5	113,524	16.8
Poland	2.1	5.7	67.8	7.0	17.4	125,230	18.6
Russia	0.0	46.0	11.2	30.9	11.9	85,777	12.7
Sweden	4.5	60.7	23.0	3.8	8.0	84,646	12.5
Baltic Sea						**675,063**	**100**

The main finding from tables 4.6 and 4.7 and figure 4.10:

- For total nitrogen: Agricultural loads are the biggest source of riverine loads to Western Baltic (77%), Archipelago (59%), The Sound (57%), Baltic Proper (55%) and Kattegat (51%). Natural background loads are the most important source to Bothnian Bay (64%), Bothnian Sea (55%) and Gulf of Finland (38%). Diff-other is the most important source to Gulf of Riga (69%), but Latvia includes agricultural loads in this source.
- For total phosphorus: Agricultural loads are the biggest source of riverine loads to Archipelago (77%), Baltic Proper (49%) and Western Baltic (38%). Natural background loads are the most important source to Bothnian Bay (59%), Kattegat (42%), Bothnian Sea (41%) and Gulf of Finland (43%). Diff-other is the most important source to Gulf of Riga (79%) and The Sound (54%), but Latvia includes agricultural loads in this source, while to The Sound it is load from scattered dwellings and storm waters that are important sources.
- For indirect point sources the shares for both total nitrogen and total phosphorus are as described for table 4.5 in chapter 4.3
- Atmospheric total nitrogen and total phosphorus loads on inland surface waters constitute only a minor proportion of the corresponding riverine inputs to the Baltic Sea sub-basins, between 0.6 to 5.0% for nitrogen and 0.1 to 3.3% for phosphorus with highest shares in the catchment to Bothnian Bay and Bothnian Sea, where other anthropogenic sources are not very important, and with a lot of lake surface, and to Kattegat for total phosphorus (rather high proportion of lake surface).

In figure 4.10 are shown four examples of country per basins Box-Whisker plots for the share of the five sources of riverine total nitrogen and total phosphorus loads in monitored rivers in the respective catchments. In chapter 9 (annex 1) it is indicated where all these plots are available.

There is also big variation in the proportion of the individual sources of riverine total nitrogen and total phosphorus inputs between rivers within the catchment to a Baltic Sea sub-basin as shown in figure 4.10. For the 14 rivers in the Danish catchment to the Sound (see table 1.6) agricultural loads have a share between nearly zero up to nearly 90% for both total nitrogen and total phosphorus of the riverine inputs, and for diffuse_other loads (scattered dwellings and storm water effluents) for total phosphorus the share ranges from 5 to 100%.

Table 4.7. As table 4.6 but for total phosphorus (TP).

Basin/ Country	TP Indir ATL %	TP Indir NBL %	TP Indir AGL %	TP Indir Dif-other %	TP Indir Point sour. %	TP Indir Total tons	TP Total of total %
Bothnian Bay	3.3	58.6	26.5	10.0	1.5	2,302	9.2
Bothnian Sea	2.8	40.8	40.5	10.9	4.9	1,179	4.7
Archipelago	0.3	12.5	76.9	10.0	0.3	557	2.2
Baltic Proper	0.9	9.7	49.3	18.8	21.3	11,180	44.7
Gulf of Finland	1.1	38.0	28.1	19.6	13.2	4,249	17.0
Gulf of Riga	0.3	9.3	9.0	78.6	2.8	3,297	13.2
Western Baltic	1.2	21.1	38.3	24.5	14.9	836	3.3
Sound	0.1	19.1	18.8	53.7	8.2	170	0.7
Kattegat	1.2	41.7	35.4	14.7	7.0	1,239	5.0
Denmark	0.2	37.0	29.5	23.5	9.9	1,271	5.1
Estonia	3.2	35.9	59.6	0.7	0.6	729	2.9
Finland	2.5	29.7	52.7	12.7	2.4	3,543	14.2
Germany	4.4	10.9	45.6	21.9	17.2	861	3.4
Lithuania	0.0	15.2	33.7	43.2	8.0	2,557	10.2
Latvia	0.0	6.4	0.0	91.0	2.6	3,248	13.0
Poland	1.0	5.0	60.9	6.2	26.9	6,926	27.7
Russia	0.0	40.5	18.4	20.2	21.0	3,562	14.2
Sweden	3.3	59.0	21.7	11.8	4.1	2,310	9.2
Baltic Sea						**2,507**	**100**

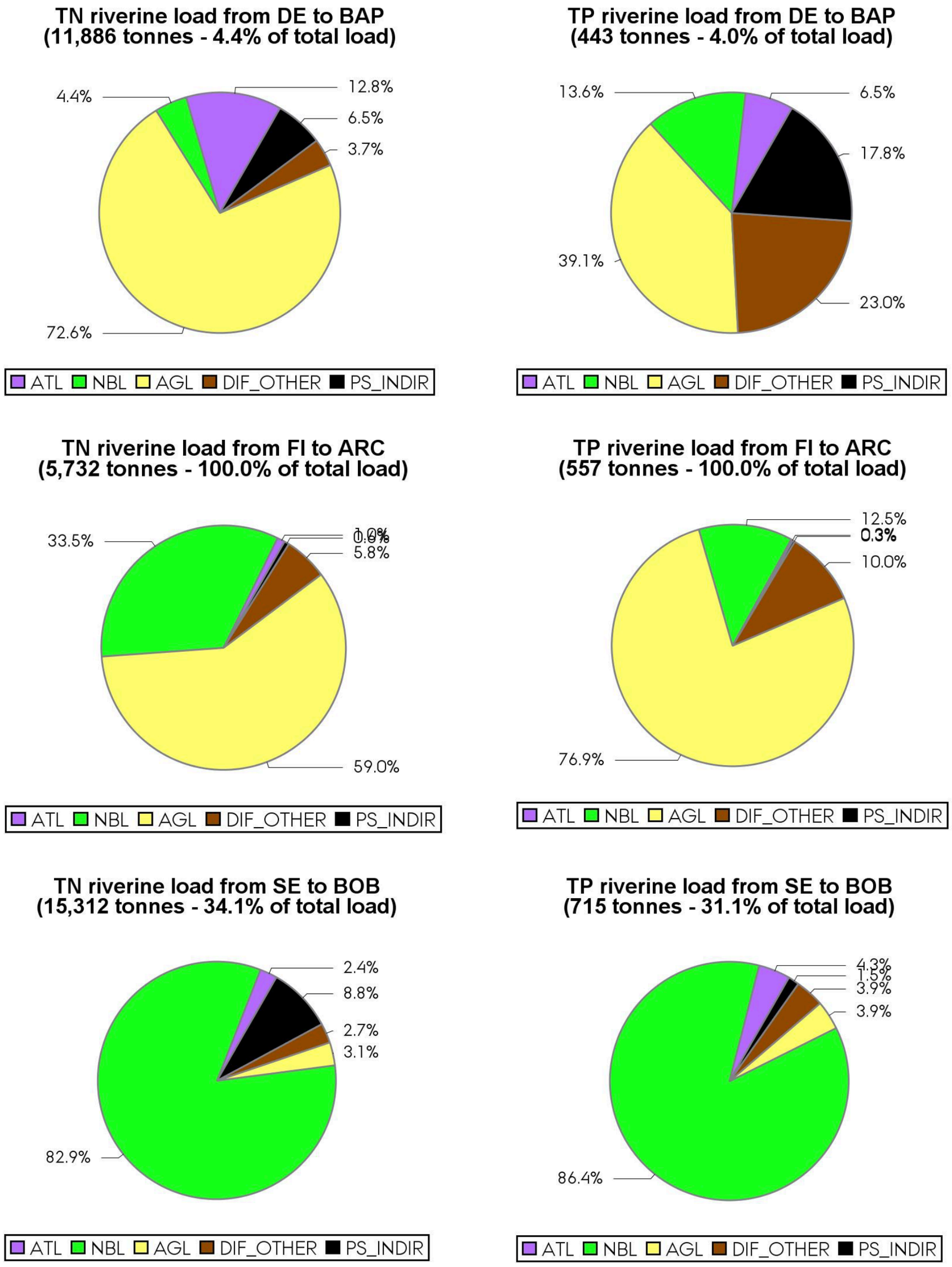


Figure 4.7. Shares (in percentages) for main sources of riverine inputs: NBL = natural background load, agricultural load (AGL), Diff-other = other diffuse loads inputs than natural background and PS_indir = load from inland point sources (indirect point sources) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea from Germany to Baltic Proper, Finland to Archipelago Sea and Sweden to Bothnian Bay. Total inputs from a country (in tonnes) to a basin are indicated in the header as is the share (in percentages) of this input of the total input to the basin.

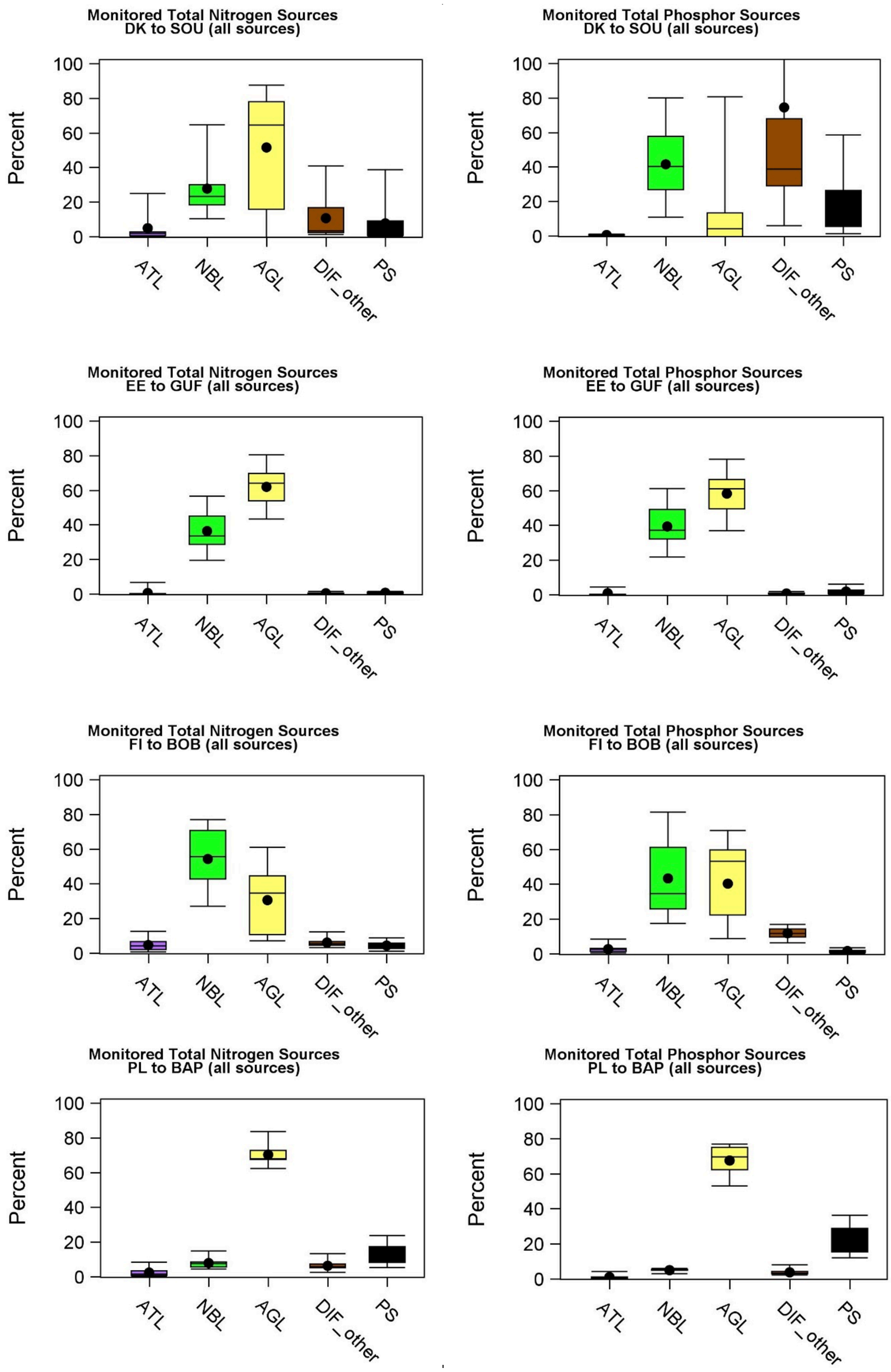


Figure 4.10. Box-Whisker plot of the share (percentages) for five sources of riverine inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers in Danish catchment to the Sound, Estonian catchment to Gulf of Finland, Finnish catchment to Bothnian Bay and Polish catchment to Baltic Proper in 2017 (Poland 2018). The sources are: ATL = atmospheric deposition on inland surface waters, NBL = natural background load, AGL= agricultural load, Diff-other = other diffuse loads than natural background, PS = point source load to inland surface waters (indirect point sources). See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

4.5. Inland diffuse sources load: atmospheric deposition on surface waters, natural background load, agricultural load, managed forestry, sum of other diffuse sources, scattered dwelling load, and storm water loads

In this sub-chapter we assess sources of diffuse riverine total nitrogen and total phosphorus inputs by sub-basin, by country, country by basin and for all monitored rivers catchments with the load-oriented approach for up to seven source categories:

— Atmospheric deposition on inland surface water (ATL)
— Natural background load (NBL)
— Agricultural load (AGL)
— Managed forestry load (MFL)
— Sum of load from other diffuse sources (Dif-other)
— Scattered dwellings
— Storm water effluents

Latvia, Lithuania, and Russia do not quantify atmospheric deposition on inland surface waters separately, it is included in Dif_other. Estonia, Finland, Poland and Sweden have quantified managed forestry separately. Some countries such as Denmark and Germany include managed forestry under agriculture. Latvia includes this source under Dif-other together with agriculture, as this in not quantified separately. In this sub-chapter transboundary inputs to Latvia are not included under Dif_other sources. Estonia, Latvia. Lithuania and Russia have not quantified inputs from scattered dwellings or storm water effluents separately but includes these sources under Dif-other. Therefore, only sources from Denmark, Germany, Poland, Finland, and Sweden are directly comparable.

In chapter 9 (annex 13) is indicated where all pie charts by basin, by country and country by basin (annex 13) are available, and below are some few examples of country by basin shown in figure 4.11. Data behind by basin and by country is in tables 4.8 (total nitrogen) and 4.9 (total phosphorus).

The main findings from tables 4.8 and 4.9 and figure 4.10:

— The main differences to chapter 4.4 are that indirect point source load is not included, loads from scattered dwellings and from storms waters are shown separately from diffuse other sources (except for Estonia, Latvia, Lithuania, and Russia), and loads for managed forestry are separated from agriculture in Estonia, Finland, Poland, and Sweden. Compared with tables 4.6 and 4.7 this increases the shares of natural background loads, agricultural loads and atmospheric loads onto inland surface waters but reduces the shares of diffuse other loads.

Table 4.8. Shares (in percentages) for sources of riverine diffuse inputs of total nitrogen (TN, tonnes) to the Baltic Sea by basin (upper part of the table) and by country (lower part of the table) in 2017 (Polish data from 2018). The columns "Total %" indicates the share of the total nitrogen inputs to the basin or from the country of the corresponding total diffuse riverine inputs to the Baltic Sea. ATL = atmospheric deposition on inland surface waters, NBL = natural background load, AGL= agricultural load, MFL = managed forestry, Dif-other = other diffuse loads (without transboundary inputs), SCL scattered dwelling load, SWL = storm water loads. "-" not quantified, the source included in Dif-other, besides for Denmark and Germany where MFL is included in AGL.

Basin/ Country	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN
	ATL %	NBL %	AGL %	MFL %	Dif-other without TRL %	SCL %	SWL %	Total tons	Total of total %
Bothnian Bay	4.4	69.2	21.4	3.5	0.0	1.4	0.1	42,104	7.5
Bothnian Sea	5.1	62.3	26.8	3.1	0.0	2.4	0.2	28,150	5.0
Archipelago	1.0	33.7	59.4	2.0	0.0	3.4	0.4	5,696	1.0
Baltic Proper	2.2	16.9	68.2	1.0	7.4	2.8	1.5	216,861	38.8
Gulf of Finland	3.6	47.7	21.3	0.7	26.0	0.6	0.1	102,212	18.3
Gulf of Riga	2.8	14.3	26.9	-	55.6	-	0.5	89,737	16.1
Western Baltic	2.3	13.2	81.1	-	0.0	0.9	2.5	26,224	4.7
Sound	0.6	34.1	59.9	0.0	0.0	1.3	4.0	6,646	1.2
Kattegat	5.3	37.7	54.1	0.4	0.0	1.5	1.0	41,438	7.4
Denmark	1.1	20.3	75.9	-	0.0	1.0	1.7	38,600	6.9
Estonia	9.4	30.9	59.2	0.1	0.4	-	-	31,335	5.6
Finland	8.0	45.4	40.4	3.5	0.0	2.5	0.3	66,188	11.8
Germany	8.9	3.7	83.3	-	0.0	0.5	3.6	22,256	4.0
Lithuania	0.0	22.4	74.9	-	-	-	2.7	72,449	13.0
Latvia	0.0	7.8	-	-	92.2	-	-	71,326	12.8
Poland	2.5	6.9	82.1	2.0	0.1	5.2	1.3	103,458	18.5
Russia	0.0	52.2	12.7	-	35.1	-	-	75,562	13.5
Sweden	4.9	66.0	25.0	1.5	0.0	2.2	0.5	77,894	13.9
Baltic Sea								**559,068**	

— The overall importance of natural background loads and agricultural loads of total nitrogen and total phosphorus for the corresponding diffuse riverine inputs are as described in chapter 4.4.
— For the four countries quantifying managed forestry loads it constitutes between 0.1 (Estonia) and 3.5% (Finland) of diffuse riverine total nitrogen inputs, and 0.3 (Estonia) and 4.1% (Finland) for total phosphorus.
— Five countries have quantified loads from scattered dwellings separately, and total nitrogen loads shares for this source range from 0.5% (Germany) to 5.2% (Poland) of diffuse riverine total nitrogen inputs from these countries, and the corresponding shares of diffuse riverine total phosphorus inputs are from 2.5% (Germany) to 9.2% (Denmark). It should be noted that while scattered dwellings are less than 30 person equivalents (PE) in Denmark the threshold in Poland is 2,000 PE which hinder direct comparison between countries.
— Six countries have quantified loads of storm waters separately, and total nitrogen loads shares from this source range from 0.3% (Finland) to 3.6% (Germany) of diffuse riverine total nitrogen inputs from these countries, and the corresponding shares of diffuse riverine total phosphorus inputs are from 0.1% (Finland) to 24% (Germany). Quantification methodology and definitions on what is included as storm waters might hamper direct comparison. Total phosphorus load from storm waters to the Sound constitutes 50% of diffuse riverine inputs.

In figure 4.12 four examples are shown of country per basins Box-Whisker plots for the shares of the seven diffuse sources of total nitrogen and total phosphorus input in monitored rivers in the respective catchments.

There is also big variation in the proportion of the individual sources of riverine total nitrogen and total phosphorus inputs between rivers within a catchment to a Baltic Sea catchment as shown in figure 4.12 (in chapter 9, annex 3 it is indicated where all Box-Whisker plots are available). It is quite clear, that the shares of the sources often vary substantially between monitored rivers within a catchment to a sub-basin in the countries.

Table 4.9. As table 4.8 but for total phosphorus (TP).

Basin/ Country	TP Indir	TP Indir	TP Indir	TP Indir	TP Indir	TP Indir	TP Indir	TP Indir	TP
	ATL %	NBL %	AGL %	MFL %	Dif-other without TRL %	SCL %	SWL %	Total tons	Total of total %
Bothnian Bay	3.4	59.5	27.0	4.5	0.0	5.2	0.5	2,266	11.8
Bothnian Sea	3.0	42.9	42.6	2.1	0.0	8.0	1.4	1,122	5.8
Archipelago	0.3	12.5	77.2	1.5	0.0	8.5	0.1	555	2.9
Baltic Proper	1.3	13.8	70.2	1.4	5.0	3.5	4.9	7,849	40.8
Gulf of Finland	1.3	43.8	32.4	0.5	19.5	2.5	0.0	3,687	19.2
Gulf of Riga	0.6	17.7	17.0	0.1	63.7	-	1.0	1,734	9.0
Western Baltic	1.4	24.8	45.0	-	0.0	8.5	20.3	711	3.7
Sound	0.2	20.8	20.4	0.0	0.0	8.8	49.7	156	0.8
Kattegat	1.3	44.9	38.1	0.2	0.0	6.9	8.7	1,152	6.0
Denmark	0.2	41.0	32.8	-	0.0	9.2	16.8	1,145	6.0
Estonia	3.2	36.2	60.0	0.3	0.4	-	-	725	3.8
Finland	2.6	30.4	54.0	4.1	0.0	8.7	0.1	3,459	18.0
Germany	5.3	13.2	55.0	-	0.0	2.5	24.0	713	3.7
Lithuania	0.0	27.8	61.6	-	0.0	-	10.7	1,398	7.3
Latvia	0.0	12.2	-	-	87.8	-	-	1,700	8.8
Poland	1.3	6.9	83.3	2.1	0.0	3.9	2.4	5,060	26.3
Russia	0.0	51.2	23.3	-	25.5	-	-	2,815	14.6
Sweden	3.4	61.6	22.6	0.6	0.0	6.7	5.1	2,215	11.5
Baltic Sea								**19,231**	

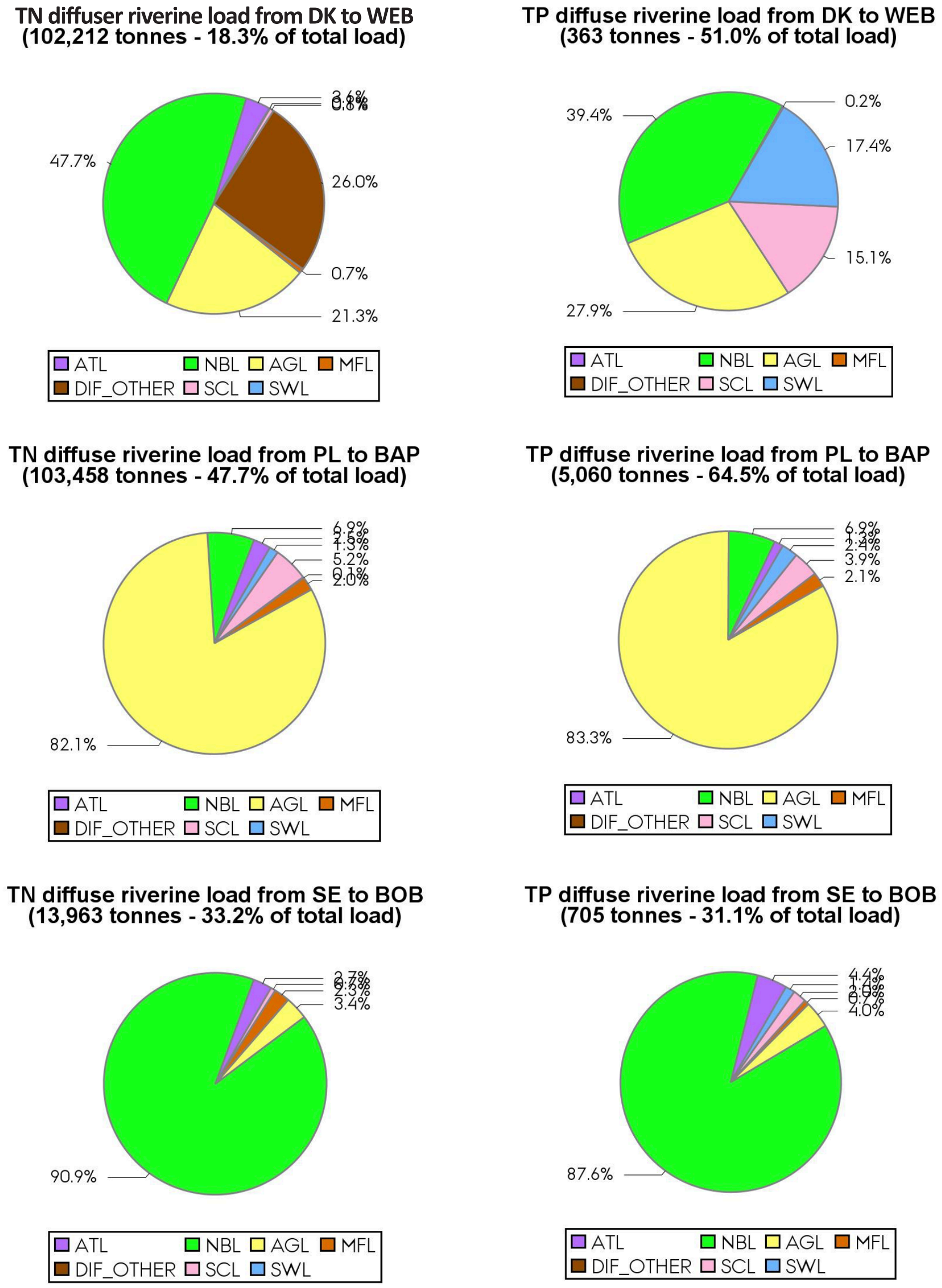


Figure 4.11. Shares (in percentages) for main source of riverine diffuse inputs: ATL = atmospheric deposition on inland surface waters, NBL = natural background load, AGL= agricultural load, MFL = managed forestry, Dif-other = other diffuse loads (without transboundary inputs), SCL scattered dwelling load, SWL = storm water loads of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea from Denmark to Western Baltic, Poland to Baltic Proper, and Sweden to Bothnian Bay in 2017 (Poland 2018). Total inputs from a country (in tonnes) to the basin are indicated in the header as is the share (in percentages) of this input of the total input to the basin. Denmark includes MFL in AGL.

