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Source apportionment of nitrogen and phosphorus inputs into the aquatic environment

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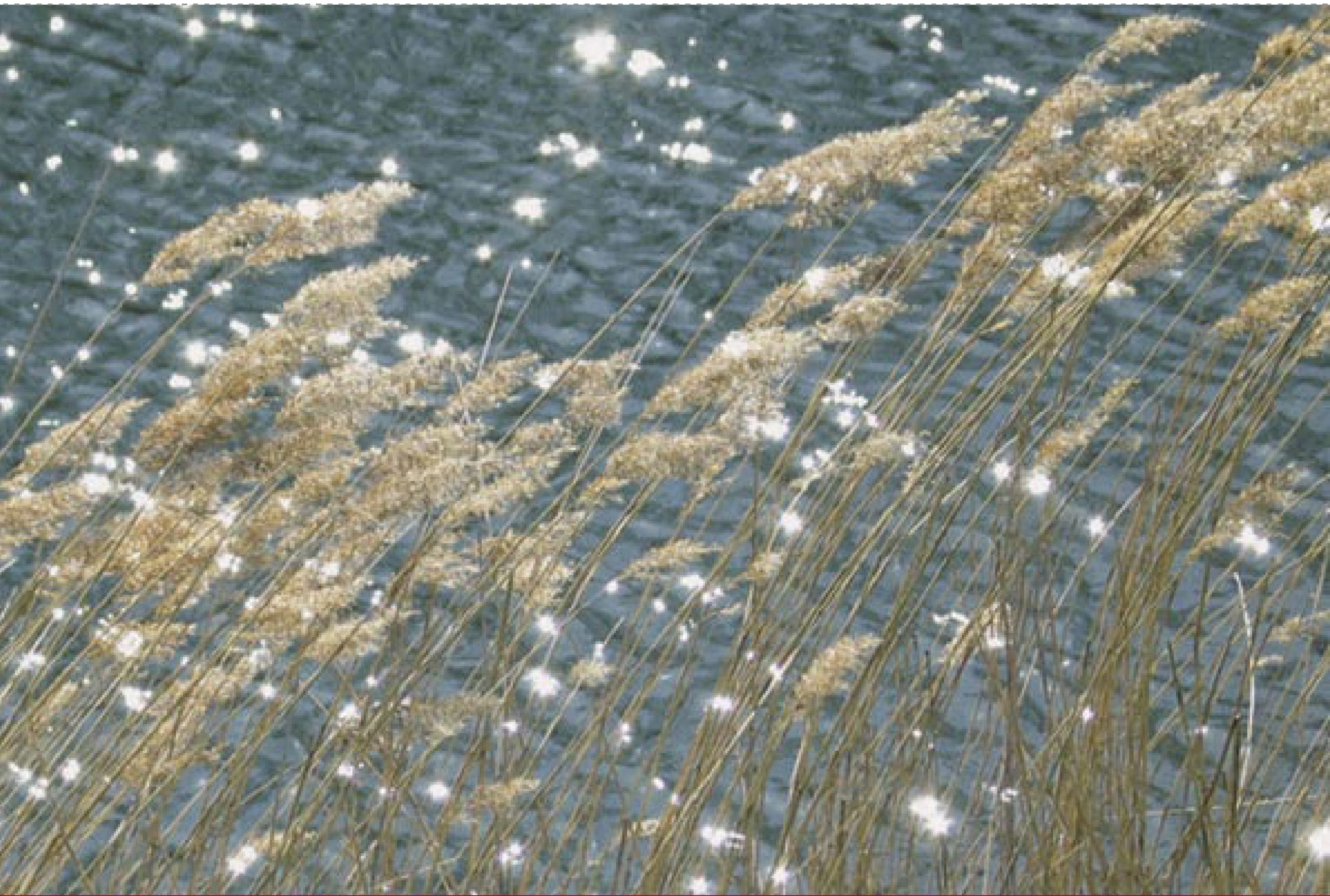

European Environment Agency

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European Environment Agency

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Contents

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Executive summary

Eutrophication is the excessive enrichment of waters with nutrients and the associated adverse biological effects, and it is still one of the major environmental problems across Europe. European waters are affected across the whole range from inland water bodies such as groundwater, rivers and lakes, to transitional and coastal waters and ecosystems in open seas. Eutrophication is caused by large anthropogenic inputs of the nutrients nitrogen (N) and phosphorus (P) to the aquatic environment from a range of societal sectors.

During the last 10 years, the EEA has in its state of the environment reports and water reports presented results on the sectoral contribution of nitrogen and phosphorus to the pollution of the aquatic environment. The study aims at updating this information on the source apportionment of the total load of nitrogen and phosphorus to the aquatic environment on a large scale: country, large river basins, and sea areas.

Source apportionment is the estimation of the contribution by different sectors to water pollution. In this study, the focus has been on the nutrients nitrogen and phosphorus from land-based activities to the aquatic environment, with the primary focus on the agricultural contribution.

The overall approach has been to compile results from existing source apportionment studies for the assessment. Source apportionment results from the following sources have been used:

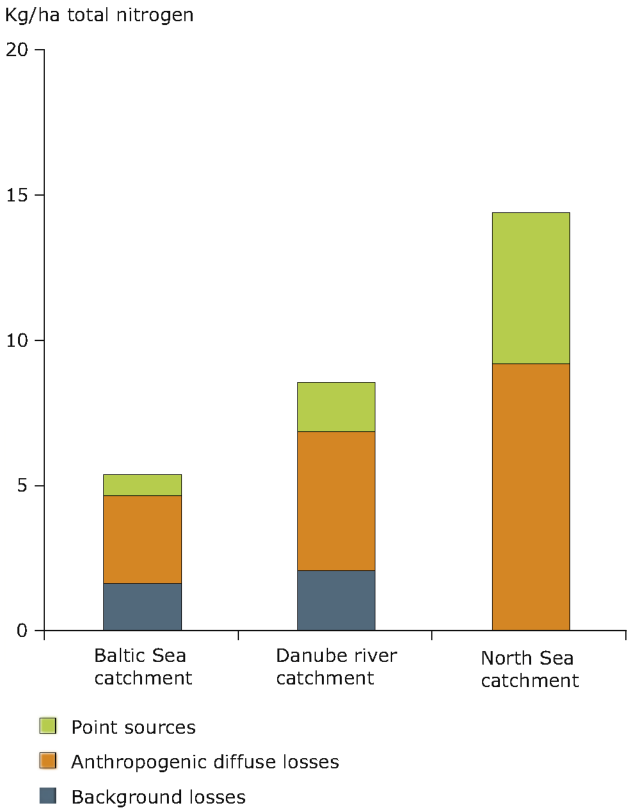
- international organisations such as transboundary river commissions and regional marine conventions;
- national and regional studies;
- research activities.

The north-western part of Europe is generally well covered by source apportionment studies, but there is a shortage of information from the Mediterranean countries and some eastern European countries.

Key messages

- Run-off from agricultural land is the principal source of nitrogen pollution. Agriculture is typically contributing 50–80 % of the total load.
- The total area-specific load (kg N/ha per year) increases with increasing human activities, in particular with more intensive agricultural production in the catchments (Figure 1).

Figure 1 Source apportionment of annual nitrogen load

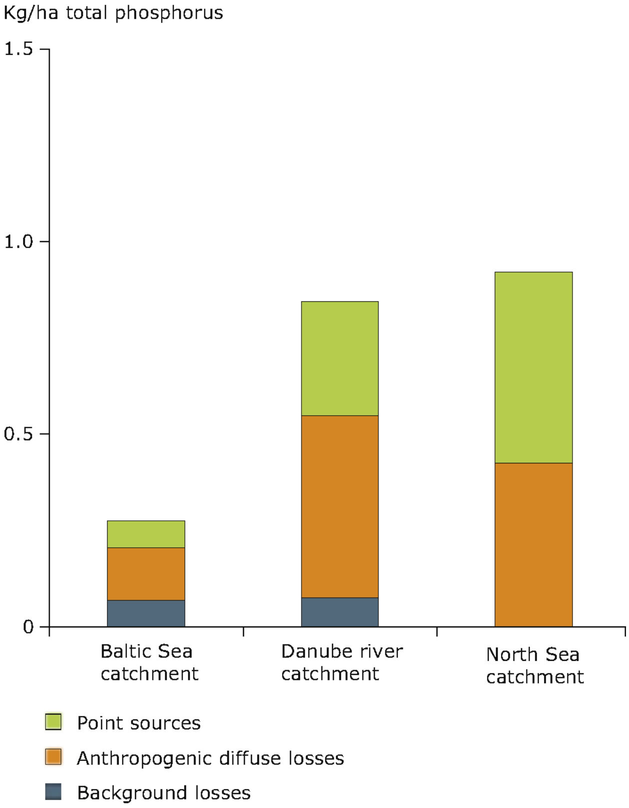


Note: For the Baltic Sea catchment (1.6 million km²), the Danube river catchment (0.8 million km²) and the North Sea catchment (0.5 million km²) (no separate information on background losses for the North Sea). Source-oriented approaches.

Sources: Helcom (2004); Schreiber *et al.* (2003); OSPAR (2003).

- For phosphorus, point sources such as households and industry still tend to be the most significant source. However, as point source discharges in many countries have been markedly reduced during the last 15 years, agriculture has sometimes become the main source.
- In regions with low population density and low percentage of agricultural land such as the Baltic

Figure 2 **Source apportionment of annual phosphorus load**



Note: For the Baltic Sea catchment (1.6 million km²), the Danube river catchment (0.8 million km²) and the North Sea catchment (0.5 million km²) (no information on background losses for the North Sea). Source-oriented approaches.

Sources: Helcom (2004); Schreiber *et al.* (2003); OSPAR (2003).

Sea catchment, the area-specific phosphorus load is only one third of the load in densely populated regions in central and north-western Europe (Figure 2).

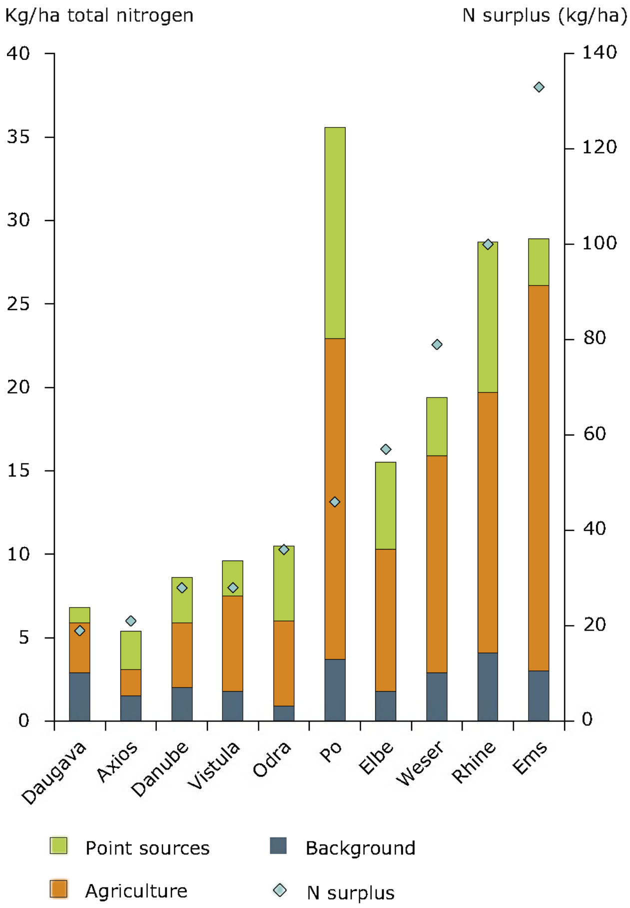
Nitrogen load in selected countries and catchments

- The total area-specific load of nitrogen (kg N/ha per year), illustrated by the area of the pie charts on Map 1, increases generally with increasing agricultural activity. The total area-specific load in the catchments/countries in north-western Europe is more than double (triple) than in the Nordic countries and Baltic States.
- For all countries and catchments examined, agricultural or diffuse losses (agriculture plus background) account for more than 60 % of the total load.

Phosphorus load in selected countries and catchments

- Similar to nitrogen, the total area-specific load of phosphorus (kg P/ha per year) is highest in countries and catchments with high population density and high share of agricultural land (Map 2).
- In countries/catchments such as Belgium and the Odra and Po catchments with high population density and without nutrient removal at the majority of wastewater treatment plants, point sources generally account for more than two thirds of the load.

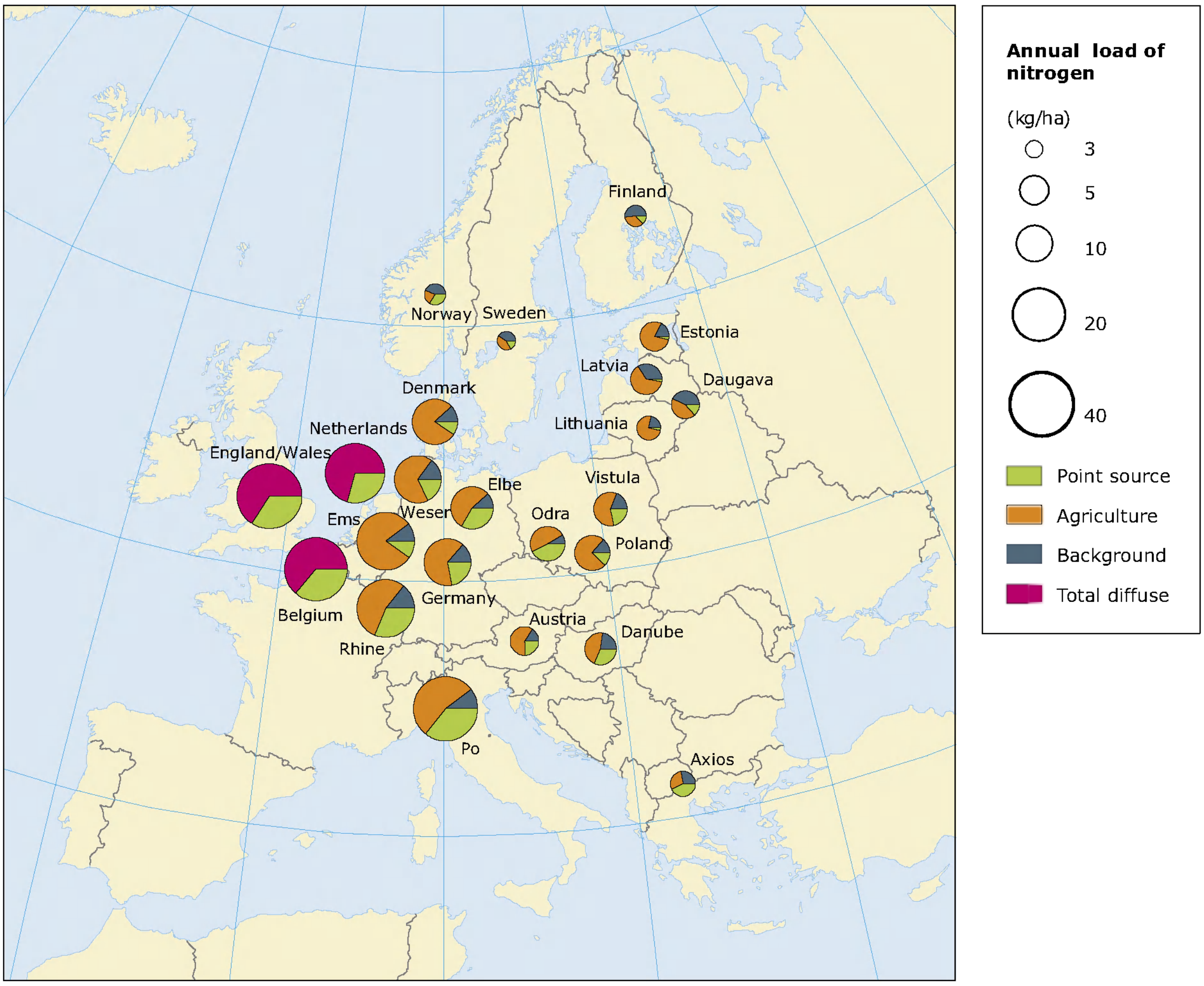
Figure 3 **Total area-specific nitrogen load (before retention) by sources and nitrogen surplus in large river catchments using the Moneris model**



Note: Sorted by increasing nitrogen surplus. Source-oriented approach.

Source: Behrendt/EuroCat (2004).

Map 1 Source apportionment of nitrogen load in selected regions and catchments



Note: The area of each pie chart indicates the total area-specific load. Mixed approaches.

Sources: See Annex 1.

Large European river catchments

- The total area-specific nitrogen load varies with a factor five for large European river catchments. There is a high area-specific nitrogen load in the agriculturally intensive catchments.
- There is a close relationship between the total area-specific nitrogen load and the surplus of nitrogen applied to agricultural catchments for large European river catchments (Figure 3).
- For most of the central European large river catchments, point sources account for the majority of the phosphorus load (Figure 4).

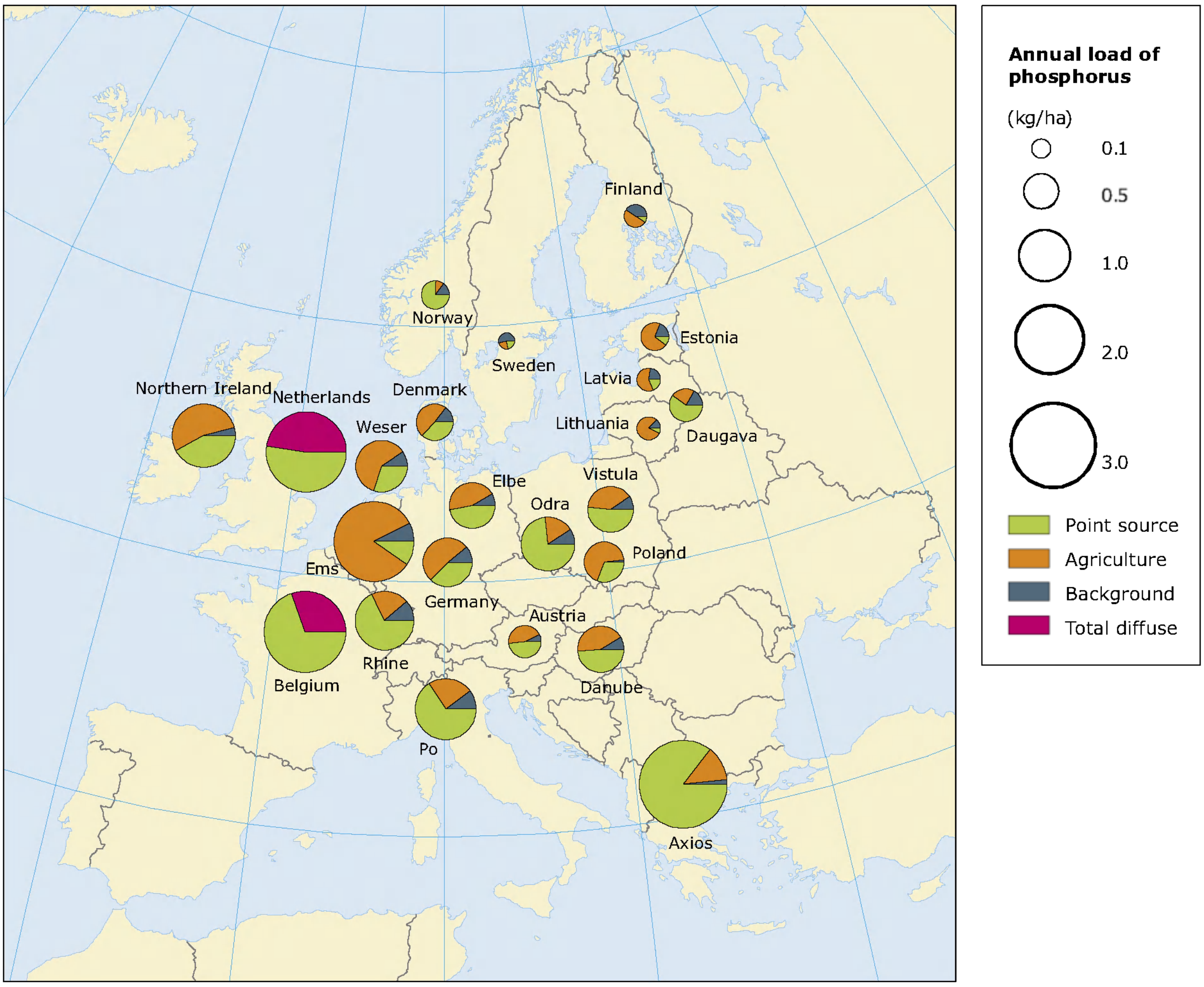
Trends during the past 30 years

- Discharges of both nitrogen and phosphorus from point sources have decreased significantly during the past 30 years, whereas the loss from diffuse sources has generally remained at a constant level (Figure 5).
- The change has been largest for phosphorus, where it has also resulted in the largest reduction in the total load due to the previously very high share of point source discharges.
- The loss from diffuse sources has become relatively more significant as a consequence of the reduced point source discharges.

