Waterborne nitrogen and phosphorus inputs and water flow to the Baltic Sea 1995-2019

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Key Message

Annual water flow in 2019 to the Baltic Sea was approximately 14,000 $m^3 s^{-1}$ which is about 11% lower than the average of 1995-2019. Annual waterborne input (inputs via rivers and direct point sources discharging directly into the sea) of total nitrogen was approximately 529,000 tonnes in 2019 or 21% lower than the average of 1995-2019. The corresponding annual total phosphorus input amounted to approximately 18,800 tonnes, which is about 41% lower than the average.

Inputs of nitrogen and phosphorus from direct point sources have decreased with approximately 55% and 81% since 1995, respectively. In 2019, inputs from direct point sources constituted 5% (TN) and 7% (TP) of the corresponding total waterborne input to the Baltic Sea. In 1995, the proportions of the direct inputs were 8% for TN and 15% for TP, respectively.

Annual flow weighted riverine TN concentration decreased significantly (95% confidence) to the Bothnian Sea, the Baltic Proper, the Danish Straits and the Kattegat, and for TP to all sub-basin besides to the Kattegat since 1995. Both TN and TP concentrations decreased significantly for the total riverine inputs to the Baltic Sea.

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Results and Assessment

Relevance of nutrient input time-series for describing developments in the environment

This fact sheet includes information on annual water flow and inputs of nitrogen and phosphorus via rivers (riverine inputs) and point sources discharging directly to the sea (direct inputs) together comprising the waterborne inputs to the Baltic Sea sub-basins during 1995-2019. The inputs are the actual (not discharge-normalized) annual inputs. A separate annual BSEFS on atmospheric nitrogen inputs is delivered by EMEP (e.g. Gauss 2020a).

The normalized waterborne inputs combined with the corresponding atmospheric nutrient inputs are annually evaluated in the HELCOM core pressure indicator: "Inputs of nutrients to the sub-basins of the Baltic Sea" (the latest is HELCOM 2020), although with about six months delay compared to this fact sheet.

Eutrophication in the Baltic Sea is largely driven by excessive inputs of the nutrients nitrogen and phosphorus due to accelerating anthropogenic activities during the 20th century. Nutrient over-enrichment (eutrophication) and/or changes in nutrient ratios in the aquatic environment cause elevated levels of algal and plant biomass, increased turbidity, oxygen depletion in bottom waters, changes in species composition and nuisance blooms of algae.

The majority of nutrient inputs originate from anthropogenic activities on land and at sea and enters the Baltic Sea either as waterborne inputs or as atmospheric deposition on the Baltic Sea. Waterborne inputs enter the sea via riverine inputs and direct point source discharges. The main sources of waterborne inputs are diffuse sources (agriculture, managed forestry, scattered dwellings, storm overflows etc.), natural background sources, and point sources (as waste water treatment plants, industries and aquaculture)[2]. In addition, excess nutrients stored in bottom sediments can enter the water column and enhance primary production of plants. Waterborne inputs are the major input pathways, e.g. providing approximately 70% of TN and more than 90% of TP input in 2018 (HELCOM, 2020).

We need time series with information on annual nutrient inputs to follow up the long-term changes in the nutrient inputs to the Baltic Sea. Quantified input data is a prerequisite to interpret, evaluate and predict the state of the marine environment and related changes in the open sea and coastal waters. Change in nutrient inputs combined with quantification of inputs from land-based sources and retention within the catchment, is crucial for determining the importance of different sources of nutrients for the pollution of the Baltic Sea as well as for assessing the effectiveness of measures taken to reduce the pollution inputs.

Assessment

The assessment dataset is produced by the Baltic Nest Institute (BNI), Stockholm University together with the Danish Centre for Environment and Energy (DCE), Aarhus University. It is based on the data on riverine and direct sources flow, total nitrogen (TN) and total phosphorous (TP) annually reported by Contracting Parties to the Helsinki Convention. Reported data are checked for outliers, data gaps are filled, and other validations procedures performed by BNI and DCE before an assessment dataset with nutrient inputs to each Baltic Sea sub-basin and from each country to each sub-basin is established. The assessment data set covers all known waterborne inputs from the entire Baltic Sea catchment area. The assessment data with annual riverine and direct point source TN and TP and total flow during 1995-2019 are included include in tables 2-7 by Baltic Sea sub-basin and for the Baltic Sea.

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[2] The main sectors contributing to atmospheric inputs are combustion in energy production and industry as well as transportation for oxidized nitrogen and agriculture for reduced nitrogen. A large proportion of atmospheric inputs originate from distant sources outside the Baltic Sea region. Emissions from shipping in the Baltic and North seas also contribute significantly to atmospheric inputs of nitrogen.

This fact sheet provides information on the actual annual TN and TP waterborne inputs (sum of riverine and direct inputs) entering to the seven main sub-basins (Figure 1). We focus mainly on riverine inputs as they constituted 95% (TN) and 93% (TP) of waterborne inputs to the Baltic Sea in 2019, respectively. In the evaluation of progress towards MAI and CART/NIC as published in HELCOM (2020) (MAI) and Svendsen et al. (2020) (NIC), we use (flow-)normalized nutrient inputs to allow for comprehensive statistical analysis for trends, break points, remaining or extra reduction as compared with reduction targets /inputs ceilings (Larsen & Svendsen, 2019).

Table 1 provides key information on the annual water flow, total waterborne TN and TP inputs, flow-weighted annual TN and TP concentration of riverine inputs (mg l^{-1}) to the sub-basins and total to the Baltic Sea in 2019 as compared with the average 1995-2019. Further, the catchment and sea surface areas of the sub-basins are provided allowing for calculation of area specific flow (l s^{-1} km^{-2}), and for TN and TP inputs per catchment area and per sea area. Flow to the Baltic Sea in 2019 was about 11% lower than the 1995-2019 average. The flow was particularly lower to the Baltic Proper (27%), Gulf of Riga (26%), and to the Danish Straits (14%) as compared with the average, and only for Gulf of Finland slightly higher than the average. Waterborne TN inputs in 2019 were 529,500 tons (exactly as in 2018) or 21% lower than average. The corresponding TP inputs with 18,820 tons were 41% lower than average. Lower than average flow usually implies lower waterborne TN and TP inputs, but the nutrient input levels also reflect an overall reduction in TN and particularly in TP inputs since 1995. The pattern is however complex since both interannual flow variations and long-term trends in nutrient inputs varies across sub-basins. TN inputs in 2019 were between 32% (Baltic Proper), 22% (Bothnian Bay) and 19% (Gulf of Riga) lower than average for seven sub-basins. Even for the Gulf of Finland where the flow in 2019 was average, the waterborne TN inputs were 14% lower than the average 1995-2019. Kattegat was the only one sub-basin with higher than average TN inputs (7%) despite nearly 5% lower flow than the average. In southern Scandinavia 2018 had an extremely dry spring and summer with a poor harvest, accumulating a lot of nitrogen in soils. Late summer and autumn 2019 were very wet, with high flow leaching high amounts of nitrogen to rivers together with high flows (in the Danish part of catchment to the Kattegat) providing rather high TN inputs (figure 2), which also are reflected in high flow weighted concentrations to the Kattegat (figure 3). For waterborne TP inputs, the 2019 input were between 23% (Danish Straits) and 48% (Gulf of Finland) lower than average beside Kattegat where TP inputs were 4% (same reason as for TN). Notably, the strongest anomaly to average was found for the Gulf of Finland despite average flow.

Annual flow-weighted riverine concentration (calculated by dividing annual riverine nutrient input with the corresponding water flow[3]) in 2019 to the Baltic Sea was 1.14 mg N l^{-1} or 12% lower than the average TN concentration, and for TP it was 0.040 mg P l^{-1} or 31% lower than average. Flow-weighted TN concentrations were lower than average to four sub-basins, Gulf of Finland (17%), Bothnian Bay (16%), Baltic Proper and Bothnian Sea (both 7%). It was higher than average for the remaining basins Danish Straits (15%), Kattegat (14%) and Gulf of Riga (10%), indicating that at least for southern Scandinavia due to the drought in 2018 a lot of TN was accumulated in soils that were leached to the rivers in second part of 2019. Flow-weighted TP was lower than average to six sub-basins between 37% (Gulf of Finland) and 12% (Danish Straits). As for TN, the flow-weighted TP concentrations to Kattegat concentration was higher than average (11%) due to afore mentioned special conditions in 2018 and 2019, which also affected TP inputs and concentration to Danish Straits. In 2019, TN and TP flow weighted concentrations to Gulf of Riga were 10% higher (TN) and 18% lower (TP) than the average, despite the flow was 26% lower than the average, probably because February to April was warmer than the climatic normal with precipitation mainly as precipitation, providing favourable conditions for leaching nitrogen to surface waters.

[3] In accordance with the HELCOM PLC-water Guideline (HELCOM, 2019b), nutrient input data is reported as annual loads for individual rivers. Calculation of annual mean flow-weighted concentrations for the Baltic Sea sub-basins is a simple method to illustrate changes in waterborne nutrient loads smoothening inter annual variation. These back-calculated annual nutrient concentrations differ from originally measured values (e.g. 12 monitored values per year) and should not be mixed up with these.

Area specific waterborne catchment inputs in 2019 were highest to the Danish Straits (1,336 kg N km^{-2}, 36 kg P km^{-2}), reflecting high population density and high agricultural land-use. The lowest area specific inputs are for the Bothnian Bay and the Bothnian Sea (approximately 150-200 kg N km^{-2} and 6.9-7.1 kg P km^{-2}), catchments reflecting overall rather low population densities and high percentages of pristine or forested areas and rather low pressure from agriculture. Average for the Baltic Sea is approx. 300 kg N km^{-2} and 11 kg P km^{-2}. On the other hand, specific waterborne inputs per sea area are highest to the Gulf of Finland (3,092 kg N km^{-2}, 116 kg P km^{-2}) and Gulf of Riga (3,327 kg N km^{-2} and 78 kg P km^{-2}) but lowest to the Bothnian Bay (585 kg N km^{-2}, 21 kg P km^{-2}). Average for the Baltic Sea is approx. 1,200 kg N km^{-2} and 45 kg P km^{-2}).

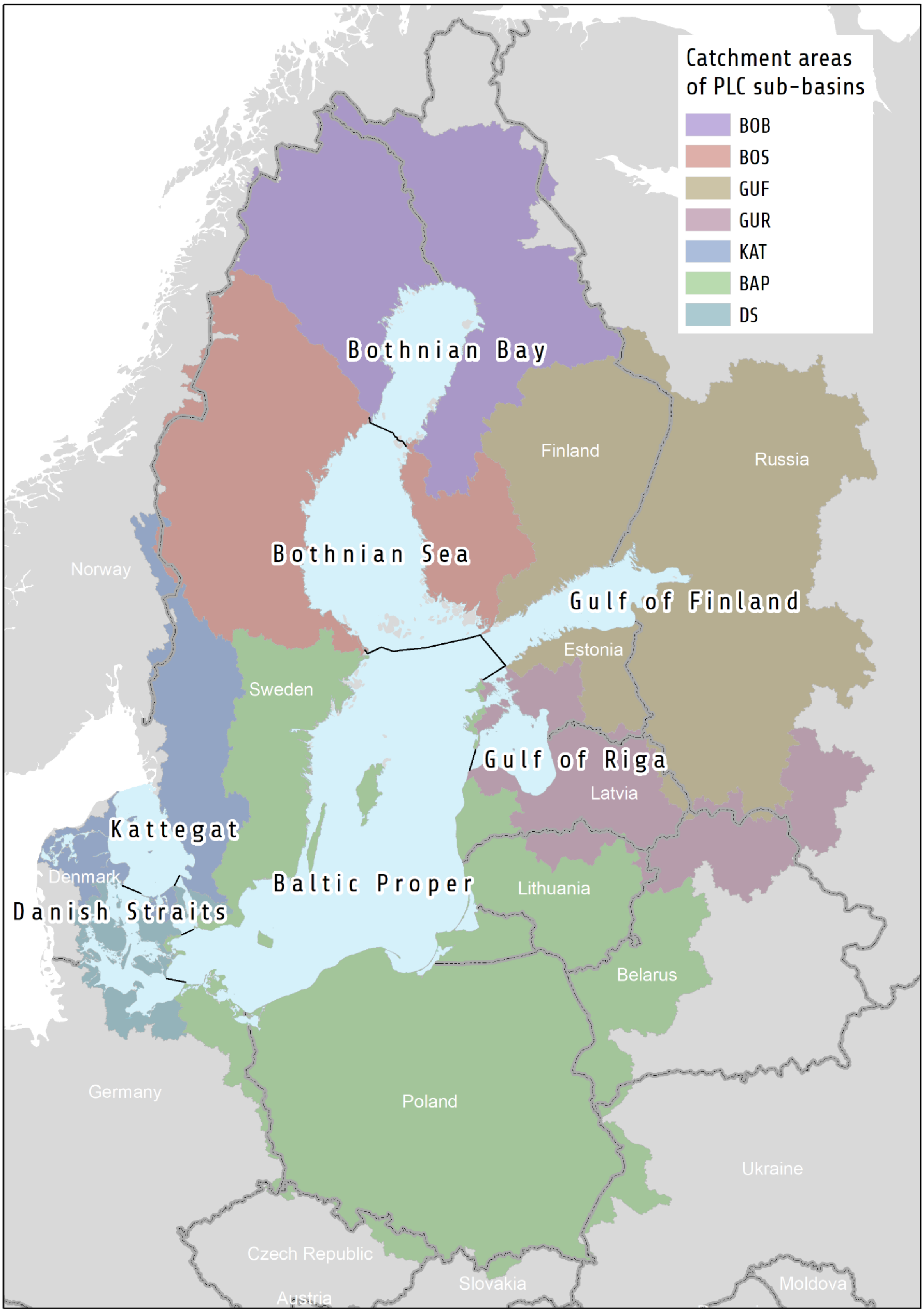
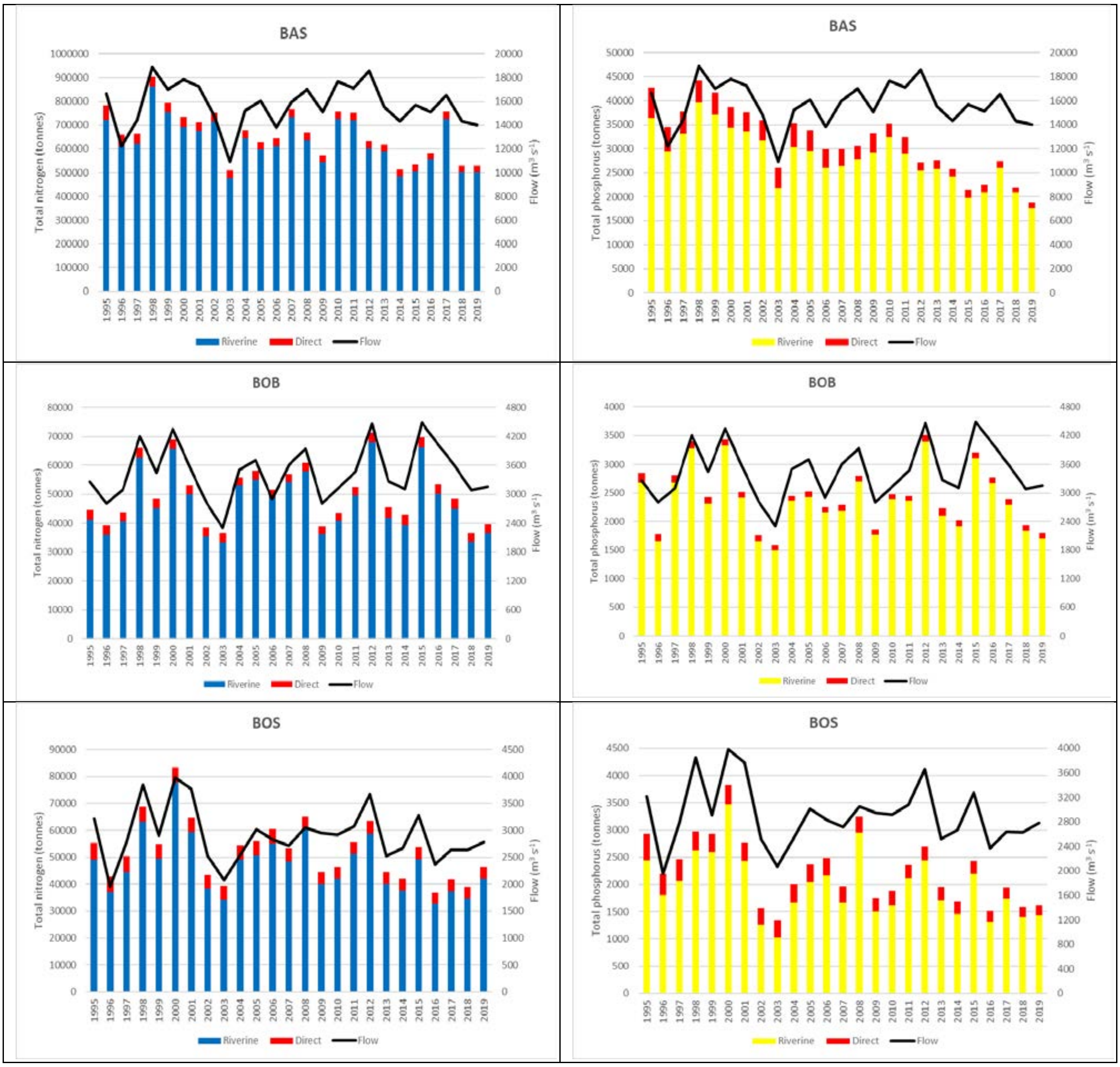


