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Aquatic and Terrestrial Environment 2004

State and trends – technical summary

NERI Technical Report, No. 579

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Data sheet

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Abstract:	This report presents the 2004 results of the Danish National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA). 2004 was the first year in which terrestrial nature was included in the monitoring programme. The report reviews the state of the groundwater, watercourses, lakes and marine waters and the pressures upon them and reviews the monitoring of terrestrial natural habitats and selected plants and animals. The report is based on the annual reports prepared for each subprogramme by the Topic Centres. The latter reports are mainly based on data collected and submitted by the regional authorities.
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Contents

Aquatic and Terrestrial Environment 2004

State and trends – technical summary of the 2004 monitoring results

This report presents the 2004 results of the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA) (*Svendsen & Norup (eds), 2005; Svendsen et al. (eds), 2005*).

The report describes the environmental status of the water bodies in 2004 as well as the trend in environmental quality over the period 1989–2004 in relation to changes in the pressures. In addition it describes the monitoring of terrestrial natural habitats and species, including the first results of this monitoring, which was initiated in 2004.

The primary aim of the present technical summary is to inform the Parliamentary Committee on the Environment and Planning of the results of the year's monitoring and of the effects of the measures and investments implemented to protect the environment. In addition, it provides a national overview to the staff of the national and regional institutions who have helped carry out the monitoring programme, or who work with environmental management. Finally, it enables the public, NGOs and other organizations to obtain key information about the state of the aquatic environment and the trends therein.

The report has been prepared by the National Environmental Research Institute (NERI) in cooperation with the Geological Survey of Denmark and Greenland (GEUS) and the Danish Environmental Protection Agency on the basis of the Topic Centre reports listed in the box below. The present report only contains a few examples of results of the species monitoring in 2004, the intention being to provide a more comprehensive account of the 2004 species monitoring when reporting the 2005 results in spring 2006.

Aquatic and Terrestrial Environment 2004 – background reports (in Danish):

Punktkilder 2004	*Miljøstyrelsen, 2005*
Atmosfærisk deposition 2004	*Ellermann et al., 2005*
Landovervågningsoplande 2004	*Grant et al., 2005*
Grundvandsovervågning 2004	*GEUS, 2005*
Vandløb 2004	*Bøgestrand (red.), 2005*
Søer 2004	*Lauridsen et al., 2005*
Marine områder 2004	*Ærtebjerg et al., 2005*
Terrestriske naturtyper 2004	*Strandberg et al., 2005*

The Topic Centre reports are based on data collected by the regional authorities, Copenhagen and Frederiksberg Municipalities and the Regional Municipality of Bornholm. NERI contributed the data on the atmosphere, open marine waters and some species. In most cases the data are also reported in regional reports.

Summary

The National Monitoring Programme for the Aquatic and Terrestrial Environments (NOVANA) replaced the former solely aquatic monitoring programme NOVA-2003 on 1 January 2004. With NOVANA, Denmark initiated integrated systematic monitoring of the aquatic and terrestrial nature and environments.

Wastewater discharges of nitrogen, phosphorus and organic matter and losses of nitrogen from cultivated land have decreased markedly since monitoring began in 1989. The decrease in nutrient discharges has resulted in moderate improvements in environmental conditions in the lakes and marine waters, where the concentration of nitrogen and phosphorus in the water has decreased. This has led to improvements, particularly in the most polluted lakes and fjords. In the more open marine waters, monitoring has only revealed minor improvements in biological conditions – among other reasons because of the level of pollution is lower.

The environmental status of the watercourses has slowly but steadily improved in recent years. The status of the watercourses is mainly determined by the physical conditions and organic matter loading.

In 2004, the currently applicable quality objectives were fulfilled in just over half of the watercourses, in less than 1/3 of the lakes and, as far as concerns the marine waters, only in Skagerrak and in the open parts of the North Sea.

A reduction in nitrate concentration has been recorded in the youngest groundwater as a result of reduced leaching of nitrate from cultivated fields.

The 2004 results of the terrestrial natural habitat and species monitoring under NOVANA provide information about the status of the monitored special areas of conservation (Natura 2000 sites), but it is not possible to describe the trend after just one year of monitoring. Once operational quality criteria have been established for terrestrial nature, the monitoring results can be used to determine compliance with the Habitats Directive.

Wastewater

Wastewater discharges from towns, industry, fish farms and sparsely built-up areas account for a considerable proportion of total pollutant input to Danish water bodies. In 2004, wastewater discharges accounted for approx. 10% of the total input of nitrogen to marine waters from the land, approx. 45% of the corresponding phosphorus load and approx. 56% of the degradable organic matter load. These calculations do not take into account the amount converted and retained in watercourses and lakes.

Nitrogen, phosphorus and organic matter

Discharges of nitrogen have decreased by approx. 73% since 1989, mainly due to the fact that nitrogen is removed at municipal wastewater treatment plants. Discharges from industry have also decreased markedly.

Discharges of phosphorus have decreased by 85% since 1989 due to the fact that phosphorus is removed at municipal wastewater treatment plants and from industrial wastewater.

Discharges of organic matter (measured as BOD_5) have decreased by 85% since 1989, mainly due to improved biological treatment at municipal wastewater treatment plants but also to a marked decrease in discharges from industry. At the same time, discharges from sparsely built-up areas and freshwater fish farms have also decreased.

The general national reduction targets for wastewater discharges of nitrogen, phosphorus and organic matter have been fulfilled since the mid 1990s. Since then, discharges from wastewater treatment plants have slowly decreased even further. In 2003, biological treatment was established at the last enterprise that discharges large amounts of organic matter via its own industrial outfall.

Hazardous substances

Few hazardous substances have been detected in discharges from municipal wastewater treatment plants, and generally only in low concentrations. In the case of substances for which quality criteria have been set, the concentrations determined are lower than the quality criteria for surface water. The concentrations of heavy metals in the discharged water are also lower than the quality criteria as the wastewater is usually diluted at least 10-fold at the outfall. Many of the hazardous substances are found in the sewage sludge produced during wastewater treatment. A small proportion of the sewage sludge contains hazardous substances in concentrations exceeding the quality criteria for sludge intended for agricultural use. This applies to mercury, nickel, LAS, nonylphenols and DEHP.

Heavy metal and hazardous substance concentrations exceeding the quality criteria for surface water have also been detected in discharges from a few industrial enterprises with separate outfalls.

Input of pollutants via the atmosphere

In 2004, inputs of pollutants to the Danish landmass and water bodies were calculated using a new, improved air pollution model. With this new model the calculated inputs of nitrogen to the landmass and water bodies were 29% and 13% lower, respectively, than those calculated using the model previously employed.

The calculations made with the new model for both 2003 and 2004 show that the input of pollutants via the atmosphere in 2004 was of the same level as in 2003. Thus the calculated nitrogen input to Danish marine waters from the atmosphere in 2004 amounted to approx. 107,000 tonnes N. The corresponding input to the landmass was approx. 68,000 tonnes. The total inputs of nitrogen to the Danish landmass and water bodies from the air have decreased by approx. 20% and 23%, respectively, over the period 1989–2004 due to a reduction in emissions to the atmosphere in both Denmark and at the European level. The calculated inputs of nitrogen remain high, and the resultant pollution considerably affects the majority of natural countryside and the marine waters.

The inputs and concentrations of heavy metals in 2004 do not differ markedly from those in previous years. Inputs of heavy metals have decreased two- to three-fold over the past 16 years, with the decrease being greatest for lead and cadmium.

Wet deposition of organopollutants in precipitation was included in the monitoring programme for the first time in 2004. Measurements made at Anholt and Sepstrup Sande show that wet deposition of pesticides is greatest at Sepstrup Sande in central Jutland. Sepstrup Sande is located in an area with greater precipitation and greater agricultural production than Anholt, an island in the middle of the Kattegat.

Agricultural monitoring catchments

Nitrogen

The field nitrogen surplus has decreased by approx. 33% at the national level over the period 1990–2004. The surplus is the difference between the amount of nitrogen applied to the fields and the amount removed in the crops. The decrease is primarily attributable to reduced consumption of commercial fertilizer combined with other changes in production conditions. During that period, annual consumption of commercial fertilizer decreased by approx. 49% from 394,000 tonnes nitrogen to 202,000 tonnes nitrogen. The nitrogen surplus is greatest for livestock holdings, and increases with livestock density. In 2004, the mean surplus was 95 kg N/ha.

Model calculations for the agricultural monitoring catchments have shown that leaching of nitrogen from the agricultural monitoring catchments has decreased by 46% over the period 1990–2004. Measurements have also shown that the concentration of nitrogen in the root zone water has decreased by approx. 34–50%. The concentration of nitrogen in the upper groundwater under sandy soils has decreased, whereas no marked changes have been recorded under clayey soils. The nitrogen concentration in the watercourses draining the agricultural monitoring catchments has decreased by approx. 20–47% over the period 1990–2004.

Phosphorus

The field phosphorus surplus was 10 kg P/ha at the national level in 2004 as compared with approx. 15 kg P/ha in 1990. On average, only livestock holdings exhibited a surplus, whereas crop holdings exhibited a deficit. Over the period 1990–2004, the input of phosphorus to watercourses averaged 0.21–0.51 kg/ha per year in the agricultural monitoring catchments. Thus only a small proportion of the net input is lost from the fields to surface water. The remainder accumulates in the surface soil or leaches to deeper soil layers. In most places the loss of phosphorus to watercourses from fields mainly takes place via surface runoff or drainage water. The loss increases with increasing accumulation of phosphorus in the field. On the other hand, the phosphorus concentration in the water percolating down from the soil to the groundwater is usually low. No change has been detected over the period 1989–2004 in phosphorus loss from cultivated land or in runoff of phosphorus via the watercourses draining the agricultural monitoring catchments.

Pesticides

One of the objectives of the first Action Plan on Pesticides was that total sales of active ingredient should be reduced 50% by 2003 relative to the level in 1981–1985. This objective has been met. Another objective was to reduce application frequency from 2.04 in 2002 to 1.7 in 2009, but this has not yet been met. The application frequency at the national level expresses the number of times the total area of cultivated land could be treated if the approved dose of each pesticide had been applied.

Pesticides or degradation products were detected one or more times in 69% of the investigated filters located in the upper groundwater. The limit value for drinking water was exceeded one or more times in 25% of the filters located in the agricultural monitoring catchments. Four of the most commonly used pesticides are among those most frequently detected in the near-surface groundwater in the agricultural monitoring catchments over the period 1993–2004, namely bentazon, glyphosate, metamitron and MCPA.

Groundwater

The available groundwater resource in Denmark is approx. 1,000 million m^3 per year. At the national level there is sufficient water to meet requirements for the water supply, which has fluctuated around 600–700 million m^3 per year in recent years. Around the large towns, however, the groundwater resource is too small to meet requirements without markedly affecting watercourses and wetlands.

The limit value for nitrate in drinking water (50 mg nitrate/l) is met by approx. 99% of the water utilized for the drinking water supply. Of the uppermost, newly formed groundwater, about half contains more nitrate than the limit value, although the variation is considerable. The nitrate concentration in the uppermost, newly formed groundwater in sandy areas has decreased in recent years. The decrease is attributable to the measures implemented to reduce leaching of nitrate from cultivated land following adoption of Action Plan on the Aquatic Environment I in 1987. The water in the remaining groundwater bodies is generally formed prior to 1987 and hence is unaffected by the initiatives implemented in connection with the action plan.

The limit value for phosphorus in drinking water is exceeded in the groundwater at approx. 20% of all water supply wells. This is of no great importance, however, as the phosphorus is removed at the waterworks. The measured phosphorus concentration in the groundwater largely reflects the natural phosphorus concentration in the groundwater. The phosphorus concentration is elevated in a small proportion of the very uppermost groundwater, however.

The decline in pesticide detection frequency in water supply wells seen in the preceding year continued in 2004. One of the main reasons for the lower detection frequency is closure of pesticide-contaminated wells. In contrast, the frequency of pesticide detection at the groundwater monitoring sites has increased for concentrations both below and above the limit value for drinking water.

Watercourses

Nutrients

The concentration and transport of nitrogen is generally decreasing in the watercourses that drain cultivated catchments and/or receive large amounts of wastewater. For all watercourses as a whole, the concentration of nitrogen in the water has decreased by an average of 29% since 1989 while the transport of nitrogen has decreased by 34%. The decrease is attributable to a decrease in nitrate leaching from cultivated land and to the fact that nitrogen removal is now carried out at all wastewater treatment plants exceeding 5,000 PE.

The concentration and transport of phosphorus in watercourses receiving wastewater discharges decreased markedly during the first half of the 1990s. It is only slightly higher than that in watercourses draining the agricultural monitoring catchments. The concentration of phosphorus in watercourses has decreased by an average of 43% since 1989, while the transport of phosphorus has decreased by 39%. The decrease is attributable to the upgrading of wastewater treatment plants with phosphorus removal, including at small treatment plants to protect local recipients. The decrease during the early 1990s was a continuation of the decrease that started when phosphorus removal at wastewater treatment plants was introduced around 1980.

Pesticides and heavy metals

The concentrations of heavy metals and pesticides are measured in five watercourses. The heavy metals concentrations recorded in 2004 were considerably lower than the quality criteria for surface waters. In a few cases the concentrations of lead and copper exceeded the quality criteria.

The pesticide monitoring encompasses 10 herbicides and eight of their degradation products. The majority of the samples analysed were found to contain one or more pesticides. Three of the most commonly used herbicides are frequently detected in both watercourses and beneath the fields in the agricultural monitoring catchments, namely glyphosate, MCPA and terbutylazine. Three herbicides whose use is now prohibited are detected in a large proportion of the samples, namely trichloroacetic acid (55%), DNOC (15%) and atrazine (8%). Quality criteria have not been set for the substances analysed for.

Compliance with objectives

The ecological status of watercourses is assessed from the presence of macroinvertebrates. The monitoring results show that the ecological status of Danish watercourses has gradually improved since 1994. This is due to improved wastewater treatment and more environmentally sound watercourse maintenance. Nationwide, 58% of the investigated watercourses met their quality objective in 2004. On Bornholm, all six monitored watercourses met their quality objective as compared with 61% on Funen, 62% in Jutland and only 34% on the island part of Denmark east of the Great Belt. Compliance with objectives is best (88%) for the watercourses with the highest quality objective.

Lakes

Nutrients

The monitoring programme was modified in 2004 and now encompasses extensive monitoring of 1,074 lakes and ponds with a limited programme every 3^{rd} or 6^{th} year. At the same time the intensive monitoring has been cut back from 31 to 23 lakes, of which 20 have been included in the programme since 1989. These changes will ensure that knowledge is procured over the next six years about the status of a large representative part of Danish lakes.

The results from the lakes that were intensively monitored in 2004 show that the environmental status has improved since 1989 due to the decrease in phosphorus loading. The latter varies considerably from lake to lake depending on the degree to which wastewater discharges in the lake catchment have been reduced. On average, the phosphorus concentration in the lakes has almost halved since 1989. Of the phosphorus input to lakes in 2004, approx. 34% derived from wastewater, approx. 44% from cultivation of the land in the catchment and the remaining approx. 22% was natural background loading.

Nitrogen loading and lake water nitrogen concentration have decreased due to the reduction in leaching of nitrate from cultivated land.

In approximately half of the intensively monitored lakes the nutrient concentration in the lake water has decreased. In approx. 1/3 of these lakes this has led to a reduction in the amount of phytoplankton.

Compliance with objectives

Even though the environmental status of the lakes has improved, the current environmental objectives were only met by five of the 23 intensively monitored lakes in 2004. The environmental status of some of the lakes will probably improve further when phosphorus release from the sediment has tailed off. This phosphorus derives from earlier wastewater inputs to the lakes.

The nutrient and algae concentrations in the large number of extensively monitored lakes are higher than in the intensively monitored lakes. As a consequence, the environmental status of Danish lakes as a whole is generally poorer than that of the intensively monitored lakes. One reason for this could be that the extensively monitored lakes are smaller and shallower than the intensively monitored lakes.

Marine waters

Nutrients and eutrophication

The concentrations of inorganic nitrogen and phosphorus have roughly halved in fjords/coastal waters since 1989. This is mainly due to the fact that phosphorus is removed from the wastewater and that leaching of nitrate from cultivated land has decreased. In the open marine waters the change in concentration is less. Due to the lower nutrient concentration, the amount of algae in the marine waters has decreased and Secchi depth has increased since the 1980s, algal production now being more limited by a lack of nitrogen and/or phosphorus than was previously the case.

In 2004 the ecological status of the open water masses was generally poorer than in the preceding five years. Among other reasons this was due to an algal bloom (silicoflagellates) in the Belt Sea in April–June 2004 that probably resulted from the input of nutrients from the bottom water. The generally poorer ecological status in 2004 could also be an after-effect of the extraordinarily great oxygen deficit in 2002 combined with the effects of the climate and sea currents. Oxygen deficit was less extensive in 2004 and lasted a shorter time than in the two preceding years. The oxygen concentration in the bottom water of the fjords/coastal waters has generally been low during the past six years.

No major changes occurred in the abundance and depth distribution of submerged macrophytes in the coastal waters except for a decrease in eelgrass coverage and depth distribution in the innermost part of the fjords. In contrast, the density of benthic invertebrates and the number of species detected in each sediment sample in the inner open marine waters have declined steadily since 1994. Pollution-sensitive species of benthic invertebrates have declined more than the more pollution-tolerant species. In the fjords/coastal waters the decline was due to the extreme oxygen deficit in 2002.

Hazardous substances

In most areas, PCB has been detected in concentrations that could possibly be ecotoxic. Brominated flame retardants were included in the monitoring for the first time in 2004. They were detected in 75% of the samples, with the highest levels being recorded in Vejle Fjord and Øresund, although in much lower concentrations than PCB.

Tributyl tin (TBT) was generally detected in lower concentrations in 2004 than in 2003. In all the areas investigated the concentrations were such as to pose a great risk of causing adverse effects in animals. The concentrations were highest in Randers Fjord and in the fjords of Funen, where there is much shipping and related activities. The use of TBT in antifouling paints is being phased out.

Evidence indicates that eelpout and mussels are affected by hazardous substances in certain coastal waters.

Compliance with objectives

The current quality objective that the flora and fauna should at most be only slightly affected by man's activities is generally considered to be met in the Skagerrak and in the open parts of the North Sea and close to being met in the open northern and central Kattegat. In the remaining Danish marine waters the quality objective is not met, primarily due to nutrient loading. In certain areas compliance with objectives is hindered by high concentrations of TBT, organochlorines, PAH or heavy metals.

Terrestrial natural habitats

Monitoring of terrestrial natural habitats was incorporated into the national monitoring programme from 2004 onwards. The monitoring carried out in 2004 concentrated on areas designated as Special Areas of Conservation (Natura 2000 sites) pursuant to the Habitats Directive. One of the main objectives was to assess Denmark's compliance with the directive.

Development of the majority of Danish terrestrial natural habitats has been governed by a combination of the natural conditions and extensive exploitation of the areas. The monitored areas have been extensively managed as heaths, dry grasslands and meadows. Only a small proportion of the natural habitats, e.g. raised bogs and dunes, have arisen independently of man's activities. The main reasons for the changes in the natural habitats are changes in the management of the land, including drainage and fertilization, and the input via the air of pollutants derived from combustion processes and agriculture. The input of nitrogen from the air favours the nutrient-demanding species at the cost of the vegetation that is characteristic for nutrient-poor natural habitats. The cessation of grazing often results in the habitats becoming overgrown with trees and bushes.

2004 was the first year in which terrestrial natural habitats were included in the monitoring programme. The results provide a foundation for assessing the environmental status of the natural habitats that are encompassed by the Habitats Directive. It is not possible to assess whether their status complies with the objectives, however, as specific operational criteria for favourable conservation status have not yet been set.

Species monitoring

Species monitoring was incorporated into the national monitoring programme from 2004 onwards. The monitoring focuses on the occurrence of selected plant and animal species encompassed by the Habitats Directive and breeding birds encompassed by the Birds Directive, as well as species of which more than 20% of the global population occurs in Denmark (vascular plants, moths and regularly occurring migratory birds). One of the main aims of the monitoring is to assess whether Denmark meets its obligations under the Habitats Directive and Birds Directive.

Some species have been monitored for many years under other programmes. By way of example, the main conclusions are presented here for four species: Otter, floating water-plantain, marsh fritillary and greylag goose.

Otter range and population size have increased markedly since 1984–86. The positive trend in the population is due to improvements in habitats, the establishment of fauna passages at roads and obligatory use of otter guards on eel traps.

The floating water-plantain grows in ponds and watercourses with slowly flowing or stagnant water at a few localities in western Jutland. No marked changes in occurrence have been detected since 2002.

The marsh fritillary butterfly lives on humid heaths and unfertilized meadows on infertile soil vegetated with their preferred host plant, the devil's-bit scabious. It was only detected in northern Jutland in 2004, and there are no signs of marked changes in its occurrence in recent years.

In connection with an international census, greylag geese have been counted each year in September at selected localities since 1984. The number of greylag geese has increased steadily over the period, although most markedly since 1995.

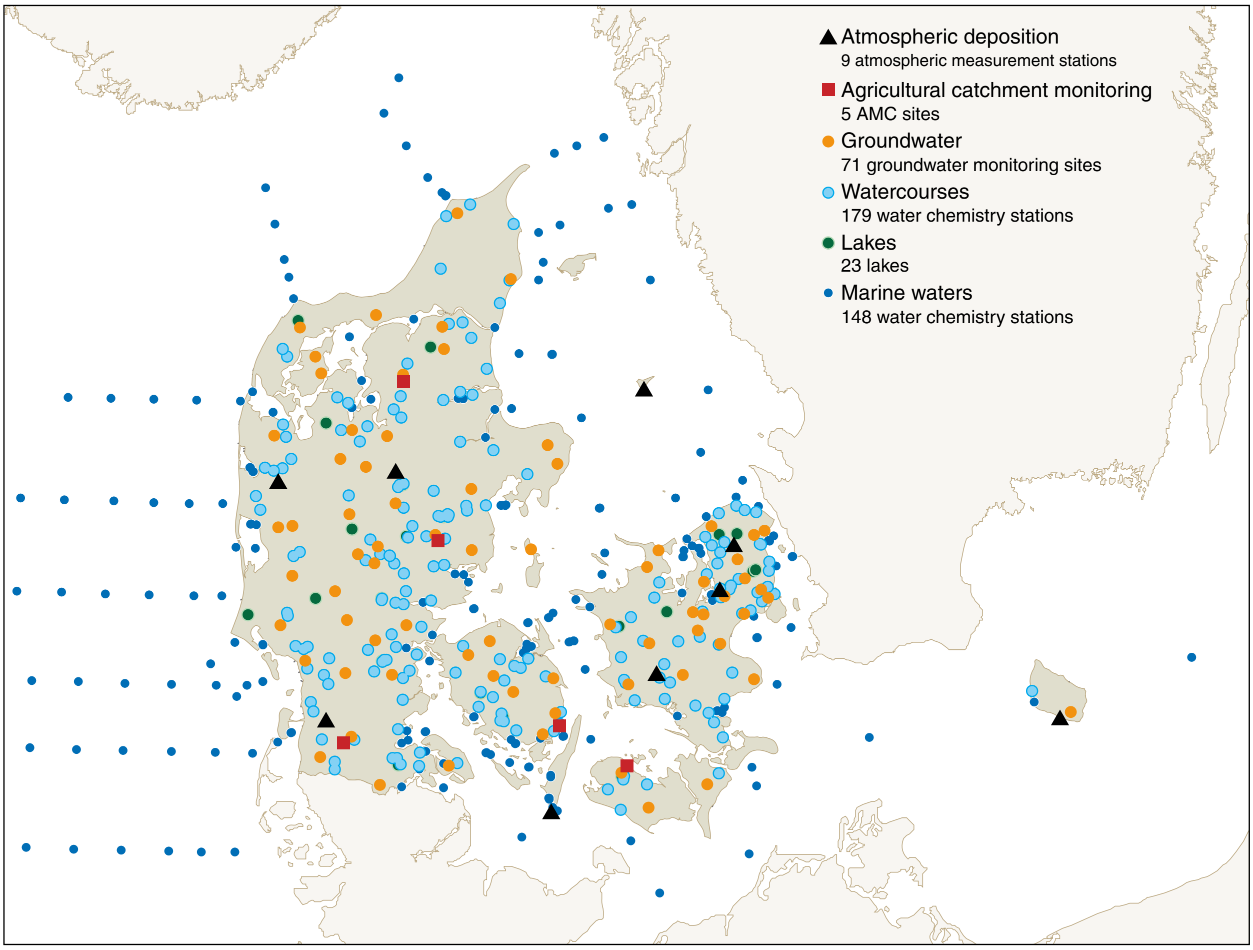
1 Introduction

1.1 The national monitoring programme

The National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA) started on 1 January 2004. Before then, Denmark had a national programme for monitoring the aquatic environment started in connection with the 1987 Action Plan on the Aquatic Environment. At that time the emphasis was on monitoring water chemistry in marine waters, coastal waters, lakes, watercourses and groundwater, as well as the main sources of pollution, namely wastewater, agriculture and atmospheric deposition. In 1998, hazardous substances were added to the monitoring programme.

Since implementation of NOVANA in 2004 Denmark has had an integrated, systematic nationwide programme for monitoring both the aquatic and terrestrial environments.

Figure 1.1 NOVANA monitoring sites for selected parts of the atmospheric, agricultural catchment, groundwater, lake, watercourse and marine water subprogrammes.

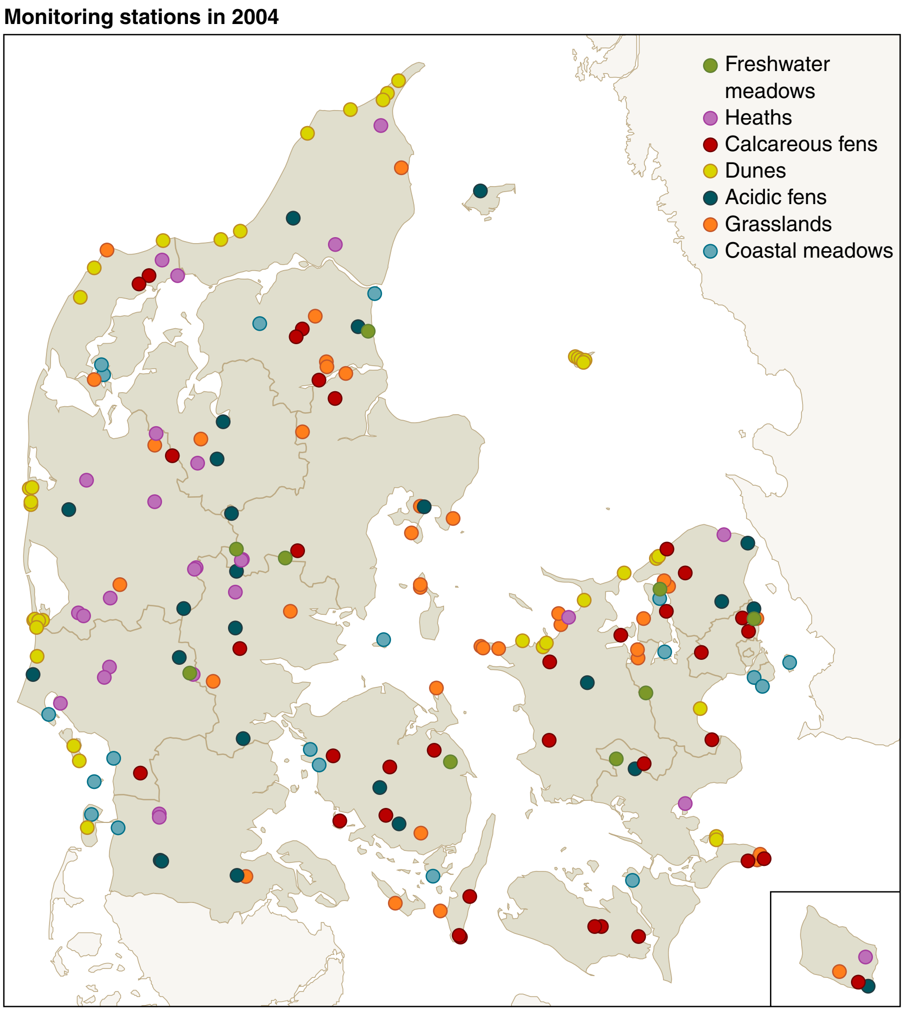


Through the present programme Denmark can meet the majority of its international monitoring and reporting obligations regarding the aquatic and natural terrestrial environments. Monitoring of terrestrial natural habitats has been included in the national monitoring programme among other reasons in order to meet Denmark's obligations pursuant to the Habitats Directive and Birds Directive. Moreover, greater priority has been accorded to monitoring of animals and plants in the water bodies. Some adjustments have been made to the aquatic environment monitoring programme in order to meet requirements pursuant to the Water Framework Directive.

In the coming years, monitoring of terrestrial natural habitats under NOVANA will be expanded with an extensive programme in order to enable a nationwide assessment of habitat conditions in Denmark.

The monitoring stations are distributed throughout the country. The location of the monitoring stations for selected parts of the subprogrammes for atmospheric deposition, agricultural catchments, groundwater, watercourses, lakes and marine waters are shown in Figure 1.1. The location of the monitoring stations for selected parts of the subprogramme for terrestrial natural habitats is shown in Figure 1.2.

Figure 1.2 NOVANA monitoring sites for terrestrial habitat types.



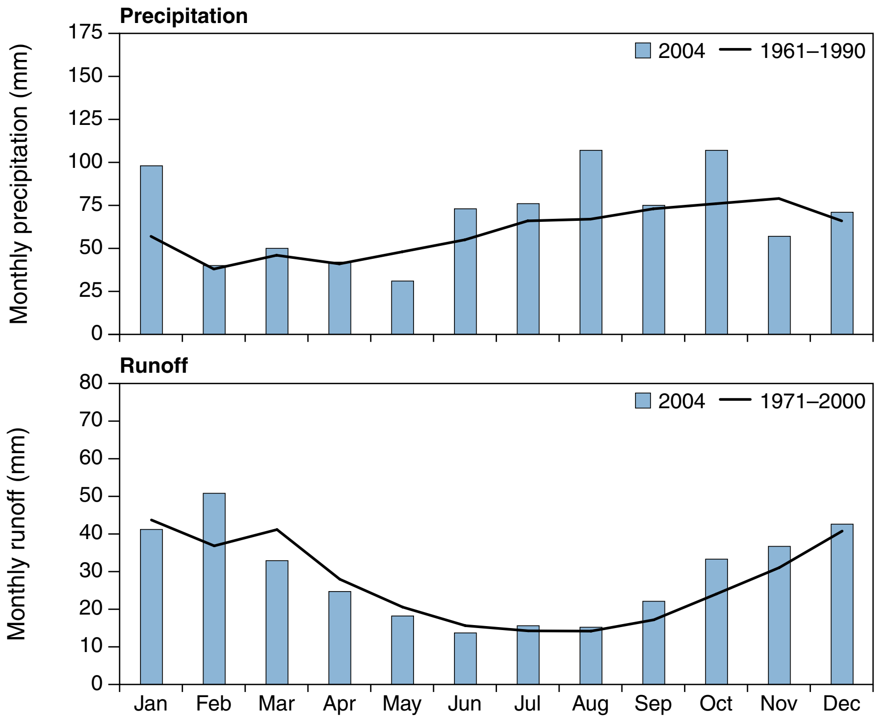
1.2 Weather and runoff in 2004

The amount of precipitation that falls during the course of a year considerably influences the amounts of water and nutrients lost to the aquatic environment from the surrounding catchment. High levels of precipitation in the autumn and winter in particular will rapidly lead to the input of large amounts of nitrogen and phosphorus to watercourses and lakes and further on out into the marine waters where they will be available for phytoplankton blooms the following spring. On the other hand, above-normal flow levels will improve conditions in watercourses as drying-out will be avoided and wastewater dilution will be enhanced. The temperature and number of hours of sunshine are important, for example for the length of the growth season, volatilization, etc. The weather conditions in combination will therefore affect nutrient and organic matter losses to the aquatic environment from land, groundwater recharge and the state of the aquatic environment.

