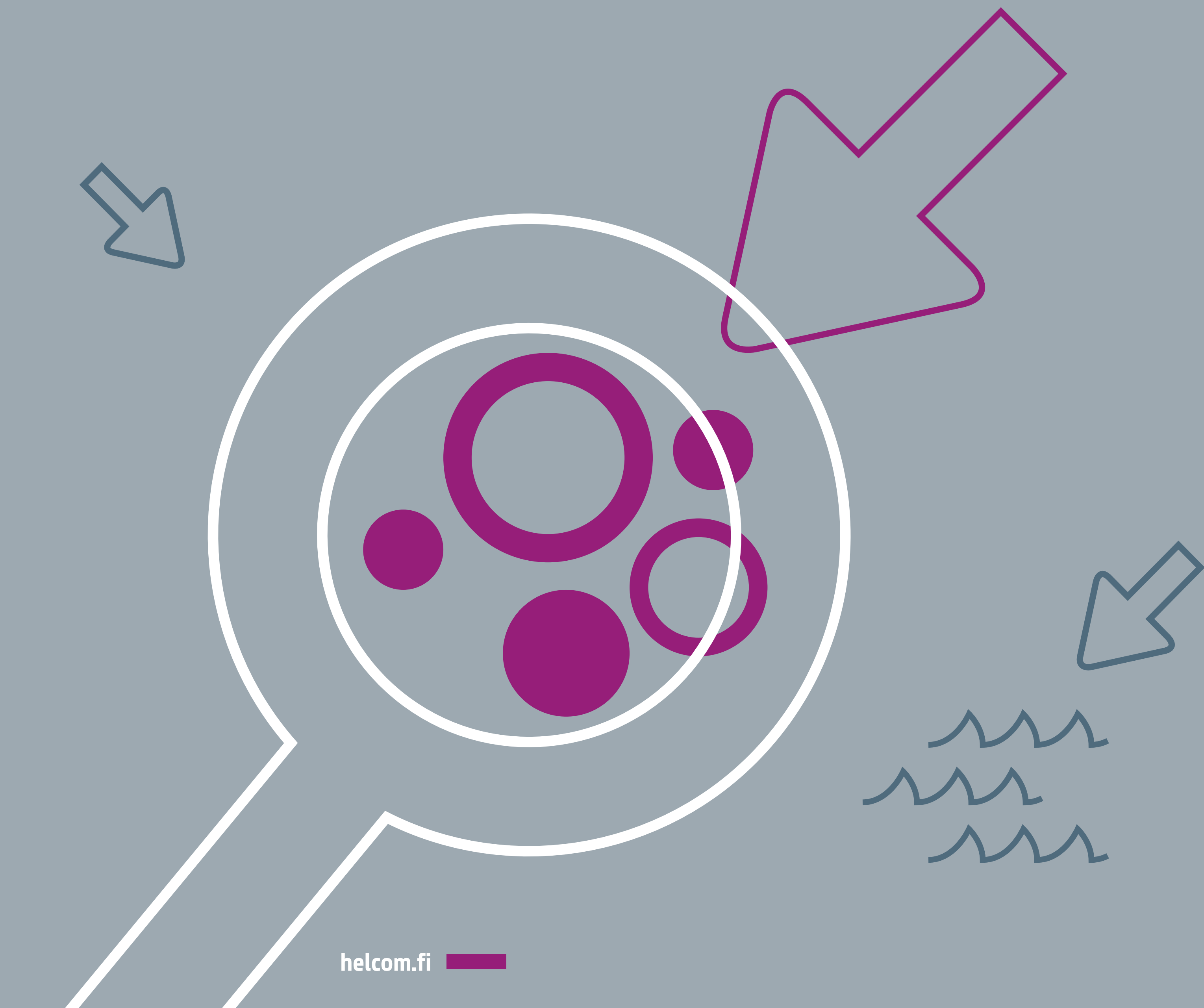
PLC-6

Quantifying nutrient sources to inland waters (source-oriented approach):

A pilot case

Baltic Marine Environment Protection Commission

Monitoring & assessment



Quantifying nutrient sources to inland waters (source-oriented approach): A pilot case

Lars M. Svendsen[1] *and Henrik Tornbjerg*[2]

[1] *DCE, Danish Centre for Environment and Energy, Aarhus University Denmark*

[2] *BIOS, Institute for Bioscience, Aarhus University Denmark*

Contribution by: Weronika Brynska (NWMA, Poland), Peeter Ennet (EEA, Estonia), Bo Gustafsson (BNI, Sweden), Dietmar Koch (UBA, Germany), Seppo Knuuttila (SYKE, Finland), Ilga Kokorite (LEGMC, Latvia), Pekka Kotilainen, (SYKE, Finland), Natalia Oblomkova (Institute for Engineering and Environmental Problems in Agricultural Production, Russia), Svajunas Plunge (EPA, Lithuania), Antti Räike (SYKE, Finland), Alexander Sokolov (BNI, Sweden) and Lars Sonesten (SLU, Sweden).

Contents

1 Introduction

The overall task of the Sixth Pollution Load Compilation (PLC-6) project is to prepare a comprehensive assessment of the water- and airborne inputs and their sources to the Baltic Sea during the period 1995-2014 with more detailed assessment for 2014. The PLC-6 assessment consists of several assessment products:

1. Statistical method report (published in 2013): http://dce2.au.dk/pub/TR33.pdf
2. Laboratory intercalibration report (published in 2013): http://dce2.au.dk/pub/TR27.pdf
3. Updated PLC guidelines (published 2015) http://www.helcom.fi/Lists/Publications/PLC-Water%20Guidelines.pdf
4. Assessment on the progress towards maximum allowable inputs of nutrients (MAI) (published in 2017): http://helcom.fi/baltic-sea-trends/indicators/inputs-of-nutrients-to-the-subbasins
5. Core pressure indicator on inputs by 2014, 2015 and 2016 (latest published in 2018): http://www.helcom.fi/baltic-sea-trends/indicators/inputs-of-nutrients-to-the-subbasins
6. Progress towards Country-wise Allocated Reduction targets (published in 2017): http://www.helcom.fi/baltic-sea-action-plan/nutrient-reduction-scheme/progress-towards-country-wise-allocated-reduction-targets/
7. CART policy message – supplementary paper with focus on consequences of changed reference inputs: https://portal.helcom.fi/meetings/HOD%2053-2017-465/MeetingDocuments/3-9%20Draft%20policy%20message%20on%20progress%20towards%20nutrient%20input%20targets.pdf
8. CART policy message (published 2018):

   https://portal.helcom.fi/meetings/HELCOM%2039-2018-504/MeetingDocuments/3-3%20Policy%20message%20on%20progress%20towards%20nutrient%20reduction%20targets.pdf#search=CART%20policy%20message
9. Sources and pathways of nutrient inputs to the Baltic Sea (published 2018):

   http://www.helcom.fi/Lists/Publications/BSEP153.pdf
10. The seven big rivers in the Baltic Sea Region (published 2019). http://www.helcom.fi/Lists/Publications/BSEP163%20-%20Seven%20biggest%20rivers%20in%20the%20Baltic%20Sea%20region.pdf
11. Input of hazardous substances (published 2019): http://www.helcom.fi/Lists/Publications/BSEP162%20-%20Inputs%20of%20hazardous%20substances.pdf
12. PLC-6 Executive Summary (published 2019):
13. http://www.helcom.fi/Lists/Publications/PLC-6%20Executive%20Summary.pdf
14. Background information (document for PRESSURE 10)
15. Applied methodologies in the PLC-6 assessment (document for PRESSURE 10)
16. Evaluation of effectiveness of measures (document for PRESSURE 10)
17. Quantifying nutrient sources to inland waters (source oriented approach): A pilot case (this report)
18. Scientific report on progress towards CART (to be finalized in 2019)

This report includes an assessment of the total nitrogen (TN) and total phosphorus (TP) sources with the source oriented approach (product 14).

Two approaches are used to quantify the nutrient input sources:

- Load oriented approach
- Source oriented approach

In the *load-oriented approach* sources of waterborne riverine TN and TP inputs to the sea were quantified to evaluate the contribution from different inland point and diffuse sources of the total riverine input of nitrogen and phosphorus entering the Baltic Sea taking into account retention in inland surface waters. Results from the load-oriented approach have been published in "Sources and pathways of nutrients to the Baltic Sea. HELCOM PLC-6, 2018" http://www.helcom.fi/Lists/Publications/BSEP153.pdf.

In the *source-oriented approach* the gross load of TN and TP from point, diffuse and natural background losses into inland surface waters within the Baltic Sea catchment area was quantified to get a comprehensive overview of the nitrogen and phosphorus discharges in the Baltic Sea catchment area. The source-oriented approach estimates the importance of the nutrient input sources to inland surface waters. After nutrients enter into inland surface waters retention processes take place, removing, transforming and retaining part of TN and TP before it enters the sea. The load-oriented approach by looking in the mouth of the rivers then estimates the importance of each source for nutrient entering the Baltic Sea after retention in the inland surface waters.

This report provides *a pilot case* on source quantification with the source oriented approach. It provides examples for some Contracting Parties on the sources of nutrient entering inland surface waters. It is a first trial on how to evaluate the source of TN and TP to inland waters. Countries have applied different methodologies to estimate the sources (and pathways), and some countries have reported some sources separately, while other countries have aggregated the sources or have not quantified all sources.

The countries and examples that providing the most comparable results were selected. It is the expectation that the experience from the PLC-6 source apportionment assessment will support a more comprehensive quantification of the sources for nitrogen and phosphorus entering inland surface waters and covering all Contracting Parties in the PLC-7 project.

All countries have reported source apportionment data on TN and TP inputs to inland surface waters based on the source oriented approach for the year 2014 (Poland and Germany for the year 2012), but only for four countries it is possible to use the detailed source apportionment data (see chapter 2).However, it is possible to present data for eight countries for the total nutrient input to inland surface waters at the most aggregated source level i.e.:

- Point sources
- Diffuse sources
- Natural background sources.

Due to delays in a national project, Germany was not able to report adequate source apportionment data and therefore German data are not included in the report.

Further, more detailed source apportionment is shown for four countries:

- Denmark
- Finland
- Poland

- Sweden

Acknowledgements

The authors want to send special thanks to the PLC-6 project team members providing data and commenting on drafts of the report: Weronika Brynska (NWMA, Poland), Peeter Ennet (EEA, Estonia), Dmitry Frank-Kamenetsky (HELCOM), Bo Gustafsson (BNI, Sweden), Juuso Haapaniemi (HELCOM), Dietmar Koch (UBA, Germany), Seppo Knuuttila (SYKE, Finland), Ilga Kokorite (LEGMC, Latvia), Pekka Kotilainen, (SYKE, Finland), Søren Erik Larsen (DCE, Aarhus University, Denmark), Wera Leujak (UBA, Germany), Natalia Oblomkova (Institute for Engineering and Environmental Problems in Agricultural Production, Russia), Svajunas Plunge (EPA, Lithuania), Antti Räike (SYKE, Finland), Alexander Sokolov (BNI, Sweden) and Lars Sonesten (SLU, Sweden).

2 Methodology

The PLC guidelines do not specify one unique method for quantifying inputs from different sources to inland waters. For some of the sources, the methods used are comparable, as for point sources (municipal wastewater treatment plants and industrial plants). The quantification of, e.g. agricultural sources, is based on different model estimates and/or some monitoring, and the results are not necessarily comparable. Some models estimate agricultural losses at the root zone, other estimate losses to the edge of inland surface waters. Most countries use actual (not normalized) data in 2014 (or 2012 for Germany and Poland), other use an average for 5 years' inputs quantifying TN and TP sources. Natural background losses are usually estimated from monitoring in catchments without or with minor influence from anthropogenic activity, but in some countries, it is difficult to find "pristine" areas, and nitrogen losses from all catchments are affected by nitrogen deposition, which is affected by human activity.

Some Contracting Parties have not quantified individual diffuse or point sources, e.g. quantified scattered dwelling separately, and only four countries have sub-divided the diffuse and point sources with comparable methods.

The results of quantifying TN and TP sources to inland waters must therefore by compared carefully, but they indicate overall what are the most important sources, including whether there is any overall pattern in sources within the Baltic Sea catchment area.

It has been agreed that more harmonized quantification methodologies on sources for nitrogen and phosphorus entering inland surface waters will be applied in the next PLC assessment (PLC-7).

3 Results

Quantified TN and TP sources to inland waters are presented in section 3.1 to 3.3:

- In 3.1 TN and TP input sources to inland surface waters for eight countries are divided in inputs from the following aggregated sources: inland point sources, diffuse sources and natural background losses (eight countries)
- In 3.2 TN and TP inputs from point sources in the catchment to inland surface waters are divided in inputs from municipal wastewater treatment plants, industrial plants and storm waters (four countries)
- In 3.3 TN and TP inputs from diffuse sources in the catchment to inland surface waters are divided in natural background sources, atmospheric deposition on surface waters, agricultural sources (where Sweden and Finland divide this source in agricultural source and managed forestry source), and scattered dwellings (four countries).

Results in sections 3.1 to 3.3 are shown by catchment area to the Baltic Sea sub-basins per country.

3.1 Main nutrient input sources of TN and TP to inland surface waters

Figure 1 provides a quantification of the overall TN and TP sources for input to inland surface waters for eight Contracting Parties, divided by catchment area to the main sub-basins of the Baltic Sea. The sources are aggregated in three categories:

- Natural background losses
- Diffuse sources
- Point sources

For TN diffuse sources are the most important sources in:

- Denmark (approx. 70-80%)
- Estonia (approx. 60-65%)
- Latvia and Lithuania (approx. 85%)
- Poland (60 %).

It is also the main source for:

- Finland in the catchment to Bothnian Sea (60 %) and Gulf of Finland (50%)
- Sweden to Baltic Proper and Kattegat (46-48%) and Danish Straits (65%).

These catchments are characterized as the part of the Baltic Sea catchment with intensive or rather intensive agriculture.