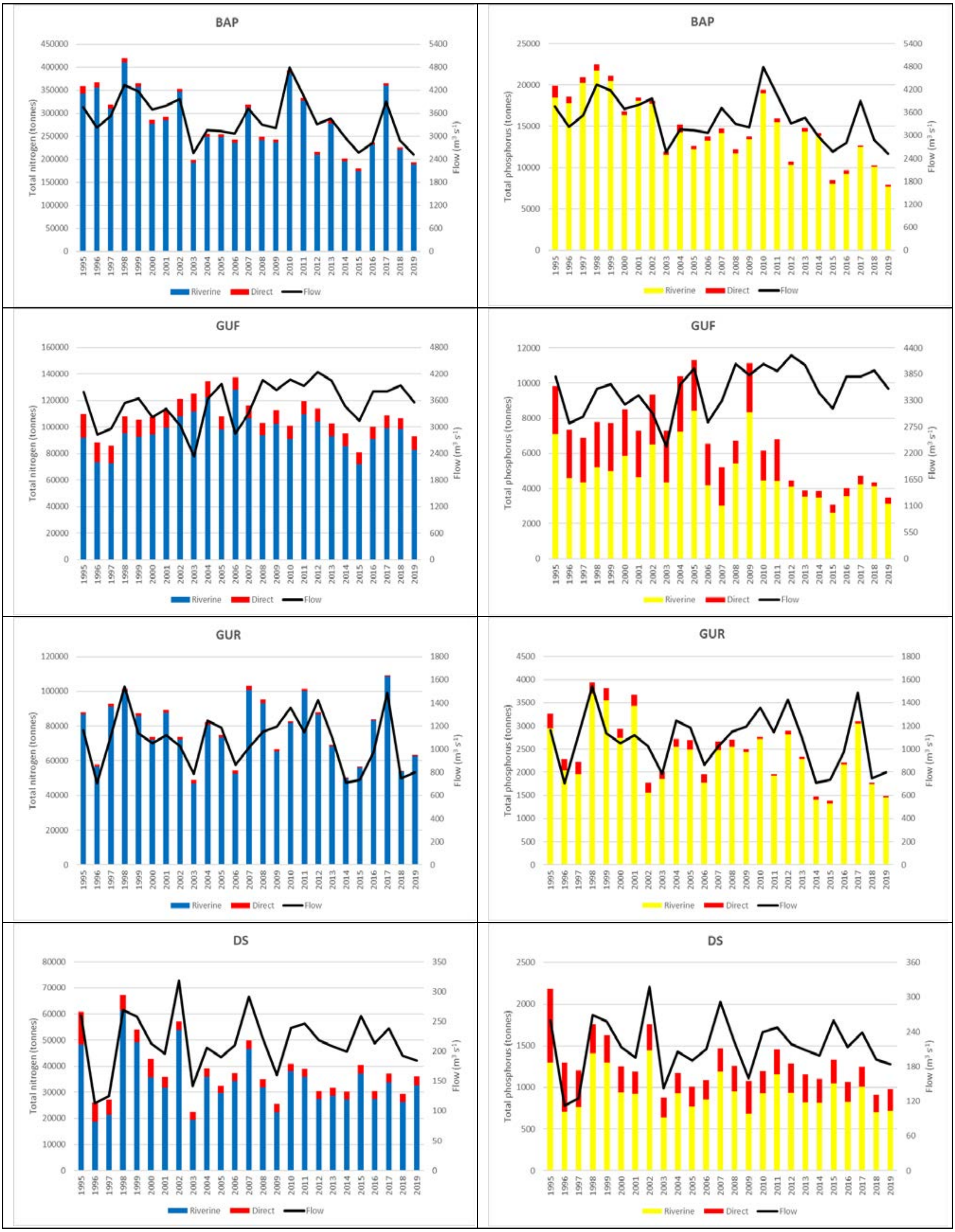
Figure 1. The catchment of the Baltic Sea is shared by nine HELCOM member states - Denmark (DK), Estonia (EE), Finland (FI), Germany (DE), Latvia (LV), Lithuania (LT), Poland (PL), Russia (RU) and Sweden (SE) and 5 transboundary countries (Belarus, Czech Republic, Slovakia, Norway and Ukraine). For the purposes of assessment of nutrient load, the Baltic Sea (BAS) is divided into 7 main sub-basins: Bothnian Bay (BOB); Bothnian Sea (BOS) with Archipelago Sea; the Gulf of Finland (GUF); the Gulf of Riga (GUR); Baltic Proper (BAP); Danish Straits (DS) consisting of the Sound and the Western Baltic and the Kattegat (KAT).

Table 1. Catchment area to and sea area of the seven sub-basins of the Baltic Sea (km^2). Annual waterborne flow (m^3 s^{-1}), area specific flow (l s^{-1} km^{-2}), waterborne total nitrogen and phosphorus inputs (tonnes) in 2019 and on average of 1995-2019. Flow weighted TN and TP concentrations (mg l^{-1}) of annual riverine inputs in 2019 and on average of 1995-2019. Further, waterborne inputs of TN and TP are given as specific inputs per km^2 catchment area and per sea area (kg N, P km^{-2}), respectively. For an explanation of abbreviations, see the caption to figure 1.

	Catchm. area	**Sub-basin sea area**	**Flow 2019**	**Flow 1995-2019**	**Flow 2019**	**Flow 1995-2019**	**TN water-borne 2019**	**TN water-borne 1995-2019**	**TN flow-weight. river conc. 2019**	**TN flow-weight. River conc. 1995-2019**	**TN water-borne /catch. area 2019**	**TN water-borne /sea area 2019**	**TP water-borne 2019**	**TP water-borne 1995-2019**	**TP flow-weight. river conc. 2019**	**TP flow-weight. River conc. 1995-2019**	**TP water-borne /catch. area 2019**	**TP water-borne /sea area 2019**
	km^{-2}	**km^{-2}**	**m^3 s^{-1}**	**m^3 s^{-1}**	**l $s^{-1}km^{-2}$**	**l $s^{-1}km^{-2}$**	**tonnes**	**tonnes**	**mg l^{-1}**	**mg l^{-1}**	**kg km^{-2}**	**kg km^{-2}**	**tonnes**	**tonnes**	**mg l^{-1}**	**mg l^{-1}**	**kg km^{-2}**	**kg km^{-2}**
BOB	261,000	36,000	3,158	3,444	12.1	13.2	39,588	50,591	0.37	0.44	152	1,100	1,796	2,460	0.017	0.022	6.9	50
BOS	230,000	79,000	2,784	2,907	12.1	12.6	46,219	52,233	0.48	0.52	201	585	1,624	2,259	0.016	0.021	7.1	21
BAP	572,000	209,000	2,522	3,436	4.4	6.0	193,329	285,956	2.39	2.57	338	925	7,912	14,988	0.098	0.133	14	38
GUF	423,000	30,000	3,552	3,536	8.4	8.4	92,753	107,845	0.75	0.90	219	3,092	3,472	6,726	0.028	0.045	8.2	116
GUR	130,000	19,000	799	1,071	6.1	8.2	63,205	77,866	2.50	2.28	486	3,327	1,486	2,503	0.058	0.070	11	78
DS	27,000	21,000	184	215	6.8	8.0	36,069	38,358	6.07	5.27	1,336	1,718	979	1,279	0.133	0.150	36	47
KAT	87,000	24,000	1,029	1,076	11.8	12.4	58,295	54,271	1.75	1.54	670	2,429	1,551	1,492	0.045	0.040	18	65
BAS	**1,730,000**	**418,000**	**14,029**	**15,686**	**8.1**	**9.1**	**529,459**	**667,120**	**1.14**	**1.29**	**306**	**1,267**	**18,821**	**31,707**	**0.040**	**0.058**	**11**	**45**

The annual water flow, direct inputs of TN and TP and riverine TN and TP inputs during 1995-2019 to the sub-basins and to the Baltic Sea are shown in Figure 2 as well as in Tables 2-7 in the "Data" section. There are significant reductions in total direct nitrogen inputs from 1995 to 2019 to the Baltic sea (55%). Significant reduction of direct TN inputs is seen to all sub-basins, except for Bothnian Bay. The highest reduction in direct TN inputs is seen to Danish Straits (74%), Baltic Proper (72%) and to Gulf of Riga (62%). There are significant reductions of direct TP inputs to all sub-basins, the highest to Gulf of Finland (88%), Gulf of Riga (88%) and Baltic proper (86%), resulting in a total reduction of 81% in the Baltic sea, although data on direct inputs are more uncertain in the beginning of the time series. Even though 2019 direct inputs to the Baltic Sea constitute only a minor share of the waterborne TN (5%) and TP (7%) waterborne inputs, they provide large proportions of the nutrient inputs to some sub-basins e.g. the Gulf of Finland (11%) for TN, and the Danish Straits (27%) and Bothnian Sea (12%) for TP in 2019.




BAP
Total nitrogen (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow
BAP
Total phosphorus (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow
GUF
Total nitrogen (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow
GUF
Total phosphorus (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow
GUR
Total nitrogen (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow
GUR
Total phosphorus (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow
DS
Total nitrogen (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow
DS
Total phosphorus (tonnes)
Flow (m³ s⁻¹)
Riverine
Direct
Flow

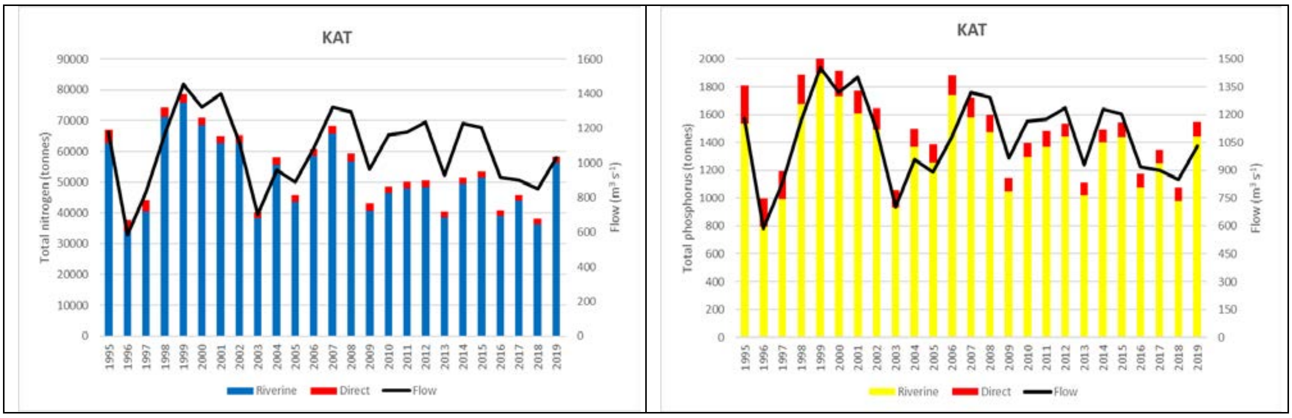
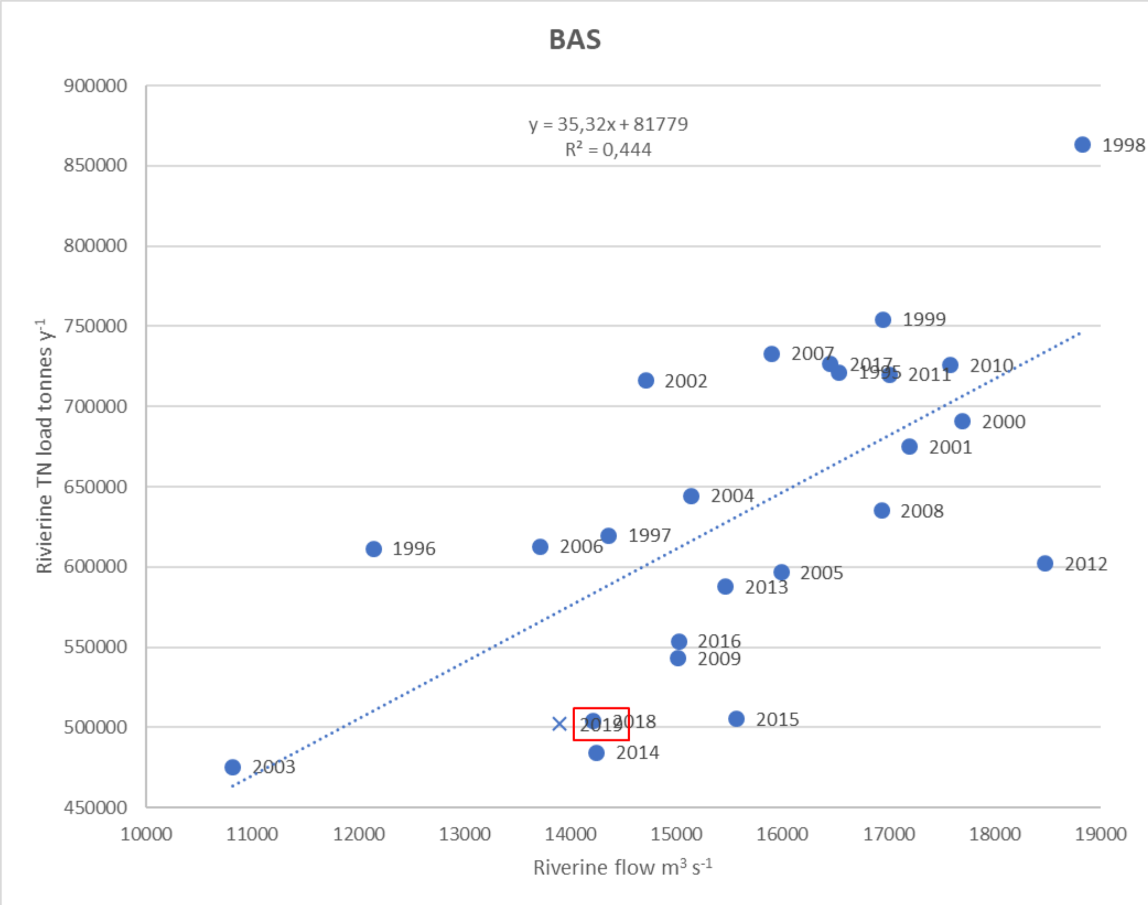