The changes are mainly due to improved purification of urban wastewater. In the Nordic and western European countries, purification is now very effective and eastern European countries are now following a similar development.

Measures to reduce the nitrogen surplus on agricultural land are now beginning to show results in terms of a reduction in diffuse losses of nitrogen

Map 2 Source apportionment of phosphorus load in selected regions and catchments



Note: The area of each pie chart indicates the total area-specific load. Mixed approaches.

Sources: See Annex 1.

to water. For example, in Denmark, the nitrogen surplus was reduced by 34 % over the period 1989 to 2003 followed by a marked decrease in the marine nitrogen load (Andersen *et al.*, 2004). However, due to a combination of processes affecting the nitrogen cycle in soil and water, the reduction in diffuse loading of the aquatic environment can be delayed by many years after measures have been implemented on land.

Outlook

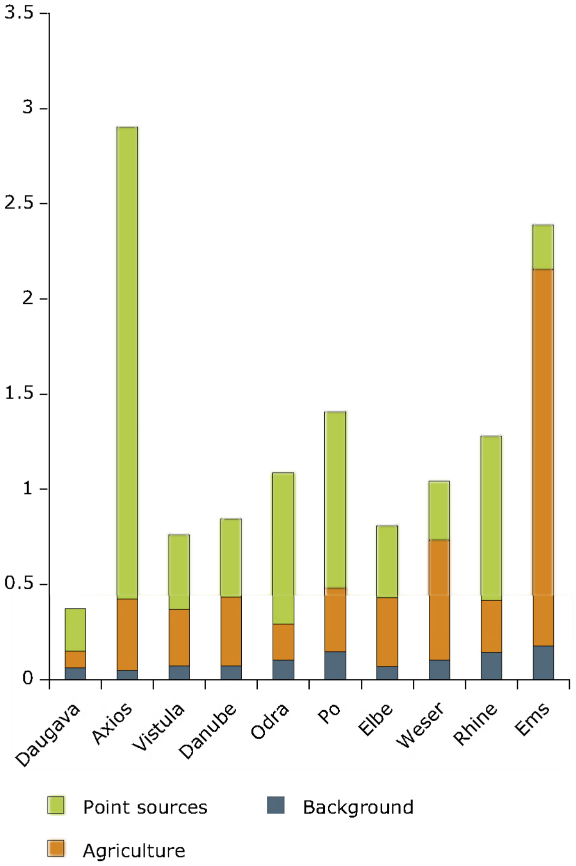
This study is the first step in a wider framework action dealing with the assessment of nutrient inputs from agriculture and other sources into water bodies of inland waters as well as transitional, coastal and marine waters and is seen in the context of ongoing EEA work on agriculture and environment.

In order to assess the effectiveness of current policies and agreements and to identify gaps, it is essential to know how nutrient inputs are distributed across sectors. Results from source apportionment studies are therefore important in the policy formulation process and in monitoring the implementation of policies and the effectiveness of measures.

To help achieve this, a European-wide source apportionment of nutrient loads could be carried out applying an appropriate source apportionment tool at regular intervals (e.g. every three to five years) for a representative part or for the entire network of stations within the Eionet-water network. This will establish time series of source apportionment for all the different regions across Europe.

Figure 4 **Total area-specific phosphorus load (before retention) by sources in large river catchments using the Moneris model**

Kg/ha total phosphorus

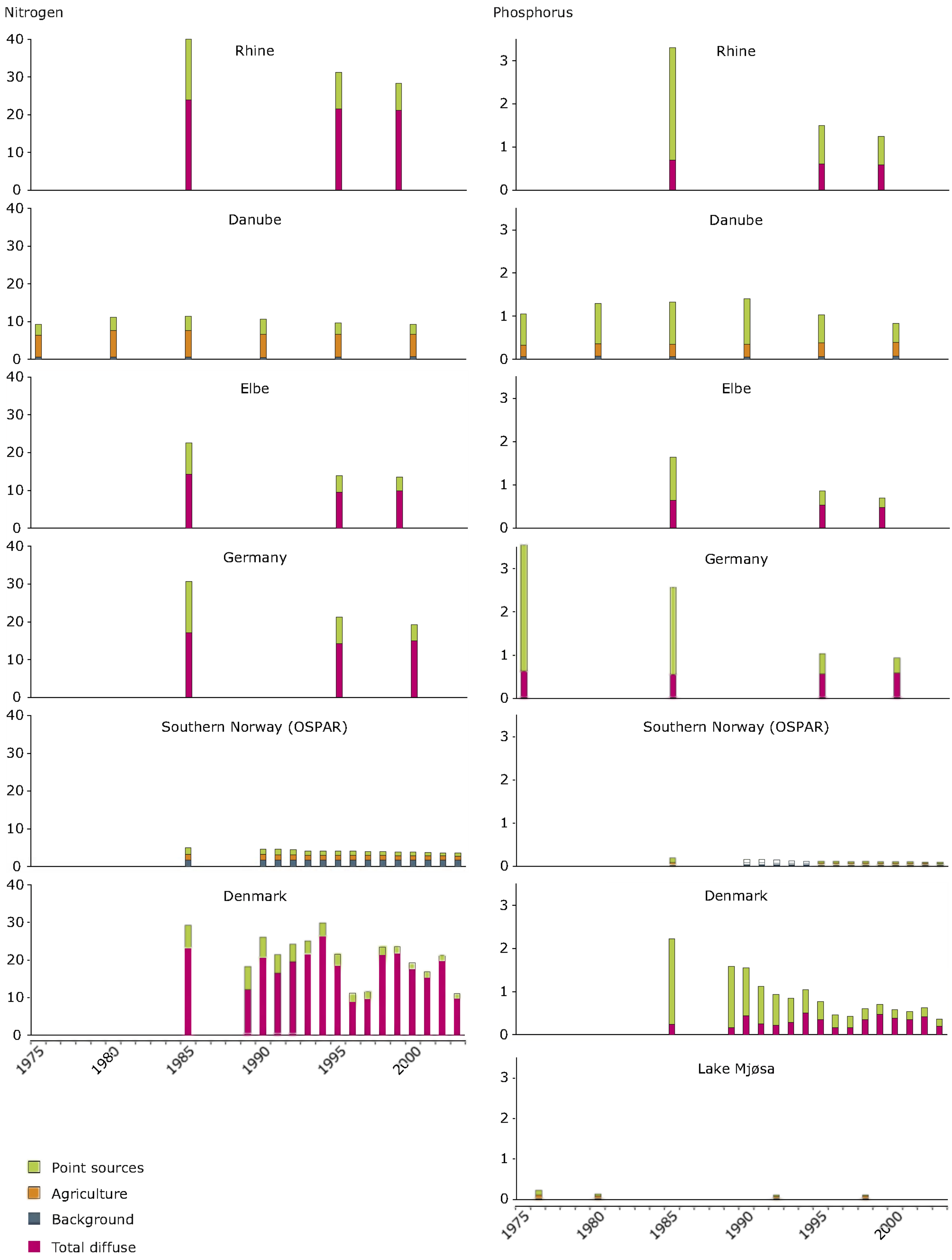


Note: Sorted by increasing nitrogen surplus as in Figure 3. Source-oriented approach.

Source: Behrendt/EuroCat (2004).

In the short term, the EEA aims at a spatially differentiated assessment of the agricultural share of the total nutrient input into the aquatic environment. Furthermore, the spatially differentiated assessment will address the relationship between agricultural activities in the catchments and resulting water quality of the rivers draining the catchments. Building upon this, the EEA intends to investigate the possible use of medium-scale models for European assessments, conceivably linked to more detailed modelling approaches in hot-spot areas.

Figure 5 Long time series of source apportioned load of nitrogen and phosphorus (kg/ha/year on y axes) in the period 1975–2003 (mixed approaches)



Sources: Behrendt/EuroCat (2004); Kroiss *et al.* (2005); Umweltbundesamt (DE) (2004); Selvik *et al.* (2004); Bøgestrand (2004); SFT (2005).

1 Introduction

This report is the output of the EEA-financed project 'Source apportionment of nitrogen and phosphorus inputs into the aquatic environment'. The study is the first step in a wider framework action dealing with the assessment of nutrient inputs from agriculture and other sources into water bodies of inland waters as well as transitional, coastal and marine waters and is seen in the context of the ongoing EEA work on agriculture and environment. EEA activities on integrated assessments in the area of water and agriculture can be found in its work programme 2004/2005 under project 4.3.3, 'Linkages between agriculture and water quality' (LARA).

Source apportionment is the estimation of the contribution of different sources to pollution. In this study, the focus has been on the nutrients nitrogen and phosphorus (N and P) from land-based activities to the aquatic environment, with the primary focus on the agricultural contribution to pollution with N and P.

The study aims at delivering as far as possible updated information on the source apportionment of the total load of nitrogen and phosphorus to the aquatic environment on a large scale:

- country,
- large river basins,
- sea areas,

from the following sources: agriculture, industry, scattered dwellings, wastewater treatment plants and the background loss.

The overall approach has been to use results from existing source apportionment studies and analyse this information. Data has been gathered from:

- international organisations such as transboundary river commissions and regional marine conventions;
- national (e.g. state of the environment reports) and regional studies;
- research activities.

A major part of the study has been to compile the available information in such a way as to make it as comparable as possible and thus to extract general conclusions at the European level.

The study consisted of the following activities:

- information inventory;
- compilation and presentation of information;
- comparison of the methods;
- analysis of regional differences in relation to driving forces and pressures;
- production of a report.

Chapter 2 presents an overview of the concepts of source apportionments, while in Chapter 3 a description of the different information sources on source apportionment is presented. European results on the sources of nutrient pollution are described and discussed in Chapters 4 to 7. Chapter 8 identifies future work needed on source apportionment.

2 Concept of source apportionment

Definition: Source apportionment is the estimation of the contribution from different sources to pollution. In this study, the focus has been on the nutrients nitrogen (N) and phosphorus (P) from land-based activities to the aquatic environment, with the primary focus on the agricultural contribution to pollution with N and P.

Source apportionment deals with the pollution load actually entering the aquatic environment, as opposed to raw emissions such as the agricultural nutrient loss from the root zone or household wastewater entering the sewerage system, i.e. before purification.

2.1 Eutrophication and sources of nitrogen (N) and phosphorus (P)

Large inputs of nitrogen and phosphorus to water bodies (including rivers) can lead to eutrophication causing ecological changes. These result in a loss of plant and animal species, and have negative impacts on the use of water for human consumption and other purposes. Eutrophication contributes to a number of water quality problems such as phytoplankton blooms, reduced recreational aesthetics, oxygen depletion, and reduced transparency and fish kills. Some algal blooms produce toxins and also tastes and odours that make the water unsuitable for water supply. Enrichment of groundwater by nitrate threatens the use of this resource for human consumption in many places across Europe.

In many catchments, run-off from agricultural land is the principal source of nitrogen pollution. In the case of phosphorus, households and industry tend to be the most significant sources, although with reduced point source discharges, the diffuse loss from agricultural soils can also be significant.

During the past three decades, several pieces of EU legislation and international agreements have addressed pollution of aquatic ecosystems by nutrients such as the urban wastewater treatment directive (Directive 91/271/EEC) and the nitrate directive (Directive 91/676/EEC). The Paris Convention and the Helsinki Convention have the objectives to prevent marine pollution from land-based sources in the North Sea and Baltic Sea areas, respectively. Both conventions have adopted targets to reduce inputs of nitrogen and phosphorus by 50 % where these inputs are likely, directly or indirectly, to cause eutrophication. Similarly, the Convention on Protection of the Mediterranean Sea (Medpol) and the strategic action plan for the rehabilitation and protection of the Black Sea have the objectives of reducing pollution with nutrients. Further information on European targets on nutrient reductions can be found in Chapter 9 of *State and pressure of the marine and coastal Mediterranean environment* (EEA, 2000).

In order to assess the effectiveness of current policies and agreements and to identify further measures, it is essential to know how nutrient inputs are distributed across sectors. Results from source apportionment studies are important in the policy formation process and in monitoring the implementation of policies and the effectiveness of measures.

During the last 10 years, the EEA has presented results on the sectoral contribution of N and P to the pollution of the aquatic environment (Table 2.1) in its state of the environment reports and thematic water reports.

This study aims at delivering as far as possible updated information on the source apportionment of the total load of nitrogen and phosphorus to the aquatic environment on a large scale, i.e. country, large river basins, and sea areas.

2.2 Sources covered

Figure 2.1 illustrates the many sources of pollution of the aquatic environment with nitrogen. Generally, there is a distinction between:

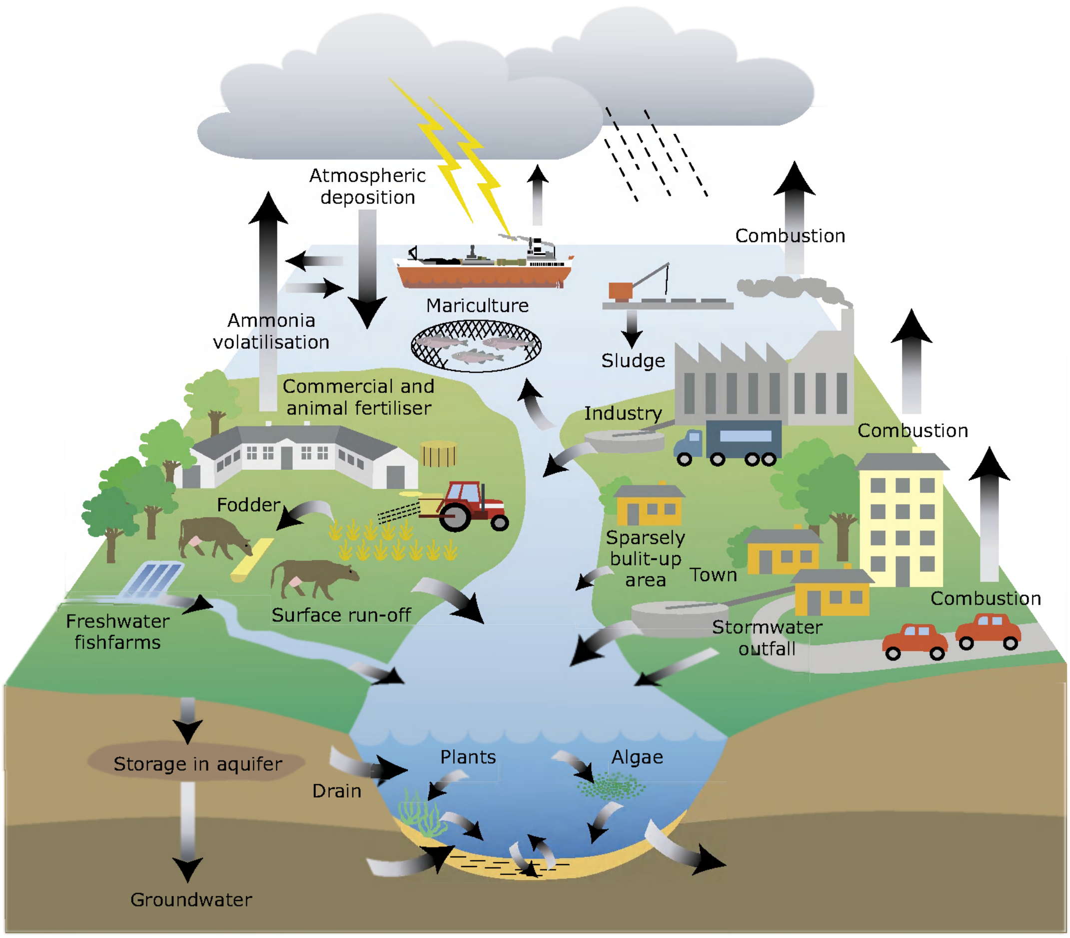
- **point sources** such as discharges from urban wastewater, industry and fish farms;
- **diffuse sources** including background losses (natural land, for example forest), losses from agriculture, losses from scattered dwellings and atmospheric deposition on water bodies, for example marine areas or lakes.

Point sources are defined as stationary locations or fixed facilities from which pollutants are

Table 2.1 Examples of results on source apportionment presented in EEA reports

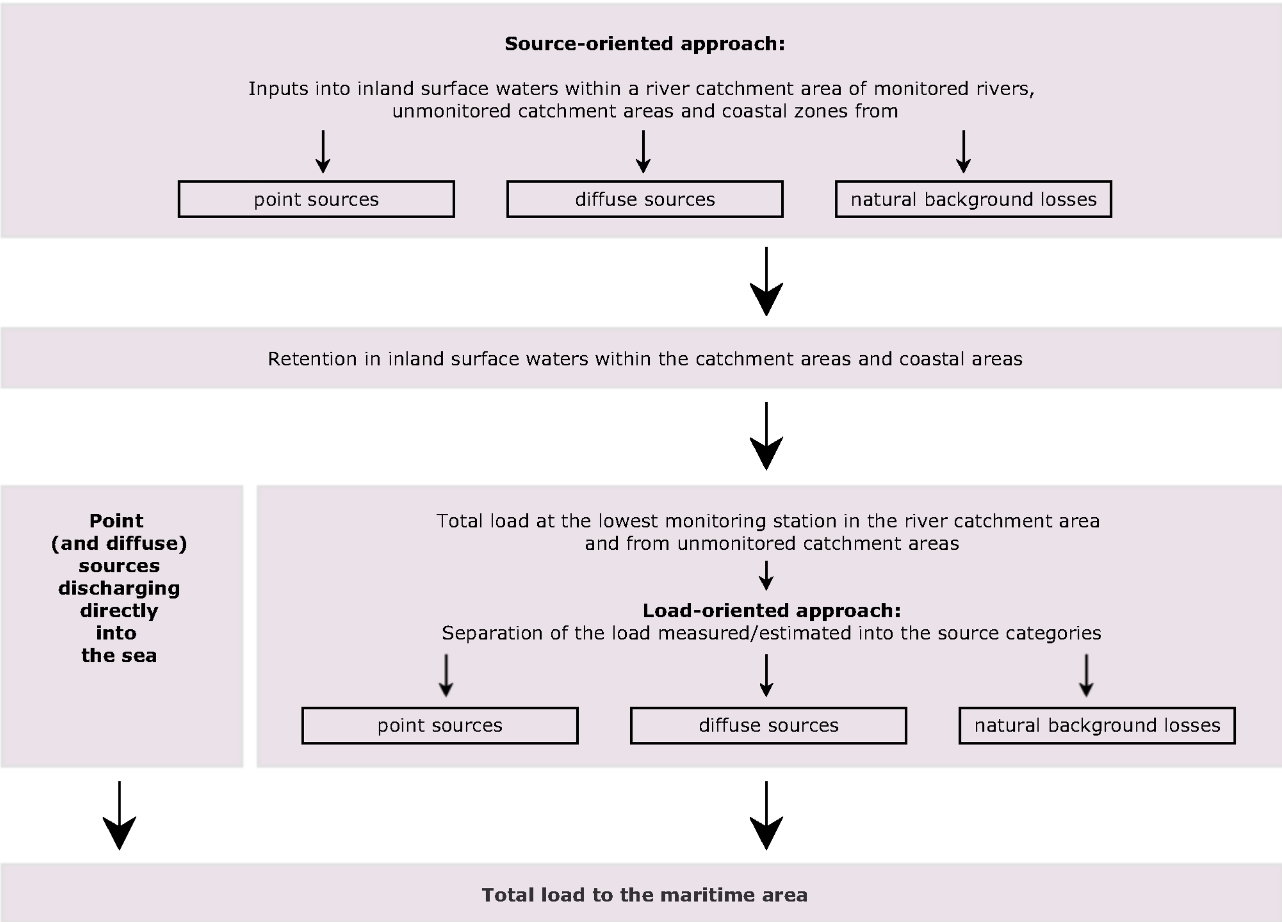
European Environment Agency (EEA) (1995). *Europe's environment: The Dobris assessment*. Office for Official Publications of the European Communities, Luxembourg. Available at http://reports.eea.eu.int.	Table 14.2: Agriculture's share of total emissions of nitrogen and phosphorus to the aquatic environment in several countries/regions of Europe Figure 14.8: Sources of phosphorus discharge to rivers and lakes Figure 14.10: Sources of nitrogen discharge to rivers and lakes
EEA (1998). *Environment in the European Union at the turn of the century*. Environmental assessment report No 2. Available at http://reports.eea.eu.int/92-9157-202-0/en/3.5.pdf.	Figure 3.5.6: Sources of N in selected larger areas (> 300 000 km²) Figure 3.5.9: Sources of phosphorus discharges in selected larger areas (> 300 000 km²)
EEA (2000). *Nutrients in European ecosystems*. Environmental assessment report No 4. Available at http://reports.eea.eu.int/ENVIASSRP04/en.	Table 3.1: Apportionment of N and P budgets for the Po catchment Figure 3.12: Source apportionment of phosphorus load Figure 3.14: Source apportionment of nitrogen load
EEA (2003). *Europe's water: An indicator-based assessment*. Environmental issue report No 34. Available at http://reports.eea.eu.int/report_2003_0617_150910/en.	Figure 3.14 B: Sectoral contribution to nitrogen and phosphorus loads in the North and Baltic Seas

Figure 2.1 Overview of the aquatic nitrogen cycle and sources of pollution with nitrogen



Source: Ærtebjerg *et al.* (2003).