Overall, diffuse sources are also the main TP sources in the same catchment as for TN constituting from 50 to 80 % of the inputs. However, for Danish Straits (Denmark and Sweden) and Kattegat, the importance of diffuse sources of TP is lower than the corresponding TN percentages, as point sources are rather important.

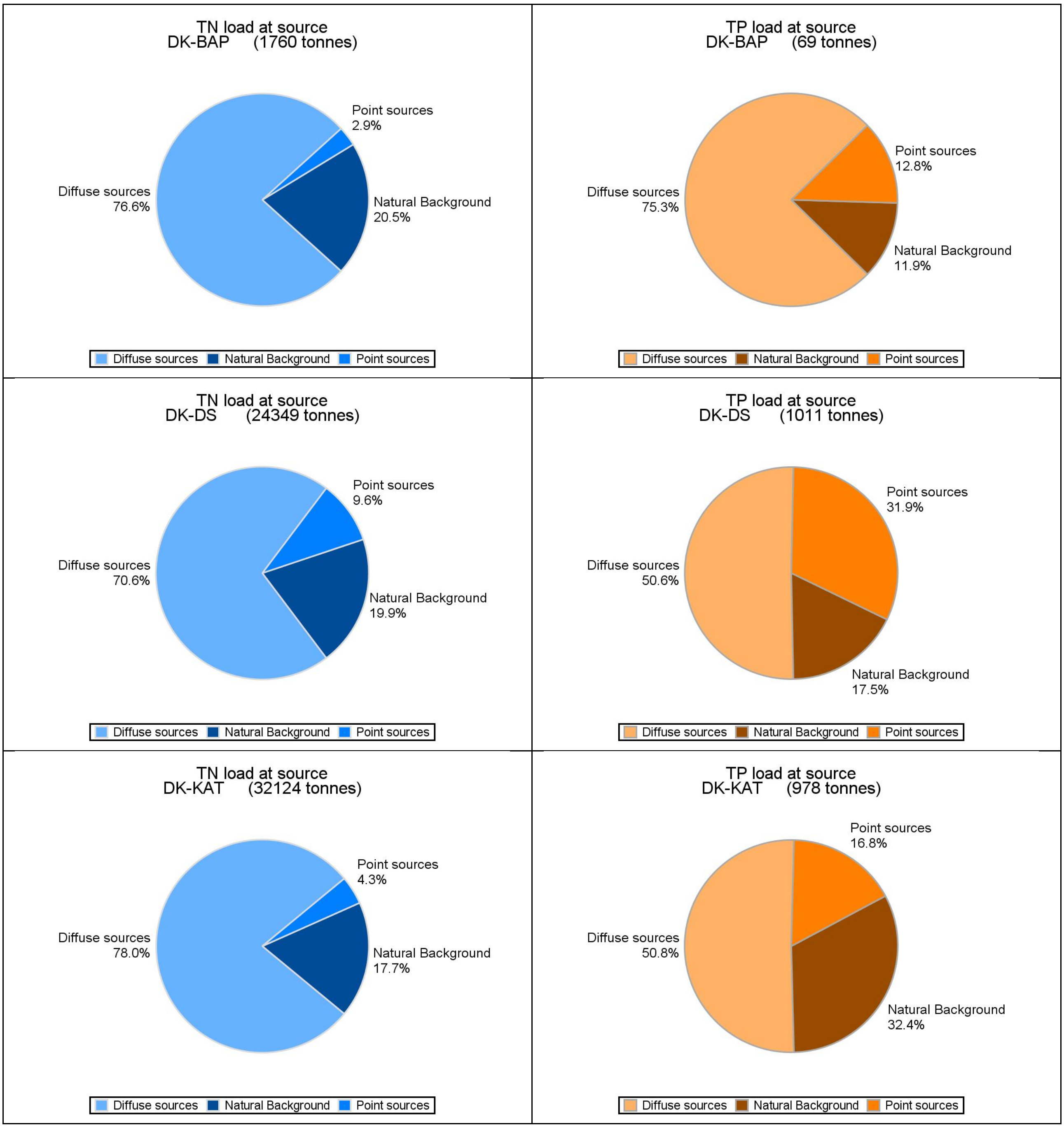
Natural background losses are the main source or are very important for both TN and TP inputs to inland waters in the northern and eastern parts of the catchment to the Baltic Sea:

- In the catchment to Baltic Proper: Estonia > 40% for TN and TP, Russia approx. 65 % TN and 35 % TP, Sweden > 40% TN and 50% TP
- In the catchment to Bothnian Bay: Finland > 50% TN and TP, Sweden > 80% TN and TP
- In the catchment to Bothnian Sea: Finland > 30% TN, Sweden > 70% for TN and TP
- In the catchment to Gulf of Finland: Russia > 87% for TN and >60% TP
- In the catchment to Kattegat: Sweden > 45 for TN and nearly 60% TP.

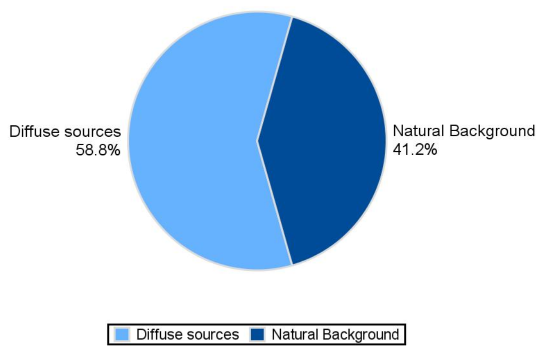
Many of these areas are scarcely populated and with rather low agricultural or managed forestry activity.

Point sources to inland waters constitute less than 10 % of the total inputs for most catchments. For some more densely populate areas, the shares are higher, especially for TP:

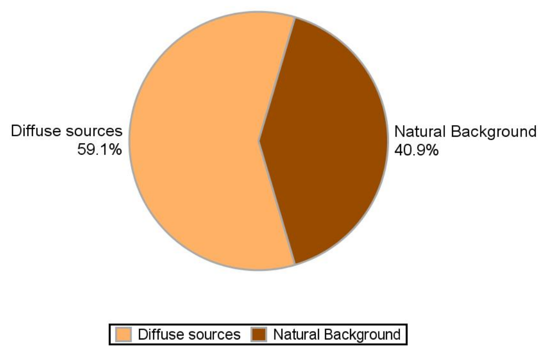
- Denmark: to Baltic Proper TP 13%, Danish Straits TP 32% and Kattegat TP 17%
- Finland: to Gulf of Finland TN 10%
- Poland: to Baltic Proper TN 24% and TP 31%
- Russia: to Gulf of Finland TP 18%
- Sweden: to Baltic Proper TN and TP 11-12%, to Danish Straits TP 30%, to Kattegat TP 11%


TN load at source
DK-BAP (1760 tonnes)
Point sources 2.9%
Diffuse sources 76.6%
Natural Background 20.5%
Diffuse sources Natural Background Point sources
TP load at source
DK-BAP (69 tonnes)
Point sources 12.8%
Diffuse sources 75.3%
Natural Background 11.9%
Diffuse sources Natural Background Point sources
TN load at source
DK-DS (24349 tonnes)
Point sources 9.6%
Diffuse sources 70.6%
Natural Background 19.9%
Diffuse sources Natural Background Point sources
TP load at source
DK-DS (1011 tonnes)
Point sources 31.9%
Diffuse sources 50.6%
Natural Background 17.5%
Diffuse sources Natural Background Point sources
TN load at source
DK-KAT (32124 tonnes)
Point sources 4.3%
Diffuse sources 78.0%
Natural Background 17.7%
Diffuse sources Natural Background Point sources
TP load at source
DK-KAT (978 tonnes)
Point sources 16.8%
Diffuse sources 50.8%
Natural Background 32.4%
Diffuse sources Natural Background Point sources

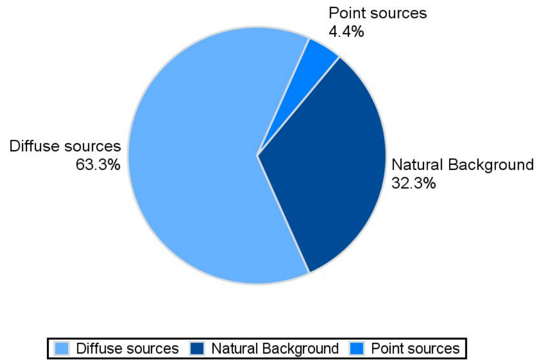
TN load at source
EE-BAP (719 tonnes)



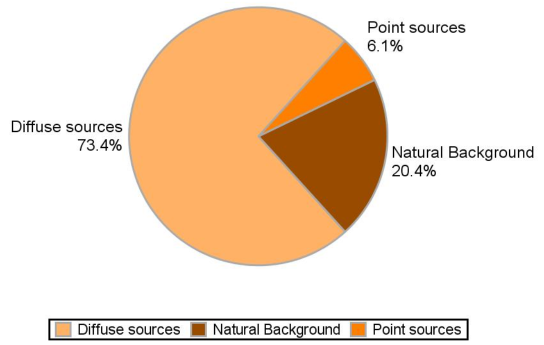
TP load at source
EE-BAP (10 tonnes)



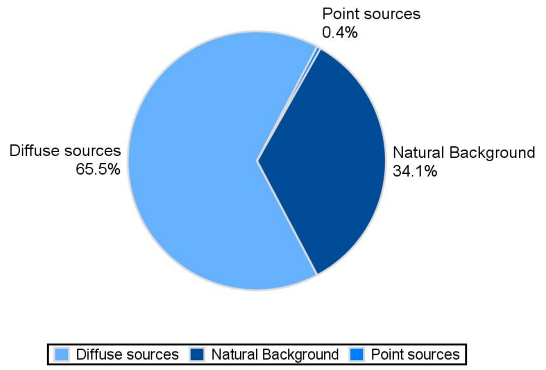
TN load at source
EE-GUF (7813 tonnes)



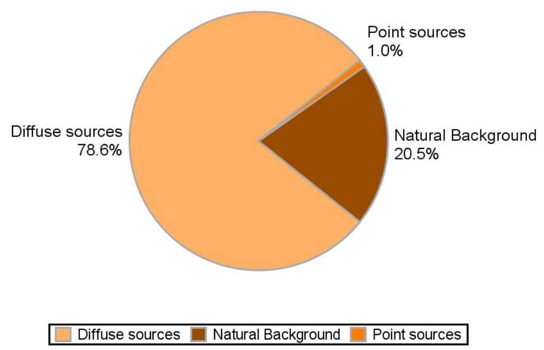
TP load at source
EE-GUF (163 tonnes)



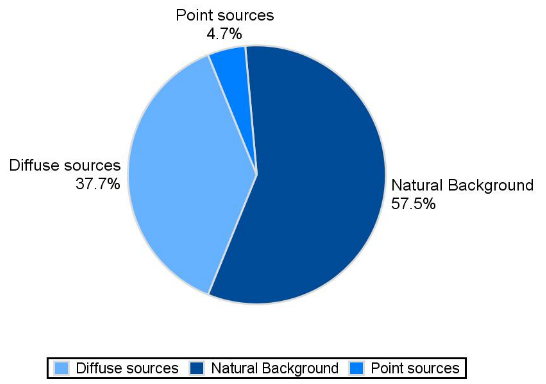
TN load at source
EE-GUR (7350 tonnes)



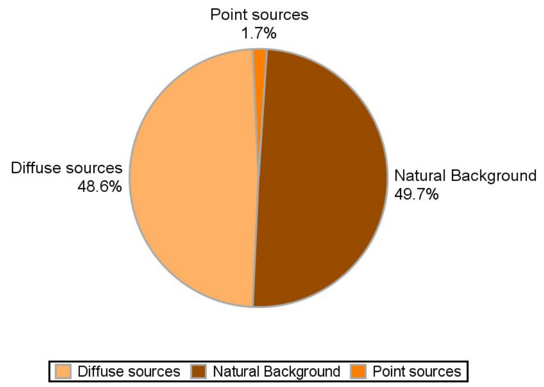
TP load at source
EE-GUR (117 tonnes)