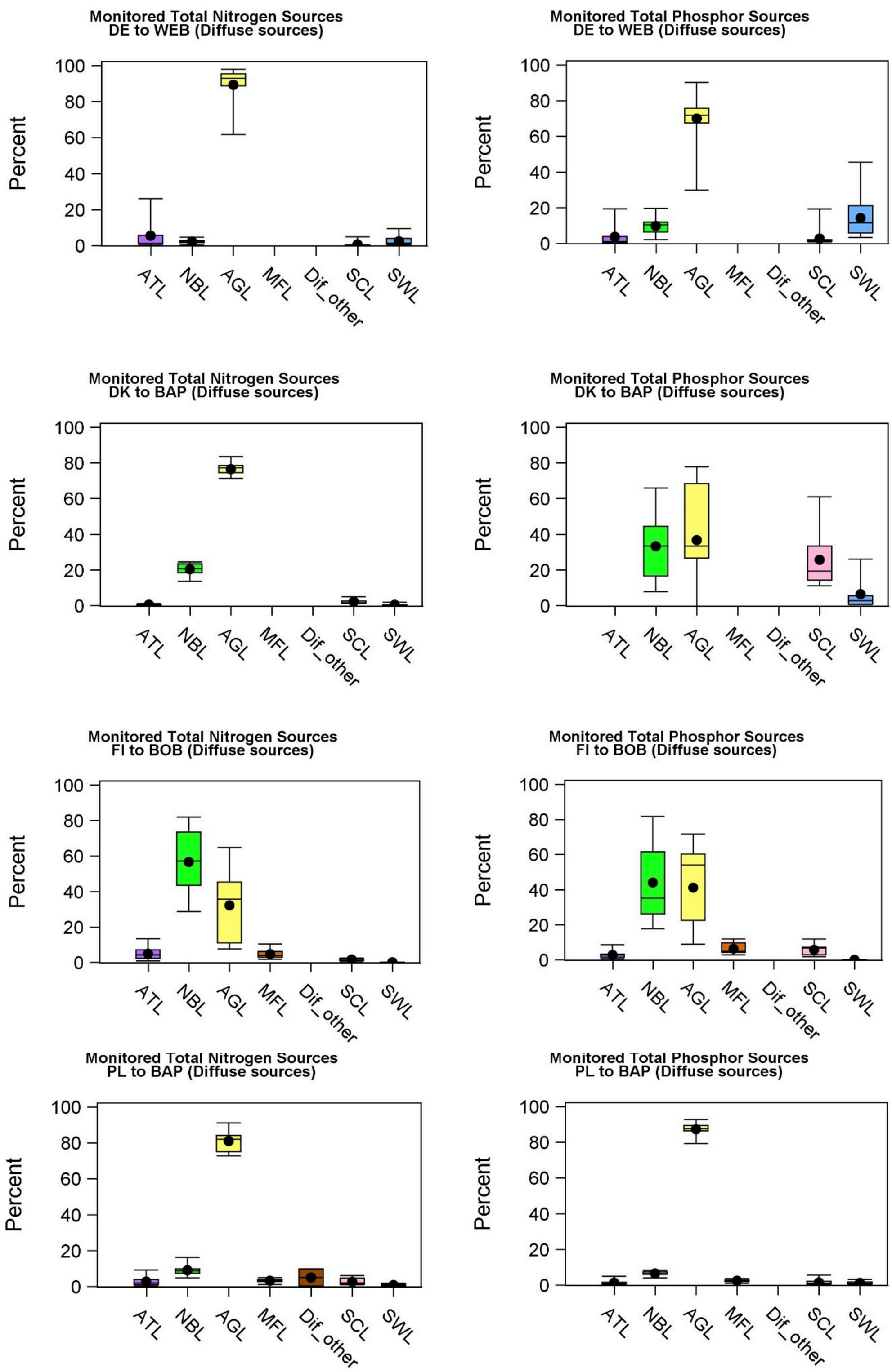


Figure 4.12. Box-Whisker plots of the share (percentages) for seven sources of diffuse inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers in German catchment to the Western Baltic, Danish catchment to Baltic Sea, Finnish catchment to Bothnian Bay and Polish to Baltic Proper in 2017 (Poland 2018). The sources are: ATL = atmospheric deposition on inland surface waters, NBL = natural background load, AGL= agricultural load, MFL = managed forestry, Dif-other = other diffuse loads (without transboundary inputs), SCL scattered dwelling load, SWL = storm water loads. Denmark and Germany include managed forestry load as a part of agricultural loads. See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

4.6. Waste water loads: municipal treatment plants loads, industrial loads, aquacultural plants loads, scattered dwelling loads, and storm water loads

In this sub-chapter we assess sources of waste water inputs, both to inland waters (indirect inputs) and discharges directly to the sea (direct sources) of total nitrogen and total phosphorus inputs by basin, by country, country by basin for the entire catchment with the load-oriented approach for five source categories:

— Municipal wastewater treatment plants (MWL indirect and direct)
— Industrial plants (INL indirect and direct)
— Aquaculture plants (AQL indirect and direct)
— Scattered dwellings (SCL – only indirect per definition)
— Storm water effluents (SWL– only indirect per definition)

Latvia, Lithuania, and Russia do not quantify these sources separately, and are therefore not included in this sub-chapter. Estonia has only reported loads from wastewater treatment plants and industrial plants separately (other waste water sources are included under Dif-other in sub chapter 4.5). Therefore, only result from Denmark, Germany, Poland, Finland, and Sweden are directly comparable. Germany reports not having aquaculture activity neither in the catchment area or in the marine environment of Baltic Sea and Western Baltic.

In chapter 9 (annex 14) is indicated where all pie charts by basin, by country and country by basin are available. There are some few examples of country by basin shown below in figure 4.13. Data behind by basin and by country is in tables 4.10 (total nitrogen) and 4.11 (total phosphorus).

Main findings from tables 4.10 and 4.11 and figure 4.13:

— For total nitrogen: Loads from municipal waste water treatment plants (indirect plus direct) are the most important total nitrogen waste water sources in the five countries with comparable data, with shares from 58% (Poland) to 70% (Germany) of total nitrogen waste water loads. Industrial loads have the second highest shares in Finland (21%) and Sweden (17%), while it is scattered dwellings loads for Poland (19%), and storm water loads for Denmark (15%) and Germany (22%). It should be noted that the threshold for scattered dwellings is up to 30 person equivalents (PE) in Denmark but 2,000 PE in Poland. Estonia has very high share for municipal waste water treatment plants (94%), because loads from scattered dwelling and storm waters are not quantified.

Table 4.10. Shares (in percentages) for sources of waste water of total nitrogen (TN, tonnes) into the catchment (Indir = indirect) to and discharging directly (Dir = direct) into the Baltic Sea by basin (upper part of the table) and by country (lower part of the table) in 2017 (Polish data from 2018). MWL = municipal waste water treatment plant load, INL = industrial plant load, AQL =aquacultural plant load, SCL scattered dwelling load (only indirect), SWL = storm water loads (only indirect). Latvia, Lithuania, and Russia do not quantify these sources separately, and therefore not include. "-" not quantified: Estonia includes SCT and SWL in Dif-other (se tables 4.8 and 4.9). The basin not included is due to missing information from the mentioned countries.

Basin/ Country	TN Indir+Dir	TN Indir+Dir	TN Indir+Dir	TN Indir	TN Indir	TN Indir+Dir
	MWL %	INL %	AQL %	SCL %	SWL%	Total tons
Bothnian Bay	56.8	33.6	0.8	8.2	0.6	7,004
Bothnian Sea	66.5	19.6	4.4	8.7	0.8	7,845
Archipelago	42.7	7.5	32.2	15.6	1.9	1,247
Baltic Proper						
Gulf of Finland						
Gulf of Riga						
Western Baltic	66.0	2.3	9.5	6.1	16.1	4,027
Sound	82.1	3.5	0.2	3.6	10.6	2,487
Kattegat	66.8	10.2	3.2	12.0	7.8	5,161
Denmark	61.1	4.5	11.3	8.6	14.5	4,435
Estonia	94.4	5.6	-	-	-	633
Finland	60.7	20.8	4.3	12.7	1.4	12,837
Germany	70.0	4.9	0.0	3.3	21.8	3,633
Lithuania						
Latvia						
Poland	57.6	15.5	4.0	18.5	4.5	28,983
Russia						
Sweden	70.3	16.8	1.9	9.0	2.0	18,690

— For total phosphorus: Loads from municipal waste water treatment plants (indirect plus direct) are the most important source in four of five countries with comparable data, with shares from 30% (Sweden) to 74% (Poland) of total phosphorus waste water loads. For Finland scattered dwelling loads have the highest share of waste water loads with 53%, and municipal waste water treatment plants constitutes only 17%. Industrial loads have the second highest shares in Finland (19%) and Sweden (29%), while it is scattered dwelling loads for Poland (9%), and storm water loads for Denmark (29%) and Germany (47%). Scattered dwelling loads also have important shares from Denmark (16%) and Sweden (21%). For Estonia a high share for municipal waste water treatment plants (62%) and the remining is industrial loads.

In figure 4.14 (in chapter 9, annex 4 is indicated where all remaining Box-Whisker plots are available) four examples are shown of country per basins Box-Whisker plots for the share of the five sources of waste water of total nitrogen and total phosphorus input in monitored rivers in the respective catchments (and therefore only includes indirect waste water sources). The proportion from the waste water sources categories varies markedly between individual rivers within a countries catchment to a sub-basin.

Table 4.11 As table 4.10 but for total phosphorus (TP).

Basin/ Country	TP Indir+Dir	TP Indir+Dir	TP Indir+Dir	TP Indir	TP Indir	TP Indir+Dir
	MWL %	INL %	AQL %	SCL %	SWL %	Total tons
Bothnian Bay	13.7	32.7	3.0	46.3	4.2	254
Bothnian Sea	14.5	42.0	10.0	28.4	5.1	316
Archipelago	9.0	2.8	42.5	45.3	0.5	104
Baltic Proper						
Gulf of Finland						
Gulf of Riga						
Western Baltic	43.3	1.2	9.0	13.7	32.7	441
Sound	60.0	1.0	0.5	5.8	32.7	238
Kattegat	38.0	8.6	4.3	21.8	27.4	366
Denmark	45.6	2.4	7.8	15.7	28.5	674
Estonia	92.3	7.7	-	-	-	32
Finland	17.0	18.6	10.5	53.2	0.6	567
Germany	47.8	0.4	0.0	4.8	46.9	365
Lithuania						
Latvia						
Poland	74.0	5.4	6.3	8.8	5.5	2,237
Russia						
Sweden	30.1	28.6	4.6	20.8	16.0	711

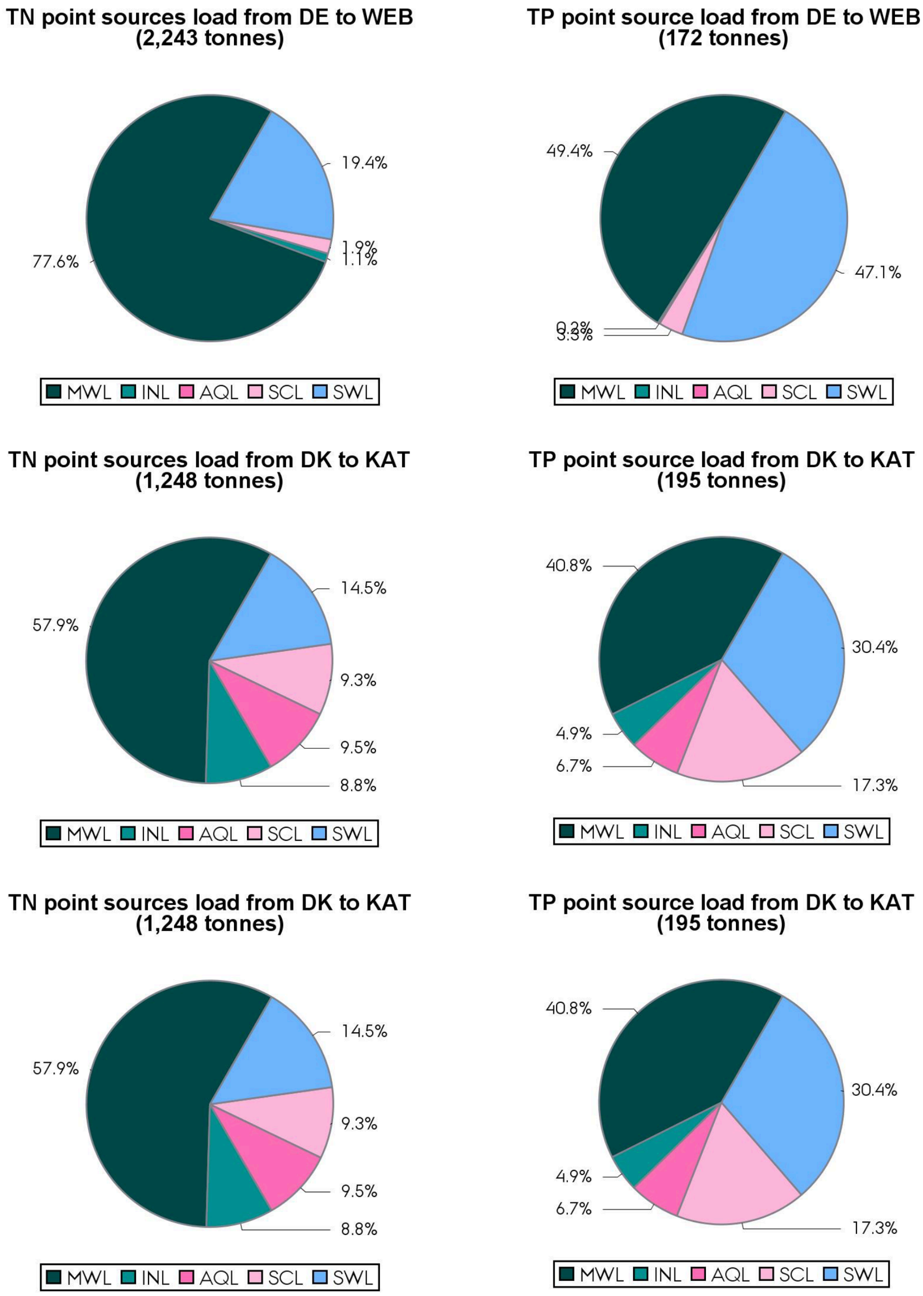


Figure 4.13. Shares (in percentages) for main source of waste water to the catchment of Baltic Sea (indirect sources) and directly to the Baltic Sea: MWL = municipal waste water treatment plant load, INL = industrial plant load, AQL =aquacultural plant load, SCL scattered dwelling load (only indirect), SWL = storm water loads (only indirect) of total nitrogen (TN, left column) and total phosphorus (TN right column) to the Baltic Sea from Germany to Western Baltic, Denmark to Kattegat, and Finland to Archipelago in 2017. Total inputs from a country (in tonnes) to the sub-basin are indicated in the header.

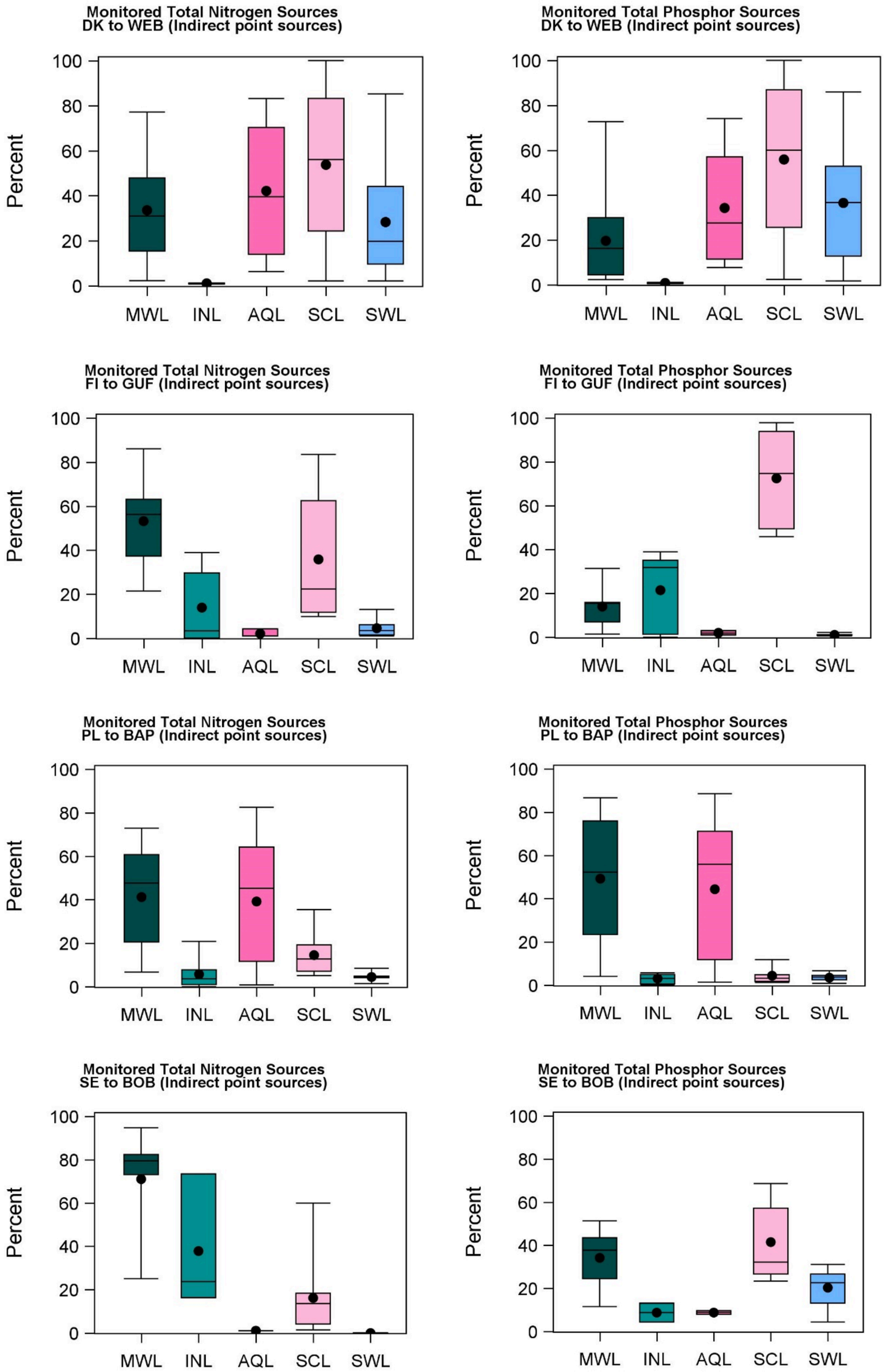


Figure 4.14. Box-Whisker plot of the share (percentages) for the five sources of waste water inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers (indirect waste water sources) in Danish catchment to the Western Baltic, Finnish catchment to Gulf of Finland, Polish catchment to Baltic Proper, and Swedish catchment to Bothnian Bay in 2017 (Poland 2018). MWL = municipal waste water treatment plant load, INL = industrial plant load, AQL =aquacultural plant load, SCL scattered dwellings load, SWL = storm water loads. See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

4.7. Direct point sources load: municipal waste water treatment plant loads, industrial loads, and aquaculture plants loads

In this sub-chapter we assess sources of direct waste water inputs i.e. discharging directly into the sea (direct point sources) of total nitrogen and total phosphorus inputs by sub-basin, by country, country by basin for the entire catchment with the load-oriented approach for three source categories:

— Municipal waste water treatment plants (MWL direct)
— Industrial plants (INL direct)
— Aquaculture plants (AQL direct)

Only Denmark, Finland, and Sweden report they have marine aquaculture/aquaculture discharging directly to the sea.

Data by sub-basin and by country is in tables 4.12 (total nitrogen and) and 4.13 (total phosphorus).

In chapter 9 (annex 15) is indicated where all pie charts by basin, by country and country by basin are available.

Overall direct inputs of total nitrogen and total phosphorus only constituted a minor share of the corresponding inputs to the Baltic Sea with 3.1% and 4.8%, respectively but it is an important anthropogenic source with potential for further reduction.

Main findings from table 4.12 for total nitrogen:

— Municipal waste water treatment plant inputs are by far the major source of direct inputs to all the Baltic Sea sub-basins and to the Baltic Sea (85%) flowed by inputs from industrial plants (12%). Direct inputs from aquaculture constitutes only about 3% of total direct inputs of nitrogen.
— Direct inputs from industrial plants are an important direct point source to Bothnian Bay (38%) and Bothnian Sea (35%), for the remaining sub-basins it constitutes between 1 and 9%.
— Aquaculture is a significant source of direct inputs to Archipelago (41%) and Western Baltic (21%), for the remaining sub-basins it constitutes between 0 and 4% of total direct point source inputs.
— Gulf of Finland receives 34% of total direct inputs followed by Baltic Proper (18%), and Bothnian Sea (13%).
— For all countries municipal waste water treatment plants are the main direct total nitrogen source, ranging from 65% (Finland) to more than 99% (Poland and Russia).
— Direct industrial total nitrogen shares are highest from Finland (27%) and Sweden (18%), but constitute only between less than 1% to 6% for the remaining countries.
— For the three countries reporting inputs of total nitrogen

Table 4.12. Shares (in percentages) for direct points of total nitrogen (TN, tonnes) into the Baltic Sea by basin (upper part of the table) and by country (lower part of the table) in 2017 (Polish data from 2018). MWL = municipal waste water treatment plant load, INL = industrial plant load, and AQL = aquacultural plant load. The columns "Total %" indicates the share of the total nitrogen inputs to the basin or from the country of the corresponding total inputs to the Baltic Sea.