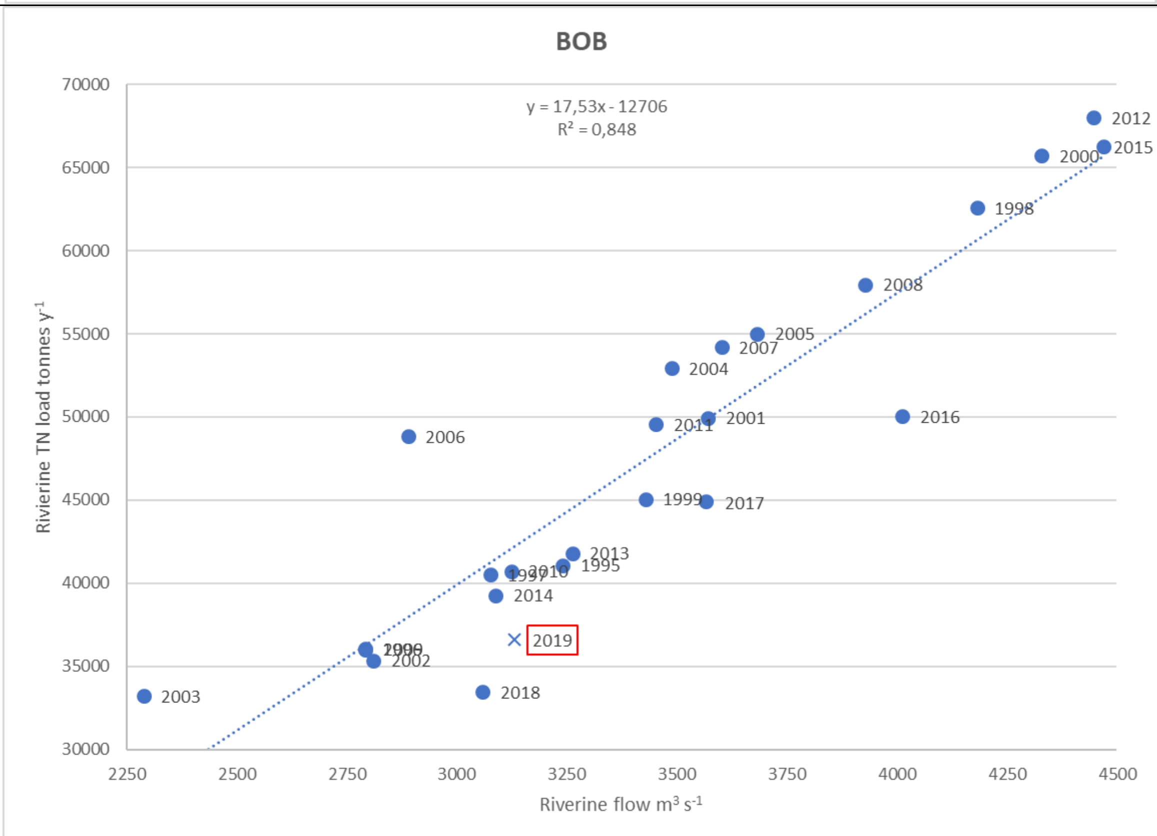
Figure 2: Annual riverine and direct inputs of total nitrogen (figures in the left column) and total phosphorus (figures in the right column) in tonnes and annual waterborne flow (m^{-3} s^{-1}) to the seven Baltic Sea sub-basin and to the Baltic Sea in 1995-2019. Data behind the figures are shown in Tables 2-7. For an explanation of the basin abbreviations, see the caption to Figure 1.

The correlation between the annual riverine TN and TP inputs, respectively, and water flow are shown as scatter and linear regression plots in Figure 3. The significance of the linear regression is tested statistically (see caption to Figure 3). The plots allow for characterization and evaluation of the TN and TP riverine inputs 1995-2019 specifically the inputs in 2019. The linear relation between riverine inputs and flow is significant for both TN and TP for all sub-basins and for the Baltic Sea except for the Gulf of Finland. Lack of significant correlation indicates some main challenges estimating input data to the GUF for some unmonitored areas and the nutrient load in some rivers particularly in the 1990' ties and up to around 2005.

Riverine TN and TP inputs in 2019 were markedly under what the regressions line indicates for the magnitude of flow during 1995-2019 to Baltic Sea, and for TP to all sub-basins except the Kattegat. For TN inputs only three sub-basins (Bothnian Bay, Bothnian Sea and Gulf of Finland (Figure 3) are under the regression line. However, the scatter indicates a rather considerable range of nutrient inputs for any particular flow.

As a rule of thumb, a decrease in riverine TN and/or TP inputs during 1995 to 2019 is significant if most of the inputs of the latest 12-13 years falls below the dotted lines in Figure 3. This is true for many sub-basins. If nutrient inputs from sources with low dependency of flow volume (e.g. as point sources, fertilization) that constituted a high share in the early parts of a times series, have been markedly reduced, values for recent years are plotted below the regression line in Figure 3. It will also give a lower regression coefficient R^2 compared with time series with low share of inputs from point sources.


BAS
y = 35,32x + 81779
R² = 0,444
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
900000
850000
800000
750000
700000
650000
600000
550000
500000
450000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
1998
1999
2007
2017
2011
2010
2002
2000
2001
2004
2008
1996
2006
1997
2005
2012
2013
2016
2009
2018
2015
2014
2003


BOB
y = 17,53x - 12706
R² = 0,848
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
70000
65000
60000
55000
50000
45000
40000
35000
30000
2250
2500
2750
3000
3250
3500
3750
4000
4250
4500
2012
2015
2000
1998
2008
2005
2007
2004
2011
2001
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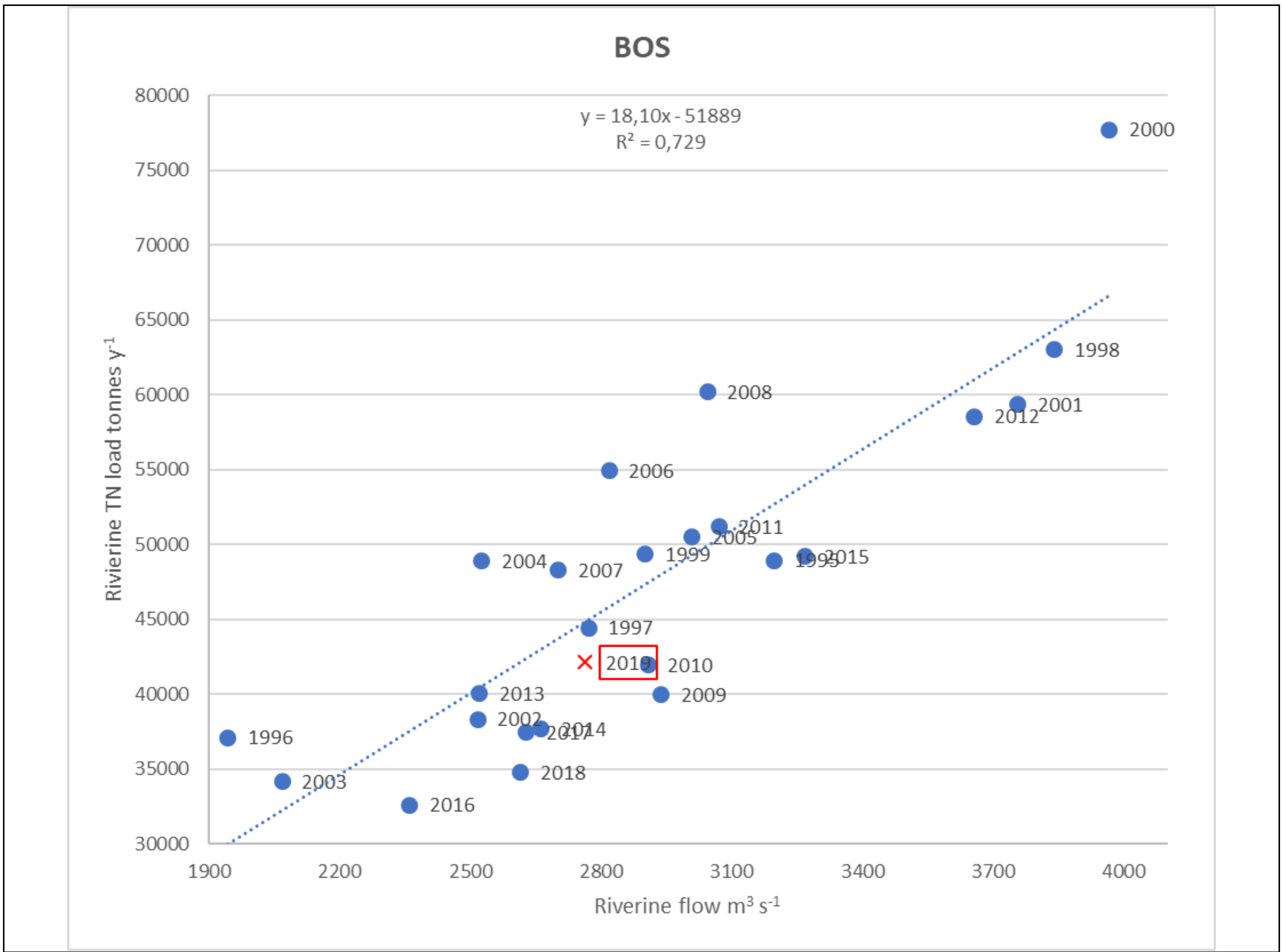
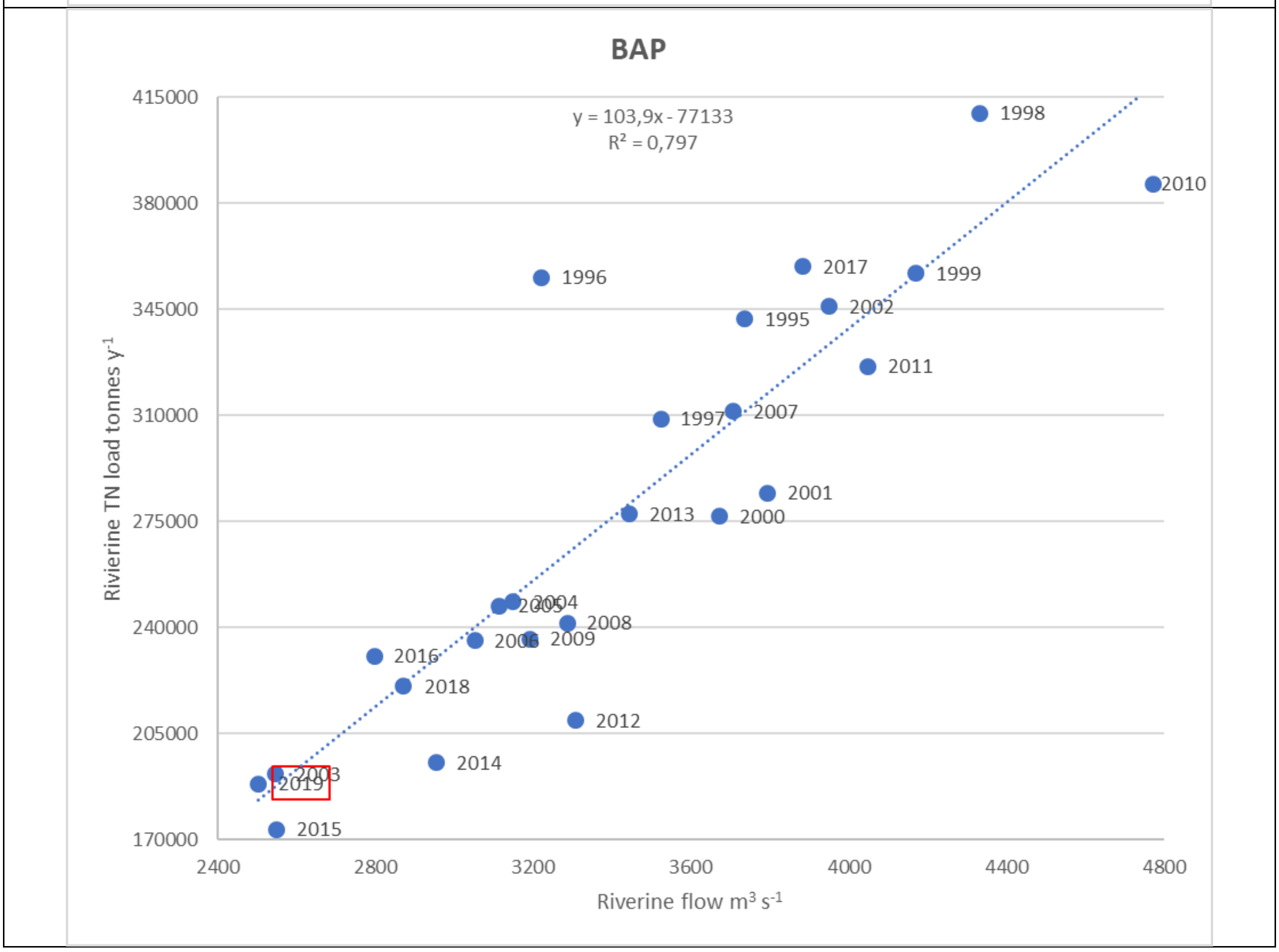
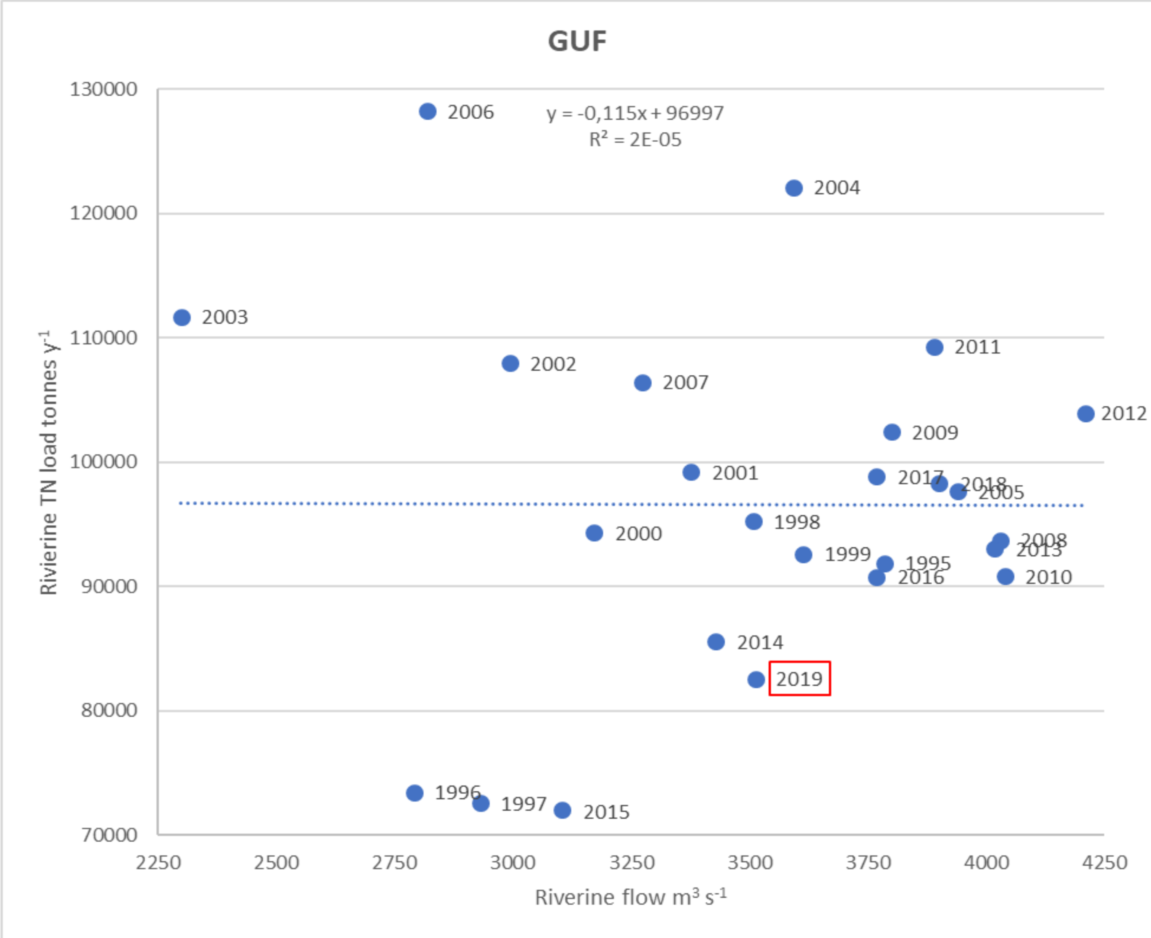
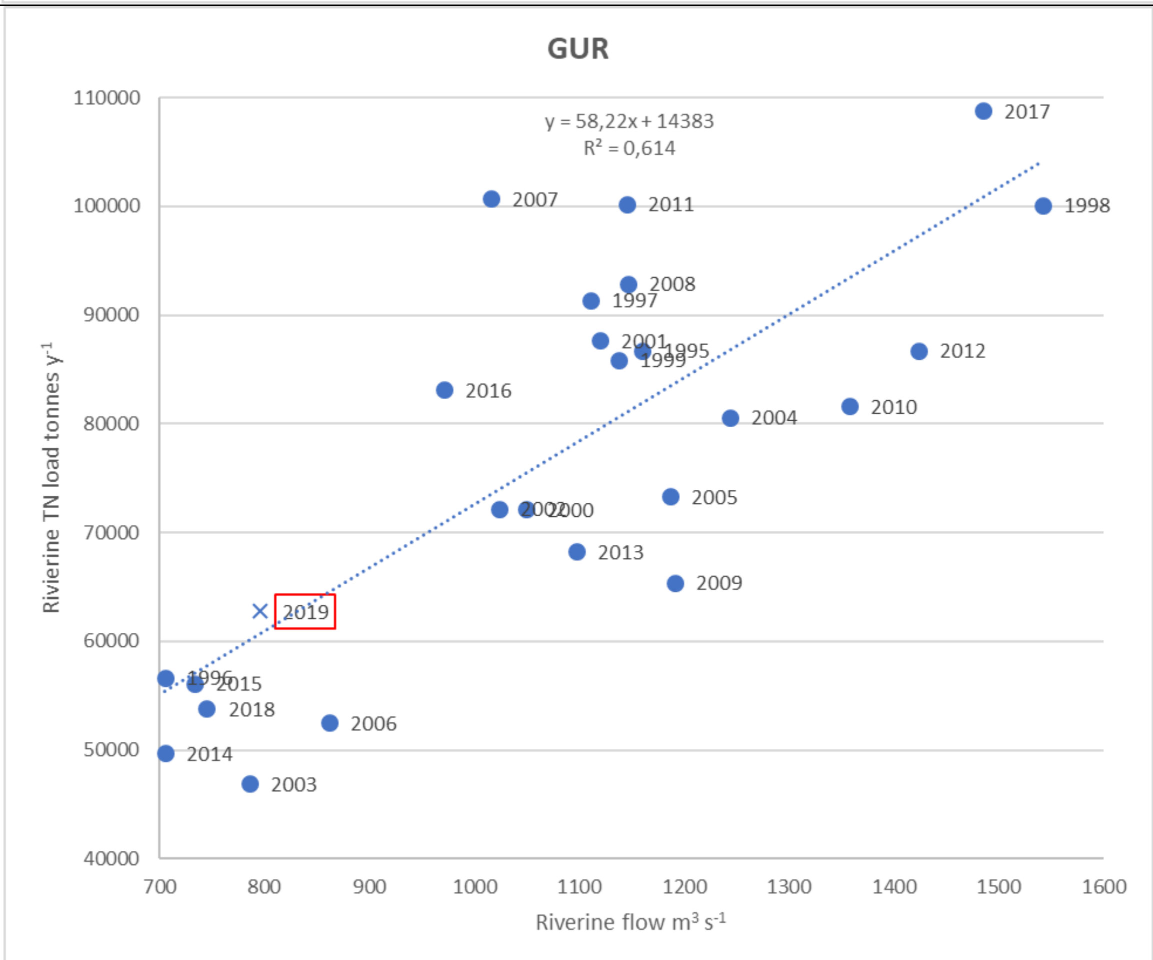
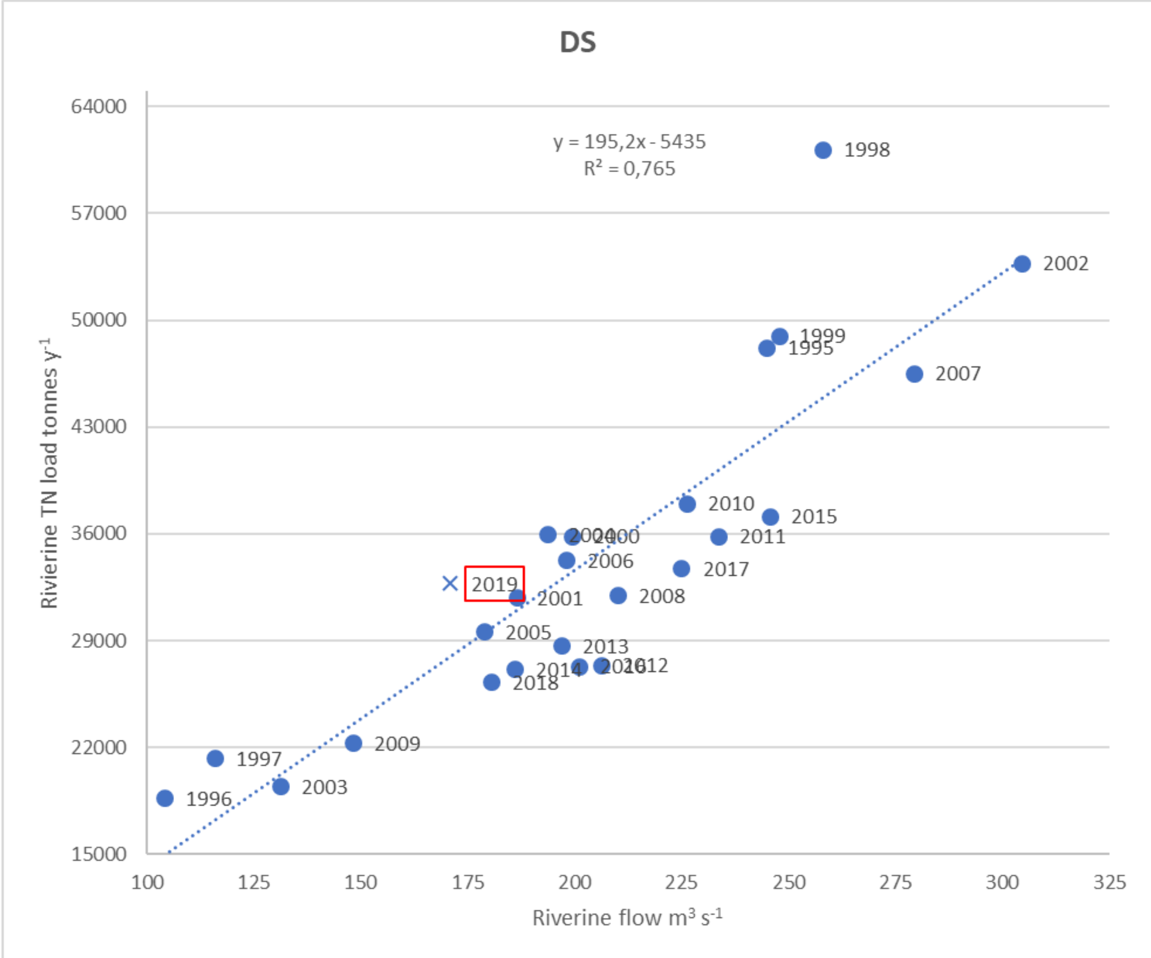
1995
2014
2019
2002
2003
2018