Figure 2.2 Classification of inputs considered in source apportionment studies



Note: After draft Helcom PLC-5 guidelines (modified)

discharged (**EEA glossary**). The discharges are often monitored at the outlet from a wastewater treatment plant, but may also be estimated based on information on the number of population equivalents connected to a wastewater treatment plant and the type of wastewater treatment. For fish farms, the amount of fodder used minus the weight of fish produced is used to estimate the discharge.

Diffuse losses are pollution from widespread activities with no specific point of discharge, such as losses from natural areas and agricultural land, losses from paved areas, etc.

Source apportionment studies may use different classifications of pollution sources. Here, a distinction is made between point sources and diffuse sources only, while other studies deal with several different classes of sources, such as background loss, atmospheric deposition, urban wastewater treatment plants, industrial discharges and fish farms. Due to the focus on agriculture, this study has generally treated all point sources as a sum, whereas the diffuse sources have been split between background loss and agricultural contribution where possible.

2.3 Different methods used in source apportionment studies

When estimating nutrient inputs to a river catchment or the sea, two approaches can be used (Figure 2.2).

- A load-oriented approach, where the diffuse loss is estimated as the difference between the total load measured at a river monitoring station and the measured emissions from point sources upstream of the monitoring station. Estimates of retention and losses in the river

Table 2.2 Required and derived data for the two different approaches

	Load-oriented approach	Source-oriented approach
Required data		
	Total load	Diffuse sources + natural background losses
	Point sources, for example • *urban wastewater* • *industry* • *fish farms*	Point sources, for example • *urban wastewater* • *industry* • *fish farms*
	(Retention)	(Retention)
Derived data		
	Diffuse sources + natural background losses	Total load

system are added to calculate the losses at source (before retention).
Diffuse sources = Catchment$_{\text{Measured load river station}}$
– Point sources$_{\text{Measured load}}$
(+ retention and losses in river system)

- A source-oriented approach, where the diffuse losses are estimated using export coefficients from catchments with similar characteristics. The natural background loss can be estimated using export coefficients from undisturbed catchments and the agricultural loss can be estimated using export coefficients from catchments with similar agricultural characteristics. Estimates of retention and losses in the river system can be subtracted to calculate the total load at the river mouth (after retention).
Total sources = Point sources$_{\text{Measured/estimated load}}$
+ Diffuse sources$_{\text{Estimated load}}$
(– retention and losses in river system)

In both approaches, the point sources are considered from a source-oriented point of view, using measured discharges or sometimes standards for per capita discharges. The main difference between the two approaches is the estimation of diffuse sources.

The principal differences in data requirements are shown in Table 2.2.

Within these two basic approaches, there are several ways to do the calculations. In the Euroharp project, Schoumans and Silgram (2003) made a review of different types of quantification tools for nutrient losses to rivers. These quantification tools were established for different regions and different tasks (Table 2.3). They differ in their complexity and their resolution in time and space, and they need different levels of detail in terms of data requirements.

The tools differ considerably as regards input data and the resources needed to run them, from a few

Table 2.3 List of tools applied in European catchments for source apportionment of nutrient export from river basins

Tool	Country	Reference
Riverine load apportionment	Many	HARP Guideline 8 (2000)
Empirical models (Sparrow etc.)	Many	Grizetti *et al.* (2005); Kronvang *et al.* (1995)
Moneris	Germany	Behrendt *et al.* (2002)
Nopolu	France	EEA/IFEN (2000)
Realta	Ireland	Kirk McClure Morton (2001)
EvenFlow	England	Anthony *et al.* (1996)
NLES-CAT	Denmark	Simmelsgaard *et al.* (2000); Müller-Wohlfeil *et al.* (2002)
INCA-N/P	England	Whitehead *et al.* (1998a, 1998b)
TRK	Sweden	Swedish EPA (1997)
SWAT	United States	Neitsch *et al.* (2001)
NL_CAT	Netherlands	Groenendijk and Kroes (1999)
DAISY/MIKE-SHE	Denmark	Nielsen *et al.* (2004)

man-days for the riverine load apportionment model to several man-months for the fully dynamic and distributed models such as NL-CAT and DAISY/MIKE-SHE. Moreover, the models differ in their ability to be applied to scenario analysis, the simplest models being of limited use for such purposes, whereas the models representing soil processes in a deterministic way are very useful (see Schoumans and Silgram, 2003).

The abovementioned nutrient source apportionment tools differ profoundly in their approach to predict the diffuse nutrient losses from rural areas to surface waters. This is caused by several factors: (i) their level of complexity; (ii) their representation of system processes and pathways; (iii) resource (data and time) requirements. The quantification tools range from complex, process-based models — which typically have demanding data requirements — to semi-empirical (conceptual) meta-models with some export coefficients, and approaches based on mineral balances and apportionment of the riverine load measured. All source apportionment tools have strengths and weaknesses that should be taken into consideration when choosing the most robust tool for a certain task.

Due to the different methodologies and approaches described in the previous sections, results of source apportionment studies are not always fully comparable. Differences in the estimation methods used for calculation of the discharges and losses from sources, and the sources to be taken into account may introduce bias between studies. Generally, the discharges from larger point sources such as urban wastewater treatment plants and industries are estimated with a relatively high level of confidence, and for source apportionments at national or large catchment levels these sources account for the majority of the point source nutrient discharge. For such calculations, some countries only include small wastewater treatment plants larger than 1 000 PE while others may include small wastewater treatment plants down to 30 PE. If discharges from minor point sources such as aquaculture and scattered dwellings/villages are taken into account, care should be taken when comparing the diffuse load from these studies with that from studies where estimations are not made for these minor point sources.

In particular, the marine conventions (HARP guidelines; Helcom, 2004) and the transboundary river commissions have tried to establish guidelines and working parties to ensure more comparable source apportionment results for their areas of responsibility.

2.4 Presentation of source apportionments

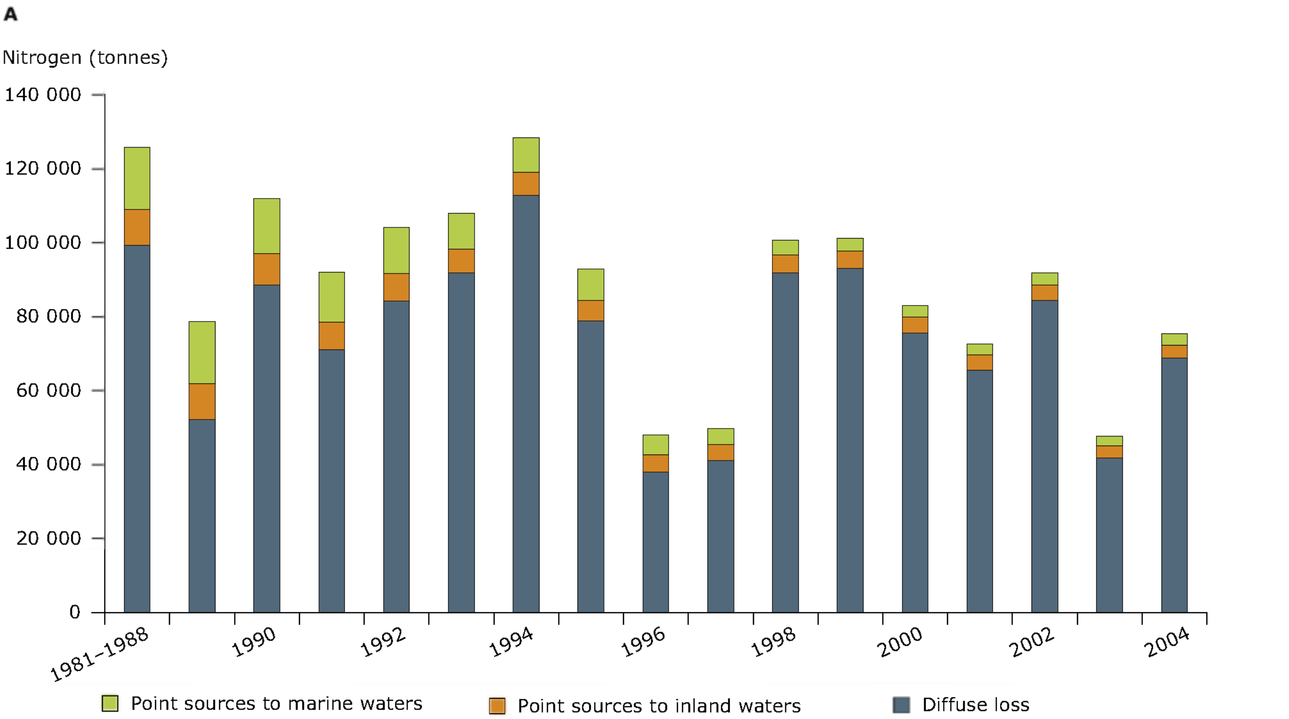
In addition to the methodological differences, natural causes and other aspects also have to be taken into account when comparing results from source apportionment studies.

- The total load from a catchment area is closely related to the water flow of the river draining the catchment. Rivers with high specific water flow (l/s/km^2) such as rivers originating in the Alps, for example the Rhine and Danube, have a higher diffuse load than rivers with a lower specific water flow such as some eastern European rivers, for example the Odra and Vistula (in Polish, Wisła). The year-to year-variation in water flow and consequently in diffuse load may be a factor of two or more and this has to be taken into account when assessing trends in source apportionments.
- The relative share of a source is dependent on the size of other sources. In a catchment with low anthropogenic pressures such as low population density and low percentage of intensive agriculture, the total load is generally low. However, the relative share of point sources and agriculture may be comparable to a catchment area with high anthropogenic pressures.
- When comparing countries and large catchments at European scale, one should bear in mind that some countries have a relatively long coastline with the majority of cities and industries discharging directly into the sea (e.g. Denmark, Ireland and Italy), while other countries such as Germany and France have the majority of cities discharging into the main rivers. This introduces a risk of misinterpretation when comparing source apportionments of loads to inland waters only.
- In some regions of Europe such as Finland, Spain and Sweden, many lakes or reservoirs are located on the main courses of the rivers resulting in high nutrient retention.

Results of source apportionment studies can be presented in three different ways.

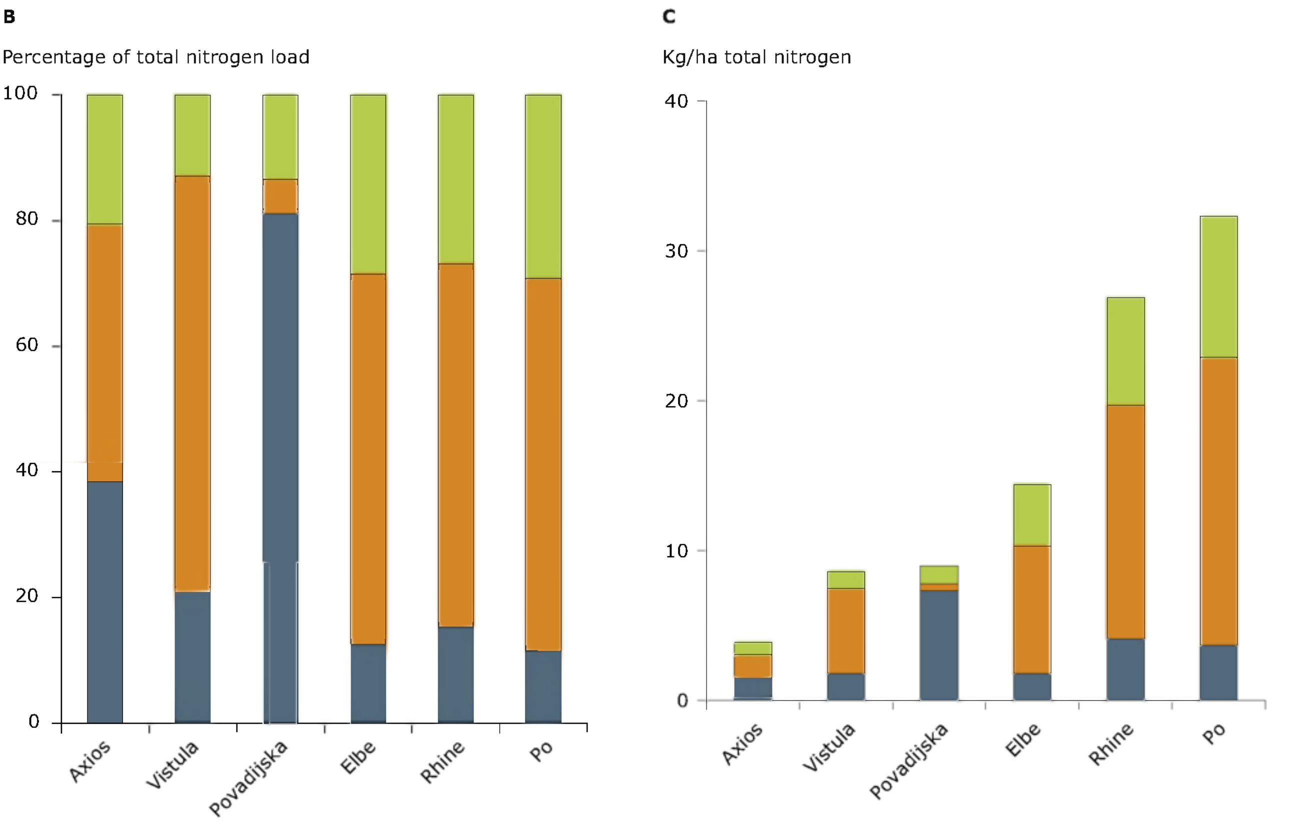
1. The **absolute** loads (weight) emitted by different sources (Figure 2.3 A).
2. The **relative** contribution or the percentage share of different sources (Figure 2.3 B).
3. The **specific** contribution by the different sources calculated as absolute amount in weight emitted by the different sources divided by the area of the catchment (t/km^2 — Figure 2.3 C) or divided by the water flow (flow-weighted concentrations).

Figure 2.3 (A) Absolute source apportioned nitrogen load to Danish coastal waters in the period 1981–2004, divided into diffuse load, point sources to freshwater and point sources to marine waters (load-oriented approach)



Source: NERI data.

Figure 2.3 (B) Relative and (C) Area-specific nitrogen source apportionments for European river catchments (source-oriented approach)



Source: Behrendt/EuroCat (2004).

Source apportionments presented as **absolute** loads are often used for illustrating changes in specific sources over time, for example the marked reduction in point source discharges to the Danish coastal waters (Figure 2.3 A). However, the **absolute** loads are not useful for comparison between countries or catchments because they depend on catchment size and run-off.

Source apportionments presented as **relative** values such as pie charts or stacked 100 % bars (Figure 2.3 B) provide an indication of the contribution from the different sources. However, these diagrams are often not well suited for comparison between different catchments. The percentage share is dependent on the size of other sources.

For comparison between different source apportionments, the **area-specific load** calculated as the load divided by the catchment area (Figure 2.3 C) often gives the best indication of the contribution of the different sources.

In this study, the results presented have generally been converted to area-specific source apportionments by dividing the load estimates by catchment area. In some cases where there has been uncertainty about the size of a catchment area or other constraints, other ways of presenting the results in a meaningful way have been chosen.

To facilitate the comparability of results, the same scale has been used on the load axes on all charts, 0–40 kg/ha nitrogen and 0–3 kg/ha phosphorus.

3 Information sources

The overall approach has been to use results from the existing source apportionment studies and analyse this information. Source apportionments from the following sources have been used:

- international organisations such as transboundary river commissions (e.g. Rhine and Danube) and regional marine conventions (e.g. Helcom, OSPAR);
- national and regional studies (state of the environment reports);
- studies and research activities. In recent years, many studies and research activities, such as the EU research projects EuroCat and Euroharp, have produced results on source apportionment.

The following sections summarise the information sources used and their geographical coverage. A more detailed bibliography of source apportionment studies can be found in Annexes 2 to 4.

3.1 Load compilation and source apportionment studies for Europe's seas

The marine conventions Helcom and OSPAR have produced source apportionment results for their respective international seas, i.e. the Baltic and the North Sea. There are also international marine conventions for the Mediterranean and the Black Sea, but the pollution load information from these conventions is sparse.

Helcom and OSPAR source apportionments are generally based on pollution load estimates and source apportionment results based on harmonised methodologies (HARP ([1]); Helcom Land ([2])) as reported by member countries. There are, however, some differences between the countries, because they may choose from a number of options for the estimation of, for example, retention. Still, it is possible to find source apportionment results for countries and sub-catchments of both sea areas. The Baltic Sea pollution load compilations before 2000 and the Black Sea pollution assessment (1998) did not split the riverine load by sources and they are therefore of limited value for evaluating the contribution from the different sources.

3.2 Source apportionments at national level

Many European countries have produced or are producing on a regular basis (e.g. annually for Denmark or every five years for Germany) source apportionment of the nutrient load. In addition, the source apportionment results reported by the member countries to the regional marine

Table 3.1 National source apportionment estimates

National state of the environment/water reports	Austria; Belgium; Denmark; Finland; France; Germany; Italy (large river catchments); the Netherlands; Norway; Sweden; the United Kingdom
Baltic Sea (Helcom PLC-4)	Denmark; Estonia; Finland; Germany; Latvia; Lithuania; Poland; Russia; Sweden
North Sea	Belgium; Denmark; Germany; the Netherlands; Norway; Sweden; Switzerland
Danube catchment	Austria; Bosnia-Herzegovina; Bulgaria; Croatia; the Czech Republic; Germany; Hungary; Moldova; Slovakia; Slovenia; Romania; Ukraine; Former Yugoslavia

Note: For the marine conventions and the Danube, the national source apportionments only cover the part of the country within the catchment area.

Sources: Helcom (2004). 'The fourth **Baltic Sea** pollution load compilation (PLC-4)'. *Baltic Sea Environmental Proceedings*, No 93.

Ministry of the Environment, Norway (2002). North Sea *Progress Report 2002*. Report produced for the Fifth International Conference on the Protection of the North Sea, 20 and 21 March 2002, Bergen, Norway.

Schreiber *et al.* (2003). 'Harmonised inventory of point and diffuse emissions of N and P for the **Danube river basin**'. Delivery 5.5 of the Danubs project.