Basin/ Country	TN Dir	TN Dir	TN Dir	TN Dir	TN
	MWL %	**INL %**	**AQL %**	**Total tons**	**Total of total %**
Bothnian Bay	61.2	38.2	0.6	3,591	12.5
Bothnian Sea	61.6	34.6	3.8	3,399	11.9
Archipelago	50.2	9.3	40.5	991	3.5
Baltic Proper	93.0	6.9	0.0	5,103	17.8
Gulf of Finland	97.3	2.4	0.3	9,822	34.3
Gulf of Riga	99.1	0.9	0.0	432	1.5
Western Baltic	73.7	5.6	20.7	1,603	5.6
Sound	98.1	1.6	0.3	1,796	6.3
Kattegat	93.4	6.6	0.0	1,918	6.7
Denmark	81.3	4.4	14.3	2,332	8.1
Estonia	95.3	4.7	0.0	508	1.8
Finland	64.5	26.5	8.9	5,553	19.4
Germany	96.1	3.9	0.0	905	3.2
Lithuania	93.8	6.2	0.0	219	0.8
Latvia	98.9	1.1	0.0	438	1.5
Poland	99.8	0.2	0.0	561	2.0
Russia	99.1	0.9	0.0	8,262	28.8
Sweden	81.3	17.7	1.0	9,877	34.5
Baltic Sea	**84.6**	**12.1**	**3.2**	**286,556**	

from marine aquaculture plants it constitutes 14% of total direct point source inputs from Denmark, 9% from Finland and 1% from Sweden.

Main findings from table 4.13 for total phosphorus:

- Municipal waste water treatment plant inputs are the major source of direct inputs of total phosphorus to the Baltic Sea (71%) followed by inputs from industrial plants (22%). Direct inputs from aquaculture constitute only about 7% of total direct inputs of phosphorus.
- Municipal waste water treatment plant inputs are the major source of direct inputs to six sub-basins except to Bothnian Bay and Bothnian Sea, where inputs from industrial plants are the most important sources with 79% of direct total phosphorus inputs to both basins.
- Direct inputs from industrial plants are also important to Baltic Proper (27%) and Kattegat (14%), but for the remaining five sub-basins it constitutes between 1 and 5%.
- Aquaculture is the most important source of direct inputs of total phosphorus to Archipelago (81%) and important to Western Baltic (30%), for the remaining sub-basins it constitutes between 0 and 9%.
- Gulf of Finland receives 35% of total direct inputs followed by Baltic Proper (15%), and Bothnian Sea (12%).
- For all countries besides Finland and Sweden municipal waste water treatment plants are the main direct total phosphorus source. It constitutes between 62% (Poland) and 98% (Russia). For Finland and Sweden, the shares are 32% and 44% respectively.
- Direct industrial total phosphorus inputs are the most import direct point source from Finland (37%) and Sweden (53%), but also important from Poland (38%). For the remaining six countries it constitutes only between 2 and 6%.
- For the three countries reporting inputs of total phosphorus nitrogen from marine aquaculture plants it constitutes 13% of total direct inputs from Denmark, 31% from Finland and 3% from Sweden.

Table 4.13. As table 4.12 but for total phosphorus (TP).

Basin/ Country	TP Dir	TP Dir	TP Dir	TP Dir	TP
	MWL %	INL %	AQL %	Total tons	Total of total %
Bothnian Bay	17.3	79.0	3.8	90	6.6
Bothnian Sea	12.4	78.8	8.9	153	11.2
Archipelago	13.6	5.3	81.1	54	4.0
Baltic Proper	73.1	26.8	0.1	198	14.6
Gulf of Finland	94.2	5.1	0.7	478	35.2
Gulf of Riga	97.5	2.5	0.0	42	3.1
Western Baltic	65.7	4.5	29.8	112	8.2
Sound	97.6	1.4	0.9	132	9.8
Kattegat	85.9	14.0	0.0	99	7.3
Denmark	83.7	3.0	13.3	251	18.5
Estonia	94.9	5.1	0.0	28	2.1
Finland	32.4	36.8	30.8	178	13.1
Germany	94.7	5.3	0.0	28	2.1
Lithuania	94.0	6.0	0.0	14	1.0
Latvia	97.2	2.8	0.0	43	3.1
Poland	62.1	37.9	0.0	51	3.7
Russia	97.8	2.2	0.0	412	30.3
Sweden	44.1	52.7	3.1	354	26.1
Baltic Sea	**71.1**	**21.6**	**7.3**	**1,357**	

5. Source–Oriented approach

This chapter includes results from the source-oriented source assessment where we assess the importance of sources of total nitrogen and total phosphorus inputs into surface waters in the catchment to the Baltic Sea, before retention in the inland surface waters. Results on retention of total nitrogen and total phosphorus in inland surface waters are presented in chapter 3.8 (on maps). The results in this chapter are shown with different aggregation level of sources, starting with the most aggregated level in chapter 5.1 and with most detailed source information in sub-chapters 5.3 and 5.4:

— Natural background sources, sum of other diffuse sources and inland (indirect) point sources for monitored, unmonitored and total areas of Baltic Sea catchment (chapter 5.1)
— Atmospheric deposition on inland waters, natural background sources, agricultural sources, other diffuse sources and indirect point sources (chapter 5.2)
— Apportionment of diffuse sources in monitored areas: atmospheric deposition on inland waters, natural background sources, agricultural sources, managed forestry, other diffuse sources, scattered dwellings, and storm waters (chapter 5.3)
— Apportionment of indirect wastewater sources for monitored areas: municipal treatment plants, industry, aquaculture plants, scattered dwellings, and storm waters (chapter 5.4)

In chapter 5 results are presented mainly as tables with the results for the total catchment (sum of monitored and unmonitored catchment). There are only few results included as country by basin presented with pie chart (figure 5.1) and Box-Whisker plots from monitored rivers in the catchment (figure 5.3).

Pie charts are produced by country, by basin and country by basin for monitored, unmonitored, and total riverine inputs of total nitrogen and total phosphorus for sub-chapters 5.1 to 5.4. In chapter 9, annexes 16-19 it is explained where all these pie charts are available. Further, in chapter 9 (annexes 5-8) it is indicated where Box-Whisker plots for all the monitored rivers can be reached, and some examples are shown in sub-chapters 5.2 (figure 5.2), 5.3 (figure 5.4), and 5.4.

5.1. Natural background sources, sum of other diffuse sources and inland (indirect) point sources

The contracting parties have assessed sources into inland surface waters in the catchment to the Baltic Sea on the aggregation level natural background sources, diffuse other (anthropogenic sources), and indirect points sources (table 5.1) with the source-oriented approach, which can be compared with the result for the load-oriented approach for the riverine load to the Baltic Sea in chapter 4.3 for the same aggregation level of sources.

Overall findings on main sources of nitrogen and phosphorus into inland surface waters in the catchment of the Baltic Sea:

— Diffuse other sources are the most important source of total nitrogen (64%) and total phosphorus (66%) into inland surface waters in the Baltic Sea catchment followed by natural background sources (29% for total nitrogen and 23% for total phosphorus).

Total nitrogen:

— Apart from the catchments to Bothnian Bay and Bothnian Sea diffuse other sources are the most important sources of total nitrogen to the remaining sub-basins with proportions ranging between 54% (Kattegat) and 85% (Gulf of Riga). For the two remaining catchments natural background sources are the most important source (56% and 65%, respectively).
— Indirect point sources provide 7% of total nitrogen input into inland surface waters in the Baltic Sea catchment area ranging between 0.7% (catchment to Archipelago) and 8.9% (catchment to Bothnian Sea).

Total phosphorus:

— Apart from Bothnian Bay other diffuse sources are the most important source of total phosphorus inputs to the inland surface waters in the catchments to the sub-basins of the Baltic Sea, ranging between 51% (Bothnian Sea) and 87% (Archipelago). Natural background losses have a share of 57% of total phosphorus inputs into inland surface waters in the catchment to Bothnian Bay.
— Indirect sources constitute the lowest share of total phosphorus inputs, from 0.2% in the catchment to Archipelago to 15% in the catchment to Baltic Proper.

Table 5.1. Shares (in percentages) for main sources of total nitrogen (TN, tonnes) and total phosphorus (TP, tonnes) into inland surface water in the Baltic Sea catchment (before retention in inland surface waters) by sub-basins in 2017 (Polish data from 2018). The rightmost column for total nitrogen and total phosphorus, respectively, indicates the share of the total nitrogen and total phosphorus inputs to the basin of the corresponding total nitrogen and total phosphorus input to the Baltic Sea. NBS = natural background losses, diff-other = remaining diffuse sources to inland waters in the catchment to the Baltic Sea including atmospheric deposition on inland surface waters, PSS = indirect point sources (inputs from municipal waste water treatment plants, industrial plants and aquaculture plants).

Basin/ Country	TN Indir NBS total %	TN Indir Dif-other %	TN Indir PSS %	TN Indir Total BL-BN tons	TN Indir Total of total %	TP Indir NBS total %	TP Indir Dif-other %	TP Indir PSS %	TP Indir Total BL-BN tons	TP Indir Total of total %
Bothnian Bay	65.2	29.6	5.2	64,475	7.2	56.8	41.6	1.6	2,573	6.4
Bothnian Sea	55.7	35.4	8.9	54,811	6.1	45.1	50.7	4.2	2,052	5.1
Archipelago	31.8	67.5	0.7	8,467	0.9	12.4	87.4	0.2	596	1.5
Baltic Proper	15.0	75.3	9.8	341,377	38.2	9.6	75.6	14.7	19,588	48.8
Gulf of Finland	45.1	47.1	7.8	176,068	19.7	35.7	52.8	11.6	9,047	22.5
Gulf of Riga	14.6	84.6	0.8	145,941	16.4	18.6	77.2	4.2	3,278	8.2
Western Baltic	15.7	81.5	2.8	30,103	3.4	21.2	71.5	7.3	920	2.3
Sound	34.5	60.9	4.6	8,139	0.9	18.5	74.8	6.6	204	0.5
Kattegat	40.3	53.9	5.8	63,193	7.1	41.4	51.7	6.9	1,903	4.7
Denmark	24.1	72.9	2.9	46,606	5.2	34.0	58.8	7.3	1,546	3.8
Estonia	30.8	68.5	0.7	38,664	4.3	35.9	62.8	1.3	877	2.2
Finland	43.0	50.5	6.5	128,244	14.4	30.6	66.5	3.0	5,704	14.2
Germany	3.6	92.8	3.6	22,892	2.6	12.6	79.6	7.8	763	1.9
Lithuania	22.4	75.1	2.5	79,128	8.9	25.6	66.4	8.0	1,838	4.6
Latvia	7.8	91.3	0.9	117,891	13.2	11.7	83.4	4.9	2,688	6.7
Poland	5.9	80.5	13.6	195,456	21.9	5.3	77.7	16.9	15,420	38.4
Russia	47.2	45.5	7.3	128,991	14.5	38.3	48.7	13.0	7,333	18.3
Sweden	60.7	30.8	8.5	134,702	15.1	52.8	41.9	5.3	3,993	9.9
BAS	**29.1**	**64.0**	**6.9**	**892,573**	**100.0**	**22.9**	**66.1**	**11.0**	**40,161**	**100**

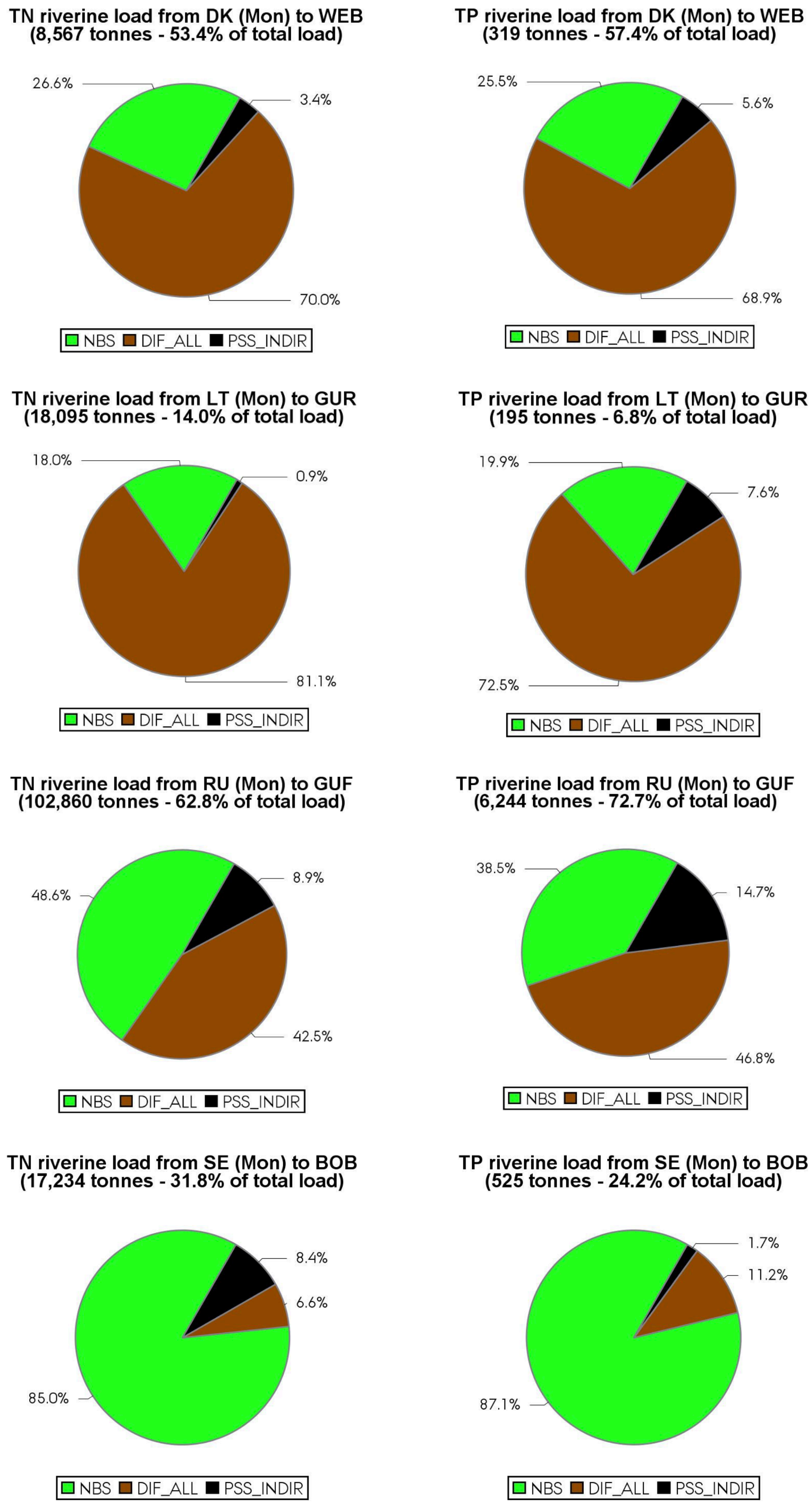


Figure 5.1.. Shares (in percentages) for main sources of inputs to inland surface waters: NBS = natural background sources, Diff_all = all diffuse sources besides natural background sources, PSS_indir = inputs from inland point sources (indirect point sources) of total nitrogen (TN, left column) and total phosphorus (TP, right column) to the Baltic Sea in monitored catchment of: Denmark to Western Baltic, Lithuania to Gulf of Riga, Russia to Gulf of Finland and Sweden to Bothnian Bay in 2017. Total monitored inputs from a country (in tonnes) to a basin are indicated in the header as is the share (in percentages) of this input of the total monitored inputs to the basin.

5.2. Atmospheric deposition on inland waters, natural background sources, agricultural sources, other diffuse sources and indirect point sources

The aggregation of sources in tables 5.2 and 5.3, and figure 5.2 using the source-oriented approach on inputs to inland surface waters corresponds to the aggregation level in chapter 4.4 for the load-oriented approach on the riverine inputs to the Baltic Sea.

The overall findings on main sources of total nitrogen and total phosphorus into inland surface waters in the catchment of the Baltic Sea:

Total nitrogen:

— Agricultural sources are the most important source of total nitrogen into inland surface waters in the Baltic Sea catchment with 41% of total inputs, flowed by natural background sources (29%), and diffuse other sources with 19%. It should be noted that Latvia has not divided diffuse other sources in table 5.1, and inputs from agriculture from Latvia are included in diffuse other sources to Gulf of Riga in table 5.2 (and table 5.3).

— Indirect point sources and atmospheric deposition on inland surface waters in the Baltic Sea catchment area constitute only 6.9% (range between 0.7 and 9.8%) and 3.5 % (range 1.1 to 7.5%), respectively of total nitrogen inputs.

— For five sub-catchments (Archipelago, Baltic Proper, Western Baltic, The Sound and Kattegat) agricultural sources are the most important sources with proportions between 43 and 75% of total nitrogen inputs. For the catchments to Bothnian Bay, Bothnian Sea, and Gulf of Finland natural background sources are the most important total nitrogen inputs source, with proportion ranging between 45 and 65%. The high proportion by diffuse other sources for Gulf of Riga is due to the missing separation of anthropogenic sources in agricultural sources and diffuse other sources and transboundary inputs.

— For most countries other diffuse sources consist of inputs from scattered dwellings and storm waters. For Poland and Russia scattered dwellings included settlements up to 2,000 person equivalents (PE's) were the limit in Denmark in less than 30 PE (with high limits it includes inputs from municipal waste water treatment plants). That is one explanation of the high share for Russia of diffuse other nitrogen inputs into inland surface waters in the catchment to Gulf of Finland.

Table 5.2. Shares (in percentages) for sources of total nitrogen (tonnes) into inland surface waters in the Baltic Sea catchment (before retention in inland surface waters) by sub-basins in 2017 (Polish data from 2018). The rightmost column, indicates the share of the total nitrogen inputs to the sub-basin of the corresponding total nitrogen inputs to the Baltic Sea. ATS = atmospheric nitrogen inputs on inland surface waters, NBS = natural background losses, AGS = agricultural sources, diff-other = other diffuse sources to inland waters in the catchment to the Baltic Sea, PSS = indirect point sources (municipal waste water treatment plants, industrial plants and aquaculture plants).

Basin/ Country	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir
	ATS %	**NBS** %	**AGS** %	**Dif-other sources** %	**PSS** %	**Total** tons	**Total of total** %
Bothnian Bay	4.6	65.2	20.2	4.7	5.2	64,475	7.2
Bothnian Sea	6.0	55.7	24.2	5.1	8.9	54,811	6.1
Archipelago	1.1	31.8	61.0	5.5	0.7	8,467	0.9
Baltic Proper	2.1	15.0	61.3	11.9	9.8	341,377	38.2
Gulf of Finland	5.1	45.1	22.7	19.4	7.8	176,068	19.7
Gulf of Riga	2.2	14.6	23.4	58.9	0.8	145,941	16.4
Western Baltic	2.8	15.7	75.1	3.6	2.8	30,103	3.4
Sound	1.1	34.5	53.7	6.1	4.6	8,139	0.9
Kattegat	7.5	40.3	43.1	3.3	5.8	63,193	7.1
Denmark	1.5	24.1	68.2	3.2	2.9	46,606	6.0
Estonia	9.6	30.8	58.3	0.5	0.7	38,664	5.0
Finland	9.8	43.0	34.8	5.9	6.5	128,244	16.6
Germany	9.3	3.6	79.6	4.0	3.6	22,892	3.0
Lithuania	0.0	22.4	72.5	2.6	2.5	79,128	10.2
Latvia							0.0
Poland	1.6	5.9	71.5	7.4	13.6	195,456	25.2
Russia	0.0	47.2	21.7	23.8	7.3	128,991	16.7
Sweden	6.8	60.7	19.9	4.1	8.5	134,702	17.4
BAS	**3.5**	**29.1**	**41.3**	**19.1**	**6.9**	**892,573**	**100**

Total phosphorus:

- Natural background sources are the most important source of total phosphorus inputs into inland surface water in the catchment of Bothnian Sea (57%), Bothnian Bay (45%), Gulf of Finland (36%) and Kattegat (41%). Agricultural sources are the most important source to Archipelago (77%), Baltic Proper (65%), and Western Baltic (46%). For the catchment to whole Baltic Sea the two sources constitute 23 and 47%, respectively.
- Due to mentioned methodological issues diffuse other sources are artificially high to Gulf of Riga. To the Sound diffuse other sources – which are scattered dwellings and storm waters – are the main phosphorus input source (48%). Together, diffuse other sources and indirect point sources constitute more than 50% of total phosphorus inputs into surface waters in the catchment to the Sound.
- Indirect point sources are quite important in the catchment to Baltic Proper (15%) and Gulf of Finland (12%), but of low importance to Archipelago (0.2%) Atmospheric deposition on inland surface waters is a minor source of total phosphorus with 1.5% for the catchment of the Baltic Sea – ranging from 0.2% in the catchment to the Sound to 4.0% in catchments to Bothnian bay and Bothnian Sea.

Figure 5.2 provides the results from tables 5.2 and 5.3 shown as pie charts.

Table 5.3. As table 5.2 but for total phosphorus (TP).

Basin/ Country	TP Indir ATS %	TP Indir NBS %	TP Indir AGS %	TP Indir Dif-other sources %	TP Indir PSS %	TP Indir Total tons	TP Indir Total of total %
Bothnian Bay	4.0	56.8	27.0	10.5	1.6	2,573	6.4
Bothnian Sea	4.0	45.1	35.9	10.7	4.2	2,052	5.1
Archipelago	0.3	12.4	77.3	9.9	0.2	596	1.5
Baltic Proper	0.8	9.6	64.7	10.1	14.7	19,588	48.8
Gulf of Finland	2.2	35.7	24.2	26.4	11.6	9,047	22.5
Gulf of Riga	0.4	18.6	23.4	53.4	4.2	3,278	8.2
Western Baltic	1.3	21.2	46.3	23.9	7.3	920	2.3
Sound	0.2	18.5	26.3	48.3	6.6	204	0.5
Kattegat	2.3	41.4	35.7	13.8	6.9	1,903	4.7
Denmark	0.2	34.0	37.0	21.6	7.3	1,546	4.1
Estonia	3.2	35.9	58.9	0.7	1.3	877	2.3
Finland	4.9	30.6	49.0	12.5	3.0	5,704	15.2
Germany	6.3	12.6	50.5	22.8	7.8	763	2.0
Lithuania	0.0	25.6	56.7	9.6	8.0	1,838	4.9
Latvia							0.0
Poland	0.6	5.3	70.5	6.6	16.9	15,420	41.1
Russia	0.0	38.3	20.0	28.6	13.0	7,333	19.6
Sweden	4.1	52.8	25.6	12.3	5.3	3,993	10.7
BAS	**1.5**	**22.9**	**46.5**	**18.1**	**11.0**	**40,161**	**100**

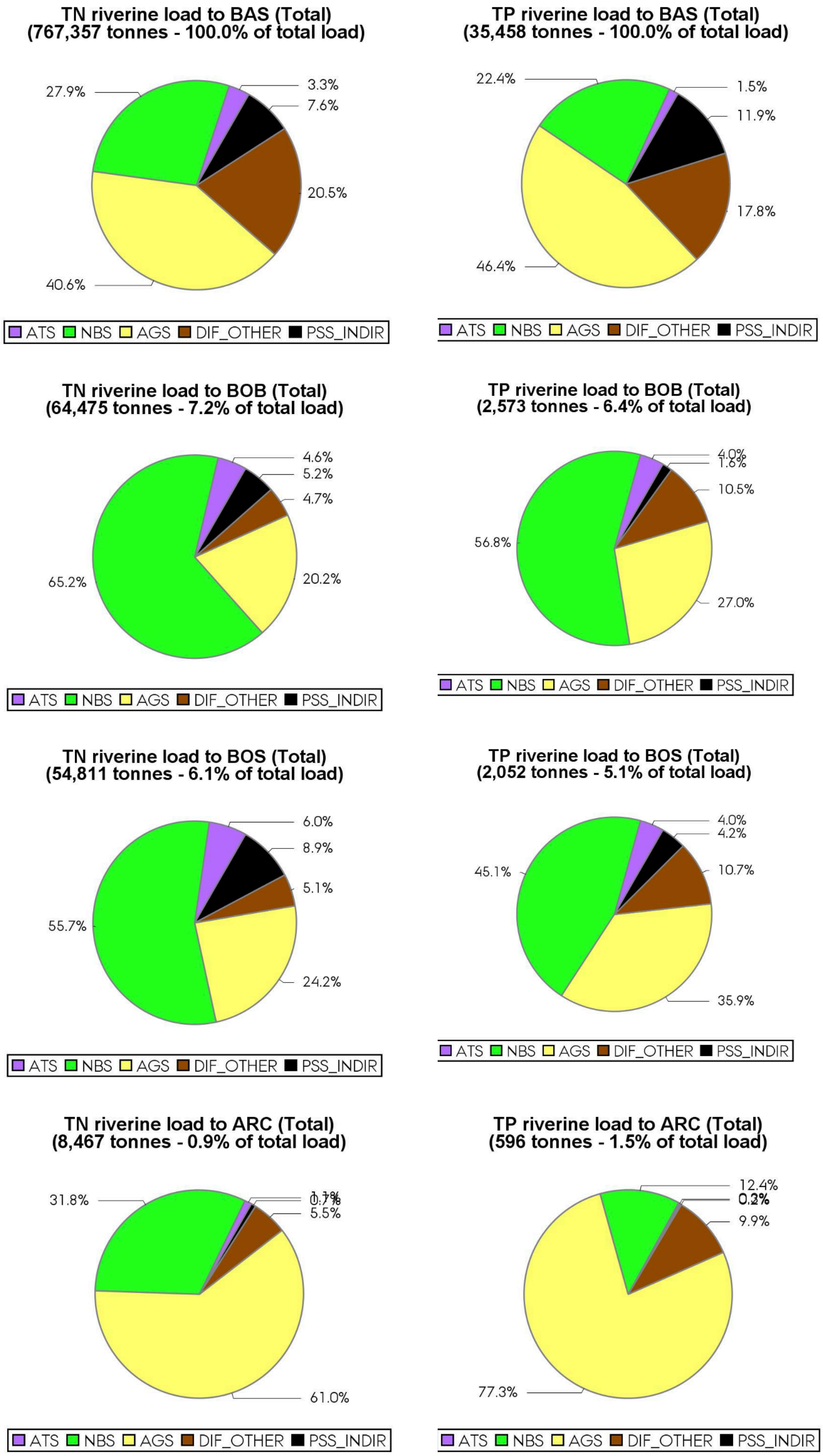


Figure 5.2. Shares (in percentages) for main sources of inputs to inland surface waters ATS = atmospheric deposition on inland surface waters, NBS = natural background sources, AGL= agricultural sources, Dif_other = other diffuse sources, PSS_indir = point source inputs to inland surface waters (indirect point sources) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea and by basin in 2017 (Poland 2018). Total inputs to a catchment to a basin (in tonnes) are indicated in the header as is the share (in percentages) of this input of the total input into the total catchment to the basin.