BOS
y = 18,10x - 51889
R² = 0,729
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
2000
1998
2008
2001
2012
2006
2011
2005
2004
2007
1999
1995
2015
1997
2019
2010
2013
2009
1996
2002
2014
2017
2003
2018
2016


BAP
y = 103,9x - 77133
R² = 0,797
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
1998
2010
2017
1999
1996
2002
1995
2011
1997
2007
2001
2013
2000
2004
2005
2008
2006
2009
2016
2018
2012
2014
2003
2019
2015


GUF
y = -0,115x + 96997
R² = 2E-05
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
2006
2004
2003
2011
2002
2007
2012
2009
2001
2017
2018
2005
2000
1998
2008
2013
1999
1995
2016
2010
2014
2019
1996
1997
2015


GUR
y = 58,22x + 14383
R² = 0,614
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
2017
2007
2011
1998
2008
1997
2001
1995
1999
2012
2016
2004
2010
2002
2000
2005
2013
2009
2019
1996
2015
2018
2006
2014
2003


DS
y = 195,2x - 5435
R² = 0,765
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
1998
2002
1999
1995
2007
2010
2015
2011
2006
2017
2019
2001
2008
2005
2013
2014
2012
2018
2009
1997
2003
1996
64000
57000
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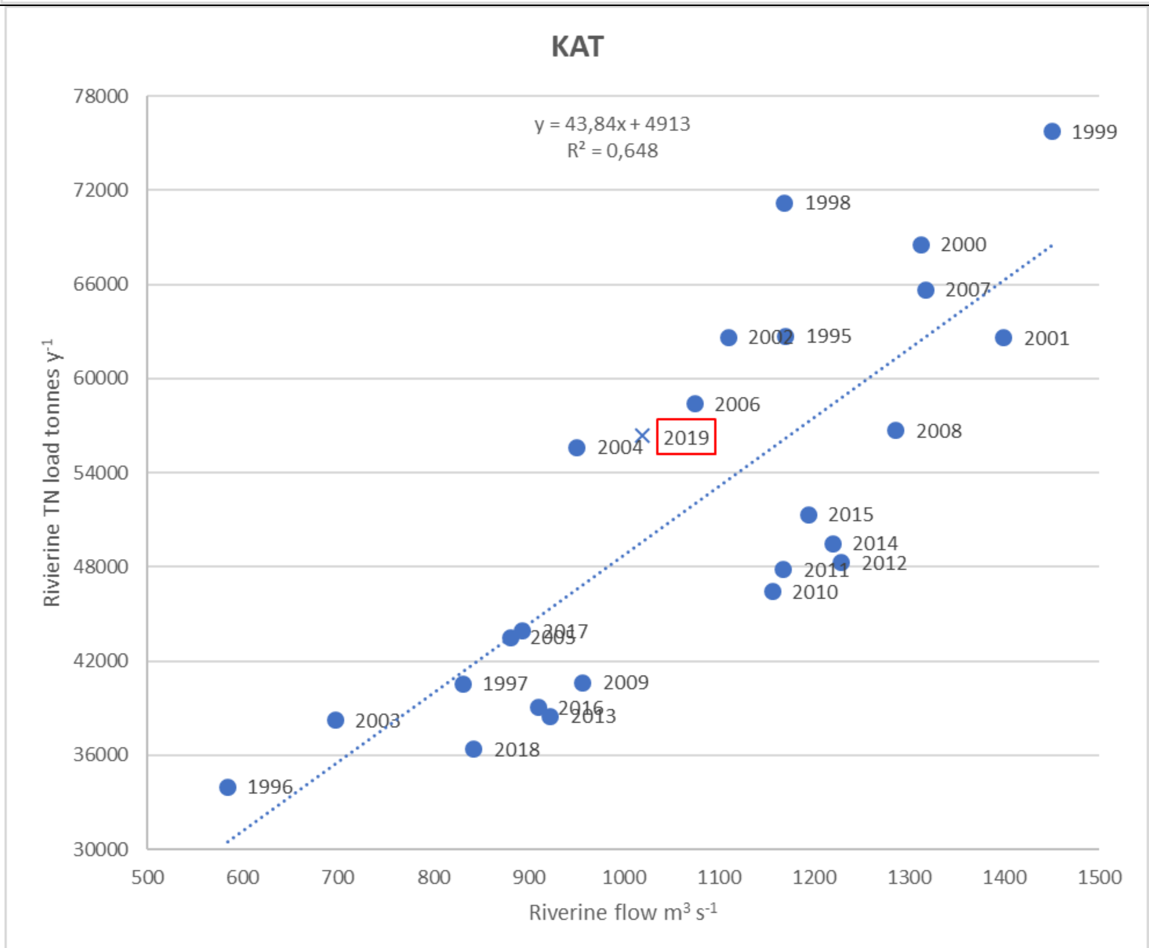
15000
100
125
150
175
200
225
250
275
300
325


KAT
y = 43,84x + 4913
R² = 0,648
Rivierine TN load tonnes y-1
Riverine flow m3 s-1
1999
1998
2000
2007
2002
1995
2001
2006
2019
2004
2008
2015
2014
2011
2012
2010
2017
2005
1997
2009
2016
2013
2003
2018
1996
78000
72000
66000
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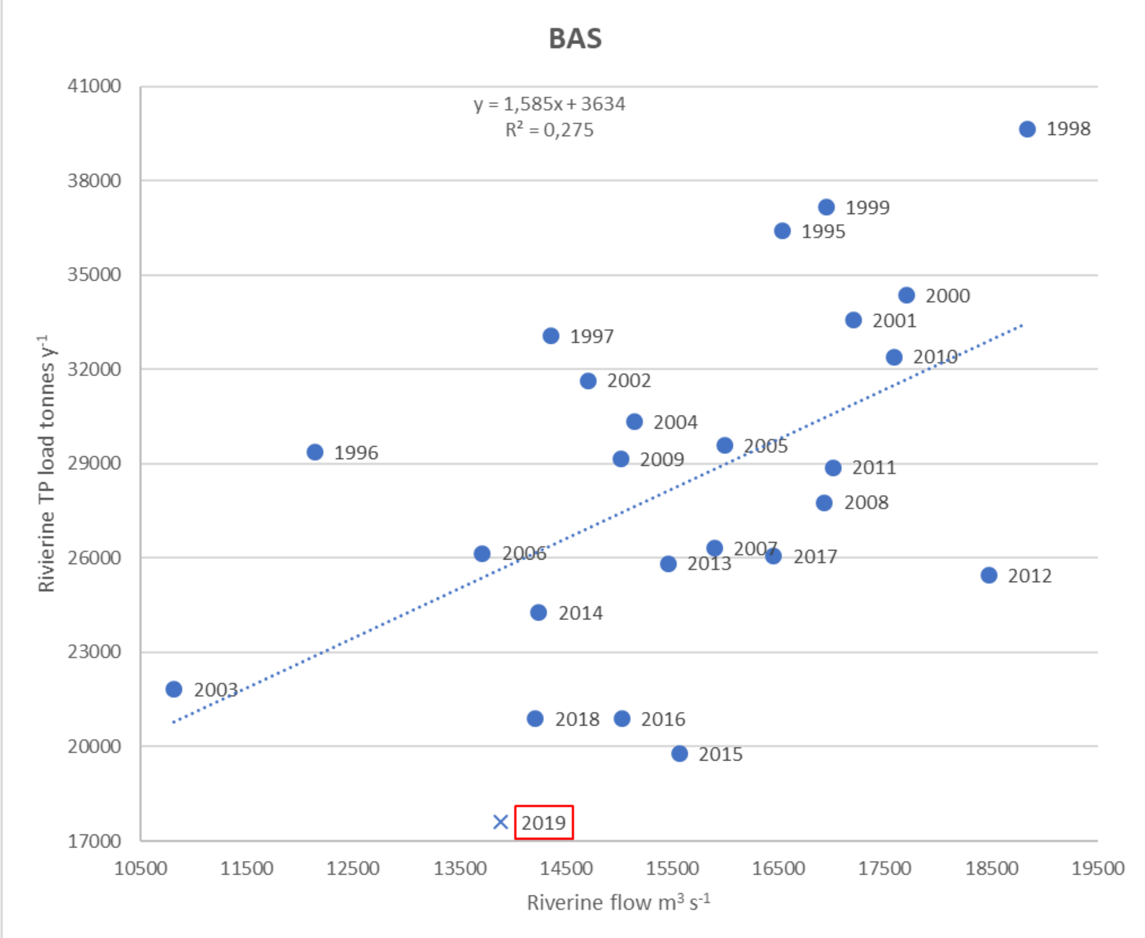
1100
1200
1300
1400
1500