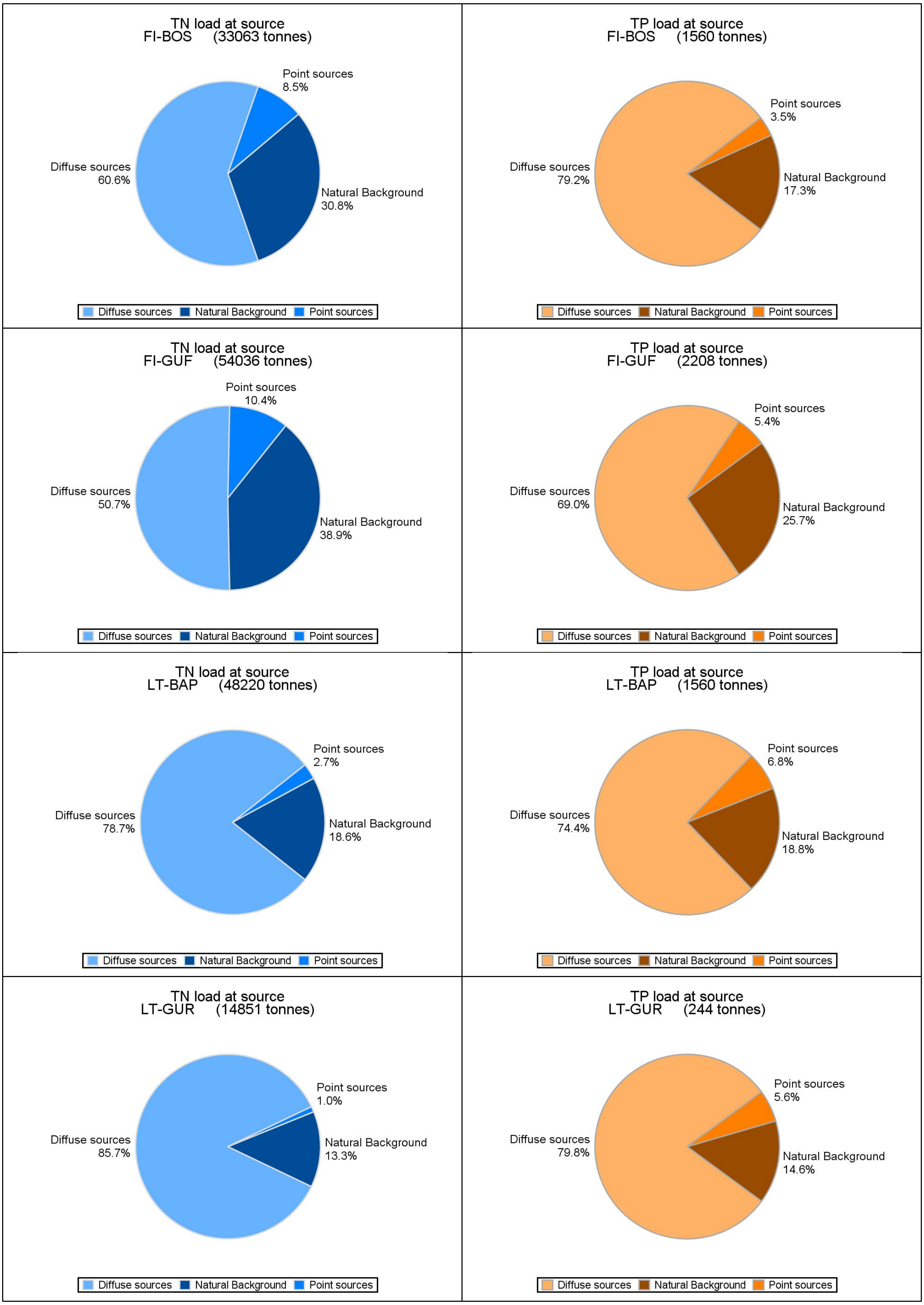


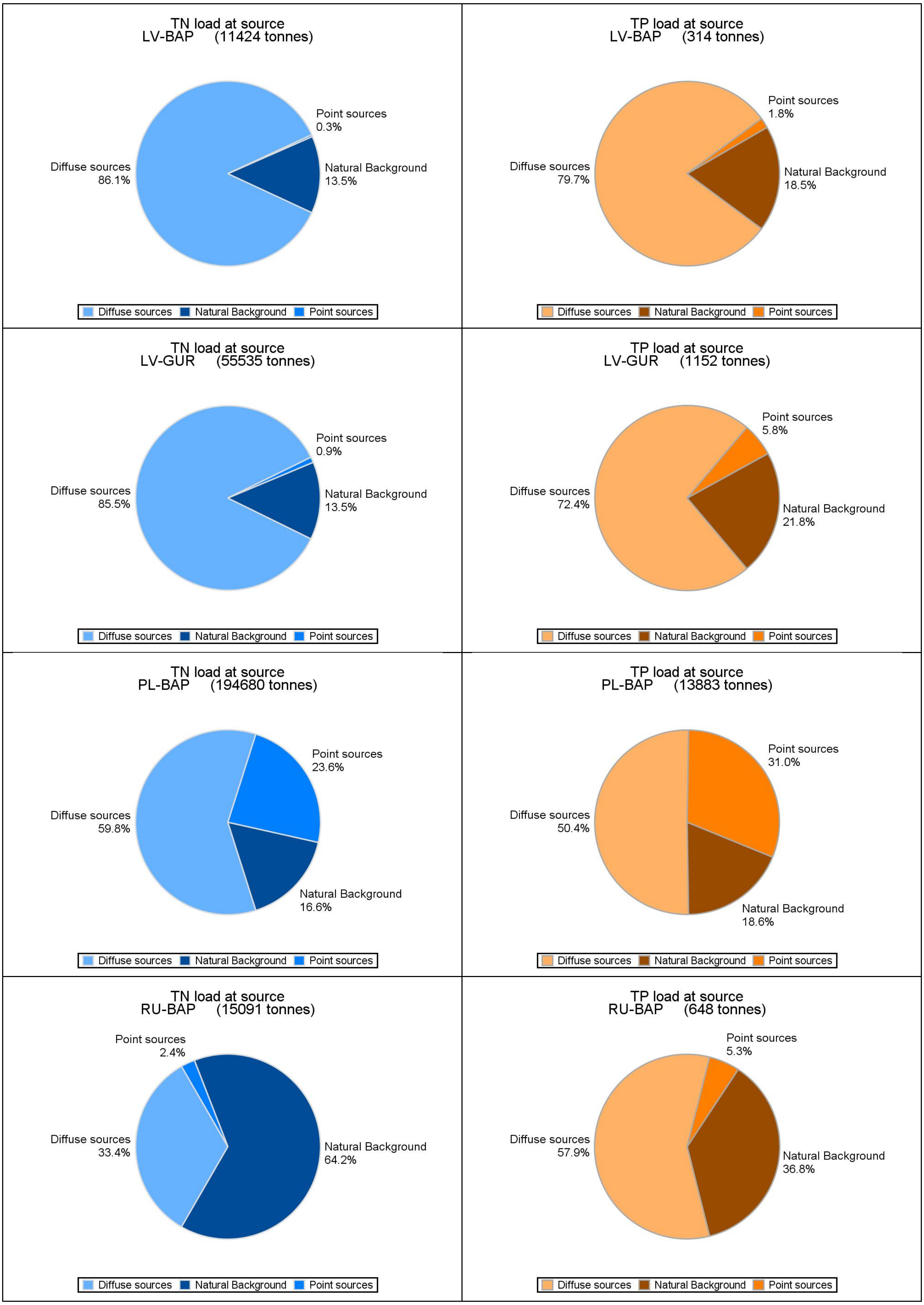
TN load at source
FI-BOB (46788 tonnes)

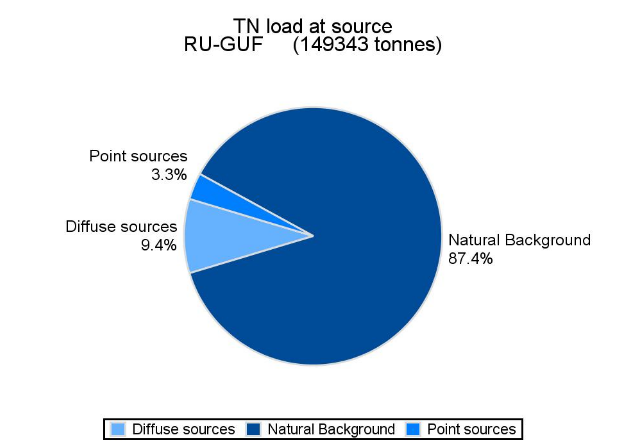


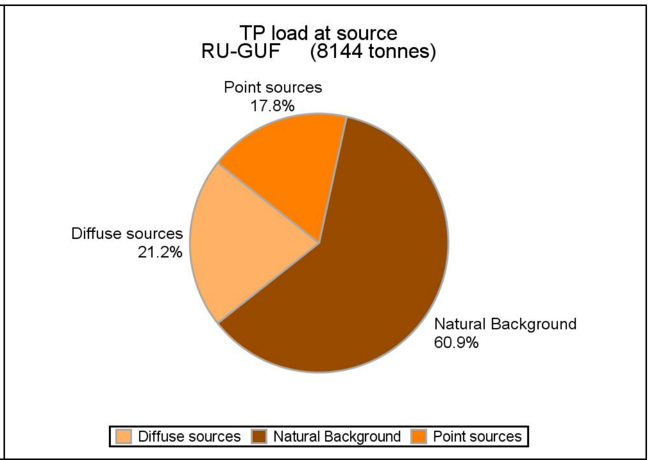
TP load at source
FI-BOB (1965 tonnes)

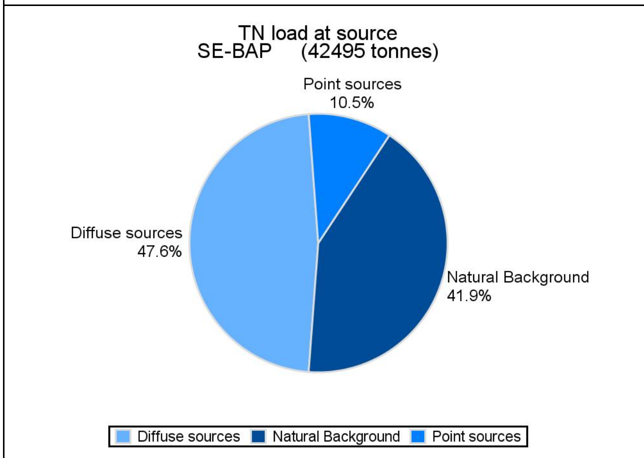


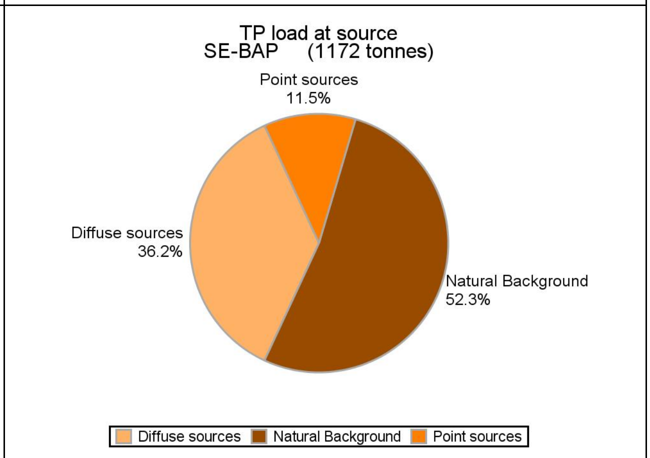

TN load at source
FI-BOS (33063 tonnes)
Point sources 8.5%
Diffuse sources 60.6%
Natural Background 30.8%
Diffuse sources
Natural Background
Point sources
TP load at source
FI-BOS (1560 tonnes)
Point sources 3.5%
Diffuse sources 79.2%
Natural Background 17.3%
Diffuse sources
Natural Background
Point sources
TN load at source
FI-GUF (54036 tonnes)
Point sources 10.4%
Diffuse sources 50.7%
Natural Background 38.9%
Diffuse sources
Natural Background
Point sources
TP load at source
FI-GUF (2208 tonnes)
Point sources 5.4%
Diffuse sources 69.0%
Natural Background 25.7%
Diffuse sources
Natural Background
Point sources
TN load at source
LT-BAP (48220 tonnes)
Point sources 2.7%
Diffuse sources 78.7%
Natural Background 18.6%
Diffuse sources
Natural Background
Point sources
TP load at source
LT-BAP (1560 tonnes)
Point sources 6.8%
Diffuse sources 74.4%
Natural Background 18.8%
Diffuse sources
Natural Background
Point sources
TN load at source
LT-GUR (14851 tonnes)
Point sources 1.0%
Diffuse sources 85.7%
Natural Background 13.3%
Diffuse sources
Natural Background
Point sources
TP load at source
LT-GUR (244 tonnes)
Point sources 5.6%
Diffuse sources 79.8%
Natural Background 14.6%
Diffuse sources
Natural Background
Point sources

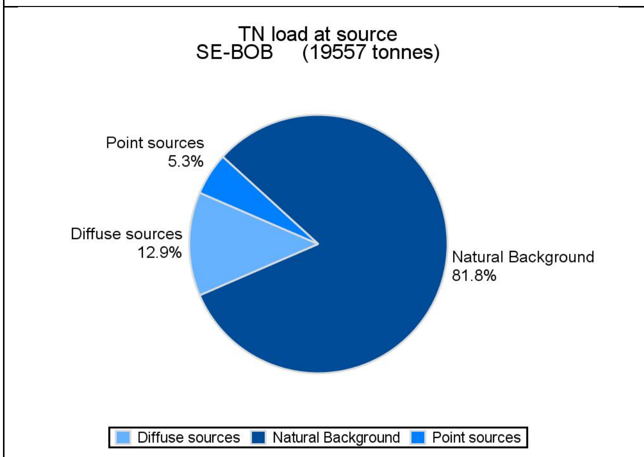

TN load at source
LV-BAP (11424 tonnes)
Point sources
0.3%
Diffuse sources
86.1%
Natural Background
13.5%
Diffuse sources Natural Background Point sources
TP load at source
LV-BAP (314 tonnes)
Point sources
1.8%
Diffuse sources
79.7%
Natural Background
18.5%
Diffuse sources Natural Background Point sources
TN load at source
LV-GUR (55535 tonnes)
Point sources
0.9%
Diffuse sources
85.5%
Natural Background
13.5%
Diffuse sources Natural Background Point sources
TP load at source
LV-GUR (1152 tonnes)
Point sources
5.8%
Diffuse sources
72.4%
Natural Background
21.8%
Diffuse sources Natural Background Point sources
TN load at source
PL-BAP (194680 tonnes)
Point sources
23.6%
Diffuse sources
59.8%
Natural Background
16.6%
Diffuse sources Natural Background Point sources
TP load at source
PL-BAP (13883 tonnes)
Point sources
31.0%
Diffuse sources
50.4%
Natural Background
18.6%
Diffuse sources Natural Background Point sources
TN load at source
RU-BAP (15091 tonnes)
Point sources
2.4%
Diffuse sources
33.4%
Natural Background
64.2%
Diffuse sources Natural Background Point sources
TP load at source
RU-BAP (648 tonnes)
Point sources
5.3%
Diffuse sources
57.9%
Natural Background
36.8%
Diffuse sources Natural Background Point sources