(1) Harmonised quantification and reporting procedures for nutrients (HARP). Available at http://EUROHARP.org/rl/guidelines/.
(2) Helcom Land-Based Pollution Group. (http://www.helcom.fi/groups/LAND/en_GB/main/).

Figure 3.1 **(A) Location of the EuroCat river catchments (and sub-catchments) and the catchments investigated by the Moneris model within other European, international and national projects. (B) Location of the Euroharp catchments. (C) Location of the Bernet catchments**

A

B

C

Sources: Behrendt/EuroCat (2004); Euroharp; Bernet (2001).

conventions and transboundary river commissions can be used to describe the contribution from different sources at national level (Table 3.1).

3.3 Source apportionments for river catchments

Source apportionment results are available for many European river catchments. Ten to fifteen years ago, source apportionments were, in particular, made for large transboundary rivers such as the Rhine and the Elbe. In addition, source apportionment was made for the load to large lakes. During the last five years, activities in relation to the Moneris model and the EU-financed research project Euroharp have produced European-wide source assessments. The Bernet project has made source apportionments along with other environmental assessments for seven relatively small catchments in the Baltic region. Figure 3.1 provides an overview of the catchments covered by these activities.

Some countries (e.g the Nordic countries and Germany) have produced source apportionments for the major rivers draining their territories. Table 3.2 provides an overview of European source apportionment studies on river catchment level — full reference to the different studies can be found in Annex 4.

Table 3.2 Overview of European river catchment source apportionment studies

Moneris methodology — EuroCat (project) — Danubs (project) — Nutrient emissions into surface waters of Germany	Behrendt/EuroCat (2004); Schreiber *et al.* (2003); Behrendt *et al.* (2003) Rivers covered: Axios; Danube; Daugava; Elbe; Ems; Humber; Odra; Po; Povadijska; Rhine; Vistula; Weser
Euroharp — 'Towards European harmonised procedures for quantification of nutrient losses from diffuse sources', EU fifth framework programme research project	17 catchments
Bernet — Baltic eutrophication regional network	7 catchments
National source apportionments split by sub-catchments — Denmark — 9 coastal area catchments and subdivision of these	Annual reporting Bøgestrand (2004 and 1999)
— Germany — 22 catchments in 6 major river basins	Behrendt *et al.* (2003)
— Italy (rivers: Po, Adige, Piave, Serchio)	ANPA (2001)
— Sweden — 119 coastal catchment areas and > 1 000 sub-catchments	Brand and Ejhed (2002)
— Norway — 6 sea catchments and 247 river catchments	Selvik *et al.* (2004)
Large rivers — Danube — 388 sub-catchments — Odra — 45 sub-catchments — Po — 33 sub-catchments — Vistula — 47 sub-catchments	 Schreiber *et al.* (2003) Behrendt *et al.* (2002) Palmeri *et al.* (2005) Kowalkowski and Buszewski (2004)
Large rivers Axios (Nikolaidis *et al.*, 2004); Danube (Somlyódy *et al.*, 1997; Schreiber *et al.*, 2003); Daugava (Behrendt/EuroCat, 2004); Elbe (De Vit *et al.*, 2001; Behrendt *et al.*, 2003); Ems (Behrendt *et al.*, 2003); Odra (Behrendt *et al.*, 2002); Po (De Vit *et al.*, 2001; Palmeri *et al.*, 2005); Rhine (IKSR, 1996; Dijk *et al.*, 1997; De Vit *et al.*, 2001; Behrendt *et al.*, 2003); Vistula (Kowalkowski and Buszewski, 2004); Weser (Behrendt *et al.*, 2003)	
European lakes — Peipsi (Vassiljev and Stålnacke, 2003); Mjøsa (Nashoug, 1999); Vättern; Lough Neagh; Danish lakes	

4 European source apportionments

4.1 Coastal and marine areas

4.1.1 *Nitrogen*

For the Baltic Sea and the North Sea, relatively comparable source apportionments using a source-oriented approach for the year 2000 exist (Tables 4.1 and 4.2). The total nitrogen losses from land-based sources are 861 000 and 761 000 t for the Baltic Sea and the North Sea, respectively. The area-specific total nitrogen loads are nearly three times higher for the North Sea than for the Baltic Sea catchment area.

For the North Sea catchment area, the natural background losses are not included in the source apportionment estimation. However, by using the area-specific loss for the Baltic Sea catchment area (1.6 kg N/ha), natural background losses account for around 10 % of the total losses for the North Sea compared with 30 % for the Baltic Sea.

Anthropogenic diffuse sources, mainly representing diffuse losses from agriculture, are the main nitrogen source for both sea catchments accounting for around 60 % of the total losses. However, the area-specific anthropogenic diffuse losses are more than three times higher in the North Sea catchment, due to the higher percentage of agricultural land and generally more intensive agricultural production in the countries bordering the North Sea compared with the Baltic Sea catchment.

The higher population density and more industrial activities are also reflected in a much higher area-specific nitrogen load to the North Sea.

4.1.2 *Phosphorus*

As for nitrogen, the absolute sizes of the total phosphorus loads are relatively similar for the two sea catchments, 44 000 and 48 700 t, respectively (Table 4.2). However, the area-specific total phosphorus loads are more than three times higher for the North Sea than for the Baltic Sea.

The natural background phosphorus losses constitute about 25 and 7 % for the Baltic Sea

Table 4.1 Source apportionment of annual loads of total nitrogen from land-based sources to the catchments of the North Sea and the Baltic Sea including point sources discharging directly to the seas (source-oriented approaches)

	Baltic Sea 2000	North Sea 2000
Catchment area	1.6 million km^2	0.53 million km^2 (1)
— agricultural land	24 %	~50 %
— population density	53 inh./km^2	~210 inh./km^2
Natural background losses	260 000 t	NI (2)
	1.6 kg N/ha	
	30 %	(10 %)
Anthropogenic diffuse losses	484 000 t	485 000 t
	3.0 kg N/ha	9.2 kg N/ha
	56 %	**64 %**
Point source discharges	118 000 t	276 000 t
	0.7 kg N/ha	5.2 kg N/ha
	14 %	**36 %**
Total losses	861 000 t	761 000 t
	5.4 kg N/ha	14.4 kg N/ha

(1) Belgium; Denmark; Germany; the Netherlands; Norway; Sweden; Switzerland.

(2) NI — No information on background losses.

Sources: Helcom (2004); Ministry of the Environment, Norway (2002).

Table 4.2 Source apportionment of annual loads of total phosphorus from land-based sources to the catchments of the North Sea and the Baltic Sea including point sources discharging directly to the seas (source-oriented approaches)

	Baltic Sea 2000	North Sea 2000
Catchment area	1.6 million km^2	0.53 million km^2 (1)
— agricultural land	24 %	~50 %
— population density	53 inh./km^2	~210 inh./km^2
Natural background losses	11 000 t	NI (2)
	0.07 kg P/ha	
	25 %	(7 %)
Anthropogenic diffuse losses	22 000 t	22 500 t
	0.14 kg P/ha	0.43 kg P/ha
	50 %	**46 %**
Point sources discharges	11 100 t	26 200 t
	0.07 kg P/ha	0.50 kg P/ha
	25 %	**54 %**
Total losses	44 000 t	48 700 t
	0.28 kg P/ha	0.92 kg P/ha

(1) Belgium; Denmark; Germany; the Netherlands; Norway; Sweden; Switzerland.

(2) NI — No information on background losses.

Sources: Helcom (2004); Ministry of the Environment, Norway (2002).

and North Sea catchments, respectively. The anthropogenic diffuse sources are the main source for phosphorus for the Baltic Sea (50 %) while it accounts for 46 % of the anthropogenic sources for the North Sea. As for nitrogen, the area-specific anthropogenic diffuse loss of phosphorus is much higher for the North Sea than for the Baltic.

Point source discharges are the main phosphorus source for the North Sea, but less so for the Baltic Sea where they account for 25 % of the total load. Much higher population density and high industrial activity explain the much higher load from point sources for the North Sea catchment compared with the Baltic Sea.

4.1.3 Regional differences in load and source apportionment to the two sea areas

The source apportionments for 2000 for the Baltic Sea by sub-catchment and the North Sea by country (Figures 4.1 and 4.2) can be compared to indicators for human activities in the catchment areas, i.e. the population density and the percentage of agricultural land (Table 4.3).

The area-specific background loss is similar for all the Baltic Sea catchments at around 1–2 kg N/ha and 0.03–0.1 kg P/ha.

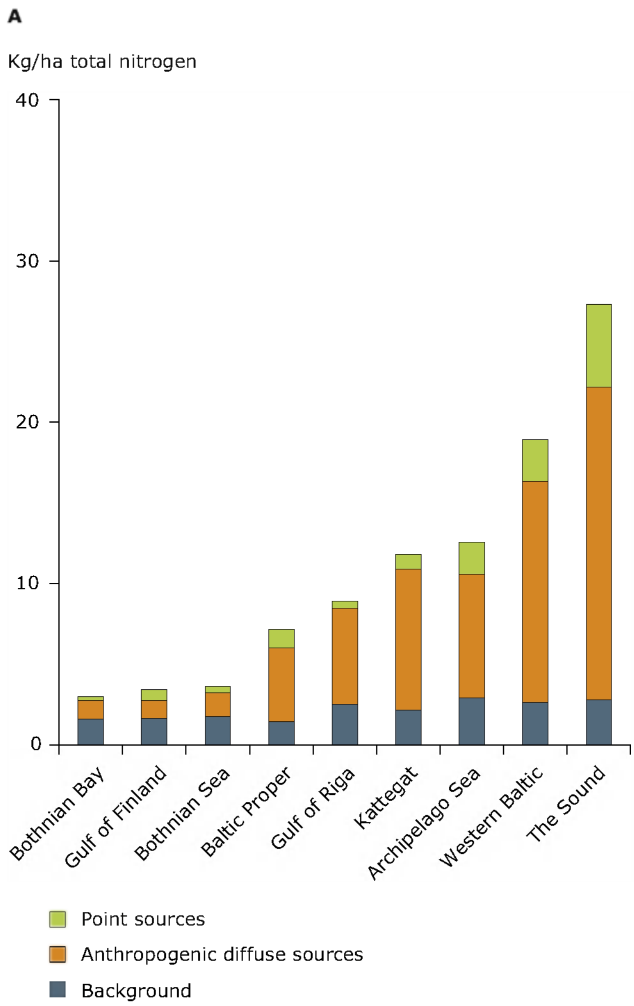
The four Baltic Sea catchments with the lowest area-specific load, and the Norwegian and Swedish catchments to the North Sea all have total area-specific losses of 3–4 kg N/ha and 0.12–0.17 kg P/ha. For these catchments, the main sources are anthropogenic diffuse losses and natural background. These catchments are characterised by being sparsely populated (less than 35 inhabitants/km^2) and having a low percentage of agricultural land which, except for the Gulf of Finland, is less than 15 %.

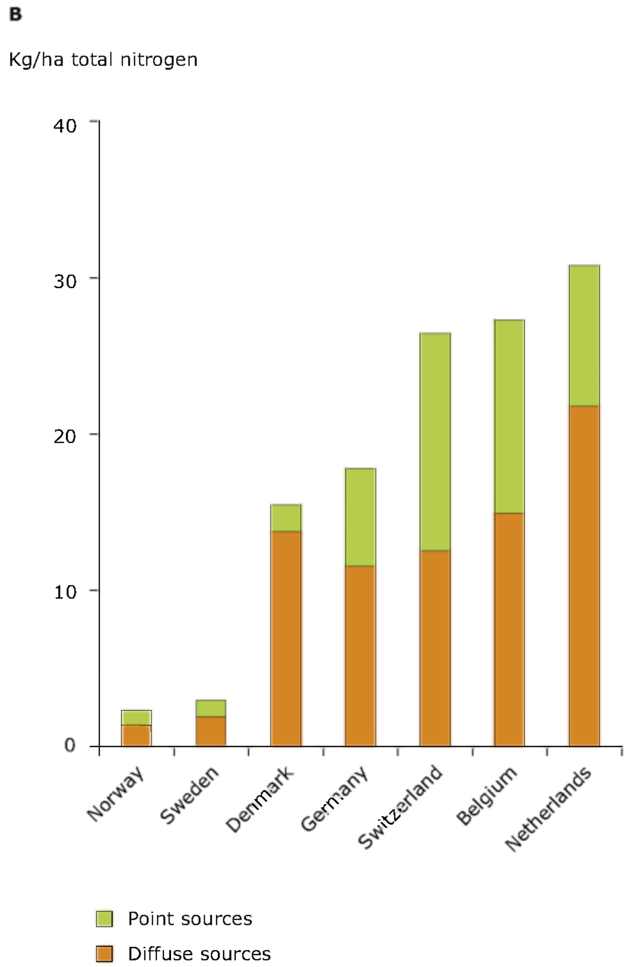
The Baltic Proper, the Archipelago Sea and the Kattegat catchments are characterised by median human activities (population density 44–110 inhabitants/km^2), and they have an area-specific nitrogen load of around 10 kg N/ha with anthropogenic diffuse losses being the main component.

For the catchments with intensive agriculture such as the western Baltic and The Sound and most of the North Sea countries, the diffuse loss is around 15 kg N/ha. Point sources constitute a significant part of the Dutch, Belgian and Swiss nitrogen loads.

In densely populated countries and sub-catchments (more than 100 inhabitants per km^2), point sources, in particular urban wastewater and industrial discharges, are generally the dominating source.

Figure 4.1 (A) Source apportioned annual load of nitrogen to inland waters in the sub-catchments of the Baltic. (B) Point source discharges and anthropogenic diffuse losses of nitrogen to the North Sea in 2000 (source-oriented approaches)





Note: The location of the Baltic Sea sub-catchments can be found at http://www.helcom.fi/environment2/nature/en_GB/facts/.

Sources: Helcom (2004); OSPAR (2003).

However, with improved wastewater treatment and phosphorus retention, diffuse anthropogenic sources can be the main phosphorus source (see also Chapter 6).

The Mediterranean and the north-east Atlantic

There is no complete source apportionment for the Mediterranean and the north-east Atlantic.

The Black Sea

The major rivers in the Black Sea catchment are the Danube, Dnieper, Don, Southern Bug and Kuban draining an area of around 2 million km^2 and receiving wastewater generated by more than 100 million inhabitants, heavy industries and agricultural areas. It has been estimated that the Danube with its catchment area of 800 000 km^2 and population of about 83 million people contributes about 65 % of the total nitrogen and phosphorus discharges from all sources, but there has not yet been a complete source apportionment for the Black Sea.

The total load to the Black Sea has been estimated to be 3.24 kg/ha N and about 0.25 kg/ha P (Tables 4.4 and 4.5). This estimate is low compared with load estimates for the Baltic Sea and North Sea and may partly be due to a high nutrient retention in the reservoirs on the Danube and other main rivers.

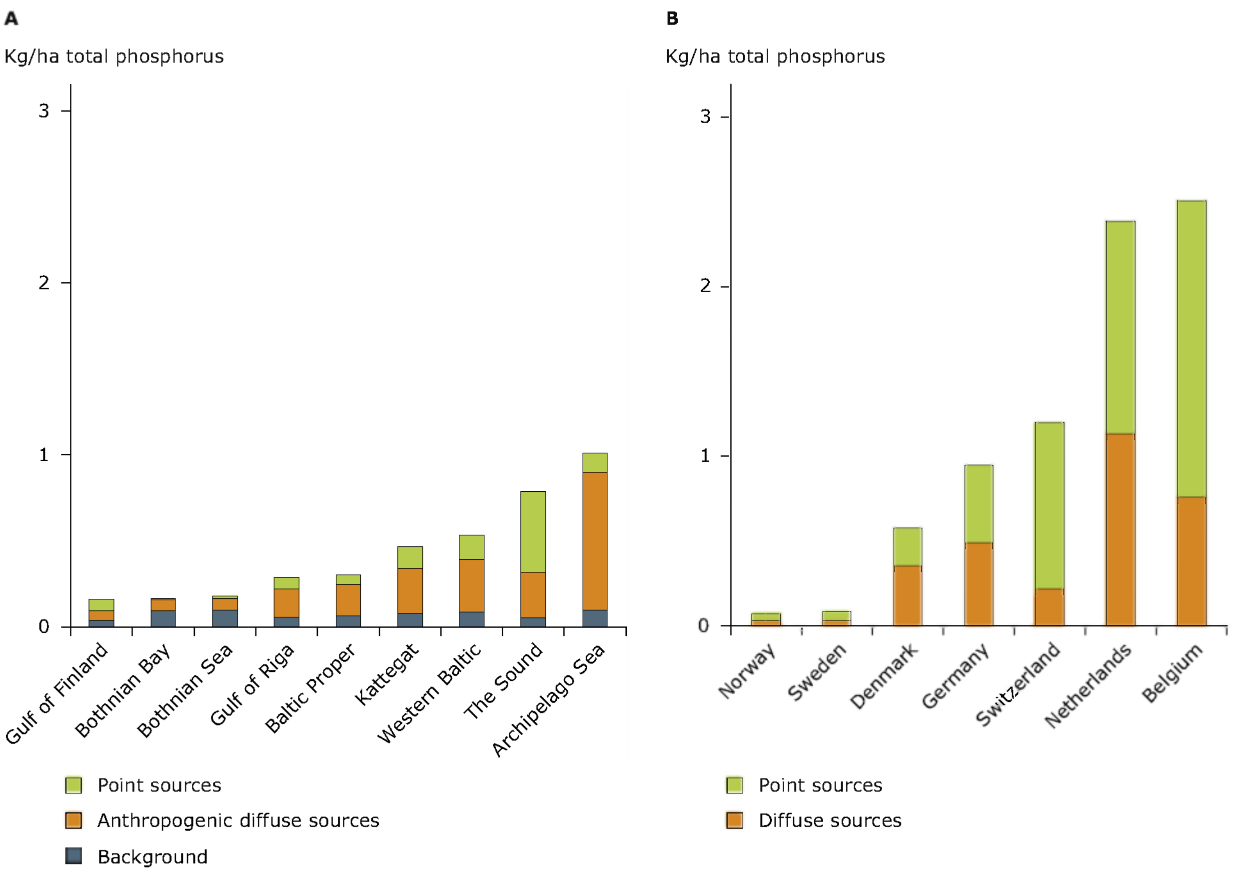
Riverine loads account for the majority of both nitrogen and phosphorus load. Based on the

Table 4.3 Population density and percentage of agricultural area in the Baltic Sea sub-catchments and the North Sea countries

	Catchment area (km²)	Population density (inh./km²)	% of agricultural land
Baltic Sea catchments			
Bothnian Bay	259 620	6	2.8
Bothnian Sea	215 910	12	5.4
Archipelago Sea	9 000	51	
Gulf of Finland	413 100	31	12.2
Gulf of Riga	102 040	33	39.9
Baltic Proper	496 185	108	50.7
Western Baltic	22 740	142	67.1
The Sound	4 625	471	56.0
Kattegat	79 530	44	22,5
North Sea countries			
Norway	98 990	14	~3
Sweden	76 495	22	~8
Denmark	27 763	122	~65
Germany	264 112	229	~51
Switzerland	9 500	172	~49
Belgium	30 518	334	~49
Netherlands	37 181	382	~54

Sources: Baltic Sea region GIS, maps and statistical database (http://www.grida.no/baltic/index.htm); Helcom (2004); OSPAR (2000).

Figure 4.2 (A) Source apportioned annual load of phosphorus to inland waters in the sub-catchments of the Baltic. (B) Point source discharges and anthropogenic losses of phosphorus to the North Sea in 2000 (source-oriented approaches)



Sources: Helcom (2004); OSPAR (2003).

Table 4.4 The estimated input of total nitrogen to the Black Sea

				(1 000 t per year)
Country	**Domestic**	**Industrial**	**Riverine**	**Subtotal**
Bulgaria	2.5	71.0	19.2	92.7
Georgia	1.6	0.0	0.0	1.6
Romania	0.9	44.4	132.0	177.3
Russian Federation	0.4	0.0	62.3	62.7
Turkey	5.4	0.6	32.0	38.0
Ukraine	9.5	31.0	36.3	76.8
Other countries				198.3
Subtotal	**20.3**	**146.9**	**281.8**	**647.3**

Source: Black Sea Commission (2002).