The weather in 2004

Precipitation in 2004 was 827 mm, approx. 16% greater than the normal value (712 mm) and as much as 197 mm greater than in 2003 (Figure 1.3).

Figure 1.3 Monthly mean precipitation and freshwater runoff in 2004 compared with normal values (*Bøgestrand (ed.), 2005* and *Capellan & Jørgensen, 2005*).



Like in 2003, the annual mean temperature was high in 2004 at 8.7 ºC – fully 1ºC more than the normal value. With a mean temperature of 8.5 ºC, the period 1989–2004 was somewhat warmer than the normal value, not least due to the very mild winters. There were 1,724 hours of sunshine in 2004 compared with the normal value of 1,495 hours.

Runoff

Freshwater runoff in 2004 is calculated to be 14,900 million m^3. This corresponds to 347 mm water from the total area of the landmass, 6% more than the normal value for the period 1971–2000, which was 328 mm. The runoff exceeded the normal value in February and from September to the end of the year, largely reflecting the distribution of precipitation, but with a delay of 1–2 months (Figure 1.3).

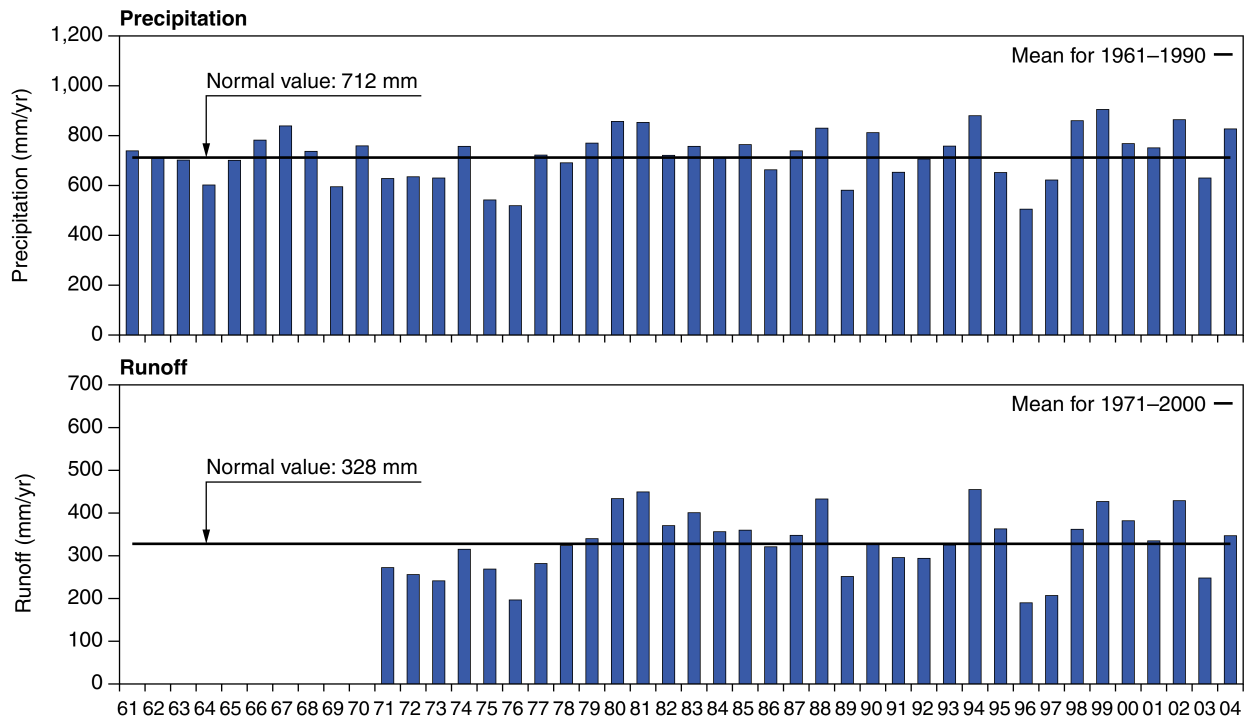
As with precipitation, there is considerable geographic variation in freshwater runoff. Thus runoff from the catchments feeding the North Sea amounted to as much as 450–500 mm (slightly above the normal value for these catchments), while runoff to the southern Belt Sea, the Great Belt, the Baltic Sea and the Øresund was typically 150–200 mm (like the normal value for these catchments).

Runoff over the period 1989–2004 amounted to 327 mm and hence was normal (Figure 1.4). Winter runoff amounted to 164 mm, 5 mm more than the normal value.

The trend in the groundwater table and hence in the amount of groundwater that runs into the surface waters typically follows the precipitation, but in sandy areas in particular with a delay of several years.

Precipitation and runoff were low in 2003, and more nitrogen may therefore have been retained in the soil on agricultural land than under normal precipitation conditions. Given the high level of precipitation at the beginning of 2004 it is therefore possible that leaching of nitrogen to the aquatic environment was higher than in a normal year.

Figure 1.4 Annual mean precipitation and runoff in Denmark over the period 1961–2004. The long-term normal values are also shown.



2 Nitrogen

2.1 Nitrogen pollution

Nitrogen loading of water bodies and terrestrial natural habitats as a result of man's activities is a major cause of pollution. In groundwater, exceedance of the limit value for nitrogen in drinking water renders the water unfit for the water supply. In marine waters and some lakes, nitrogen loading leads to enhanced algal growth. In watercourses, in contrast, ecological conditions are independent of the nitrogen concentration unless it is in the form of ammonium, which can have toxic effects and reduce the oxygen content. In terrestrial natural habitats, input of nitrogen compounds via the atmosphere leads to fertilization of the habitats and thereby often to changes in the habitat in question.

Objectives

Groundwater intended for use as drinking water may not contain more than 50 mg nitrate/l, corresponding to 11.4 mg nitrogen/l. Upon adoption of the forthcoming EU Groundwater Directive this limit is expected to apply to all groundwater. No general objectives have been set for the nitrate content of watercourses, lakes or marine waters. Pursuant to Action Plan on the Aquatic Environment I from 1987, however, nitrogen discharges to the aquatic environment have to be reduced to no more than 50% of the level in the mid 1980s. In addition, it is a general objective that nitrogen loading must not hinder achievement of the environmental objectives for water bodies and terrestrial natural habitats.

Nitrogen loading from the landmass in 2004

Total inputs of nitrogen compounds to the sea from the landmass amounted to 75,400 tonnes N in 2004 (Table 2.1). Total inputs to water bodies amounted to 87,600 tonnes N, of which 12,200 tonnes N was retained in inland waters on its way to the sea. Leaching of nitrate from cultivated land is by far the greatest source (67,800 tonnes N), accounting for 77% of the total inputs to water bodies. It should also be noted that background loading exceeds the sum of all wastewater discharges.

Table 2.1 Total nitrogen input to the aquatic environment in 2004 apportioned by source (*Bøgestrand (ed.), 2005* and *Danish EPA, 2005*).

Nitrogen source	Nitrogen load in 2004 (tonnes N)
Background loading	12,200
Leaching from farmland	67,800
Sparsely built-up areas	900
Wastewater to inland waters	3,600
Retention in inland waters	-12,200
Runoff to the sea via watercourses	72,300
Wastewater direct to the sea	2,800
Marine and saltwater fish farms	300
Total to the sea	75,400

Trend in nitrogen loading from the landmass

The trend in annual nitrogen loading of marine waters since the 1980s is shown in Figure 2.1. There is considerable interannual variation due to differences in the amount of precipitation (see Section 1.2). As a consequence, no clear reduction in nitrogen input can be identified. The reduction becomes clearer if the figures are corrected for interannual differences in freshwater runoff.

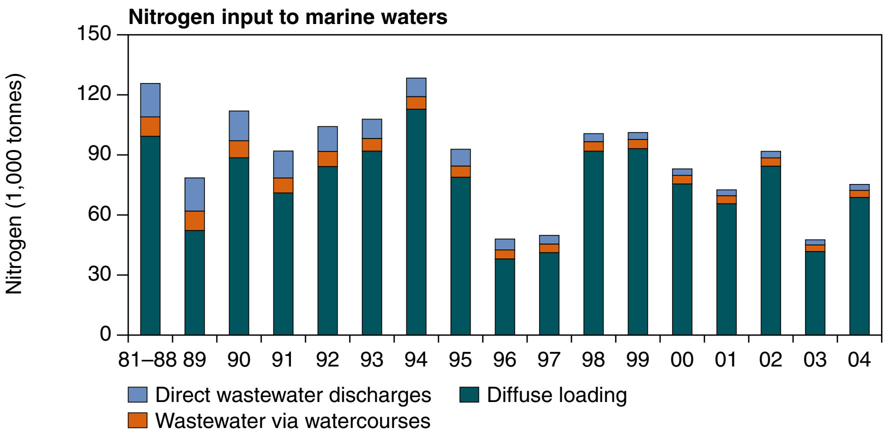


Figure 2.1 Total annual nitrogen input to marine waters via watercourses and direct wastewater discharges (*Bøgestrand (ed.), 2005*).

Nitrogen loading via the atmosphere

Nitrogen input via the atmosphere is an important source of nitrogen pollution of terrestrial natural habitats and the open marine waters. Input is greatest over land and diminishes the greater the distance from the sources of the pollution, which are both Danish and foreign. The main sources are the nitrogen compounds emitted in connection with combustion processes and the volatilization of ammonia from livestock holdings. The total input and mean input per hectare are shown in Table 2.2.

Table 2.2 Nitrogen input via the air in 2004 (data from *Ellermann et al., 2005*).

Nitrogen input via the air in 2004	Total input (tonnes N)	Mean (kg N/ha)
Danish landmass (43,000 km^2)	68,000	16
Danish marine waters (103,000 km^2)	107,000	10

Compliance with objectives

The nitrogen reduction targets specified in Action Plan on the Aquatic Environment I for wastewater and leaching from cultivated land have already been met. Compliance with the quality objectives for water bodies is dealt with in the chapters on groundwater, watercourses, lakes and marine waters.

2.2 Nitrogen deposition from the atmosphere in 2004

Deposition of nitrogen from the atmosphere makes a major contribution to total nitrogen loading of Danish marine waters and terrestrial natural habitats. One of the main aims of the atmospheric part of NOVANA is therefore to determine annual deposition of nitrogen, the geographic distribution of deposition and the trends therein.

Objective

The EU Directive on national emission limits and the Gothenburg Protocol require Denmark to reduce emissions of nitrogen oxides and ammonia by 60% and 43%, respectively, in 2010 relative to emissions in 1990. Overall, the Gothenburg Protocol will entail a 41% and 17% reduction in emissions of nitrogen oxides and ammonia, respectively, relative to emissions in 1990.

Table 2.3 Measured nitrogen deposition in 2004. The value for Anholt represents deposition on the sea surface, while the other values represent deposition on land surfaces with low vegetation (data from *Ellermann et al., 2005*).

Measurement station	Nitrogen (kg N/ha)
Tange	17
Ulfborg	11
Lindet	20
Anholt	7
Frederiksborg	11
Keldsnor	15

Measured nitrogen deposition in 2004

Annual nitrogen deposition measured at the six main Danish measurement stations in 2004 was 11–20 kg N/ha on the land and 7–11 kg N/ha on the marine waters (Table 2.3). This is roughly the same level as in 2003, when deposition was 8% higher on land and 13% lower on marine waters than in 2004, i.e. largely unchanged, despite the fact that precipitation was somewhat higher in 2004 than in 2003 (827 mm versus 630 mm).

The lowest deposition was recorded at the measurement station on Anholt, which is located in the centre of the Kattegat and hence far from local sources of nitrogen. Deposition was highest at the Lindet and Tange stations, both of which are located in agricultural areas with high emissions of ammonia from livestock holdings.

Modelled deposition on the sea

Total deposition of nitrogen on Danish marine waters (103,000 km^3) in 2004 is calculated to be approx. 107,000 tonnes N. This corresponds to a mean deposition of approx. 10 kg N/ha. Modelled deposition of nitrogen in 2004 was approx. 13% lower than the modelled deposition in 2003. The difference is solely attributable to the fact that the 2004 calculations were made using a new, improved model, DEHM. This yields results that are 12% smaller than the model previously used, ACDEP.

Deposition varied two-fold between the various stations (Figure 2.2) and was highest on the coastal waters and fjords, where deposition is affected by local sources. Thus calculated deposition was highest on parts of Limfjorden (16 kg N/ha) and lowest on the Skagerrak (9 kg N/ha). Moreover, a gradient is apparent with deposition being highest in the south and lowest in the north. This is attributable to the influence of areas of high nitrogen emission in the countries south of Denmark.

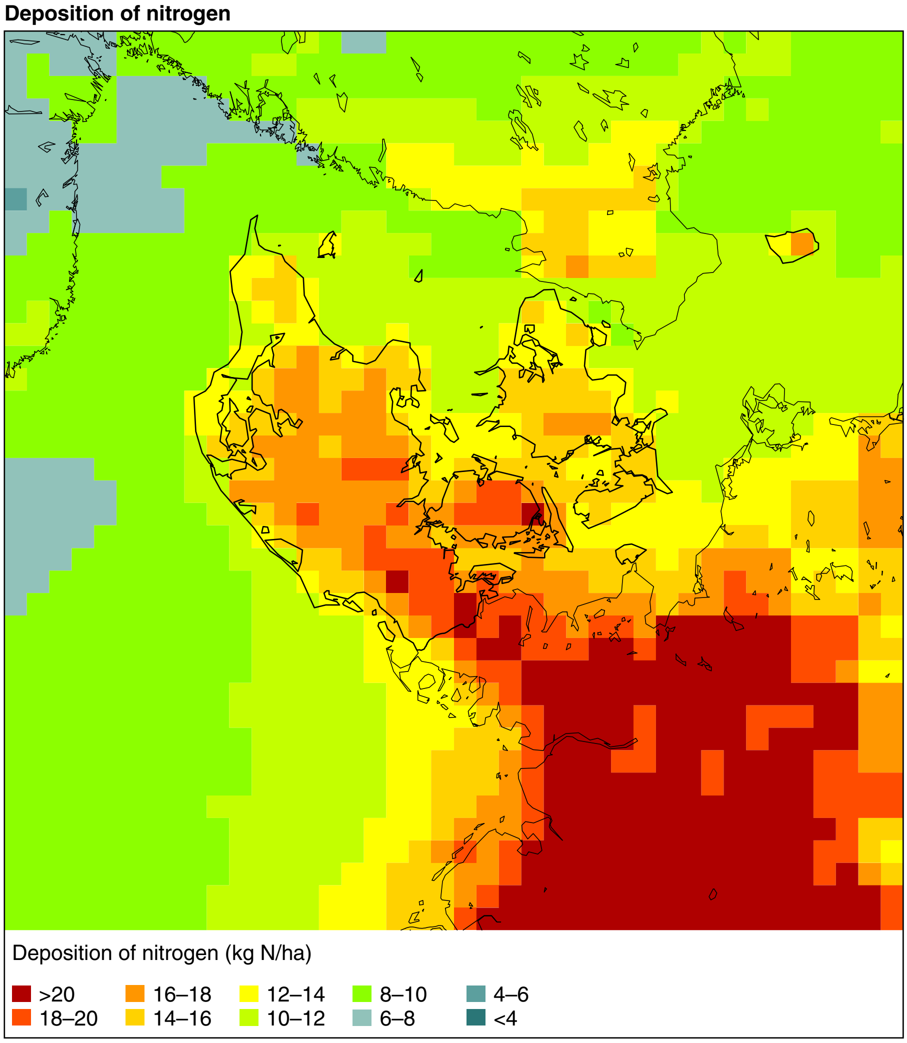


Figure 2.2 Calculated total deposition of nitrogen compounds in 2004. The mean value is shown for each 17 x 17 km quadrant (*Ellermann et al., 2005*).

Modelled deposition on the landmass

Total nitrogen deposition on the Danish landmass in 2004 was approx. 68,000 tonnes N. The level of modelled deposition was the same in 2003 and 2004, but has been adjusted due to the switch to an improved calculation model. Mean deposition, which is approx. 16 kg N/ha, is on par with or just above the critical loads for many of the vulnerable Danish habitat types such as raised bogs (5–10 kg N/ha) and heaths (10–15 kg N/ha (*Bak, 2003*).

Deposition on land varied between approx. 10 kg N/ha and 20 kg N/ha (Figure 2.2). The magnitude of deposition also depends on local agricultural activity because ammonia is deposited close to its source. On the local scale the variation can therefore be considerably greater than the mean values calculated for the model's 17 km x 17 km quadrants (Figure 2.9).

Total deposition

Total deposition of nitrogen on the Danish marine waters and landmass is summarized in Table 2.4. The table shows that dry deposition per km^2 is greater on the land than on the sea. Among other reasons this is due to the fact that dry deposition of nitrogen is greater on vegetated land than on water, and that the concentration of ammonia is higher over land than over water due to the closer proximity to the sources.

Table 2.4 Atmospheric deposition of nitrogen on Danish marine waters and landmass in 2004 (data from *Ellermann et al., 2005*).

Nitrogen deposition in 2004	Dry deposition (tonnes N)	Wet deposition (tonnes N)	Total deposition (tonnes N)	Deposition/ha (kg N/ha)	Area (km^2)
Danish marine waters	44,000	65,000	107,000	10	103,000
Danish landmass	36,000	32,000	68,000	16	43,000

2.3 Atmospheric deposition: Source apportionment and trend

The nitrogen deposited on the Danish landmass and marine waters derives from a large number of Danish and foreign sources. In order to be able to assess the effect of action plans aimed at reducing emissions it is necessary to quantify the influence of the various Danish and foreign sources of the nitrogen deposited on Denmark.

Sources of nitrogen deposition

Through modelling it is possible to estimate the proportion of the deposition on Denmark that derives from Danish and foreign sources, respectively. It is also possible to differentiate between deposition attributable to nitrogen oxides derived from combustion processes (e.g. transport, power stations, incineration plants and industrial production) and ammonia derived from agricultural production.

By far the majority of the nitrogen deposited on Danish marine waters derives from foreign sources (Figure 2.3). On average the Danish share of the deposition on the Danish open marine waters is only approx. 20%, being greatest in the northern Belt Sea (34%) and Little Belt (33%) and least in the North Sea (17%). The proportion deriving from Denmark can be considerably greater for closed fjords, coves and bays due to the close proximity to Danish sources. Figure 2.3 also shows that the Danish share of the deposition mainly derives from agricultural production.

As regards the Danish landmass the Danish share of the deposition (Figure 2.4) is greater than for the Danish marine waters, averaging approx. 46%. The primary reason for this is the greater deposition of ammonia from local farm holdings. In Jutland, ammonia from Danish agriculture accounts for approx. 38% of total nitrogen deposition as compared with only 11% on Bornholm. This ammonia derives from livestock production.

Figure 2.3 Deposition of nitrogen on selected Danish marine waters in 2004 apportioned by domestic and foreign sources subdivided as emissions from combustion processes and agricultural production (*Ellermann et al., 2005*).

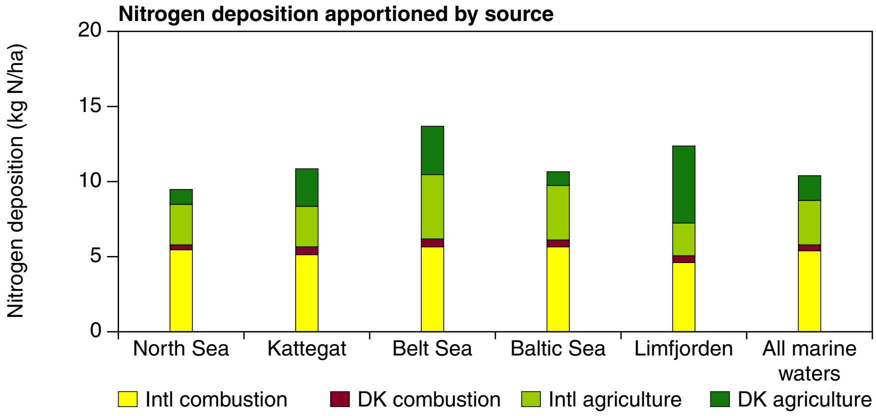
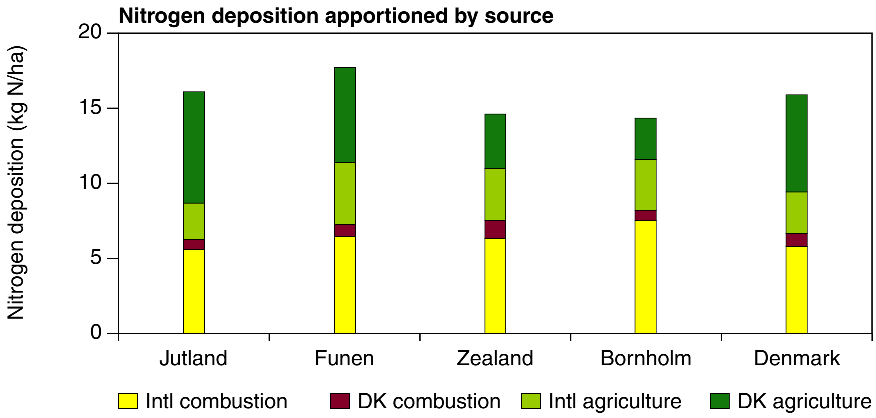


Figure 2.4 Mean nitrogen deposition on Jutland, Funen, Zealand, Bornholm and Denmark as a whole in 2004 apportioned by domestic and foreign sources subdivided as emissions from combustion processes and agricultural production (*Ellermann et al., 2005*).



Trend in nitrogen deposition

The trend in deposition calculated as the mean nitrogen deposition at NERI's main measurement stations (see Figure 1.1) is shown in Figure 2.5. The results reveal an approx. 20% decrease in nitrogen deposition on Danish marine waters since 1989 and an approx. 23% decrease in nitrogen deposition on the Danish landmass.

The magnitude of atmospheric nitrogen deposition follows the changes in emissions of nitrogen in Denmark and the other European countries (Figure 2.5). As the majority of the deposited nitrogen derives from abroad, the reduction is largely attributable to reductions in emissions from foreign sources. The decrease in emissions from Danish sources also contributes to the reduction in nitrogen deposition, though, namely in certain parts of Jutland where up to half of the deposited nitrogen derives from Danish sources.

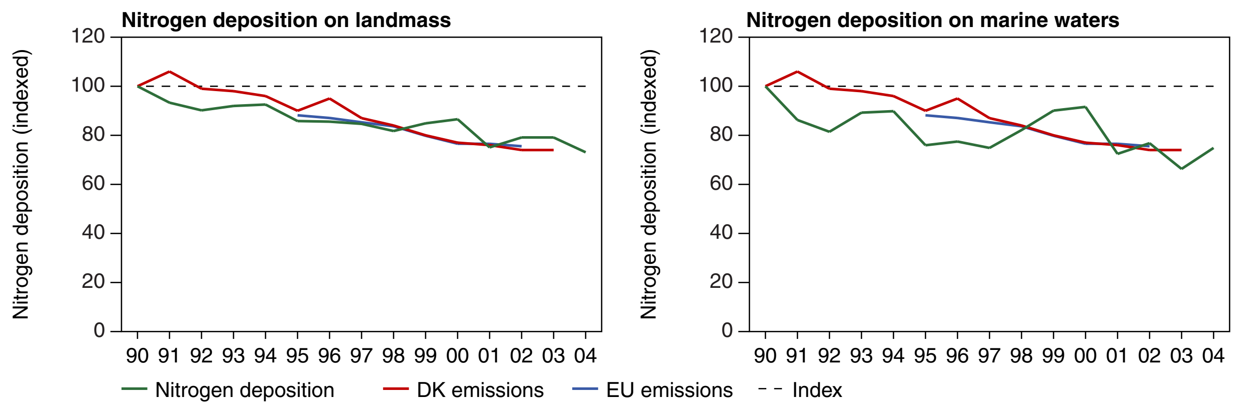


Figure 2.5 Trend in total deposition and emission of nitrogen. All values are indexed to 100 in 1990 (*Ellermann et al., 2005*).

2.4 Nitrogen loading of terrestrial natural habitats from the air

Terrestrial natural and semi-natural habitats that are not deliberately fertilized are affected by nitrogen loading from the air. It is undesirable that nitrogen loading from the air reaches such high levels that the species composition of the natural habitats changes, i.e. that the critical load for nitrogen is exceeded for the ecosystem in question.

In order to be better able to assess the relationship between nitrogen loading and the ecological status of the terrestrial natural habitats, measurement of ammonia and particulate ammonium was initiated at Idom Heath and Hjelm Heath near Holstebro in Western Jutland in 2004. As part of the general determination of nitrogen loading, measurement of gaseous ammonia and nitric acid and of particulate ammonium and nitrate has been improved at some of the permanent measurement stations.

Seasonal variation in the ammonia concentration in the air

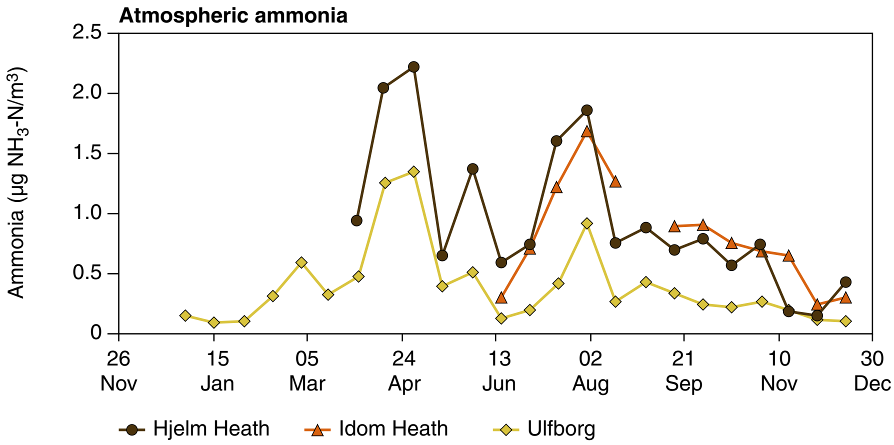


Figure 2.6 Atmospheric concentration of ammonia at Hjelm Heath, Idom Heath and above woodland at Ulfborg. The measurements are half-month mean values (*Ellermann et al., 2005*).

The ammonia concentration at Hjelm Heath, Idom Heath and above the woodland at Ulfborg is shown in Figure 2.6. No uniform pattern is apparent, but the concentration levels are slightly higher on the heaths than at the woodland station, which is located further away from local sources than the heaths. The concentrations peak in the spring, as this is the season for spreading fertilizer on the fields. The high concentrations in August are probably the combined result of agricultural activities and warm weather conditions – all things being equal, a raised temperature increases emissions.

The corresponding values for the atmospheric concentration of particulate ammonium are shown in Figure 2.7. The seasonal variation is roughly the same as for ammonia (Figure 2.6), but with much less variation and a uniform concentration at all three stations. This is due to the fact that the particulate ammonium derives from long-range transboundary transport, among other places from areas south of Denmark.

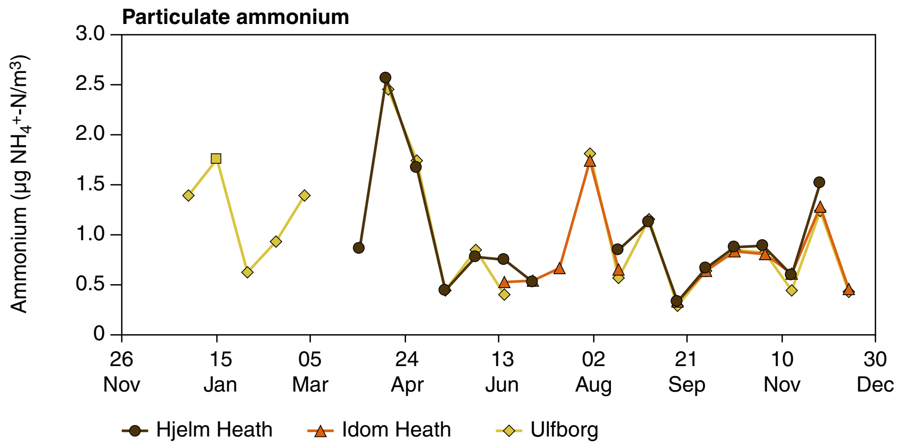


Figure 2.7 Atmospheric concentration of particulate ammonium at Hjelm Heath, Idom Heath and above woodland at Ulfborg. The measurements are half-month mean values (*Ellermann et al., 2005*).

Short-term variation in atmospheric ammonia concentration

In September 2004, intensive measurements were made of the ammonia concentration in the air at a height of 3 m above Idom Heath.

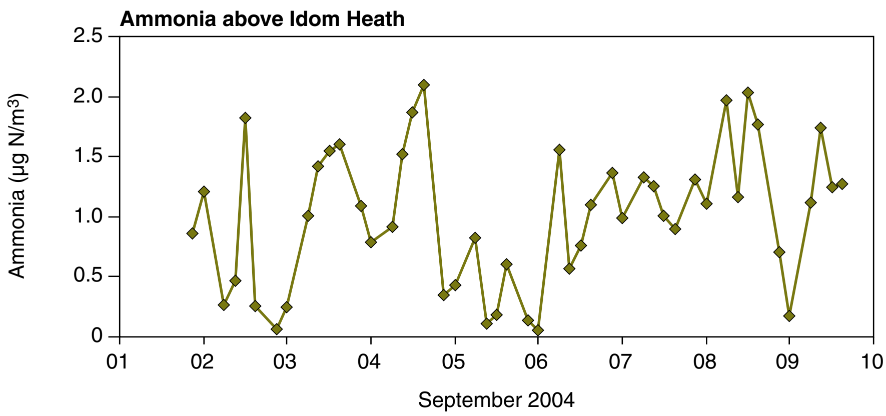


Figure 2.8 Concentration of ammonia at a height of 3 m above Idom Heath. The measurements are 3-hr mean values (*Ellermann et al., 2005*).

The ammonia concentration is shown as 3-hr mean values in Figure 2.8. It can be seen that the concentration fluctuates considerably from less than 0.1 µg N/m^3 to 2 µg N/m^3. This fluctuation is associated with the very changeable wind direction and hence input from various sources, especially ammonia emissions from livestock holdings.

The low night-time concentrations on the 3rd, 6th and 9th occurred concomitantly with surface mist/fog, and it is possible that the surface fog had absorbed the ammonia. Mist/fog was also recorded on the 5th and 7th, however, when the ammonia concentration did not fall to such low levels.

Ammonia deposition on terrestrial natural habitats – modelling at the local scale

Atmospheric deposition of nitrogen on the Danish landmass varies from region to region, but there is also considerable variation on the local scale, in particular depending on the local livestock density. In order to elucidate this variation, dry deposition of nitrogen has been modelled at high geographic resolution (400 m x 400 m) in 25 selected terrestrial natural habitats.