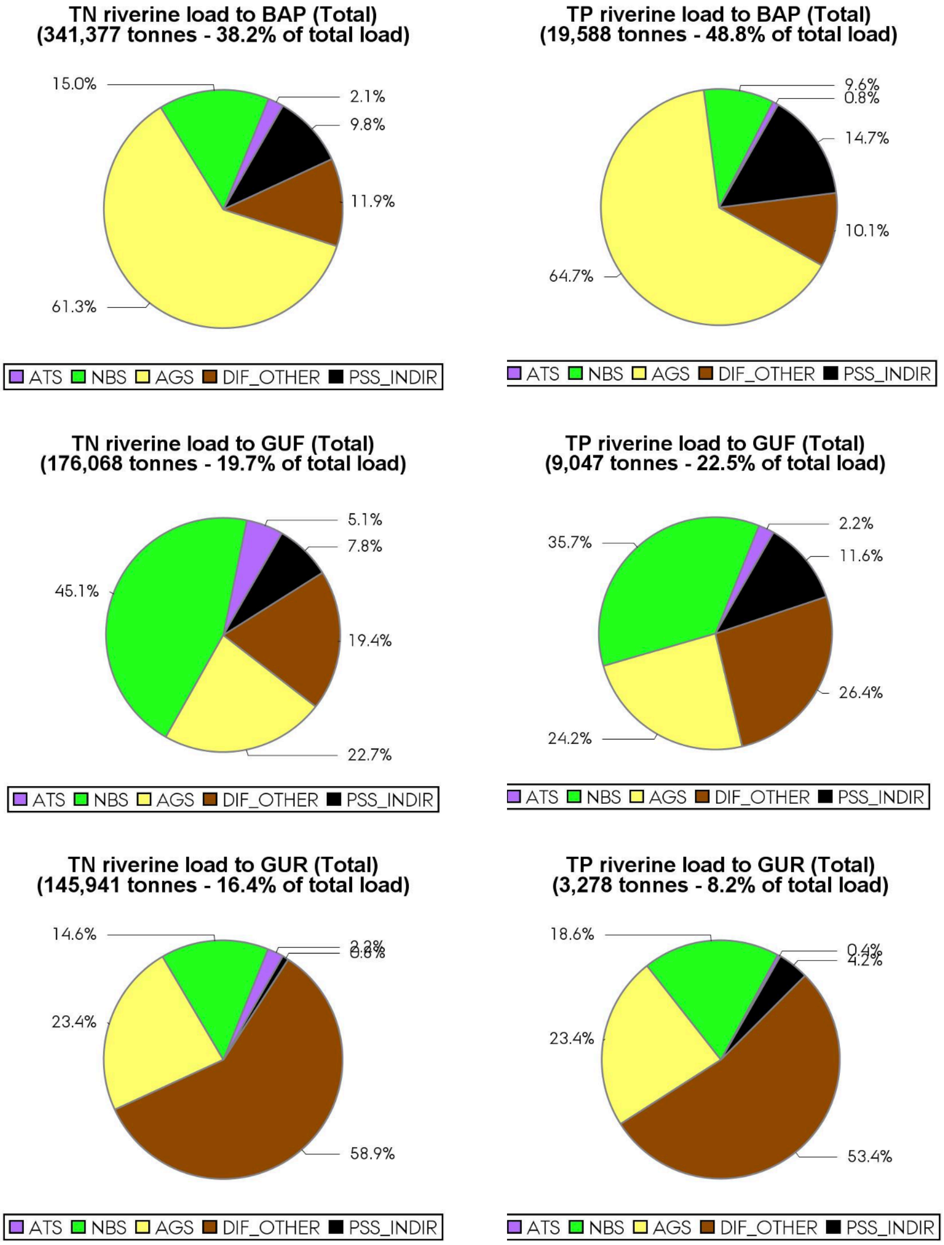


Figure 5.2. Continued. Shares (in percentages) for main sources of inputs to inland surface waters ATS = atmospheric deposition on inland surface waters, NBS = natural background sources, AGL= agricultural sources, Dif_other = other diffuse sources, PSS_indir = point source inputs to inland surface waters (indirect point sources) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea and by basin in 2017 (Poland 2018). Total inputs to a catchment of a basin (in tonnes) are indicated in the header as is the share (in percentages) of this input of the total input into the total catchment to the basin.

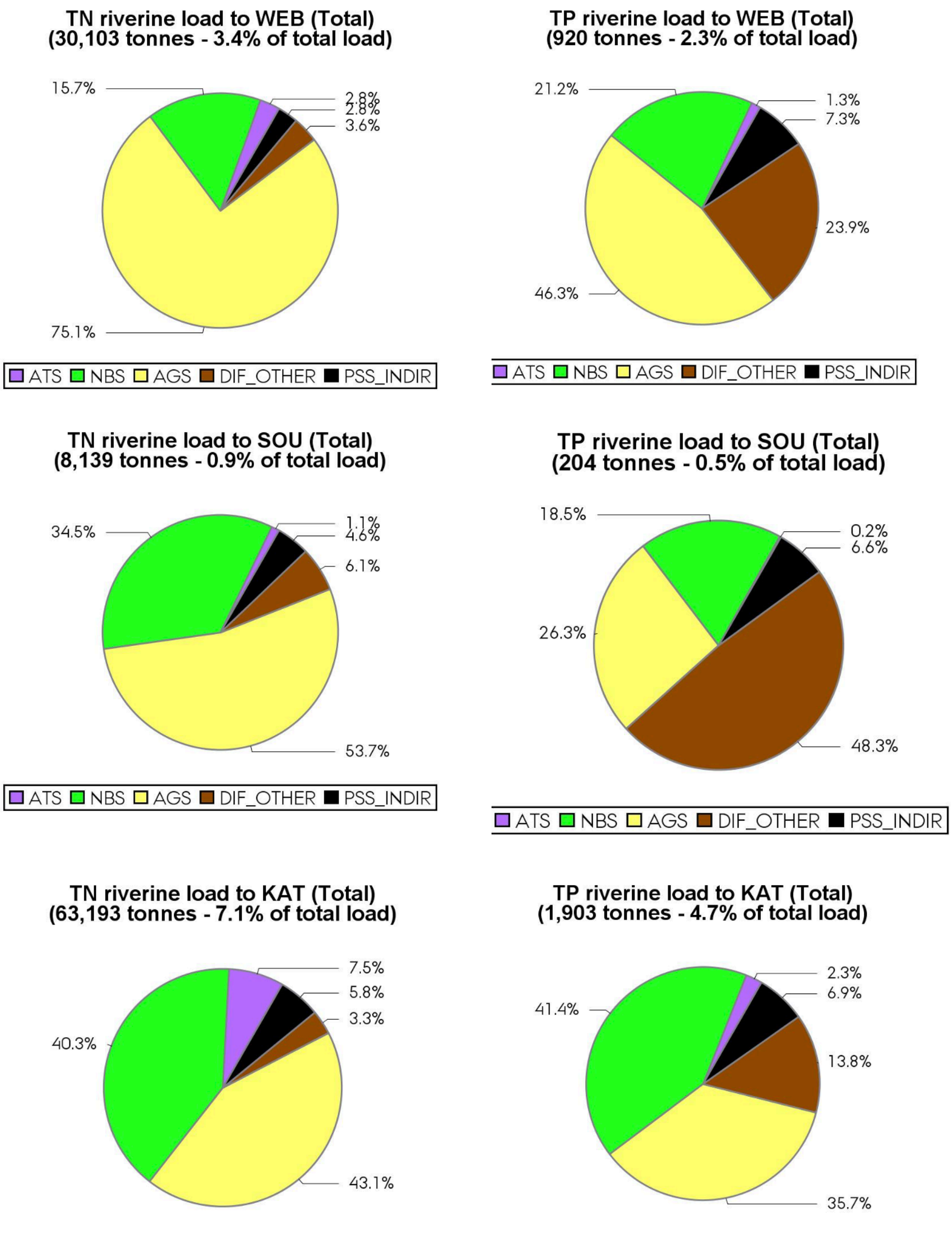


Figure 5.2. Continued. Shares (in percentages) for main sources of inputs to inland surface waters ATS = atmospheric deposition on inland surface waters, NBS = natural background sources, AGL= agricultural sources, Dif_other = other diffuse sources, PSS_indir = point source inputs to inland surface waters (indirect point sources) of total nitrogen (TN – left column) and total phosphorus (TP – right column) to the Baltic Sea and by basin in 2017 (Poland 2018). Total inputs to a catchment of a basin (in tonnes) are indicated in the header as is the share (in percentages) of this input of the total input into the total catchment to the basin.

Within the catchments to the Baltic Sea basins there is a high variation between rivers in the importance of the individual source as shown in examples in figure 5.3. For example, see the agricultural sources of total nitrogen in the catchment of The Sound in Denmark. It is explained in chapters 4.3 and 9.2 how to interpret a Box Whisker plot. In chapter 9, annex 5 it is described where to find all Box Whisker plots.

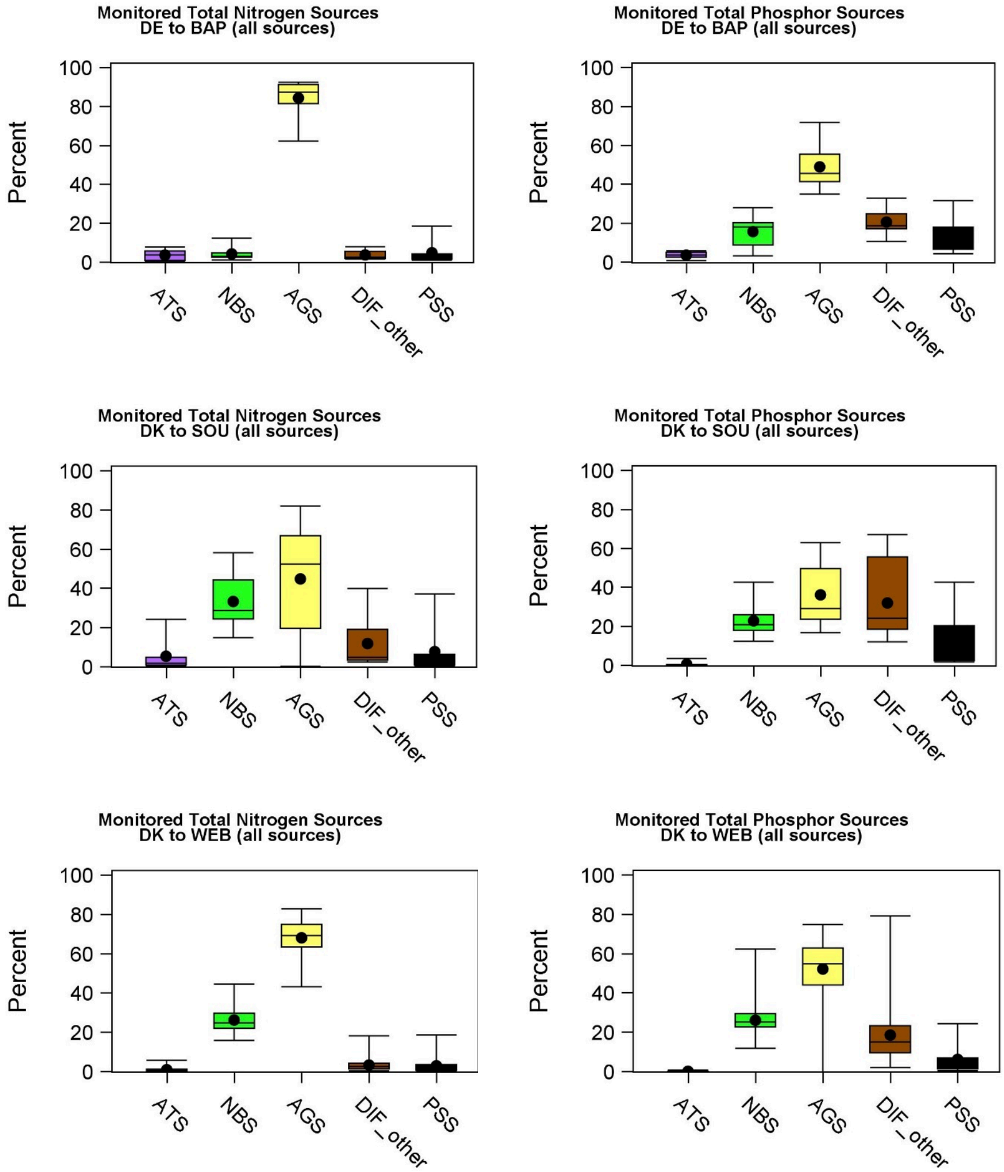


Figure 5.3. Box-Whisker plots of the share (percentages) for five sources of inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers to inland surface waters (before retention in inland surface waters) in German catchment to Baltic Proper, Danish catchment to the Sound and Western Baltic, Estonian catchment to Gulf of Finland, Finnish catchment to Bothnian Bay, Lithuanian catchment to Baltic Proper, Polish catchment to Baltic Proper, and Swedish catchment to Bothnian Sea. The sources are: ATS = atmospheric nitrogen inputs on inland surface waters, NBS = natural background sources, AGS = agricultural sources, DIF_other = other diffuse sources to inland waters in the catchment to the Baltic Sea, PSS = indirect point sources (municipal waste water treatment plants, industrial plants and aquaculture plants). See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

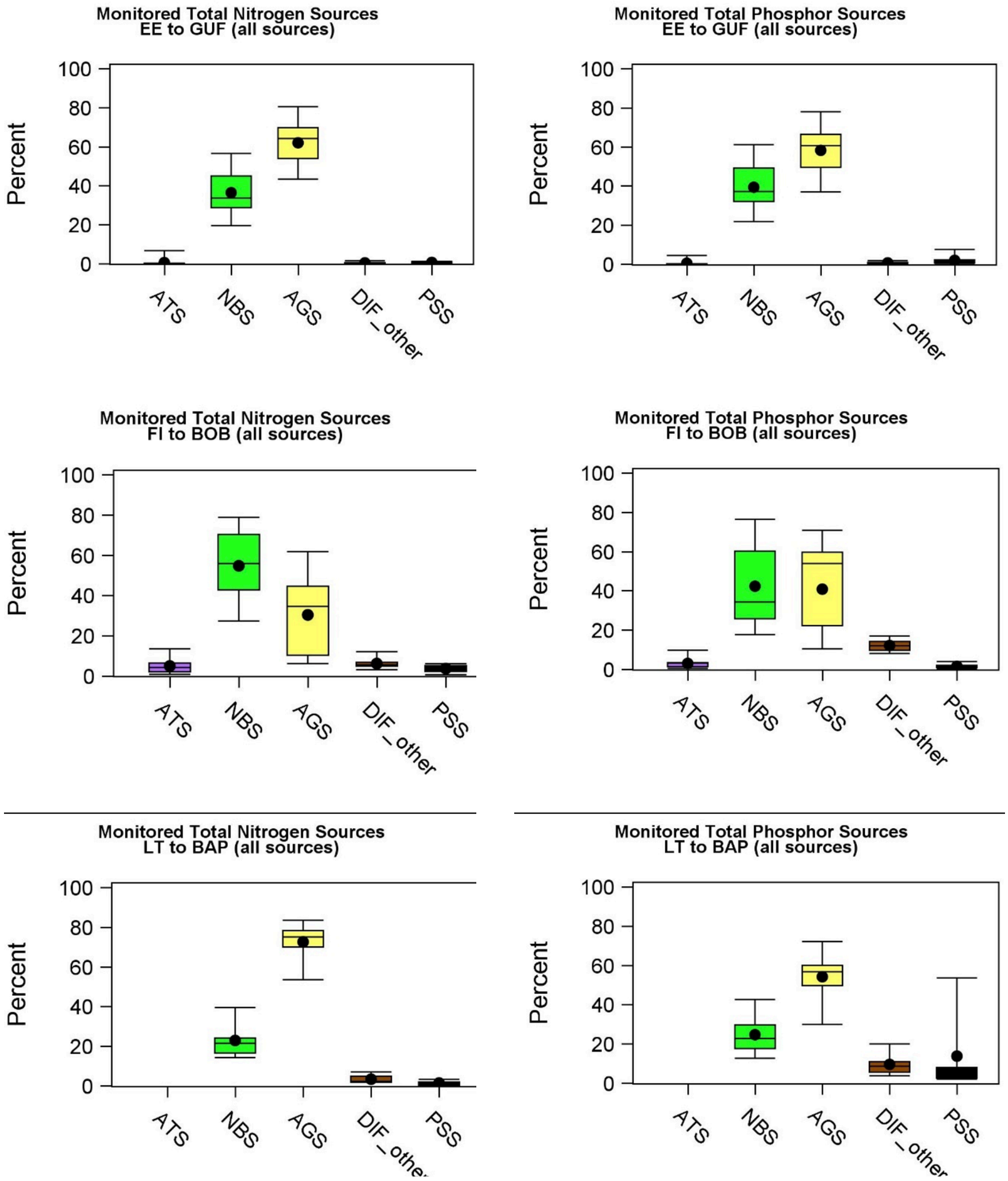


Figure 5.3. Continued. Box-Whisker plots of the share (percentages) for five sources of inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers to inland surface waters (before retention in inland surface waters) in German catchment to Baltic Proper, Danish catchment to the Sound and Western Baltic, Estonian catchment to Gulf of Finland, Finnish catchment to Bothnian Bay, Lithuanian catchment to Baltic Proper, Polish catchment to Baltic Proper, and Swedish catchment to Bothnian Sea. The sources are: ATS = atmospheric nitrogen inputs on inland surface waters, NBS = natural background sources, AGS = agricultural sources, DIF_other = other diffuse sources to inland waters in the catchment to the Baltic Sea, PSS = indirect point sources (municipal waste water treatment plants, industrial plants and aquaculture plants). See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

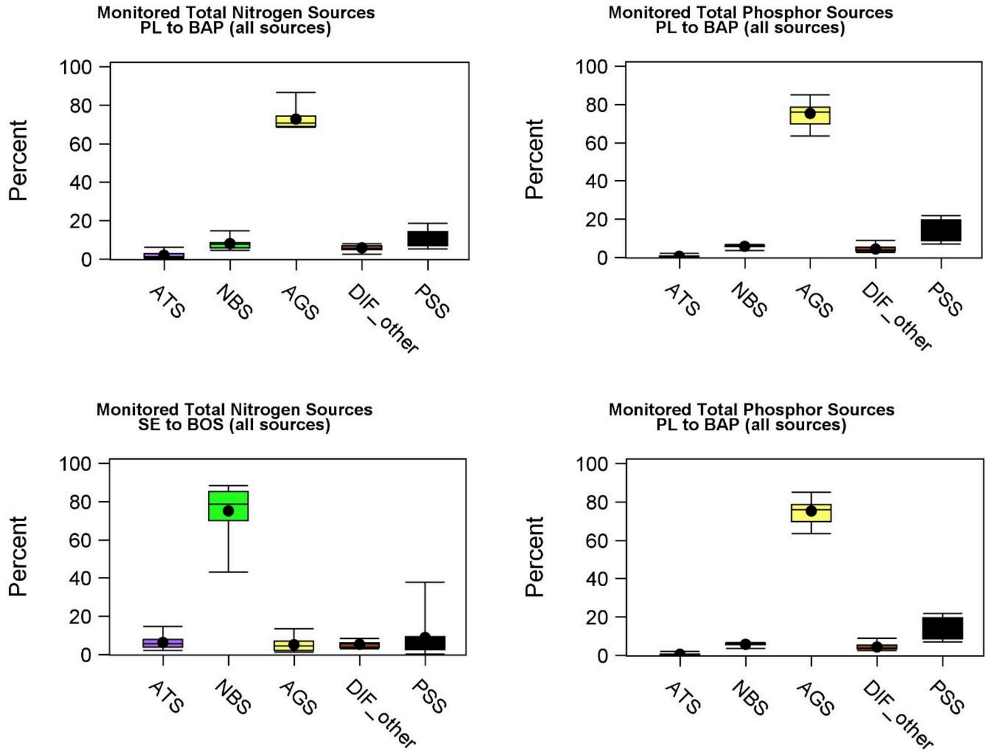


Figure 5.3. Continued. Box-Whisker plots of the share (percentages) for five sources of inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers to inland surface waters (before retention in inland surface waters) in German catchment to Baltic Proper, Danish catchment to the Sound and Western Baltic, Estonian catchment to Gulf of Finland, Finnish catchment to Bothnian Bay, Lithuanian catchment to Baltic Proper, Polish catchment to Baltic Proper, and Swedish catchment to Bothnian Sea. The sources are: ATS = atmospheric nitrogen inputs on inland surface waters, NBS = natural background sources, AGS = agricultural sources, DIF_other = other diffuse sources to inland waters in the catchment to the Baltic Sea, PSS = indirect point sources (municipal waste water treatment plants, industrial plants and aquaculture plants). See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

5.3. Apportionment of diffuse sources in monitored areas: atmospheric deposition on inland waters, natural background sources, agricultural sources, managed forestry, other diffuse sources, scattered dwellings, and storm waters

In this sub chapter we assess the importance of diffuse sources of total nitrogen and total phosphorus entering inland surface waters for the monitored part only of the catchment to the Baltic Sea.