BAS
y = 1,585x + 3634
R² = 0,275
Rivierine TP load tonnes y-1
Riverine flow m3 s-1
41000
38000
35000
32000
29000
26000
23000
20000
17000
10500
11500
12500
13500
14500
15500
16500
17500
18500
19500
1998
1999
1995
2000
2001
1997
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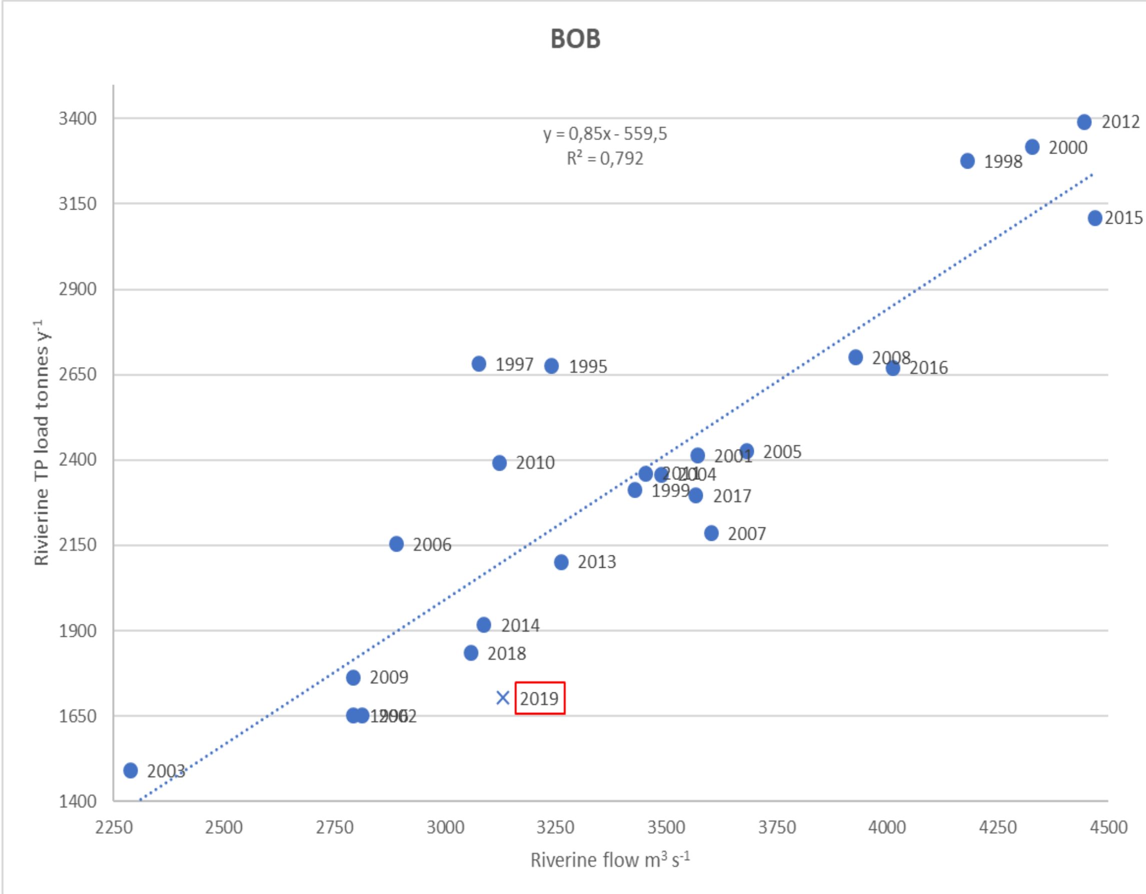
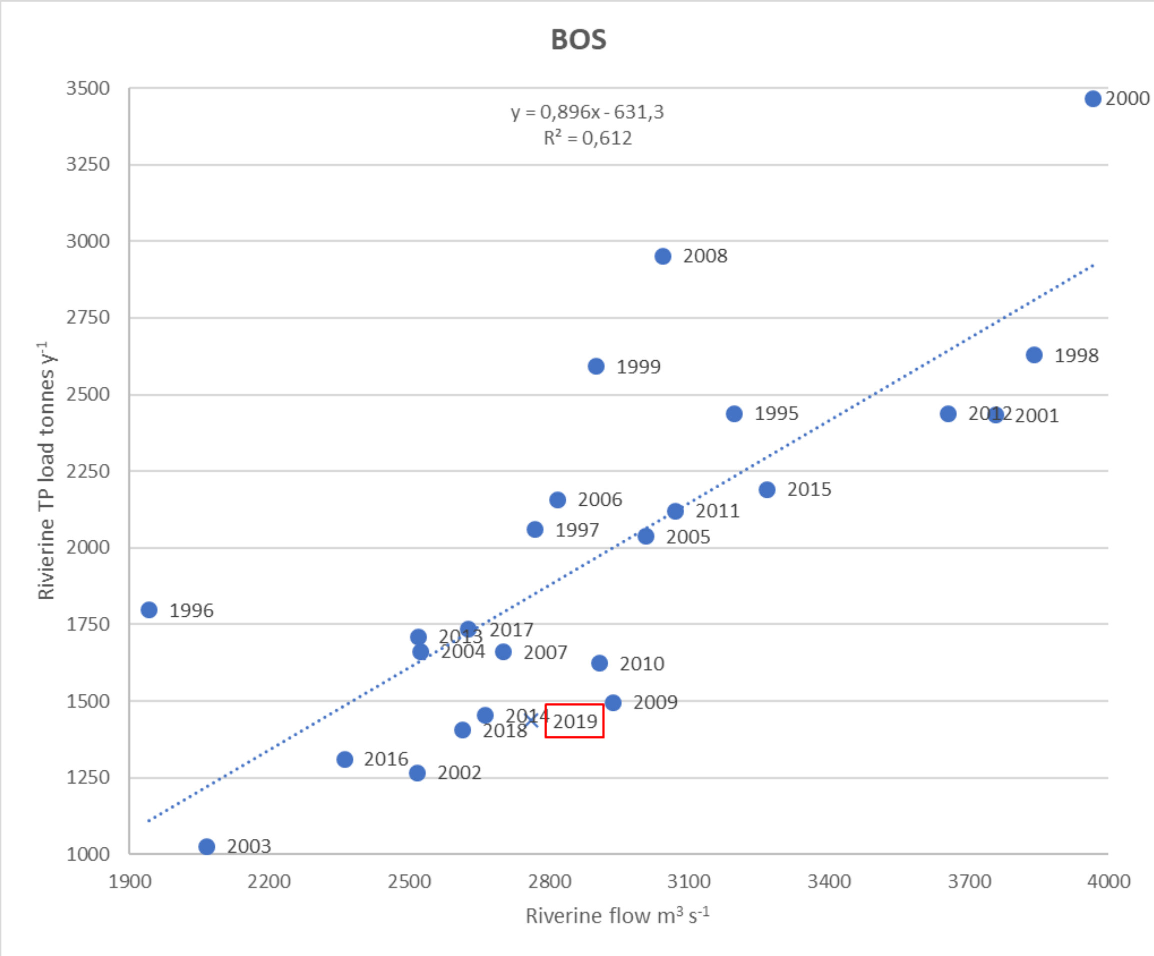
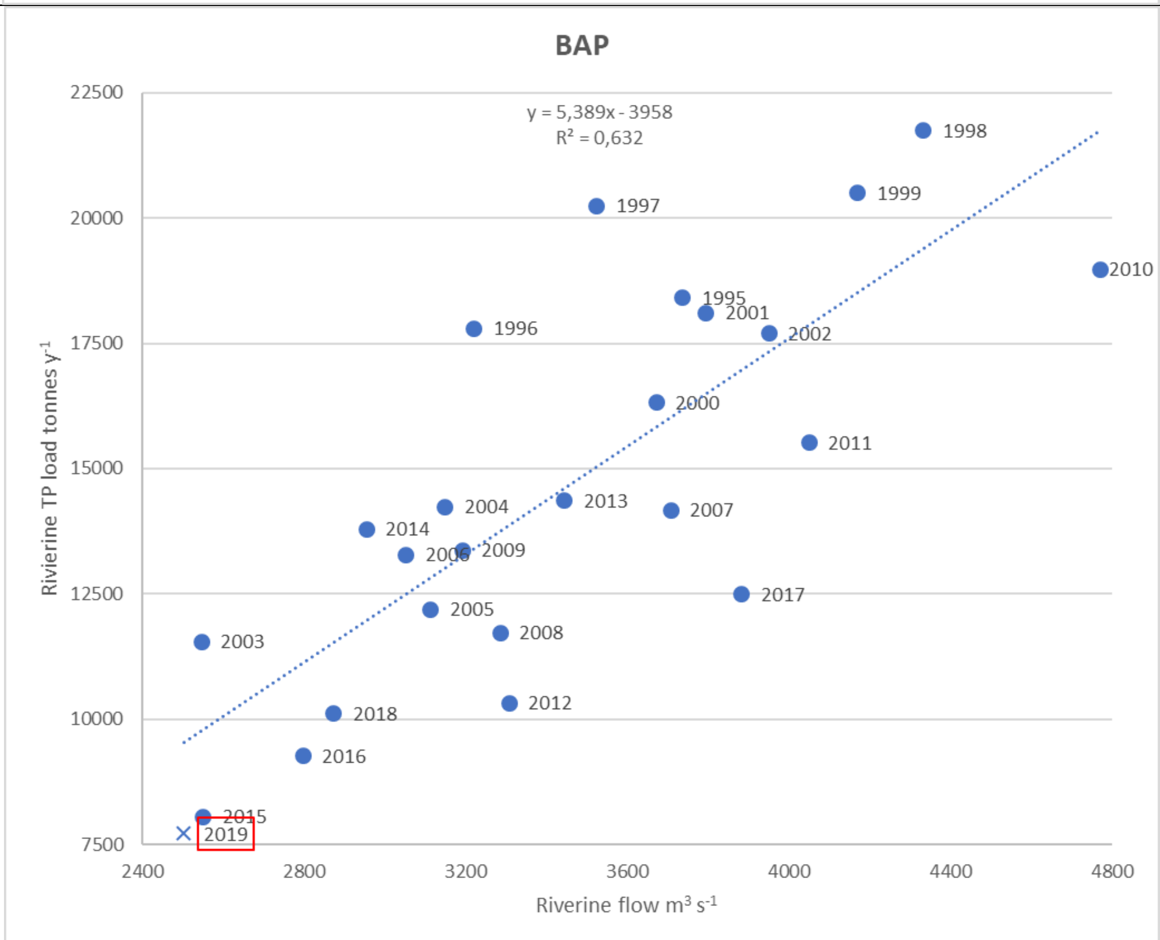
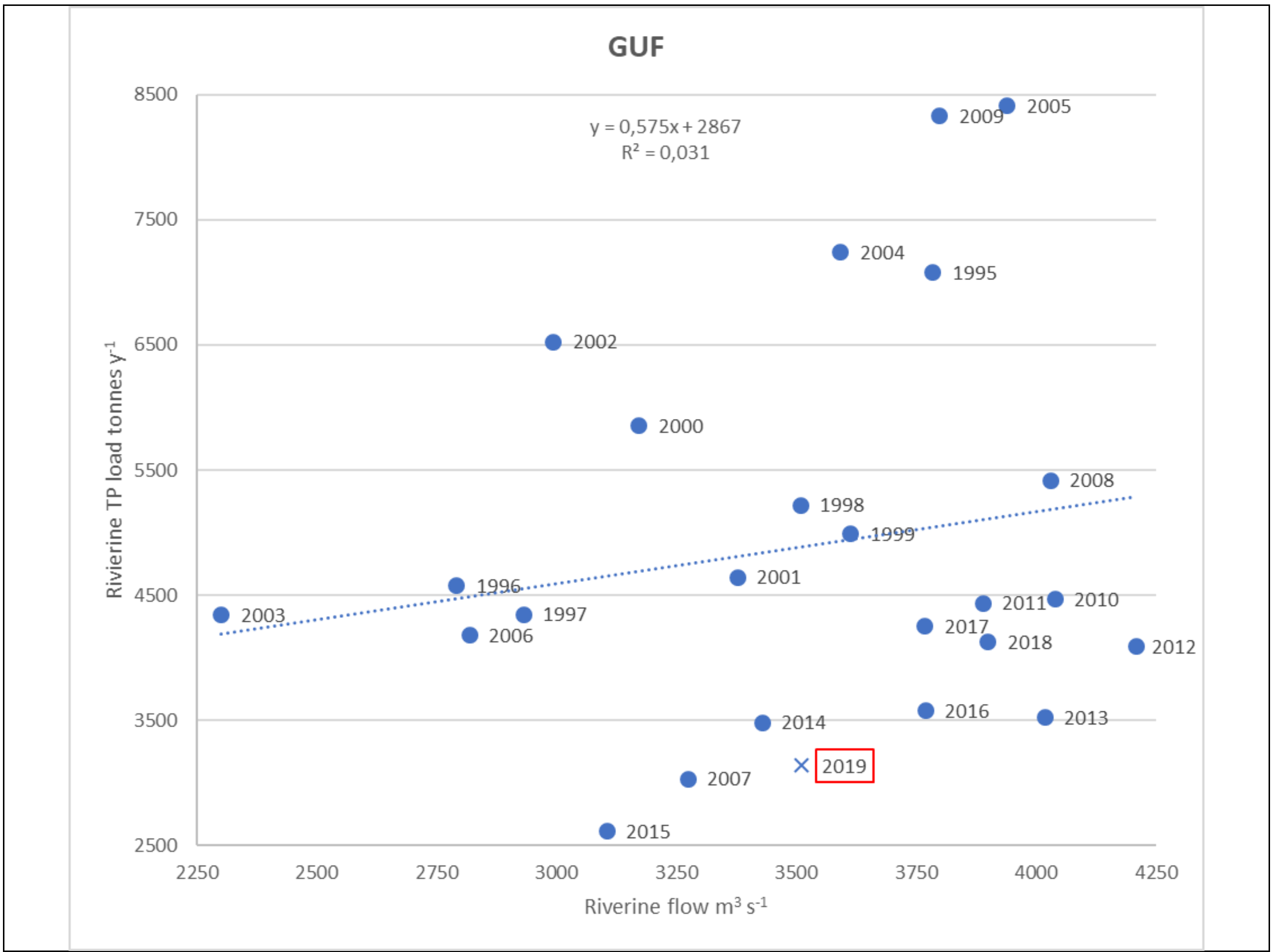
2014
2003
2018
2016
2015
2019