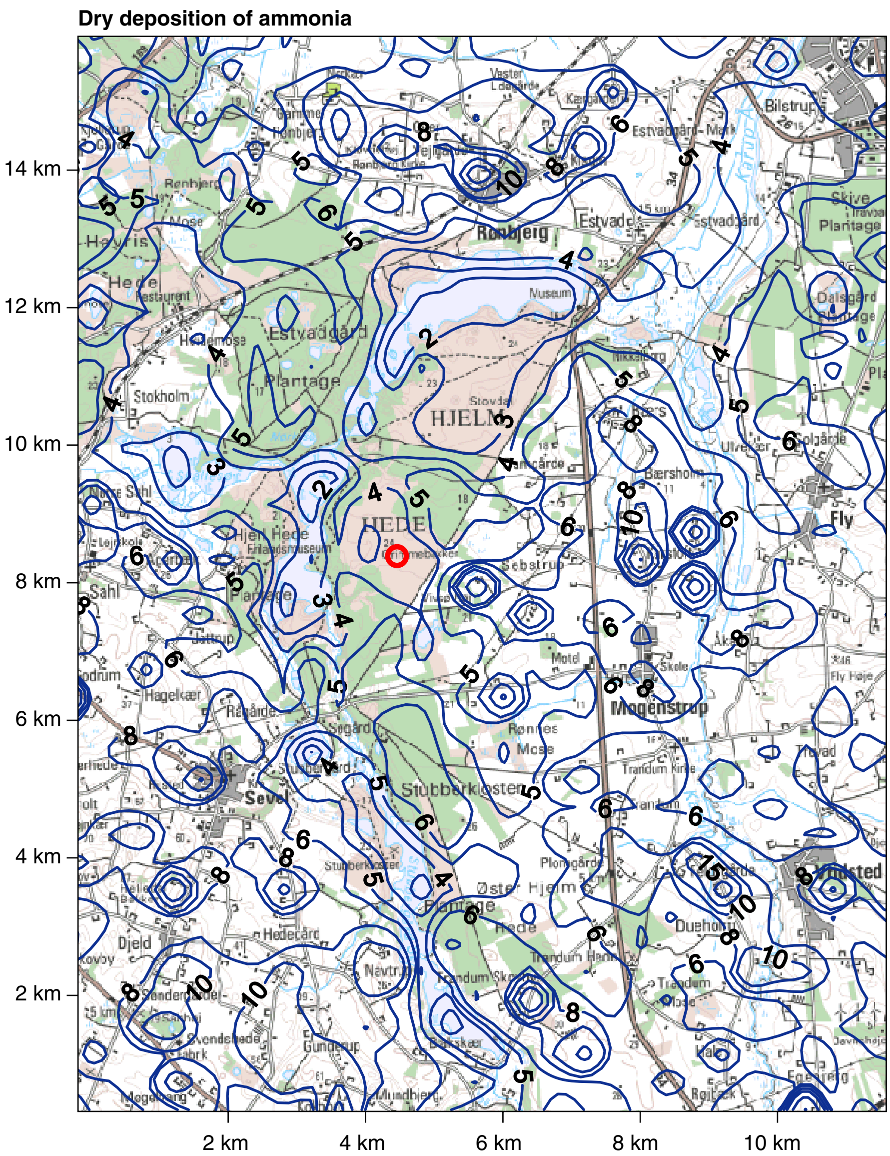


Figure 2.9 Calculated geographic variation in dry deposition of ammonia (kg N/ha) in an approx. 10 km x 16 km area of Hjelm Heath in 2004. The levels shown are 3, 3.5, 4, 5, 6, 7, 8, 9, 10, 15, 20, 30 and 50 kg N/ha. The total deposition of nitrogen at a given point in the area is determined by adding 10 kg N/ha to the values shown in the figure (*Ellermann et al., 2005*).

An example of the results of these calculations is shown for Hjelm Heath in Figure 2.9. The highest values for calculated annual dry deposition of ammonia in a 400 m x 400 m quadrant are approx. 50 kg

N/ha in the immediate vicinity of livestock housing/manure stores. Deposition decreases to under 10 kg N/ha within a few hundred metres of the individual sources, though. On Hjelm Heath, which is free of concentrated livestock holdings, annual ammonia deposition amounts to approx. 3 kg N/ha.

2.5 Wastewater discharges of nitrogen

Municipal wastewater treatment plants

Nitrogen removal has been established at virtually all wastewater treatment plants with a capacity exceeding 5,000 PE in order to meet the discharge standard of 8 mg N/l specified in the 1987 Action Plan on the Aquatic Environment I. The 286 wastewater treatment plants subject to nitrogen removal requirements treated 90% of all the wastewater in 2004. The mean effluent concentration from these wastewater treatment plants was 4.9 mg N/l in 2004. The total amount of wastewater discharged from all treatment plants in 2004 amounted to 712 million m^3. This contained 4,027 tonnes N, corresponding to 5.7 mg N/l.

The trend in annual discharge of nitrogen from municipal wastewater treatment plants since the 1980s is shown in Figure 2.10. Since 1995, the total discharge has been less than the target specified in Action Plan on the Aquatic Environment I. Since the 1980s, nitrogen discharge has been reduced by 80%.

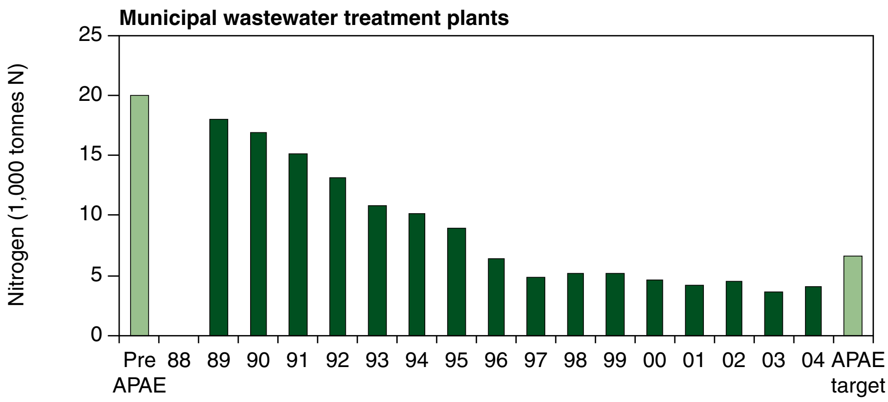
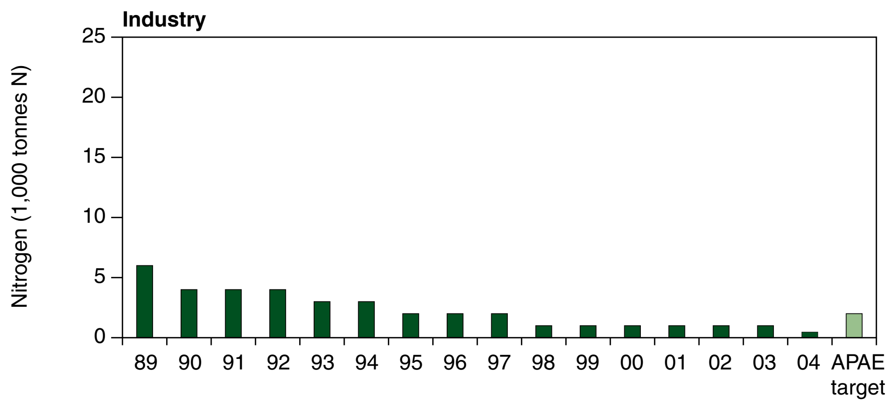


Figure 2.10 Trend in annual discharge of nitrogen from municipal wastewater treatment plants (*Danish EPA, 2005*).

Separate industrial discharges

The magnitude of direct industrial discharges to water bodies is much less than that of discharges via municipal wastewater treatment plants. Thus total discharges in 2004 amounted to 63 million m^3 containing 469 tonnes N, which corresponds to a mean concentration of 7.5 mg N/l. Total discharges of nitrogen have decreased from approx. 6,500 tonnes N in the 1980s to approx. 500 tonnes N in the past two years, or approximately ¼ of the target of 2,000 tonnes N per year stipulated in the 1987 Action Plan on the Aquatic Environment I. The reduction is due to the fact that many enterprises have connected up to the municipal wastewater treatment plants or have installed cleaner technology and improved treatment methods. In all, separate industrial discharges of nitrogen have been reduced by 93% since 1989 (Figure 2.11).

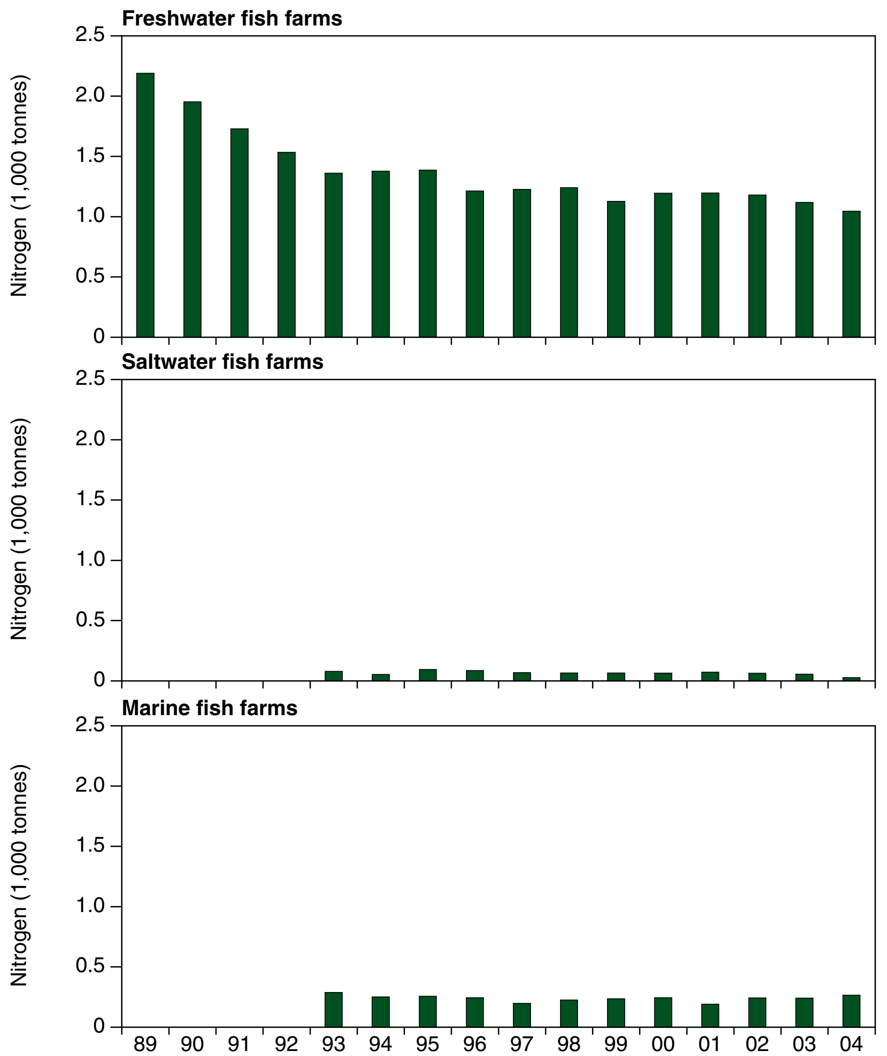
Figure 2.11 Trend in annual discharge of nitrogen from separate industrial discharges (*Danish EPA, 2005*).



Aquaculture

Total discharges of nitrogen from the production of fish in freshwater fish farms, saltwater fish farms and marine fish farms are calculated from theoretical calculations, among other things based on the feed consumption.

Figure 2.12 Trend in theoretically calculated annual discharges of nitrogen from freshwater fish farms, saltwater fish farms and marine fish farms (*Danish EPA, 2005*).



The trend in calculated discharges is shown in Figure 2.12. A considerable reduction can be seen in discharges from freshwater and saltwater fish farms, whereas discharges from marine fish farms have not decreased. Total calculated discharges for the three types of fish production in 2004 were 1,046 tonnes N, 27 tonnes N and 265 tonnes N, respectively.

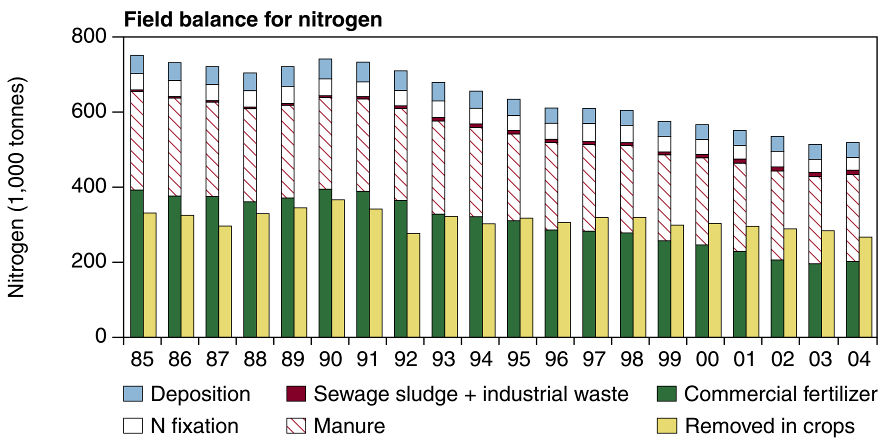
In 2004, discharges were also calculated on the basis of specific measurements at approx. 125 freshwater fish farms. Assuming that these fish farms are representative of all freshwater fish farms it can be calculated that the total annual discharge was 668 tonnes N, considerably less than the theoretically calculated discharge of 1,046 tonnes N.

2.6 Nitrogen in agriculture

Fertilizer consumption

Nationwide consumption of commercial fertilizer has decreased from 394,000 tonnes N in 1990 to 202,000 tonnes N in 2004. Over the same period the amount of nitrogen applied as manure has decreased from 244,000 tonnes N to 232,000 tonnes N. The total surplus in the field balance has thereby decreased from 375,000 tonnes N in 1990 to 251,000 tonnes N in 2004, a reduction of 33% (Figure 2.13). A small part of the reduction is due to the fact that some arable land is no longer cultivated. If the surplus is calculated on a per hectare basis, the surplus has decreased by 29%. In 2004 the surplus was 95 kg N/ha.

Figure 2.13 Trend in applied nitrogen and nitrogen removed in the crops for all agricultural land in Denmark over the period 1985–2004 (*Grant et al., 2005*).



The nitrogen surplus is least for crop holdings (49 kg N/ha) and somewhat greater for livestock holdings (80 kg N/ha). The surplus increases with increasing livestock density (Figure 2.14).

Utilization of the nitrogen content of manure has improved markedly due to the increase in storage capacity, the increasing proportion of the manure that is applied in the spring and summer, and the implementation of improved spreading techniques.

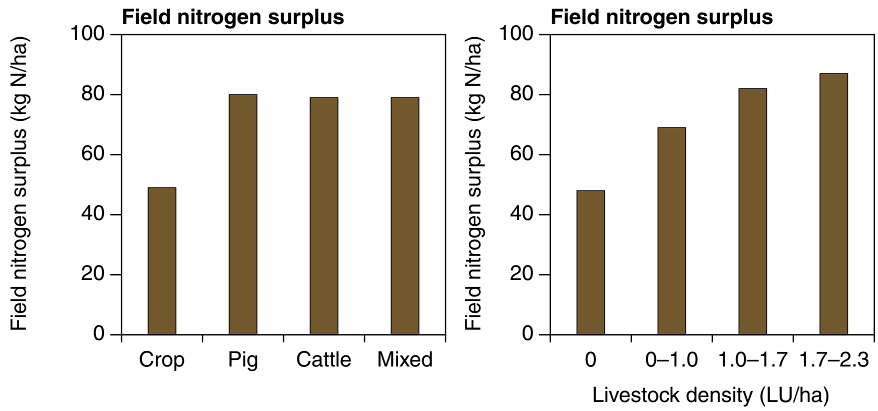


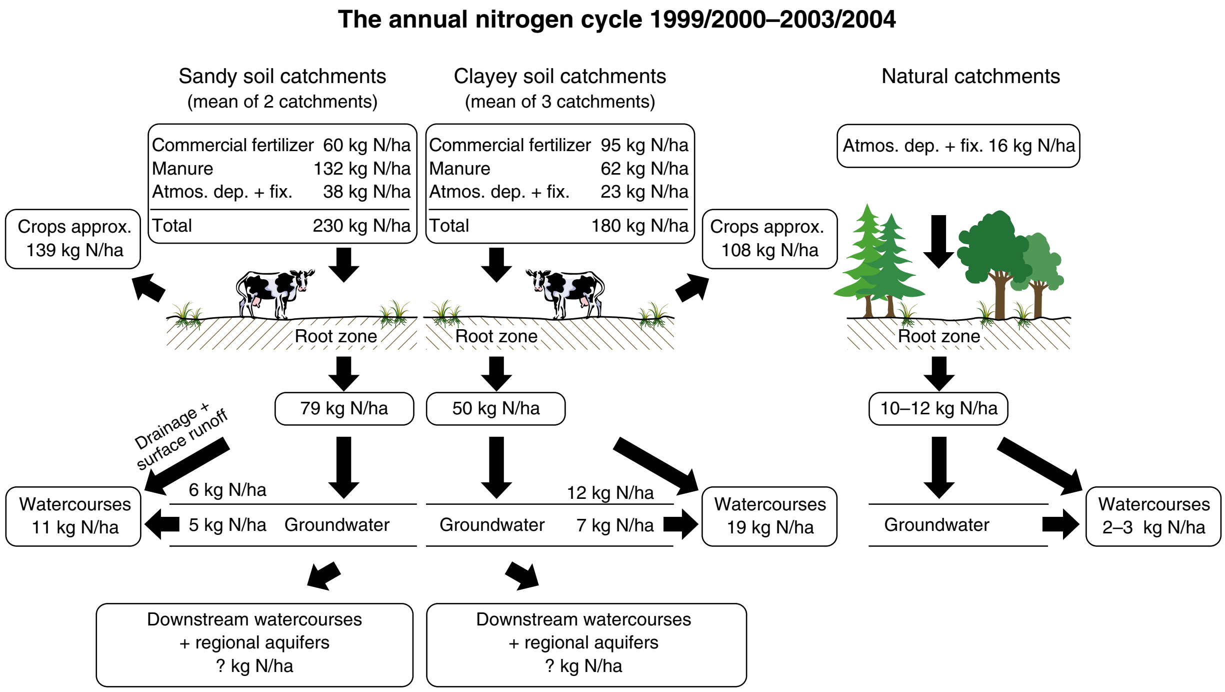
Figure 2.14 Field nitrogen surplus in 2004 for various types of holding and for holdings grouped according to increasing livestock density (*Grant et al., 2005*).

The nitrogen cycle

From Figure 2.15 it is apparent that leaching from the agricultural monitoring catchments amounts to 79 kg N/ha on sandy soils and 50 kg N/ha on clayey soils. This corresponds to 34% and 28%, respectively, of the total amount of nitrogen applied. Even though leaching is greatest from sandy soils, more nitrogen nevertheless runs off to watercourses in clayey areas. This is due to the fact that a great proportion of the water from sandy areas percolates down to the deeper groundwater, where a large proportion of the nitrogen is converted to atmospheric nitrogen by denitrification. Thus only approx. 7–20% of the leached nitrogen reaches watercourses in sandy areas as compared with approx. 38% in clayey areas.

Leaching from uncultivated natural catchments typically amounts to 10–12 kg N/ha or slightly less than input from the air, which averages approx. 16 kg N/ha. If the arable land had not been cultivated, leaching would probably have been at the same level as in the natural catchments.

Figure 2.15 Diagram of the nitrogen cycle in cultivated clayey soil and sandy soil catchments and in natural catchments for the hydrological years 1999/2000–2003/2004. The values for watercourse transport include both the diffuse load and wastewater from sparsely built-up areas (*Grant et al., 2005*).

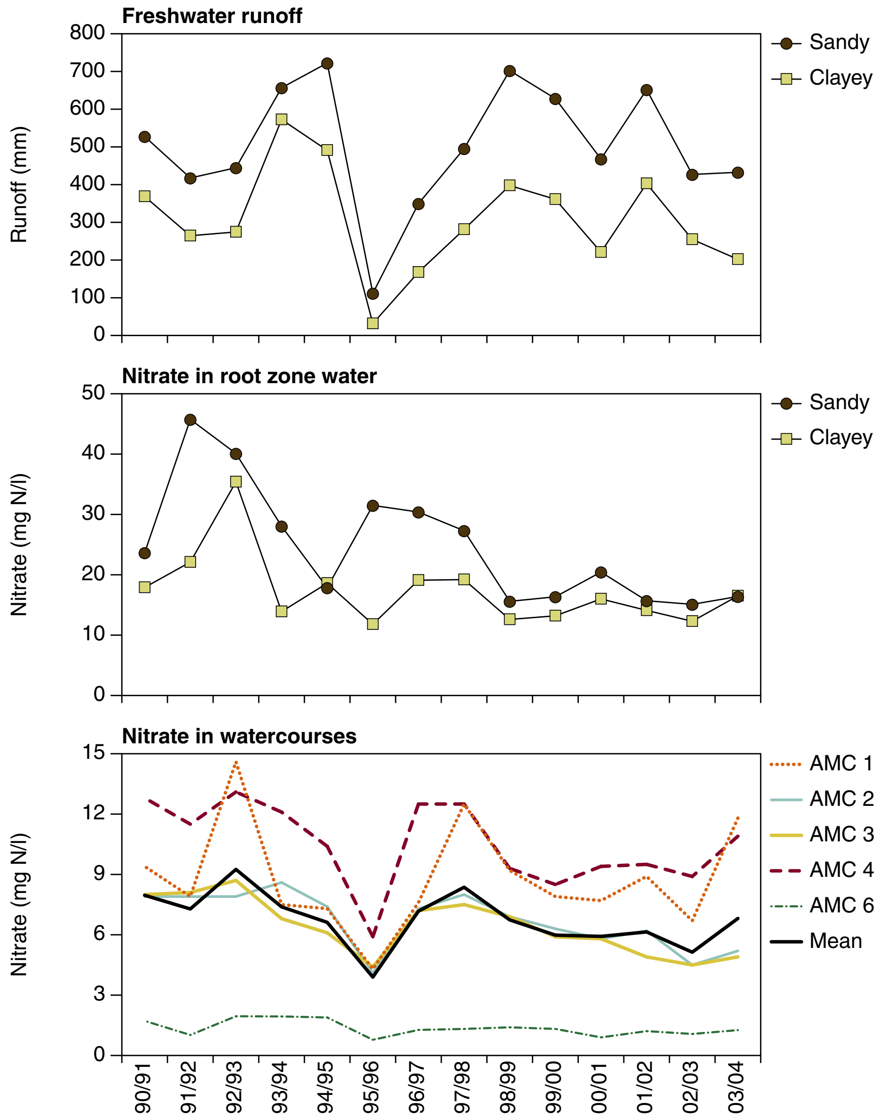


2.7 Nitrogen in water from cultivated fields

Nitrogen concentrations

The measured concentration of nitrate in the water percolating down from the root zone in cultivated fields has decreased since 1990 by 0.56 mg N/l per year in clayey soils and by 1.27 mg N/l per year in sandy soils (Figure 2.16). This corresponds to a 34% decrease in clayey soils and a 50% decrease in sandy soils, although the deviation is considerable (20–46% and 38–64%, respectively). On average, the nitrogen concentration in the water has decreased since 1990 from 21.5 to 16.5 mg/l in clayey soils and from 30.4 to 16.8 mg/l in sandy soils. More than 80% of the leached nitrogen is in the form of nitrate.

Figure 2.16 Trend in freshwater runoff and measured nitrate concentrations in the root zone water and in watercourses in sandy soil and clayey soil agricultural monitoring catchments (AMCs) over the years 1999/2000–2003/2004 (*Grant et al., 2005*).



The nitrate concentration in the percolating water seems to be highest in years with low runoff, when there is least water to dilute the leached nitrate. Figure 2.16 also shows that the nitrogen concentration in the watercourses draining the agricultural monitoring catchments is lower than in the water leaving the root zone. This is mainly attributable to denitrification of nitrate during its journey from the root zone to the watercourse.

Table 2.5 Flow-weighted mean concentrations of total nitrogen in watercourses in the agricultural monitoring catchments (AMCs) (*Grant et al., 2005*).

Agricultural monitoring catchment	Nitrogen concentration (mg/l)	
	1990–2003	2003/2004
Højvads Rende (clayey, AMC 1)	8.7	11.8
Lillebæk (clayey, AMC 4)	10.7	10.9
Horndrup Bæk (clayey, AMC 3)	6.8	4.9
Odderbæk (sandy, AMC 2)	6.8	5.2
Bolbro Bæk (sandy, AMC 6)	1.4	1.1

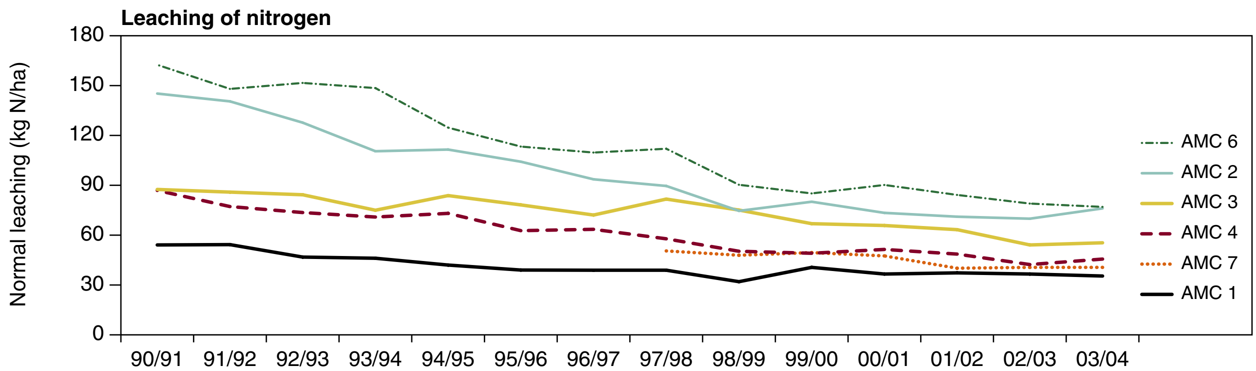
The watercourse nitrate concentration differs considerably between the various catchments (Table 2.5). In the Bolbro Bæk catchment the watercourse nitrate concentration is far lower than in the other catchments because a large part of the runoff takes place through reducing aquifers. Runoff was low from the clayey catchments in particular in winter 2003/2004. The leached nitrate was therefore diluted in a smaller amount of water and the watercourse nitrate concentration was therefore higher in some of the clayey catchments (Table 2.5) even though nitrogen transport was lower than normal in 2004.

2.8 Nitrogen loss from cultivated fields

Loss from the root zone

The amount of nitrogen that leaches from the root zone in the agricultural monitoring catchments is calculated by modelling each year based on the measured nitrate concentration in the root zone water and the calculated amount of water that percolates down from the fields. The model calculations incorporate climate data and information on agricultural practice in the catchments (*Grant et al., 2005*). The amount leached is highly dependent on the precipitation conditions. In order to show the trend in leaching under normal climatic conditions it is calculated using the mean precipitation. The results presented in Figure 2.17 thus show the leaching that would have occurred if the weather had matched that of a normal year.

Figure 2.17 Modelled leaching of nitrate at average climatic conditions for the six agricultural monitoring catchments (AMCs) over the period 1990/1991–2003/2004 (*Grant et al., 2005*).



The modelled annual leaching from the root zone decreased from 154 to 77 kg N/ha (50%) in the sandy soil catchments (northern and southern Jutland) and from 76 to 45 kg N/ha (41%) in the clayey soil catchments (Storstrøm County, Funen and Aarhus Counties). Weighting the soil types relative to the country as a whole yields a mean decrease in leaching of 46%.

Transport in the watercourses draining the agricultural monitoring catchments

Transport of total nitrogen in the watercourses draining the agricultural monitoring catchments is shown in Table 2.6. The transport is considerably less than the leaching from the root zone in the catchments. Mean leaching in 2003/2004 was 58 kg N/ha whereas mean transport in the watercourses was 12 kg N/l, corresponding to 21% of the leaching. The large difference in these values is primarily due to denitrification of nitrate to atmospheric nitrogen during the water's passage from the root zone to the watercourse.

Table 2.6 Annual transport of nitrogen in watercourses in the agricultural monitoring catchments (AMCs) (*Grant et al., 2005*).

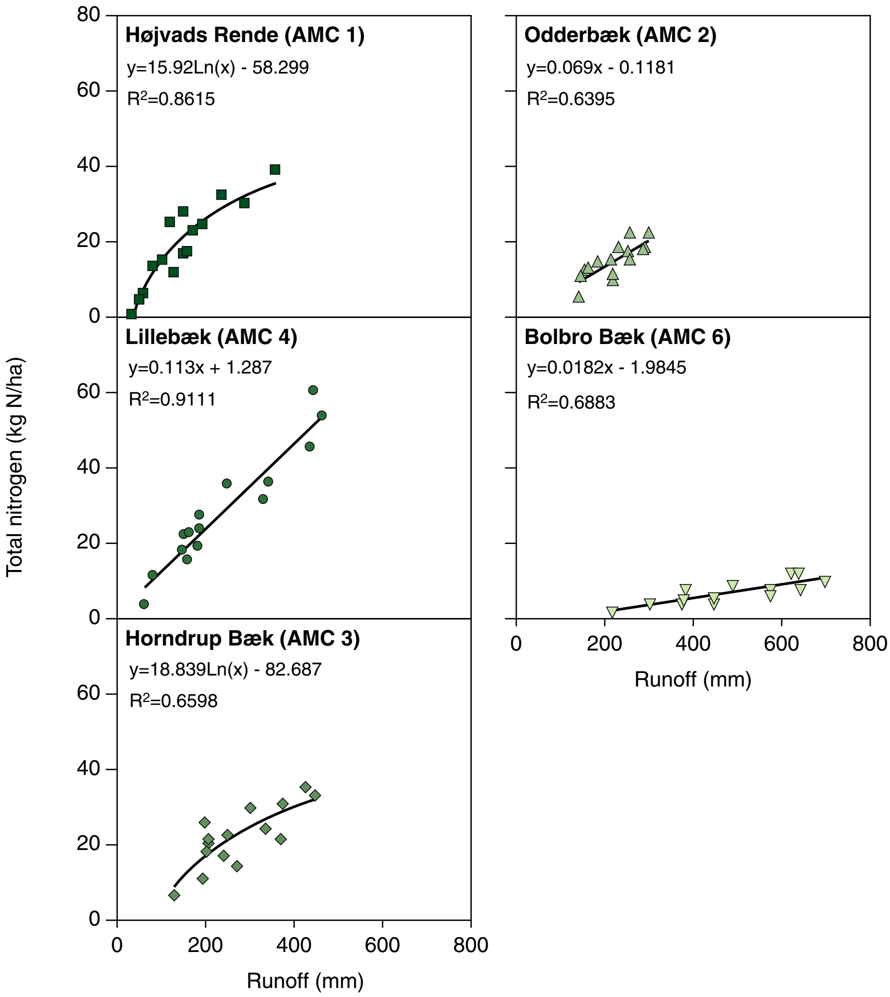
Agricultural monitoring catchment	Nitrogen transport (kg/ha per year)	
	1990–2003	2003/2004
Højvads Rende (clayey, AMC 1)	19.5	13.2
Lillebæk (clayey, AMC 4)	29.1	18.0
Horndrup Bæk (clayey, AMC 3)	23.0	11.1
Odderbæk (sandy, AMC 2)	15.3	11.7
Bolbro Bæk (sandy, AMC 6)	6.9	5.6

Nitrogen loss increases with runoff

The magnitude of nitrogen loss from cultivated fields is highly dependent on the amount of precipitation and hence the runoff in the individual years. Significant relationships between annual freshwater runoff and annual loss of total nitrogen can therefore be established for the watercourses in each of the five agricultural monitoring catchments. The annual loss of nitrogen from agricultural land increases with increasing runoff in the individual catchments (Figure 2.18), most in the clayey catchments (Højvads Rende, Lillebæk and Horndrup Bæk), while nitrogen loss is less dependent on precipitation and freshwater runoff in the sandy catchments (Odderbæk and Bolbro Bæk).