Table 4.5 The estimated input of total phosphorus to the Black Sea

				(1 000 t per year)
Country	**Domestic**	**Industrial**	**Riverine**	**Subtotal**
Bulgaria	0.7	0.0	1.9	2.6
Georgia	0.4	0.0	0.0	0.4
Romania	0.3	0.3	11.0	11.6
Russian Federation	0.5	0.0	6.1	6.6
Turkey	2.2	0.1	3.6	5.9
Ukraine	2.6	1.7	5.7	9.9
Other countries				13.6
Subtotal	**6.7**	**2.0**	**28.2**	**50.5**

Source: Black Sea Commission (2002).

source apportionment results from the Danube (see Section 4.3), agriculture together with point sources are the dominating sources.

4.2 Countries

Several countries have estimated their loading of the marine environment with nitrogen and phosphorus, either as a national estimate or as the part of the national contribution coming from the sub-catchments draining to a particular sea (Figure 4.3). This section contains a compilation of the national/regional figures, supplemented with figures from the marine conventions. Thus, there may be differences in methods and in the time periods considered.

The national estimates have been related to national statistics such as the Food and Agriculture Organisation's (FAO) data on fertiliser consumption. These data disregard the use of animal manure, but still there is a clear relationship between fertiliser consumption and diffuse or agricultural losses. The countries in central-western Europe — Belgium, Denmark, Germany, the Netherlands and the United Kingdom — have high rates of fertiliser application and at the same time high area-specific diffuse losses of nutrients to the aquatic environment. Countries with large nature areas (e.g. Nordic countries) or more extensive agriculture (e.g. eastern Europe) have much lower fertiliser consumption and lower diffuse loads.

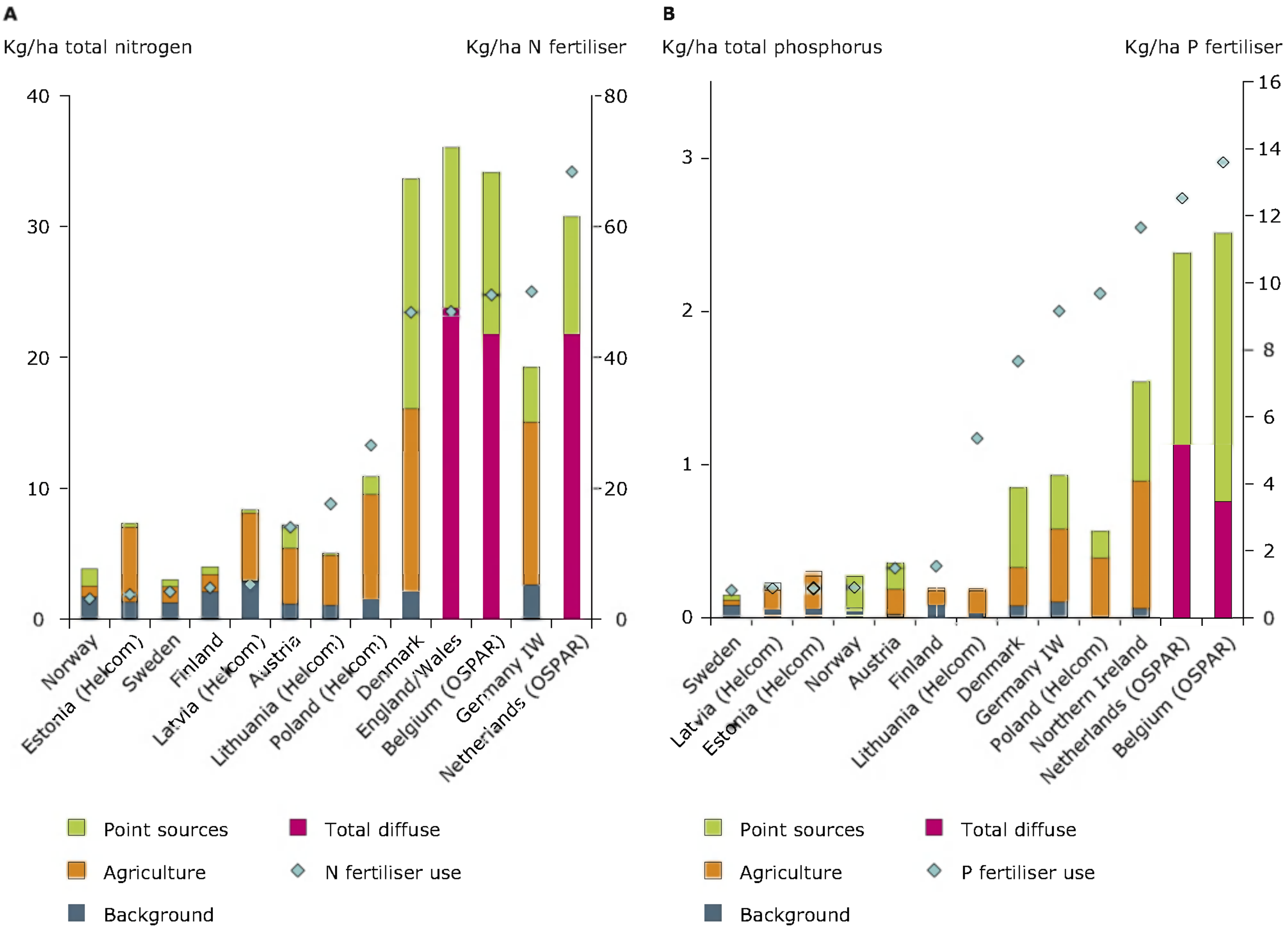
4.3 Large river catchments

Europe's largest rivers are located in central Europe, and they drain most of this area. Source apportionments have been made for several large European rivers.

The Moneris model has been applied to several of these rivers, offering a relatively comparable set of source apportionments (Figure 4.4).

The rivers included in the figure have a total catchment area of 1.7 million km^2 or more than a quarter of the EEA-31 area (5.5 million km^2). The population density ranges from 32 (Daugava) to 309 (Rhine) inhabitants per km^2, and the agricultural area covers 33 % (Daugava) to 80 % (Ems) of the river catchments. The nitrogen surplus ranges from 19 (Daugava) to 133 (Ems) kg/ha.

Figure 4.3 National or regional source apportionments and fertiliser use (Faostat fertiliser consumption) for nitrogen (A) and phosphorus (B)



Note: UK figures on fertilisers used for England/Wales and Northern Ireland. Sorted by fertiliser use. Mixed approaches.

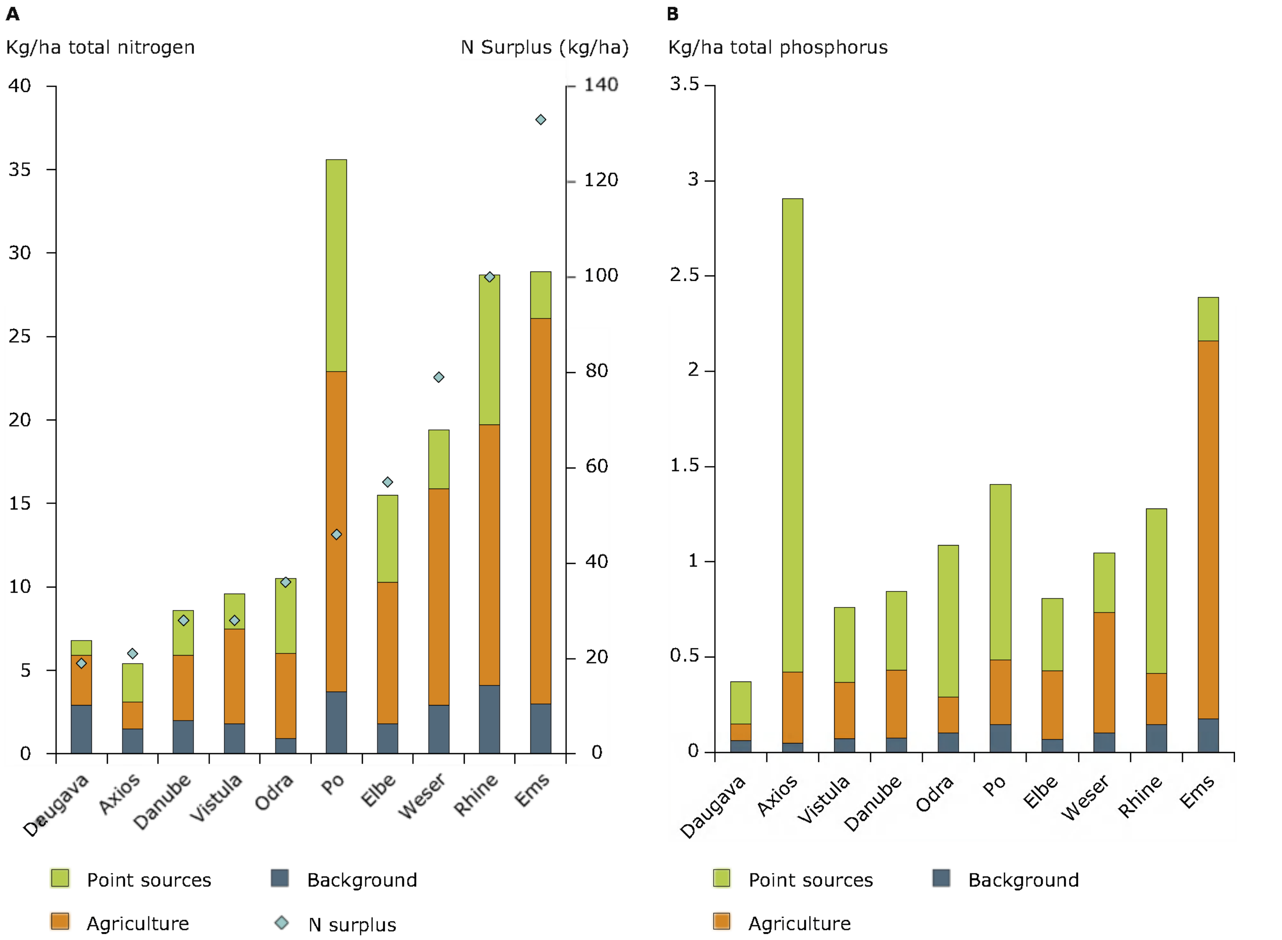
Sources: Helcom (2004); OSPAR (2003); Selvik *et al.* (2004); SLU and SMHI; Finlands miljöcentral (2005); Umweltbundesamt (AT) (2001); Bøgestrand (2004); WRc (2004); Umweltbundesamt (DE) (2004); Smith *et al.* (2004).

The results support the conclusions observed for source apportionments covering the marine conventions or countries/regions regarding geographical differences. Western European rivers have a high agricultural loss of nitrogen and (less pronounced) phosphorus, whereas the eastern European rivers have lower losses. The pressures on each catchment are partly characterised by the abovementioned indicators — population density, agricultural area and nitrogen surplus — which are calculated for all these catchments. The agricultural loss of nitrogen is closely related to the surplus of nitrogen. The percentage of agricultural area in a catchment is a simple indicator of agricultural pressure, but the agricultural intensity, for example fertiliser application rates, must also be taken into account. There is no phosphorus surplus estimate available. For comparison, Figure 4.4 A and B for both nitrogen and phosphorus is sorted by nitrogen surplus as a proxy indicator for agricultural intensity, although it is less convincing regarding phosphorus. However, there are higher levels of agricultural phosphorus loads in western European rivers.

4.4 Smaller catchments

While source apportionments of large catchments tend to average the variation between sub-catchments, source apportionments from small catchments may elucidate the significance of

Figure 4.4 Source apportioned annual load of nitrogen (A) and phosphorus (B) in large river catchments based on the Moneris model, and nitrogen surplus



Note: Sorted by increasing nitrogen surplus. Source-oriented approach.

Source: Behrendt/EuroCat (2004).

differences in the driving forces, such as population density and agricultural practice.

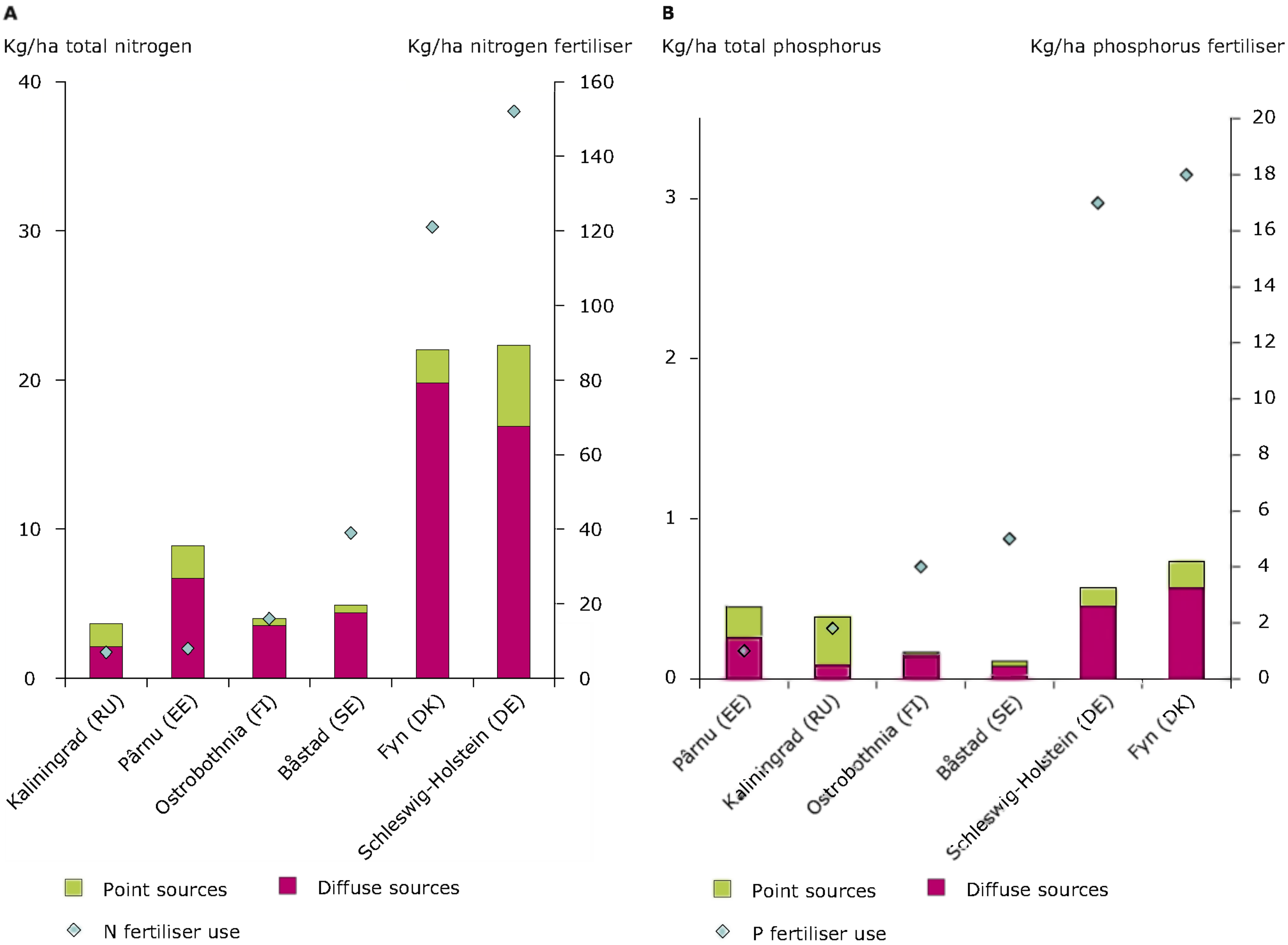
In the Bernet project, source apportionments were prepared for six of the seven small coastal catchments in the Baltic region (Figure 4.5).

Despite some methodological differences, it is obvious that the catchments of Schleswig-Holstein and Fyn have a far higher diffuse loss of nitrogen than the others. The two catchments are characterised by a high degree of cultivation (65–70 % agricultural area) and high rates of fertiliser application (plotted on the figure). However, there are also high population densities, which may contribute to the diffuse losses from scattered dwellings.

The load of phosphorus in the same catchments is less dominated by the diffuse contribution, and the point source discharges are relatively high. The highest diffuse loss of phosphorus is found in the same two catchments as for nitrogen. Although it could be expected that high population densities would give high point source loads, this is not evident from the figure. A possible explanation is that wastewater treatment has been of the highest priority in the most densely populated areas where it is also relatively easy to connect most of the population to large and effective wastewater treatment plants.

As part of the Euroharp project, source apportionments will be done for 17 small river catchments across Europe. The same method will be applied to all catchments, which facilitates comparability. Figure 4.6 shows the results for the catchments processed so far. The figure indicates that the highest agricultural losses of nitrogen occur in catchments with high fertiliser use (average for

Figure 4.5 Source apportioned annual load and estimated fertiliser use in six Bernet catchments (A) Total nitrogen (B) Total phosphorus



Source: Bernet (2001).

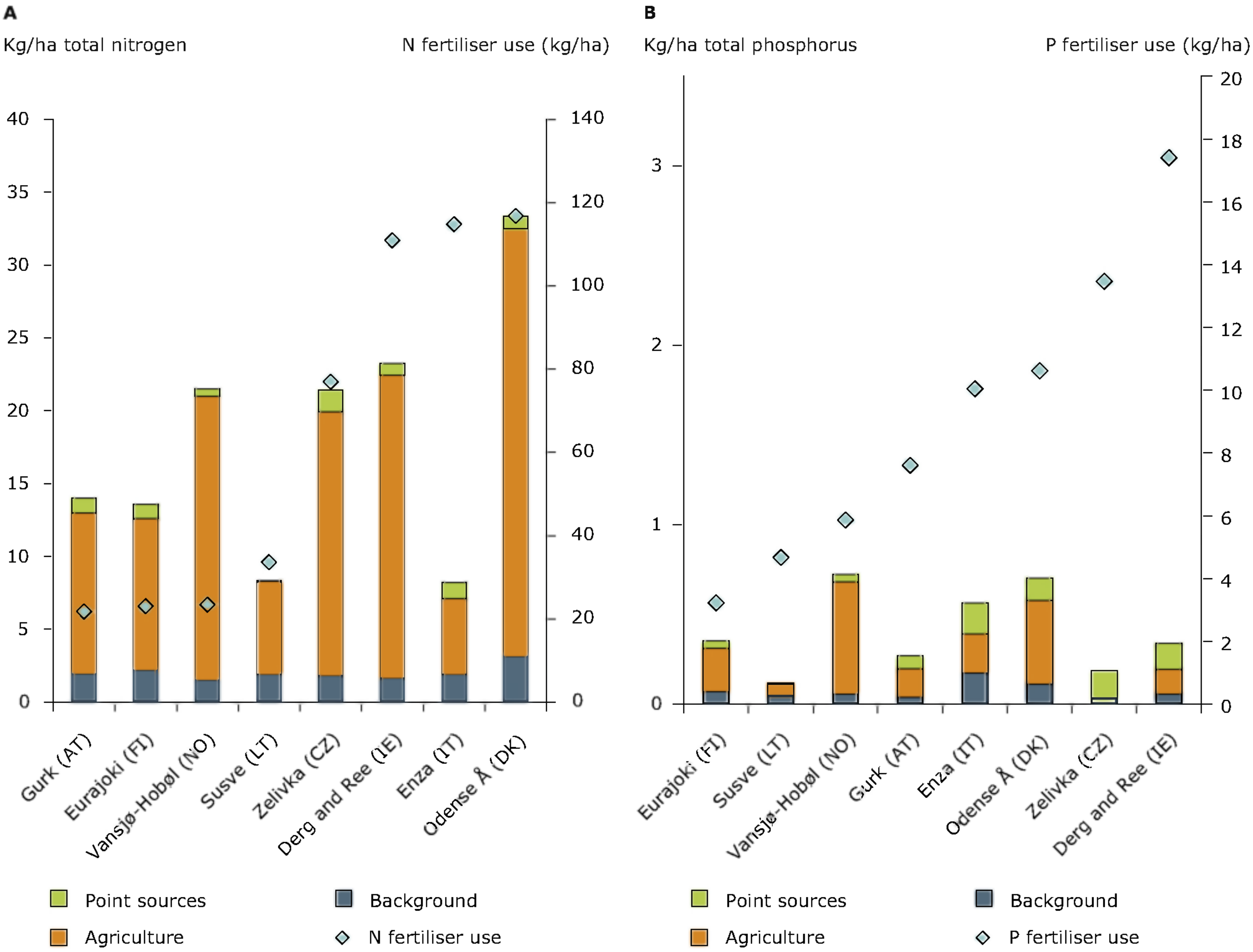
the catchment), but there are also exceptions to this rule. There is no clear relationship between the use of phosphorus fertiliser and the agricultural loss of phosphorus indicated in the figure. Although the agricultural losses of both nitrogen and phosphorus are significant, there are large differences between the individual catchments. Part of the differences may be caused by the hydrological conditions in the actual year (1999), because the diffuse losses depend very much on the water flow, but the general hydrological characteristics of the catchments can also be an important factor. The agricultural practice and general characteristics such as livestock density and percentage of permanent grassland are additional factors determining the response in each catchment to fertiliser application.