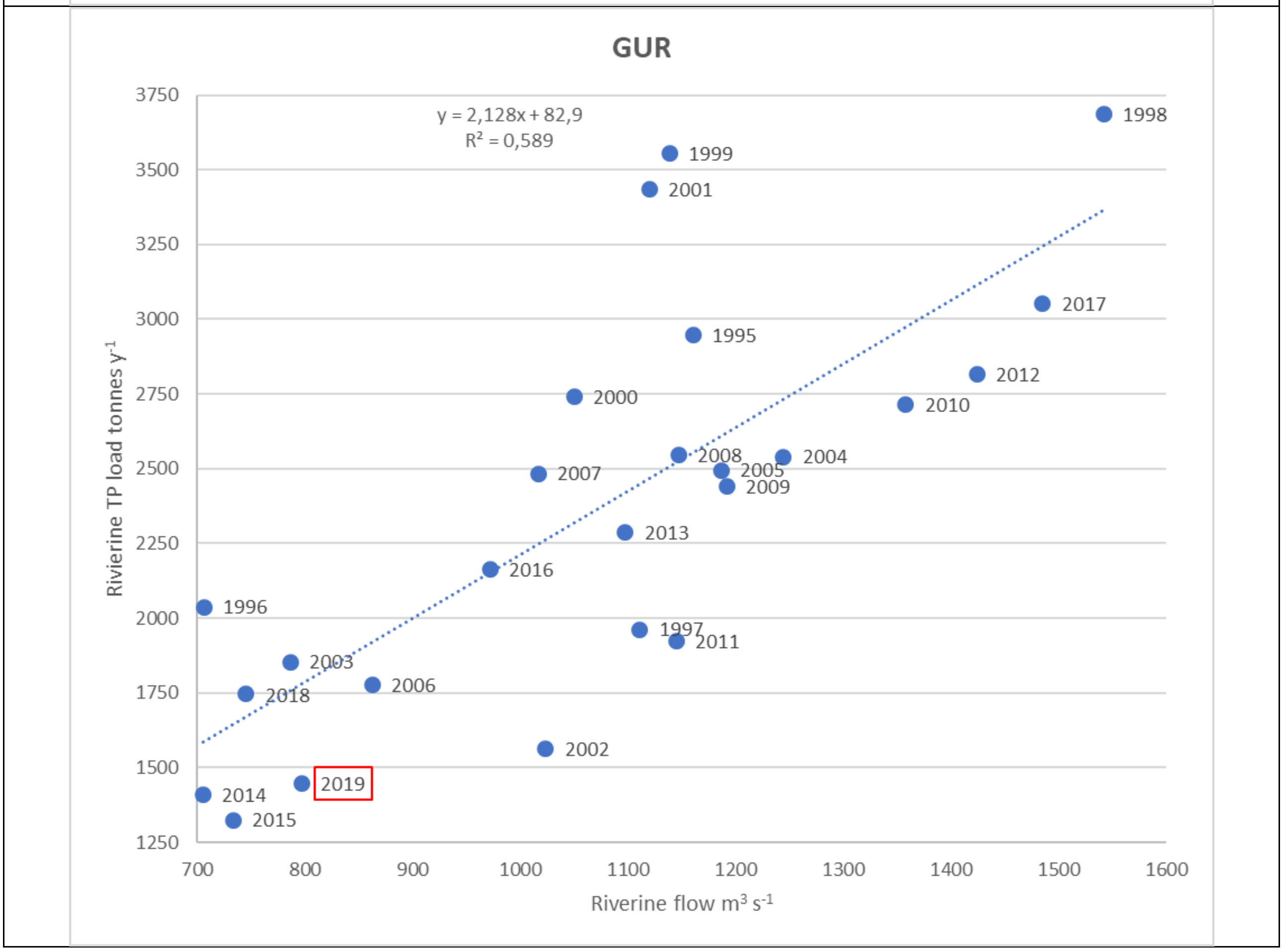

BOB
y = 0,85x - 559,5
R² = 0,792
Rivierine TP load tonnes y-1
Riverine flow m3 s-1
3400
3150
2900
2650
2400
2150
1900
1650
1400
2250
2500
2750
3000
3250
3500
3750
4000
4250
4500
2012
2000
1998
2015
1997
1995
2008
2016
2010
2001
2005
1999
2017
2007
2006
2013
2014
2018
2009
2019
2003


BOS
y = 0,896x - 631,3
R² = 0,612
Rivierine TP load tonnes y-1
Riverine flow m3 s-1
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
1900
2200
2500
2800
3100
3400
3700
4000
2000
2008
1999
1998
1995
2012
2001
2015
2006
2011
1997
2005
1996
2013
2017
2004
2007
2010
2009
2014
2018
2019
2016
2002
2003


BAP
y = 5,389x - 3958
R² = 0,632
Rivierine TP load tonnes y-1
Riverine flow m3 s-1
22500
20000
17500
15000
12500
10000
7500
2400
2800
3200
3600
4000
4400
4800
1998
1999
1997
2010
1995
2001
1996
2002
2000
2011
2004
2013
2007
2014
2006
2009
2017
2005
2008
2003
2018
2012
2016
2015
2019



GUF
y = 0,575x + 2867
R² = 0,031
2005
2009
2004
1995
2002
2000
2008
1998
1999
2001
1996
2003
1997
2006
2011
2010
2017
2018
2012
2016
2013
2014
2019
2007
2015
Rivierine TP load tonnes y-1
Riverine flow m3 s-1



GUR
y = 2,128x + 82,9
R² = 0,589
1998
1999
2001
2017
1995
2012
2000
2010
2008
2004
2005
2009
2007
2013
2016
1996
1997
2011
2003
2006
2018
2002
2019
2014
2015
Rivierine TP load tonnes y-1
Riverine flow m3 s-1

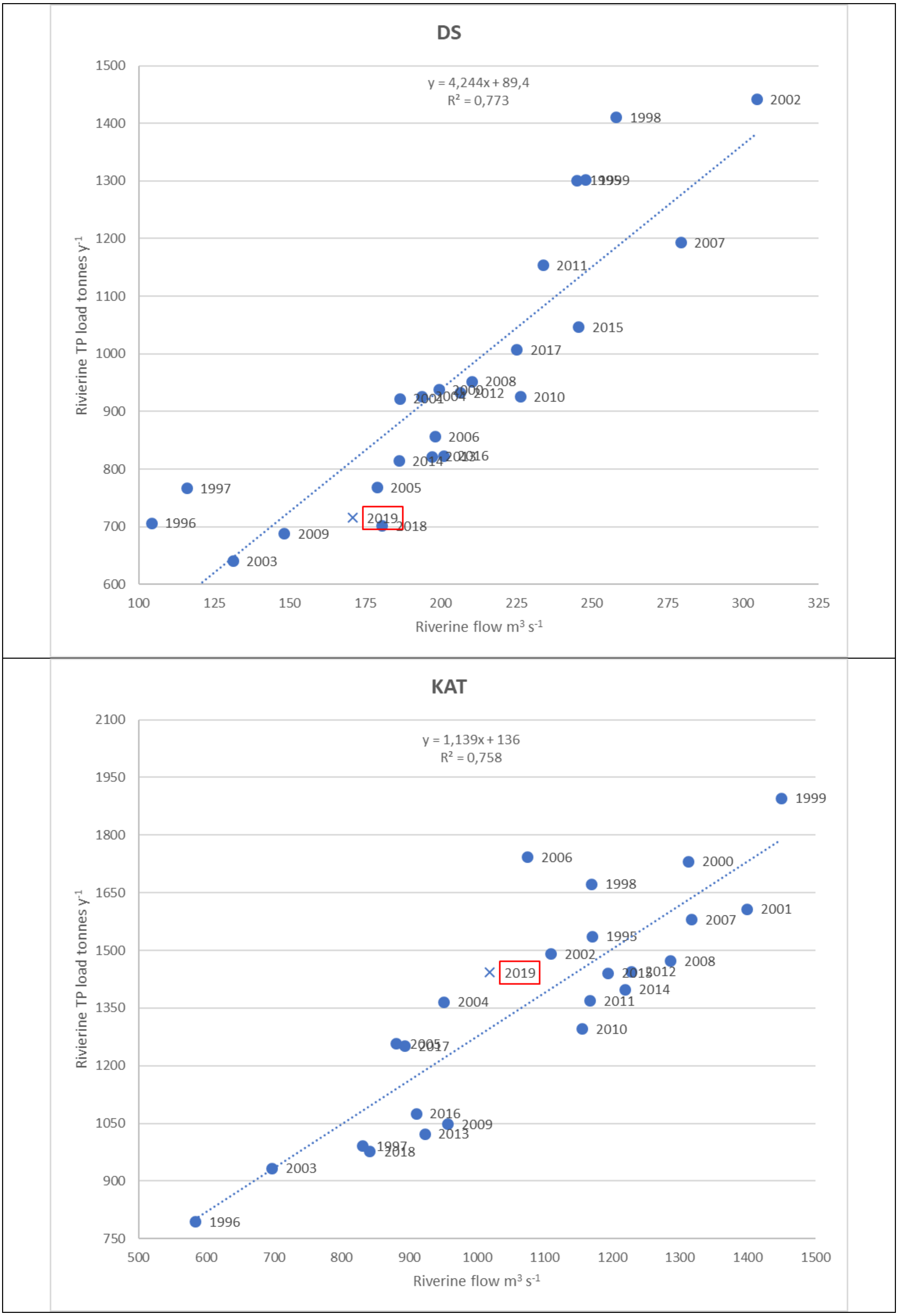
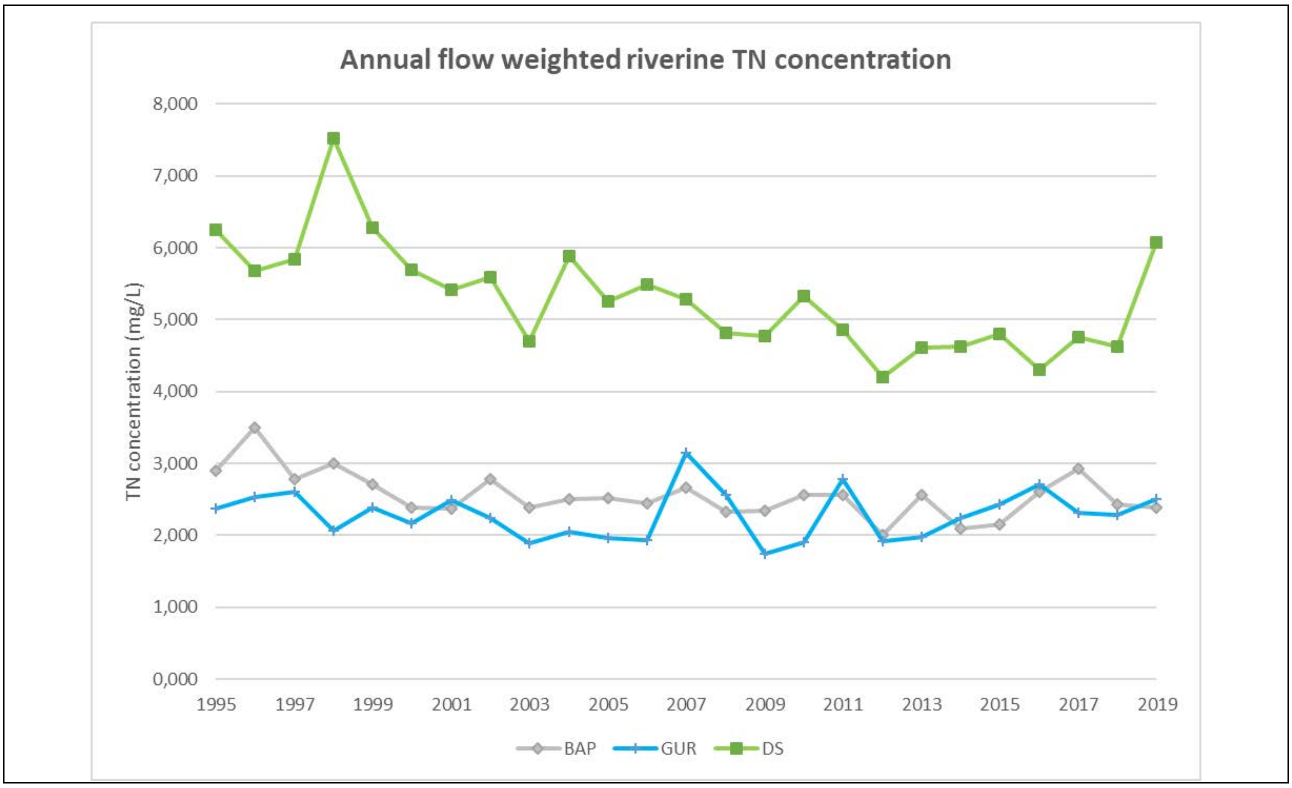


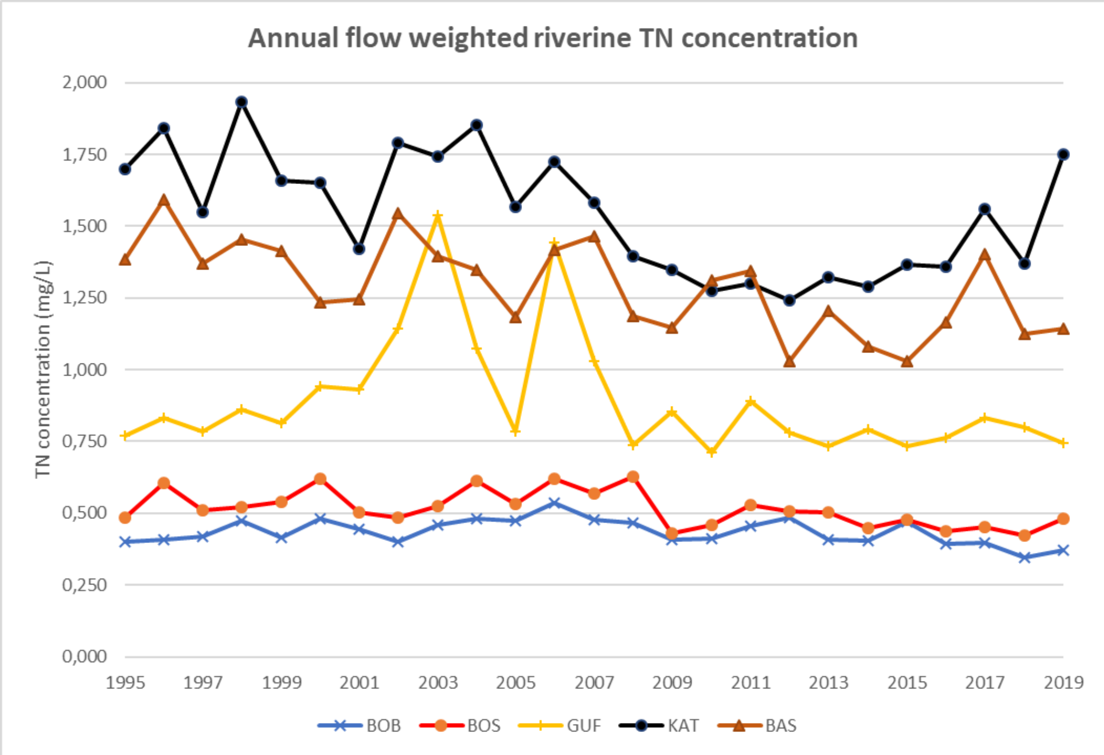
Figure 3. Linear regression plots of annual riverine flows ($m^3\ s^{-1}$) against annual riverine total nitrogen inputs - TN - (the eight uppermost figures) and total phosphorus inputs – TP – (the eight lowermost figures) to the seven

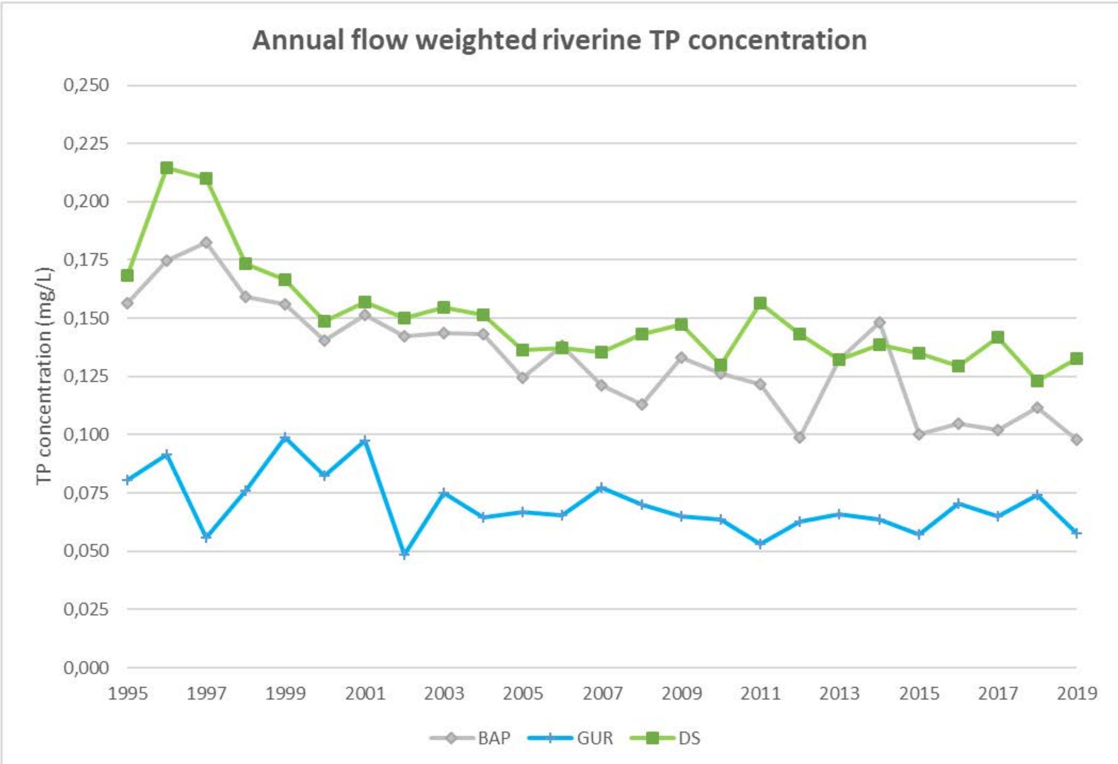
Baltic Sea sub-basins and to the Baltic Sea during 1995-2019. Most recent year (2019) is marked with “X” and “2019” surrounded by a red box. The linear regression is indicated as y = a·X + b, where Y = riverine input (TN, TP), a = slope, b = intercept Y-axis. R^2 indicates how much of the variation is explained by the regression, e.g. R^2 =0.867 say that nearly 87 % of the variation is explained (good correlation) by the regression. The statistical test calculates an F-value and analyses if the linear relation is significant (95 % confidence). All relations besides TN and TP for the GUF are significant. For an explanation of abbreviations, see the caption to Figure 1.