The sources are divided in:

— Atmospheric deposition on inland surface waters (except for Russia)
— Natural background sources
— Agricultural sources (Denmark, Germany, Lithuania includes managed forestry in this category)
— Managed forestry (only Estonia, Finland, Poland, and Sweden quantify this source separately)
— Diffuse other sources (for Estonia it includes sum of scattered dwellings and storm waters, for Latvia is includes agricultural sources, scattered dwellings, storm waters and some transboundary inputs, Russia it includes atmospheric deposition, storm waters and some transboundary inputs)
— Scattered dwellings sources (except for Estonia, Latvia and Lithuania)
— Storm water sources (except for Estonia, Latvia, and Russia)

Data for Latvia is not comparable with other countries and not included in the country part of tables 5.4 and 5.5. Main findings from the tables:

Total nitrogen:

— Agricultural sources are the most important diffuse source of total nitrogen into inland surfaces waters in the monitored part of the catchments from Denmark (69%), Estonia (66%), Germany (87%), Lithuania (74%) and Poland (83%). Natural background sources are the most important source for Finland (47%), Russia (51%) and Sweden (70%).
— Managed forestry is only a minor source, ranging between

0.1% (Estonia) to 3.9% (Finland) of total nitrogen input into inland surface waters in the monitored catchments in these countries.

— Atmospheric deposition on inland surface waters is important in the monitored part of Finnish (12%), Swedish (10%) and German (6%) catchments. For the remaining countries the share is less than 2%.
— Scattered dwellings and storm waters are as overall total nitrogen sources of less importance, but for Russia and Poland it is important with shares of 18% and 7%, respectively.

Total phosphorus:

— Agricultural sources are the main total phosphorus source to inland surface waters in monitored part of the catchment of Denmark (49%), Estonia (63%), Finland (48%), Germany (61%), and Poland (85%).
— Natural background sources are the most important source in Russia (43%) and Sweden (59%).
— Managed forestry is a source of minor importance in the four countries quantifying it, ranging from 0.3% for Estonia to 5.2% for Finland.
— The proportion of total phosphorus inputs to inland surface waters in monitored part of the catchment is higher for scattered dwellings and storm waters that the corresponding shares for total nitrogen. The shares for total phosphorus are for Russia 28%, Germany 23%, and Denmark 16%. In Poland these sources have the lowest share with only 6%.

Table 5.4. Shares (in percentages) for diffuse sources of total nitrogen (TN, tonnes) into inland surface water in monitored part of the Baltic Sea catchment (before retention in inland surface waters) by basins in 2017 (Polish data from 2018). The righter most column, indicates the share of the total nitrogen inputs to the sub-basin of the corresponding total nitrogen inputs to the Baltic Sea. ATS = atmospheric nitrogen inputs on inland surface waters, NBS = natural background sources, AGS = agricultural sources, MFS = managed forestry sources, dif-other = other diffuse sources to inland waters in the catchment to the Baltic Sea, SCS scattered dwellings, SWS = storm water sources. Latvia is not included, they do not quantify all the source categories. "-" not quantified, the source included in Dif-other, besides for Denmark, Germany and Lithuania where MFS is included in AGS.

	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir	TN Indir
	ATS %	**NBS %**	**AGS %**	**MFS %**	**Dif-other %**	**SCS %**	**SWSn%**	**Total tons**	**Total of total %**
Bothnian Bay	5.3	70.4	19.6	3.5	0.0	1.1	0.1	51,086	7.2
Bothnian Sea	7.5	61.9	25.6	2.8	0.0	2.0	0.2	40,011	5.6
Archipelago	1.2	22.9	72.2	0.9	0.0	2.5	0.3	3,601	0.5
Baltic Proper	2.0	14.5	70.4	1.2	6.9	3.5	1.5	275,835	38.9
Gulf of Finland	5.8	48.7	24.2	1.3	6.0	14.0	0.1	150,232	21.2
Gulf of Riga	0.1	13.4	22.2	0.0	64.0	0.0	0.3	128,380	18.1
Western Baltic	3.9	15.7	77.4	0.0	0.0	1.0	2.0	15,578	2.2
Sound	3.9	32.8	57.4	0.0	0.0	1.7	4.2	1,388	0.2
Kattegat	10.5	46.0	39.8	0.8	0.0	2.0	0.9	42,871	6.0
Denmark	1.7	26.6	69.3	-	0.0	1.1	1.3	24,290	4.0
Estonia	2.0	31.4	66.0	0.1	0.4	-	-	23,532	3.9
Finland	12.2	46.8	35.1	3.9	0.0	1.8	0.2	99,739	16.6
Germany	6.2	3.2	86.9	-	0.0	0.6	3.1	14,626	2.4
Lithuania	0.0	22.9	74.4	-	0.0	-	2.6	76,207	12.7
Latvia									0.0
Poland	1.9	6.6	83.0	1.9	0.0	5.4	1.3	164,094	27.4
Russia	0.0	50.6	23.0	-	8.1	18.3	0.0	110,438	18.4
Sweden	9.7	70.4	15.3	1.8	0.0	2.3	0.5	87,045	14.5
BAS	**3.8**	**31.3**	**44.4**	**1.2**	**14.2**	**4.3**	**0.8**	**831,197**	**100**

Table 5.5. As table 5.4 but for total phosphorus (TP).

	TP Indir ATS %	TP Indir NBS %	TP Indir AGS %	TP Indir MFS %	TP Indir Dif-other %	TP Indir SCL %	TP Indir SWL %	TP Indir Total tons	TP Indir Total of total %
Bothnian Bay	4.6	60.3	25.3	5.5	0.0	4.0	0.3	2,128	6.8
Bothnian Sea	4.9	48.4	37.0	1.9	0.0	6.6	1.2	1,582	5.1
Archipelago	0.4	9.2	83.0	0.7	0.0	6.6	0.1	221	0.7
Baltic Proper	0.8	10.6	77.1	1.6	2.6	3.6	3.6	15,105	48.3
Gulf of Finland	2.6	40.6	26.5	1.3	4.3	24.8	0.0	7,555	24.2
Gulf of Riga	0.1	18.2	23.6	0.0	57.3	0.0	0.7	2,759	8.8
Western Baltic	2.0	19.0	61.2	0.0	0.0	6.0	11.9	524	1.7
Sound	0.5	23.8	38.4	0.0	0.0	8.3	29.0	51	0.2
Kattegat	3.2	45.0	38.2	0.3	0.0	7.3	5.9	1,320	4.2
Denmark	0.2	35.1	49.2	0.0	0.0	6.5	9.0	855	2.9
Estonia	2.4	34.3	62.5	0.3	0.5	0.0	0.0	583	2.0
Finland	6.2	34.3	47.5	5.2	0.0	6.6	0.1	4,439	15.3
Germany	4.2	12.5	60.5	0.0	0.0	2.6	20.2	470	1.6
Lithuania	0.0	27.3	62.3	0.0	0.0	0.0	10.4	1,645	5.7
Latvia									0.0
Poland	0.7	6.5	84.5	2.0	0.0	3.9	2.3	11,968	41.3
Russia	0.0	43.4	23.0	0.0	5.2	28.4	0.0	6,131	21.1
Sweden	5.2	58.8	24.9	0.5	0.0	6.6	4.0	2,909	10.0
BAS	1.7	25.7	52.2	1.5	7.3	8.6	2.9	35,751	100.0

Within the catchments to the Baltic Sea sub-basins there is a high variation between rivers in the importance of the individual diffuse sources as shown in examples in figure 5.4, e.g., the agricultural sources of total phosphorus in the catchment of Western Baltic in Germany and Kattegat in Denmark. Further it is remarkable to compare the Danish catchment to Kattegat with the corresponding Swedish one. In the Danish part agricultural sources range between approx. 30 and 80%, in the Swedish part between approx. 10 and 50%. It is explained in chapter 4.3 and 9.2 how to interpret a Box Whisker plot. In chapter 9, annex it is described where to find all Box Whisker plots.

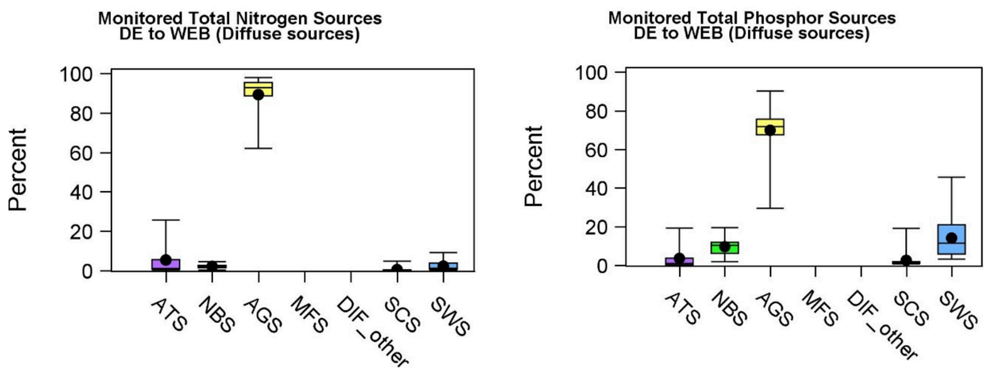


Figure 5.4. Box-Whisker plot of the share (percentages) for five sources of diffuse riverine inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers in German catchment to Western Baltic, Danish catchment to Kattegat, Finnish catchment to Bothnian Bay, Polish catchment to Baltic Proper and Swedish catchment to Kattegat in 2017 (Poland 2018). The sources are: ATS = atmospheric nitrogen inputs on inland surface waters, NBS = natural background sources, AGS = agricultural sources, MFS = managed forestry sources (Germany and Denmark include this source in AGS), DIF_other = other diffuse sources to inland waters in the catchment to the Baltic Sea, SCS = scattered dwellings sources, SWS = storm water sources. See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

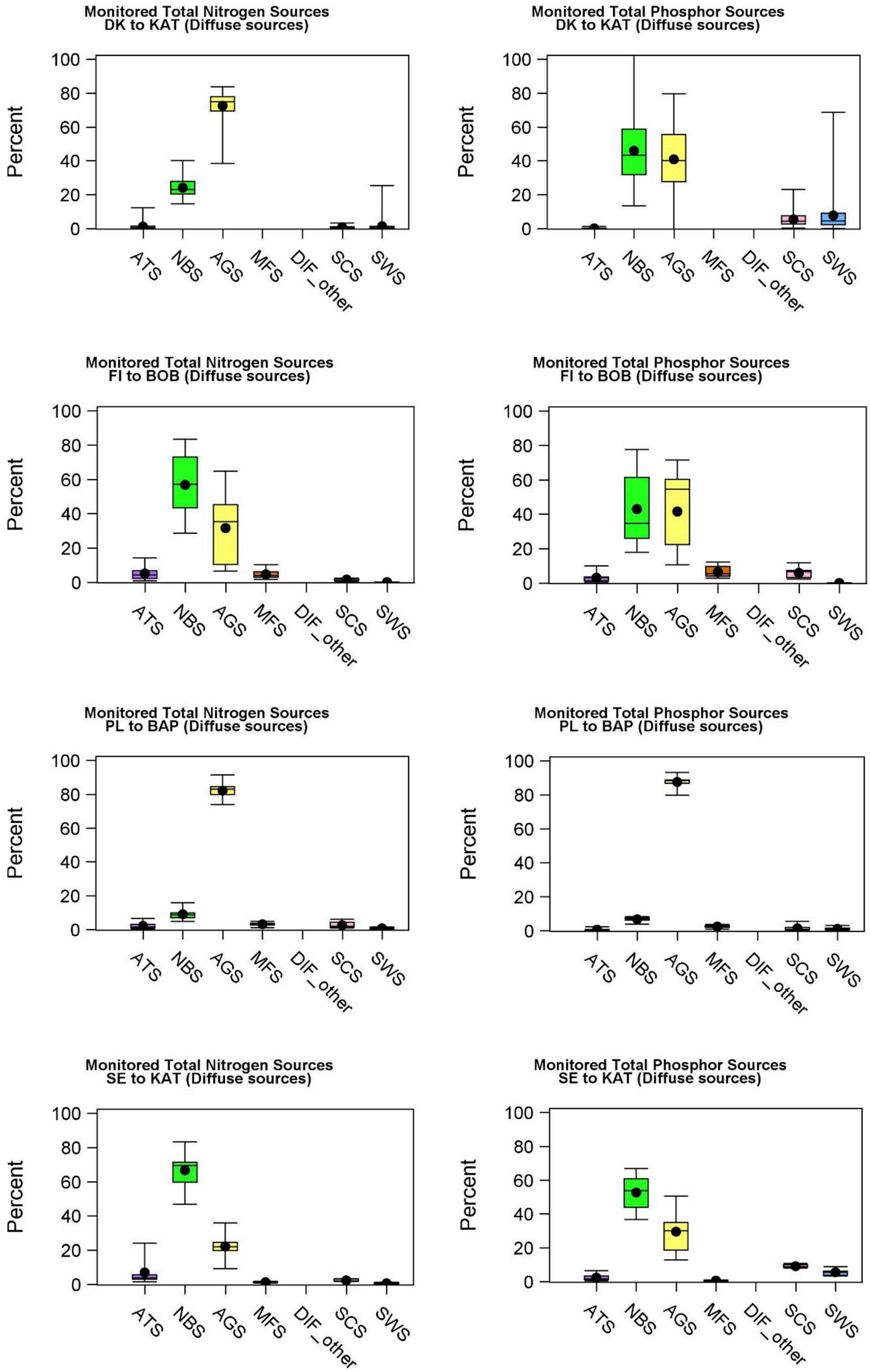


Figure 5.4. Continued. Box-Whisker plots of the share (percentages) for five sources of diffuse riverine inputs of total nitrogen (left column) and total phosphorus (right column) for monitored rivers in German catchment to Western Baltic, Danish catchment to Kattegat, Finnish catchment to Bothnian Bay, Polish catchment to Baltic Proper and Swedish catchment to Kattegat in 2017 (Poland 2018). The sources are: ATS = atmospheric nitrogen inputs on inland surface waters, NBS = natural background sources, AGS = agricultural sources, MFS = managed forestry sources (Germany and Denmark include this source in AGS), DIF_other = other diffuse sources to inland waters in the catchment to the Baltic Sea, SCS = scattered dwellings sources, SWS = storm water sources. See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

5.4. Apportionment of indirect wastewater sources for monitored areas: municipal treatment plants, industry, aquaculture plants, scattered dwellings, and storm waters

This sub-chapter presents results of assessing importance of all waste water sources discharging total nitrogen and total phosphorus into inland surface waters in the monitored part of the catchment to the Baltic Sea to evaluate which waste water sources are the most important (tables 5.6 and 5.7). In chapter 4.6 we assess inputs from these sources via rivers and direct inputs to the Baltic Sea with the load-oriented approach after retention in inland surface waters in the entire catchment.

We include scattered dwellings and storm water sources together with input from municipal waste water treatment plants, industrial sources, and aquacultural sources to evaluate all waste water sources. Estonia and Latvia have not reported these sources separately, and Russia have merged storm waters and atmospheric inputs under scattered dwellings. Therefore, we will only consider data from the following countries: Denmark, Finland, Germany, Lithuania, Poland, and Sweden. It should be noted that the assessment therefore also is incomplete for several sub-basins, particularly Gulf of Riga, but also to Baltic Proper and Gulf of Finland there are substantial shortages. Further, it should be noted that scattered dwellings in e.g., Poland includes settlements up to 2,000 person equivalents (PE) as compared with max. 30 PE in Denmark, indicating that assessment results are not fully comparable.

Total nitrogen:

- Municipal waste water treatment plants are the most important source of total nitrogen into inland surface waters for monitored catchment of Denmark (38%), Finland (57%), Germany (44%), Poland (53%) and Sweden (62%). For Lithuania storm waters (which might include scattered dwellings) are the most important source (50%).
- Losses from scattered dwellings is rather important in many countries as Denmark, Finland, Poland and Sweden with share of total nitrogen waste water inputs between 15 and 24 %.

Table 5.6. Shares (in percentages) for sources of waste water of total nitrogen (TN, tonnes) entering inland surface waters (before retention in inland surface waters) in monitored part of the catchment to the Baltic Sea by basin (upper part of the table) and by country (lower part of the table) in 2017 (Polish data from 2018). MWS = municipal waste water treatment plant sources, INS = industrial plant sources, AQS =aquacultural plant sources, SCS scattered dwellings sources, SWS = storm water sources. Estonia and Latvia do not quantify these sources separately and are therefore not included. "-" not quantified. Due to missing data from Estonia and Latvia, the amounts to Gulf of Riga and partly to Gulf of Finland are underestimated.

Basin/ Country	TN Indir MWS %	TN Indir INS %	TN Indir AQS %	TN Indir SCS %	TN Indir SWS %	TN Indir Total tons	TN Indir Total of total %
Bothnian Bay	54.3	27.7	2.3	14.8	1.0	3,709	3.8
Bothnian Sea	69.0	9.6	5.3	14.5	1.5	5,539	5.7
Archipelago	28.3	2.8	0.0	61.7	7.1	145	0.1
Baltic Proper	53.7	13.8	2.6	21.1	8.8	46,041	47.4
Gulf of Finland	29.9	8.8	0.3	60.8	0.3	34,605	35.6
Gulf of Riga	60.8	10.4	0.0	0.0	28.8	1,501	1.5
Western Baltic	42.9	0.1	6.4	17.1	33.6	925	1.0
Sound	39.7	0.0	0.0	17.0	43.2	135	0.1
Kattegat	54.2	13.2	4.6	19.1	8.8	4,482	4.6
Denmark	37.9	0.3	13.6	21.5	26.7	1,209	1.3
Estonia							0.0
Finland	57.1	21.1	1.7	18.0	2.0	9,991	10.4
Germany	44.0	15.5	0.0	6.6	33.9	1,332	1.4
Lithuania	44.3	5.5	0.1	0.0	50.2	4,015	4.2
Latvia							0.0
Poland	52.7	14.4	3.2	24.0	5.6	36,835	38.4
Russia	26.3	5.3	0.0	68.4	-	29,599	30.8
Sweden	62.2	16.0	3.1	15.4	3.3	13,016	13.6
BAS	**45.4**	**11.7**	**2.0**	**34.3**	**6.6**	**103,810**	**100**

— Industry is also a rather important source in Finland, Germany, Poland, and Sweden with shares ranging between 14 and 21 %.
— Total nitrogen inputs from aquaculture is an important source in Denmark, with 14% of total nitrogen waste water inputs.

Total phosphorus:

— Storm water sources are - maybe surprisingly - the most important source of total phosphorus inputs to inland surface waters in monitored part of the catchment in Denmark (42%), Germany (58%), and Lithuania (54%).
— For two countries scattered dwellings are the most important waste water source: Finland (64%), and Sweden (38%), but it is also important in Denmark (31 %).
— Only for Poland municipal waste water treatment plants are the most important waste water phosphorus sources with 68% of total inputs, but it is also important for the other five countries with shares ranging from 14 % (Finland to 43% (Lithuania).
— Waste water from industrial plants accounts for 18% in Finland and 10% in Sweden, but only between 0.2 and 4.3% in the remaining four countries.
— Total phosphorus inputs from aquaculture are overall only a minor source in the countries with these activities ranging from 0.2% for Lithuania to 9% for Sweden (no aquaculture in German catchments).

Table 5.7. As table 5.6 but for total phosphorus (TP).

Basin/ Country	TP Indir	TP Indir	TP Indir	TP Indir	TP Indir	TP Indir	TP Indir
	MWS %	INS %	AQS %	SCS %	SWS %	Total tons	Total of total %
Bothnian Bay	14.9	6.8	8.1	66.0	4.2	130	1.7
Bothnian Sea	17.8	5.1	17.0	50.8	9.3	206	2.7
Archipelago	6.4	0.4	0.0	92.3	0.9	16	0.2
Baltic Proper	63.0	4.3	4.6	14.2	13.9	3,882	50.3
Gulf of Finland	20.2	14.9	0.3	64.6	0.1	2,906	37.6
Gulf of Riga	74.0	11.8	0.3	0.0	13.8	148	1.9
Western Baltic	25.4	0.0	0.3	24.9	49.3	126	1.6
Sound	21.1	0.0	0.0	17.6	61.3	24	0.3
Kattegat	18.7	13.0	6.0	34.4	27.9	282	3.6
Denmark	23.0	0.2	4.0	30.6	42.2	183	2.4
Estonia	65.2	34.8	0.0	0.0	0.0	3.9	0.1
Finland	13.7	17.6	3.9	63.9	0.9	461	6.1
Germany	30.6	4.3	0.0	7.4	57.7	164	2.2
Lithuania	43.3	2.8	0.2	0.0	53.8	318	4.2
Latvia							0.0
Poland	68.4	3.4	5.4	14.2	8.6	3,274	43.1
Russia	20.6	14.5	0.0	64.9	0.0	2,685	35.3
Sweden	19.7	10.3	9.1	38.1	22.8	507	6.7
BAS	**40.3**	**8.4**	**3.1**	**36.2**	**12.1**	**8,521**	**100**

Within the catchments to the Baltic Sea sub-basins there is a high variation between monitored rivers in the importance of the individual waste water sources as shown in examples in figure 5.5, e.g., industrial sources of total nitrogen in the catchment of Sweden to Bothnian Bay ranging between approx. 20 and nearly 80% and for total phosphorus in the Polish catchment to Baltic Proper aquaculture sources range from 0 to nearly 90% of total inputs. It is explained in 9.2 how to interpret a Box Whisker plot. In chapter 9, annex is described where to find all Box Whisker plots.