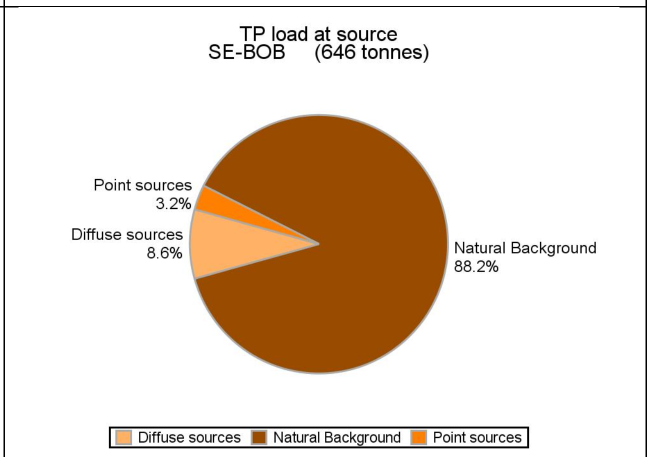

TN load at source
RU-GUF (149343 tonnes)
Point sources
3.3%
Diffuse sources
9.4%
Natural Background
87.4%
Diffuse sources
Natural Background
Point sources

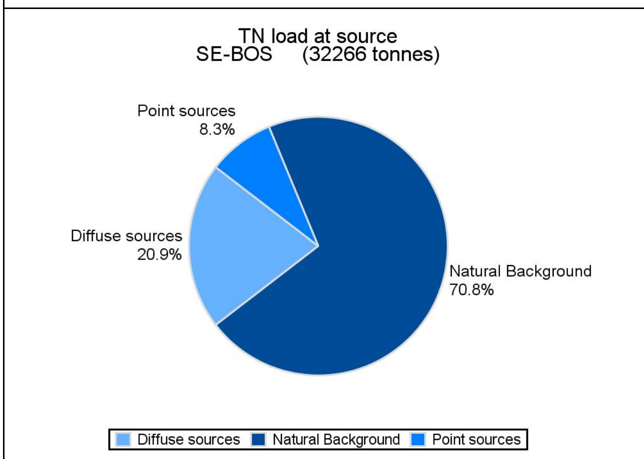

TP load at source
RU-GUF (8144 tonnes)
Point sources
17.8%
Diffuse sources
21.2%
Natural Background
60.9%
Diffuse sources
Natural Background
Point sources

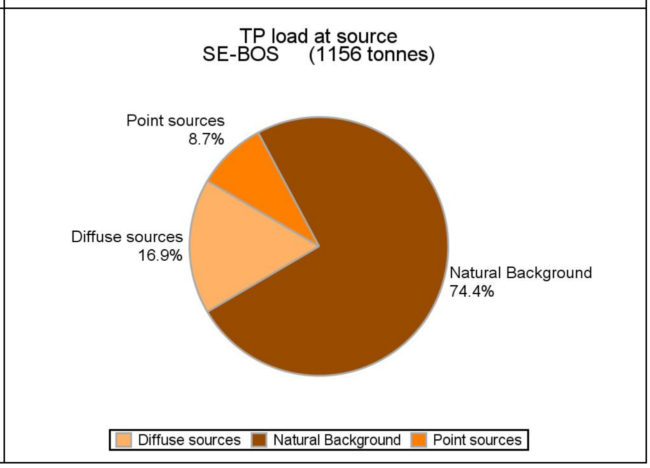

TN load at source
SE-BAP (42495 tonnes)
Point sources
10.5%
Diffuse sources
47.6%
Natural Background
41.9%
Diffuse sources
Natural Background
Point sources


TP load at source
SE-BAP (1172 tonnes)
Point sources
11.5%
Diffuse sources
36.2%
Natural Background
52.3%
Diffuse sources
Natural Background
Point sources


TN load at source
SE-BOB (19557 tonnes)
Point sources
5.3%
Diffuse sources
12.9%
Natural Background
81.8%
Diffuse sources
Natural Background
Point sources


TP load at source
SE-BOB (646 tonnes)
Point sources
3.2%
Diffuse sources
8.6%
Natural Background
88.2%
Diffuse sources
Natural Background
Point sources


TN load at source
SE-BOS (32266 tonnes)
Point sources
8.3%
Diffuse sources
20.9%
Natural Background
70.8%
Diffuse sources
Natural Background
Point sources


TP load at source
SE-BOS (1156 tonnes)
Point sources
8.7%
Diffuse sources
16.9%
Natural Background
74.4%
Diffuse sources
Natural Background
Point sources

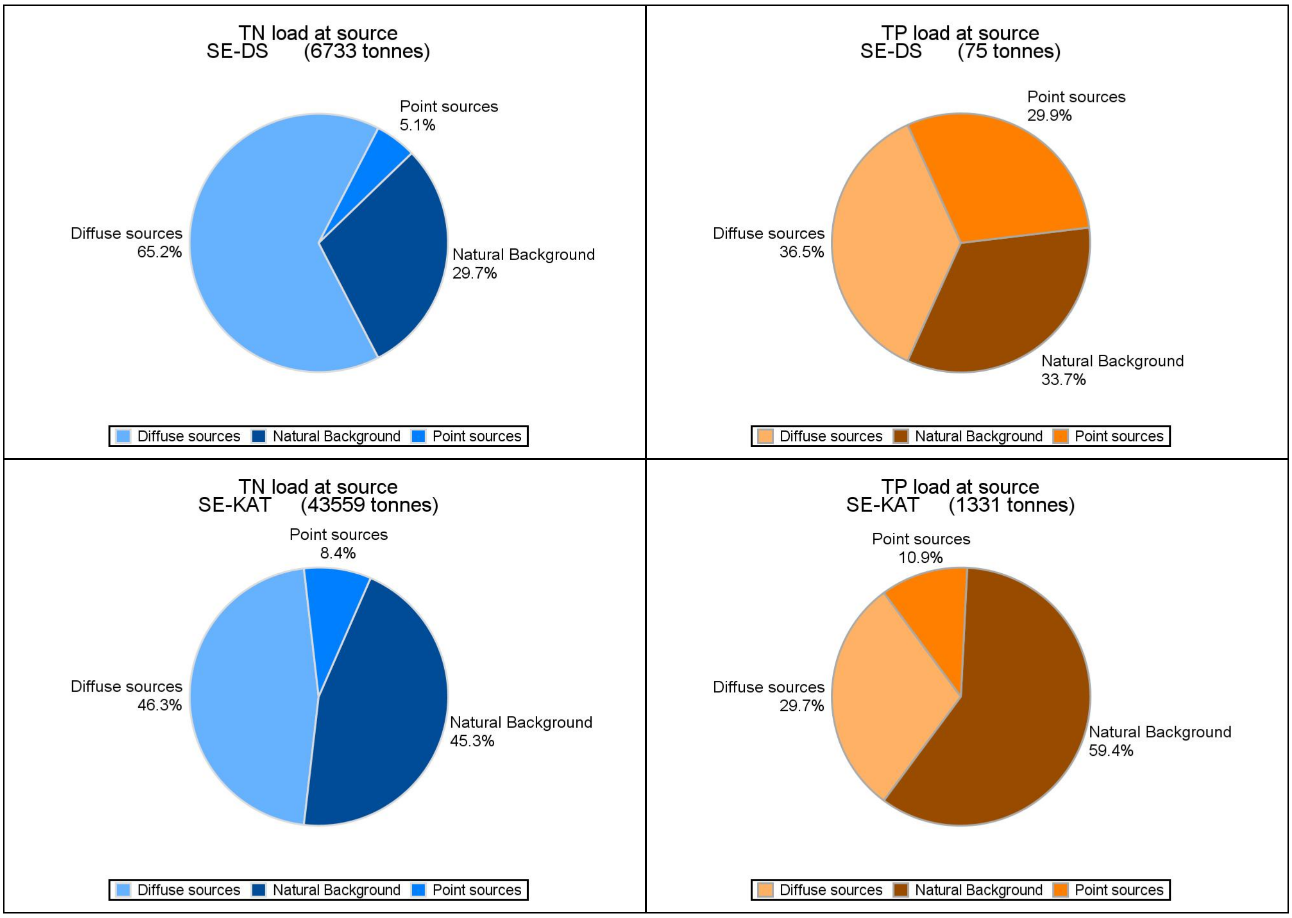


Figure 1 Overall sources (point sources, diffuse sources and natural background losses) of total nitrogen (TN) – left column – and total phosphorus (TP) – right column - to inland surface waters in the catchment to the Baltic Sea divided by country (German results not included, by their request due to challenges with quantifying the natural background). Data mainly from 2014, Poland from 2012 and Lithuania average 2007-14. The importance of the sources is given in percentages of the total TN and TP inputs to inland surface waters (the number indicated in tonnes in the heading to each figure). DK = Denmark, EE = Estonia, FI = Finland, LT = Lithuania, LV = Latvia, PL = Poland, RU = Russia, SE = Sweden, BAP = Baltic Proper, BOB = Bothnian Bay, BOS = Bothnian Sea, DS = Danish Straits, GUF = Gulf of Finland, GUR = Gulf of Riga and KAT = Kattegat.

3.2 Nutrient point sources to inland surface waters

In Figure 2 the point source inputs to inland waters shown in Figure 1 are sub-divided in:

- Municipal wastewater treatment plants
- Industrial effluents
- Storm waters
- Aquaculture

It is shown for four countries - Denmark, Finland, Sweden (with 2014 data) and Poland (data from 2012). It should be taken into account that point sources according to Figure 1 mostly constitute less than 10 % of the total inputs to inland waters.

3.2.1 Denmark

Storm waters are the biggest point source for TN and TP in the Danish catchments constituting between 40 and 65% of TN and TP inputs. Municipal wastewater is the second most important source in the catchment to Baltic Proper and Danish Straits (between 23 and 46%). In the catchment to Kattegat, freshwater fish farms are the second biggest sources (41% of TN and 34% of TP). There are no fish farms located in the catchment to Baltic Proper. Industry is overall a minor source providing 1-12% of the total point source inputs to inland surface waters.

3.2.2 Finland

Municipal wastewater treatment plants are the most important point sources of TN in the Finnish catchments (between 55 and 87%). Industry is also an important TN source in the catchment of Bothnian Bay and Gulf of Finland (22% and 31%, respectively).

Industry is the biggest TP point source in the catchment to Bothnian Sea and Gulf of Finland (53 and 61%). In the catchment to Bothnian Bay municipal wastewater treatment plants (42%), industry (35%) and fish farms (19%) are the main TP point sources.

Storm waters are minor point sources in the Finnish catchments.

3.2.3 Poland

Municipal wastewater treatment plants are the biggest TN (66%) and TP (65%) sources in Polish catchments with storm waters as the second most important source (36 % TN and 33% TP). Industry constitutes only 9% of TN and less than 2% of TP inputs to inland surface waters in Poland. Fish farms are the smallest sources with less than 1% of TN and TP inputs.

3.2.4 Sweden

Municipal wastewater treatment plants are, with the exception of the catchment to Bothnian Sea, the main TN point sources in Sweden constituting 65-83% of point source inputs to inland waters (only 46% to Bothnian Bay).

Industry is the biggest TN point source in the catchment to Bothnian Bay (53%). In the other catchment, industry constitutes 10-22% of point source TN inputs as the second biggest source.

Storm water TN constitutes 1-10 % of the point source inputs to surface inland waters.

Fish farms provide 9% of TN point inputs to inland surface waters in the catchment of Bothnian Sea and 4% in the catchment to Kattegat, but in the remaining catchment it is less than 1%.

Storm waters are the biggest TP point sources in the catchment to Baltic Proper (55%), Bothnian Bay (53%), Danish Straits (56%) and Kattegat (36%).

Fish farms are the biggest TP source to inland surface waters in the catchment to Bothnian Sea constituting 43 %. In the remaining catchment the share of fish farms is less than 3% besides in the catchment to Kattegat (11%).

Municipal wastewater treatment plants constitute between 24-42% of TP point inputs to inland waters in the catchments with the highest proportion to Bothnian Sea.

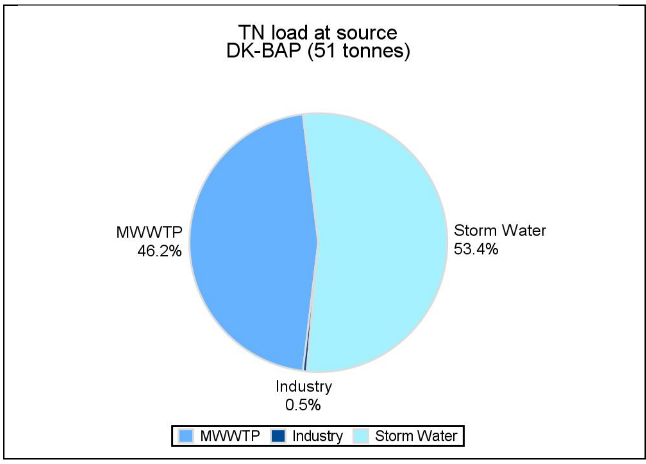
Industry is a rather big TP source in the catchment to Danish Straits and Kattegat (20 and 26%, respectively) and in the catchment to Baltic Proper (9%). In the remaining catchments it is a minor point source (<5%).

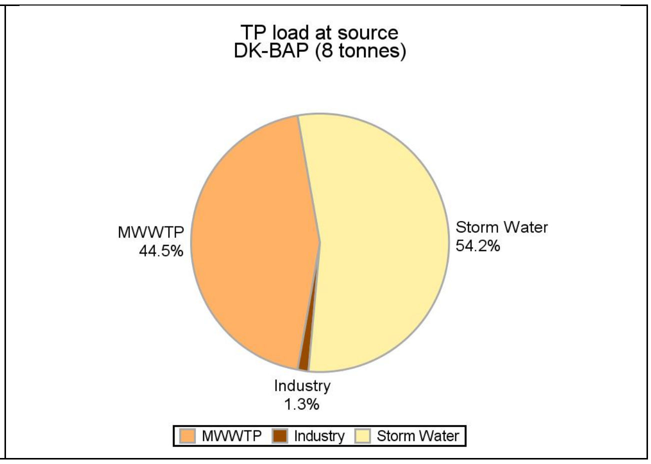
3.2.5 Comparing the four countries

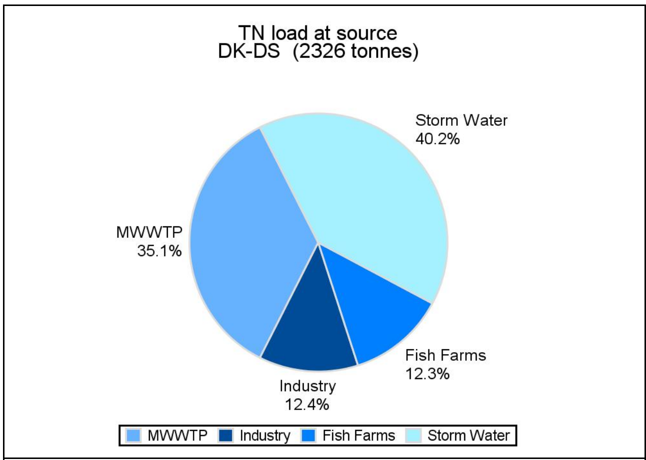
When comparing the share of sources between countries it should be taken into account that in Denmark, Finland and Sweden big efforts and measures to reduce TN and TP inputs to inland surface waters from municipal wastewater treatment plants and industry started in the 1970s but later in Poland. In Finland and Sweden some big industries are located within the catchments, which explains relative high shares of TN and TP inputs in spite of the high degree of treatment on their effluents. Discharges from many industries are connected to municipal wastewater treatment plants and included in the inputs for the MWWTP.