Flow weighted annual concentrations are used as a rough evaluation of any trends in nutrient inputs combined with a simple linear regression analysis. In Figure 4 the flow weighted riverine TN and TP annual concentrations during 1995-2019 are shown for the Baltic Sea and its seven sub-basins. A statistical test on the linear regressions (test explained in the caption to Figure 3) indicates that the discharged weighted TN riverine concentrations decreased significantly (95% significance) to the Bothnian Sea, the Baltic Proper, the Danish Straits, the Kattegat and the Baltic Sea. The discharged weighted TP riverine concentrations decreased significantly to all sub-basins and to the Baltic Sea besides to the Kattegat with a not significant decrease.

Figure 4 have been sub-divided as the flow-weighted TN and TP concentrations to the Baltic Proper, the Danish Straits and the Gulf of Riga are higher than for the four remaining sub-basins. Particularly flow-weighted TN and TP concentrations to the Bothnian Bay and the Bothnian Sea are of an order of magnitude lower than for the inputs to the Danish Straits concentrations. This is the result of both scarce population and low agricultural pressures combined together with high area specific flow to these sub-basins: BOB, BOS and Kattegat have area specific flow of about 12 l s^{-1} km^{-2} on average for 1995-2019, see Table 1. On average, the area specific flow to the Baltic Sea is 9 l s^{-1} km^{-2}, with only 6 to 8 l s^{-1} km^{-2} to the Baltic Proper, the Gulf of Finland, the Gulf of Riga and the Danish Straits during 1995-2019. There is a remarkable increase in the flow weighted TN concentration from 2018 to 2019 to the Danish Straits and the Kattegat. It is related to a rather severe drought in 2018, with poor harvest, accumulation of nitrogen in the soils with a subsequent leaching out of to the rivers during a wet late summer and autumn 2019, with rather high flow at least in the Danish catchments to the Danish Straits and Kattegat. A corresponding pattern was seen for Swedish catchment to Kattegat,




Annual flow weighted riverine TN concentration
TN concentration (mg/L)
2,000
1,750
1,500
1,250
1,000
0,750
0,500
0,250
0,000
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
BOB
BOS
GUF
KAT
BAS


Annual flow weighted riverine TP concentration
TP concentration (mg/L)
0,250
0,225
0,200
0,175
0,150
0,125
0,100
0,075
0,050
0,025
0,000
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
BAP
GUR
DS

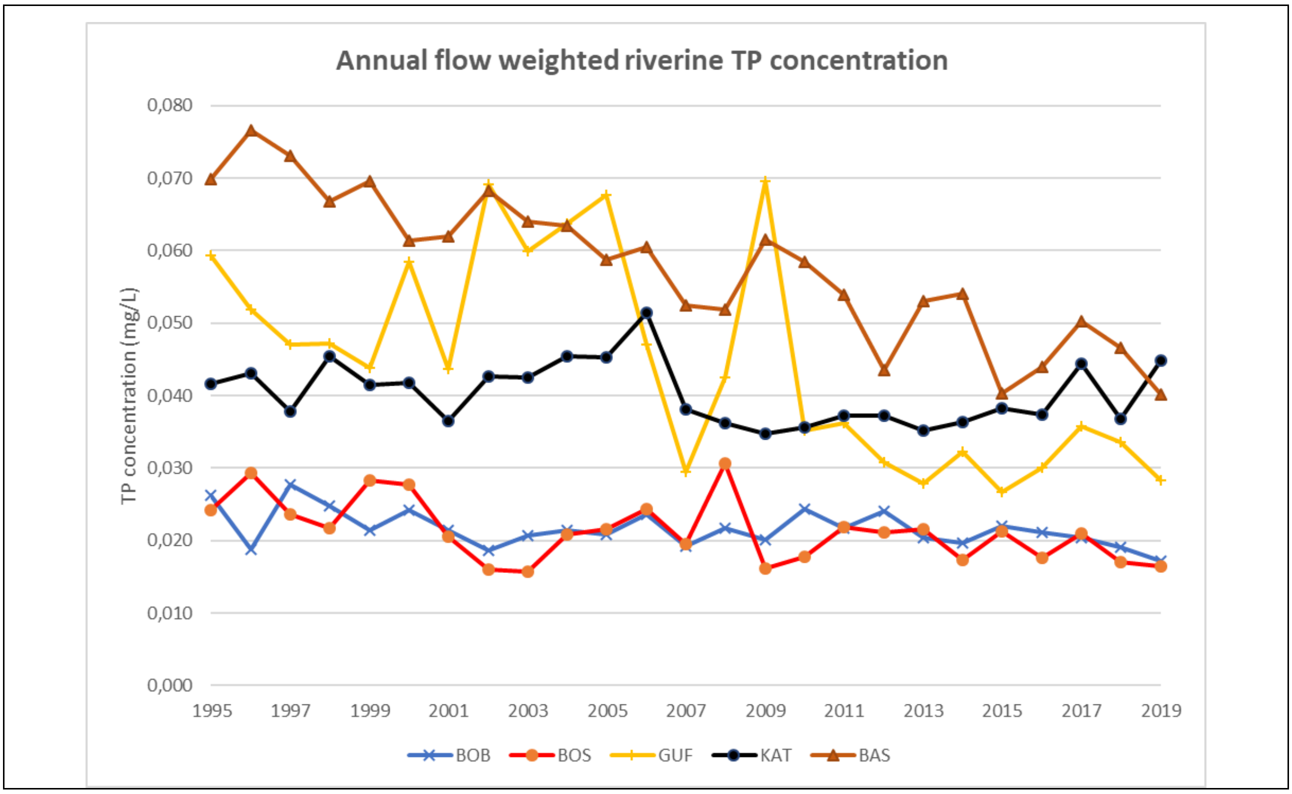


Figure 4. Annual average flow weighted riverine TN (the two upmost figures) and TP (the two lower most figures) concentrations for the seven Baltic Sea sub-basins and the Baltic Sea (calculated as total annual riverine inputs divided with the corresponding annual flow) during 1995-2019. TN and TP for Baltic Proper, Gulf of Riga and Danish Straits are given in separate plots (1 and 3) due to higher flow-weighted concentrations than to the remaining sub-basins (2 and 4). Explanation of abbreviations are given in the caption to Figure 1.

Policy relevance and policy references[4]

Since the establishment of the Convention for the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) in 1974, the Commission for the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Commission or HELCOM for short) has been working to reduce the inputs of nutrients to the sea.

In Article 3 and Article 16 of the Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992 (Helsinki Convention), the Contracting Parties agreed to undertake measures to prevent and eliminate pollution of the marine environment of the Baltic Sea and to provide pollution load data, as far as available. Through coordinated monitoring, since the mid-1980s HELCOM has been compiling information about the magnitude and sources of nutrient inputs into the Baltic Sea. By regularly compiling and reporting data on pollution inputs, HELCOM follows the progress towards reaching politically agreed nutrient reduction input targets.

The HELCOM Baltic Sea Action Plan (BSAP) was adopted in 2007 by the Baltic Sea coastal countries and the European Union (HELCOM 2007). The BSAP sets the overall objective of reaching good environmental status in the Baltic Sea by 2021, by addressing eutrophication, hazardous substances, biodiversity and maritime activities. As an innovative feature, the BSAP included a scientific based

[4] Regarding atmospheric inputs the relevant policies are: The Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone under UNECE Convention on Long-range Transboundary Air pollution (CLRTAP); EU NEC Directive (2016/2284/EU); IMO designation of the Baltic Sea as a ”special area” for passenger ships under MARPOL (International Convention for the Prevention of Pollution from Ships) Annex IV (on sewage from ships); EC Directive 2000/59/EC on port reception facilities; and the Application of the Baltic Sea NOx emission control area (NECA).

nutrient input reduction scheme identifying Maximum Allowable Inputs (MAI) of nutrients to achieve good status in terms of eutrophication. The plan also adopted provisional country-wise allocation of reduction targets (CARTs), and the CARTs are converted to nutrient input ceilings (NIC) for each country and Baltic Sea sub-basin.

The 2013 HELCOM Copenhagen Ministerial Declaration (HELCOM 2013a, 2013b and 2013c) revised maximum allowable inputs of nutrients and reduction targets using the best available scientific data and models. Further, national nutrient input ceilings (NIC) were calculated for each country and each Baltic Sea sub-basin.

The HELCOM Brussels Ministerial Declaration 2018 committed HELCOM member states to act further to achieve national reduction requirements based on Maximum Allowable Inputs of nutrients to the Baltic Sea sub-basins.

Reducing the effects of human-induced eutrophication is the stated goal of Descriptor 5 in the EU Marine Strategy Framework Directive (MSFD). Inputs of nutrients to the Baltic Sea marine environment have an effect on the nutrient levels under criterion D5C1 of the MSFD.

The information provided in this BSEFS also supports the follow-up of the implementation of the targets and measures under the following policies addressing reduction of nutrient inputs: EU Maritime Strategy Framework Directive (MSFD); EU Water Framework Directive (WFD); EU Nitrates Directive; EU Urban Waste-Water Treatment Directive; EU Industrial Emissions Directive (IED); Water Code of Russian Federation; Federal Act on the internal maritime waters, territorial sea and contiguous zone of the Russian Federation.

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Data

Table 2. Annual waterborne flow (sum of riverine flow and direct flow (flow for point sources discharging direct into the Baltic Sea)) to the seven Baltic Sea sub-basins and the Baltic Sea (in $m^3 s^{-1}$). For an explanation of abbreviations, see the caption to Figure 1.

Flow Sum	m3/s **BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**	**BAS**
1995	3263	3217	3754	3796	1164	260	1179	16632
1996	2805	1951	3222	2824	706	112	586	12206
1997	3092	2779	3525	2964	1111	125	833	14429
1998	4198	3846	4334	3542	1541	269	1171	18903
1999	3445	2907	4171	3647	1138	258	1453	17018
2000	4349	3981	3691	3217	1052	213	1321	17824
2001	3585	3762	3797	3413	1122	196	1402	17277
2002	2829	2524	3965	3029	1026	318	1118	14807
2003	2305	2075	2561	2336	788	142	704	10911
2004	3505	2531	3163	3631	1244	206	958	15237
2005	3701	3015	3130	3972	1187	190	889	16084
2006	2902	2826	3067	2852	864	210	1083	13805
2007	3613	2713	3714	3307	1018	292	1320	15978
2008	3941	3054	3303	4065	1149	223	1294	17028
2009	2802	2943	3207	3833	1193	160	964	15103
2010	3135	2914	4787	4071	1360	239	1163	17669
2011	3466	3077	4065	3922	1147	247	1176	17101
2012	4460	3661	3321	4243	1426	219	1237	18566
2013	3276	2526	3460	4050	1099	209	930	15550
2014	3101	2667	2971	3461	707	199	1227	14335
2015	4486	3277	2570	3137	735	259	1204	15668
2016	4023	2371	2816	3801	973	214	918	15116
2017	3584	2639	3905	3803	1487	239	902	16559
2018	3079	2633	2892	3934	747	192	851	14327
2019	3158	2784	2522	3552	799	184	1029	14029

Table 3. Annual total nitrogen (TN) direct inputs to the seven Baltic Sea sub-basins and the Baltic Sea (in tonnes). For an explanation of abbreviations, see the caption to Figure 1.

TN Direct	tonnes **BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**	**BAS**
1995	3421	6319	16636	17730	1164	12676	4236	62182
1996	3193	5707	11747	15051	1224	7339	3718	47980
1997	3270	5825	10289	13421	1250	5800	3549	43404
1998	3524	5565	9103	12598	1247	6130	3080	41249
1999	3397	5381	8140	12958	1251	5004	2768	38899
2000	3305	5613	8829	13129	1400	6966	2451	41693
2001	3047	5392	6937	13285	1521	4116	2431	36730
2002	3047	5169	6814	13318	1430	3371	2509	35659
2003	3246	5199	6682	13258	1815	2991	2095	35284
2004	2911	5364	6542	12130	1442	3107	2286	33781
2005	3013	5336	6395	10229	1573	2906	2227	31679
2006	2729	5377	6886	9328	1768	3083	2477	31650
2007	2788	4916	7705	9750	2379	3303	2640	33481
2008	2900	4965	6898	9266	2460	2981	2702	32171
2009	2712	4659	6424	10164	1277	3213	2466	30915
2010	2823	4422	6908	9890	1121	2860	2228	30252
2011	2996	4348	6965	10242	1143	3187	2253	31135
2012	3311	4697	6623	9898	1107	3087	2188	30912
2013	3676	4514	6469	9731	696	3201	2000	30286
2014	3733	4272	5970	9406	516	3128	2039	29063
2015	3452	4574	6276	8968	543	3341	2151	29305
2016	3426	4254	5271	9278	518	3156	1935	27838
2017	3591	4390	5501	9822	432	3351	1901	28987
2018	3094	4111	4497	8201	402	2994	1659	24958
2019	3013	4142	4674	10181	442	3348	1998	27797

Table 4. Annual total nitrogen (TN) riverine inputs to the seven Baltic Sea sub-basins and the Baltic Sea (in tonnes). For an explanation of abbreviations, see the caption to Figure 1.