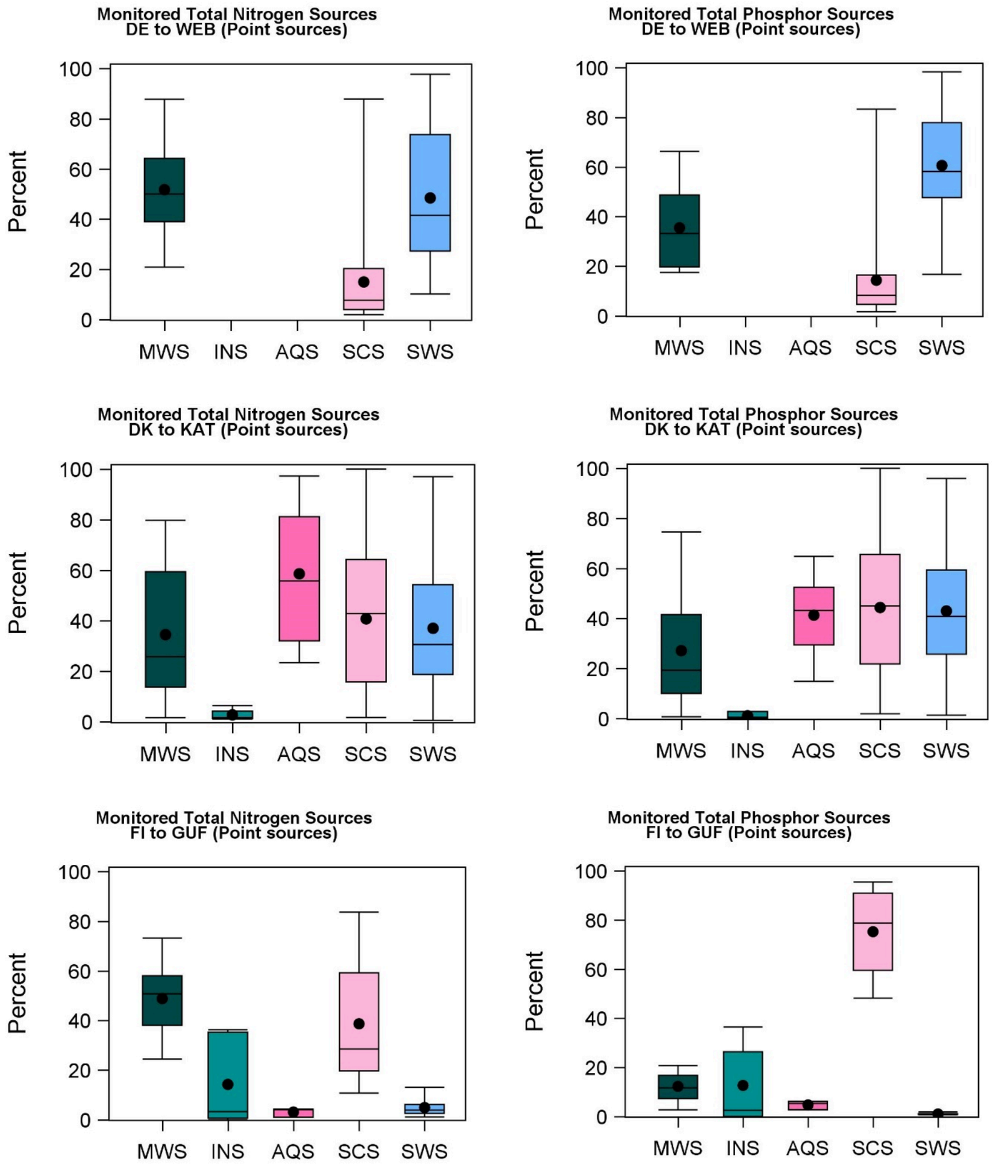


Figure 5.5. Box-Whisker plots of the share (percentages) for the five sources of waste water inputs into inland surface waters of total nitrogen (left column) and total phosphorus (right column) for monitored rivers (indirect waste water sources) in German catchment to Western Baltic, Danish catchment to Kattegat, Finnish catchment to Gulf of Finland, Polish catchment to Baltic Proper, and Swedish catchment to Bothnian Bay in 2017 (Poland 2018). MWS = municipal waste water treatment plant sources, INS = industrial plant sources, AQS =aquacultural plant sources, SCS scattered dwellings sources, SWS = storm water sources. See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

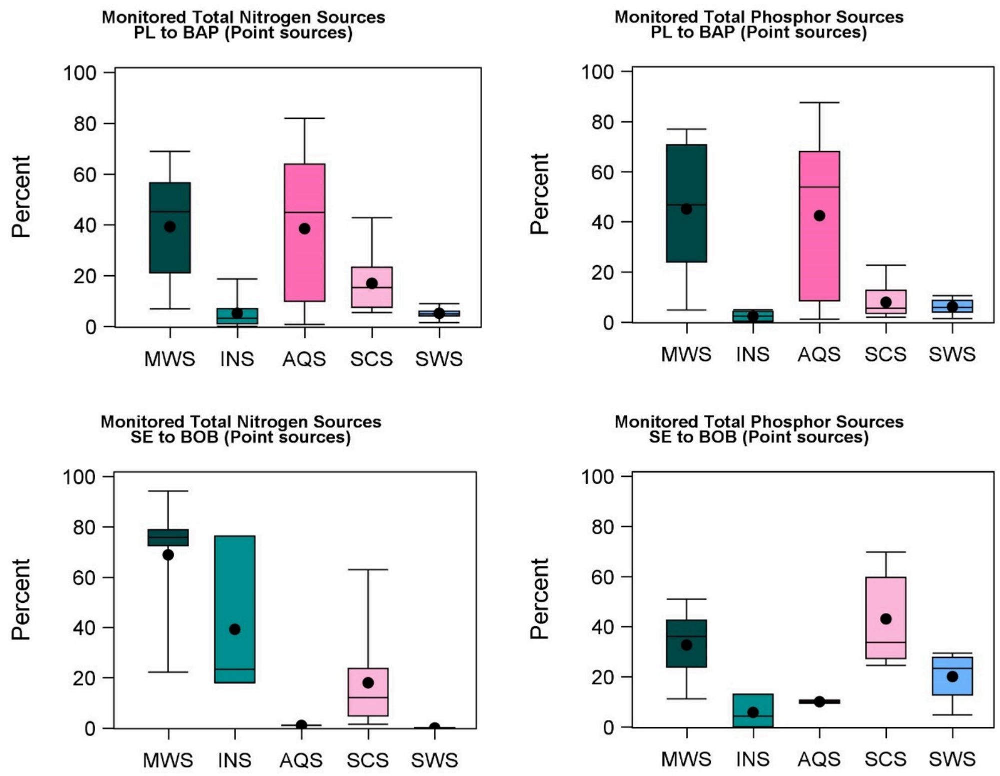


Figure 5.5. Continued. Box-Whisker plots of the share (percentages) for the five sources of waste water inputs into inland surface waters of total nitrogen (left column) and total phosphorus (right column) for monitored rivers (indirect waste water sources) in German catchment to Western Baltic, Danish catchment to Kattegat, Finnish catchment to Gulf of Finland, Polish catchment to Baltic Proper, and Swedish catchment to Bothnian Bay in 2017 (Poland 2018). MWS = municipal waste water treatment plant sources, INS = industrial plant sources, AQS =aquacultural plant sources, SCS scattered dwellings sources, SWS = storm water sources. See chapter 9.2 for how to interpret the figure. Number of rivers in the catchment are in table 1.6.

6. Development in importance of main pathways

In this chapter we compare the main pathways for total nitrogen and total phosphorus inputs to the Baltic Sea for Baltic Sea sub-basins and HELCOM contracting parties. At the highest level of integration of sources and with the load-oriented apportionment approach these can also be seen in results of five PLC periodic assessments (PLC-3 to PLC-7).

a. For TN the shares of total input to the Baltic Sea of riverine, direct point sources and atmospheric deposition in 1995 (PLC-3), 2000 (PLC-4), 2006 (PLC-5), 2014 (PLC-6) and 2017 (PLC-7) are shown. Atmospheric inputs from shipping and non-HELCOM countries are not included in this chapter
b. For TP assessment results of riverine and direct input by country, and for atmospheric deposition by basin in 1995, 2000, 2006, 2014 and 2017 (PLC-7) are shown. Atmospheric phosphorus deposition is not included by countries because it is not possible to allocate this input to specific sources.

It should be underlined that results from former periodic assessments of PLC projects are used, and the results are based on the former published results of periodic assessments (HELCOM, 1998; HELCOM, 2004; HELCOM, 2011; HELCOM, 2018 and Svendsen & Tornbjerg, 2019), and we have not made any recalculations due to later revisions of the atmospheric deposition data from EMEP, re-reporting of older data from some countries etc.

Weather conditions during individual years influence the assessment results – as described in chapter 1, because source apportionment data are not flow/weather normalized. It is recommended for the PLC-8 periodic assessment to recalculate former periodic assessments at least for the main pathways. For this aggregated level of sources, it would be possible to use normalized riverine and atmospheric depositions data or use assessments toward reaching the nutrient input ceilings (NIC assessments).

It is important to note as mentioned in chapter 1, that countries are not using fully comparable methodologies, particularly not for the earlier periodic assessments, and that for PLC-6 German and Polish data are from 2012 and for PLC-7 Polish data are from 2018 but from 2017 for the other countries and for atmospheric deposition.

Tables 6.1 summarizes per periodic assessment total nitrogen inputs by country and by basin. Atmospheric nitrogen deposition by Contracting Parties is included, but the total inputs to the sub-basins are not including nitrogen deposition from shipping or from non HELCOM countries. Sum of riverine and direct inputs per country are shown for total phosphorus, and for sub-basin are also atmospheric deposition of total phosphorus included. As flow plays an important role when input data are not normalized table 6.2 provides information on how much the flow deviated to the basin for the years where total nitrogen and total phosphorus inputs have been used for the periodic assessment. The index shows how many percentages flow was higher or lower than the average of 1995-2018 for a specific basin, e.g. for PLC-7 flow to Gulf of Finland is 10 % higher than the average, but for the same year it is more than 16% higher to Kattegat.

Flow characteristics for the periodic assessments:

— PLC-3: Overall flow is higher than average (for six of seven sub-basins and 6% for the Baltic Sea)
— PLC-4: Overall flow is higher than average (four and seven sub-basins and 13 % for the Baltic Sea)
— PLC-5 has low flow for six of seven sub-basins and one with average flow, and with flow to Baltic Sea more than 12% lower than average.
— PLC-6: Flow is 9% lower to Baltic Sea and with 6 sub-basins having lower flow, but Germany and Poland reported 2012 data, when flow to Baltic Proper was only 4% under average and flow to Danish Straits 1% above the average.
— PLC-7: Overall flow is higher than average (five of seven sub-basins and 5% for Baltic Sea), although Poland reports data in 2018, when flow to Baltic Proper is 17% below average.

It is important to take into account that within a calendar year there are periods with high and low flow conditions. If the high or low flow continues for a longer period, this will affect the importance for riverine total nitrogen and total phosphorus inputs and might also influence nutrient inputs to the sea the following year. If we use a deviation of ±10% from the average flow as high/

low flow and ±20% as very high/low flow, we can characterize the periodic assessments by:

- PLC-3: High flow to Bothnian Sea and Danish Straits (very high).
- PLC-4: Very high flow to Bothnian Bay, Bothnian Sea, Kattegat, and high to Baltic Sea.
- PLC-5: Very low flow to Gulf of Riga and low flow to Bothnian Bay, Baltic Proper, Gulf of Finland, and Baltic Sea.
- PLC-6: Extreme low flow to Gulf of Riga (35% under the average), low flow to Bothnian Bay, and Baltic Proper (but not for Poland in 2012), but high flow to Kattegat.
- PLC-7: Extreme high flow to Gulf of Riga (37% over the average), high flow to Baltic Proper (but not for Poland where flow is low in 2018), and high flow to Danish Straits, but low flow to Kattegat.

Despite variating flow the inputs of particularly total phosphorus decrease to the Baltic Sea from the first periodic assessment to the PLC-7. To allow for a comparison that partly can smooth out the influence of variating flow conditions (via rivers and direct point source inputs), but not take into account that also atmospheric deposition depends upon weather conditions, in the bottom row in table 6.1 a flow weighted total nitrogen and total phosphorus concentration for the Baltic Sea is calculated. This is a rough estimate particularly for PLC-6 and PLC-7 where one or two countries have reported for another year than the remaining countries – but it provides a good idea of the overall tendency for the Baltic Sea. For total phosphorus there is a reduction from PLC-3 to PLC-7 in the order of 30% which also is indicated in the annual Baltic Sea Environmental fact sheet on waterborne inputs (Svendsen & Gustafsson, 2019).

It seems that the highest reductions in total phosphorus inputs take place from Poland and Russia. The high phosphorus inputs for PLC-7 from Lithuania and Latvia might unfortunately reflect that these countries in PLC-7 include transboundary inputs from upstream countries, which is not the case in former PLC's. The same pattern is valid to Baltic Proper (decrease) and Gulf of Riga (increase).

Table 6.1. Total nitrogen and total phosphorus inputs to the Baltic Sea via riverine, direct and atmospheric inputs for five period assessments (PLC-3 in 1995, PLC-4 in 2000, PLC-5 in 2006, PLC-6 in 2014 (Germany and Poland in 2012) and PLC-7 in 2017 (Poland in 2018)). For total nitrogen atmospheric inputs on the Baltic Sea sub-basins are included in country numbers, but this is not possible for total phosphorus. Atmospheric nitrogen deposition from shipping, and non HELCOM countries are not included in the inputs to the basin and to the Baltic Sea (see e.g. table 2.3). Bottom line in the table presents the discharge weighted concentrations for total nitrogen and total phosphorus (total inputs of total nitrogen and total phosphorus to the Baltic Sea divided with the corresponding total flow the given year.

Country/ Basin	Total nitrogen (tonnes)					Total phosphorus (tonnes)				
	1995	2000	2006	2014	2017	1995	2000	2006	2014	2017
Denmark	85,611	72,102	63,925	56,630	57,836	2,585	1,903	1,753	1,802	1,521
Germany	84,212	77,904	70,392	61,396	71,285	701	603	600	520	889
Estonia	25,760	28,011	28,150	25,011	34,225	819	703	790	413	757
Finland	84,220	98,493	103,058	82,484	83,281	3,813	3,988	3,915	3,255	3,721
Lithuania	56,515	42,080	49,244	56,426	103,250	1,893	1,989	1,239	1,076	2,571
Latvia	56,570	50,283	52,297	51,970	116,517	1,194	1,378	970	1,263	3,290
Poland	262,159	201,049	207,057	169,941	156,838	14,846	11,490	11,651	12,776	6,976
Russia	101,300	95,203	130,497	92,467	106,197	9,773	8,656	8,441	4,449	3,974
Sweden	133,681	133,804	131,049	109,596	106,316	4,219	3,601	3,700	3,226	2,664
Bothnian Sea	83,538	91,150	88,217	72,851	65,325	2,611	2,577	2,487	2,086	2,337
Bothnian Bay	57,687	61,514	67,364	53,903	55,964	3,034	2,605	2,573	2,284	2,573
Baltic Proper	520,298	428,610	438,245	381,965	399,394	19,523	16,095	16,244	17,099	12,424
Gulf of Finland	127,421	124,336	158,086	112,163	137,219	10,245	9,262	8,616	4,374	4,877
Gulf of Riga	96,347	89,921	87,695	82,657	139,332	1,984	2,279	2,481	2,316	3,432
Danish Straits	80,822	69,272	62,311	54,523	61,313	2,065	1,405	1,325	1,383	1,355
Kattegat	90,810	84,107	81,329	67,763	65,216	1,701	1,549	1,818	1,406	1,456
Baltic Sea	**1,056,922**	**948,910**	**983,247**	**825,825**	**923,763**	**41,163**	**35,771**	**35,545**	**30,949**	**28,452**
Concentration BAS (mg/L)	**2.0**	**1.7**	**2.3**	**1.8**	**1.8**	**0.078**	**0.063**	**0.082**	**0.068**	**0.054**

Table 6.2. Index for flow to Baltic Sea sub-basins, where index 100 = average of flow to the basins and the Baltic Sea during 1995-2018. This average of flow (in m3 s-1) is bottom line of the table. Index is given for years with periodic assessment. Germany and Poland used 2012 for their PLC-6 assessment, and Poland used 2018 for the PLC-7 periodic assessment. Abbreviations for sub- basins are in table 1.2.

Year	BOB	BOS	BAP	GUF	GUR	DS	KAT	BAS
PLC-3: 1995	94.4	110	108	107	107	120	109	106
PLC-4: 2000	126	137	106	91.0	97.1	98.6	122	113
PLC-5: 2006	84.0	97.0	88.3	80.7	79.8	97.3	100	87.6
PLC-6: 2012	129	125.7	95.6	120	132	101	115	118
2014	89.7	91.6	85.5	97.9	65.3	92.1	114	91.0
PLC-7: 2017	104	90.6	112	108	137	110	83.7	105
2018	89.1	90.4	83.2	111	69.0	89.0	78.9	90.9
1995-2018	**3,456**	**2,912**	**3,474**	**3,535**	**1,083**	**216**	**1,078**	**15,755**

Figure 6.1 includes information on the three main pathways: riverine inputs, direct point source inputs and atmospheric deposition for total nitrogen and riverine and direct point source inputs for total phosphorus by country as percentages of the total inputs by the countries given in table 6.1. Figure 6.2 provides the corresponding information as figure 6.1 but by sub-basin, but include atmospheric phosphorus deposition, and percentages are for the corresponding total inputs in table 6.1. Taking into account the fact that with high flow the shares of riverine inputs will be higher and with low flow lower than on average conditions, we can make some overall observation on the shares of the main pathways by country:

- Riverine inputs are the main pathways of total nitrogen and total phosphorus with exception for Germany for nitrogen, where atmospheric deposition is the main pathway.
- From all countries except Poland the share of atmospheric nitrogen deposition has decreased slightly (see dot 3 in the paragraph commenting figure 6.2). Poland reported PLC-7 in 2018, when flow was low, and riverine inputs are lower that with average flow conditions. This will increase the share of direct point sources inputs and atmospheric deposition. Overall atmospheric inputs have been reduced quite markedly from many countries to the Baltic Sea (Svendsen et el., 2022), but as there also are measures taken against waste water emissions it is not necessarily easy to interpret how the shares for the three shown pathways develop since PLC-3.
- The share of total nitrogen from direct point sources have decreased from all countries compared with PLC-3 and PLC-4 – and in the Core indicator on nutrients inputs it is also shown that inputs from direct point sources have decreased significantly since 1995 for both total nitrogen and total phosphorus (Figure 6.3, Svendsen et al., 2022). It is very clear that the share of total phosphorus from direct point sources are reduced markedly from all countries except Sweden.
- For six countries the share of total phosphorus from direct point sources is less than 5%, but higher than 10 % for Denmark (17%), Russia (10%) and Sweden (13%). IN PLC-5 (1995) more than 35% of total phosphorus from Denmark entered as direct point sources, and from Latvia the share was also very high (29%). Since 1995 many measures have been implemented and resources invested to clean waste waters from households and industries and also scattered dwellings, which have reduced input from direct point sources for both total nitrogen and total phosphorus, but also several measures have been taken to reduce waste water input to inland surface waters. Particularly Sweden but also Finland have taken most measures on direct point source losses before 1995, and their direct point sources inputs of total nitrogen and total phosphorus has therefore decrease less than from other countries.

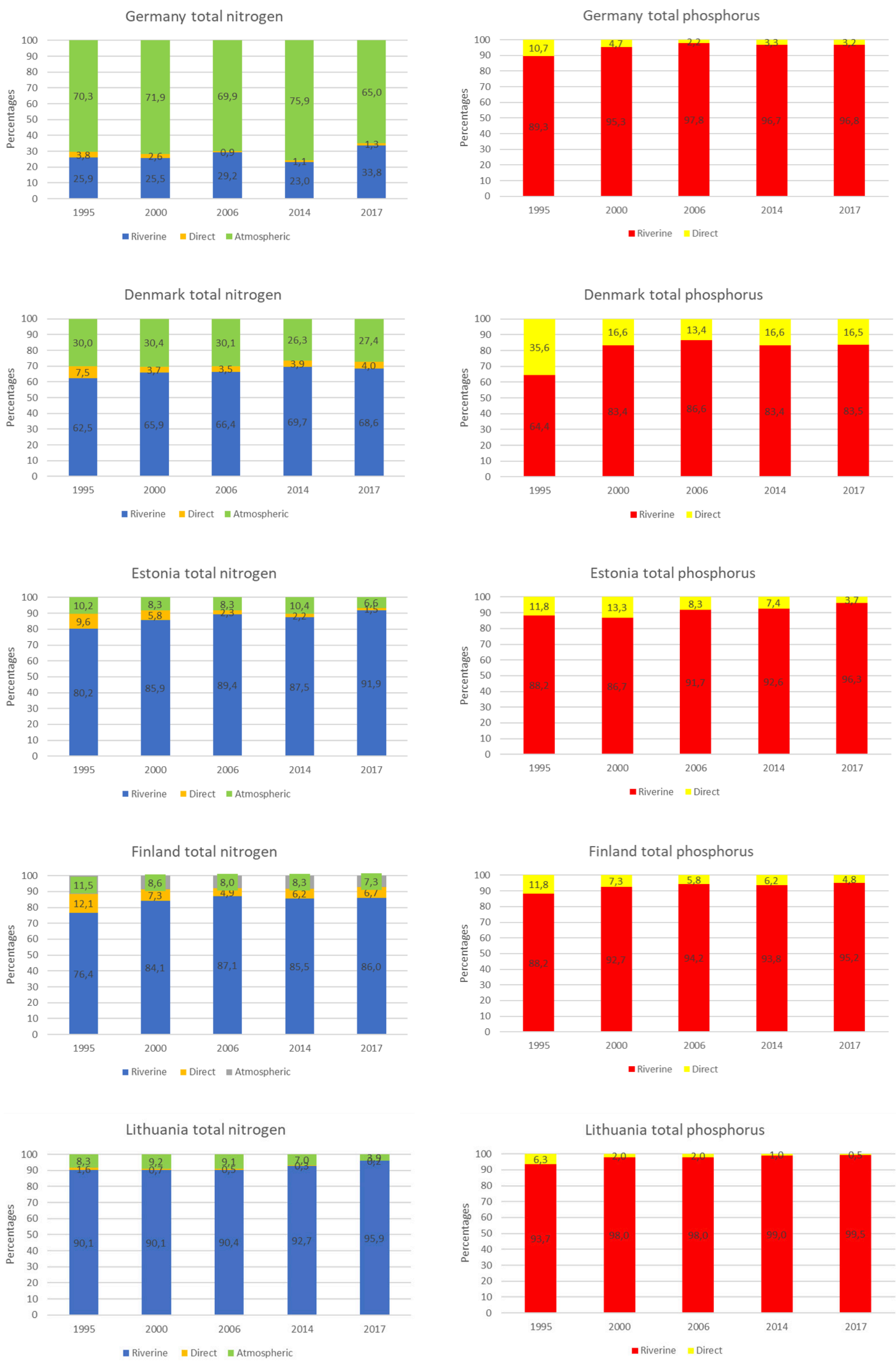


Figure 6.1. Shares (%) of pathways of total nitrogen inputs (left column) and total phosphorus inputs (right column) to the Baltic Sea for five periodic assessments (PLC-3 in 1995, PLC-4 in 2000, PLC-5 in 2006, PLC-6 in 2014 (for Germany and Poland 2012) and PLC-7 in 2017 (for Poland 2018). Nitrogen pathways are riverine inputs, direct point sources and atmospheric deposition, while phosphorus pathways are riverine inputs and direct point sources. The percentages are of the corresponding total inputs in table 6.1.

Figure 6.1. Continued. Shares (%) of pathways of total nitrogen inputs (left column) and total phosphorus inputs (right column) to the Baltic Sea for five periodic assessments (PLC-3 in 1995, PLC-4 in 2000, PLC-5 in 2006, PLC-6 in 2014 (for Germany and Poland 2012) and PLC-7 in 2017 (for Poland 2018). Nitrogen pathways are riverine inputs, direct point sources and atmospheric deposition, while phosphorus pathways are riverine inputs and direct point sources. The percentages are of the corresponding total inputs in table 6.1.

For sub-basins we make following overall observations on the shares of the 3 sources:

— Overall, the same patterns as for countries are reflected in the development of shares to the Baltic Sea sub-basins.
— Riverine inputs are the most important pathway for total nitrogen and total phosphorus to all sub-basins to the Baltic Sea in all PLC assessments, particularly for total phosphorus. The second most important pathway is atmospheric deposition for nitrogen to all basins. For total phosphorus in PLC-7 for six sub-basins atmospheric deposition of phosphorus is the second most important pathway. On the other hand, in PLC-3 total phosphorus from direct point sources was the second most important pathway to six basins, reflecting the marked decrease in inputs of total phosphorus from direct point sources to the basins.
— The share for atmospheric nitrogen deposition decreases for five to six basins but don't change for the remaining, despite the overall reduction in atmospheric inputs (Svendsen et al, 2022). But it should be noted that we have not included total nitrogen deposition due to ship emissions or emissions from non-HELCOM countries. Further, total nitrogen deposition in the former PLCs is based on older EMEP deposition calculations, and we know that the revised calculation from EMEP for the period 1995-2012 increased total nitrogen deposition with at least 30 % compared with the numbers used in PLC-3 to PLC-6 – making the shares for atmospheric total nitrogen deposition in the original PLC-3 to PLC-6 markedly underestimated.
— Total phosphorus deposition is calculated as a fixed rate per km^2 sea surface (5 kg P km^{-2}), why the share from atmospheric deposition of total phosphorus gradually will increase when inputs of total phosphorus from direct point sources (and riverine inputs) decreases.
— The share of direct point source inputs for total nitrogen decreases particularly to Gulf of Finland, Danish Straits and Kattegat.