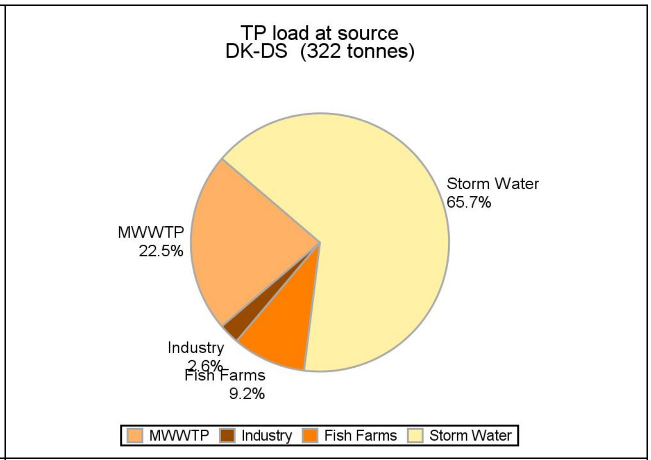
Denmark has many fish farms in the catchment to Kattegat. Further, in densely populated areas as in Denmark and Poland and parts of Finland and Sweden, there are a lot of fortified areas, which might contribute with considerable amounts of storm waters.

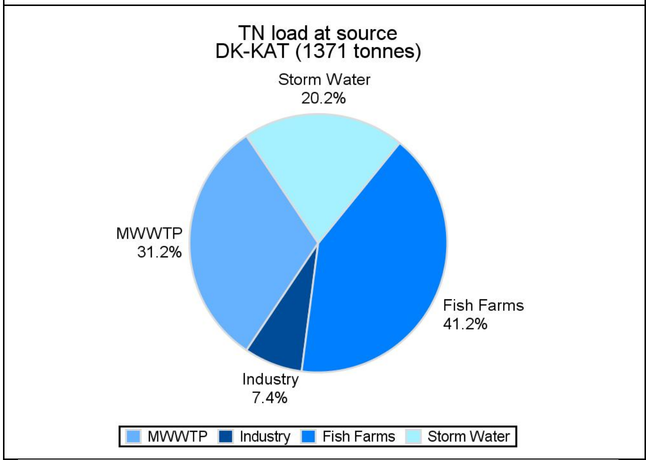
In scarcely populated areas with few towns and no industrial plants, e.g. storm water will have a relative higher importance even though the total amount in tonnes is low. As the quantification methodology of TN and TP from storm waters is rather different between the Contracting Parties, the significance of this source should be cautiously considered.

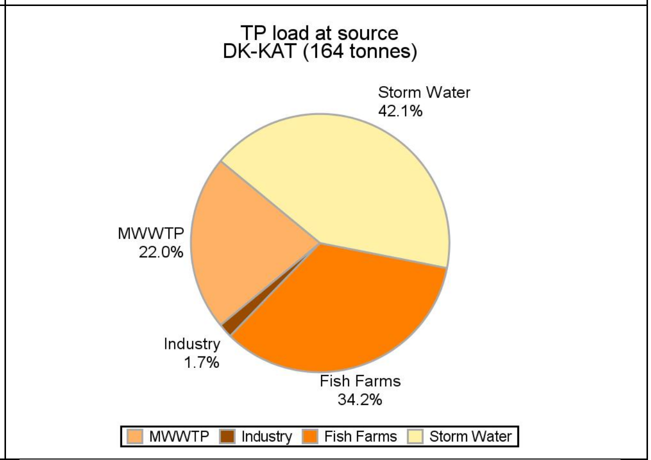


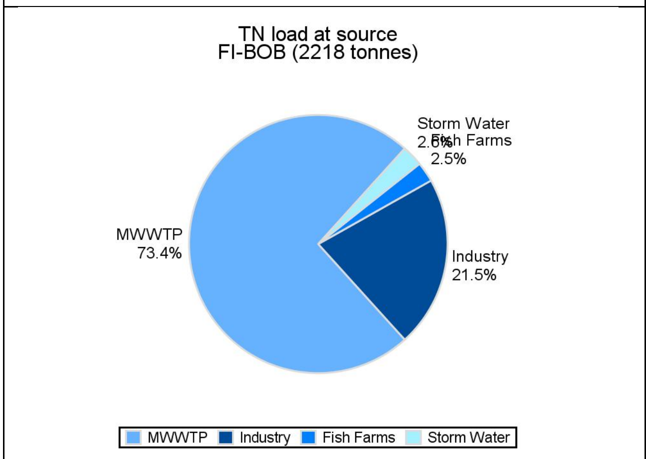


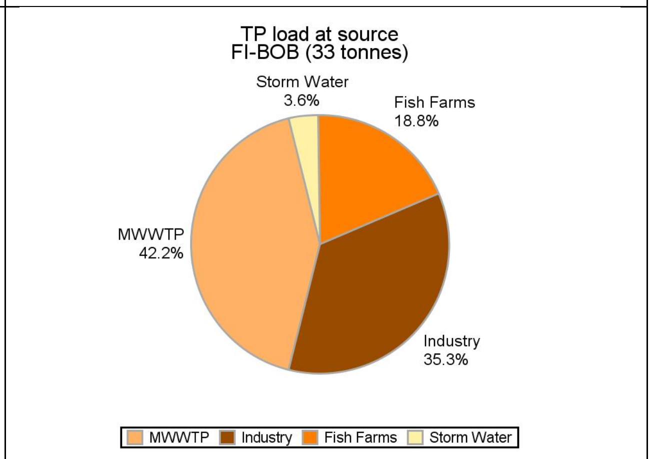

TN load at source
DK-DS (2326 tonnes)
Storm Water
40.2%
MWWTP
35.1%
Fish Farms
12.3%
Industry
12.4%
MWWTP Industry Fish Farms Storm Water

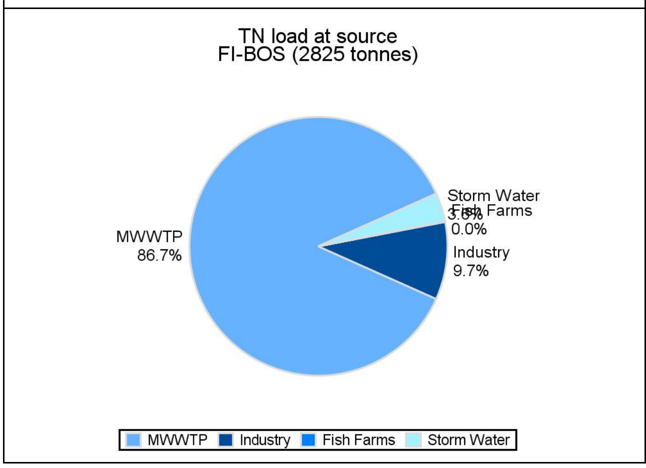

TP load at source
DK-DS (322 tonnes)
Storm Water
65.7%
MWWTP
22.5%
Industry
2.6%
Fish Farms
9.2%
MWWTP Industry Fish Farms Storm Water

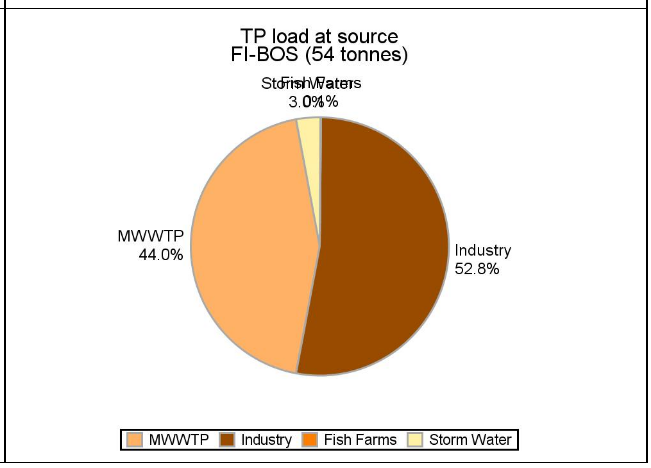

TN load at source
DK-KAT (1371 tonnes)
Storm Water
20.2%
MWWTP
31.2%
Fish Farms
41.2%
Industry
7.4%
MWWTP Industry Fish Farms Storm Water


TP load at source
DK-KAT (164 tonnes)
Storm Water
42.1%
MWWTP
22.0%
Industry
1.7%
Fish Farms
34.2%
MWWTP Industry Fish Farms Storm Water

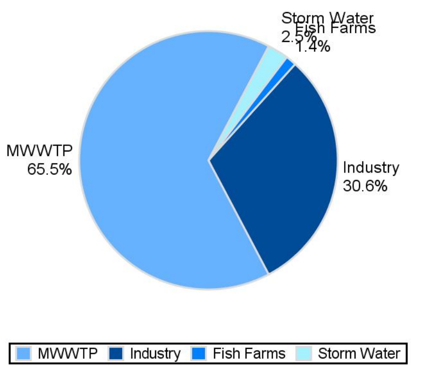

TN load at source
FI-BOB (2218 tonnes)
Storm Water
2.6%
Fish Farms
2.5%
MWWTP
73.4%
Industry
21.5%
MWWTP Industry Fish Farms Storm Water


TP load at source
FI-BOB (33 tonnes)
Storm Water
3.6%
Fish Farms
18.8%
MWWTP
42.2%
Industry
35.3%
MWWTP Industry Fish Farms Storm Water

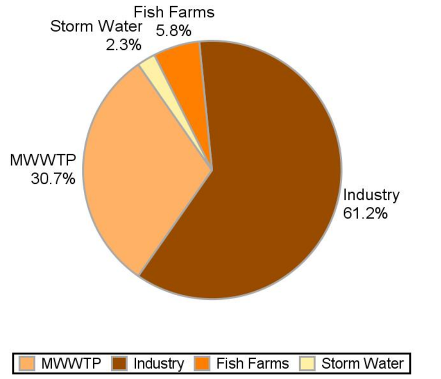

TN load at source
FI-BOS (2825 tonnes)
Storm Water
3.6%
Fish Farms
0.0%
MWWTP
86.7%
Industry
9.7%
MWWTP Industry Fish Farms Storm Water


TP load at source
FI-BOS (54 tonnes)
Storm Water
3.0%
Fish Farms
MWWTP
44.0%
Industry
52.8%
MWWTP Industry Fish Farms Storm Water

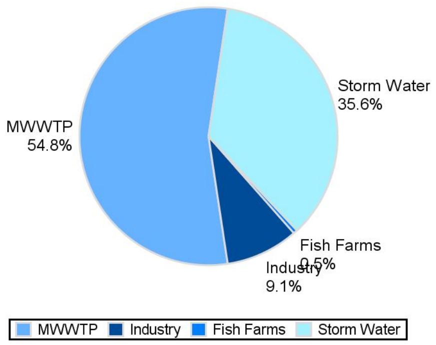
TN load at source
FI-GUF (5602 tonnes)



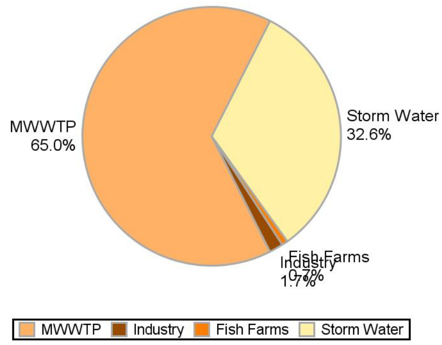
TP load at source
FI-GUF (118 tonnes)



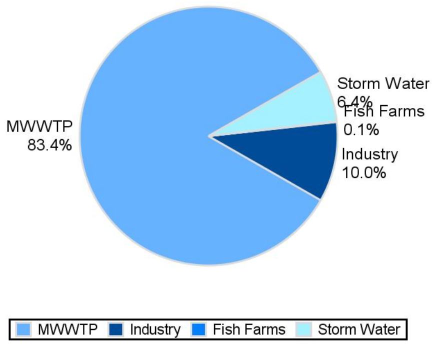
TN load at source
PL-BAP (45911 tonnes)



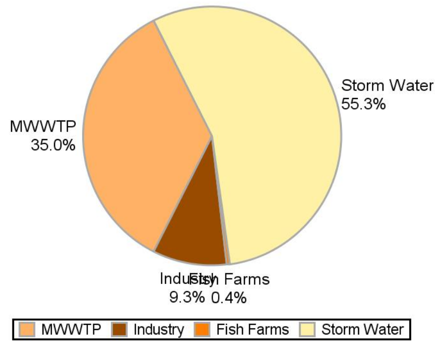
TP load at source
PL-BAP (4298 tonnes)



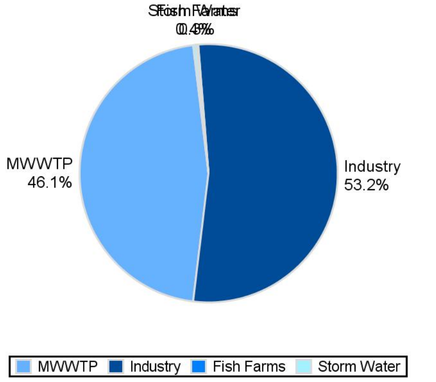
TN load at source
SE-BAP (4460 tonnes)