At Højvads Rende and Horndrup Bæk, nitrogen loss does not increase linearly with freshwater runoff but levels off at high runoff rates, probably because the soil starts to become depleted of nitrate when runoff is high.

Figure 2.18 Correlation between annual nitrogen loss from fields and freshwater runoff in the period 1989/90–2003/04 for the five agricultural monitoring catchments (AMCs) (*Grant et al., 2005*).



3 Phosphorus

3.1 Phosphorus pollution

Phosphorus loading of water bodies and terrestrial natural habitats as a result of man's activities is a major cause of pollution. Lakes and fjords in particular and to some extent also more open marine waters are polluted by phosphorus, causing enhanced algal growth and resultant environmental problems. In watercourses the phosphorus concentration is of less significance for their ecological status. At very low phosphorus concentrations, though, an increase in the phosphorus concentration will affect the amount of algae that grow on the stream bed. There is considerable geologically dependent regional variation in the phosphorus concentration of the groundwater that flows out into the water bodies.

Objectives

One of the objectives of Action Plan on the Aquatic Environment I from 1987 was to reduce phosphorus loading from wastewater and agriculture by 80% by implementing phosphorus removal and by stopping unlawful agricultural discharges. In Action Plan on the Aquatic Environment III from 2004 it was further decided to attempt to reduce phosphorus loading from cultivated fields. The County Regional Plans set specific objectives for many lakes and fjords, stipulating limit values for phosphorus loading and/or the water phosphorus concentration in the individual water bodies. These limit values have often led to more extensive phosphorus removal from wastewater than necessary pursuant to the general, nationwide requirements.

Phosphorus loading from the landmass in 2004

The total phosphorus input to the sea from the land amounted to 2,170 tonnes P in 2004 (Table 3.1). This is virtually the same as the calculated total input to the aquatic environment, which amounted to 2,200 tonnes. Retention of phosphorus in inland waters was minor (approx. 30 tonnes) because retention is counteracted by the release of phosphorus accumulated in the sediment in many lakes. Wastewater sources accounted for approx. 46% of the total input to the aquatic environment, while leaching from agriculture accounted for approx. 37%. Natural background loading, i.e. loading that does not derive from pollution, accounted for approx. 18% of the total input to the aquatic environment.

Table 3.1 Phosphorus input to the aquatic environment in 2004 apportioned by source (*Bøgestrand (ed.), 2005* and *Danish EPA, 2005*).

Phosphorus source	Phosphorus load in 2004 (tonnes P)
Background loading	400
Leaching from farmland	810
Sparsely built-up areas	210
Wastewater to inland waters	410
Retention in inland waters	-30
Runoff to the sea via watercourses	1,800
Wastewater direct to the sea	340
Marine and saltwater fish farms	30
Total to the sea	2,170

Trend in phosphorus loading from the landmass

Annual phosphorus input to marine waters from the landmass has decreased since the 1980s from almost 10,000 tonnes P/yr to around 2,000 tonnes P/yr (Figure 3.1). The reduction is attributable to the establishment of phosphorus removal at wastewater treatment plants. Since the mid 1990s, when phosphorus removal had largely been established, phosphorus loading of the sea has correlated with freshwater runoff from the land. This is due to the fact that the diffuse loads, especially from cultivated areas, are largest in years when precipitation and runoff are high (in Figure 3.1, wastewater from sparsely built-up areas is counted as a diffuse source).

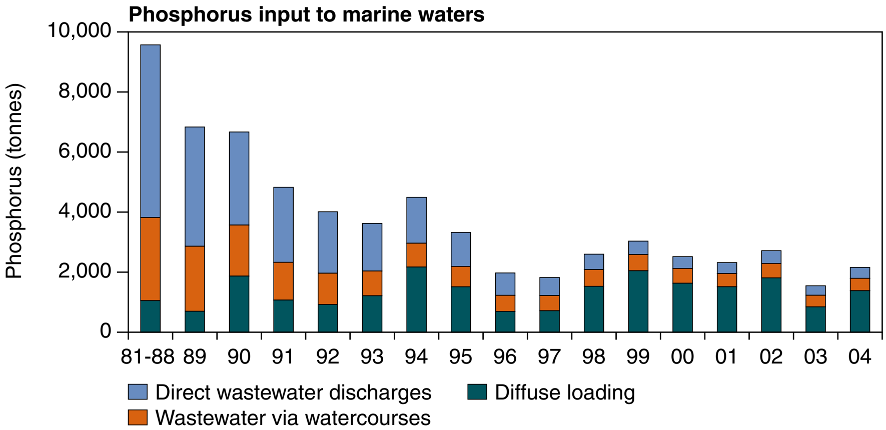


Figure 3.1 Total annual phosphorus input to marine waters via watercourses and direct wastewater discharges in 2004 (*Bøgestrand (ed.), 2005*).

Phosphorus loading from the air

Atmospheric phosphorus is largely bound to particles and is transported around with them. This phosphorus derives from both natural and anthropogenic sources, e.g. wind erosion of cultivated fields and combustion of coal and straw. As in previous years, atmospheric deposition of phosphorus on the inner Danish marine waters and landmass is estimated to be approx. 0.04 kg P/ha. Deposition on the inner Danish marine waters (area 31,500 km^2) in 2004 is thus calculated to be approx. 130 tonnes P, while that on the Danish landmass (area 43,000 km^2) is approx. 170 tonnes P.

Compliance with objectives

The general national targets specified in Action Plan on the Aquatic Environment I for discharges of phosphorus have already been met. The national requirements stipulated in Action Plan on the Aquatic Environment I for wastewater discharges have been met since 1995, and the requirements regarding agricultural discharges are considered to have been met upon cessation of direct discharges from farm properties around 1990.

This does not mean that the reduction targets stipulated in the regional aquatic environment plans have been met for all water bodies, however, or that phosphorus pollution has decreased so much that the quality objectives for the water bodies can be fulfilled. Fulfilment of these quality objectives is dealt with in the chapters on watercourses, lakes and marine waters.

3.2 Wastewater discharges of phosphorus

Municipal wastewater treatment plants

Phosphorus removal has been established at all wastewater treatment plants with a capacity exceeding 5,000 PE in order to meet the discharge criterion of 1.5 mg P/l specified in the 1987 Action Plan on the Aquatic Environment I. In many places a more stringent discharge criterion has been imposed to protect lakes and fjords. In many lake and fjord catchments, moreover, phosphorus removal is performed at all wastewater treatment plants. The 446 wastewater treatment plants required to remove phosphorus treated 89% of all the wastewater in 2004. The mean effluent concentration from these plants was 0.5 mg P/l. The total amount of wastewater discharged from all treatment plants in 2004 amounted to 712 million m^3. This contained 426 tonnes P, corresponding to 0.6 mg P/l.

The trend in annual discharge of phosphorus from municipal wastewater treatment plants since the 1980s is shown in Figure 3.2. The total discharge has been lower than the target specified in Action Plan on the Aquatic Environment I since 1995. Since the 1980s, phosphorus discharge has decreased by 96%.

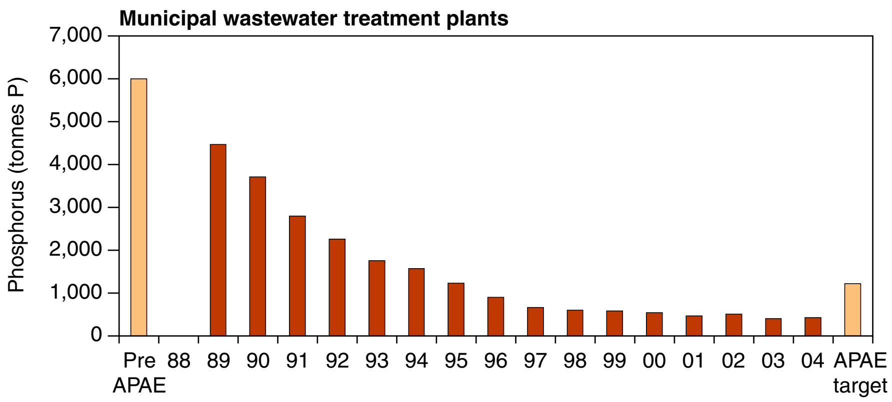
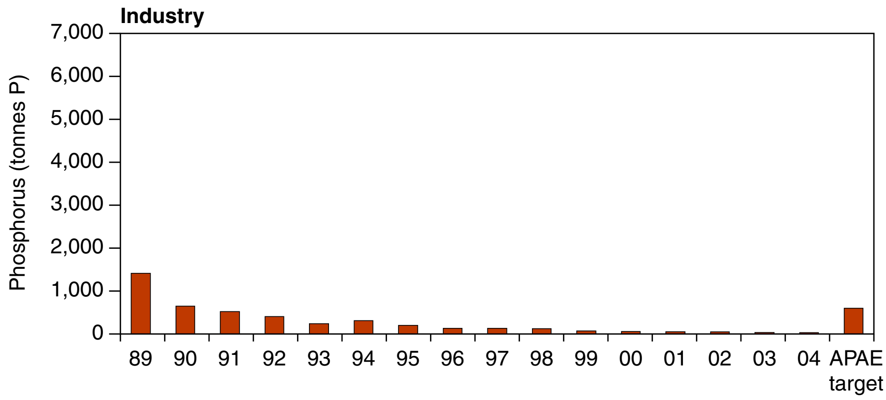


Figure 3.2 Trend in annual discharge of phosphorus from municipal wastewater treatment plants (*Danish EPA, 2005*).

Separate industrial discharges

The magnitude of direct industrial discharges to water bodies is much less than that of discharges via municipal wastewater treatment plants. Thus total discharges in 2004 amounted to 62.8 million m^3 containing 31 tonnes P, corresponding to a mean concentration of 0.5 mg P/l. From Figure 3.3 it can be seen that total discharge of phosphorus has decreased from approx. 1,400 tonnes P/yr in the 1980s to less than 50 tonnes P/yr in the past two years, or to far less than the target of 600 tonnes P/yr stipulated in the 1987 Action Plan on the Aquatic Environment I. The reduction is due to the fact that many enterprises have connected up to the municipal wastewater treatment plants or have installed cleaner technology and improved treatment methods over the years. In all, separate industrial discharges of phosphorus have decreased by 98% since 1989.

Figure 3.3 Trend in annual discharge of phosphorus from separate industrial discharges (*Danish EPA, 2005*).

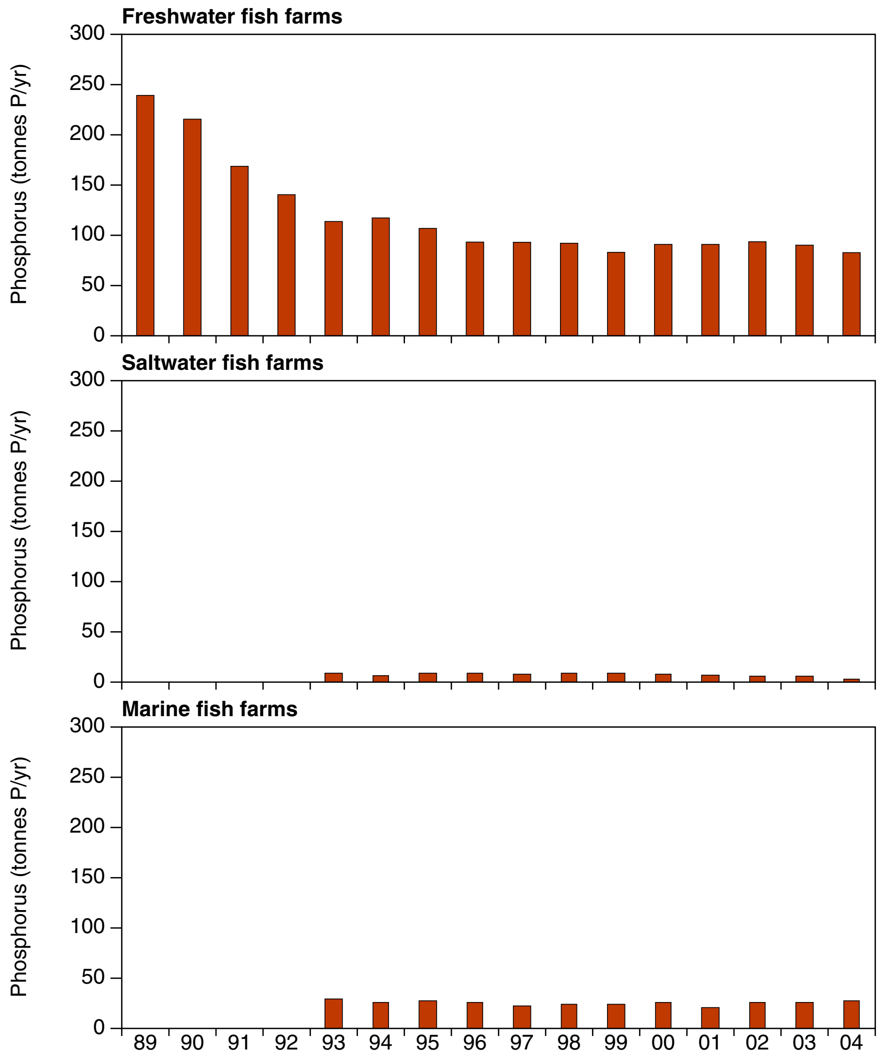


Aquaculture

Total discharges of phosphorus from the production of fish in freshwater fish farms, saltwater fish farms and marine fish farms are calculated using theoretical calculations, among other things based on feed consumption. The trend in calculated discharges is shown in Figure 3.4. A considerable reduction can be seen in discharges from freshwater and saltwater fish farms, whereas discharges from marine fish farms have not decreased. Total calculated discharges in 2004 were 82.7, 3 and 28 tonnes P, respectively, for the three types of fish production.

In 2004, discharges from freshwater fish farms were also calculated on the basis of analyses of specific measurements at approx. 125 fish farms. Assuming that these fish farms are representative of all freshwater fish farms it can be calculated that the total annual discharge was 58 tonnes P, considerably less than the theoretically calculated discharge of 82.7 tonnes P.

Figure 3.4 Trend in the theoretically calculated annual discharge of phosphorus from freshwater fish farms, saltwater fish farms and marine fish farms (*Danish EPA, 2005*).



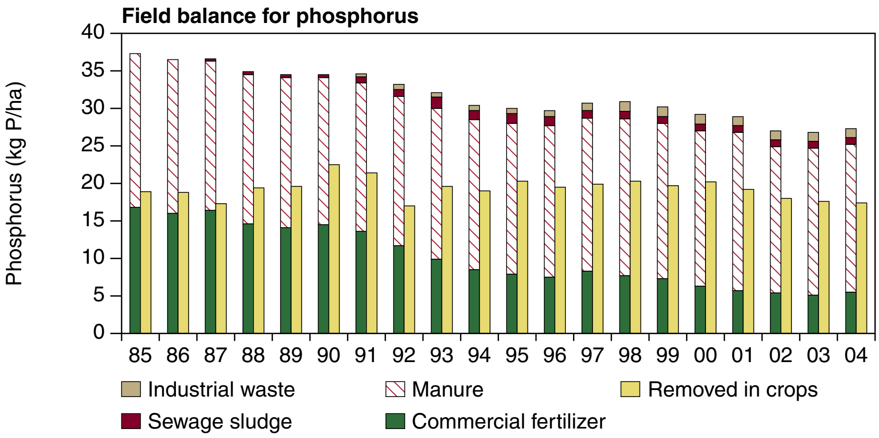
3.3 Phosphorus in agriculture

Fertilizer consumption

Nationwide annual consumption of phosphorus in commercial fertilizer has decreased by 11.4 kg P/ha over the period 1985–2004, while phosphorus input in the form of manure has slowly increased. Net input (also referred to as the field surplus) has decreased during the period and in 2004 was 9.9 kg P/ha, corresponding to 26,000 tonnes P at the national level (Figure 3.5). Action Plan on the Aquatic Environment III sets the goal that the total field surplus should be reduced by 50% before 2015 relative to the surplus in 2001, in part through levies on fodder phosphates and in part through improved utilization of fodder.

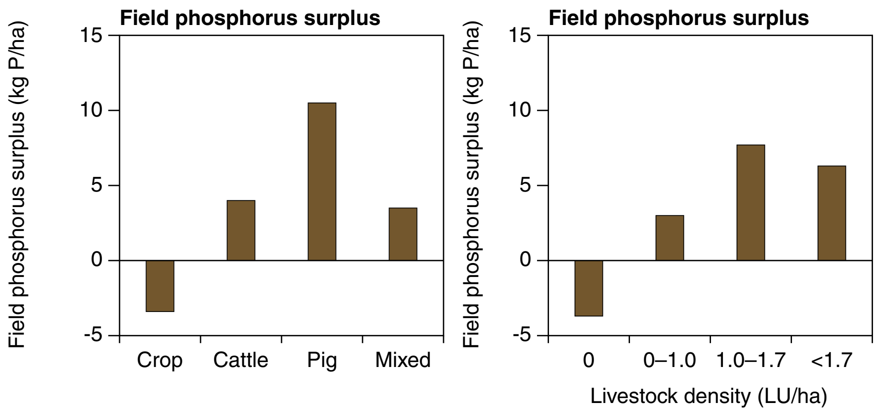
The field surplus for phosphorus in the agricultural monitoring catchments is slightly less than that calculated for the country as a whole. Consumption of commercial fertilizer in the agricultural monitoring catchments was lower than at the national level at the beginning of the period, and the amount of phosphorus removed in the crops at the end of the period was greater.

Figure 3.5 Trend in applied phosphorus and phosphorus removed in the crops for all agricultural land in Denmark over the period 1985–2004 (*Grant et al., 2005*).



The phosphorus surplus differs considerably depending on the type of holding and the livestock density. On the crop holdings in the agricultural monitoring catchments, less phosphorus was added to the soil than was removed in the crops. In contrast, there was a phosphorus surplus on the livestock holdings, especially on the pig holdings (Figure 3.6). The calculations at the national level show that the phosphorus surplus was greater for the country as a whole than for the agricultural monitoring catchments, especially for livestock holdings.

Figure 3.6 Field phosphorus surplus in 2004 for various types of holding and for holdings grouped according to increasing livestock density (*Grant et al., 2005*).



3.4 Phosphorus concentrations and loss

Monitoring programme

Leaching of phosphorus from the root zone is measured at 32 soil water stations and in around 20 wells located in the upper groundwater 1.5–5 m below ground surface distributed throughout the five agricultural monitoring catchments. In 2004, soil samples were collected at the soil water stations at three depths (0–25 cm, 25–50 cm and 50–100 cm) to determine the soil phosphorus saturation. Transport of phosphorus to surface water via drains is measured at 10 stations and in the watercourses that drain the whole catchments.

Phosphorus concentrations in the water

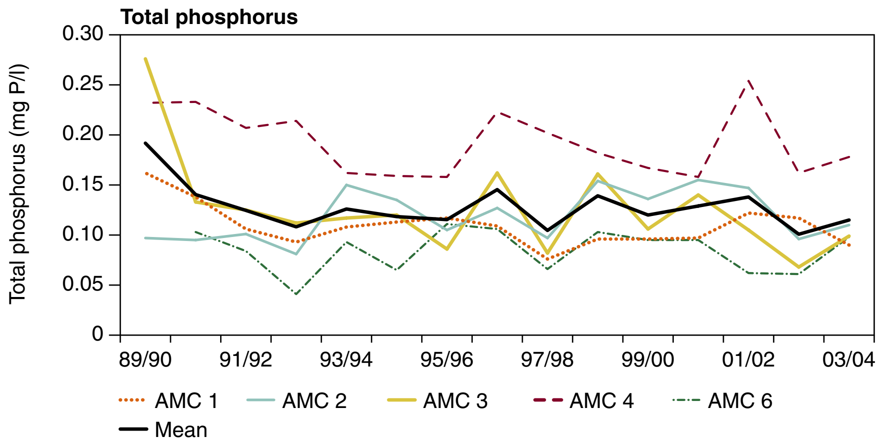
24% of the soil water stations are located on soils with high phosphorus mobility, and the phosphorus concentration of the water is therefore higher than the usual low level of around 0.02 mg P/l (Table 3.2). The high phosphorus mobility also results in a high phosphorus concentration in the tile drains that drain these soils. None of the watercourses in the agricultural monitoring catchments solely drain soils with high phosphorus mobility and hence are not subdivided in Table 3.2.

Table 3.2 Phosphorus concentration levels in the root zone water, drainage water, upper groundwater and watercourses in the agricultural monitoring catchments (AMCs) (Data from *Grant et al., 2005*).

Phosphorus concentration levels in AMCs	Soils with low P mobility (mg P/l)	Soils with high P mobility (mg P/l)
Root zone water	0.016–0.021	0.1–0.5
Drainage water	0.028–0.066	0.11–0.18
Upper groundwater	0.03–0.24	
Watercourses	0.11	

The phosphorus concentration in the water running off from the agricultural monitoring catchments via watercourses differs considerably (Figure 3.7) and is highest at Lillebæk on Funen (AMC 4). No general changes in phosphorus concentration are apparent over the period for either the individual watercourses or the mean of all agricultural monitoring catchment watercourses, except perhaps for a fall around 1990.

Figure 3.7 Trend in annual mean phosphorus concentration in watercourses in the agricultural monitoring catchments (AMCs) over the years 1989/1990–2003/2004 (Data from *Grant et al., 2005*).



Reasons for the high phosphorus concentration in soil water

The measured phosphorus concentration in the root zone water in the agricultural monitoring catchments has been compared with the agricultural practice and phosphorus status of the fields (*Grant et al., 2005*). The phosphorus concentration in the soil water and hence the total amount lost by leaching depends in part upon the phosphorus content of the soil.

Phosphorus loss versus water runoff

The clayey soil catchments in particular (left side of Figure 3.8) exhibit great interannual variation in phosphorus transport out of the catchment via watercourses, with the magnitude of transport closely following freshwater runoff. This increase at high runoff is not attenuated at the highest flows as was the case with nitrogen, where some of the corresponding curves levelled off at very high runoff (see Figure 2.18). With phosphorus, the opposite will often be the case in cultivated catchments as some soil can be washed out into the watercourses by surface runoff or via drains, particularly when runoff is high. Interannual variation is least in the case of the coarse sandy catchment at Bolbro Bæk, where a large proportion of the water in the watercourse derives from groundwater flow.

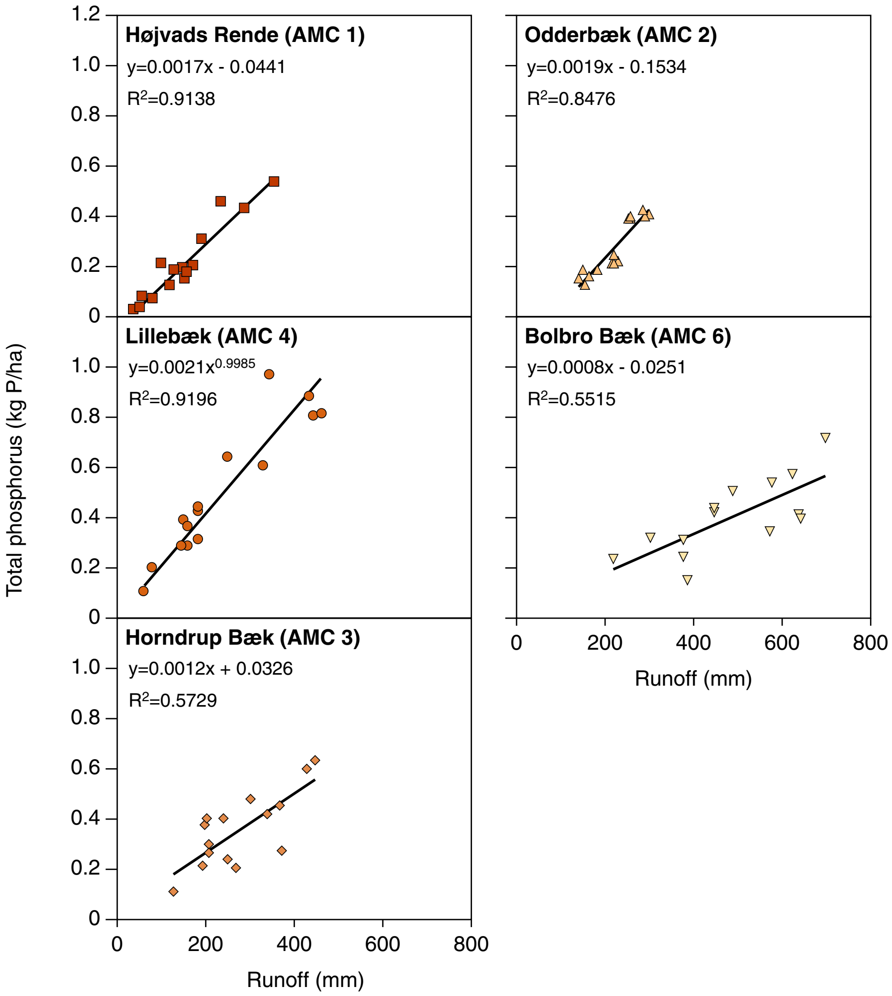


Figure 3.8 Correlation between annual phosphorus loss from fields and freshwater runoff over the period 1989/90–2003/04 for the five agricultural monitoring catchments (AMCs) (*Grant et al., 2005*).

4 Organic matter pollution

Discharges of degradable organic matter previously comprised a significant source of pollution of the aquatic environment. The discharges caused sludge deposits in the watercourses and in the vicinity of major wastewater discharges to the marine waters, and the oxygen consumed to degrade the organic matter deteriorated oxygen conditions in the water body. Wastewater treatment has considerably reduced pollution with organic matter.

Sources of organic matter pollution

Pollution with degradable organic matter is normally measured as the oxygen consumption upon degradation of the organic matter during a 5-day period, the so-called BOD_5. In the absence of pollution there is a certain amount of natural BOD_5 in the water that flows from a catchment out into the water bodies – normally about or less than 1 mg/l. The organic matter load from wastewater discharges is still considerable, while cultivation of the land does not normally lead to any major increase in the organic matter content of the water from fields. The organic matter load is shown apportioned by source in Table 4.1. The trend in discharges from each of the major sources is described below.

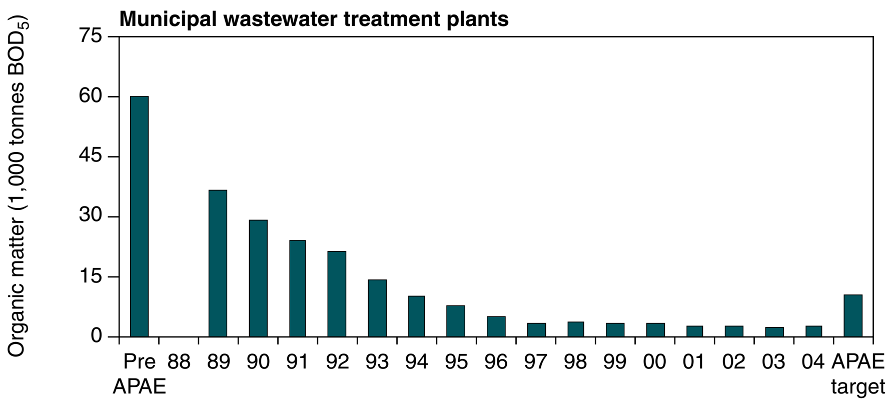
Table 4.1 Sources of input of degradable organic matter to the aquatic environment in 2004. The background load has been calculated from measurements in watercourses in uncultivated countryside. The figure for leaching from fields only indicates the magnitude of the load (*Bøgestrand (ed.), 2005* and *Danish EPA, 2005*).

Organic matter source	Organic matter load in 2004 (tonnes BOD_5)
Background loading	9,900
Leaching from farmland	(1,200)
Sparsely built-up areas	3,600
Wastewater to inland waters	6,000
Retention in inland waters	-
Runoff to the sea via watercourses	20,700
Wastewater direct to the sea	3,200
Marine and saltwater fish farms	1,800
Total to the sea	25,700

Discharges from wastewater treatment plants

In 2004, municipal wastewater treatment plants discharged 712 million m^3 of wastewater containing 2,625 tonnes organic matter (BOD_5), corresponding to an average of 3.9 mg/l. This is far less than the general quality criterion of 15 mg/l for plants exceeding 5,000 PE stipulated in Action Plan on the Aquatic Environment I (Figure 4.1).

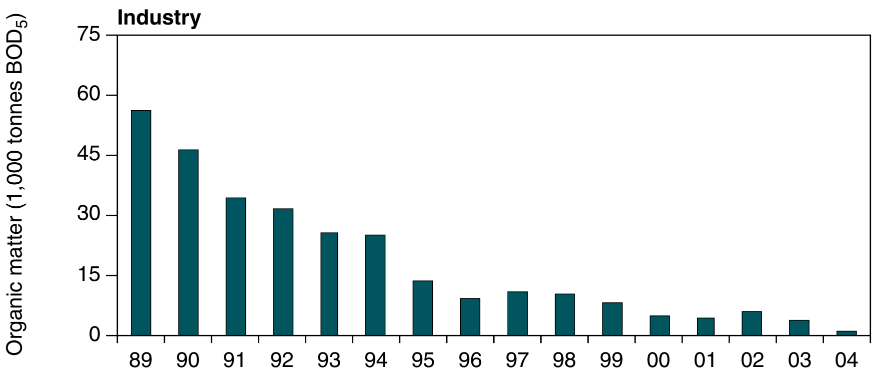
Figure 4.1 Trend in annual discharge of degradable organic matter (BOD_5) from municipal wastewater treatment plants (*Danish EPA, 2005*).



Separate industrial discharges

In 2004, separate industrial discharges amounted to 62.8 million m^3 of wastewater containing 1,019 tonnes organic matter (BOD_5), corresponding to an average of 16 mg/l. These discharges decreased up to the mid 1990s in particular, although a considerable reduction has also taken place since then. In 2003, biological treatment was established at the last major enterprise discharging considerable amounts of organic matter (Figure 4.2).

Figure 4.2 Trend in annual discharge of degradable organic matter (BOD_5) from separate industrial discharges (*Danish EPA, 2005*).



Discharges from aquaculture

The majority of fish production in aquaculture plants takes place in freshwater fish farms, all of which are located in Jutland. The discharges from freshwater fish farms are calculated using theoretical calculations based on feed consumption and production (Figure 4.3). In 2004, discharges were also calculated on the basis of analyses of the inlet and outlet concentrations at approx. 125 freshwater fish farms. Assuming that these fish farms are representative of the industry as a whole, this corresponds to a total discharge of 1,494 tonnes BOD_5, considerably less than the theoretically calculated discharge of 2,933 tonnes BOD_5.

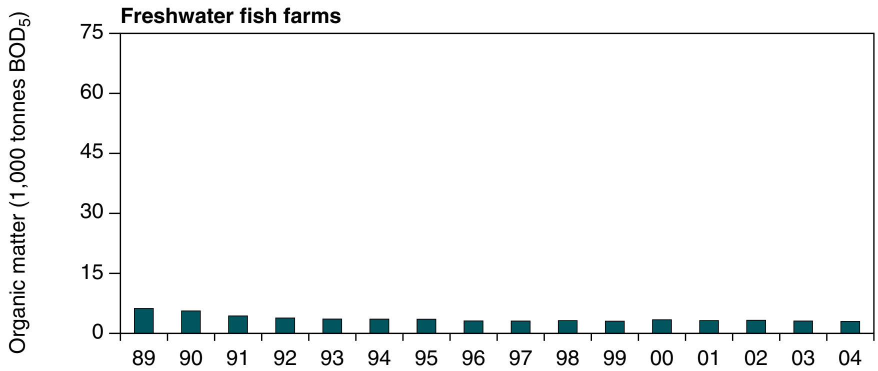


Figure 4.3 Trend in theoretically calculated annual discharge of degradable organic matter (BOD_5) from freshwater fish farms (*Danish EPA, 2005*).