4.5 Large lake catchments

In most lakes, phosphorus is the nutrient determining the eutrophic state. The major focus during the past decades has been on reducing the phosphorus load to eutrophied lakes, and the majority of available source apportionments on lakes deal with phosphorus.

The catchment areas of the lakes in Figure 4.7 are smaller (5 000–45 000 km^2) than those of the large rivers.

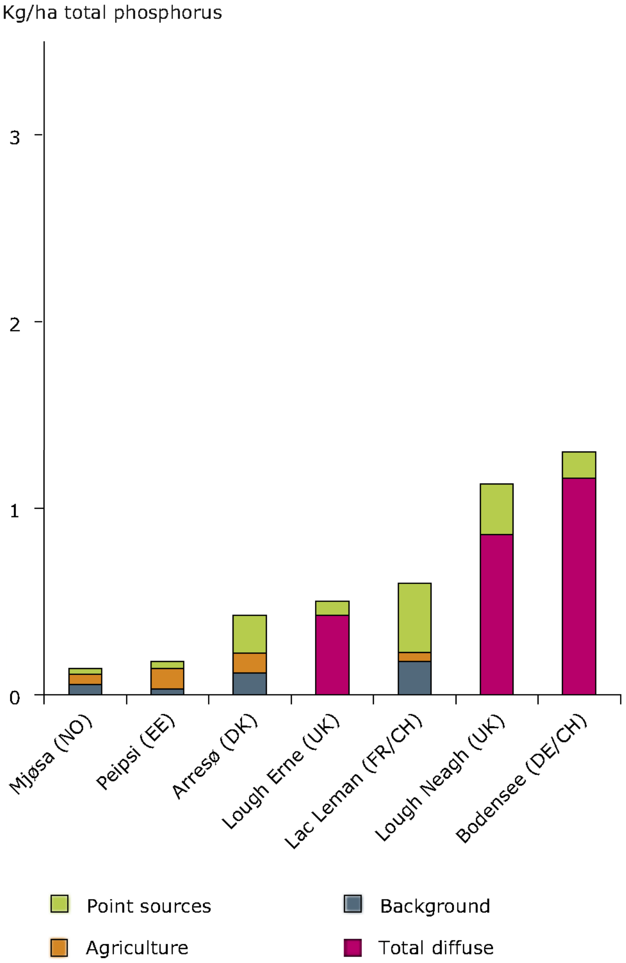
Figure 4.6 Source apportioned annual load in 1999 and estimated fertiliser use in Euroharp catchments (A) Total nitrogen. (B) Total phosphorus (load-oriented approach)



Note: The fertiliser use is roughly estimated from nationally recommended or estimated application rates in combination with the percentage of agricultural land.

Source: Euroharp catchment reports and data.

Figure 4.7 Source apportioned annual load of phosphorus in the catchments of large lakes (mixed approaches)



Sources: SFT (2005); Stålnacke *et al.* (2000); NERI data; Heathwaite (2003); Dardni; CIPEL (2004 and 2004a); IGKB (2004).

5 Sources of pollution

5.1 Background loss

The background loss of nitrogen is usually small compared with other diffuse and point sources. Only in very sparsely populated areas such as northern Scandinavia or the Alps is it a major source. The background loss is typically estimated at 1–2 kg/ha for nitrogen, and is lowest in, for example, northern Scandinavia. The background loss does not reflect a reference condition, because most areas are subject to substantial atmospheric depositions of ammonia and NO_x from nearby or far away sources.

The background loss of phosphorus is relatively significant compared to other sources. It depends on the geological conditions, and may differ even over short distances. In areas dominated by marine sediments, there may be naturally high phosphorus concentrations in surface water and groundwater. In the source apportionments of this study, the average background loss is usually considered to be about 0.1 kg/ha for phosphorus.

5.2 Agricultural diffuse loss

In most of Europe, agriculture is a dominating anthropogenic source of pollution with nitrogen and phosphorus. Its current relative significance is partly a result of the great efforts to reduce point source pollution during the past decades. The estimates of agricultural diffuse loss range from about 0 to 30 kg/ha for nitrogen and about 0 to 1 kg/ha for phosphorus. The highest loss is found in agriculturally intensive regions in the north-western part of Europe, where the average (mineral) fertiliser consumption per country is commonly about 40–70 kg/ha of nitrogen and 8–13 kg/ha of phosphorus (FAO).

At large scale, agriculture is the single dominating source of nitrogen pollution, typically contributing 50–80 % of the total load. The situation may be different in smaller catchments with high population densities (e.g. large cities), very poor wastewater treatment, or many industrial facilities discharging poorly treated wastewater.

Agriculture is also one of the largest contributors to phosphorus pollution, along with various point sources. But contrary to nitrogen, there are larger differences between the different regions and catchments. The agricultural share is often about half the total load, and in most source apportionments it is between 25 and 75 %. The relative share is to a large extent affected by the point source share, which is in turn a result of population density, industrial activities and wastewater treatment. Wastewater treatment is better developed in the northern part of Europe than in eastern Europe and the Mediterranean countries (EEA, 2004).

5.3 Atmospheric deposition

Both nitrogen and phosphorus are deposited in water and soil in different forms: nitrogen as ammonia which has evaporated from animal manure, and as NO_x coming from combustion of fossil fuels, i.e. power plants and transportation; phosphorus as dust, falling leaves and bird faeces.

The annual deposition of oxidised nitrogen (NO_x) is 1–10 kg/ha (EMEP), being highest in the centre of western Europe around Germany and lowest in northern Scandinavia, where it may even be below 1 kg/ha. The deposition of ammonia nitrogen is of the same order of magnitude, and it is highest in regions with high livestock densities. For comparison, agriculturally intensive countries typically apply 40–70 kg/ha of nitrogen fertiliser as an average for the whole country.

The proportion that falls on the ground is usually not considered separately in source apportionments, but becomes a part of leaching from the soil. The proportion that falls directly on the surface of inland or marine water is assessed separately in several source apportionments. It is often very small compared with other sources, but in lakes with a large surface area compared with the total catchment, or in coastal or marine waters, it may constitute a significant part of the total inputs. Atmospheric deposition constitutes about 25 % of the total input to the Baltic Sea, about 10 % of the input to Lake Peipsi, and about 3 % of the input to the Bodensee.

The deposition of phosphorus is generally small and difficult to estimate. Previous estimates in Europe range from 0.05 to 0.50 kg/ha. For comparison, agriculturally intensive countries typically apply

Table 5.1 Diffuse losses of nitrogen and phosphorus from scattered dwellings

Country	(kg/ha/year)	
	Nitrogen	Phosphorus
OSPAR — 'households not connected'		
Belgium	0.44	0.067
Denmark	0.45	0.104
Germany	0.78	0.107
Netherlands	0.16	0.017
Norway	0.13	0.012
Sweden	0.26	0.019
Switzerland	0.11	0.011
Helcom — 'other diffuse sources'		
Denmark	0.26	0.058
Estonia	0.33	0.075
Finland	0.13	0.015
Germany	0.47	0.056
Poland	1.26	0.057
Sweden	0.12	0.028

Sources: OSPAR (2003); Helcom (2004).

Table 5.2 A: Percentage split of point source discharges to the Baltic, 2000

	Nitrogen		Phosphorus	
	Inland waters	Direct	Inland waters	Direct
Municipal wastewater	84	82	85	81
Industry	15	15	14	14
Fish farms	1	3	1	4

Source: Helcom (2004).

Table 5.2 B: Percentage split of point source discharges to the North Sea, 2000

	Nitrogen	Phosphorus
Sewage treatment works	75	68
Households not connected to sewage treatment works	10	15
Industry	14	16
Aquaculture	1	1

Source: OSPAR (2003).

Table 5.2 C: Percentage split of point source discharges to the Danube basin, 1996/97

	Nitrogen	Phosphorus
Municipal point sources	73	78
Industrial point sources	19	15
Agricultural point sources	8	7

Source: UNDP/GEF (1999).

8–13 kg/ha of phosphorus fertiliser as an average for the whole country.

Atmospheric deposition of phosphorus is estimated to constitute 1 % of the load to Lake Geneva and 1 % of the load to Lake Constance. Even in the Baltic Sea, the deposition is assessed to be very small, 1–5 % of the total load (Helcom, 'Pathways and sources of nutrient inputs', http://www.helcom.fi/environment2/eutrophication/en_GB/inputs/).

5.4 Rural population

The majority of the population in scattered dwellings is usually not connected to wastewater treatment plants. The wastewater is discharged directly to surface water or to a percolation system, possibly through a septic tank or other purification system. Scattered dwellings are in principle point sources, but due to their abundance they are often considered as a diffuse source or even as part of the agricultural contribution.

At large scale (OSPAR and Helcom data), the annual discharges from scattered dwellings are typically 0.1–0.5 kg/ha for nitrogen and 0.01–0.1 kg/ha for phosphorus, and occasionally higher (Table 5.1). The data shown in the table to some extent include other diffuse sources such as the urban population not connected to sewers (OSPAR) and stormwater overflows (Helcom).

Scattered dwellings are relatively insignificant sources of nitrogen and phosphorus. The contribution of nitrogen is generally smaller than the background contribution and much smaller than the agricultural contribution. The contribution of phosphorus is also small, usually of the same order of magnitude as the background loss, but in some catchments it is not insignificant.

5.5 Point sources

In Europe, nutrient discharges from municipal wastewater treatment plants are in general higher than for any other point source. Results from large inland and marine catchments (Tables 5.2 A, B and C) show that municipal wastewater constitutes about 75 % of the point source discharges of both nitrogen and phosphorus. Industrial sources constitute about 17 % and other point sources are also relatively insignificant. Locally, in smaller catchments, all types of point sources may be significant in relation to pollution management.

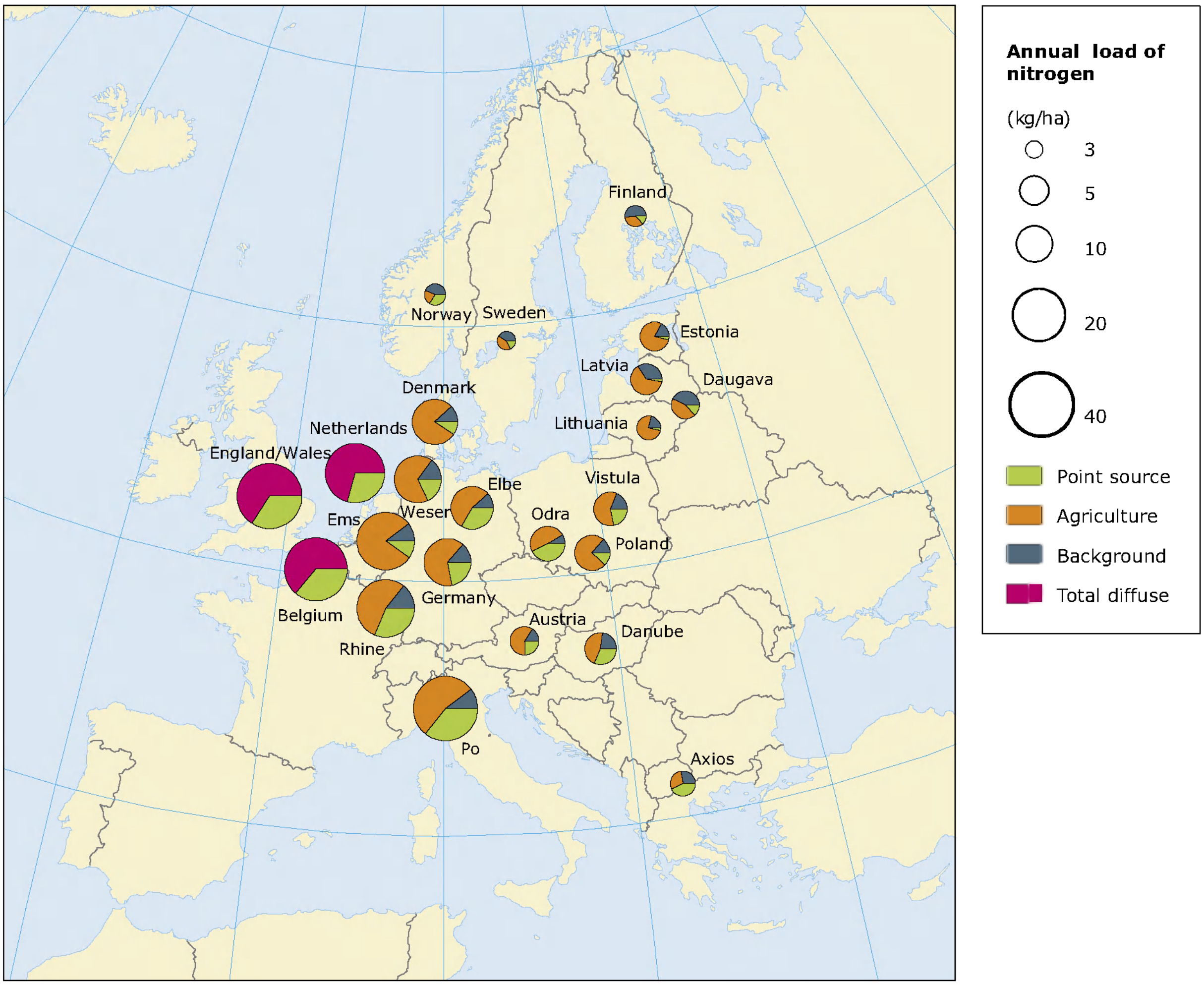
6 Geographical differences

A broad view of the source apportioned load of nitrogen and phosphorus to the aquatic environment across Europe can be obtained by pulling together national estimates, contributions to marine conventions and source apportionments for selected river or lake catchments. Maps 6.1 and 6.2 show the relative contribution to the nutrient load from various sources in different parts of Europe. The geographical coverage is not complete due to missing data from some countries, particularly in the Mediterranean region and eastern Europe.

Data are heterogeneous regarding calculation methods and the year or period of concern and should be interpreted cautiously as indicative rather than absolute.

The total nitrogen load (area of the pie charts on the maps) is high in the central–north-western part of the region, i.e. in England/Wales, the Netherlands, Belgium, Denmark and the western part of Germany. The Po river catchment in northern Italy also has a high total load. The total nitrogen load is smaller in

Map 6.1 Source apportionment of nitrogen load in selected regions and catchments



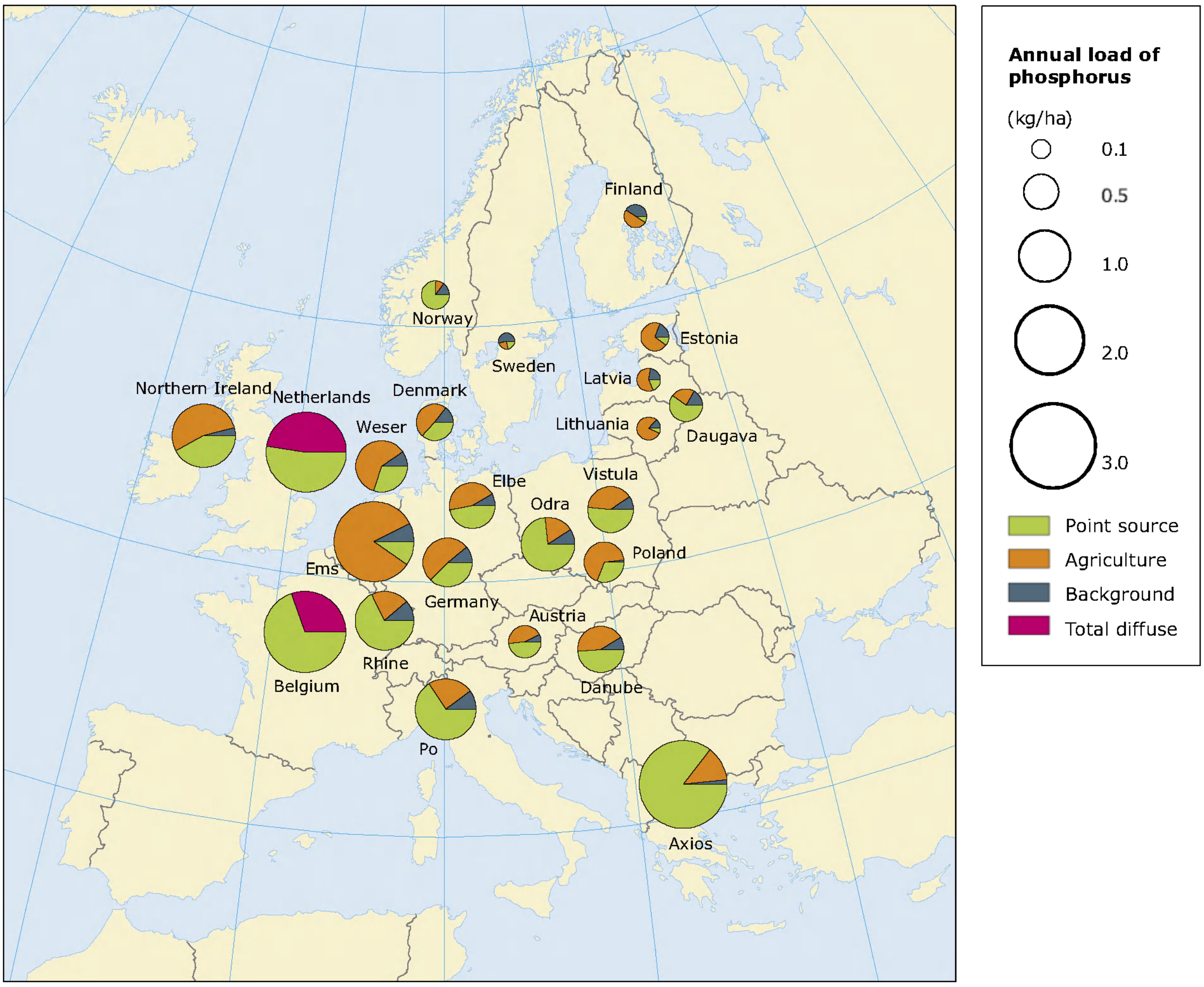
Note: The area of each pie chart indicates the total area-specific load. Mixed approaches.

Sources: See Annex 1.

eastern Europe and the Baltic States, and even lower in the Nordic countries. The main anthropogenic source is agriculture except for Norway, where point sources constitute most of the (small) anthropogenic load, and the Axios river, where a very high percentage of households unconnected to sewerage systems are included in 'point sources' in this compilation.

The total phosphorus load shows the same overall picture as for nitrogen with high loads in the north-west, smaller loads in eastern Europe and the smallest loads in the Baltic States and the Nordic countries. However, in contrast to nitrogen, the relative significance of the different sources is more diverse, with some areas being dominated by high shares of point source discharges, and others by agricultural contributions. The Axios river has, for example, a very high load from industrial discharges, while Norway has high point source discharges because of its many marine fish farms. The Ems and Weser rivers have, on the contrary, very high agricultural shares, which are due to the agricultural exploitation of bog soils in downstream parts of these rivers. The bog soils have poor phosphorus-binding capacities and the surplus of phosphorus is lost to the aquatic environment relatively fast, whereas in many other soils there is still a high capacity for immobilising phosphorus more or less permanently. However, the Ems and Weser cases suggest the potential magnitude of the pollution by continued application of surplus phosphorus to the soils. For Europe as a whole, it seems that both point sources and agricultural sources are significant, but the relative significance of each source can differ quite a lot from one catchment to another.