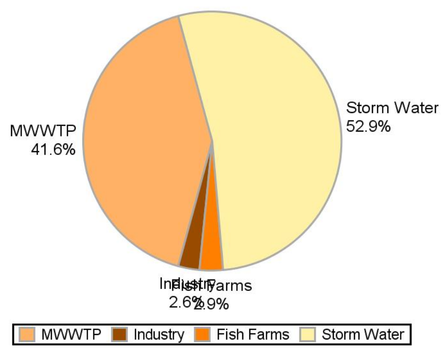
TP load at source
SE-BAP (134 tonnes)



TN load at source
SE-BOB (1035 tonnes)



TP load at source
SE-BOB (20 tonnes)



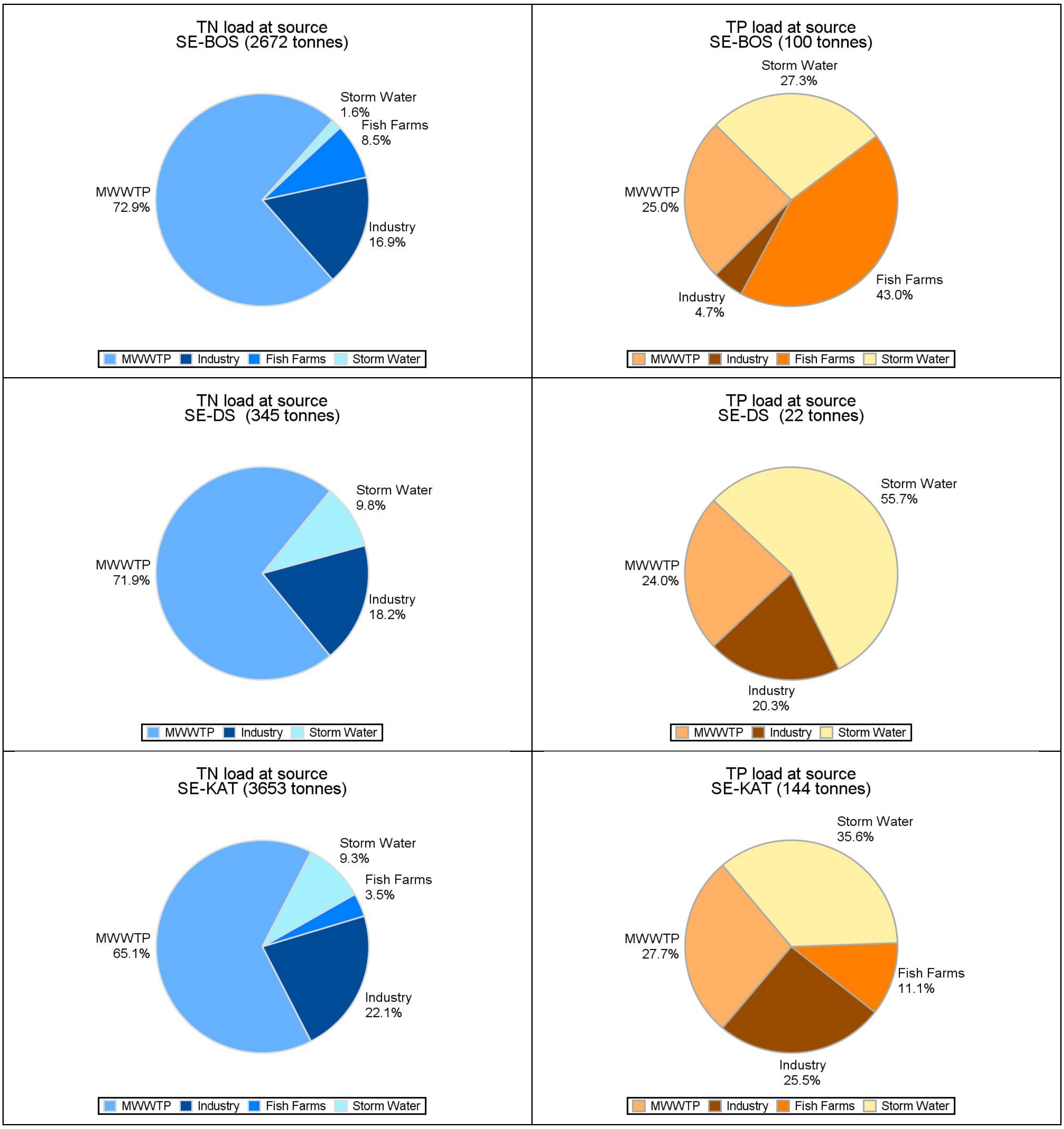


Figure 2 Importance of inputs from point sources of total nitrogen (TN) – left column - and total phosphorus (TP) – right column - to inland surface waters in the catchment to the Baltic Sea divided by country for 4 countries. Data from 2014, but Poland from 2012. The importance of the sources is given in percentages of the total TN and TP inputs from point sources to inland surface waters (the number indicated in tonnes in the heading to each figure). The point sources are divided in municipal wastewater treatment plants (MWWTP), industry, fish farms and storm waters. DK = Denmark, FI = Finland, PL = Poland, SE = Sweden, BAP = Baltic Proper, BOB = Bothnian Bay, BOS = Bothnian Sea, DS = Danish Straits, GUF = Gulf of Finland, and KAT = Kattegat.

3.3 Diffuse input source to inland surface waters

In Figure 3 the diffuse sources to inland waters shown in Figure 1 are sub-divided in:

- Agricultural sources
- Managed forestry (only Finland and Sweden)
- Scattered dwellings
- Atmospheric deposition on inland surface waters
- Natural background losses

Results are shown for four countries - Denmark, Finland, Sweden (with 2014 data) and Poland (data from 2012). Countries use rather different quantification methodology for especially quantification of agricultural sources, scattered dwellings and atmospheric deposition on surface waters. Therefore, comparison of the importance of the diffuse source should be done with care.

Agricultural sources are the major diffuse source of TN and TP to inland waters in the catchment to the Baltic Sea for:

- Denmark: approx. 75-80% for TN and 55-65% for TP
- Poland: approx. 60% for TN and 50% for TP
- Finland: for the catchment to Bothnian Sea 55% for TN and 68% for TP
- Sweden: for the catchment to Danish Straits regarding TN (67%).

Finland and Sweden have quantified managed forestry, but the share of TN and TP from this source of diffuse inputs to inland surface waters is rather low (between 1-6%). In Denmark, e.g. growing Christmas trees is included under agriculture losses.

Especially the Danish and Polish catchments have a lot of agriculture land. Besides the Swedish catchment to Bothnian Bay and Bothnian Sea, agriculture constitutes at least nearly 30% of TN and over 20% of TP diffuse nutrient inputs.

Natural background losses are the main sources in the northern catchments in Sweden and Finland to Bothnian Bay constituting:

- Approx. 60% of TN and 50% of TP in the Finnish part
- Over 85% of TN and over 90% of TP in the Swedish part

Further, natural background losses are the main diffuse source (77% for TN and 82% for TP) in the Swedish catchment to Bothnian Sea, to Baltic Proper (nearly 50% TN and 60% TP) and to Kattegat (approx. 50% for TN and 66% for TP). These areas are dominated by mountainous or pristine areas, uncultivated areas and not managed forest.

Natural background losses constitute more than 19 % of TN and 14% of TP in all catchments.

TP inputs from *scattered dwellings* are important in some catchments:

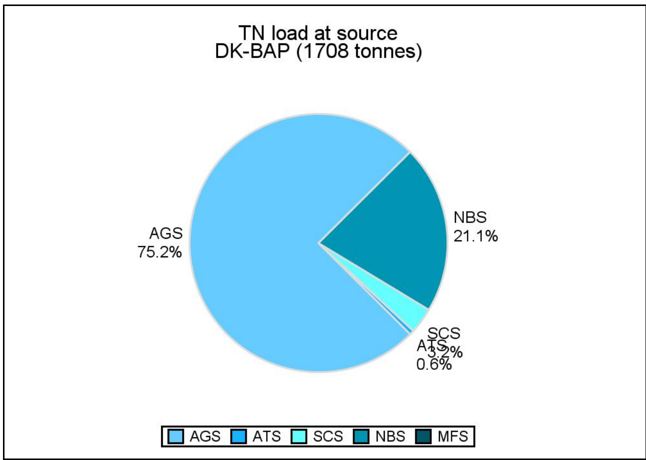
- Denmark: Baltic Proper (20%) and Danish Straits (13%)
- Finland: Bothnian Sea and Gulf of Finland (9%)
- Poland: Baltic Proper (20%)
- Sweden: Baltic Proper and Danish Straits (approx. 10%).

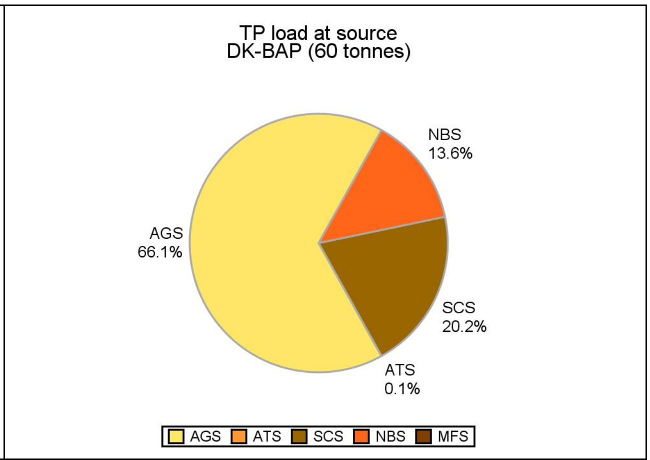
For the remaining catchments the share of scattered dwellings is less than 5-6%. For TN the share from scattered dwellings is less than 3% except for the Polish catchment to Baltic Proper with 14%. The importance of scattered dwellings reflects areas with many people living in rural areas, areas with many summer cottages, areas with lower connectivity to municipal wastewater treatment plants, and degree of treatment on this source.

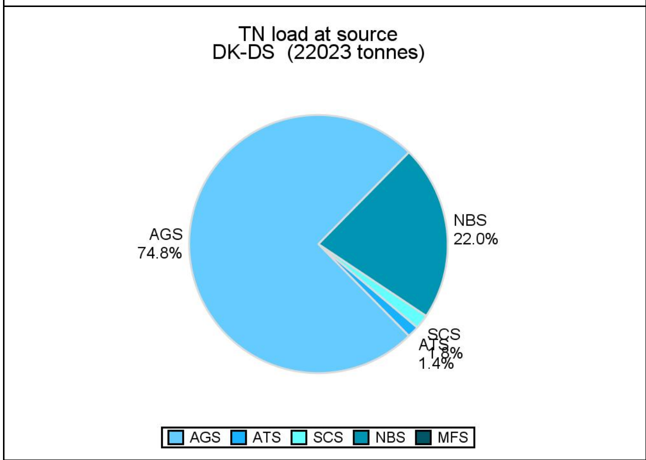
Atmospheric deposition on inland surface waters depends on the percentages of the catchment covered by lakes and big rivers as well as the area specific TN and TP deposition. TN deposition is highest in the south-western parts of the Baltic Sea catchment areas and lowest in the north-eastern part. This source can be important in catchment where area of lakes constitutes a high proportion of total catchment area and when losses from other diffuse source are low. The highest shares for atmospheric inputs are estimated in the catchment to:

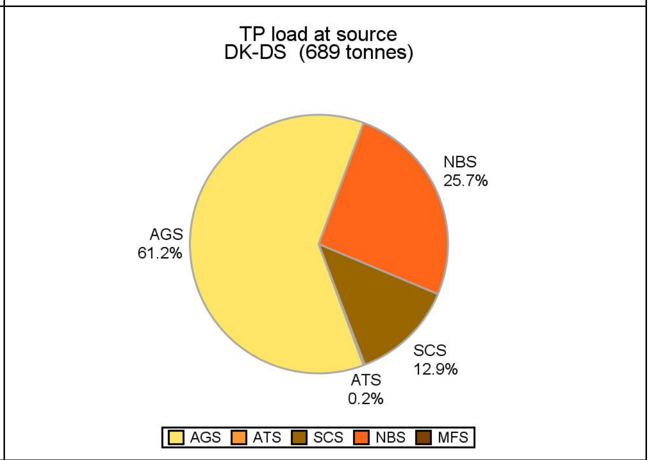
- Gulf of Finland (18% for TN and 9% for TP)
- Sweden in the catchment to Baltic Proper (12% TN), Bothnian Bay (9% TN and 6% TP), Bothnian Sea (11% TN and 5% TP), and Kattegat (16%).

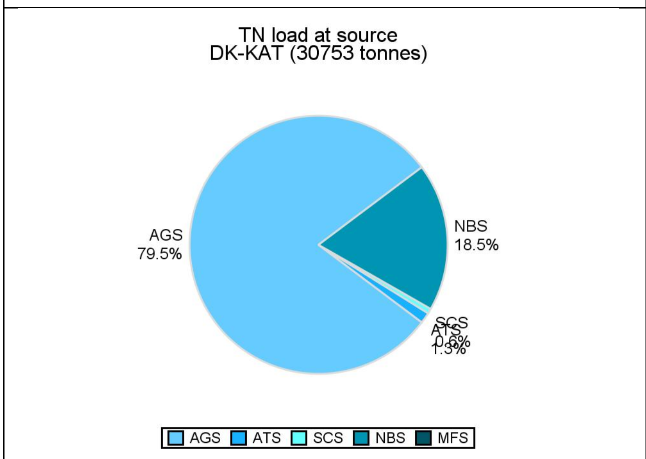
For the remaining catchments, the shares for TN are less than 6% and for TP less than 4%. The importance of TP deposition is very uncertain, as it is difficult to monitor TP deposition.