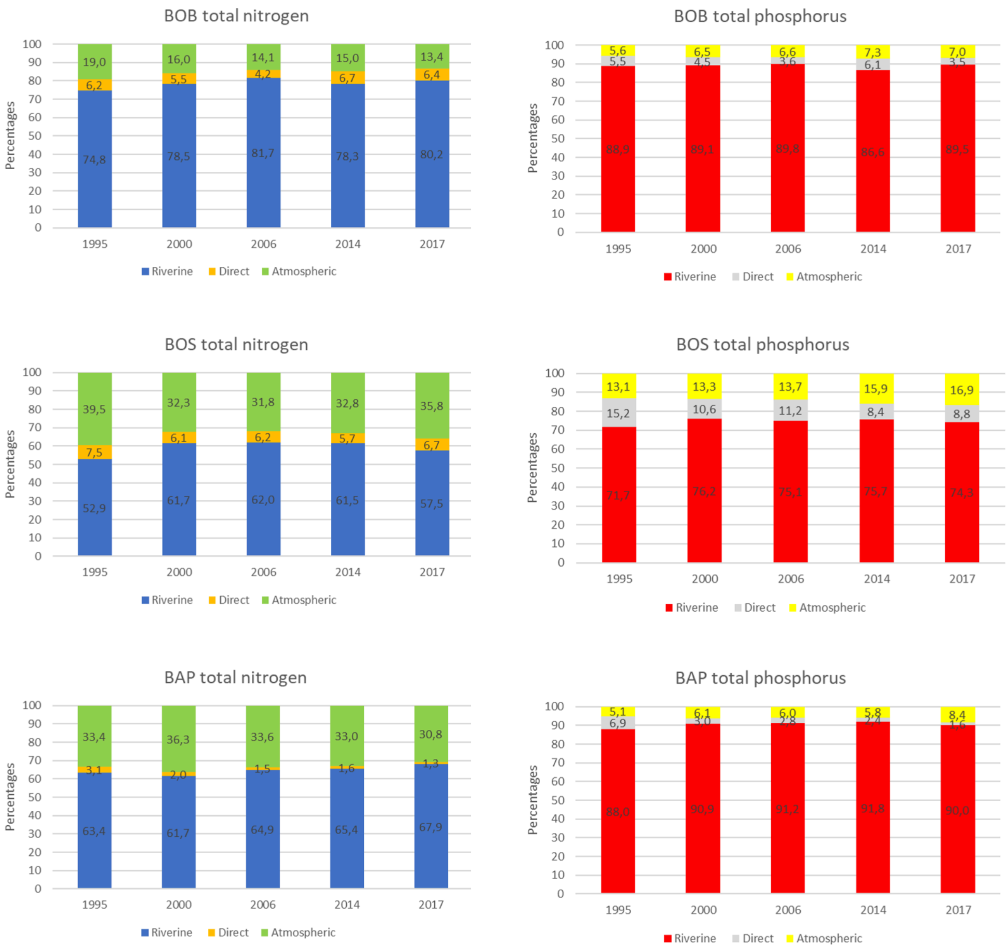


Figure 6.2. Shares (%) of sources of total nitrogen inputs (left column) and total phosphorus (right column) to the Baltic Sea for five periodic assessments (PLC-3 in 1995, PLC-4 in 2000, PLC-5 in 2006, PLC-6 in 2014 (for Germany and Poland 2012) and PLC-7 in 2017 (for Poland 2018).Total nitrogen and total phosphorus pathways are riverine, direct point sources and atmospheric deposition. The percentages are of the corresponding total inputs in table 6.1. Atmospheric deposition from shipping and non-HELCOM countries are not included.

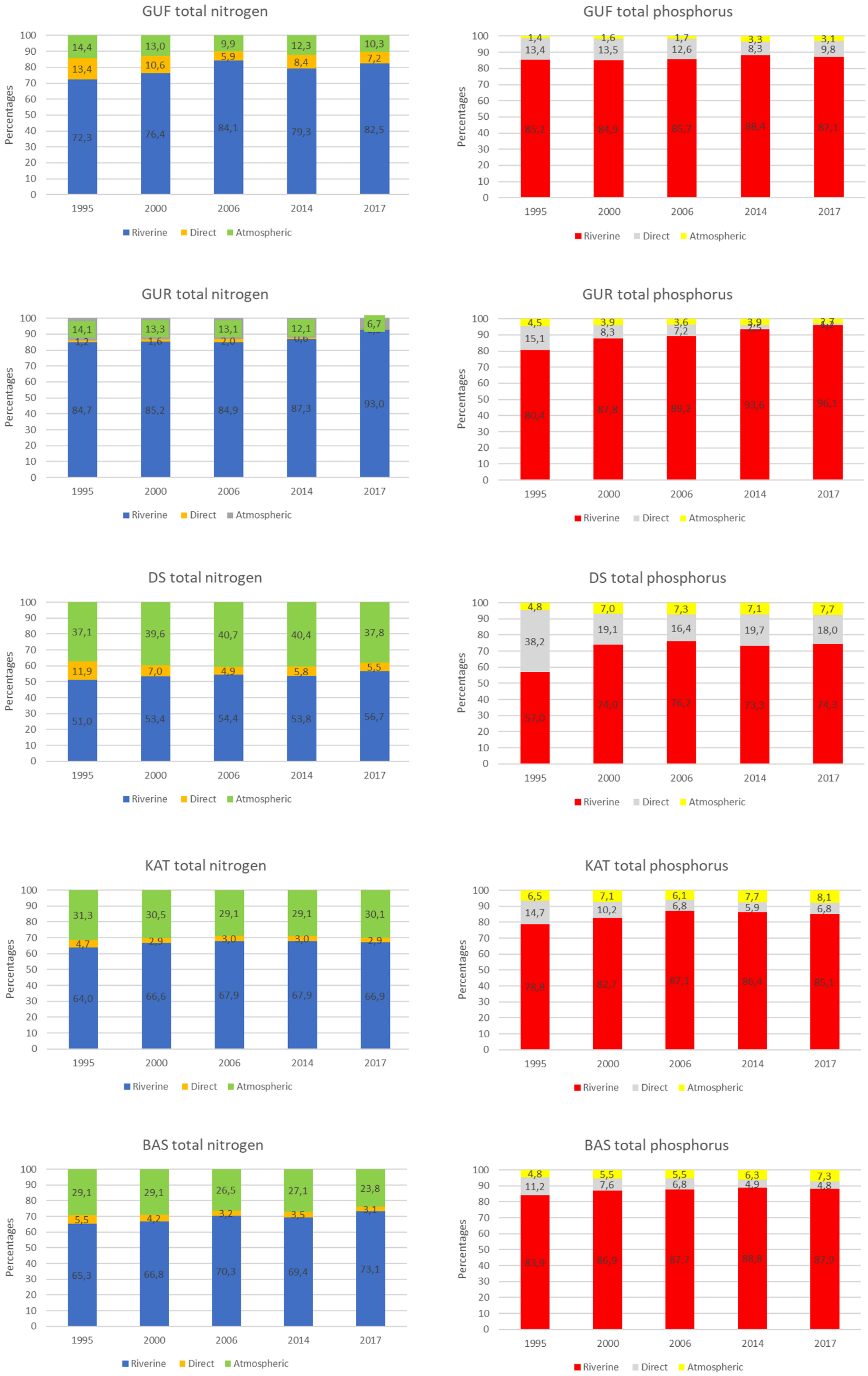
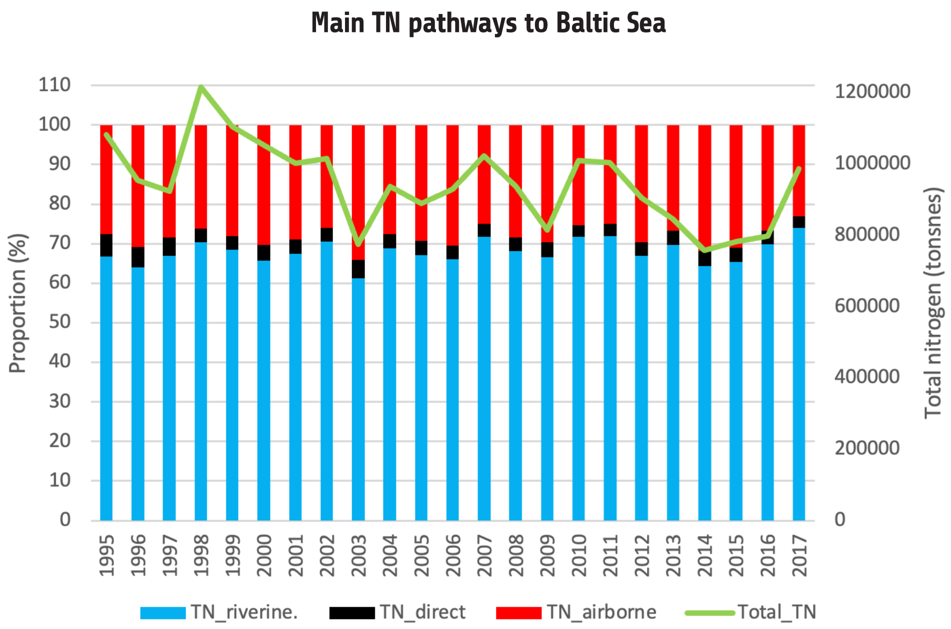


Figure 6.2. Continued. Shares (%) of sources of total nitrogen inputs (left column) and total phosphorus (right column) to the Baltic Sea for five periodic assessments (PLC-3 in 1995, PLC-4 in 2000, PLC-5 in 2006, PLC-6 in 2014 (for Germany and Poland 2012) and PLC-7 in 2017 (for Poland 2018).Total nitrogen and total phosphorus pathways are riverine, direct point sources and atmospheric deposition. The percentages are of the corresponding total inputs in table 6.1. Atmospheric deposition from shipping and non-HELCOM countries are not included.



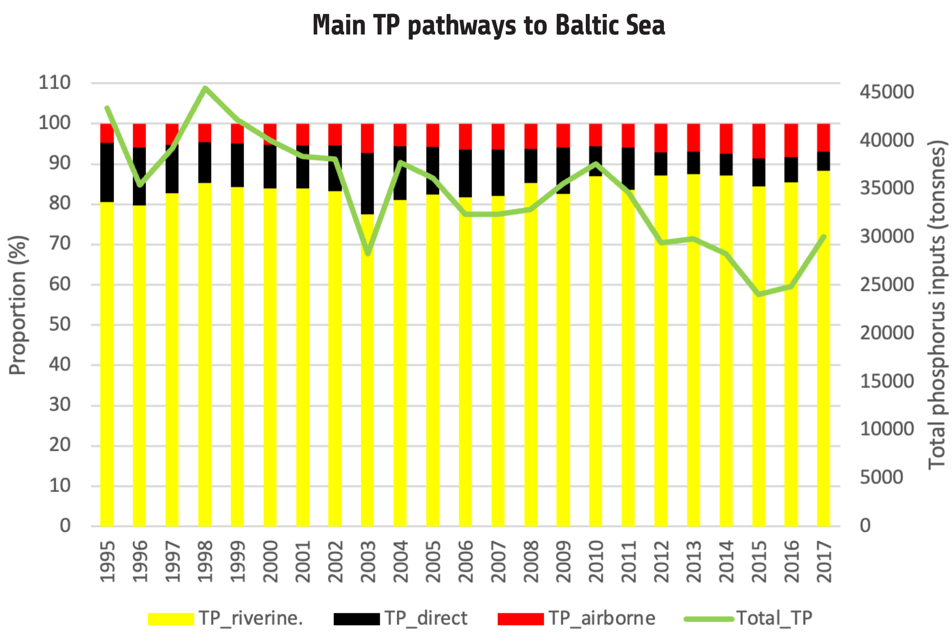


Figure 6.3. Main pathways (riverine inputs, direct point source inputs and atmospheric deposition) for annual total nitrogen (TN – upper figure) and total phosphorus TP – lower figure) in percentages of annual total nitrogen and total phosphorus inputs which are shown on the right y-axes, respectively, to the Baltic Sea during 1995–2017.

7. Conclusions, recommendations for next source apportionment assessment

7.1. Conclusions

Below some main conclusions are summarized, based on the assessment results presented in chapters 2-6 and focused on the results from the load-oriented source apportionment:

— The PLC-7 source apportionment assessment is by far the most comprehensive periodic pollution load source apportionment performed. We have managed to assess the main sources to all Baltic Sea sub-basins and for all HELCOM countries on total nitrogen and total phosphorus, and with both the load- and source-oriented apportionment approach. It is the most complete source apportionment assessment data set, but still have some shortages.

— The methodologies to assess the different nutrient sources are not fully harmonized between countries, and results are therefore not completely comparable. This is e.g. valid for estimated natural background loads, which is based from monitored data in some countries, and modelling approach in others, and further the exact criteria on natural background loads are not exactly the same between all countries. Definitions of scattered dwellings and storm waters and methodology on quantification of these sources are also quite different between countries, thus results from these sources should be used cautiously.

— The boundary between scattered dwellings and municipal waste water treatment plants differs between countries from 30 person equivalents (PE) in e.g. Denmark to 2,000 PE in e.g. Poland.

— Some countries have not divided diffuse inputs in same number of sources. Therefore, for some countries and basins some of the more detailed partitioning of diffuse sources are not included. For some transboundary rivers it is not always clear if contribution from upstream countries have been source apportioned and included in respective countries' sources, included as a part of other diffuse sources category in the country receiving the transboundary inputs or given as a separate transboundary inputs source.

— The assessment is challenged by the fact that eight countries reported PLC-7 data based on the year 2017, but Poland reported 2018 data.

— Weather and the resulting flow conditions in rivers are important when quantifying sources. With high flow (related to a lot of precipitation and/or snow melting) diffuse sources are typically high (high precipitation over an area will also increase atmospheric nitrogen deposition), while load from point sources typically are not (or only partly) dependent on flow conditions in rivers. In a catchment with flow markedly over average the proportion of diffuse sources will be higher as compared with a year with low flow, and the importance of point sources will be lower in year with high flows and vice versa. The deviation in flow from the normal (average over a longer period) as shown in figure 3.4 and in table 1.3 for each river catchment is important to take into account. Overall, in 2017 flow to Baltic Sea was 5% above the average (1995-2017), covering from up to 36% higher flow to Gulf of Riga and 12-13% to Baltic Proper and Danish Straits to lower than average flows to Kattegat (17%) and Bothnian Sea (10%). For Poland in 2018 flow was markedly below the average (about 10-20%).

— The four biggest contributors of total nitrogen to the Baltic Sea in 2017 are Poland (17%, data from 2018), Latvia (13%, but that includes some transboundary inputs), Russia (12%) and Sweden (12%). Baltic Sea and North Sea shipping contribute with approx. 2.5% and total nitrogen inputs and other countries (both airborne and waterborne inputs) have a share of more than 7% (table 2.5).

— The four biggest contributors of total phosphorus to the Baltic Sea in 2017 are Poland (25%, data from 2018), Russia (14%), Finland (13%), and Latvia (12%, but that includes some transboundary inputs). Atmospheric deposition and some waterborne transboundary inputs from non HELCOM countries contributes with approx. 7% (table 2.6).

— Three main pathways of nutrient inputs to the Baltic Sea have been quantified: atmospheric deposition on the sea surface, inputs from point sources (municipal waste water treatment plants, industrial plants and aquaculture plants) discharging directly into the sea, and riverine inputs (from inland sources). The riverine input is a dominating pathway for both nutrients in 2017 by constituting 73% of total nitrogen and 88% of total phosphorus inputs to the Baltic Sea (figure 2.1, and tables 4.1-4.4). The second most important pathway is airborne inputs, nearly 24% for total nitrogen and more than 7% for total phosphorus.

— The share of pathways differs markedly between sub-basins. The contribution of airborne deposition for total nitrogen varies from less than 7% in the Gulf of Riga up to nearly 48% in the Archipelago (figure 2.1). For total phosphorus the shares are from less than 3 % to the Gulf of Riga to more than 21% to the Bothnian Sea. The proportion of direct input of total nitrogen is from less than or around 1% to the Gulf of Riga and Baltic Proper to more than 16% to the Sound. For total phosphorus direct point sources proportion of total inputs varies from 1-2% in the Gulf of Riga and Baltic Proper to more than 42% to the Sound.

— Total nitrogen and total phosphorus inputs to the Baltic can be divided in four main sources which overall have been quantified by all HELCOM countries: Natural background load, other diffuse sources load entering via rivers (as load from agriculture, managed forestry, scattered dwellings, and storm waters), point sources load (entering Baltic Sea via rivers and direct discharging into the sea) and deposition from air on the Baltic Sea (figures 2.3-2.6 and tables 2.3-2.6). Other diffuse sources are most important to the Baltic Sea for both total nitrogen (49%) and total phosphorus (56%), but with big variation to the individual basins, ranging for total nitrogen from only 20% to Bothnian Sea to more than 83% to Gulf of Riga. For total phosphorus it ranges from less than 36% to Bothnian Bay up to more than 84% to Gulf of Riga.

— Deposition from air with 24% and natural background loads (18%) are the second and third most important total nitrogen sources to the Baltic Sea. For total phosphorus natural background loads (20%) and point sources loads (17%) are the second and third most important sources to the Baltic Sea, respectively. However, the shares differ between the basins, as contribution of total nitrogen for natural background loads varies from less than 7% to Western Baltic to more than 52% to Bothnian Bay. The variation for total phosphorus is between less than 9% to Baltic Proper and Gulf of Riga to more than 52 % to Bothnian Bay. Airborne total nitrogen inputs constitute less than 7% of total nitrogen inputs to Gulf of Riga but nearly 48 % of the corresponding inputs to the Archipelago. The shares of total phosphorus point sources load constitute less than 5% to Bothnian Bay and Gulf of Riga to nearly 47% to the Sound.

— There is big variation in the importance of main sources of total nitrogen and total phosphorus from the HELCOM countries. The most important total nitrogen source is other diffuse for Latvia (92%), nitrogen depositions from air for Germany and natural background loads for Sweden (48%), while point source load are the less important source (besides for Latvia) ranging between 1 and 17% of total inputs. For total phosphorus other diffuse sources are the most important source for Latvia (90%), and for Sweden natural background load is the most important source (51%). The shares from point sources ranges from less than 4 % for Latvia to more than 29% for Russia.

— All countries have estimated the share of natural background loads and indirect point sources of riverine loads. Eight countries have estimated load from agricultural sources and half of these countries have separately estimated shares of managed forestry (and the remaining countries include this source under agriculture). Seven countries have estimated the shares from atmospheric inputs on inland surface waters, and five countries estimated importance of scattered dwellings and storm waters.

— Diffuse sources not quantified separately have been reported aggregated under “other diffuse sources”, which for countries specifying all sources only includes loads from scattered dwellings and storm waters. Therefore, we can compare natural background loads, diffuse other loads (were all other diffuse sources than natural background loads have been integrated in this category) and point source loads.

— Natural background loads of total nitrogen and total phosphorus constitute nearly about one quarter of the total riverine load of nutrients to the Baltic Sea in 2017 (table 4.5, and figure 4.7). However, there are large differences for the different basins. The largest proportion is for the Bothnian Bay (65% for nitrogen, and 59% for phosphorus), and Bothnian Sea (55 % for nitrogen and 41% for phosphorus). The lowest proportions are in the Gulf of Riga (10% for nitrogen and 9% for phosphorus, respectively).

— The other diffuse sources which are anthropogenic sources such as agriculture (usually the biggest), managed forestry, waste water from scattered dwellings and storm waters etc. make up about two thirds of the riverine total nitrogen and total phosphorus load to the Baltic Sea in 2017. Large differences in the amounts of agricultural land, areas with managed forestry and further number of inhabitants living in scattered dwellings are reflected by varying contributions over the Sea area. Area with high agricultural activity and/or inhabitants living in scattered dwellings gives high shares as e.g., Gulf of Riga (90 % for total nitrogen, and 88% for total phosphorus), and for total nitrogen also Western Baltic (82%), and Baltic Proper (76%) and for total phosphorus Archipelago (87%) and The Sound (73%).

— Within the catchment to a Baltic Sea basin there is also big differences in the importance of different sources for individual river catchment. As an example, in the Danish catchment to Western Baltic there there are 73 monitored rivers reported. For total phosphorus the share of natural background loads ranges between 25 to 100%, from other diffuse sources between 0 and 75% and from inland point sources between 1 to nearly 80 % for the individual rivers, figure 4.8.

— To evaluate the most important diffuse source riverine source of total nitrogen and total phosphorus, five countries (Denmark, Finland, Germany, Poland and Sweden) have quantified atmospheric load on inland surface waters, natural background loads, agricultural loads (of which some countries have sub-divided these inputs in agricultural and managed forestry loads), load from scattered dwellings, and load from storm waters separately (tables 4.8 and 4.9). From Denmark (76%), Germany (83%) and Poland (82%) agricultural total nitrogen loads are the most important diffuse source. From Finland and Sweden agricultural load have only second highest share (40 and 25%, respectively) as natural background loads are the biggest source with 45% and 66% respectively. Natural background loads of total nitrogen are the most important in the northern and northeastern part of the Baltic Sea catchment area while agricultural loads are dominating for southern og south-western part of the Baltic Sea catchment area.

— Agricultural loads are the most important total phosphorus diffuse source from Finland (54%), Germany (55%) and Poland (83%). From Denmark and Sweden agricultural loads have only second highest share (33% and 23%, respectively) as natural background loads are the biggest source with 41% and 62% respectively. The shares of diffuses riverine inputs from scattered dwellings plus storm waters load are low for total nitrogen (Poland have the highest shares with less than 7%) but more important for total phosphorus, with proportion of up to 26% from Denmark and Germany, but 6 to 11% from Germany, Finland, and Sweden. The highest shares are related to catchments with high number of inhabitants and many living in scattered dwellings.

— The importance of sources of waste water from municipal waste water treatment plants, industrial plants, aquaculture plants, scattered dwellings, and storm waters have been assessed separately by Denmark, Finland, Germany, Poland and Sweden for both indirect and direct waste water sources. Municipal waste water treatment plants are the most important total nitrogen source of waste waters for all five countries ranging from 58% in Poland up to 70% for Germany and Sweden. Waste water from industrial plants are the second most important source for Poland, Finland and Sweden with shares between 16 and 21%. For Denmark and Germany storm waters with 15% and 22%, respectively are the second most important total nitrogen waste water source of riverine input. Scattered dwellings have rather high shares for Finland (13%) and Poland (19%) while aquaculture also has a rather high share for Demark (11%). For total phosphorus municipal waste water treatment plants are the most important source for Denmark (46%), Germany (48%), Poland (74%) and Sweden (30%), but for Finland it is storm waters with 47%. Industrial loads are the second most important waste water source for Finland (19%) and Sweden (29%), for Denmark and Germany with 29% and 47% it is loads from storm waters and for Poland it is scattered dwellings (9%). Scattered dwellings also have considerable shares of phosphorus waste water loads from Denmark (16%) and Sweden (21%), as aquaculture for Finland (11%) and Denmark (8%).

— Municipal waste treatment plants are markedly the most important total nitrogen source of direct point sources inputs to the Baltic Sea constituting about 85%, followed by industrial direct loads (12%). For phosphorus municipal waste treatment plants also are the most important direct source (71%), followed by industrial loads (22%). For total nitrogen municipal waste water treatment plants are also the most important direct point source to all basins and from all countries, but to Bothnian Bay and Bothnian Sea industrial loads constitutes 35-38%. Aquaculture loads to Archipelago provides more than 40% of total nitrogen and more than 80% of total

Table 7.1. Sources of total nitrogen inputs to the Baltic Sea for the six basins to Baltic Sea and from the five countries that have made the most detailed source assessment. Abbreviations are explained in table 1.1. ATL_indir are atmospheric deposition on inland surface waters reaching the Baltic Sea, and ATL-dir are the direct atmospheric deposition on the sea. For the three point sources (MWL, INL and AQL) it is the sum of loads from these point sources discharging to inland surface water in the catchment and directly to the sea. Denmark and Germany include managed forestry loads (MFL)under agricultural loads (AGL). Sources are assessed with load-oriented approach.

Total nitrogen	NBL %	ATL_indir %	AGL %	MFL %	SCL %	SWL %	MWL %	INL %	AQL %	ATL_dir %	Total tons
Bothnian Bay	52.1	3.3	16.1	2.6	1.0	0.1	7.1	4.2	0.1	13.4	55,964
Bothnian Sea	33.4	2.7	14.4	1.7	1.3	0.1	9.9	2.9	0.7	32.9	52,499
Archipelago	15.0	0.5	26.4	0.9	1.5	0.2	4.1	0.7	3.1	47.6	12,826
Western Baltic	6.9	1.2	42.4	0.0	0.5	1.3	5.3	0.2	0.8	41.5	50,224
The Sound	20.4	0.4	35.9	0.0	0.8	2.4	18.4	0.8	0.0	20.8	11,089
Kattegat	24.0	3.4	34.3	0.3	0.9	0.6	5.3	0.8	0.3	30.1	65,216
Denmark	13.6	0.7	50.7	0.0	0.7	1.1	4.7	0.3	0.9	27.4	57,836
Finland	36.1	6.4	32.1	2.8	2.0	0.2	9.4	3.2	0.7	7.3	83,281
Germany	1.2	2.8	26.0	0.0	0.2	1.1	3.6	0.2	0.0	65.0	71,285
Poland	4.6	1.7	54.1	1.3	3.4	0.8	10.6	2.9	0.7	19.8	156,838
Sweden	48.3	3.6	18.3	1.1	1.6	0.4	12.4	2.9	0.3	11.1	106,316

phosphorus direct inputs. Municipal waste treatment plants are the most important direct point source to six basins constituting 66 to 98% of the direct total phosphorus inputs, but to Bothnian Bay and Bothnian Sea industrial loads constitute nearly 90% of the direct inputs, and to Archipelago aquaculture plants have a share of more than 80% of the inputs. Municipal waste water treatment plants are the most important total nitrogen and total phosphorus direct input from all countries, except Sweden for phosphorus, were industrial loads have the highest share (53%).