Map 6.2 Source apportionment of phosphorus load in selected regions and catchments



Note: The area of each pie chart indicates the total area-specific load (mixed approaches).

Sources: See Annex 1.

7 Temporal changes

Comparison of the source apportioned pollution load from year to year or between different periods should also be dealt with cautiously. The observed changes take place over a period of several years, and in that period there may be substantial changes in the availability or quality of data. Furthermore, climatic factors have a huge influence on the diffuse load of both nitrogen and phosphorus. High annual precipitation may increase the leaching of nitrogen particularly, and extreme hydrological events may influence the erosion of nitrogen and phosphorus. There are, however, several time series on source apportioned pollution load (Figure 7.1), or at least estimates of the changes in load from certain pollution sources.

During the past decades, there have been major improvements in wastewater treatment. This has been particularly important for reducing phosphorus emissions, because point sources are, and particularly were, responsible for a large proportion of the total load of phosphorus. The point source discharges of phosphorus were reduced from being the dominating source to being at the same level as the diffuse sources.

Throughout the period, point sources have only been minor contributors to nitrogen pollution. Nevertheless, there have been significant reductions in the discharges of nitrogen from point sources in many catchments due to the efforts to improve wastewater treatment in the municipal and industrial sectors.

Contrary to the point source discharges, there is only slight evidence of a reduction in the diffuse losses of nitrogen and phosphorus. However, because of the high climatically caused interannual variations, it is also difficult to reveal such trends, and a correction for climatic factors (mainly riverine water discharge) is needed. In Denmark, there has been a significant reduction in the diffuse losses of nitrogen during the last 15 years, whereas no significant trend can be shown for the diffuse loss of phosphorus.

OSPAR has compared the reported point source discharges and diffuse losses for the reporting years 1985 and 2000 (Table 7.1). In most of the countries, there have been significant reductions in point source discharges, often by more than 50 %. For the most important point source, sewage treatment works, the reduction has been dramatic for phosphorus and smaller for nitrogen.

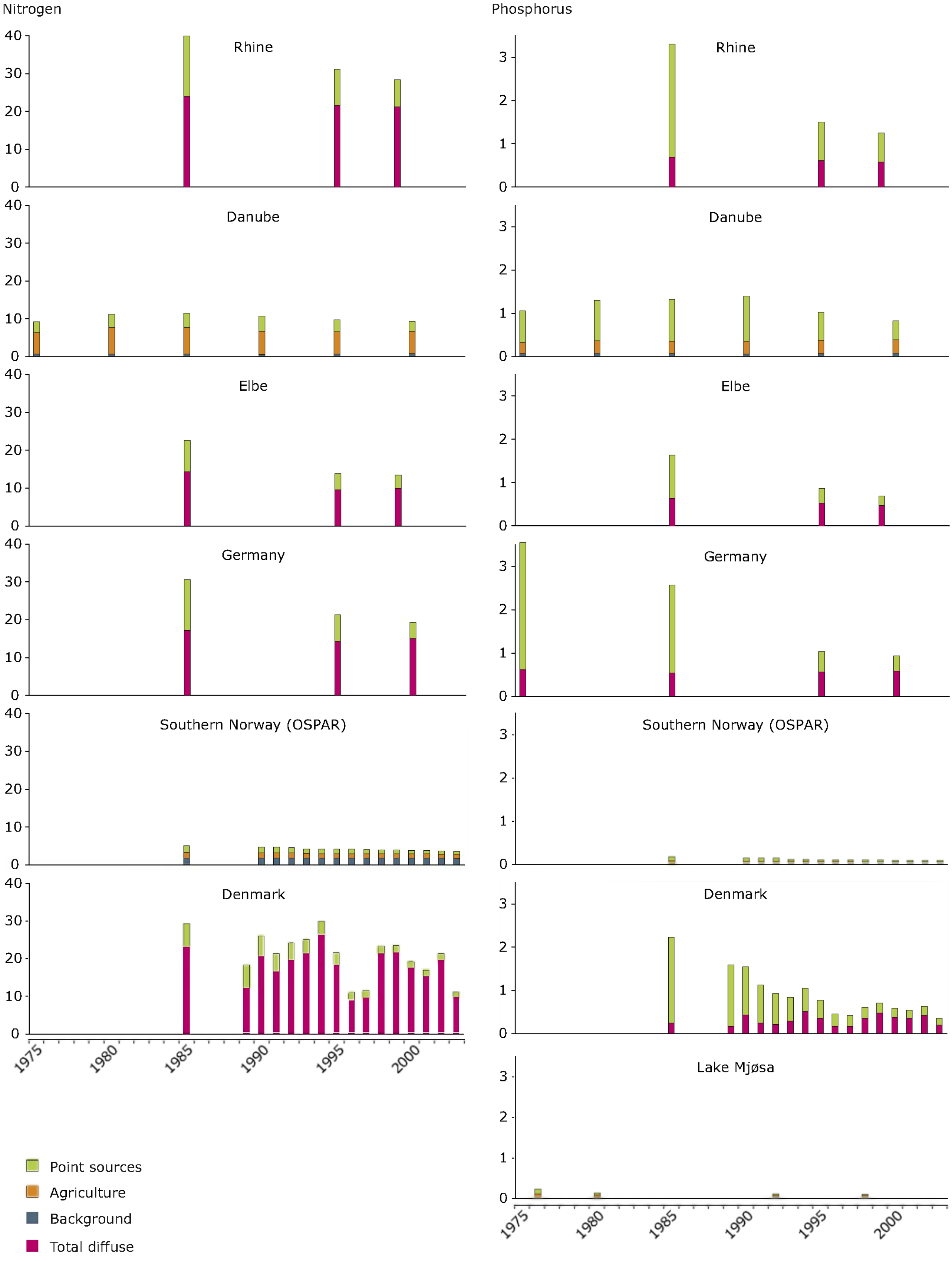
The diffuse losses have not been reduced to the same degree, although a moderate reduction in diffuse loss of both N and P has been recorded in most countries. The reduction rates on diffuse losses should be treated with care due to the sensitivity to climatic factors. For example, the seemingly high increase in diffuse losses of phosphorus in Denmark does not reflect a real trend.

Table 7.1 Percentage reductions of nutrients achieved per source at source between 1985 and 2000 (source-oriented approach)

	Diffuse losses		Sewage treatment works, sewerage		Households not connected		Industry	
	N	P	N	P	N	P	N	P
Belgium	– 15	6	4	26			80	85
Denmark	36	– 65	80	89			85	99
Germany	16	4	51	83	35	59	79	82
Netherlands	19	13	25	74	93	96	80	87
Norway	20	28	36	86	27	55	73	38
Sweden	18	33	14	36	39	34	27	25
Switzerland	18	43	32	61	90	96	20	87

Source: OSPAR (2003).

Figure 7.1 Long time series of source apportioned load of nitrogen and phosphorus (kg/ha/year on y axes) in the period 1975–2003 (mixed approaches)



Sources: Behrendt/EuroCat (2004); Kroiss *et al.* (2005); Umweltbundesamt (DE) (2004); Selvik *et al.* (2004); Bøgestrand (2004); SFT (2005).

8 What additional work on source apportionment is needed?

In order to assess the effectiveness of current policies and agreements and to identify gaps, it is essential to know how nutrient inputs are distributed across sectors. Results from source apportionment studies are important in the policy formation process and in monitoring the implementation of policies and the effectiveness of measures.

In this context, a European-wide source apportionment of nutrient loads could be carried out applying a relevant source apportionment tool at regular intervals. The source apportionment could be done and reported every three to five years for a representative part or for the entire network of river stations within the Eionet-water network. This will establish time series for all the different regions in Europe, hence adopting the strategy chosen by international conventions such as Helcom and OSPAR.

Data on nutrient loads and information on point source discharges, etc., from Eionet-water should be used for developing and/or calibrating statistical models for diffuse nutrient losses (see Grimvall and Stålnacke, 1996; Kronvang *et al.*, 1995; and Grizetti *et al.*, 2005). Such statistical models can be developed for the different regions in Europe, and when calibrated for present-day conditions regarding nutrient surplus and agricultural practices, they can easily be used for estimating diffuse nutrient loads of surface waters across the entire European continent based on input data from central databases (e.g. Waterbase).

This will require various input data from the selected Eionet-water stations and their catchments:

- data making it possible to quantify annual nutrient discharges from various point sources (sewage treatment plants, industrial plants, scattered dwellings, fish farms, urban stormwater run-off, etc.);
- data making it possible to quantify annual nutrient retention in streams, lakes, reservoirs and inundated riparian wetlands utilising a harmonised method;
- information that enables a calculation of average groundwater residence times in European hydrogeological regions and the potential degradation of nitrogen in groundwater aquifers;
- information on agricultural practices (nutrient surplus), soil types, geology, land use, topography and climate for the selected Eionet-water stations that makes it possible to develop statistical models for diffuse nutrient losses.

9 References

Andersen, J. M., Boutroup, S., Svendsen, L. M., Bøgestrand, J., Grant, R., Jensen, J. P., Ellermann, T., Rasmussen, M. B., Jørgensen, L. F. and Laursen, K. D. (2004). *Aquatic environment 2003. State and trends — Technical summary*. Technical report from the National Environmental Research Institute No 500, 52 pp. Available in PDF format (2.4 Mb).

Anthony, S. G., Quinn, P. and Lord, E. I. (1996). 'Catchment scale modelling of nitrate modelling'. *Aspects of Applied Biology*, 46, pp. 23–32.

Behrendt, H., Dannowski, R., Deumlich, D., Dolezal, F., Kajewski, I., Kornmilch, M., Korol, R., Mioduszewski, W., Opitz, D., Steidl, J. and Stronska, M. (2002). 'Nutrient and heavy metal emissions into the river system of Odra — Results and comparison of models'. Schriftenreihe des Institutes für Abfallwirtschaft und Altlasten, Technische Universität Dresden, Bd. 28, Vol. 2, pp. 213–221.

Behrendt/EuroCat (2004). 'Past, present and future changes in catchment fluxes'. Deliverable 4.4 of the EuroCat project.

Bernet (2001). *Eutrophication management in the Baltic Sea region — A regional approach*.

Black Sea Commission (2002). *State of the environment in the Black Sea 1996–2000*. Available at http://www.blacksea-commission.org/Publications/Reports_SOE.htm.

Bøgestrand, J. (ed.) (2004). *Vandløb 2003. NOVA 2003*. Technical report No 516 from NERI. Available in PDF format at http://www2.dmu.dk/1_Viden/2_Publikationer/3_Fagrapporter/rapporter/FR516.pdf.

CIPEL (2004). 'Rapports sur les études et recherches entreprises dans le bassin Lémanique. Programme quinquennal 2001–05. Campagne 2003'. Commission Internationale pour la Protection des Eaux du Léman contre la Pollution. http://www.cipel.org/sp/IMG/pdf/rap-2003.pdf.

CIPEL (2004a). Tableau du bord du plan d'action 'Pour que vivent le Léman et ses rivières'. Commission Internationale pour la Protection des Eaux du Léman contre la Pollution. http://www.cipel.org/classic/tb/garde.htm.

Dardni. 'Phosphorus inputs to Lough Neagh'. Presentation. Department of Agriculture and Rural Development, Northern Ireland. http://www.afsni.ac.uk/Research/P_sources/sld012.htm.

EEA (2000). *Nutrients in European ecosystems*. Environmental assessment report No 4. Available at http://reports.eea.eu.int/ENVIASSRP04/en.

EEA (2004). *Urban wastewater treatment. Indicator [2004.05]*. http://themes.eea.eu.int/Specific_media/water/indicators/WEU16 %2C2004.05/index_html.

EEA/IFEN (2000). *Calculation of nutriment surplus from agricultural sources. Statistics spatialisation by means of Corine land cover. Application to the case of nitrogen*. Technical report No 51.

Finlands miljöcentral (2005). 'Näringsbelastning på vattendrag och naturlig urlakning'. http://www.miljo.fi/default.asp?contentid=118735&lan=SV.

Grimvall, A. and Stålnacke, P. (1996). 'Statistical methods for source apportionment of riverine loads of pollutants'. *Environmetrics*, 7, pp. 201–213.

Grizetti, B., Bouraoui, F., de Marsily, G. and Bidoglio, G. (2005). 'A statistical method for source apportionment of riverine nitrogen loads'. *J. Hydrol.*, 304, pp. 302–315.

Groenendijk, P. and Kroes, J. G. (1999). *Modelling the nitrogen and phosphorus leaching to groundwater and surface water with ANIMO 3.5*. Report 144. Winand Staring Centre, Wageningen.

HARP Guideline 8 (2000). 'Principles for source apportionment for quantifying nitrogen and phosphorus discharges and losses' (Reference Number: 2000–12).
(*Source:* OSPAR 00/9/2 Add.8 and OSPAR 00/20/1, § 9.5a.)

Heathwaite, L. (2003). 'Agricultural-driven eutrophication'. Presentation. http://www.fwr.org/eutrophi/lhefprsn.pdf.

Helcom (2004). 'The fourth Baltic Sea pollution load compilation (PLC-4)'. *Baltic Sea Environmental Proceedings*, No 93. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep93.pdf.

IGKB (2004). *Der Bodensee. Zustand — Fakten — Perspektiven. Bilanz 2004*. Internationale Gewässerschutzkommission für den Bodensee. http://www.igkb.de/html/publikationen/index.html.

Kirk McClure Morton (2001). *The Lough Derg and Lough Ree catchment monitoring and management system*. Final report.

Kroiss, H. *et al.* (2005). *Nutrient management in the Danube basin and its impact on the Black Sea*. Danubs final report. http://danubs.tuwien.ac.at/.

Kronvang, B., Grant, R., Larsen, S. E., Svendsen, L. M. and Kristensen, P. (1995). 'Non-point-source nutrient losses to the aquatic environment in Denmark. Impact of agriculture'. *Marine and Freshwater Research*, 46, pp. 167–177.

Ministry of the Environment, Norway (2002). *North Sea Progress Report 2002*. Report produced for the Fifth International Conference on the Protection of the North Sea, 20 and 21 March 2002, Bergen, Norway. Available at http://odin.dep.no/md/html/nsc/progressreport2002/hoved.html.

Müller-Wohlfeil, D.-I., Jørgensen, J. O., Kronvang, B. and Wiggers, L. (2002). 'Linked catchment and scenario analysis of nitrogen leaching and load. A case-study from a Danish catchment-fjord system, Mariager Fjord'. *Physics and Chemistry of the Earth*, 27, pp. 691–699.

Neitsch, S. L., Arnold, J. G., Kiniry, J. R. and Williams, J. R. (2001). *Soil and water assessment tool user manual — Version 2000*. Blackland Research Center — Agricultural Research Service, Texas.

Nielsen, K., Andersen, H. E., Larsen, S. E., Kronvang, B., Stjernholm, M., Styczen, M., Poulsen, R. N., Villholth, K., Krogsgaard, J., Dahl-Madsen, K. I., Friis-Christensen, A., Uhrenholdt, T., Hansen, I. S., Pedersen, S. E., Jørgensen, O., Windolf, J., Jensen, M. H., Refsgaard, J. C., Hansen, J. R., Ernstsen, V., Børgesen, C. D. and Wiggers, L. (2004). *Odense Fjord. Scenarier for reduktion af næringsstoffer. Danmarks Miljøundersøgelser*. Faglig rapport fra DMU 485, 246 pp. Available in Danish at http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/default.asp.

OSPAR (2000). *Quality Status Report 2000*. OSPAR Commission, London. http://www.ospar.org/eng/html/qsr2000/QSR2000welcome3.htm.

OSPAR (2003). *Nutrients in the convention area. Inputs of nutrients into the convention area: Implementation of PARCOM Recommendations 88/2 and 89/4*. Report in the Eutrophication and Nutrients series. OSPAR report No 191. Available at http://www.ospar.org/v_publications/browse.asp?v3=54&lang=0.

Schoumans, O. F. and Silgram, M. (eds), with contributions from Andersen, H. E. and Kronvang, B. (2004). *Review and literature evaluation of quantification tools for the assessment of nutrient losses at catchment scale*. Norwegian Institute for Water Research (NIVA). Euroharp report 1–2003; NIVA report SNO 4739–2003, 120 pp.

Schreiber *et al.* (2003). 'Harmonised inventory of point and diffuse emissions of N and P for the Danube river basin'. Delivery 5.5 of the Danubs project. http://128.130.103.159/D5.5 web version.pdf.

Selvik, J. R., Borgvang, S. A., Eggestad, H. O. and Tjomsland, T. (2004). *Tilførsler av næringssalter til Norges kystområder 2003, beregnet med tilførselsmodellen TEOTIL*. Report from NIVA to Statens forurensningstilsyn (SFT). Available at http://www.sft.no/publikasjoner/overvaking/2059/ta2059.pdf.

SFT (2005). Home page: Miljøstatus i Norge, Fosfor til Mjøsa. http://www.miljostatus.no/oppland/tema/Vannkvalitet/fosfor_til_mjosa.htm.

Simmelsgaard, S. E., Kristensen, K., Andersen, H. E., Grant, R., Jørgensen, J. O. and Østergaard, H. S. (2000). *An empirical model for calculation of root zone nitrate leaching*. DJF rapport Markbrug No 32, Danmarks JordbrugsForskning, 67 pp. (in Danish).

Smith, R. V., Jordan, C. and Annett, J. A. (2005). 'A phosphorus budget for Northern Ireland: Inputs to inland and coastal waters'. *Journal of Hydrology* 304, pp. 193–202.

SLU and SMHI, Sweden. TRK — belastning på havet. Home page at http://www-nrciws.slu.se/TRK/ (in Swedish).

Stålnacke, P., Sults, Ü., Vasiliev, A., Skakalsky, B., Botina, A., Roll, G., Pachel, K. and Maltsman, T. (2000). *Nutrient loads to Lake Peipsi*. Jordforsk report No 4/01. Norwegian Centre for Soil and Environmental Research.

Swedish EPA (1997). *Nitrogen from land to sea*. Main report. Swedish Environmental Protection Agency, Report 4801, Nordstedts tryckeri AB, Stockholm.

UNDP/GEF (1999). Danube pollution reduction programme. Transboundary analysis report.

Available at the ICPDR home page: http://www.icpdr.org/pls/danubis/danubis_db.dyn_navigator.show.

Umweltbundesamt (AT) (2001). *Umweltkontrollbericht 2001*. Chapter 5 'Wasser'. http://www.umweltbundesamt.at/fileadmin/site/umweltkontrolle/2001/05_wasser.pdf.

Umweltbundesamt (DE) (2004). 'Nährstoffeinträge in die Flußgebiete Deutschlands'. http://osiris.uba.de/gisudienste/Herata/npbilanz/.

Whitehead, P. G., Wilson, E. J. and Butterfield, D. (1998a). 'A semi-distributed integrated nitrogen model for multiple source assessment in catchments (INCA): Part I — Model structure and process equations'. *The Science of the Total Environment*, 210/211, pp. 547–558.

Whitehead, P. G., Wilson, E. J. and Butterfield, D. (1998b). 'A semi-distributed integrated nitrogen model for multiple source assessment in catchments (INCA): Part II — Application to large river basins in south Wales and eastern England'. The Science of the Total Environment, 210/211, pp. 559–583.