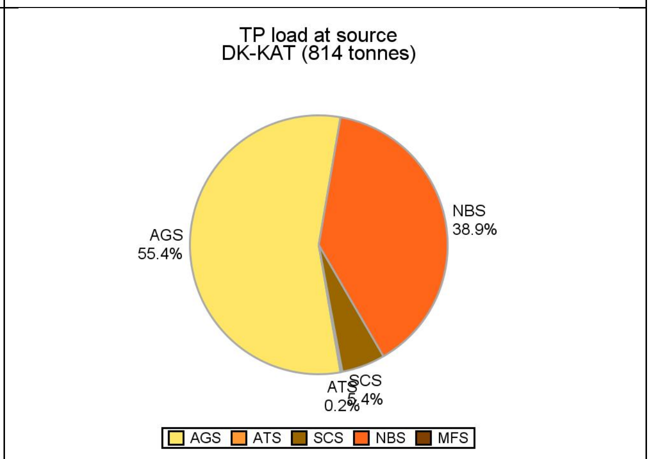

TN load at source
DK-BAP (1708 tonnes)
AGS
75.2%
NBS
21.1%
SCS
ATS
0.6%
AGS ATS SCS NBS MFS

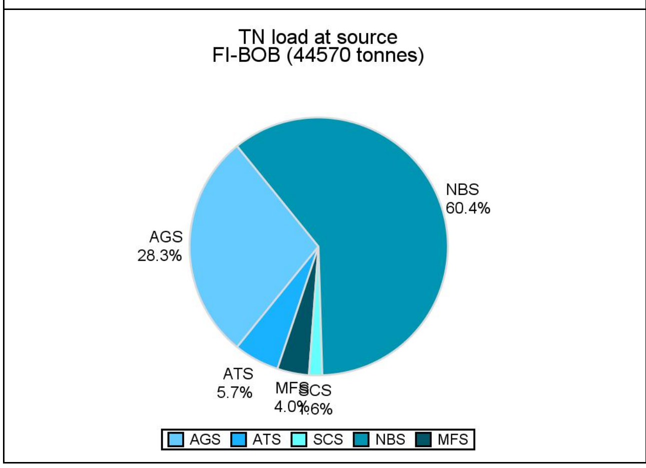

TP load at source
DK-BAP (60 tonnes)
AGS
66.1%
NBS
13.6%
SCS
20.2%
ATS
0.1%
AGS ATS SCS NBS MFS

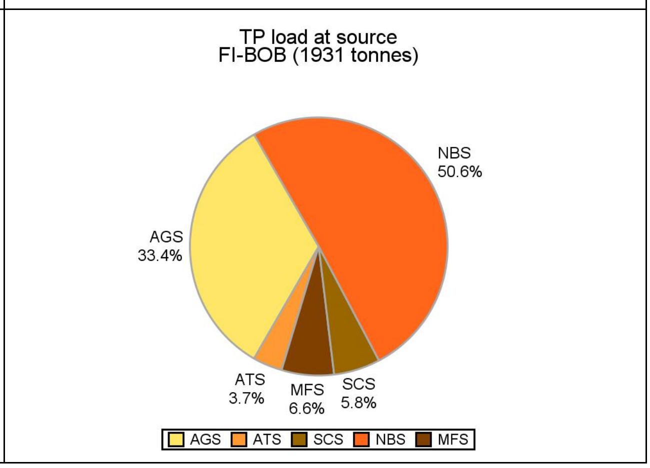

TN load at source
DK-DS (22023 tonnes)
AGS
74.8%
NBS
22.0%
SCS
1.4%
AGS ATS SCS NBS MFS

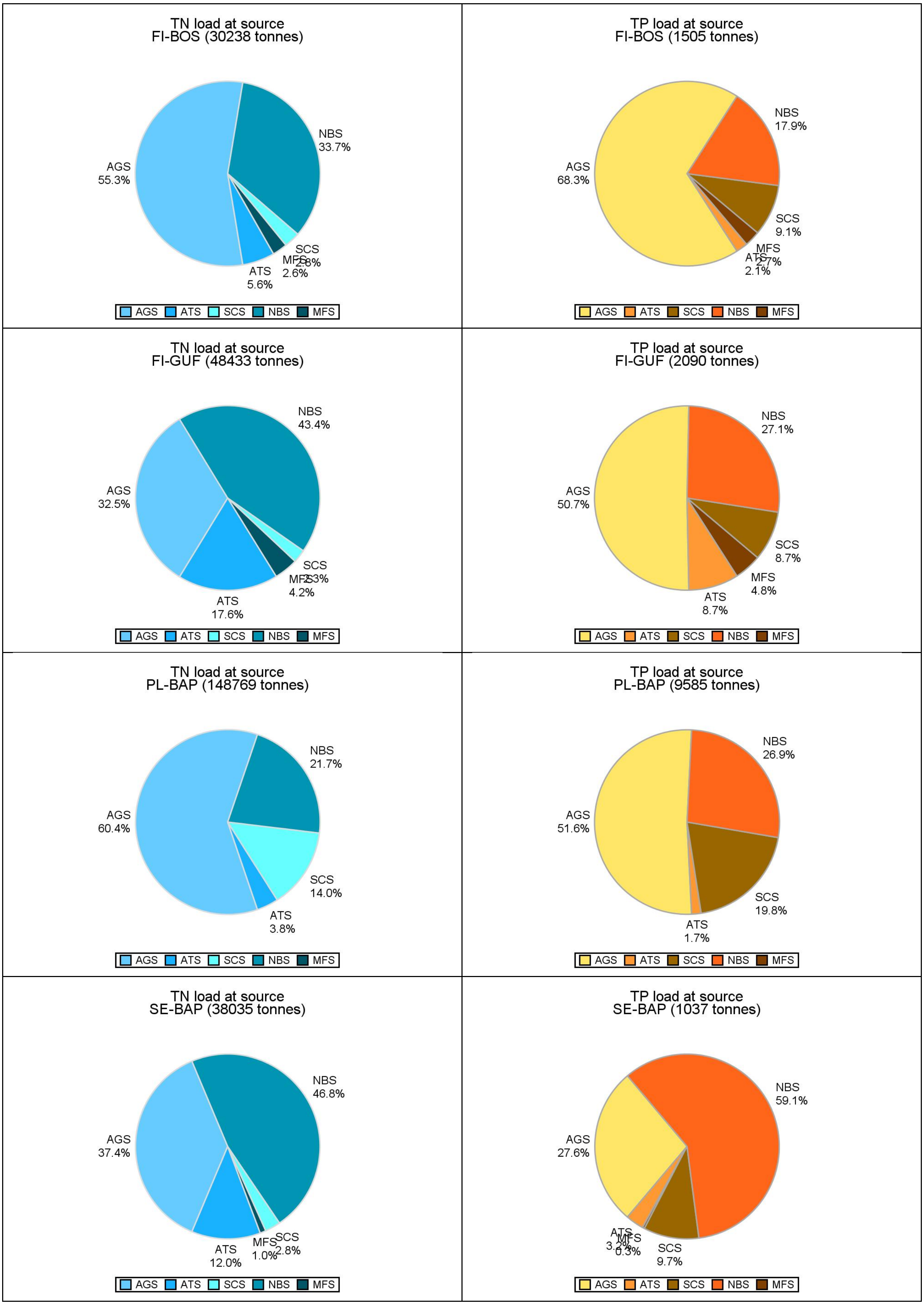

TP load at source
DK-DS (689 tonnes)
AGS
61.2%
NBS
25.7%
SCS
12.9%
ATS
0.2%
AGS ATS SCS NBS MFS

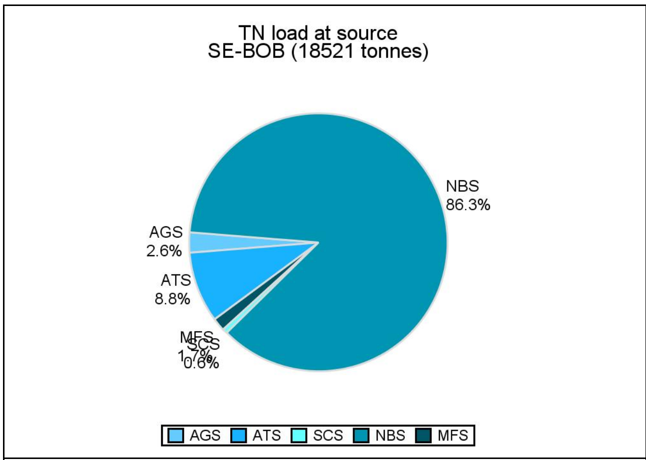

TN load at source
DK-KAT (30753 tonnes)
AGS
79.5%
NBS
18.5%
SCS
1.3%
AGS ATS SCS NBS MFS

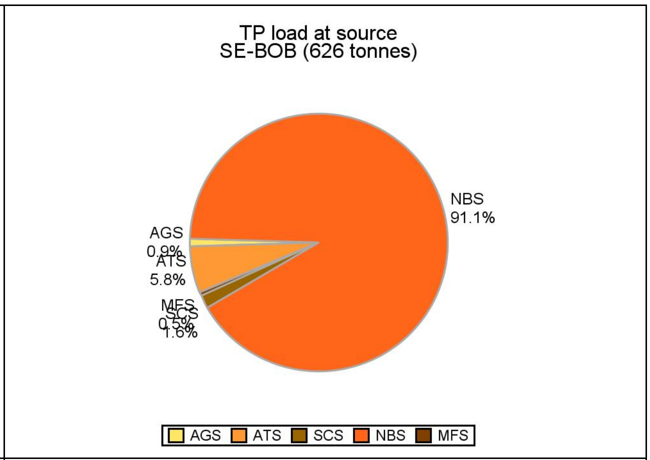

TP load at source
DK-KAT (814 tonnes)
AGS
55.4%
NBS
38.9%
SCS
0.2%
AGS ATS SCS NBS MFS

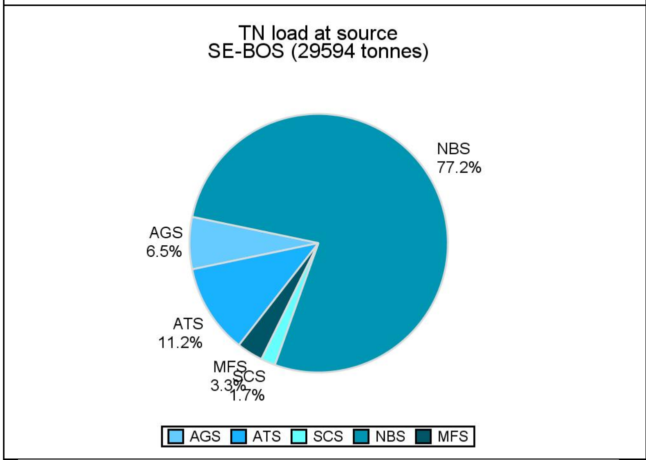

TN load at source
FI-BOB (44570 tonnes)
AGS
28.3%
NBS
60.4%
ATS
5.7%
SCS
4.0%
AGS ATS SCS NBS MFS

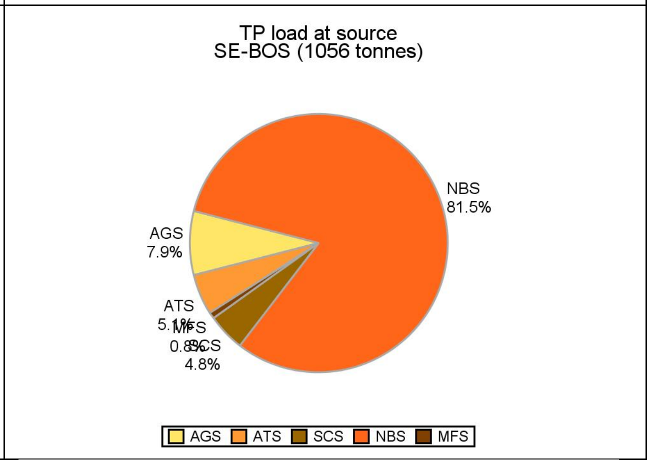

TP load at source
FI-BOB (1931 tonnes)
AGS
33.4%
NBS
50.6%
ATS
3.7%
MFS
6.6%
SCS
5.8%
AGS ATS SCS NBS MFS

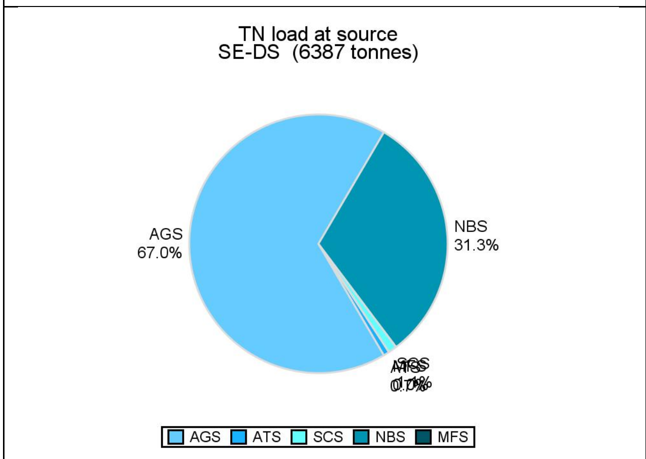

TN load at source
FI-BOS (30238 tonnes)
AGS
55.3%
NBS
33.7%
SCS
2.8%
MFS
2.6%
ATS
5.6%
AGS ATS SCS NBS MFS
TP load at source
FI-BOS (1505 tonnes)
AGS
68.3%
NBS
17.9%
SCS
9.1%
MFS
2.7%
ATS
2.1%
AGS ATS SCS NBS MFS
TN load at source
FI-GUF (48433 tonnes)
AGS
32.5%
NBS
43.4%
SCS
2.3%
MFS
4.2%
ATS
17.6%
AGS ATS SCS NBS MFS
TP load at source
FI-GUF (2090 tonnes)
AGS
50.7%
NBS
27.1%
SCS
8.7%
MFS
4.8%
ATS
8.7%
AGS ATS SCS NBS MFS
TN load at source
PL-BAP (148769 tonnes)
AGS
60.4%
NBS
21.7%
SCS
14.0%
ATS
3.8%
AGS ATS SCS NBS MFS
TP load at source
PL-BAP (9585 tonnes)
AGS
51.6%
NBS
26.9%
SCS
19.8%
ATS
1.7%
AGS ATS SCS NBS MFS
TN load at source
SE-BAP (38035 tonnes)
AGS
37.4%
NBS
46.8%
SCS
2.8%
MFS
1.0%
ATS
12.0%
AGS ATS SCS NBS MFS
TP load at source
SE-BAP (1037 tonnes)
AGS
27.6%
NBS
59.1%
SCS
9.7%
MFS
0.3%
ATS
3.2%
AGS ATS SCS NBS MFS