Overall assessment of organic matter pollution

Organic matter discharges have decreased so much that they only cause marked pollution locally in the vicinity of the outfalls. Small watercourses in particular can be polluted by discharges from properties in sparsely built-up areas or stormwater discharges from towns. Moreover, organic matter pollution can occur downstream of freshwater fish farms or locally around marine fish farms.

5 Heavy metals and hazardous substances

5.1 Heavy metals and hazardous substances

Heavy metals occur naturally in the environment. Their significance for man and animals varies, some being essential, some being toxic and others being of little significance. The essential heavy metals can be toxic in high concentrations.

Metals can be released from their original environment due to man's activities such as lowering of the water table. Lowering of the water table can result in oxidation of the soil layers and the consequent release of a number of metals into the groundwater. Metals are widely used in our daily lives, and wastewater therefore comprises an important source of their dissemination in the environment. Finally, heavy metals contained in commercial fertilizer and liquid manure are input to the soil when they are spread on fields.

The hazardous substances primarily encompass organic compounds manufactured to utilize the properties they posses. For example, the plasticizing properties of phthalates are utilized to make plastics pliable, and the ability of the anionic detergent LAS to blend water and oil or fat is utilized in soaps and cleaning agents. The hazardous substances also include PAHs (polyaromatic hydrocarbons). PAHs are formed upon incomplete combustion of organic compounds and hence are also naturally occurring in the environment, albeit in very low background concentrations. Pesticides are used in agriculture, forestry, market gardening, etc. to combat plant diseases, pest attacks and weeds, etc.

The following groups of hazardous substances are monitored:
- Pesticides
- Aromatic hydrocarbons
- Phenols
- Halogenated aliphatic hydrocarbons
- Halogenated aromatic hydrocarbons
- PCBs (polychlorinated biphenyls)
- Chlorophenols
- PAHs (polyaromatic hydrocarbons)
- Phosphotriesters
- Plasticizers
- Dioxins and furans
- Organotin compounds
- Brominated flame retardants.

Focused programme

The various substances or groups of substances have different physical and chemical properties. The programme has been planned such that the monitoring focuses on those matrices (e.g. water, sludge, sediment, animals) in which the individual substances are either known to occur or, based on their properties, are most likely to occur. Among these properties are the substances' ability to bind to particles, their degradability and their water solubility. For example, PCBs are monitored in mussels and sediment in the subprogramme for marine waters, but are not monitored in the groundwater. PCBs as a group have a great ability to bind to particles. Correspondingly, a large number of pesticides are monitored in the groundwater but not in the subprogramme for marine waters. The pesticides in question are characterized by their high water solubility.

In addition, the programme has been designed taking into account the possibility of following the same substance in several parts of the environment. For example, a number of pesticides have been included in the subprogramme for background monitoring of air quality and atmospheric deposition.

Biological effect monitoring

The subprogramme for marine waters includes the monitoring of effects on certain marine organisms. Imposex in marine gastropods, which has been monitored since 1998, is a specific effect of exposure to tributyl tin (TBT). The remaining biological monitoring is not directly associated with exposure to specific substances or stressors.

Screening studies

In parallel with the routine monitoring of heavy metals and hazardous substances, exploratory studies are carried out on "new substances" in order to establish a foundation for a decision as to whether or not new substances should be included in the monitoring.

In 2004, screening studies were initiated on PFOS (perfluorooctane sulphonate compounds) and organotin compounds. The studies encompass wastewater and fresh water, as well as sediment and biota from watercourses and lakes.

5.2 Deposition of heavy metals from the air

Deposition of heavy metals makes a major contribution to total loading of Danish marine waters and the landmass with these substances. In many cases, input of heavy metals to the aquatic environment via atmospheric deposition is considerable compared with other sources.

The deposition and atmospheric content of particle-bound heavy metals have been measured for a number of years at six stations distributed throughout the country.

Objective

A current objective in Denmark and at EU level is that natural habitats should receive no more heavy metals via the air than they can tolerate. A new EU directive (the 4th daughter directive on heavy metals, etc.) requires Member States to measure the atmospheric concentrations and deposition of such metals as arsenic, cadmium and nickel in order to reduce the harmful effects of these substances on man and the environment.

Deposition of heavy metals in 2004 and the trend

Deposition of heavy metals in 2004 did not differ markedly from that in the preceding years. The same applies to the atmospheric concentration of heavy metals (Figure 5.1). The measurements made over the past 25 years show that deposition has decreased considerably since the end of the 1970s.

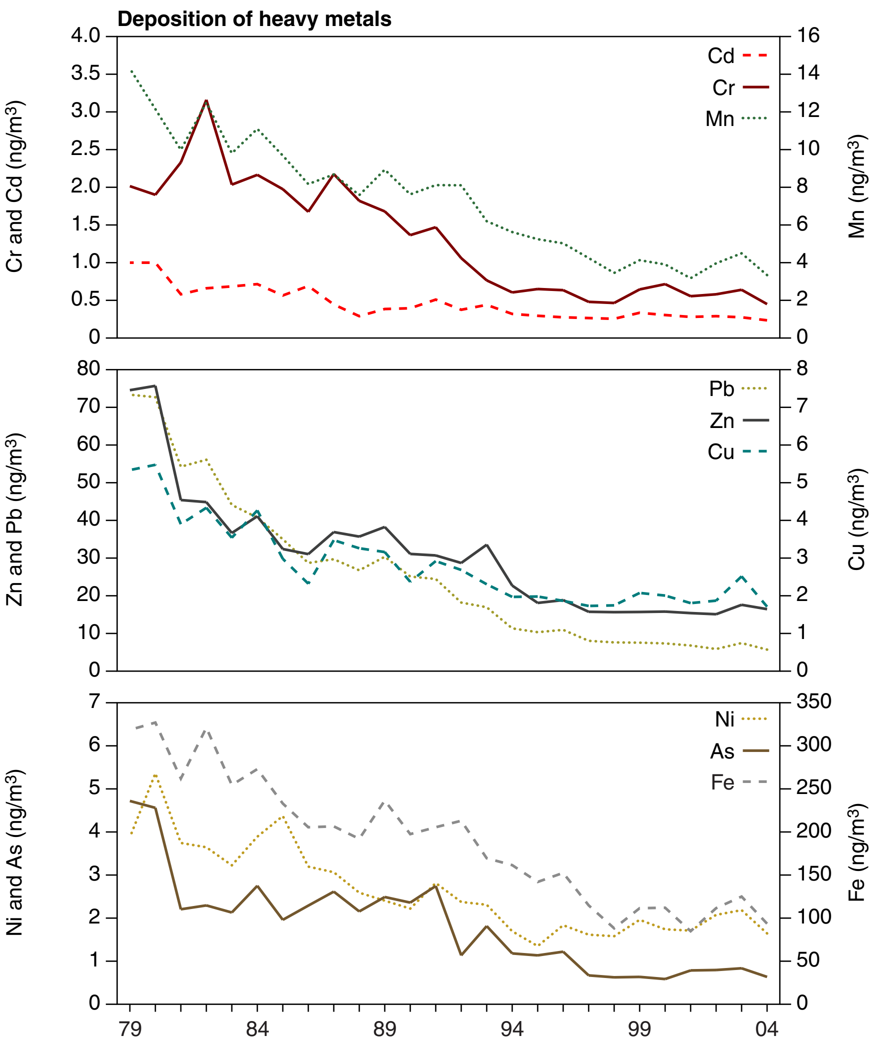


Figure 5.1 Trend in the atmospheric concentration of selected heavy metals over the past 26 years. The curves represent the mean of measurements at Keldsnor and Tange (*Ellermann et al., 2005*).

A large proportion of the heavy metals present in the atmosphere over Denmark derives from sources outside Denmark. Comparison of the estimated deposition on the inner Danish marine waters and the Danish landmass with Danish emissions of heavy metals reveals for the majority of the monitored heavy metals that Danish emissions

Table 5.1 Annual deposition estimated from measurements at eight stations in Denmark (*Ellermann et al., 2005*).

are considerably less than deposition (Table 5.1). The estimates are subject to an uncertainty of ±30–50%.

	Mean for the measurement stations		Estimated deposition		Emissions
Wet deposition	Deposition on land ($\mu g/m^2$)	Deposition on water ($\mu g/m^2$)	Landmass 43,000 km^2 (tonnes/yr)	Inner marine waters 31,500 km^2 (tonnes/yr)	Danish sources (tonnes/yr)
Chromium (Cr)	110	100	5	3	2.4
Nickel (Ni)	310	270	13	8	13
Copper (Cu)	830	790	36	25	9.3
Zinc (Zn)	7,000	6,700	300	210	23
Arsenic (As)	110	100	5	3	0.71
Cadmium (Cd)	48	40	2	1	0.72
Lead (Pb)	1,000	880	43	28	6
Iron (Fe)	36,000	34,000	1,500	1,100	-

5.3 Deposition of hazardous substances from the air

Deposition of hazardous substances is monitored by measuring the deposition of pesticides, nitrophenols and PAHs at two stations, Anholt and Sepstrup Sande. This is the first time that hazardous substances have been included in the monitoring of deposition.

The substances that are included in the monitoring programme all have some ability to evaporate. The majority of the substances are still in use in Denmark or neighbouring countries, while a few are only used in countries located far from Denmark. One of these is γ-HCH, which was used worldwide between 1950 and approx. 1970 to combat pests, but which was banned in a large number of countries after its persistence and accumulation in the food chain became known.

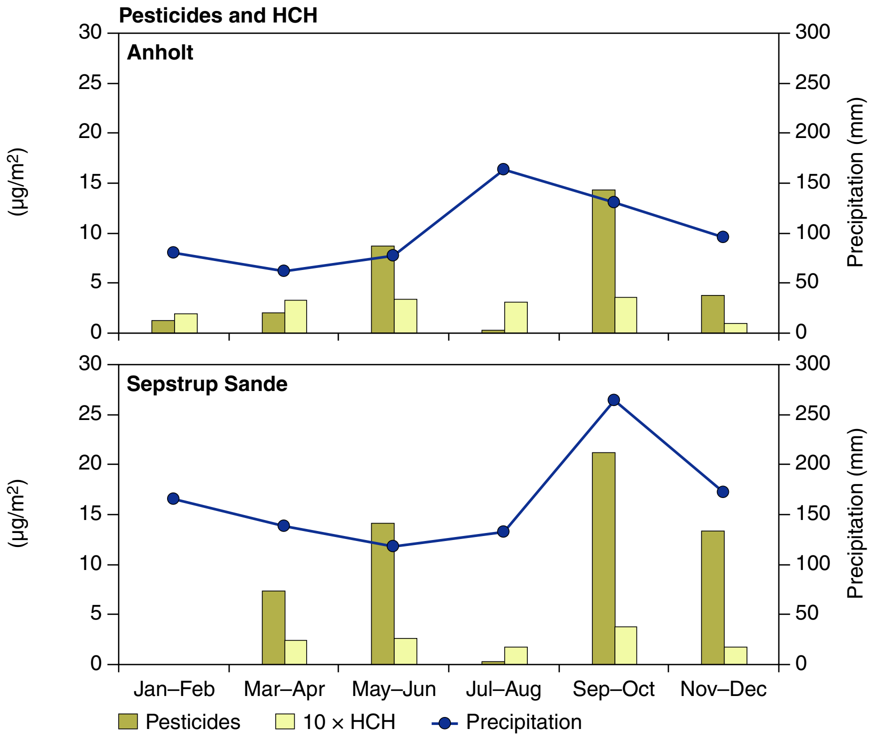
Objective

A current objective in Denmark and at EU level is that natural habitats should not receive more air pollution than they can tolerate. However, there is currently no specific objective stipulating the magnitude of deposition of hazardous substances.

Deposition of pesticides

Deposition of pesticides is greatest in the spring and autumn months, i.e. the times when pesticides are applied (Figure 5.2). Virtually no deposition takes place in July–August. Total deposition of the individual pesticides differs considerably. Pendimethalin, MCPA, isoproturon and terbuthylazine account for by far the greatest proportion of total wet deposition. Pendimethalin, MCPA and terbuthylazine are among the substances used in the greatest amounts in the agricultural monitoring catchments in 2004 (Section 5.4).

Figure 5.2 Wet deposition (µg/m^2) of common pesticides (including five degradation products) and chlorinated pesticides (HCH) in 2004 measured over 2-month periods at Anholt and Sepstrup Sande (*Ellermann et al., 2005*).



Wet deposition is twice as great at Sepstrup Sande as at Anholt. This reflects the greater amount of precipitation at Sepstrup Sande, as well as the fact that this station is located in central Jutland surrounded by agricultural production, whereas the Anholt station is located far from local sources. The pesticide levels in the wet deposition are low and do not have any acute toxic effects.

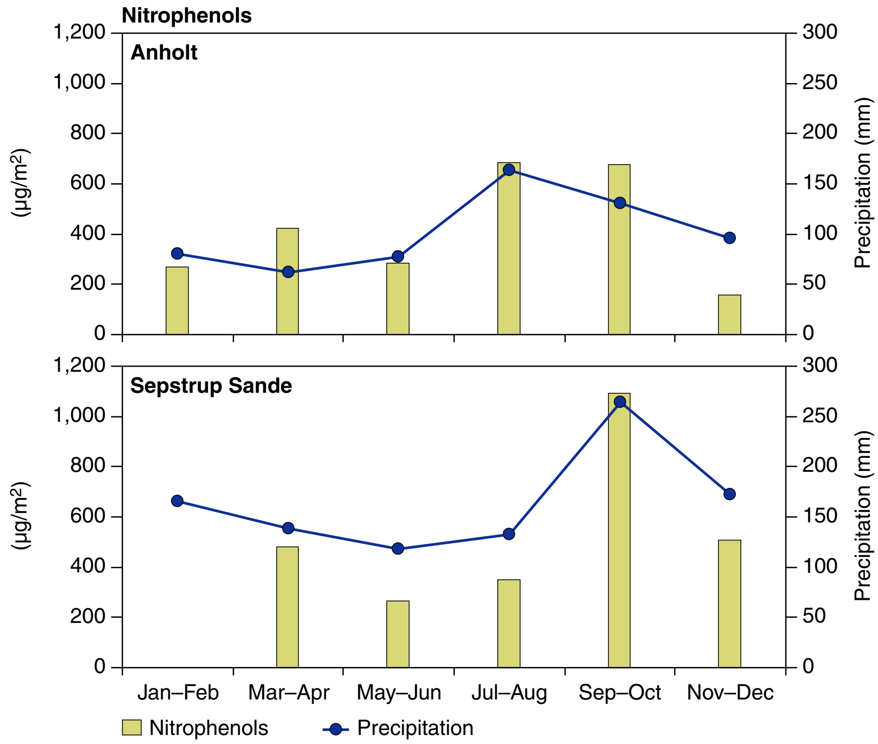
The pattern for HCH is not the same as for the other pesticides. This is due to the fact that HCH does not derive from Danish sources, but comes from far away, and that HCH degrades very slowly in the environment.

Deposition of nitrophenols

Nitrophenols are formed photochemically in the air through a reaction between nitrogen oxides and aromatic hydrocarbons. Both are emitted in connection with combustion processes, e.g. from vehicles and power stations.

The mean concentrations and annual deposition of nitrophenols recorded at the two stations are comparable (Figure 5.3). The seasonal variation largely follows the variation in precipitation. This reflects the fact that there is little seasonal variation in the compounds that generate nitrophenols in the atmosphere. The seasonal variation and the similar concentration levels at the two stations together indicate that the nitrophenols predominantly derive from long-range transboundary transport to Denmark.

Figure 5.3 Total wet deposition of nitrophenols in 2004 measured over 2-month periods at Anholt and Sepstrup Sande (µg/m²) (*Ellermann et al., 2005*).



Deposition of PAHs

The mean concentrations and annual deposition of PAHs at the two stations are comparable. The seasonal variation in wet deposition largely follows the variation in precipitation, with wet deposition being greatest in July–October and September–December at the Anholt and Sepstrup Sande stations, respectively. The relatively high deposition of PAHs at Sepstrup Sande in November–December could be attributable to a contribution from local sources in the form of the combustion of wood in wood-burning stoves.

5.4 Wastewater discharges

Wastewater discharges of heavy metals and hazardous substances are monitored at wastewater treatment plants and industrial enterprises. At the wastewater treatment plants the levels are monitored in the inflow and effluent, as well as in the sewage sludge. At industrial enterprises only the effluent is monitored. Assessment of the input of heavy metals and hazardous substances to the environment is based on the content in the discharged wastewater and in the sewage sludge from wastewater treatment plants.

In 2004, heavy metals and hazardous substances were monitored at nine wastewater treatment plants corresponding to approx. one third of the total number of wastewater treatment plants included in the monitoring programme for these substances. Four wastewater samples and one sewage sludge sample have been analysed from each plant. At the industrial enterprises only the discharged wastewater has been analysed. In addition, the results of the enterprises' in-house control have been incorporated. The number of analyses for each industrial enterprise varies depending on the type of industry.

Objective

Statutory Order No. 921 on recipient water quality (*Ministry of Environment and Energy, 1996*) stipulates quality criteria for the substances encompassed by List I and List II of that Order. List I encompasses substances for which pollution should be brought to an end, while List II encompasses other substances that have harmful effects on the aquatic environment. The discharge of List II substances has to be curtailed both nationally and regionally so that the quality criteria can be fulfilled.

When assessing the concentration in an effluent relative to the quality criteria it is normally assumed that the effluent is diluted 10-fold in the water body.

In the case of sewage sludge to be used for agricultural purposes, the Statutory Order on sewage sludge stipulates limit values for seven heavy metals and for some organopollutants (*Ministry of the Environment, 2003*).

Discharges from wastewater treatment plants in 2004

Heavy metals have been detected in both the effluent from wastewater treatment plants and in sludge. The heavy metals most frequently detected in effluent are nickel and zinc. Zinc is also the metal detected in the highest concentrations (Table 5.2). In sewage sludge, all the heavy metals included in the monitoring programme have been detected in virtually all samples. As with wastewater, zinc is the metal found in the highest concentration in sludge.

Table 5.2 Detection frequency and concentration of metals in effluent from wastewater treatment plants (*Danish EPA, 2005*) and the quality criteria for inland surface waters (*Ministry of Environment and Energy, 1996*).

Metals in effluent	Detection frequency (%) (number of samples = 36)	Mean (µg/l)	5% percentile (µg/l)	95% percentile (µg/l)	Quality criteria for inland surface waters or proposed quality criteria (µg/l)
Lead	56	2.6	0.3	8.6	3.2
Cadmium	53	0.10	0.03	0.3	5.0
Copper	89	16	0.05	67.6	12
Chromium	81	6.0	0.6	14.2	10
Nickel	100	17	3.1	70.4	160
Zinc	97	89	30.1	205	110

Together with nonylphenols and phenol, the hazardous substances most frequently detected in effluent from wastewater treatment plants are the phosphotriesters tris(chloropropyl)phosphate (TCPP) and tributhylphosphate. The detection frequencies and concentrations are shown in Table 5.3 for those organopollutants detected in more than 25% of the analysed samples.

Table 5.3 Detection frequency and concentrations of hazardous substances found in more than 25% of analysed effluent samples from wastewater treatment plants (*Danish EPA, 2005*) and the quality criteria for inland surface waters (*Ministry of Environment and Energy, 1996*).

Hazardous substances in effluent	Detection frequency (%) (number of samples = 36)	Mean (µg/l)	5% percentile (µg/l)	95% percentile (µg/l)	Quality criteria for inland surface waters or proposed quality criteria (µg/l)
Aromatic hydrocarbons					
Benzene	27	0.03	0	0.11	2
Phenol compounds					
Bisphenol A	67	0.47	0.05	1.4	-
Nonylphenol (NP1EO)	42	0.56	0	2.5	-
Nonylphenol (NP2EO)	28	0.18	0	0.8	-
Nonylphenols	69	0.52	0.06	1.6	-
Phenol	69	14	0.06	72	1,000
Halogenated aliphatic hydrocarbons					
Chloroform	28	0.04	0	0.12	10
Tetrachloroethylene	28	0.02	0	0.089	10
Chlorophenols					
4-chloro-3-methylphenol	31	0.08	0	0.38	-
Phosphotriesters					
TCPP	67	2.4	0.5	6.1	-
Tributylphosphate	84	0.21	0.07	0.57	-
Triphenylphosphate	47	0.03	0.003	0.077	-
Plasticizers					
DEHP	59	1.9	0.2	5.2	-
Dibutylphthalate	36	0.14	0	0.27	-
Diethylphthalate	56	1.5	0.09	7.1	-
Anionic detergents					
LAS	42	417	0	2,052	-

A number of the organopollutants are frequently detected in sewage sludge. There are substances whose physical and chemical properties are such that they are not degraded during the treatment process at the wastewater treatment plants but become bound to particles. This applies to the following substances/groups of substances: Biphenyl, ethylbenzene, toluene and xylene, phenol compounds, halogenated aromatic hydrocarbons, pentachlorophenol, PAHs, phosphotriesters, plasticizers, LAS and MTBE. Phenol and the plasticizer DEHP are detected in the highest concentrations.

2004 is the first year that brominated flame retardants (BDE) have been included in the monitoring programme for wastewater and sewage sludge. Only few results are yet available for the substances. In a few cases BDE-47 and BDE-99 have been detected in trace amounts around the detection limit in the inflow to wastewater treatment plants. Apart from these cases, brominated flame retardants have not been detected in wastewater treatment plant inflow or effluent or in sewage sludge.

Compliance with quality criteria

Taking into account the dilution that takes place after the effluent reaches the recipient water body the heavy metals content of effluent from wastewater treatment plants is considered to be lower than the quality criteria for inland surface waters.

To the extent that quality criteria have been set for organopollutants, the concentrations detected have been considerably lower than the quality criteria, even prior to dilution.

Compared with the limit values for sewage sludge intended for agricultural use the concentrations of heavy metals and hazardous substances detected in sludge are generally lower (Table 5.4). Cadmium and mercury have been found in mean concentrations exceeding the limit values. With nickel, LAS, PAHs and nonylphenols, the concentration 95% percentiles exceed the limit values, indicating that a few individual samples contained more than the limit value.

Table 5.4 Concentration in sewage sludge and corresponding 95% percentile for substances for which limit values have been set for sludge intended for use as agricultural fertilizer (*Ministry of the Environment, 2003*; *Danish EPA, 2005*).

Substance	Limit value in sewage sludge for agriculture (mg/kg dry matter)	Mean concentration (mg/kg dry matter)	95% percentile (mg/kg dry matter)
Lead	120	45	73
Cadmium	0.8	1.9	5.8
Copper	1,000	222	287
Chromium	100	26	42
Mercury	0.8	0.85	1.69
Nickel	30	24	35
Zinc	4,000	779	1,070
LAS	1,300	604	1,430
PAH	3	2.1	4.1
Nonylphenols	20	12	30
DEHP	50	21	34

Separate industrial discharges in 2004

An assessment has been made of the number of separate industrial discharges in which the mean concentration was higher than the quality criterion for the recipient water body. The assessment was based on the mean concentration applicable for the individual industry taking into account the dilution factor. With most of the substances discharged, no quality criterion has been set.

The substances most frequently detected in concentrations exceeding the quality criteria are copper and chromium. In both cases this applied to approximately half of the enterprises investigated. A few organopollutants were also found in concentrations that after taking into account the dilution factor were higher than the quality criteria (Table 5.5).

Table 5.5 Total discharge of heavy metals and hazardous substances from industrial enterprises together with the total number of enterprises monitored and the number of enterprises discharging a mean concentration that multiplied by the assumed dilution factor exceeds the quality criterion or the quality criterion for the recipient water body (from *Danish EPA, 2005*).

Substance	Total discharge (kg)	No. of enterprises	No. of enterprises where conc. x dilution factor exceeds the criterion*)
Arsenic	110	15	2
Lead	783	10	3
Chromium	78	29	14
Copper	237	34	18
Mercury	1.3	14	1
Nickel	211	28	6
Zinc	411	30	4
Tetrachloroethylene	7.2	18	1
Trichloroethylene	15	28	1
Anthracene	0.006	4	1
Benzo(e)pyrene	0.003	4	4
Benzo(b+j+k)fluoranthenes	0.007	4	4

*In cases where national or regional water quality criteria have not been set, the figures are based on national quality criteria (*Ministry of Environment and Energy, 1996*).

5.5 Agriculture

The data for pesticide use in the agricultural monitoring catchments in 2004 show that of the 15 active ingredients used in the largest amounts, five were detected in the near-surface groundwater under the fields. These are bentazone, terbuthylazine, metamitron, MCPA and glyphosate.

Objective

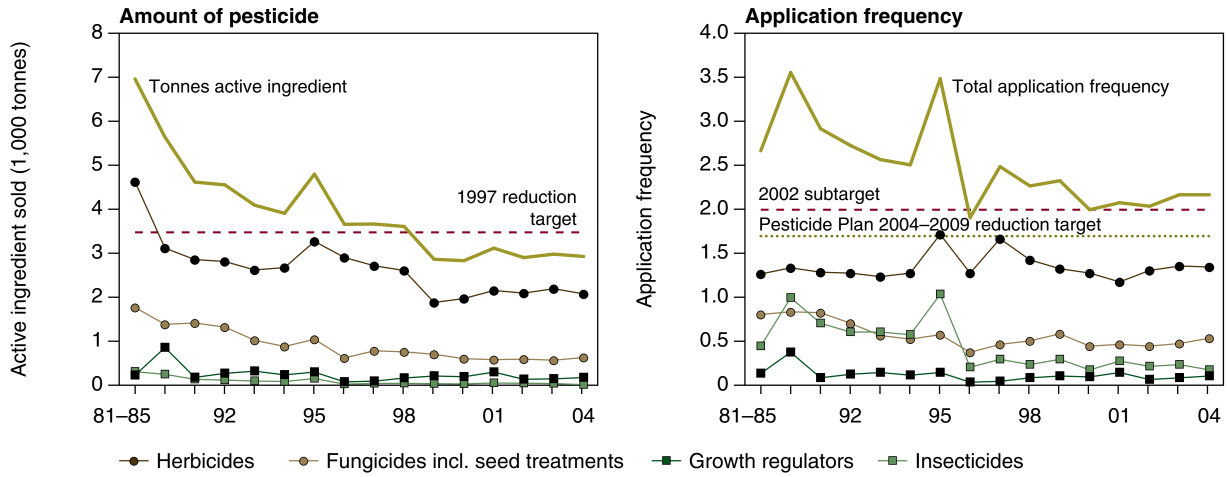
The objective stipulated in the Pesticide Action Plan for the period 2004–2009 is that the pesticide application frequency[1] should be reduced from 2.04 in 2002 to 1.7 by the end of 2009, and that conversion to pesticide-free cultivation should be promoted (*Ministry of Environment and Energy & Ministry of Food, Agriculture and Fisheries, 2000*). The reduction target stipulated in this pesticide action plan is lower than the objective stipulated in the 1998 plan, which required halving of pesticide consumption expressed in terms of both the amount of active ingredient and the application frequency. Pesticide Action Plan II from 2000 aimed at reducing the application frequency to less than 2 before 2003 (*Ministry of Environment and Energy & Ministry of Food, Agriculture and Fisheries, 2003*).

[1] The pesticide application frequency is the number of times the total area of arable land in Denmark can be treated with the amount of active ingredient sold assuming it is used in the recommended dose.

Figure 5.4 Trend in amount of active ingredient and application frequency over the period 1990–2004. The reduction target is based on the mean for the period 1981–1985 (*Grant et al., 2005*).

Application frequency in 2004

At the national level the pesticide application frequency has increased to 2.18 in 2004 from 2.04 in 2002 (Figure 5.4). Relative to the original reference period (1981–1985), application frequency has fallen by approx. 18% and total consumption (expressed as the amount of active ingredient sold) by approx. 58%.



The most used pesticides in 2004

The pesticide consumption data for the agricultural monitoring catchments show that mancozeb was the pesticide used in the greatest amount expressed in terms of the amount of active gradient used relative to the catchment area (Table 5.6). The pesticide used on the greatest proportion of the total catchment area was azoxystrobin.

Table 5.6 Consumption of the 15 active ingredients used in the largest amounts in five agricultural monitoring catchments in 2004. The application rates are the mean for the whole of the catchment area. The treated area is indicated in percent of the total area (*Grant et al., 2005*).

Active ingredient	g a.i./ha	Treated area of catchment (%)
Mancozeb	115	2.1
Glyphosate	88	9.8
Pendimethalin	87	15.3
Prosulfocarb	71	10.8
Chlormequat chloride	47	6.0
MCPA	45	10.4
Metamitron	41	4.1
Terbutylazine	37	6.0
Fenpropimorph	32	22.5
Bentazon	24	8.4
Azoxystrobin	23	38.5
Aclonifen	20	2.6
Pyridat	19	6.6
Glyphosate-trimesium	19	2.2
Phenmedipham	17	4.1

Four of the most used pesticides are among those most frequently detected in the near-surface groundwater in the agricultural monitoring catchments during the period 1993–2004 (*Grant et al., 2005*). These are bentazone, glyphosate, metamitron and MCPA listed in order of decreasing detection frequency.

Compliance with objectives

The subtarget stipulated in Pesticide Action Plan I that the amount of active ingredient sold should be reduced by 50% before 2003 relative to that in the period 1981–1985 has been met (Figure 5.4).

The reduction target stipulated in Pesticide Action Plan 2004–2009 that the application frequency should be reduced to 1.7 in 2009 from 2.04 in 2000 has not yet been met. The application frequency was 2.18 in both 2003 and 2004, which is slightly higher than in the preceding few years (Figure 5.4).

6 Groundwater

6.1 Groundwater

The drinking water supply in Denmark is based almost solely on groundwater. It is therefore important that the quality of the groundwater is such that it is suitable for use as drinking water. In addition, a large proportion of the water in the watercourses, lakes and fjords derives from the groundwater in their catchments. Contamination of the groundwater might therefore also affect these water bodies.

Groundwater monitoring

The objective of monitoring the groundwater is to follow the trend in the quality and the size of the resource.

Figure 6.1 Location of the groundwater monitoring sites and agricultural monitoring catchments (*GEUS, 2005*).

Groundwater monitoring

The monitoring is predominantly carried out through the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA) in approx. 1,200 wells at 51 different groundwater monitoring sites and five agricultural monitoring catchments (Figure 6.1), as well as in 20 areas in which a restricted monitoring programme is carried out in wells located in young groundwater.

The waterworks well control data and data on the amount of groundwater abstracted are also included as an element of the monitoring. The groundwater monitoring focuses on the general quality of the groundwater, while the waterworks well control focuses on the groundwater that is abstracted for the drinking water supply.

The main elements of the groundwater monitoring are the size of the groundwater resource, the concentration of natural chemical elements and not least, the trend in the content of contaminants such as nitrate, heavy metals, pesticides and other hazardous substances.

Water abstraction

The water supply in Denmark is based almost solely on groundwater. Thus 98% of the water is abstracted from aquifers. A modest amount of surface water is also abstracted for the water supply from Lake Haraldsted north of Ringsted and on the island of Christiansø.

Water abstraction over the period 1989–2004 is shown in Figure 6.2 apportioned according to the four main abstraction categories. The proportion of total groundwater abstraction in 2004 accounted for by each category is as follows:

- Public waterworks (61%)
- Commercial watering and fish farms (29%)
- Enterprises with their own well (10%)
- Surface water for all uses.