Annex 1

Data table for Maps 1, 2, 6.1 and 6.2

N (kg/ha)

	Total diffuse	Background	Agriculture	Point sources	Sum	Source
Austria	—	1.14	4.29	1.72	7	Umweltbundesamt (AT) (2001)
Belgium	21.75	—	—	12.38	34	OSPAR (2003)
Denmark	—	2.05	14.02	1.65	18	Bøgestrand (2004)
England/ Wales	23.74	—	—	12.32	36	WRc (2004)
Estonia	—	1.28	5.76	0.27	7	Helcom (2004)
Finland	—	2.07	1.36	0.53	4	Finlands miljöcentral (2005)
Germany	—	2.61	12.43	4.24	19	Umweltbundesamt (DE) (2004)
Latvia	—	2.84	5.27	0.24	8	Helcom (2004)
Lithuania	—	1.06	3.80	0.18	5	Helcom (2004)
Netherlands	21.75	—	—	9.02	31	OSPAR (2003)
Norway	—	1.68	0.87	1.33	4	Selvik *et al.* (2004)
Poland	—	1.51	8.04	1.33	11	Helcom (2004)
Sweden	—	1.25	1.22	0.54	3	SLU and SMHI
Axios	—	1.50	1.60	2.30	5	Behrendt/EuroCat (2004)
Danube	—	2.00	3.90	2.70	9	Behrendt/EuroCat (2004)
Daugava	—	2.90	3.00	0.90	7	Behrendt/EuroCat (2004)
Elbe	—	1.80	8.50	5.20	16	Behrendt/EuroCat (2004)
Ems	—	3.00	23.10	2.80	29	Behrendt/EuroCat (2004)
Odra	—	0.90	5.10	4.50	11	Behrendt/EuroCat (2004)
Po	—	3.70	19.20	12.70	36	Behrendt/EuroCat (2004)
Rhine	—	4.10	15.60	9.00	29	Behrendt/EuroCat (2004)
Vistula	—	1.80	5.70	2.10	10	Behrendt/EuroCat (2004)
Weser	—	2.90	13.00	3.50	19	Behrendt/EuroCat (2004)

P (kg/ha)

	Total diffuse	Background	Agriculture	Point sources	Sum	Source
Austria	—	0.025	0.161	0.172	0.4	Umweltbundesamt (AT) (2001)
Belgium	0.760	—	—	1.750	2.5	OSPAR (2003)
Denmark	—	0.077	0.252	0.194	0.5	Bøgestrand (2004)
Estonia	—	0.057	0.215	0.031	0.3	Helcom (2004)
Finland	—	0.080	0.098	0.018	0.2	Finlands miljöcentral (2005)
Germany	—	0.101	0.480	0.348	0.9	Umweltbundesamt (DE) (2004)
Latvia	—	0.052	0.131	0.043	0.2	Helcom (2004)
Lithuania	—	0.026	0.152	0.013	0.2	Helcom (2004)
Netherlands	1.130	—	—	1.250	2.4	OSPAR (2003)
Northern Ireland	—	0.062	0.831	0.647	1.5	Smith *et al.* (2004)
Norway	—	0.039	0.026	0.203	0.3	Selvik *et al.* (2004)
Poland	—	0.010	0.380	0.175	0.6	Helcom (2004)
Sweden	—	0.080	0.036	0.034	0.1	SLU and SMHI
Axios	—	0.048	0.373	2.484	2.9	Behrendt/EuroCat (2004)
Danube	—	0.073	0.359	0.412	0.8	Behrendt/EuroCat (2004)
Daugave	—	0.061	0.088	0.221	0.4	Behrendt/EuroCat (2004)
Elbe	—	0.068	0.360	0.381	0.8	Behrendt/EuroCat (2004)
Ems	—	0.177	1.981	0.231	2.4	Behrendt/EuroCat (2004)
Odra	—	0.100	0.189	0.798	1.1	Behrendt/EuroCat (2004)
Po	—	0.144	0.339	0.925	1.4	Behrendt/EuroCat (2004)
Rhine	—	0.143	0.271	0.865	1.3	Behrendt/EuroCat (2004)
Vistula	—	0.071	0.296	0.393	0.8	Behrendt/EuroCat (2004)
Weser	—	0.100	0.633	0.312	1.0	Behrendt/EuroCat (2004)

Annex 2

Bibliography on source apportionment (and load) for European seas

Baltic Sea
Helcom (1993). 'Second Baltic Sea pollution load compilation'. *Baltic Sea Environmental Proceedings*, No 45. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep45.pdf.

Helcom (1993). 'Nitrogen and agriculture'. International workshop (1993), 9–12 April 1991, Schleswig, Germany. *Baltic Sea Environmental Proceedings*, No 44. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep44.pdf.

Helcom (1997). 'The evaluation of the relation of atmospheric deposition to riverine input of nitrogen to the Baltic Sea'. *Baltic Sea Environmental Proceedings*, No 68. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep68.pdf.

Helcom (1998). 'Third Baltic Sea pollution load compilation 1998'. *Baltic Sea Environmental Proceedings*, No 70. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep70.pdf.

Helcom (1998). 'Agenda 21 for the Baltic Sea region, sustainable development of the agricultural sector in the Baltic Sea region'. *Baltic Sea Environmental Proceedings*, No 74. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep74.pdf.

Helcom (2003). 'The review of more specific targets to reach the goal set up in the 1988/1998 Ministerial Declarations regarding nutrients'. *Baltic Sea Environmental Proceedings*, No 89. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep89.pdf.

Helcom (2004). 'The fourth Baltic Sea pollution load compilation (PLC-4)'. *Baltic Sea Environmental Proceedings*, No 93. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep93.pdf.

Helcom (2005). 'Nutrient pollution to the Baltic Sea in 2000'. *Baltic Sea Environmental Proceedings*, No 93. Available at http://www.helcom.fi/stc/files/Publications/Proceedings/bsep100.pdf.

Lääne *et al.* (2002). *Evaluation of the implementation of the 1988 Ministerial Declaration regarding nutrient load reductions in the Baltic Sea catchment area*. The Finnish environment report No 524. Available at http://www.environment.fi/download.asp?contentid=21608&lan=en.

OSPAR — North Sea/north-east Atlantic
Compilation of submitted inputs to the progress report to the Fifth International Conference on the Protection of the North Sea (2002). *Further reduction of nutrient inputs to the North Sea*. Available at http://odin.dep.no/filarkiv/160835/Nutrient-Compl.doc.

Ministry of the Environment, Norway (2002). *North Sea Progress Report 2002*. Report produced for the Fifth International Conference on the Protection of the North Sea, 20 and 21 March 2002, Bergen, Norway. Available at http://odin.dep.no/md/html/nsc/progressreport2002/hoved.html.

OSPAR (1995). *Nutrients in the convention area — Overview of implementation of PARCOM Recommendation 88/2, 1995*. OSPAR report No 40.

OSPAR (2003). *Nutrients in the convention area. Inputs of nutrients into the convention area: Implementation of PARCOM Recommendations 88/2 and 89/4*. Report in the Eutrophication and Nutrients series. OSPAR report No 191. Available at http://www.ospar.org/v_publications/browse.asp?v3=54&lang=0.

Black Sea
Black Sea Commission (2002). *State of the environment in the Black Sea 1996–2000*. Available at http://www.blacksea-commission.org/Publications/Reports_SOE.htm.

EEA (2002). *The rivers of the Black Sea*. Technical report No 71. Available at http://reports.eea.eu.int/technical_report_2002_71/en.

Mee, L. (ed.) (1998). *Black Sea pollution assessment*.

Mediterranean Sea
EEA (2000). *State and pressure of the marine and coastal Mediterranean environment*. Environmental assessment report No 5. Available at http://reports.eea.eu.int/ENVSERIES05/en.

UNEP/MAP/Medpol (1996). *Survey of pollutants from land-based sources in the Mediterranean*. MAP technical report series No 109, UNEP/MAP, Athens. Available at http://www.unepmap.gr/include/MAPMeetingsSearch/Download.asp?allegato=MTS/ALL_LANGUAGES/mts109.pdf.

UNEP/MAP/Medpol (2003). *Riverine transport of water, sediments and pollutants to the Mediterranean Sea*. MAP technical report series No 141, UNEP/MAP, Athens. Available at http://www.unepmap.gr/include/MAPMeetingsSearch/Download.asp?allegato=MTS/ALL_LANGUAGES/mts141.pdf (29.5 Mb).

UNEP/MAP/Medpol/WHO (2000). *Municipal wastewater treatment plants in Mediterranean coastal cities*. MAP technical report series No 128. UNEP/MAP, Athens. Available at http://www.unepmap.gr/include/MAPMeetingsSearch/Download.asp?allegato=MTS/ENGLISH/mts128eng.pdf.

UNEP/MAP/Medpol/WHO (2004). *Municipal wastewater treatment plants in Mediterranean coastal cities (II)*. MAP technical report series No 157. UNEP/MAP, Athens. Available at http://www.unepmap.gr/include/MAPMeetingsSearch/Download.asp?allegato=MTS/ENGLISH/mts157eng.pdf.

Annex 3

Bibliography on national source apportionment

Austria: Umweltbundesamt (2001). *Umweltkontrollbericht 2001*. Chapter 5 'Wasser'. http://www.umweltbundesamt.at/fileadmin/site/umweltkontrolle/2001/05_wasser.pdf.

Belgium: MIRA (2004). Milieu- en Natuurrapport Vlaanderen. MIRA Achtergronddocument 2004, Kwaliteit oppervlaktewater, De Cooman, W., Maeckelberghe, H., Vos, G., Meers, B., Van Erdeghem, M., Van Wauwe, P., Vannevel, R., Belpaire, C., Breine, J., Van Thuyne, G., Schneiders, A., Martens, K., Peeters, B. and Tieleman, B. 'Vlaamse Milieumaatschappij'. http://www.milieurapport.be.

Denmark: NERI/Andersen *et al.* (2004). *Aquatic environment 2003. State and trends — Technical summary*. NERI Technical report No 500. http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR500.pdf.

Finland: Statistics Finland (2004). *Finland's natural resources and the environment 2004*. http://tilastokeskus.fi/tk/tt/nature4.pdf.

France: European Topic Centre on Water (2002). *EUROWATERNET-Emissions. A European inventory of emissions to water: Proposed operational methodology*. Internal report. Primary source IOW and IFEN, 2001.

Germany: Behrendt, H., Huber, P., Kornmilch, M., Opitz, D., Schmoll, O., Scholz, G. and Uebe, R. (2000). 'Nutrient emissions into river basins of Germany'. UBA-Texte, 23/00, p. 266.

Umweltbundesamt home page. Nährstoffe (http://www.umweltbundesamt.de/wasser/themen/ow_s5_2.htm) and Quantifizierung der Nährstoffeinträge der Flussgebiete (http://osiris.uba.de/gisudienste/Herata/npbilanz/).

Italy: ANPA. *Stato dell'Ambiente*, 3/2001. Primo rapporto SINAnet sulle Acque. Table 9 ('Source apportionments for large rivers').

The Netherlands: 'MilieuCompendium (online) Indicator Vermestende emissies naar water, 1990–2002' (http://www.rivm.nl/milieuennatuurcompendium/nl/i-nl-0192-05.html) — or indicator D4.3 'Emissions to water for the eutrophication theme, 1990–2000' (http://arch.rivm.nl/environmentaldata/D_Environmental_themes/D4_Introduction_to_the_theme_of_eutrophication/index.html).

Emission monitor for the Netherlands, 2000, and estimates for 2001.

Norway: Selvik, J. R., Borgvang, S. A., Eggestad, H. O. and Tjomsland, T. (2004). *Tilførsler av næringssalter til Norges kystområder 2003, beregnet med tilførselsmodellen TEOTIL*. Report from NIVA to Statens forurensningstilsyn (SFT). http://www.sft.no/publikasjoner/overvaking/2059/ta2059.pdf.

SFT/NIVA (2003). *Tilførsler av næringssalter til Norges kystområder i 2002, beregnet med tilførselsmodellen TEOTIL*. Statlig program for forurensningsovervåking. http://www.sft.no/publikasjoner/overvaking/1999/ta1999.pdf.

Sweden: Brandt, M. and Ejhed, H. (2002). *Transport — Retention — Källfördelning Belastning på havet*. Report from Naturvardsverket No 5247 (in Swedish). Del 1: http://www.naturvardsverket.se/bokhandeln/pdf/620-5247s1_44.pdf — pp. 1–44. Del 2: http://www.naturvardsverket.se/bokhandeln/pdf/620-5247s45_117.pdf — pp. 45–177.

SLU and SMHI, Sweden. TRK — belastning på havet. http://www-nrciws.slu.se/TRK/.

United Kingdom: Morse *et al.* (1993).

Smith, R.V., Jordan, C. and Annett, J. A. (2004). 'A phosphorus budget for Northern Ireland: Inputs to inland and coastal waters'. *Journal of Hydrology* xx (2004), pp. 1–10.

WRc (2004). *Updating an estimate of the source apportionment of nitrogen to waters in England and Wales*. Report to DEFRA.

Annex 4

Bibliography on European river catchment source apportionment studies

ANPA. *Stato dell´Ambiente*, 3/2001. Primo rapporto SINAnet sulle Acque.

Behrendt/EuroCat (2004). 'Past, present and future changes in catchment fluxes'. Deliverable 4.4 of the EuroCat project.

Behrendt, H., Bach, M., Kunkel, R., Opitz, D., Pagenkopf, W.-G., Scholz, G. and Wendland, F. (2003). *Nutrient emissions into surface waters of Germany on the base of a harmonised procedure.* Report to the Federal Environment Agency. Available at http://osiris.uba.de/gisudienste/Herata/npbilanz/ under 'Publications' and http://osiris.uba.de/gisudienste/Herata/npbilanz/bericht/english/summary.pdf.

Behrendt, H., Dannowski, R., Deumlich, D., Dolezal, F., Kajewski, I., Kornmilch, M., Korol, R., Mioduszewski, W., Opitz, D., Steidl, J. and Stronska, M. (2002). 'Nutrient and heavy metal emissions into the river system of Odra — Results and comparison of models'/'Nährstoff und Schwermetalleinträge in das Flusssystem der Oder'. In IGB- Leibniz, Institute of Freshwater Ecology and Inland Fisheries annual report 2001. http:\\www.igb-berlin.de\institut\deutsch\2001\Research\nutrient_heavymetal_emissions.pdf.

Bernet. Baltic eutrophication regional network. http://www.bernet.org/wm125051.

Brandt, M. and Ejhed, H. (2002). *Transport — Retention — Källfördelning Belastning på havet*. Report from Naturvardsverket No 5247 (in Swedish). Del 1: http://www.naturvardsverket.se/bokhandeln/pdf/620-5247s1_44.pdf — pp. 1–44. Del 2: http://www.naturvardsverket.se/bokhandeln/pdf/620-5247s45_117.pdf — pp. 45–177.

Bøgestrand, J. (ed.) (1999). *Vandløb og kilder 1998. NOVA 2003*. Technical report from NERI No 292.

Bøgestrand, J. (ed.) (2004). *Vandløb 2003. NOVA 2003*. Technical report from NERI No 516. http://www2.dmu.dk/1_Viden/2_Publikationer/3_Fagrapporter/rapporter/FR516.pdf.

De Wit, M., van Gaans, P., Bleuten, W., Bendoricchio, G. and Behrendt, H. (2001). 'The contribution of agriculture to nutrient pollution in three European rivers'. *European Water Management*, 2/2002 (published online). http://www.ewaonline.de/journal/2002_02.pdf.

Euroharp. 'Towards European harmonised procedures for quantification of nutrient losses from diffuse sources'. EU fifth framework programme research project. Information available at http://EUROHARP.org/.

Finlands miljöcentral (2005). 'Näringsbelastning på vattendrag och naturlig urlakning'. http://www.miljo.fi/default.asp?contentid=118735&lan=SV.

IKSR (1996). *Bestandsaufnahme der Phosphor- und Stickstoffeinträge 1996.*

Kowalkowski, T. and Buszewski, V. (2004). 'Modelling of past, present and future state of nutrient emission into the Vistula river system. Implementation of Moneris model to the Vistula river catchment'. Deliverable WP4 of the EuroCat project.

Nashoug (ed.) (1999). *Vannkvaliteten i Mjøsa — før og nå Mjøsovervåkingen gjennom 25 år*. Report from Styringsgruppa for overvåking av Mjøsa. http://www.fylkesmannen.no/fmt_liste_kort.asp?tgid=5374&gid=5383&amid=1003083&g5375=x&g5374=x&.

Nikolaidis, N. P., Karageorgis, A., Kapsimalis, V., Drakopoulou, P., Skoulikidis, N. and Behrendt, H. (2004). 'Modelling of Axios river basin'. Deliverable WP4 of the EuroCat project.

OSPAR (2000). *Quality Status Report 2000*. OSPAR Commission, London. http://www.ospar.org/eng/html/qsr2000/QSR2000welcome3.htm.

Palmeri, L., Bendoricchio, G. and Artioli, Y. (2005). 'Modelling nutrient emissions from river systems and loads to the coastal zone: Po river case study, Italy'. *Ecological Modelling*, 184, 2005, pp. 37–53.

Schreiber *et al.* (2003). 'Harmonised inventory of point and diffuse emissions of N and P for the Danube river basin'. Delivery 5.5 of the Danubs project. http://128.130.103.159/D5.5 web version.pdf.

Selvik, J. R., Borgvang, S. A., Eggestad, H. O. and Tjomsland, T. (2004). *Tilførsler av næringssalter til Norges kystområder 2003, beregnet med tilførselsmodellen TEOTIL*. Report from NIVA to Statens forurensningstilsyn (SFT). http://www.sft.no/publikasjoner/overvaking/2059/ta2059.pdf.

Somlyódy, L., Brunner, P. H., Fenz, R., Kroiß, H., Lampert, C. and Zessner, M. (1997). 'Nutrient balances for Danube countries'. Project EU/AR/102A/91. Danube applied research programme, Phare, Vienna.

Tonderski, A. (1997). 'Control of nutrient fluxes in large river basins'. *Linköping Studies in Arts and Science*, No 157. Abstract. http://www.bibl.liu.se/liupubl/disp/disp97/arts157s.htm.

Umweltbundesamt (DE) (2004). 'Nährstoffeinträge in die Flußgebiete Deutschlands'. http://osiris.uba.de/gisudienste/Herata/npbilanz/.

UNDP/GEF (1999). Danube pollution reduction programme. Transboundary Analysis Report. Available at the ICPDR home page: http://www.icpdr.org/pls/danubis/danubis_db.dyn_navigator.show.

van Dijk, S., Knoop, J., De Wit M. J. M. and Leewis, R. J. (1997). *Source apportionment and quantification of nitrogen transport, and retention, in the River Rhine.* RIVM report 733008004. http://www.rivm.nl/bibliotheek/rapporten/733008004.html.

Vassiljev, A. and Stålnacke, P. (2003). 'Statistical modelling of riverine nutrient sources and retention in the Lake Peipsi drainage basin'. Paper presented at the Diffuse Pollution Conference, Dublin, 2003. http://www.ucd.ie/dipcon/docs/theme10/theme10_09.PDF.

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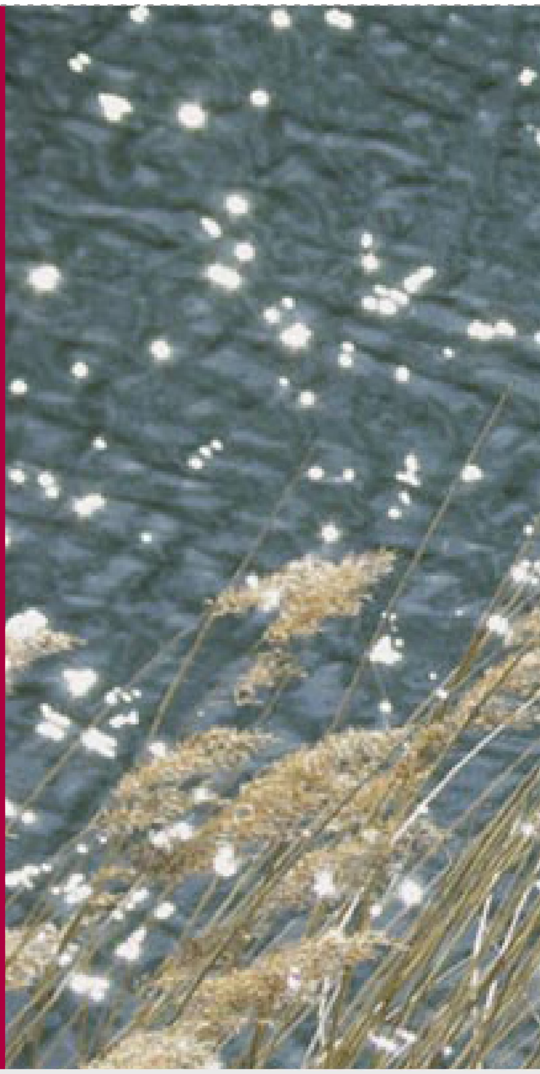

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