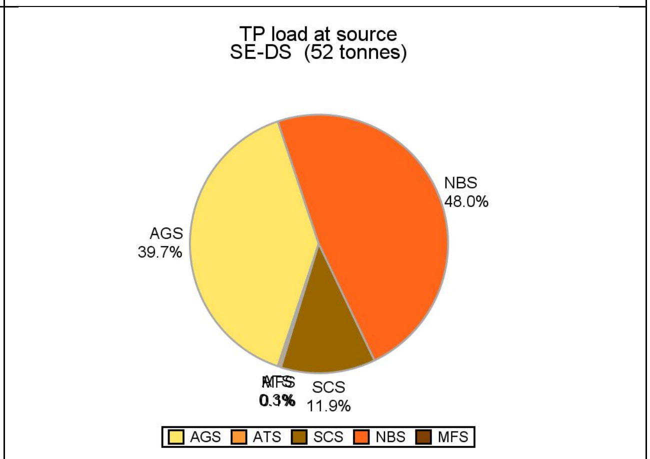

TN load at source
SE-BOB (18521 tonnes)
NBS 86.3%
AGS 2.6%
ATS 8.8%
MFS
SCS
0.6%
AGS ATS SCS NBS MFS

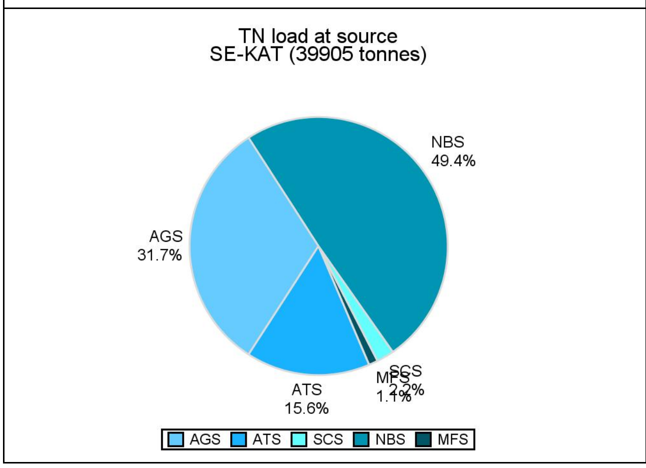

TP load at source
SE-BOB (626 tonnes)
NBS 91.1%
AGS 0.9%
ATS 5.8%
MFS
SCS
1.6%
AGS ATS SCS NBS MFS


TN load at source
SE-BOS (29594 tonnes)
NBS 77.2%
AGS 6.5%
ATS 11.2%
MFS 3.3%
SCS 1.7%
AGS ATS SCS NBS MFS


TP load at source
SE-BOS (1056 tonnes)
NBS 81.5%
AGS 7.9%
ATS 5.1%
MFS 0.8%
SCS 4.8%
AGS ATS SCS NBS MFS


TN load at source
SE-DS (6387 tonnes)
AGS 67.0%
NBS 31.3%
AGS ATS SCS NBS MFS


TP load at source
SE-DS (52 tonnes)
NBS 48.0%
AGS 39.7%
MFS 0.3%
SCS 11.9%
AGS ATS SCS NBS MFS


TN load at source
SE-KAT (39905 tonnes)
NBS 49.4%
AGS 31.7%
ATS 15.6%
MFS 1.1%
SCS 2.2%
AGS ATS SCS NBS MFS

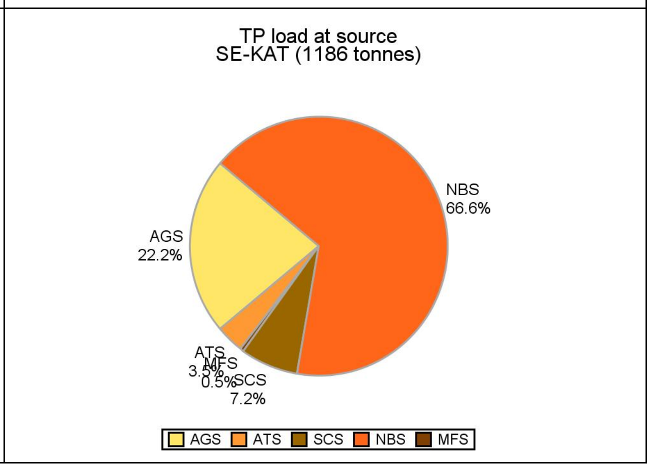

TP load at source
SE-KAT (1186 tonnes)
NBS 66.6%
AGS 22.2%
ATS 3.5%
MFS 0.5%
SCS 7.2%
AGS ATS SCS NBS MFS

Figure 3 Importance of inputs from diffuse sources of total nitrogen (TN) – left column - and total phosphorus (TP) – right column - to inland surface waters in the catchment to the Baltic Sea divided by country for 4 countries. Data from 2014, but Poland from 2012. The importance of the sources is given in percentages of the total TN and TP inputs from point sources to inland surface waters (the number indicated in tonnes in the heading to each figure). The diffuse sources are divided in agricultural sources (AGS), managed forestry (MFS only Finland and Sweden), scattered dweling (SCS), atmospheric deposition on inland surface waters (ATS) and natural background losses (NBL). DK = Denmark, FI = Finland, PL = Poland, SE = Sweden, BAP = Baltic Proper, BOB = Bothnian Bay, BOS = Bothnian Sea, DS = Danish Straits, GUF = Gulf of Finland, and KAT = Kattegat.

4. Summary and Conclusion

The source oriented approach estimates the importance of total nitrogen (TN) and total phosphorus (TP) sources to inland surface waters. This report includes the first trial under the PLC assessment to assess the reported source data with the source oriented approach. The assessment does not include all nine HELCOM countries as they have applied different methodologies to estimate sources (and pathways), some countries have reported some sources separately, while other countries have reported, e.g. all diffuse sources aggregated or not quantified all sources. The results from countered with the most comprehensive and complete data sets were assessed. It should be noted that data are from 2014 but Polish data are from 2012 and data from Lithuania are aggregated average for 2007-2014.

At the most aggregated assessment level, the data from eight countries (all countries apart from Germany) were divided the sources in three categories:

- Point sources
- Diffuse anthropogenic sources
- Natural background sources

The most comparable data are on the point sources, while countries use rather different methods for estimating losses from diffuse anthropogenic sources and natural background sources. By aggregating the diffuse anthropogenic sources, the results from eight HELCOM countries can be compared with caution. *Natural background sources* constitute the highest shares and are the most important sources in the northern part of the Baltic Sea catchment area up to more than 80%: for both TN and TP in the Swedish catchment to Bothnian Bay (BOB). These areas are scarcely populated and with low agricultural activity, the main human impact is by forestry, industry and atmospheric TN deposition.

Natural background sources are also the most important sources of TN and TP in the catchment to BOB both for Finland (FI) and for Sweden (SE), to Bothnian Sea (BOS) for SE, to Gulf of Finland (GUF) for Russia (RU), to Baltic Proper (BAP) for RU and SE and to Kattegat (KAT) for SE.

The lowest share from natural background sources constituting less than 20% for TN to Gulf of Riga (GUR), Danish Straits (DS) and Kattegat (KAT) for Denmark (DK), and the southern part of BAP where agricultural activities are extensive. For TP the lowest natural background shares (less than 20%) are to BAP (for DK, Lithuania (LT), Latvia (LV) and Poland (PL)), BOS (FI) and Gulf of Riga (LT). High population density especially as scattered dwelling and high amount of agriculture will reduce the importance of natural background sources.

Anthropogenic diffuse sources are, besides the cases mentioned above, the biggest sources within the catchments. The highest shares constitute more than 75% to BAP (DK, LT, LV), GUR (LT, LV) and KAT (DK) for TN, and more than 70% in the catchment to BAP (DK, LT, LV), BOS (FI), GUF (EE) and GUR (EE, LT, LV) for TP.

The highest share from *point sources* is for TP and is in the catchment to DS (DK 32% and SE 30%) and to BAP (PL 31%). For TN the highest point source share is to BAP (PL 24%). In many catchments to point sources the share is less than 10% for both TN and TP.

For four countries (DK, FI, PL and SE) the point source inputs to inland waters are divided into inputs from:

- Municipal wastewater treatment plants (MWWTP)
- Industry
- Storm waters
- Fish Farms

Overall, the most important point source into inland waters is *MWWTP* often constituting more than 50 % of the inputs, but due to high degree of treatment from MWWTP and industry, storm waters have a high share in some catchments. Storm waters have the highest share of inputs from point sources for DK to BAP (TN: 53%, TP: 54%), DK to DS (TN: 40%, TP: 66%), DK to KAT (TP: 42%), SE to BAP (TP: 55%), SE to BOB (TP: 53%), SE to DS (TP: 56%) and SE to KAT (TP: 36%). Industry are the most important point source in some catchments where industrial activity are rather high or with big plants: FI to BOS (TP: 53%), FI to GUF (61%) and SE to BOB (53%).

Inland fish farms are usually a minor point source to inland surface waters with a share of less than 5%. But within some catchments there is a relatively high intensity of fish farming where the share from fish farms are higher as for DK to KAT (TN: 41% and TP: 34%) and SE to BOS (TP: 43%).

The data for assessing different diffuse sources to inland waters separately were available for the same four countries. The data included:

- Natural background sources (NBS) – same sources as discussed for the eight countries above
- Atmospheric deposition (ATS)
- Agricultural sources (AGS)
- Managed forestry (MFS) – in Poland and Denmark it is included in AGS
- Scattered dwellings (SCS)

The importance of anthropogenic diffuse sources is closely related to agricultural extend of activities including forestry, number of people living in scattered dwelling and how the activities are conducted in relation to losses of TN and TP and treatment of these losses.

Agricultural sources are the major diffuse sources into inland waters in the catchment in the south and western part of the Baltic Sea catchment area where agricultural land constitutes up to 2/3 of the catchment. It is the major diffuse source of TN and TP for:

- Denmark: to BAP, DS and KAT: approx. 75-80% for TN and 55-65% for TP
- Poland: to BAP: approx. 60% for TN and 50% for TP
- Finland: to BOS 55% for TN and 68% for TP
- Sweden: to DS for TN (67%).

Finland and Sweden have quantified *managed forestry* separately from agricultural sources. However, the share is low, as the share of TN and TP to inland surface ranges between 1-6%.

Besides the Swedish catchment to Bothnian Bay and Bothnian Sea, agricultural sources constitute at least nearly 30% of TN and over 20% of TP diffuse nutrient inputs.

The importance of natural background losses to inland surface waters was described earlier and the importance of these sources are even higher considering diffuse sources separately. Natural background sources will have high shares in areas dominated by mountainous or pristine areas, uncultivated areas and not managed forest as seen in the northern part of Sweden and Finland in the catchment to BOB where this source constitutes:

- Approx. 60% of TN and 50% of TP in the Finnish part
- Over 85% of TN and over 90% of TP in the Swedish part

It is also the main diffuse source (77% for TN and 82% for TP) in the Swedish catchment to Bothnian Sea, to Baltic Proper (nearly 50% TN and 60% TP) and to Kattegat (approx. 50% for TN and 66% for TP).

Natural background sources constitute more than 19 % of TN and 14% of TP in all catchments.

Losses from scattered dwellings play significant role in areas with high percentage of rural population, areas with many summer cottages, areas with lower connectivity to municipal wastewater treatment plants, and the degree of treatment on this source. TP inputs from *scattered dwellings* are important in some catchments:

- Denmark: BAP (20%) and DS (13%)
- Finland: BOS and GUF (9%)
- Poland: BAP (20%)
- Sweden BAP and DS (approx. 10%).

For the remaining catchments the share of scattered dwellings on TP inputs is less than 5-6%.

For TN the share from scattered dwellings is less than 3% except for the Polish catchment to BAP (14%).

The importance of atmospheric deposition on inland surface waters is related to the percentages of the catchment covered by lakes and big rivers as well as the area specific TN and TP deposition. Overall, TN deposition is highest on the south-western part of the Baltic Sea catchment areas and lowest in the north-eastern part. The highest shares for atmospheric inputs are in the catchment to:

- Gulf of Finland (TN: 18%, TP: 9%)
- Sweden: BAP (TN: 12%), BOB (TN: 9%, TP: 6%), BOS (TN: 11%, TP: 5%), and Kattegat (TN: 16%).

For the remaining catchments, the shares for TN are less than 6% and for TP less than 4%. The importance of TP deposition is very uncertain, as it is difficult to monitor TP deposition.

Even though the results of the source-oriented assessment is based on only four countries, and the methods used by these countries for the diffuse sources are not fully comparable, it can be concluded:

- in the southern and south-western parts of the Baltic Sea catchment areas and the southern part of Finland losses from agriculture are the most important sources of TN and TP to the inland surface waters
- in the catchment of BOB natural background losses are the main TN and TP sources
- losses from scattered dwellings are an important source in some catchments (e.g. in BAP and DS) for some countries
- with a few exceptions (as to DS and GUR) point sources are a minor source to surface inland waters. Of point sources usually MWWTP are often the biggest, but storm waters constitute more than 50% of point sources inputs in some catchments. Industrial wastewater and fish farms are usually constituting less than 10% of point source inputs each, but have a considerably higher share in some catchments.