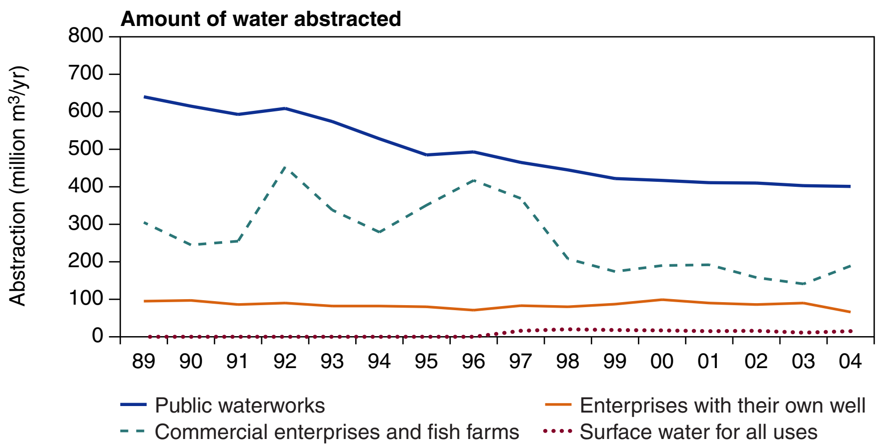


Figure 6.2 Water abstraction in Denmark apportioned by usage. No figures are available for abstraction of surface water before 1997 (*GEUS, 2005*).

The total amount of water abstracted in 2004 amounted to 656 million m^3, while abstraction of surface water amounted to 15 million m^3.

The amount of groundwater abstracted for field irrigation and fish farms increased by approx. 30% in 2004 compared with 2003. The increase was due to increased field irrigation as a result of the low precipitation in the early summer.

The decrease in water abstraction by public waterworks stagnated in 2000 relative to the preceding years (Figure 6.2). Over the period 1989–2004 as a whole, both total groundwater abstraction (Figure 6.3) and groundwater abstraction by the waterworks decreased by 37%.

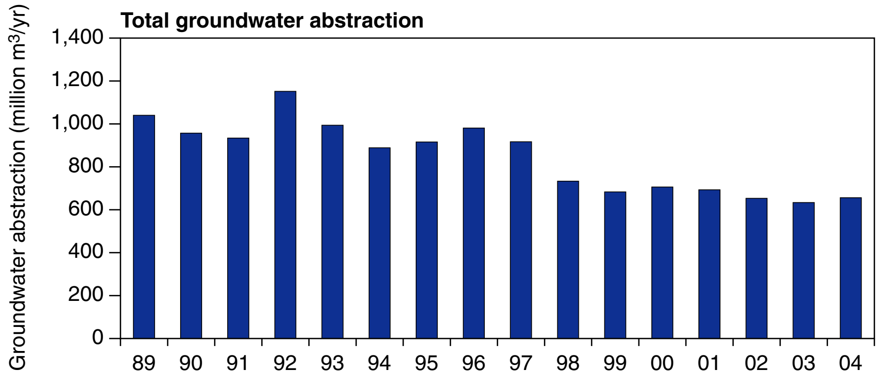


Figure 6.3 Total groundwater abstraction in Denmark (*GEUS, 2005*).

Compliance with objectives

The quality criterion for nitrate in drinking water of 50 mg nitrate/l is fulfilled by approx. 90% of the water that is used for the water supply. The nitrate concentration in the uppermost layer of the newly formed groundwater averages around this limit value, although the variation is considerable. Even though the nitrate content of the newly formed groundwater has generally been decreasing slightly in recent years, part of it thus still contains more than 50 mg nitrate/l.

In approx. 20% of the wells the phosphorus concentration exceeds the limit value for drinking water. This is of minor importance, however, as the phosphorus is removed at the waterworks. Whereas the nitrate in the groundwater derives almost solely from agricultural activities on the surface, a high phosphorus content is nearly always due to the geological conditions.

In 2004 the pesticide concentration in the waterworks wells continued the decline seen in the preceding years. Among other reasons the lower pesticide concentration is attributable to the closure of wells containing pesticide-contaminated water. The groundwater monitoring revealed an increase in the detection frequency of samples containing pesticides in concentrations exceeding the limit value for drinking water.

The available groundwater resource in Denmark exceeds approx. 1,000 million m^3 per year. At the national level there is sufficient water to meet requirements, which have amounted to around 600–700 million m^3 per year over the past 6–7 years. At the regional level, though, the groundwater resource around the major towns is insufficient to meet requirements without affecting watercourses and wetlands. In addition, dry summers can markedly change the needs for abstraction for field irrigation, as was the case in the mid and late 1990s.

6.2 Nitrate content of the groundwater – status

High concentrations of nitrate in the groundwater render it unsuitable as drinking water because a high nitrate concentration in the drinking water can inhibit oxygen transport by the blood. The risk is greatest in children. In addition, groundwater with a high nitrate concentration could represent a significant source of pollution of water bodies.

For the period 1990–2004 as a whole, 12,454 nitrate analyses are available from the groundwater monitoring sites, the agricultural monitoring catchments and the waterworks abstraction wells. The groundwater from nearly all these filters was formed before 1987. Thus the nitrate content does not reflect the measures implemented to reduce nitrate leaching under the 1987 Action Plan on the Aquatic Environment and later initiatives.

Depth distribution of nitrate

The majority of the samples with a raised nitrate content derive from filters located down to 40 m b.g.s. Not unexpectedly, the highest concentration was found in the upper 10 m of the soil column, where it was over 1 mg/l in more than 57% of the filters and over 50 mg/l in 17% (Figure 6.4).

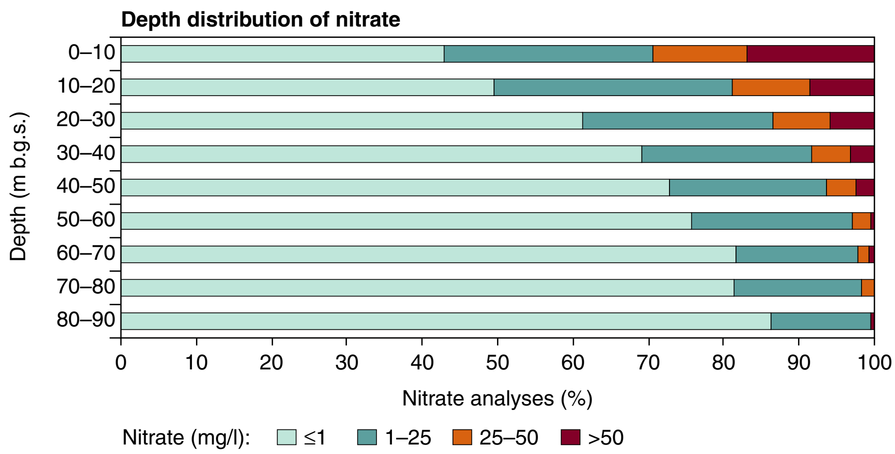


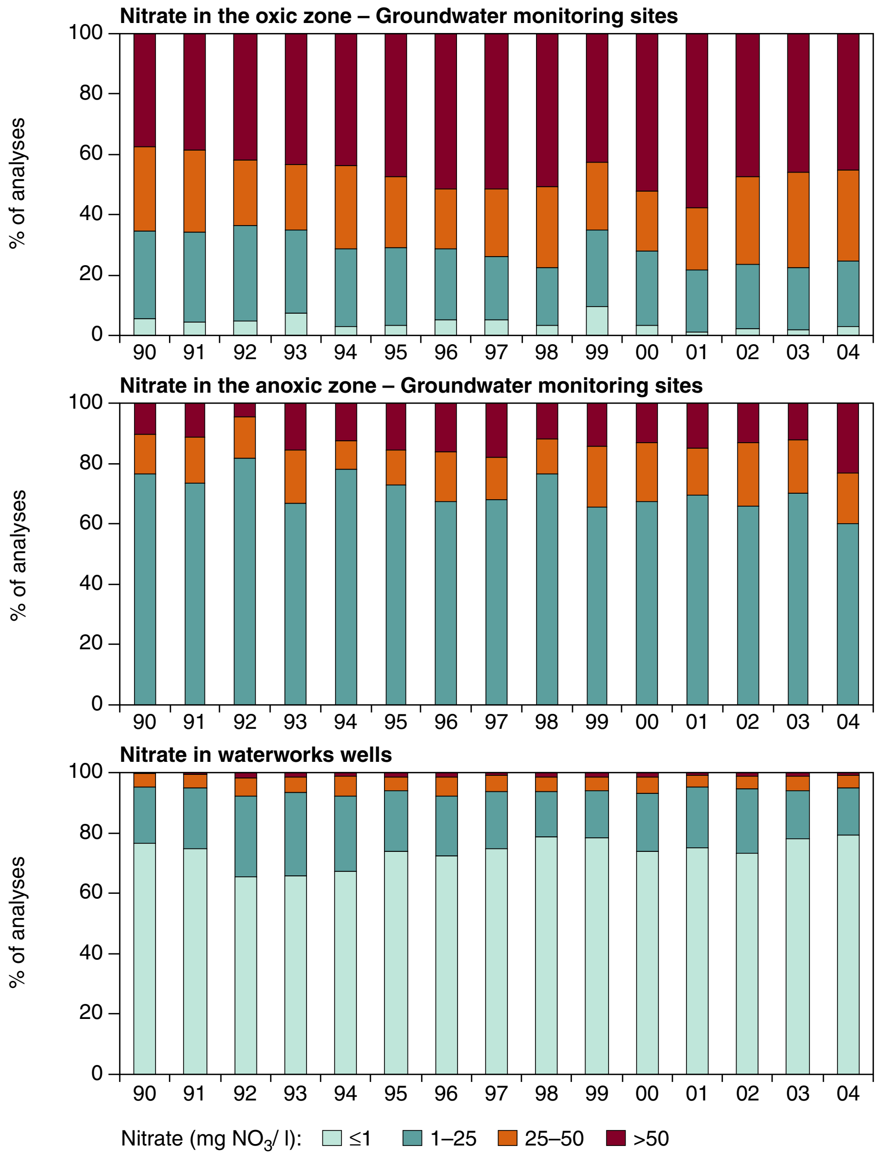
Figure 6.4 Distribution of nitrate content according to filter depth for agricultural monitoring catchments, groundwater monitoring sites, waterworks wells and "Other wells". All data for the period 1990–2004 are included (*GEUS, 2005*).

Distribution of nitrate by redox zone

From the geochemical point of view the groundwater can be subdivided into four redox zones, where the uppermost – the oxic zone – has a high oxygen concentration corresponding to that in the precipitation. In addition, the nitrate concentration can be high due to leaching from the root zone. Oxygen is utilized as the oxidant before nitrate and the oxygen concentration therefore decreases towards the next zone – the nitrate zone, where the oxygen concentration is low and where it is nitrate that is utilized (anoxic zone, oxygen concentration less than 1 mg/l and nitrate concentration over 1 mg/l). Beneath this zone lie the iron/sulphate and methane zones, both of which are devoid of nitrate and oxygen.

The frequency distribution of nitrate in four concentration intervals over the period 1990–2004 is shown for the oxic and anoxic zones at the groundwater monitoring sites and for the waterworks abstraction wells in Figure 6.5.

Figure 6.5 Distribution of nitrate content in four concentration intervals over the period 1990–2004. The upper figure panel is for the oxic zone (>1 mg O_2/l). The centre panel is for the anoxic zone (<1 mg O_2/l and >1 mg nitrate/l). The lower panel is based on the waterworks well control data. The individual columns represent groundwater from several filters differing markedly in age (*GEUS, 2005*).



No general trend in nitrate concentration is detectable over the period, and the depth distribution is as expected with the highest concentration in the oxic groundwater and a lower nitrate concentration in the anoxic groundwater. The lower nitrate concentration in this anoxic zone is attributable to the fact that nitrate is consumed here to oxidize reducing compounds, e.g. iron-sulphur compounds such as pyrite (FeS_2). The groundwater from filters located in the even more reducing zones (iron/sulphate and methane zones) does not contain any nitrate at all.

6.3 Nitrate content of the groundwater – trend

The trend in groundwater nitrate content over the period 1990–2004 is shown in Figure 6.6 for the upper groundwater in the agricultural monitoring catchments. The trend is shown for the sandy soil and clayey soil catchments and for all the active filters in oxic groundwater included in the groundwater monitoring programme (Figure 6.1).

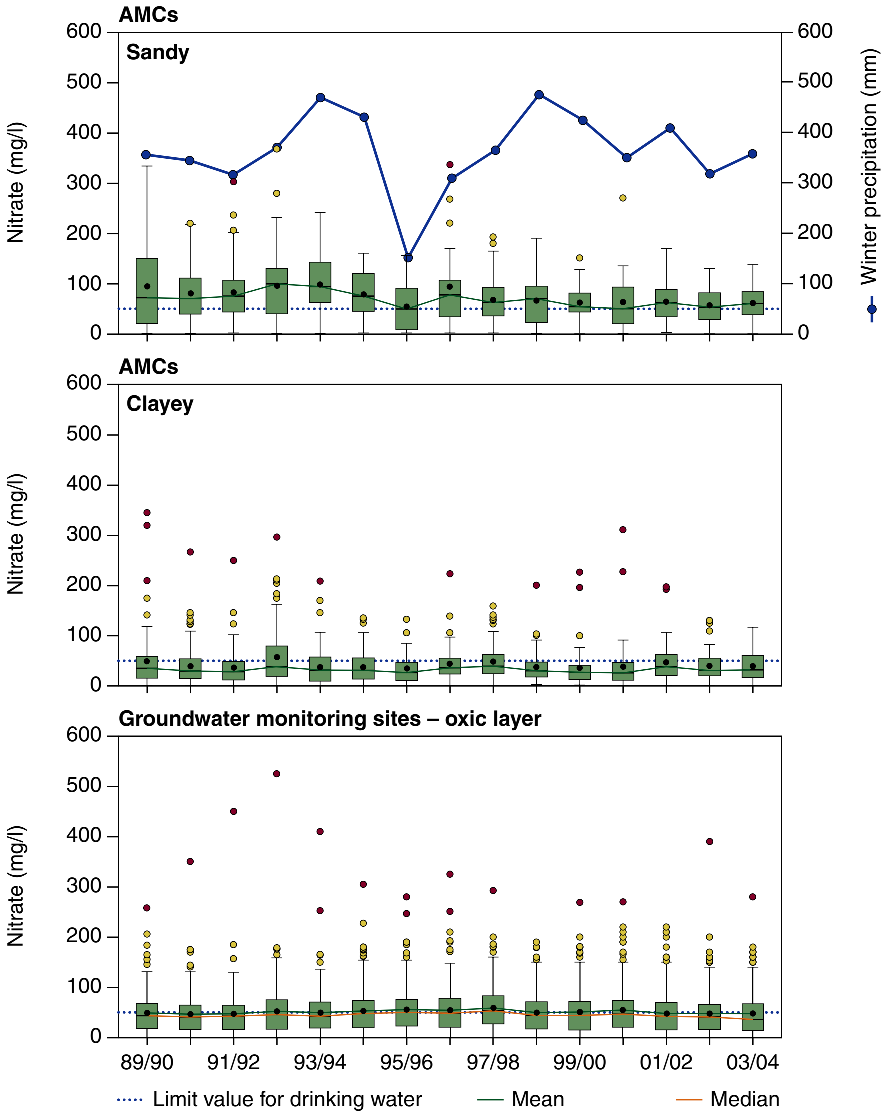


Figure 6.6 Trend in groundwater nitrate concentration over the period 1990–2004. The upper two panels show the concentration in upper groundwater in the winter months in sandy soil and clayey soil agricultural monitoring catchments (AMCs). The lower panel shows the oxic groundwater at the groundwater monitoring sites in these areas. The green curve is the mean concentration, and the orange curve is the median concentration. The figures also show the 10% and 25% percentiles for each year's analysis results and the limit value for nitrate in drinking water (50 mg/l). The upper panel also shows the interannual variation in winter precipitation (*GEUS, 2005*).

Regional distribution of nitrate in waterworks wells

As in previous years, the proportion of filters revealed by the waterworks well control data to have a nitrate concentration exceeding 25 mg/l is highest in Nordjylland, Viborg and Aarhus Counties – especially in the so-called "Nitrate belt" stretching from the northwestern part of Aarhus County into Viborg County. This is due to the combination of high nitrate loading and geological conditions (low nitrate reduction capacity) in the area. The groundwater that is abstracted for the drinking water supply in poorly protected areas such as on Mors, near Aalborg, on Djursland, around Roskilde Fjord and on Bornholm also has a high nitrate content. Thus it is still in Jutland, where the sandiest soils are located, that the proportion of abstraction wells with a relatively high groundwater nitrate content is greatest.

Agricultural monitoring catchments

From Figure 6.6 it can be seen that there is considerable spread in the winter nitrate concentration data for the near-surface groundwater of the agricultural monitoring catchments. The nitrate concentration is slightly higher in the clayey catchments than in the sandy catchments, where the reduction capacity is greater. As the oxygen concentration has not been measured, the agricultural monitoring catchments data cannot be related to the oxic or nitrate zones.

Over the period 1990–2004 the nitrate concentration in the uppermost groundwater of the sandy agricultural monitoring catchments decreased from approx. 90 mg nitrate/l to approx. 60 mg nitrate/l (Figure 6.6, upper panel). The decrease occurred up to winter 1999/2000, whereafter the change was small. The highest value during the period was 740 mg nitrate/l. In most years the mean concentration exceeded the limit value for drinking water (50 mg/l).

In the clayey catchments the mean nitrate concentration fluctuated around 40 mg/l (median values between 25 and 40 mg/l) and did not exhibit a clear decrease such as seen in the sandy catchments. The highest concentration during the period was 345 mg nitrate/l.

Groundwater monitoring sites

Over the period 1990–2004 the median nitrate concentration in the oxic groundwater at the groundwater monitoring sites (Figure 6.6, lower panel) increased steadily up to 1998 whereafter it fell to the lowest value of 36 mg nitrate/l in 2004. The mean values were somewhat higher than the median values. The mean concentration fell from 56 mg/l in 1998 to approx. 48 mg/l in 2002, whereafter it remained largely unchanged until 2004. Of the filters in the oxic zone, 25% contained more than 67 mg nitrate/l, and the highest measured value during the period was over 500 mg nitrate/l.

Effect of measures to reduce the nitrate concentration

The measures implemented to reduce nitrate leaching from fields following adoption of Action Plan on the Aquatic Environment I in 1986 have led to a reduction in the nitrate concentration in the uppermost groundwater in sandy areas. The water in the remaining groundwater bodies generally percolated down through the surface soil prior to 1987 and hence is unaffected by decisions made and measures implemented after that date.

6.4 Phosphorus in groundwater

Phosphorus in the groundwater does not generally pose any problem for the drinking water supply. The limit value of 0.15 mg/l for drinking water has been set because a higher concentration in shallow wells indicates some contamination with wastewater or other pollutants and hence that the water is unsuitable as drinking water.

As the majority of the phosphorus is removed during routine treatment of the water, a naturally high phosphorus content does not pose any problem for the public water supply.

Distribution of phosphorus in the groundwater

A total of 11,888 analyses of the total phosphorus content of groundwater are available for the period 1990–2004. There is no close relationship between phosphorus concentration and depth (Figure 6.7). The proportion of filters at which the phosphorus concentration is less than 0.15 mg/l decreases with depth, however, while the group with very high phosphorus concentrations has not changed noticeably.

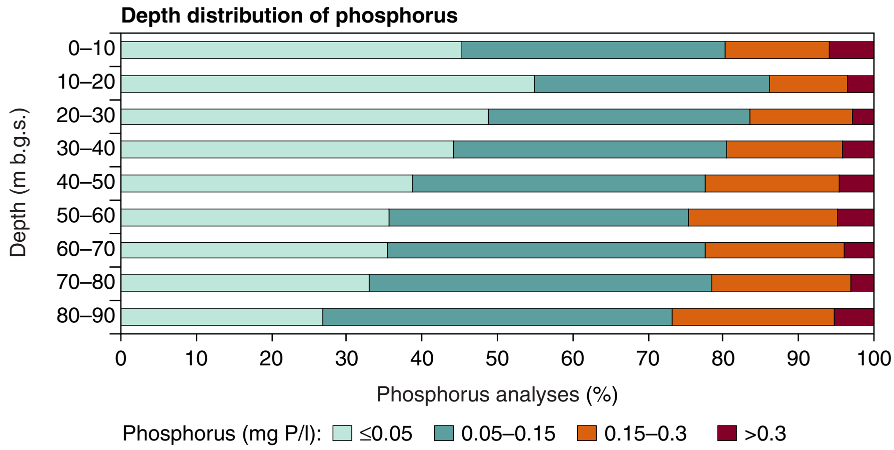


Figure 6.7 Distribution of phosphorus content according to filter depth for agricultural monitoring catchments, groundwater monitoring sites, waterworks wells and "Other wells". All data for the period 1990–2004 are included (*GEUS, 2005*).

At the groundwater monitoring sites approx. 2/3 of the filters contain more than 0.15 mg phosphorus/l, while the corresponding figure for waterworks abstraction wells is only 46%.

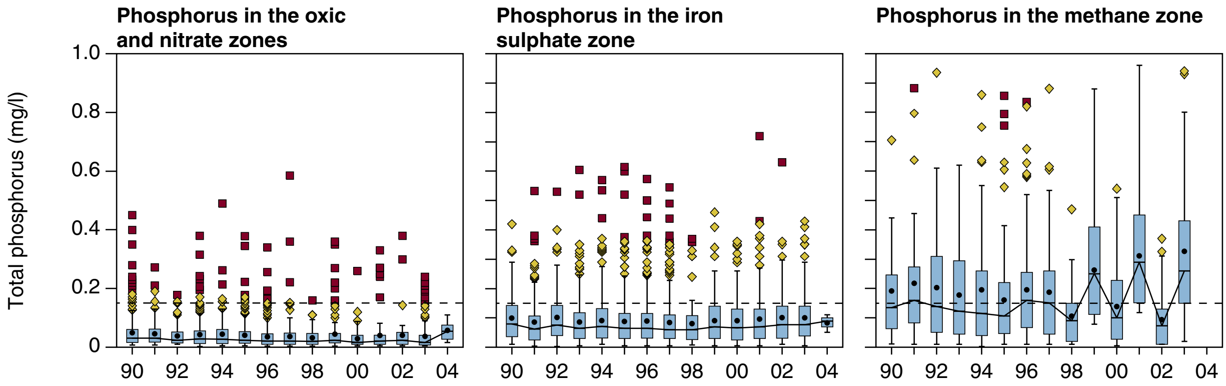
Trend in phosphorus concentration at the groundwater monitoring sites

The distribution of total phosphorus in three redox zones at the groundwater monitoring sites is shown in Figure 6.8.

In both the oxic and nitrate zones the concentration of dissolved phosphorus is low and at the same level. The two zones have therefore been combined. The concentration is below the limit value of 0.15 mg/l for drinking water in more than 90% of the filters. Under oxidizing redox conditions phosphorus is largely bound to soil particles, especially to iron compounds. No change in concentration is seen during the period. The number of filters analysed each year varies considerably from 56 to 250. In 2004 the number was only six, and hence not representative of the redox zone. The highest recorded concentration of dissolved phosphorus was 0.585 mg/l.

The phosphorus concentration is higher in the iron and sulphate zone, but is below the limit value for drinking water in more than 75% of the filters. The mean value fluctuates around 0.1 mg/l and has increased slightly over the past six years. The number of filters analysed each year also varies considerably in this zone, ranging from 64 to 333. In 2004 the number was only nine, and hence not representative of the redox zone. The highest recorded concentration of dissolved phosphate was 1.8 mg total phosphorus/l.

Figure 6.8 Trend in groundwater concentration of dissolved total phosphorus over the period 1990–2004 for three redox zones. The oxic and nitrate zones have been plotted together as they show the same phosphorus distribution. See also the legend to Figure 6.6 (*GEUS, 2005*).



The filters located in the methane zone often have a high concentration of dissolved phosphorus, with the mean concentration exceeding the limit value for drinking water. The number of filters analysed each year also varies considerably in this zone, ranging from 32 to 101. No filters in this redox zone were analysed in 2004. The highest recorded concentration of dissolved phosphorus was 1.125 mg total phosphorus/l.

Regional distribution of phosphorus in waterworks wells

In certain parts of the country the phosphorus concentration in the waterworks wells is relatively high. In approx. 20% of the filters for which data have been submitted the concentration of dissolved phosphorus was higher than 0.15 mg P/l (1,392 filters/wells). The highest phosphorus concentrations (over 0.3 mg/l) can often be related to wells in which the water has been in contact with interglacial clayey marine deposits, such as in northern and southern Jutland and on Als, Ærø and Langeland. In areas where there are limestone deposits beneath the Quaternary deposits and *no* interglacial marine deposits such as in large parts of Zealand and on Lolland, Falster and Møn and in Djursland, Himmerland and Hanherred, there are only very few wells with a phosphorus concentration exceeding 0.15 mg/l. In these areas, where the water flows through limestone, phosphate can react with calcium and precipitate out as insoluble apatite. In cases where phosphorus is present in near-surface groundwater this is probably due to contamination from the surface. Thus very high concentrations of phosphorus (approx. 1 mg/l) have been recorded in the agricultural monitoring catchments, indicating periodic leaching of phosphorus from the surface.

Conclusion regarding phosphorus content

The measured phosphorus concentrations in the groundwater most likely reflect the natural concentration in the groundwater, and this has remained unchanged during the monitoring period. The phosphorus concentration is raised in some of the very uppermost groundwater, however.

6.5 Inorganic trace elements

Nickel and arsenic are among a large number of inorganic trace elements included in both the groundwater monitoring and the waterworks' control of their abstraction wells. Both substances are naturally occurring in the groundwater, and both affect health. Nickel is increasingly causing allergy, and arsenic is highly toxic to man.

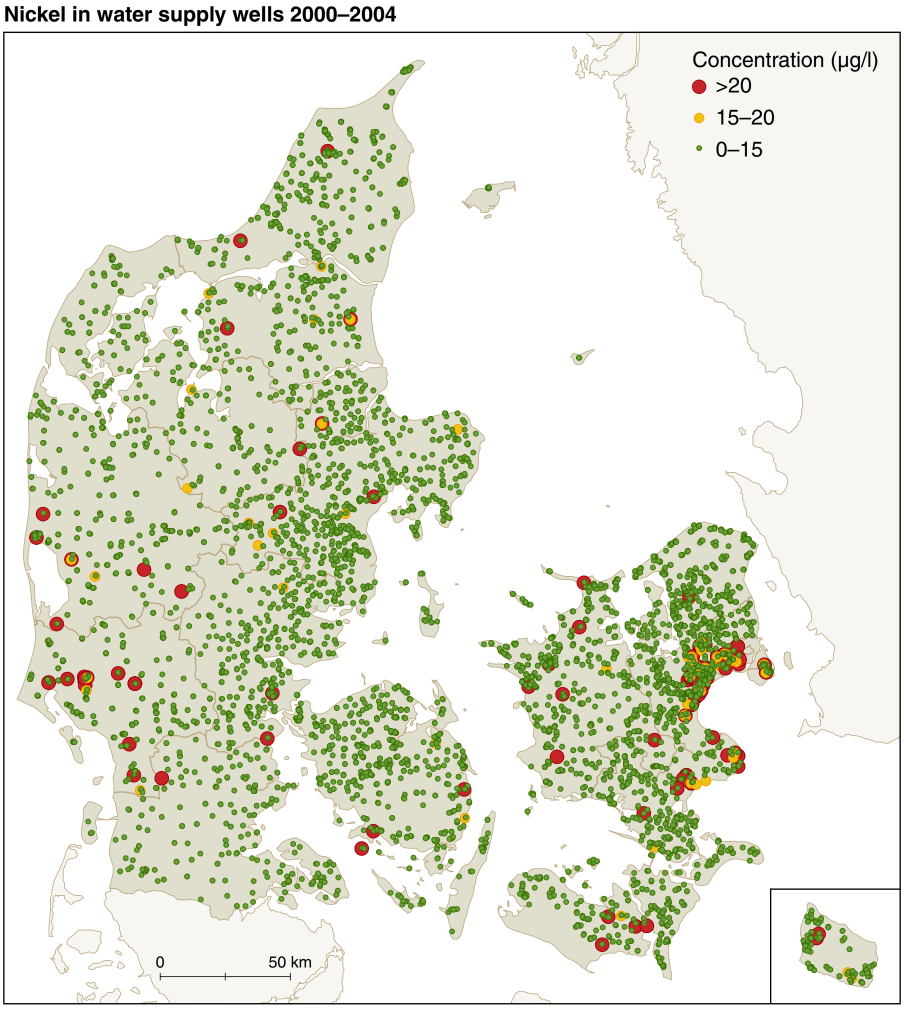
Objective

The preliminary quality criteria for nickel and arsenic in drinking water are 20 µg/l and 5 µg/l, respectively, at the supply pipe feeding each property (*Ministry of Environment and Energy, 2001*). Both nickel and arsenic can to some extent be removed in the waterworks' traditional sand filters and retained in the ochre sludge. Pursuant to the Water Framework Directive the concentration may not increase to a degree that necessitates more comprehensive water treatment.

Nickel

Nickel is present in the soil in pyrite (iron sulphide). If the groundwater table is lowered, for example in connection with overpumping, the oxygen in the air will have free access to the pyrite-containing soil layers. This results in the conversion of pyrite to dissolved iron and sulphate and the release of nickel. During the period 2000–2004, nickel was detected in concentrations exceeding the detection limit of 0.03 µg/l in 65% of the wells investigated, while the concentration exceeded the limit value for nickel in drinking water of 20 µg/l in just under 3%. In just under 2% of the wells all the analysed samples exceeded the limit value. This corresponds to the level in the period 1998–2003. Exceedance of the limit value is particularly common in the eastern part of Zealand (Figure 6.9), where extensive groundwater abstraction and the consequent penetration of atmospheric air into the near-surface limestone aquifers containing nickel-rich sulphides has resulted in dissolution of the sulphides and hence to high nickel concentrations.

Figure 6.9 Nickel concentration in water supply wells based on waterworks well control data for the period 2000–2004 (*GEUS, 2005*).



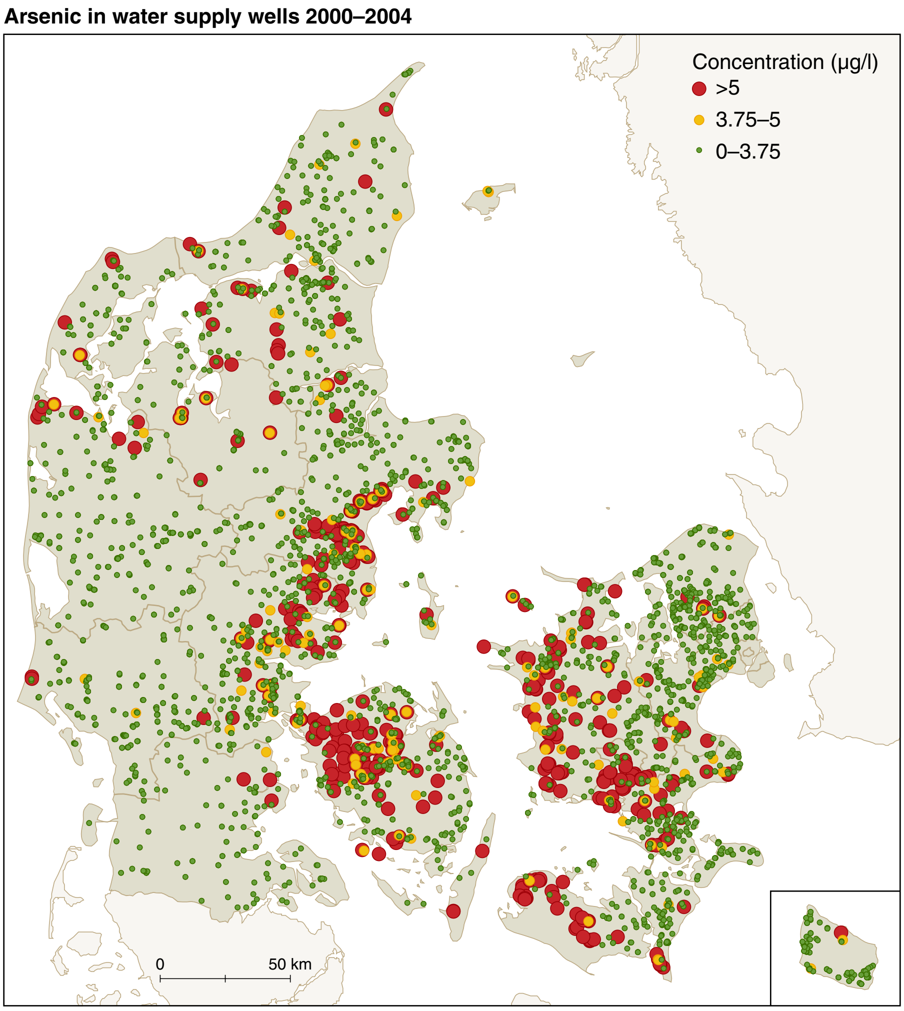
Arsenic

Arsenic is virtually only present in groundwater devoid of oxidants such as oxygen, nitrate or sulphate. Under oxidizing conditions, arsenic is present in a form that is virtually insoluble in water.