TN	tonnes							
River	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**	**BAS**
1995	41102	48951	342064	91913	86782	48217	62735	721764
1996	36029	37116	355660	73450	56695	18678	33998	611625
1997	40513	44464	309104	72569	91385	21327	40575	619936
1998	62564	63056	409894	95253	100132	61204	71244	863347
1999	45064	49395	356970	92635	85896	48986	75791	754736
2000	65728	77735	276837	94340	72176	35847	68562	691224
2001	49948	59393	284570	99232	87660	31833	62613	675250
2002	35367	38357	346119	107992	72212	53752	62657	716456
2003	33239	34196	191875	111697	46935	19462	38260	475664
2004	52949	48918	248584	122129	80593	35989	55645	644806
2005	55010	50530	247402	97663	73307	29619	43530	597060
2006	48822	54970	235813	128229	52558	34263	58417	613073
2007	54194	48310	311515	106440	100741	46517	65701	733418
2008	57971	60223	241695	93737	92898	31974	56720	635217
2009	36075	39981	236507	102425	65424	22288	40652	543353
2010	40719	41986	386591	90839	81637	38001	46463	726235
2011	49542	51197	326307	109315	100218	35858	47866	720304
2012	67999	58595	209626	103959	86744	27404	48279	602607
2013	41812	40073	277593	93048	68255	28662	38511	587954
2014	39284	37698	195735	85578	49743	27155	49514	484707
2015	66246	49209	173662	71974	56117	37161	51370	505740
2016	50058	32636	230880	90795	83156	27334	39065	553922
2017	44874	37468	359233	98850	108734	33748	43933	726840
2018	33469	34781	220827	98257	53782	26312	36386	503813
2019	36576	42078	188655	82572	62762	32721	56297	501661

Table 5. Annual total nitrogen (TN) waterborne (riverine + direct) inputs to the seven Baltic Sea sub-basins and the Baltic Sea (in tonnes). For an explanation of abbreviations, see the caption to Figure 1.

TN	tonnes							
Sum	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**	**BAS**
1995	44523	55270	358700	109642	87946	60893	66970	783945
1996	39222	42823	367408	88500	57919	26017	37716	659605
1997	43783	50288	319394	85990	92635	27126	44124	663340
1998	66088	68621	418997	107851	101379	67335	74325	904596
1999	48461	54776	365109	105594	87146	53990	78558	793636
2000	69033	83348	285665	107469	73576	42813	71013	732917
2001	52995	64785	291507	112518	89182	35949	65044	711980
2002	38414	43526	352933	121310	73642	57123	65166	752114
2003	36484	39395	198557	124955	48749	22453	40355	510948
2004	55860	54282	255126	134258	82034	39096	57931	678587
2005	58022	55866	253797	107892	74880	32524	45757	628739
2006	51551	60347	242700	137558	54326	37346	60894	644722
2007	56982	53226	319220	116190	103120	49820	68341	766898
2008	60870	65188	248593	103003	95357	34955	59421	667388
2009	38787	44640	242931	112589	66701	25501	43118	574268
2010	43541	46409	393498	100729	82758	40862	48691	756488
2011	52539	55545	333273	119557	101361	39046	50119	751439
2012	71309	63292	216250	113857	87851	30492	50468	633518
2013	45488	44587	284062	102779	68951	31863	40511	618241
2014	43017	41970	201705	94984	50258	30283	51552	513770
2015	69698	53783	179938	80942	56660	40502	53521	535045
2016	53484	36890	236151	100073	83674	30490	40999	581760
2017	48465	41859	364734	108672	109166	37098	45833	755827
2018	36563	38892	225324	106457	54184	29306	38045	528772
2019	39588	46219	193329	92753	63205	36069	58295	529459

Table 6. Annual total phosphorus (TP) direct inputs to the seven Baltic Sea sub-basins and the Baltic Sea (in tonnes). For an explanation of abbreviations, see the caption to Figure 1.

TP Direct	tonnes **BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**	**BAS**
1995	171	485	1456	2738	314	885	271	6319
1996	126	398	750	2760	253	592	204	5083
1997	124	400	687	2553	255	437	203	4658
1998	124	341	731	2561	253	349	216	4575
1999	115	337	594	2724	254	325	188	4539
2000	108	355	527	2649	197	312	184	4333
2001	100	332	338	2656	230	271	161	4089
2002	100	296	385	2817	208	314	153	4272
2003	90	310	414	2941	163	240	124	4281
2004	85	336	959	3141	175	248	128	5073
2005	97	329	411	2898	203	236	128	4302
2006	100	330	496	2356	184	235	140	3841
2007	103	303	527	2181	179	277	140	3712
2008	100	293	470	1303	157	308	122	2752
2009	93	252	397	2811	59	391	99	4101
2010	87	254	415	1667	46	270	99	2838
2011	90	239	415	2370	38	300	115	3565
2012	116	250	418	371	76	358	88	1678
2013	130	245	403	366	55	331	89	1620
2014	107	233	409	371	61	289	92	1561
2015	99	234	401	462	64	285	102	1646
2016	94	204	385	444	46	244	97	1514
2017	90	207	196	477	42	238	95	1345
2018	94	187	176	221	36	210	95	1019
2019	93	190	199	337	38	264	109	1229

Table 7. Annual total phosphorus (TP) riverine inputs to the seven Baltic Sea sub-basins and the Baltic Sea (in tonnes). For an explanation of abbreviations, see the caption to Figure 1.

TP	tonnes							
River	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**	**BAS**
1995	2678	2440	18423	7084	2949	1301	1537	36412
1996	1653	1799	17807	4579	2038	707	795	29379
1997	2683	2061	20259	4349	1964	767	992	33075
1998	3277	2630	21761	5223	3689	1411	1673	39663
1999	2314	2593	20507	4994	3556	1302	1897	37163
2000	3318	3467	16325	5858	2741	938	1732	34379
2001	2415	2435	18119	4645	3437	923	1609	33583
2002	1654	1268	17712	6529	1564	1442	1491	31660
2003	1493	1027	11550	4345	1856	641	934	21846
2004	2359	1664	14249	7244	2542	926	1366	30351
2005	2428	2039	12201	8414	2496	769	1258	29605
2006	2155	2160	13292	4183	1777	857	1744	26168
2007	2188	1662	14176	3035	2486	1194	1581	26322
2008	2702	2954	11731	5423	2548	953	1473	27784
2009	1766	1498	13380	8334	2442	689	1049	29156
2010	2394	1625	18982	4472	2717	926	1296	32411
2011	2363	2122	15523	4440	1925	1154	1370	28897
2012	3392	2440	10335	4095	2818	933	1446	25459
2013	2103	1712	14367	3529	2288	822	1023	25843
2014	1918	1455	13801	3484	1411	814	1399	24282
2015	3111	2193	8065	2618	1326	1047	1442	19802
2016	2672	1312	9273	3581	2164	823	1076	20902
2017	2296	1736	12485	4250	3054	1007	1252	26079
2018	1837	1405	10116	4129	1745	701	978	20910
2019	1704	1435	7713	3135	1448	715	1443	17593

Table 8. Annual total phosphorus (TN) waterborne (riverine + direct) inputs to the seven Baltic Sea sub-basins and the Baltic Sea (in tonnes). For an explanation of abbreviations, see the caption to Figure 1.

TP **Sum**	tonnes **BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**	**BAS**
1995	2848	2925	19879	9821	3263	2186	1808	42730
1996	1779	2197	18558	7339	2291	1299	999	34462
1997	2807	2461	20945	6901	2219	1204	1195	37733
1998	3401	2972	22492	7784	3942	1760	1889	44238
1999	2429	2931	21101	7719	3810	1627	2085	41702
2000	3426	3823	16852	8507	2938	1250	1916	38712
2001	2516	2767	18457	7302	3667	1194	1770	37672
2002	1754	1564	18097	9346	1773	1756	1644	35932
2003	1583	1337	11965	7286	2018	881	1057	26127
2004	2444	2000	15208	10385	2718	1175	1495	35424
2005	2525	2368	12612	11312	2699	1005	1385	33907
2006	2255	2490	13789	6539	1962	1091	1884	30009
2007	2291	1965	14704	5216	2665	1471	1721	30034
2008	2802	3247	12201	6726	2704	1260	1596	30536
2009	1858	1749	13777	11145	2501	1080	1147	33257
2010	2481	1879	19396	6139	2763	1196	1395	35249
2011	2452	2361	15938	6809	1962	1454	1485	32462
2012	3509	2690	10753	4466	2894	1291	1534	27137
2013	2233	1957	14770	3896	2343	1153	1112	27463
2014	2024	1688	14209	3855	1471	1103	1491	25843
2015	3209	2427	8465	3080	1390	1332	1544	21448
2016	2766	1515	9658	4025	2211	1068	1173	22416
2017	2385	1943	12682	4727	3096	1245	1346	27424
2018	1930	1592	10292	4350	1781	911	1072	21929
2019	1796	1624	7912	3472	1486	979	1551	18821

Metadata

Technical information

1. Source:

The HELCOM Contracting Parties annually report annual water flow, inputs of total nitrogen and total phosphorus from rivers (riverine inputs) and annual inputs from direct point sources (direct inputs) to the Baltic Sea sub-basins to the HELCOM PLC database (PLUS) according to HELCOM Recommendation 37-38-1 "Waterborne pollution input assessment (PLC-Water) (HELCOM, 2016a). Further, data on atmospheric emissions and monitored atmospheric deposition are submitted by countries to the Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP) according to HELCOM Recommendation 37-38-2 "Monitoring of airborne pollution input" (HELCOM 2016c). EMEP subsequently compiles and reports this information to HELCOM including a BSEF on nutrient emissions and deposition (e.g. Gauss, 2020a and 2020b).

Total nutrient inputs (air- + waterborne inputs) to the Baltic Sea and its sub-basins are assessed annually in a HELCOM core indicator report on water and airborne inputs (e.g. HELCOM, 2020) and periodically in HELCOM PLC reports (e.g. HELCOM, 2012, HELCOM, 2013d and HELCOM, 2015) and when assessing progress towards national nutrient ceilings (e.g. Svendsen et al., 2020).

Link to available reported annual water flow, inputs of total nitrogen and total phosphorus from rivers and annual inputs from direct point sources: http://nest.su.se/helcom_plc/.

2. Description of data:

Annual water flow together with load of nitrogen and phosphorus are reported from more than 300 monitoring stations in rivers covering the monitored part of the Baltic Sea catchment area. Direct inputs from point sources discharging directly into the Baltic Sea are reported from nearly 500 municipal wastewater treatment plants, approx. 200 industries and at least 150 marine fish farms[5]. Further the nine HELCOM member countries model or estimate inputs for the unmonitored parts of the catchments to the seven sub-basins shown in Figure 1.

3. Geographical coverage:

Flow, nitrogen and phosphorus inputs from the entire catchment area to the Baltic Sea (approximately 1.73 mio. km^2) are covered by monitoring (monitored part of the catchment which constitutes 90% of the catchment area) or modelling/estimates (unmonitored part of the catchment constituting 10% of the catchment area). It includes catchments in the nine HELCOM member countries and catchments in five transboundary countries (see Figure 1). Further, annual flow and nutrient inputs from point sources discharging directly into the Baltic Sea are included in the compilation of total waterborne inputs to the Baltic Sea.

4. Temporal coverage:

Time series with annual water flow, total nitrogen and total phosphorus riverine and direct inputs summing up to total flow and waterborne inputs to the seven sub-basins covering the Baltic Sea are available for the period 1995 – 2019.

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[5] Some countries report point-sources aggregated by river basin or sea area (e.g. municipal wastewater treatment plants, industry and/or the marine fish farms). Given numbers are average for the past reported years.

5. Methodology and frequency of data collection:

Monitored part of the catchment and direct inputs

For rivers with hydrological stations, the location of these stations, measurement equipment, frequency of water level and flow (velocity) measurement should at least follow the World Meteorological Organization (WMO) Guide to Hydrological Practices (WMO-No. 168, 2008) and national quality assurance (QA) standards.

Preferably, the discharge (or at least the water level) should be monitored continuously and close to where water samples for chemical analyses are taken. The flow should be monitored at least 12 times every year. If the discharges are not monitored continuously the measurements must cover low, mean and high river flow rates, i.e. they should as a minimum reflect the main annual river flow pattern. Further details are provided in the PLC-guidelines (HELCOM 2019a).

For riverine inputs, as a minimum 12 water samples for measuring nutrients concentrations should be taken each year at a frequency that appropriately reflects the expected river flow pattern. If more samples are taken (e.g. 18, 26 or more) and/or the flow pattern does not show major annual variations, the samples can be evenly distributed during the year (see PLC-guideline HELCOM 2019a). Overall, for substances transported in connection with suspended solids, lower bias and better precision is obtained with higher sampling frequency. National and EU regulation regulate the number of water samples from big point sources. For big point sources the sampling frequency is at least 24 each year, and often much higher.

The load in rivers is typically calculated by multiplying daily flow with a daily concentration of TN and TP, respectively. Daily flow for most rivers is obtain from a stage-discharge relationship and daily concentration by linear interpolation between days with chemical sampling (HELCOM, 2019a). For some rivers monthly average concentration are multiplied with the corresponding flow.

Unmonitored parts of the catchment

The nine HELCOM member countries estimate annual flow, load of total nitrogen and total phosphorus from the unmonitored catchment areas to the Baltic Sea by simple empirical or more advance physico-hydro-geochemical modelling, and/or extrapolation (see PLC-guidelines HELCOM, 2019a and HELCOM, 2019b). In average 10% of the catchment is unmonitored, ranging from 4% unmonitored catchment (Gulf of Finland) to 48% (Danish Straits).

Total waterborne inputs:

Riverine and direct inputs and water flow data are quality assured by the Contracting Parties reporters before reporting to the PLC-PLUS database with the reporting WEB application. The data are further verified and quality assured using the PLC-PLUS database verification tools and national expert quality assurance.

After the national expert quality assurance in the PLC-PLUS database, BNI and DCE under the auspices of HELCOM RedCore DG make a quality assessment of the data in the PLC-PLUS database. The experts amend the dataset filling in missing and correcting suspicious data to establish an assessment dataset, which is finally approved by the countries according to procedures described in HELCOM (2016b). The assessment dataset is used in the PLC assessments including this Baltic Sea Environmental Fact Sheet. A description of the methods used to fill data gaps is given in PLC guidelines (HELCOM 2019b) and HELCOM (2013d).

Quality information

6. Strengths and weaknesses:

Strength: The data set is the most comprehensive and consistent time series of annual riverine and direct inputs 1995-2019 of total nitrogen and phosphorus to the Baltic Sea and its seven sub-basins covering the entire Baltic Sea catchment area. Data has been checked with standardized quality assurance methods and some of them have been updated. For example, Denmark has re-reported all flow and input data (monitored, unmonitored and direct) for 1995-2019 together with reporting 2019 data.

Weakness: Data from some parts of the Baltic Sea catchment and some of the direct inputs in the beginning of the time series (1995-2019) are rather uncertain, and many estimates of missing data were required for the early years, particularly for direct inputs of nitrogen and phosphorus to some Baltic Sea sub-basins. Methods/models for estimating water flow and nutrient inputs from unmonitored areas are not completely comparable and consistent between countries.

Further, the monitoring frequency and strategy are probably not adequate in some rivers with high variation in water flow and/or nitrogen and phosphorus concentrations, and where a substantial part of the annual load occurs within some days/few weeks.

7. Uncertainty:

The uncertainty of total nitrogen and total phosphorus inputs has not been estimated systematically by contracting parties. The PLC-group has roughly estimated an uncertainty (precision and bias) of 15-25% for annual total waterborne nitrogen and 20-30% for total inputs to the Kattegat, the Danish Straits, the main part of the Baltic Proper, the Bothnian Sea and the Bothnian Bay. For the remaining part of the BAP, and for the Gulf of Finland and the Gulf of Riga the uncertainty might be higher and up to 50% for waterborne TP inputs (HELCOM, 2015).

8. Further work required:

Total nitrogen and phosphorus inputs from all unmonitored areas must be modelled/estimated with methods that provide consistent and comparable results. The sampling frequency and strategy in rivers should be adjusted to flow and concentrations regime and patterns in individual rivers, and at least 12 samples should be taken annually. Water flow or at least the water level should be monitored continuously in rivers and in outlets from big direct point sources. Further, laboratories should use methods that actually provide the total nitrogen and phosphorus and with methods providing reproducible and comparable results between the involved laboratories. Regular laboratory intercalibration are performed and results reported (Lassen & Larsen, 2019). Changing laboratory it is important with a sufficient period with concurrent analysis of samples to allow for evaluation of and correction for systematic bias between laboratories.