— For five countries and six basins of the Baltic Sea the total loads of nitrogen and phosphorus have been separated in several sources, and the results are summarized in table 7.1 (nitrogen) and 7.2 (phosphorus). For total nitrogen, agricultural loads are the most important source to Western Baltic, The Sound and Kattegat (ranging between 34 and 42%), while it is natural background loads to Bothnian Bay and Bothnian Sea (52 and 33% respectively). To Archipelago atmospheric deposition to the sea is the most important source (48%), but also a very important source to Bothnian Sea (33%) and Western Baltic (42%) basins with relative high proportion of sea area as compared with catchment area.

— It should be noted that of atmospheric deposition agricultural source also have important shares to several basins. For total phosphorus, agricultural load have the highest share of total phosphorus inputs to Archipelago (67%) and Western Baltic (31%), while natural background loads are most important source to Bothnian Bay (52%) and Kattegat, and the two sources are of equal importance (28%) to Bothnian Sea. For The Sound municipal waste water treatment plants have the highest share, providing about 46% of total phosphorus inputs, and with storm waters being second biggest source (25%), waste water contributes with 75% of total phosphorus inputs to the Sound. The share for natural background total nitrogen inputs from Germany are very low (1%) which mainly is related to what are encountered as natural background losses and how it is estimated. Loads from managed forestry, scattered dwellings, storm waters, industrial plants and aquaculture plants are sources of minor importance for total nitrogen with maximum 4% of total inputs for the individual source categories. For total phosphorus the corresponding sources of minor importance are atmospheric inputs on inland waters, and managed forestry. But for individual river catchments some of these sources might have important shares of the inputs.

— Annual variation in weather conditions and the connected flow from rivers affects the importance of different sources and the importance of pathways of total nitrogen and total phosphorus to the Baltic Sea. From chapter 6 we conclude that importance of direct point sources of total nitrogen and total phosphorus has decreased. For total nitrogen, a minor decrease from about 5% of total inputs in mid-1990s to about 3 % in latest years, and for total phosphorus a marked decrease correspondingly from about 15% to under 6%. For total nitrogen there is no clear tendency for the shares of total nitrogen inputs via riverine inputs and atmospheric deposition, with shares of about 67-68% and 27-28%, respectively during 1995-2017. For total phosphorus we use the same amounts of atmospheric deposition every year with a fixed rate of 5 kg P km^2 on the sea surface. With reduced inputs from direct point sources the atmospheric total phosphorus inputs get a higher share, rising from about 5% in mid 1990ties to 8% in recent years. The riverine total phosphorus inputs share also increases, from about 83% to 87% recently. But looking on the inputs in tonnes to the Baltic Sea it have been reduced from about 34,000 tonnes as average of 1995-1999 to 24,000 tonnes tonnes as average for 2013-2017. For total nitrogen the corresponding numbers are from about 710,000 tons to 575,000 tonnes.

Table 7.2. As table 7.1 but for total phosphorus. Phosphorus deposition on the sea cannot be allocated to countries.

Total phosphorus	NBL %	ATL_indir %	AGL %	MFL %	SCL %	SWL %	MWL %	INL %	AQL %	ATL_dir %	Total tons
Bothnian Bay	52.4	3.0	23.7	3.9	4.6	0.4	1.4	3.2	0.3	7.0	2,573
Bothnian Sea	28.4	2.0	28.2	1.4	5.3	1.0	2.7	7.8	1.9	21.4	1,695
Archipelago	10.8	0.2	66.7	1.3	7.3	0.1	1.4	0.5	6.9	4.8	642
Western Baltic	16.9	0.9	30.7	0.0	5.8	13.8	18.3	0.5	3.8	9.1	1,042
The Sound	10.4	0.1	10.2	0.0	4.4	24.9	45.7	0.8	0.4	3.2	312
Kattegat	35.5	1.0	30.1	0.1	5.5	6.9	9.6	2.2	1.1	8.1	1,456
Denmark	30.9	0.1	24.7	0.0	7.0	12.6	20.2	1.1	3.5	0.0	1,521
Finland	28.3	2.4	50.2	3.9	8.1	0.1	2.6	2.8	1.6	0,0	3,721
Germanry	10.6	4.3	44.1	0.0	2.0	19.2	19.6	0.2	0.0	0.0	889
Poland	5.0	1.0	60.5	1.5	2.8	1.8	23.7	1.7	2.0	0,0	6,976
Sweden	51.2	2.9	18.8	0.5	5.6	4.3	8.0	7.6	1.2	0.0	2,664

7.2. Recommendations for next source apportionment assessment

Based on the experience from the previous source apportionments we have some recommendations for the next periodic assessment of sources of nitrogen and phosphorus:

- It is crucial that all countries report data from the same year for the PLC-8 assessment (2021)
- Countries should provide some information on the weather and flow conditions for the year with data collection, particular on any special conditions that should be taken into account when assessing data
- The applied methods/methodologies by countries should be as comparable as possible e.g., on natural background losses, what is included as agricultural losses, quantifying loads from scattered dwellings and storm waters, for unmonitored areas, and for retention
- Agriculture should be quantified by all countries separately and other diffuse sources should consist of only scattered dwellings and storm water sources/loads, and it should be very clear if scattered dwellings have been reported together with storm waters or separately
- Atmospheric deposition on inland surface waters should be reported separately from other diffuse sources
- Reporting should clearly separate sources within a country, and what is transboundary inputs. It must be clarified if transboundary inputs are included in other diffuse sources, as transboundary inputs, not included or apportioned as a part of all sources
- The reported catchment area (monitored, unmonitored, countries and transboundary) for PLC-7 results in rather many inconsistencies. It is important to ensure that reported monitored, unmonitored and transboundary areas are reported correctly, allowing for easy aggregating of correct total catchment areas to the sub basins, from the countries, transboundary areas in other countries, and monitored and unmonitored areas per sub basin and per country. The area is used for many different calculations as specific runoff and area specific losses from different sources.
- It would improve comparability if the definition on scattered dwellings versus municipal waste water treatment plants was more comparable between countries.
- To improve comparability with PLC3 - PLC6 countries should consider to update/re-report source data – at least on the load-oriented approach
- It should be considered how to reduce variability of importance of sources due to weather conditions - without creating a lot of extra work or trying to make normalization exercises
- It should be considered how much extra information we get from the source-oriented approach as compared with the load-oriented approach besides the importance of retention on the inputs from different sources
- Include some other sources discharging into the sea as e.g., from shipping (scrubber, ballast waters)
- It would be interesting to use information on sources of atmospheric nitrogen deposition and combine it with the results from the load-oriented approach to get a more comprehensive source evaluation. Until now atmospheric inputs have seen as one separate source, but actually there are assessments of how much at the deposition originates from agriculture, transportation, combustion etc.

8. References

Copernicus Global Land Services, 2015 https://land.copernicus.eu/global/

Corine land Cover, 2018. (https://land.copernicus.eu/pan-european/corine-land-cover/clc2018)

Gauss, M., Gusev, A., Aas, W., Hjellbrekke, A., Ilyin, I., Klein, H., Nyiri, A., Rozovskaya, O., Shatalov, V., Strijkina, V., Travnikov, O. 2020. Atmospheric Supply of Nitrogen, Cadmium, Lead, Mercury, PCDD/Fs, PCB-153, and B(a)P to the Baltic Sea. EMEP Centres Joint Report for HELCOM EMEP MSC-W TECHNICAL REPORT 3/2020, 126 pp. https://emep.int/publ/helcom/2020/EMEP_TechnicalReport_3_2020.pdf

HELCOM, 1998. Third Baltic Sea Pollution Load Compilation (PLC-3). Baltic Sea Environment Proceedings No. 70. https://helcom.fi/wp-content/uploads/2019/10/BSEP70.pdf

HELCOM, 2004. Fourth Baltic Sea Pollution Load Compilation (PLC-4). Baltic Sea Environment. Proceedings No. 93. https://helcom.fi/wp-content/uploads/2019/08/BSEP93.pdf

HELCOM, 2011. Fifth Baltic Sea Pollution Load Compilation. Baltic Sea Environment Proceedings 128. https://helcom.fi/wp-content/uploads/2019/08/BSEP128.pdf

HELCOM, 2012. Fifth Baltic Sea Pollution Load Compilation – An Executive Summary. https://helcom.fi/wp-content/uploads/2019/08/BSEP128A.pdf

HELCOM, 2013. Review of the Fifth Baltic Sea Pollution Load Compilation for the 2013 HELCOM Ministerial Meeting. Balt. Sea Environ. Proc. No. 141, 54 pp. https://helcom.fi/wp-content/uploads/2019/08/BSEP141.pdf

HELCOM 2014. Information on atmospheric deposition of phosphorus. Document 9-3. Seventh meeting of the HELCOM Expert Group on follow-up of national progress towards reaching BSAP nutrient reduction targets (HELCOM LOAD 7-2014).

HELCOM, 2018. Sources and pathways of nutrients to the Baltic Sea - HELCOM PLC-6. . Baltic Sea Environment Proceedings No. 153. https://helcom.fi/wp-content/uploads/2019/08/BSEP153.pdf

HELCOM. 2021a – HELCOM Baltic Sea Action Plan– 2021 update, 31pp. https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf

HELCOM, 2021b. Background information on the Baltic Sea catchment area for the Seventh Baltic Sea Pollution load compilation (PLC-7), 49 pp. https://helcom.fi/wp-content/uploads/2021/12/Background-information-on-the-Baltic-Sea-catchment-area-for-the-Seventh-Baltic-Sea-Pollution-load-compilation-PLC-7-211202.pdf

HELCOM, 2021c. Applied methodology for the PLC-7 assessment, 82 pp. https://helcom.fi/wp-content/uploads/2021/12/Applied-methodology-for-the-PLC-7-assessment-211202.pdf

HELCOM, 2022. HELCOM Guidelines for the annual and periodical compilation and reporting of waterborne pollution inputs to the Baltic Sea (PLC-Water). 173 pp. https://helcom.fi/wp-content/uploads/2022/04/HELCOM-PLC-Water-Guidelines-2022.pdf

Svendsen, L.M., Gustafsson, B., 2019: Waterborne nitrogen and phosphorus inputs and water flow to the Baltic Sea 1995-2017, 24p. Baltic Sea Environment Fact Sheet (BSEFS). https://helcom.fi/wp-content/uploads/2020/09/BSEFS-Waterborne-nitrogen-and-phosphorus-inputs-and-water-flow-to-the-Baltic-Sea-1995-2017.pdf

Svendsen. L. M., Tornbjerg. H., 2019. Quantifying nutrient sources to inland waters (source-oriented approach): A pilot case. 28 pp. HELCOM project report, 27 pp. https://helcom.fi/wp-content/uploads/2020/01/PLC-6-pilot-case.pdf

Svendsen, L.M., Gustafsson, B., Larsen, S.E. & Frank-Kamenetsky, D., 2022. Inputs of nutrients (nitrogen and phosphorus) to the sub-basin (2019), 38 p. HELCOM Indicators. https://helcom.fi/wp-content/uploads/2017/06/HELCOM-core-indicator-on-inputs-of-nutrients-for-period-1995-2019.pdf

9. Annexes

9.1. Introducing annex 1–19

A complete set of pie charts and Box-Whisker plots have been produced presenting results of the load- and sources-oriented approach assessment, respectively and following the principles and the order of chapters 4 and 5.

There are 19 annexes/files, and they are called annex_n + some letters and numbers:

— Annex_x, e.g. Annex_1 is just a running number
— B = Box-Whisker plot
— L = load-oriented approach assessment results
— S = source-oriented approach assessment result results
— BL is Box-Whiskers plot with load-oriented approach assessment results
— BS is Box-Whiskers plot with source-oriented approach assessment results
— L+ a number: Pie chart with load-oriented approach assessment results
— S+ a number: Pie chart with source-oriented approach assessment results
— Number after L and S refers to the level of aggregation of sources (as followed in chapter 4 and 5) and as indicated below

All files include results for both total nitrogen and total phosphorus, and total nitrogen are figures to the left and phosphorus are figures to the right.

The 19 files which contains 1,063 pie charts and 346 Box-Whiskers plots are available on the workspace of the PLC8 project "load-oriented" and "source-oriented" folders.

Content of the files:

In the description of the content of the 19 annexes TN is abbreviation for total nitrogen and TP for total phosphorus.

Annex1_BL1:
Load oriented approach: Box-Whisker plots with the proportion of natural background, other diffuse and indirect point TN and TP sources (%) of loads in individual rivers shown country per basin for the monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex2_BL2:
Load oriented approach: Box-Whisker plots with the proportion of atmospheric deposition on inland waters, natural background, agricultural, other diffuse and indirect point TN and TP sources (%) of loads in individual rivers shown country per basin for the monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex3_BL3:
Load oriented approach: Box-Whisker plots with the proportion of atmospheric deposition on inland waters, natural background, agricultural, managed forestry, other diffuse, scattered dwellings and storm waters TN and TP sources (%) of diffuse loads in individual rivers shown country per basin for the monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex4_BL4:
Load oriented approach: Box-Whisker plots with the proportion of municipal wastewater treatment plants, industry, fish farms, scattered dwellings and storm waters TN and TP sources (%) of indirect point source loads in individual rivers shown country per basin in monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex5_BS1:
Source oriented approach: Box-Whisker plots with the proportion of natural background, other diffuse and indirect point TN and TP sources (%) of total inputs to individual rivers shown country per basin in monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex6_BS2:
Source oriented approach: Box-Whisker plots with the proportion of atmospheric deposition on inland surface waters, natural background, agricultural, other diffuse and indirect point TN and TP sources (%) of total inputs to individual rivers shown country per basin in monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex7_BS3:
Source oriented approach: Box-Whisker plots with the proportion of atmospheric deposition on inland surface waters, natural background, agricultural, managed forestry, other diffuse, scattered dwellings and storm waters TN and TP sources (%) of total diffuse inputs to individual rivers shown country per basin in monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex8_BS4:
Source oriented approach: Box-Whisker plots with the proportion of municipal wastewater treatment plants, industry, fish farms, scattered dwellings and storm waters TN and TP sources (%) of total indirect wastewater inputs to individual rivers shown country per basin in monitored part of the catchment to Baltic Sea basin. Number of rivers in each catchment to a Baltic Sea basin is in table 1.6 of the report.

Annex9_L1:
Load oriented approach: Pie charts with the proportion of atmospheric deposition on the sea, riverine and direct point TN and TP source (%) of total inputs to the sea shown per basin, per country and country per basin, respectively. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total input either to the Baltic Sea or to the specific basin.

Annex10_L2:
Load oriented approach: Pie charts with the proportion of atmospheric deposition on the sea, natural background, other diffuse and total og indirect and direct point TN and TP source (%) of total inputs to the sea given shown per basin, per country and country per basin. the heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total input either to the Baltic Sea or to the specific basin.

Annex11_L3:
Load oriented approach: Pie charts with the proportion of natural background, other diffuse and indirect point TN and TP sources (%) of total riverine inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total riverine input either to the Baltic Sea, or to the specific basin.

Annex12_L4:
Load oriented approach: Pie charts with the proportion of atmospheric deposition on inland surface waters, natural background, agricultural, other diffuse, and indirect TN and TP point sources (%) of riverine inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total riverine input either to the Baltic Sea or to the specific basin.

Annex13_L5:
Load oriented approach: Pie charts with the proportion of atmospheric input on inland surface waters, natural background, agricultural, managed forestry, other diffuse, scattered dwellings and storm waters TN and TP sources (%) of diffuse riverine inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total diffuse riverine inputs either to the Baltic Sea or to the specific basin.

Annex14_L6:
Load oriented approach: Pie charts with the proportion of municipal wastewater treatment plants, industrial, fish farms, scattered dwellings and storm waters TN and TP sources (%) of wastewater (indirect and direct) inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin of the total wastewater (direct and indirect) inputs.

Annex15_L7:
Load oriented approach: Pie charts with the proportion of municipal wastewater treatment plants, industrial and aquaculture plants TN and TP sources (%) of direct wastewater inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the direct wastewater inputs either to the Baltic Sea or to the specific basin.

Annex16_S1:
Source oriented approach: Pie charts with the proportion of natural background, other diffuse and indirect TN and TP point sources (%) of riverine input shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total riverine inputs either to the Baltic Sea, or to the specific basin. The pie charts are shown for monitored (mon), unmonitored (unmon) and total (total) catchment areas, respectively.

Annex17_S6:
Source oriented approach: Pie charts with the proportion of atmospheric deposition on inland surface waters, natural background, agricultural, other diffuse and indirect TN and TP point sources (%) of riverine inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total riverine inputs either to the Baltic Sea, or to the specific basin. The pie charts are shown for monitored (mon), unmonitored (unmon) and total (total) catchment areas, respectively.

Annex18_S3:
Source oriented approach: Pie charts with the proportion of atmospheric deposition on inland surface waters, natural background, agricultural, managed forestry, other diffuse, scattered dwellings and storm waters TN and TP sources (%) of riverine diffuse inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total diffuse riverine inputs either to the Baltic Sea, or to the specific basin. The pie charts are shown for monitored (mon), and total (total) catchment areas, respectively.

Annex19_S4:
Source oriented approach: Pie charts with the proportion of municipal wastewater treatment plants, industry, fish farms, scattered dwellings and storm waters TN and TP sources (%) og indirect wastewater inputs shown per basin, per country and country per basin. The heading includes inputs (in tonnes) to either the basin, the country or the country to a specific basin, and the percentage indicates the proportion of the total indirect wastewater input either to the Baltic Sea, or to the specific basin. The pie charts are shown for monitored, and total catchment areas, respectively.

9.2. Explaining Box-Whisker plots

Box-Whisker plots are used to show the variation in the importance of different sources in monitored rivers from a country to a Baltic Sea sub-basin. Figure 9.1 illustrates a Box-Whisker plot of table 9.1 for the 10 monitored (table 1.5) rivers in Swedish catchment to the Baltic Proper for total nitrogen with the source-oriented approach to illustrate variation in importance of a specific sources in a catchment between individual rivers. For the 10 rivers the importance of e.g. agriculture (AGL in figure 9.1) varies from minimum 5.2% in Alsterån to 33.7% in Norrström, outlet from Mäleren.

Table 9.1. Shares of total nitrogen diffuse sources for each of the 10 monitored rivers in the Swedish catchment to the Baltic Proper (BAP) with the source-oriented source apportionment approach in 2017. E.g., atmospheric deposition on inland water constitutes 20.4% of total load from Motala Ström (4,915 tons N). Maximum, minimum, 75% and 25% percentile, median and average proportion for each source are shown e.g., median share for natural background source (NBS) for the 10 rivers is 69.7%. Data in the table is presented in the Box-Whisker plot in figure 9.1. Explanation of sources abbreviation is in table 1.1.

River	ATS %	NBS %	AGS %	MFS %	Diff-other %	SCL %	SWL %	Total tons
ALSTERÅN	7.1	82.7	5.2	2.5	0.0	2.3	0.1	350
BOTORPSSTRÖMMEN	13.5	67.0	13.5	2.0	0.0	3.7	0.2	171
EMÅN	6.6	77.9	9.7	2.0	0.0	3.2	0.6	1,195
HELGE Å	2.8	64.0	29.8	0.8	0.0	2.4	0.2	3,484
LJUNGBYÅN	0.8	72.6	19.1	2.0	0.0	4.2	1.2	217
LYCKEBYÅN	5.1	83.6	2.9	2.8	0.0	4.9	0.7	223
MOTALA STRÖM	20.4	49.5	24.7	0.9	0.0	3.5	0.9	4,915
MÖRRUMSÅN	12.4	72.3	9.5	1.3	0.0	3.9	0.6	1,254
NORRSTRÖM, MÄLARENS UTLOPP	8.8	50.1	33.7	1.5	0.0	5.2	0.8	7,028
NYKÖPINGSÅN	12.3	52.1	28.7	1.2	0.0	4.9	0.8	792
Maximum	20.4	83.6	33.7	2.8	0.0	5.2	1.2	7028
75% percentile	12.4	76.6	27.7	2.0	0.0	4.7	0.8	2926
Median	8.0	69.7	16.3	1.7	0.0	3.8	0.6	994
Average	9.0	67.2	17.7	1.7	0.0	3.8	0.6	1963
25% percentile	5.5	55.1	9.5	1.2	0.0	3.2	0.3	255
Minimum	0.8	49.5	2.9	0.8	0.0	2.3	0.1	171

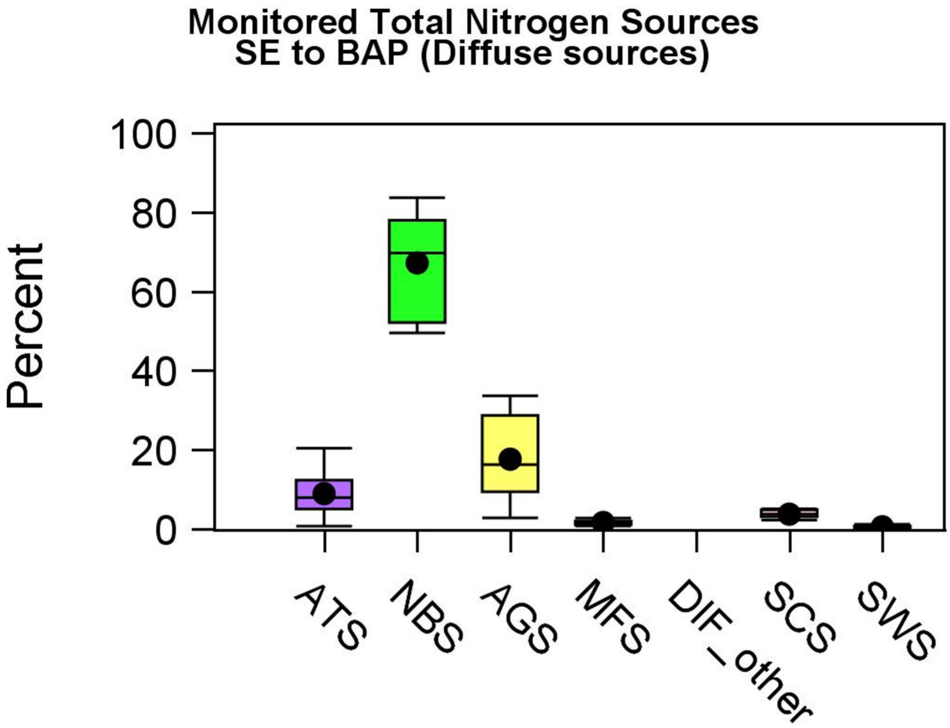


Figure 9.1. Box-Whisker plots of the shares (percentages) of diffuse sources for 10 monitored rives in the Swedish catchment area to the Baltic Proper in 2017. The data behind the plot is in table 9.1. Abbreviations for sources are in table 1.1. Upper line segment for each source box is the maximum value e.g., for natural background sources (NBS) 83.6%. Top line of the rectangle is the 75% percentile (76.6% for NBS), the line segment in the rectangle is the median (69.7% for NBS) and the dot in the rectangle the average (67.2% for NBS), the bottom-line segment in the rectangle in the 25 % percentile (55.1% for NBS) and the line segment in the bottom is the minimum share (49.5% for NBS) – see table 9.1.