Over the period 2000–2004, arsenic was detected in concentrations exceeding the detection limit of 0.03 µg/l in 89% of the investigated wells, while the concentration exceeded the limit value for arsenic in drinking water of 5 µg/l in 16%. In approx. 3% of the wells, all the analysed samples exceeded the limit value. This corresponds to the level in the period 1998–2003.

The geographic distribution of arsenic shows that its occurrence mainly depends on the geological conditions (Figure 6.10), with the highest concentrations being found in areas where the rock is Tertiary marine clay.

Figure 6.10 Arsenic concentration in water supply wells based on waterworks well control data for the period 2000–2004 (*GEUS, 2005*).



6.6 Pesticides

Pesticides and their degradation products in groundwater derive from the use of pesticides in agriculture and forestry and on uncultivated land in urban areas. The substances are not retained or degraded upon traditional water treatment at Danish waterworks. Thus the groundwater concentration must not increase to a degree that necessitates more comprehensive water treatment before it can by used as drinking water.

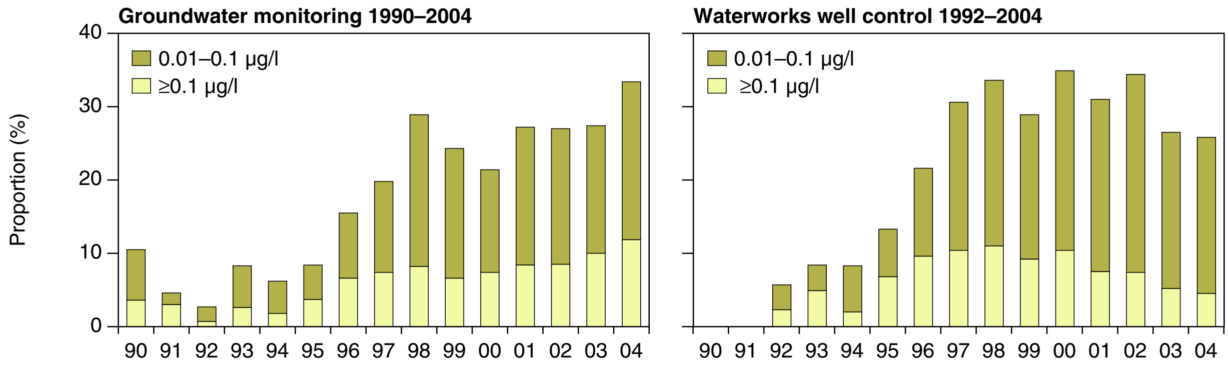
Objective

The pesticide concentration in drinking water must not exceed 0.1 µg/l for single substances, i.e. pesticides and relevant degradation products. If several substances are present in the drinking water the sum concentration must not exceed 0.5 µg/l. Among other places the limit values are stipulated in the EU Drinking Water Directive (*European Parliament and Council, 2000*) and in the Statutory Order on drinking water (*Ministry of Environment and Energy, 2001*) based on the principle that drinking water should not contain pesticides. The limit values are not based on a direct assessment of the substances' effects on health.

Pesticides in groundwater in 2004

The frequency of pesticide detection at the groundwater monitoring sites was greater in 2004 than in the preceding years. Moreover, the proportion of investigated filters exceeding the limit value for drinking water increased relative to 2003. This was also the case in 2003, when a small increase was recorded relative to the period 1996–2002, whereas the proportion of filters exceeding the limit value for drinking water was nearly constant over the period 1996–2002 (Figure 6.11).

Figure 6.11 Pesticide and degradation product detection frequency in the groundwater monitoring over the period 1990–2004 and in the waterworks well control over the period 1992–2004 (*GEUS, 2005*).



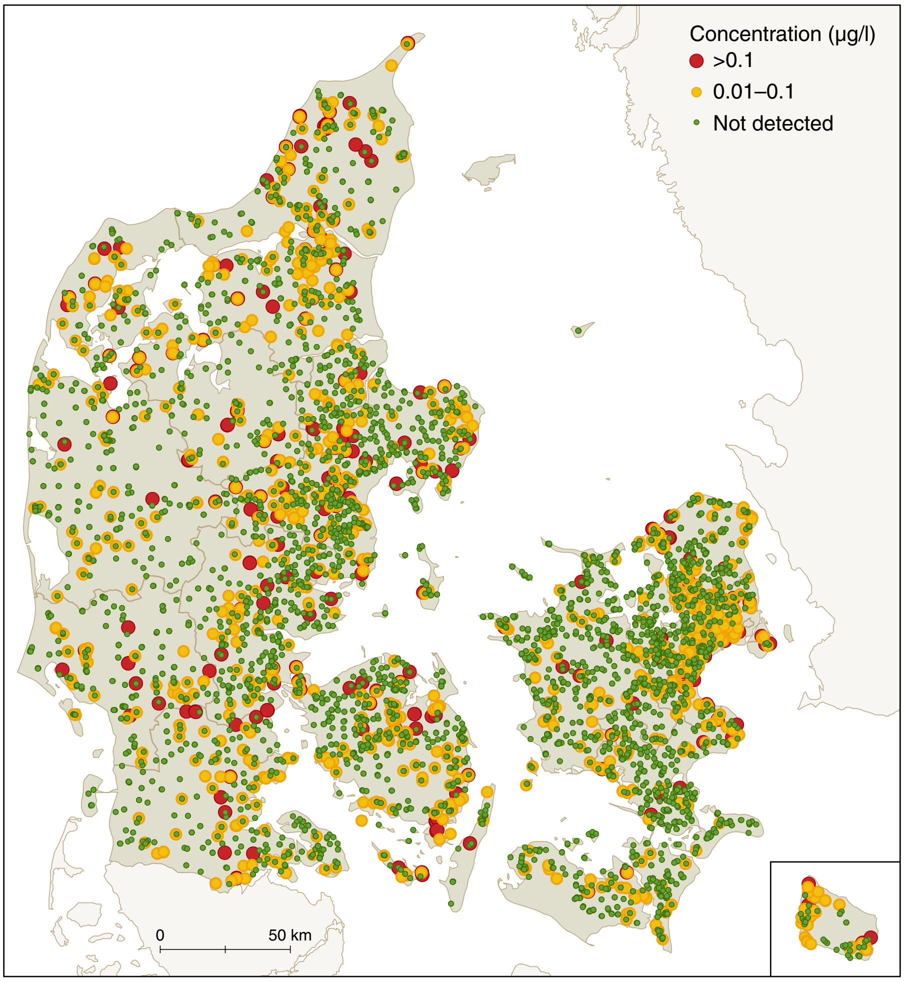
The pattern for pesticides in the waterworks wells does not correspond to that in the groundwater monitoring wells. The proportion of abstraction wells exceeding the limit value for drinking water in 2004 was the lowest since 1995. In 2004 the limit value for drinking water was exceeded in approx. 5% of the wells investigated and pesticides were detected in 26%. The decrease in the proportion of wells exceeding the limit value for drinking water in recent years is due to the fact that the waterworks take contaminated wells out of production. The increase in the proportion of wells affected by pesticides during the 1990s is not attributable to increasing contamination of the groundwater but to the fact that many waterworks have analysed for an increasing number of pesticides and degradation products. At the groundwater monitoring sites the presently banned pesticide metribuzin was frequently detected in sandy areas of Jutland, where it had been used in potato cultivation. In these areas the monitored groundwater is relatively close to the surface. In a single county the metribuzin degradation products diketo-metribuzin and desamino-diketo-metribuzin have been detected in more than 50% of the analysed samples. In other sandy areas, the degradation products have been detected in around 10% of the analysed samples. The substances have not been detected on the island part of Denmark. They are not expected to be detected in the near-surface groundwater in the agricultural monitoring catchments as potatoes are not cultivated in any of the catchments. 2004 is the first year that the degradation products of metribuzin were included in the monitoring programme.

Regional distribution

Many pesticides and degradation products have been detected around the large towns. The dominant substances are BAM and its mother compound dichlobenil, which was the active ingredient in the herbicide Prefix and others. The pesticide detection frequency also seems to be high in the clayey areas (Figure 6.12). The detection frequency is low in the sandy heaths of Jutland and on the former seabed in northern Jutland; this can be explained by the fact that the waterworks generally abstract from greater depths here than in the remainder of the country due to the presence of nitrate in the uppermost groundwater.

Figure 6.12 Pesticides and degradation products detected in water supply wells based on waterworks well control data for the period 1993–2004. Only active abstraction wells are included in the figure. Wells in which pesticides have been detected on one or more occasions are indicated as large points. The individual wells thus do not necessarily contain pesticides today (*GEUS, 2005*).

Pesticides in water supply wells 1993–2004



7 Watercourses

7.1 Watercourses

The main environmental problem with Danish watercourses is that the habitats for plants and animals have become impoverished due to watercourse regulation, obstructions and watercourse maintenance, and that the watercourses are polluted with degradable organic matter discharged with wastewater. In addition, abstraction of water in the catchments reduces flow in many watercourses, especially in the vicinity of large towns. In wetlands with a high content of pyrite, moreover, drainage has led to pollution with ochre.

The problem of organic matter pollution has largely been solved through biological treatment of wastewater, and the effects of these efforts have rapidly become apparent in the watercourses. In contrast, regulated and channelized watercourses are unable or only slowly able to re-establish natural morphological conditions and hence habitats for animals and plants.

Monitoring programme

The monitoring programme is designed such that the measurements provide information about four important factors:

- *Ecological status and compliance with quality objectives at a representative network of stations*. The key elements here are investigations of the macroinvertebrate fauna and physical conditions 1–2 times during each 6-year period at 800 representative watercourse stations. At 250 of the stations, though, the investigations are performed yearly. In addition, more comprehensive biological investigations are performed each year at 50 stations, including investigations of aquatic plants, fish and riparian areas.
- *Nutrient concentrations in watercourses in different loading categories*. Measurements in watercourses in semi-natural catchments provide an indication of what nutrient levels would have been in the complete absence of pollution. By comparing with measurements from watercourses in agricultural catchments it is possible to determine the magnitude of the agricultural nutrient losses.
- *Nutrient transport to marine waters and some lakes via watercourses*. This transport is determined 18 times a year in 179 watercourses on the basis of daily measurements of water flow and the concentration of nutrients, organic matter, etc.
- *Hazardous substance concentrations*. Heavy metals, pesticides and other hazardous substances are measured 12 times a year in five watercourses.

Climate and runoff in 2004

Mean freshwater runoff amounted to 347 mm, corresponding to 14,930 million m^3 (Figure 1.4). Precipitation exceeded the normal value in six of the seven preceding years, and watercourse flow was therefore also greater than normal. This helps enhance watercourse biological quality. Due in particular to the geographical differences in the magnitude of precipitation, freshwater runoff varies considerably from one part of the country to another (Figure 7.1). Freshwater runoff was lowest in the catchments draining into the southern Belt Sea, the Great Belt, the Baltic Sea and Øresund, typically in the range 150–250 mm, and as usual highest in western Jutland, with values between 450 and 500 mm. Moreover, runoff was generally slightly above the normal values in Jutland, but close to the normal value in the eastern part of Denmark.

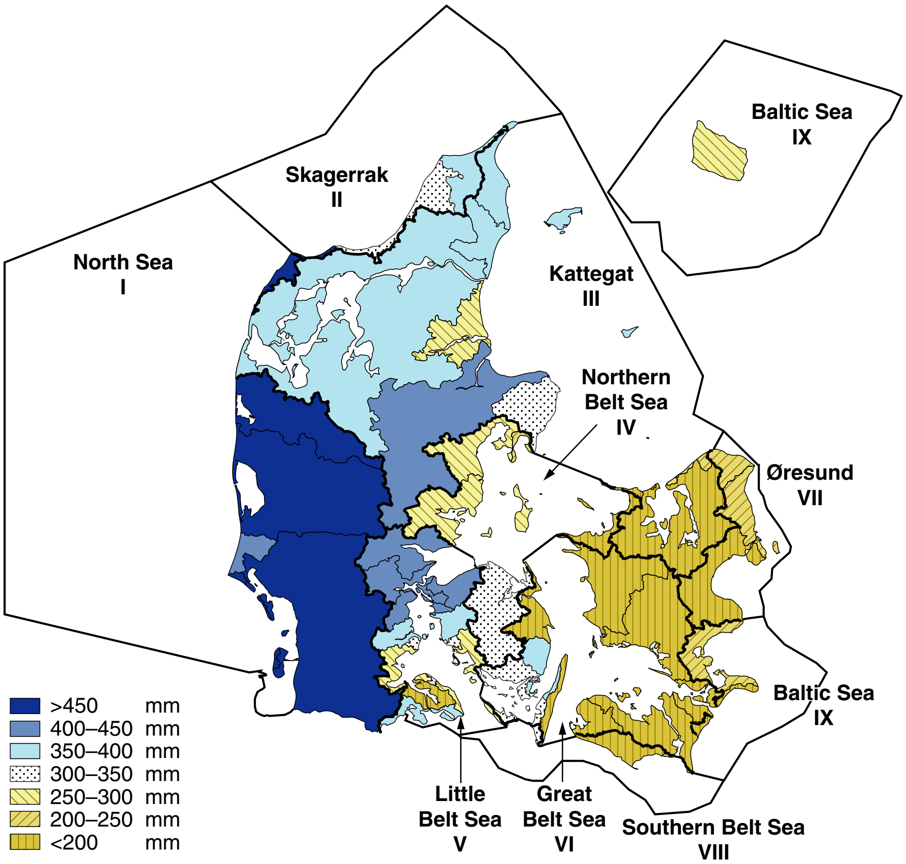


Figure 7.1 Freshwater runoff from the various river basins in Denmark in 2004 (*Bøgestrand (ed.), 2005*).

Compliance with quality objectives

The quality objectives for watercourses are set in each County's Regional Plan. Compliance with the quality objectives is generally assessed using a quality index – the Danish Stream Fauna Index (DSFI). The DSFI is typically 7 in unpolluted streams with a diverse macroinvertebrate fauna and 1 or 2 in strongly polluted streams. The quality objective specified for most streams in the Regional Plans is that DSFI should be at least 5, but the objective can be as low as 3 or as high as 7 for some watercourses. Danish watercourses are not subject to any general requirements as regards water flow, nutrient concentrations or physical conditions.

The monitoring results show that the ecological quality of Danish watercourses has improved steadily since 1994. This is chiefly due to improved wastewater treatment and more environmentally sound watercourse maintenance. At the national level, 58% of the investigated watercourses met their quality objective in 2004. All six of the watercourses investigated on Bornholm met their quality objective as compared with 61% of the watercourses on Funen, 62% of those in Jutland and only 34% of those on the island part of Denmark east of the Great Belt. Compliance with objectives is best (88%) for watercourses with a high quality objective, where the DSFI normally has to be at least 6.

7.2 Watercourse biological quality – macroinvertebrates

Watercourse biological quality is assessed on the basis of the macroinvertebrate community. The fauna is characterized using the so-called Danish Stream Fauna Index (DSFI) on a scale ranging from 1 (very severely affected) to 7 (unaffected). The quality objective is usually considered to be met if the DSFI is 5, 6 or 7.

In 2004, approx 51% of the watercourses were fauna classes 5, 6 or 7, which are characteristic for relatively clean and physically varied watercourses (Figure 7.2). In a further 40% of the watercourses the macroinvertebrate fauna was moderately affected (fauna class 4). Less than 10% of the watercourses were fauna classes 1, 2 or 3, which characterize poor and bad biological quality.

Large and small streams

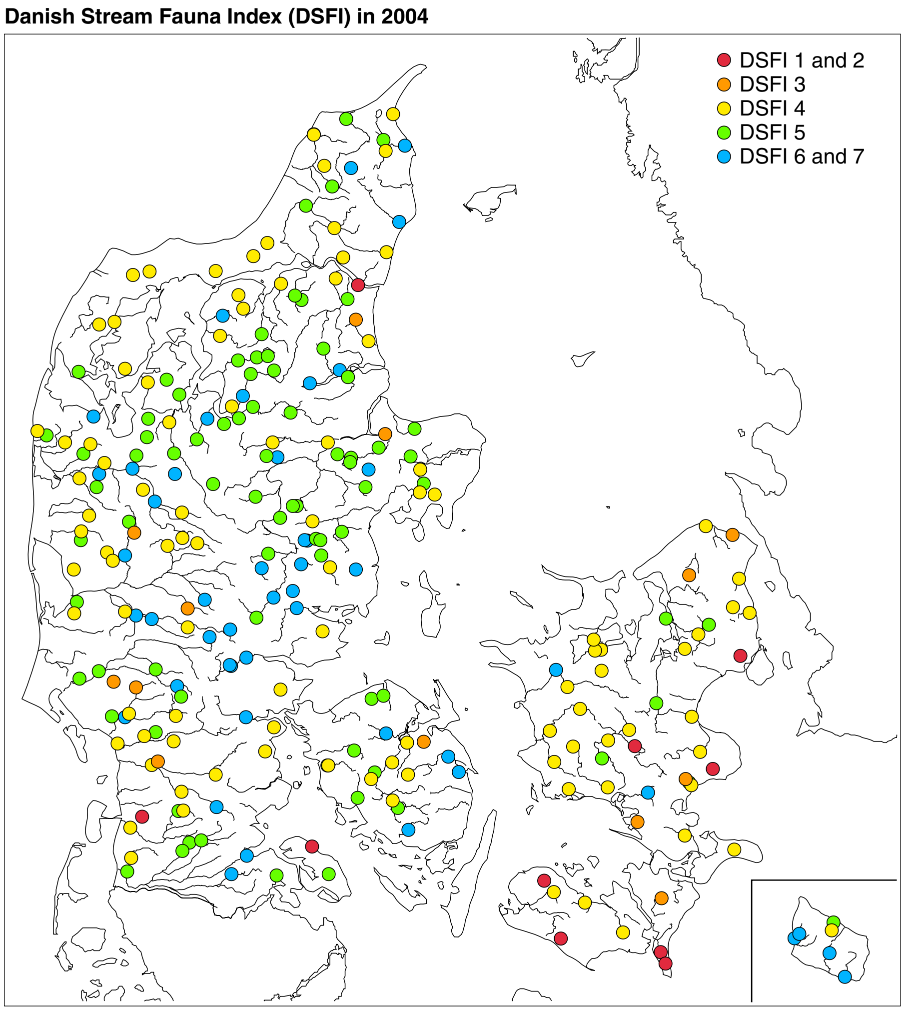
The biological quality of the large watercourses was generally better than that of the small watercourses. The proportion of watercourses with fauna class 6 or 7 thus increased with increasing width from 15% (0–2 m) to 50% (>10 m). Moreover, none of the large watercourses had fauna class 1, 2 or 3.

The biological quality of the watercourses was best in Jutland and on Funen and Bornholm, and worst on the island part of Denmark east of the Great Belt and in watercourses with a slight fall, e.g. around Limfjorden (Figure 7.2).

Trend in watercourse biological quality

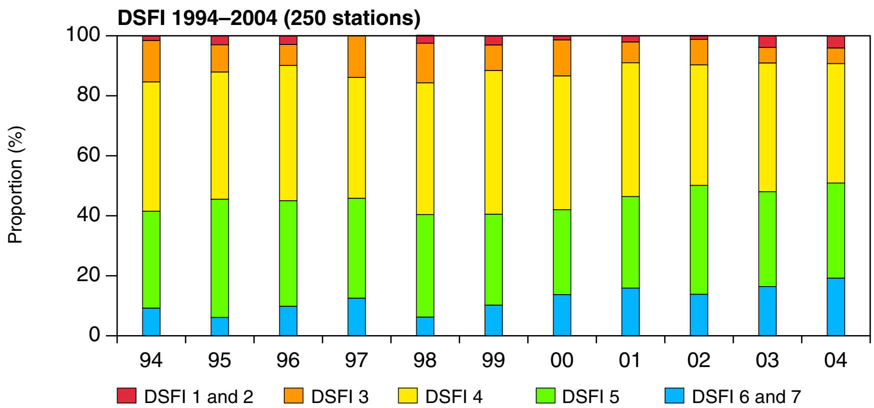
The monitoring programme has not utilized the same sampling methods and watercourse stations throughout the whole monitoring period since 1989. Thus until 1997, the biological quality of the watercourses was assessed using a different method and characterized from the degree of pollution on a scale from I to IV. Moreover, the station network was revised in connection with the transition from the NOVA to the NOVANA monitoring programme in 2004.

Figure 7.2 Environmental state of Danish watercourses in 2004 assessed from the macroinvertebrates using the Danish Stream Fauna Index (DSFI). Blue circles (DSFI 6 and 7) indicate watercourses with a natural or only slightly affected macroinvertebrate fauna. Red circles (DSFI 1 and 2) indicate severely polluted watercourses (*Bøgestrand (ed.), 2005).*



The trend in watercourse biological quality shown in Figure 7.3 is based on data from the 250 stations that will continue to be monitored each year under the NOVANA programme. From the figure it is apparent that the proportion of stations rated as DSFI 5, 6 and 7 has increased from 42% to 51%.

Figure 7.3 Environmental state of Danish watercourses over the period 1994–2004 assessed using the Danish Stream Fauna Index (DSFI). The number of stations on which the figures are based are as follows: 1994–1997 (65–72), 1998 (114), 1999–2003 (231–234) and 2004 (250) *(Bøgestrand (ed.), 2005).*



At 65 of the stations, biological quality has been assessed each year since 1994 using the DSFI. Based on these stations alone the proportion of watercourses rated DSFI 5, 6 or 7 has increased from 42% to 62%.

Conclusion regarding watercourse biological quality

The overall conclusion is that the biological quality of the watercourses has slowly improved since 1994 such that the quality of approximately half of the watercourses was acceptable in 2004. The improvements are due to the more varied physical conditions in many watercourses as a result of a switch to more environmentally sound watercourse maintenance and to improved wastewater treatment. The improvements in watercourse biological quality usually occur within a few years of the physical conditions being improved or wastewater loading being reduced. The improvements should be viewed in the perspective that improvements also took place in the decades prior to 1994.

7.3 Nitrogen in watercourses

The nitrogen in watercourses is generally of little significance for their biological quality, but is nevertheless important because it is transported by them to downstream lakes and marine waters. The majority of the nitrogen in Danish watercourses has leached from cultivated fields, while natural background loading and the various forms of wastewater account for a minor proportion.

Nitrogen concentrations in 2004

The nitrogen concentration is generally lower in the watercourses of western Jutland than in the watercourses located east of the glacial boundary of the last Ice Age (Figure 7.4). In western Jutland a large proportion of the precipitation percolates a long way through reducing (anoxic) aquifers before it reaches the watercourses. Underway, nitrate is converted by biological or chemical denitrification. In the watercourses of eastern Denmark a large proportion of the precipitation and the nitrate it contains will flow through the upper aquifers or drains without passing through anoxic zones. Thus less nitrate will be removed from the water before it reaches the watercourses. Low nitrate concentrations are also found in the water flowing out of lakes as considerable amounts of nitrogen are also removed by denitrification in lakes. The nitrogen concentration is lowest in watercourses that drain semi-natural areas and woodland.

The nitrogen concentration depends on land use in the watercourse catchment. The mean concentrations in watercourses draining semi-natural catchments and cultivated catchments with and without wastewater discharges are shown in Table 7.1. The concentration levels are 4–5-fold lower in watercourses draining semi-natural catchments than in those draining the cultivated catchments, and wastewater discharges do not significantly affect the nitrogen level. The difference in nitrogen transport in the cultivated and uncultivated catchments is even greater – approximately 10–15-fold (Table 7.1). This is due to the fact that water flow in the small natural watercourses is relatively lower than in the other watercourses. The large standard deviation within each loading category is due to differences in geology and land use in the various catchments.

Figure 7.4 Concentration of total nitrogen (flow-weighted annual mean values) in watercourses in 2004. The station network to which each station belongs is indicated. MLN: Marine loading network. CLCN: Catchment loading category network (*Bøgestrand (ed.), 2005).*

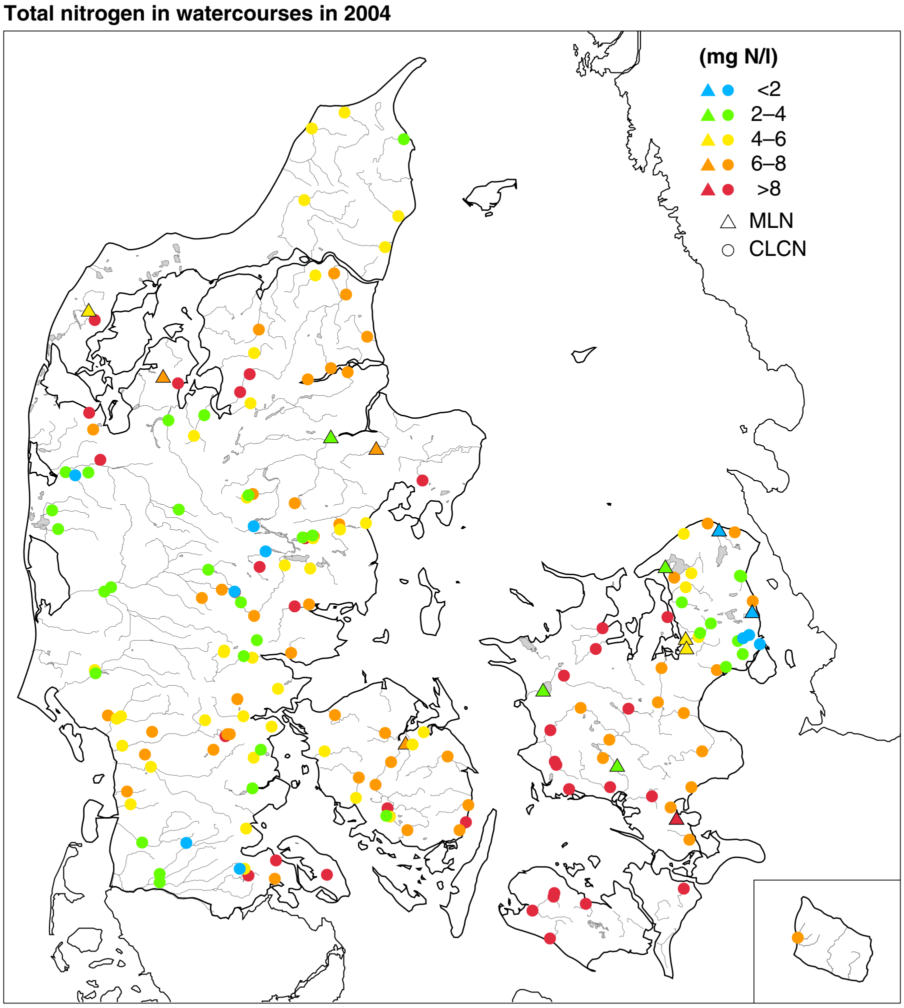


Table 7.1 Mean flow-weighted total nitrogen concentration and area coefficient (transport per ha catchment) in watercourses in different catchment loading categories in 2004. Both the lower watercourse categories receive wastewater from sparsely built-up areas (*Bøgestrand (ed.), 2005*).

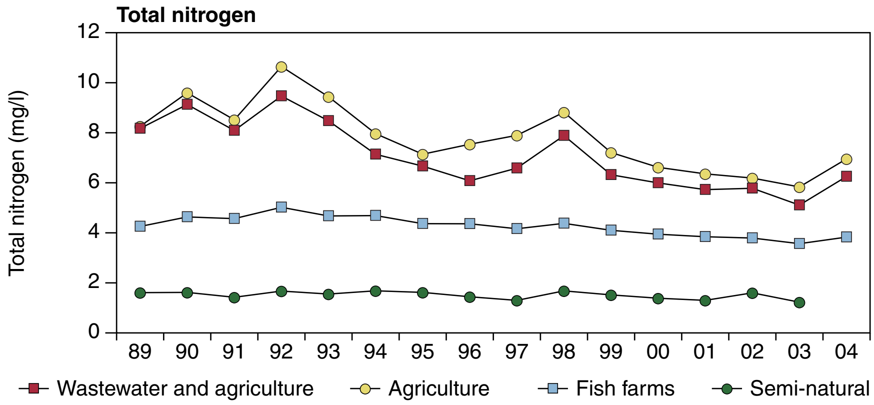
Catchment loading category	No. of watercourses	Concentration (mg N/l)	Area coefficient (kg N/ha)
Watercourses in semi-natural areas*	10	1.19 ±0.68	1.26 ±0.61
Agriculture and urban wastewater	64	5.38 ±1.93	17.1 ±8.41
Agriculture – no urban wastewater	100	6.98 ±2.10	18.2 ±8.34

* Data from 2003. After 2003 measurements are only made every three years.

Trend since 1989

The nitrogen concentration in watercourses is generally decreasing, although it remains virtually unchanged in watercourses in semi-natural catchments. The decrease is clearest for the watercourses classified as being located in cultivated catchments and cultivated catchments exposed to significant discharges of urban or industrial wastewater (Figure 7.5). In watercourses receiving significant discharges from freshwater fish farms the reduction in nitrogen concentration is minor. The concentration in these watercourses has been relatively low during the whole period, however, primarily because the fish farming industry is concentrated in groundwater-fed watercourses located in areas where the nitrate concentration in the groundwater is low. Taking all watercourses together, the mean flow-weighted nitrogen concentration has decreased by 29% since 1989, while nitrogen transport has decreased by 34%.

Figure 7.5 Trend in nitrogen concentration (flow-weighted annual mean values) in watercourses since 1989 in different catchment loading categories classified on the basis of conditions in 1991 (*Bøgestrand (ed.), 2005*).



7.4 Phosphorus in watercourses

The phosphorus in watercourses is only of minor significance for their biological quality, but is nevertheless important because it is transported by them to downstream lakes and marine waters. The phosphorus in Danish watercourses derives from three main sources: Natural background loading, leaching from cultivated fields and various wastewater discharges. The magnitude of these sources varies markedly from watercourse to watercourse depending on wastewater discharges, land use and geological conditions.

Total phosphorus in watercourses in 2004

High phosphorus concentrations are generally found in densely populated areas (e.g. northern Zealand) where there is little dilution of the wastewater that is discharged into the watercourses, including wastewater from sparsely built-up areas (Figure 7.6).

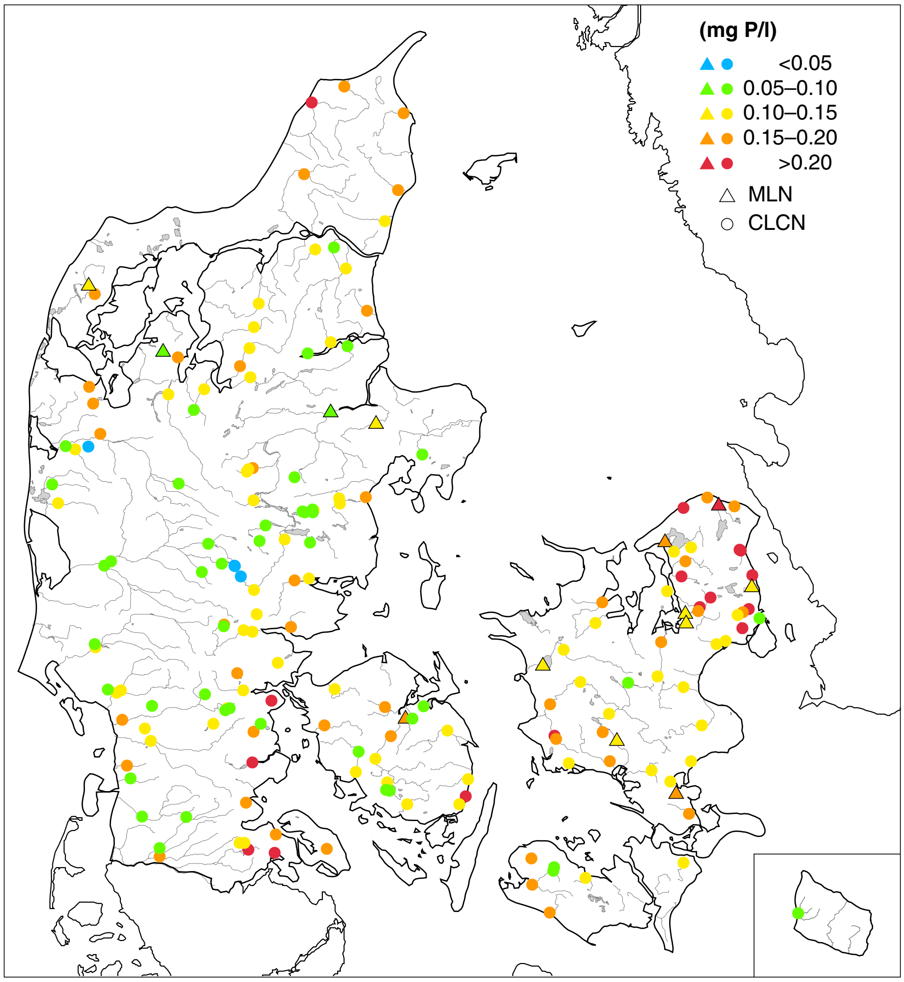
On average, the concentration of phosphorus in watercourses located in cultivated catchments or catchments with considerable point-source discharges was 2–3-fold higher than in watercourses in semi-natural catchments in 2004 (Table 7.2) and the area coefficient was approximately 5-fold higher. The concentration differs between watercourses only affected by agricultural production and wastewater from sparsely built-up areas outside the sewerage catchments and those that are also affected by urban wastewater, the concentration being highest in the latter watercourses.

Table 7.2 Mean total phosphorus concentration and area coefficient (transport per ha catchment) in watercourses in different catchment loading categories in 2004. Both the lower watercourse categories receive wastewater from sparsely built-up areas (*Bøgestrand (ed.), 2005*).

Catchment loading category	No. of watercourses	Concentration (mg P/l)	Area-coefficient (kg P/ha)
Watercourses in semi-natural areas*	10	0.05 ±0.03	0.06 ±0.04
Agriculture and urban wastewater	64	0.16 ±0.08	0.50 ±0.21
Agriculture – no urban wastewater	62	0.12 ±0.05	0.33 ±0.22

* Data from 2003. After 2003 measurements are only made every three years.

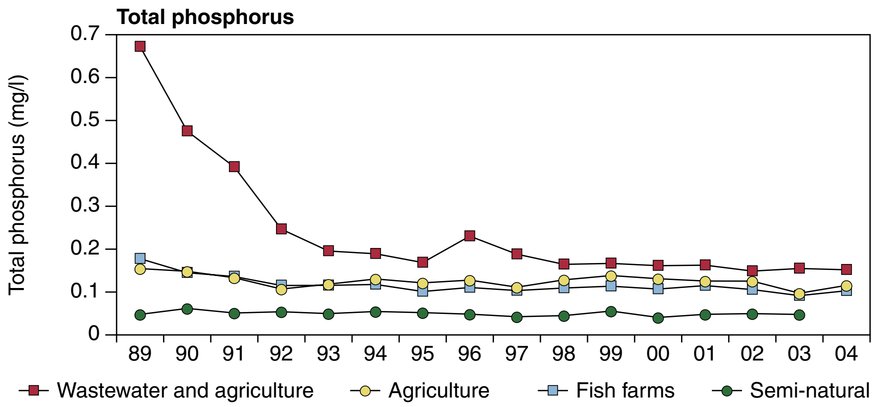
Figure 7.6 Concentration of total phosphorus (flow-weighted annual mean values) in watercourses in 2004. The station network to which each station belongs is indicated. MLN: Marine loading network. CLCN: Catchment loading category network (*Bøgestrand (ed.), 2005*).



Trend since 1989

The concentration of total phosphorus in watercourses receiving wastewater discharges from point sources decreased markedly during the first half of the 1990s and is now only slightly higher than in catchments solely affected by cultivation (Figure 7.7). The decrease is attributable to the upgrading of wastewater treatment plants with phosphorus removal, often also including small treatment plants to protect local recipients. The decrease in the early 1990s is a continuation of the decrease resulting from earlier implementation of phosphorus removal and the ban on discharges of seepage water from manure stores, etc. The phosphorus concentration in watercourses affected by freshwater fish farms has also decreased due to the reduction in discharges from the fish farms. No significant change has taken place in the watercourses draining semi-natural catchments, whereas both increases and decreases in the phosphorus concentration are seen in the watercourses in cultivated catchments. The decrease in the phosphorus concentration in some of these watercourses is attributable to both the reduction in wastewater discharges from sparsely built-up areas and changes in agricultural practice.

Figure 7.7 Trend in phosphorus concentration (flow-weighted annual mean values) in watercourses since 1989 in different catchment loading categories classified on the basis of conditions in 1991 (*Bøgestrand (ed.), 2005*).



Wastewater discharges from towns and sparsely built-up areas still account for a significant proportion of phosphorus input to watercourses, but are no longer the dominant source as was the case many years ago. Leaching of phosphorus from cultivated land presently comprises an equally great source of phosphorus input to watercourses.

7.5 Heavy metals in watercourses

Heavy metals are naturally occurring in the environment and occur in watercourses in natural background levels. Heavy metal concentrations are often elevated in watercourses where a large proportion of the water derives from wastewater discharges, even if the concentrations in the wastewater are low. In addition, atmospheric deposition of heavy metals contributes to their occurrence in watercourses.

Table 7.3 Quality criteria or proposed quality criteria for inland surface waters (*Ministry of Environment and Energy, 1996*).

Lead	3.2 µg/l
Cadmium	2.5 µg/l
Copper	12 µg/l
Mercury	1.0 µg/l
Zinc	110 µg/l

Objective

A quality criterion for inland surface waters for cadmium and proposed quality criteria for lead, chromium, copper, nickel and zinc are set in Statutory Order No. 921 (*Ministry of Environment and Energy, 1996*) (Table 7.3).

Heavy metal concentrations in 2004

The median heavy metal concentrations in the five investigated watercourses differ, and no one single watercourse differs from all the other watercourses with respect to all the metals (Figure 7.8):

- The median concentration of lead in the River Odense is twice that in the other watercourses
- The median concentration of zinc is highest in the River Skjern and River Odense and twice as high as in the River Tryggevælde
- The median concentrations of cadmium, mercury and copper are at the same level in all of the watercourses.

Compliance with quality criteria

The median concentrations of all heavy metals included in the monitoring programme are lower than the quality criteria for inland surface waters (Table 7.3) (*Ministry of Environment and Energy, 1996*). In five cases the concentrations detected exceeded the quality criterion – in three cases for lead, one for copper and one for mercury. In each of these cases the concentration was approximately twice the quality criterion for inland surface waters.

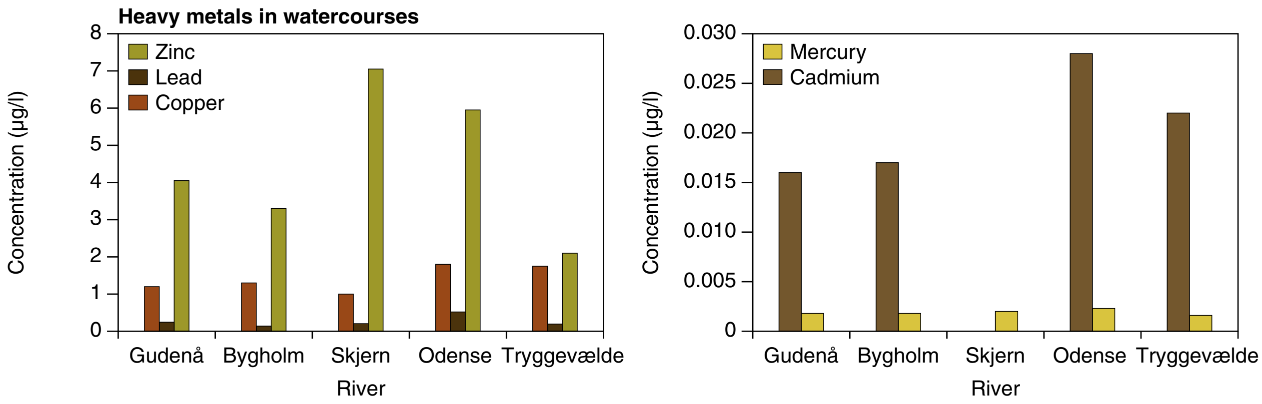


Figure 7.8 Median heavy metal concentrations in five large rivers in 2004 (*Bøgestrand (ed.), 2005*).

7.6 Pesticides in watercourses

Pesticides are widely detected in watercourses, particularly herbicides used in agriculture, forestry and in areas where vegetation is unwanted. The substances are toxic and can have harmful effects if they are present in high concentrations and/or are present for long periods. The effect of the substances on watercourse flora and fauna are not fully understood.

Pesticides detected in 2004

In 2004, one or more pesticides were detected in the majority of the samples analysed from five large watercourses. The pesticide monitoring programme for watercourses encompasses ten herbicides and eight of their degradation products (Figure 7.9).

Three of the five most commonly used herbicides have been detected in the investigated watercourses. They have also been detected in the near-surface groundwater beneath the fields in the agricultural monitoring catchments. These are as follows:

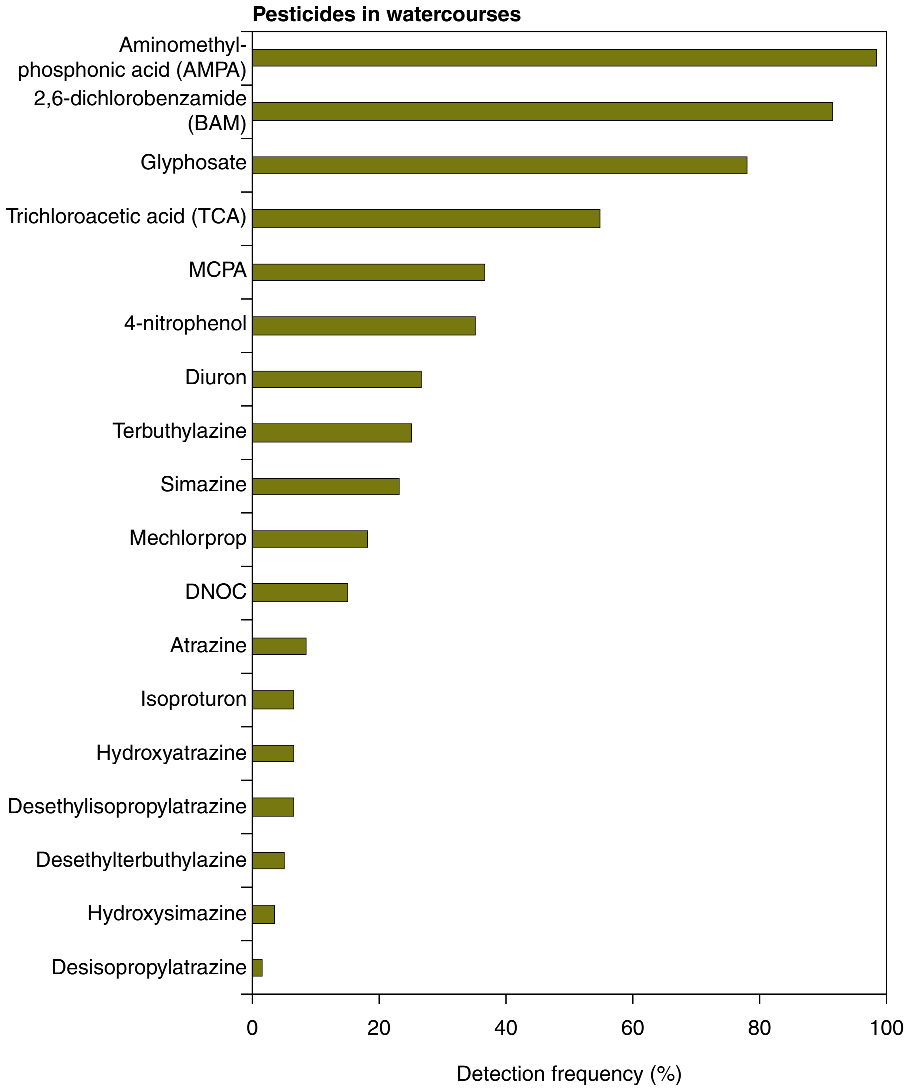
- Glyphosate – detected in all five watercourses and in 77% of all the samples analysed. The degradation product AMPA has been detected in 97% of the samples analysed
- MCPA – detected in all five watercourses and in 37% of the samples analysed
- Terbuthylazine – detected in four of the five watercourses and in 25% of the samples analysed.

Use of four of the monitored herbicides is no longer permitted. These are:

- Trichloroacetic acid (TCA) – detected in all five watercourses and in 55% of all the samples analysed

- 4-nitrophenol – detected in four of the five watercourses and in 35% of all the samples analysed. The substance is a degradation product of parathion, which was banned in Denmark in 2003. 4-nitrophenol is input via atmospheric deposition (see Section 5.3)
- DNOC – detected in four of the five watercourses and in 15% of all the samples analysed
- Atrazine – detected in three of the five watercourses and in 8% of all the samples analysed. Degradation products of atrazine have been detected in a few samples.

Figure 7.9 Pesticide detection frequency in watercourse samples expressed as the percentage of analysed samples containing pesticide in concentrations exceeding the detection limit (*Bøgestrand (ed.), 2005*).



Metribuzin, which is frequently detected in the groundwater (see Section 6.6), was only detected in a few watercourse samples under the NOVA-2003 monitoring programme and hence has not been included in the NOVANA subprogramme for watercourses.

Compliance with quality criteria

No Danish quality criteria have been set for the investigated herbicides.

8 Lakes

8.1 Lakes

The main environmental problem with Danish lakes is the excessive amount of phytoplankton in the water due mainly to wastewater and agricultural inputs of phosphorus. This makes the water unclear, reduces the occurrence of submerged macrophytes, causes oxygen problems at the lake bed and thereby changes the whole of the lake flora and fauna.

Phosphorus removal at wastewater treatment plants and the cessation of wastewater discharges have markedly reduced wastewater inputs of phosphorus. This has reduced the level of pollution in many lakes, but improvement in the lakes is limited due to the considerable phosphorus loading that still takes place from cultivated land and via wastewater from sparsely built-up areas and stormwater runoff from towns. In addition, the improvements in the lakes generally take place very slowly because of the release from the lake sediment of accumulated phosphorus derived from wastewater discharges in earlier years.

Monitoring programme

The monitoring programme was modified in 2004 and now encompasses extensive monitoring of 1,074 lakes and ponds with a limited programme every 3rd or 6th year. At the same time the number of intensively monitored lakes has been cut back to 23, of which 20 have been included in the programme since 1989.

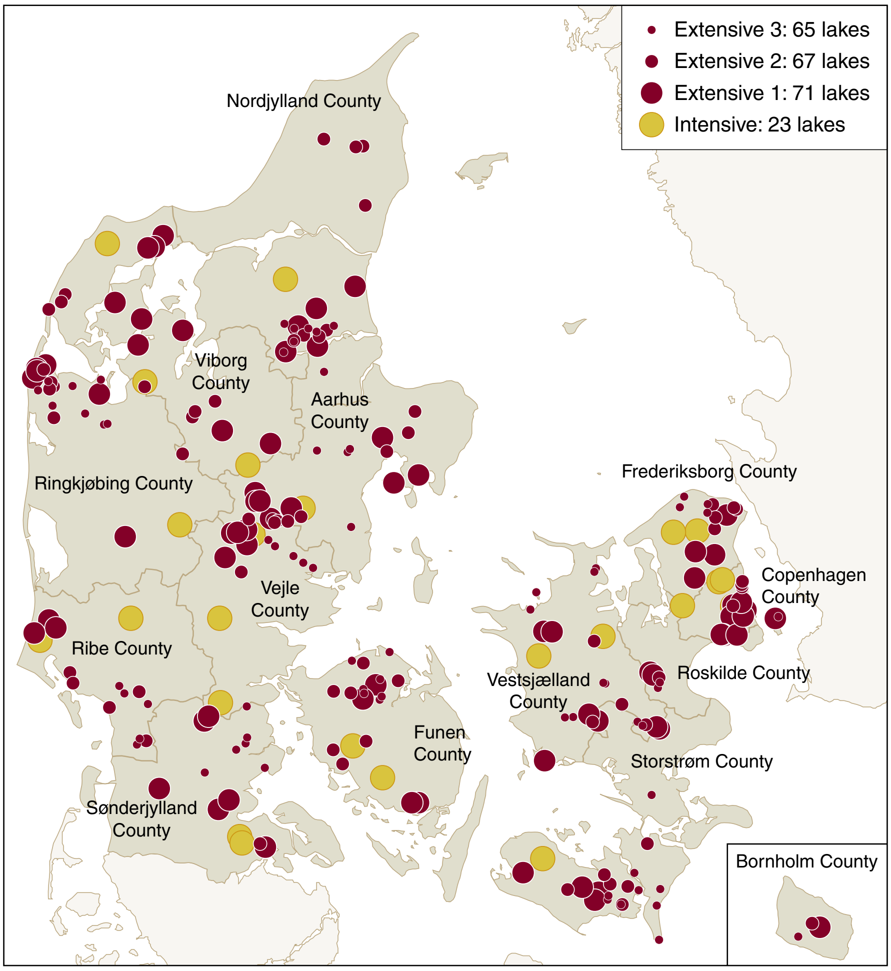
The location of the lakes investigated in 2004 is shown in Figure 8.1 subdivided into the following monitoring groups:

- Intensively monitored lakes: Investigations performed every year, including measurements of nutrient and organic matter loading
- Extensively monitored lakes larger than 5 ha: Investigations performed every 3rd year: Water chemistry, plankton and plants. Every 6th year: Benthic invertebrates and fish
- Extensively monitored lakes 0.1–5 ha: Investigations performed every 6th year: Water chemistry and plants
- Extensively monitored lakes 0.01–0.1 ha: Investigations performed every 6th year: Water chemistry, plants and amphibians.

Quality objectives

The environmental quality objectives for individual lakes are set in the County Regional Plans, although common general quality objectives have been set for small lakes. The quality objectives are usually specified as criteria for phosphorus, chlorophyll or Secchi depth, and sometimes also for the depth distribution of submerged macrophytes.

Figure 8.1 Location of the lakes investigated in 2004 subdivided into the four monitoring programmes: The intensive programme and the three extensive programmes for lakes 1) larger than 5 ha, 2) 0.1–5 ha, and 3) 0.01–0.1 ha (after *Lauridsen et al., 2005*).



Trend in environmental quality and compliance with objectives

The monitoring results from the intensively monitored lakes show that their environmental status has improved since 1989 due to a reduction in phosphorus loading. The extent of the reduction varies considerably from lake to lake depending on what sources it has been possible to reduce. Nitrogen loading and lake water nitrogen concentration have also decreased due to the reduction in nitrate leaching from fields. The number of lakes in which biological quality has improved is not as great as the number in which the phosphorus and nitrogen concentrations have decreased, however (Table 8.1).

Table 8.1 Change in water quality in 20 intensively monitored lakes over the period 1989–2004 (summer mean) (*Lauridsen et al., 2005*).

Variable	Improved	Deteriorated	Unchanged
Lake P concentration	10	2	9
Lake N concentration	13	0	8
Secchi depth	8	1	12
Chlorophyll *a*	7	0	14

Even though the status of the lakes has improved, the environmental objectives were only met by five of the 23 intensively monitored lakes in 2004. The environmental status of some of the lakes will probably

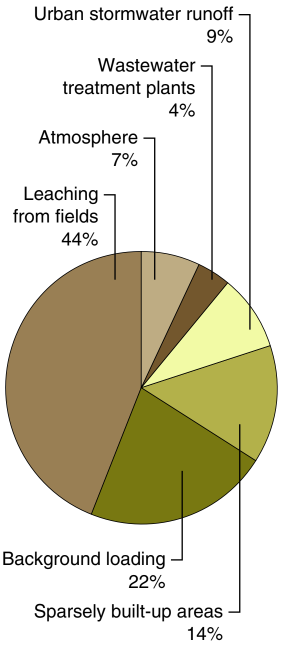


Figure 8.2 Source apportionment of phosphorus in 20 intensively monitored lakes in 2004 (after *Lauridsen et al., 2005*).

improve when the release of phosphorus accumulated in the sediment tails off.

The nutrient levels in the extensively monitored lakes are higher than in the intensively monitored lakes, and compliance with the quality objectives is therefore hardly likely to be better. In conclusion, it is therefore necessary to further reduce phosphorus loading of the majority of lakes if they are to meet the current quality objectives.

8.2 Phosphorus in lakes – state and trend

Phosphorus loading of the intensively monitored lakes

Source apportionment of phosphorus loading of lakes differs from that for the country as a whole as most lakes are located in the rural areas where their catchments are free of major wastewater sources. Thus from Figure 8.2 it is apparent that on average, inputs from rural areas (background loading and leaching from fields) account for approximately 2/3 of the total phosphorus load. In the case of watercourses it has been calculated that 2/3 of the load from rural areas derives from leaching (see Table 3.1). The same probably applies to lakes such that on average, leaching accounts for approx. 44% of the total phosphorus load.

Lake water phosphorus concentration

The lake water phosphorus concentration levels in all the lakes investigated in 2004 are shown in Figure 8.3.

Lakewater phosphorus concentrations are generally very high throughout Denmark. Only a few lakes in Jutland have a phosphorus concentration below 0.025 mg/l. In completely unpolluted lakes the phosphorus concentration will normally be less than 0.025 mg/l.

The phosphorus concentration is generally highest in the small lakes and ponds (Figure 8.4). The concentration exceeds 0.1 mg/l in 39% of the intensively monitored lakes and in fully 95% of all lakes smaller than 0.1 ha. The high phosphorus concentrations in small lakes and ponds can be due to the fact that little attention has hitherto been accorded to reducing phosphorus loading of such lakes and ponds and that the shallow lakes are the lakes most affected by phosphorus release from the sediment in summer.

Trend in phosphorus concentration

Phosphorus loading decreased in the 1980s and 1990s in particular as a result of wastewater treatment, cessation of wastewater discharges and cessation of unlawful agricultural discharges.

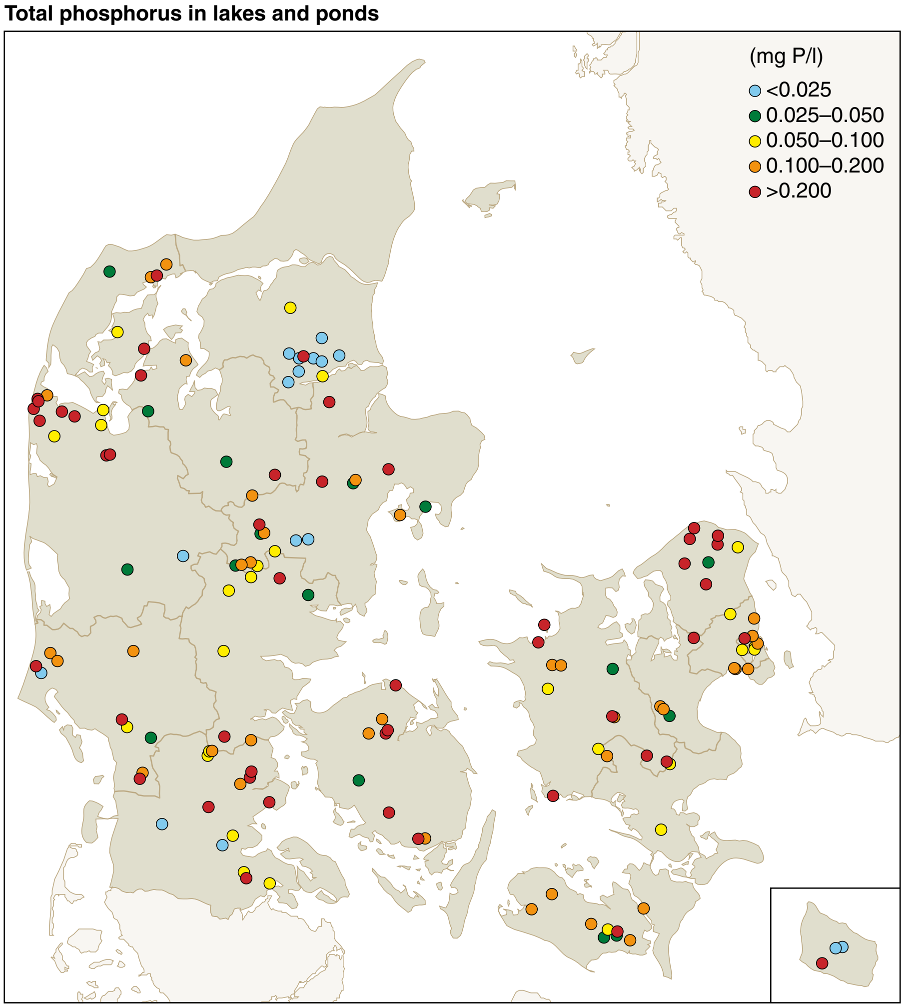


Figure 8.3 Summer total phosphorus concentration levels in the monitored lakes and ponds in 2004 (after *Lauridsen et al., 2005*).

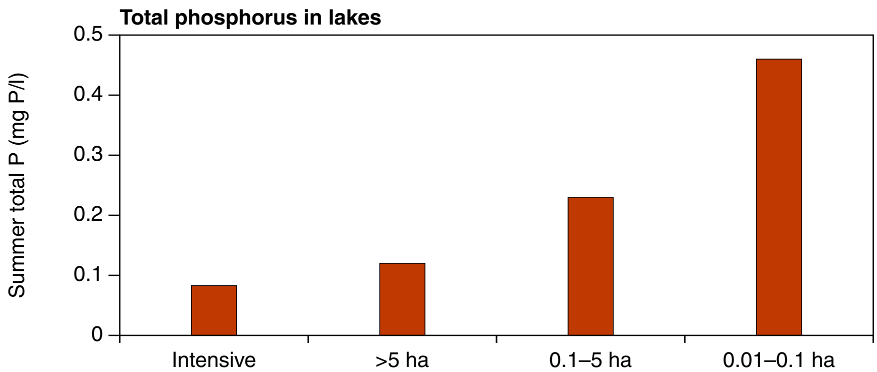


Figure 8.4 Median summer total phosphorus concentration in the intensively monitored lakes and the three sizes of extensively monitored lakes in 2004 (after *Lauridsen et al., 2005*).

The phosphorus concentration in the intensively monitored lakes has decreased in the lakes that previously received large wastewater inputs of phosphorus (Figure 8.5). The annual mean lake water concentration of total phosphorus has decreased from 0.18 mg/l in 1989–95 to 0.106 mg/l in 2004, while the corresponding concentration of dissolved organic phosphorus has decreased from 0.074 mg/l to 0.034 mg/l. In approximately half of the lakes, however, the concentrations have remained unchanged.

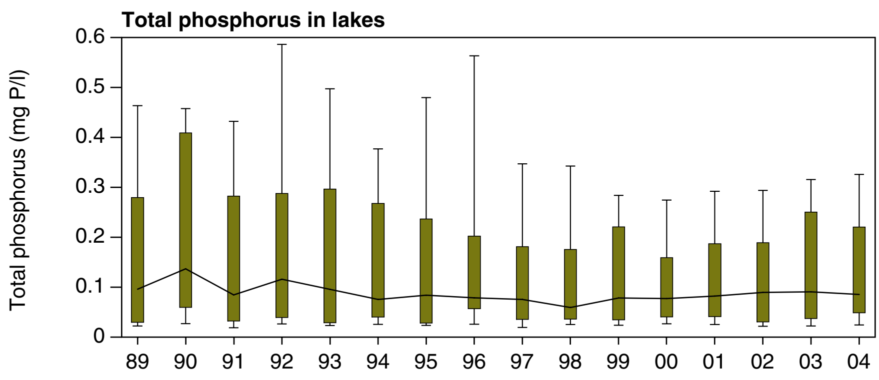


Figure 8.5 Trend in the summer total phosphorus concentration in the intensively monitored lakes. The columns indicate the 10%, 25%, 75% and 90% percentiles (*Lauridsen et al., 2005*).

8.3 Nitrogen in lakes

Like phosphorus, nitrogen is a plant nutrient that influences the amount of algae in the lakes, although phosphorus is usually the limiting factor in most lakes. Recent findings indicate that nitrogen plays an important role for submerged macrophytes, and that it is difficult to attain clear water conditions if the nitrogen concentration is high. Denitrification in the lakes reduces the amount of nitrogen that is transported out of the lakes and onwards via watercourses to the sea. Monitoring of the nitrogen concentration provides information about the denitrification capacity and thereby enables assessment of the overall capacity of the lakes to remove nitrogen.

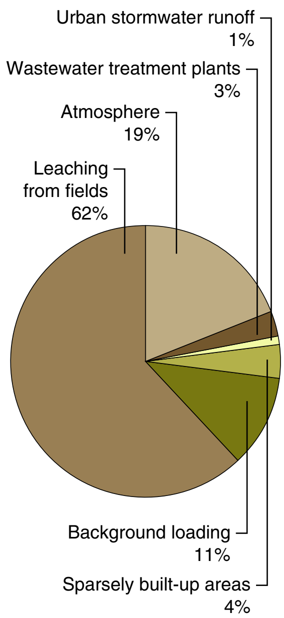


Figure 8.6 Source apportionment of nitrogen in 20 intensively monitored lakes in 2004 (after *Lauridsen et al., 2005*).

Nitrogen loading

Nitrogen loading of most lakes is dominated by leaching from cultivated land within the lake catchment. Some lakes also receive considerable amounts of nitrogen from the air. This largely derives from combustion processes and ammonia volatilization from agriculture (see Chapter 3). The average source apportionment of nitrogen in 2004 is shown for the intensively monitored lakes in Figure 8.6. The assumption has been made that leaching accounts for the same percentage of loading from rural areas as is the case for watercourses (85%: see Table 2.1).

The nitrogen concentration in the water flowing into the monitored lakes has decreased since around 1990 due to a reduction in leaching from cultivated land (Figure 8.7). The concentrations were particularly low in the dry years 1995 and 1996. In 2004, the concentration was higher than in 2003 due to the higher precipitation.

Considerable nitrogen is removed in the lakes by denitrification whereby nitrate is converted to atmospheric nitrogen. The longer the water resides in a lake, the greater the proportion of the nitrogen load that will be denitrified and hence not transported onwards towards the sea. In 2004, mean nitrogen retention in the intensively monitored lakes averaged 40%. This is roughly the same level as in previous years.

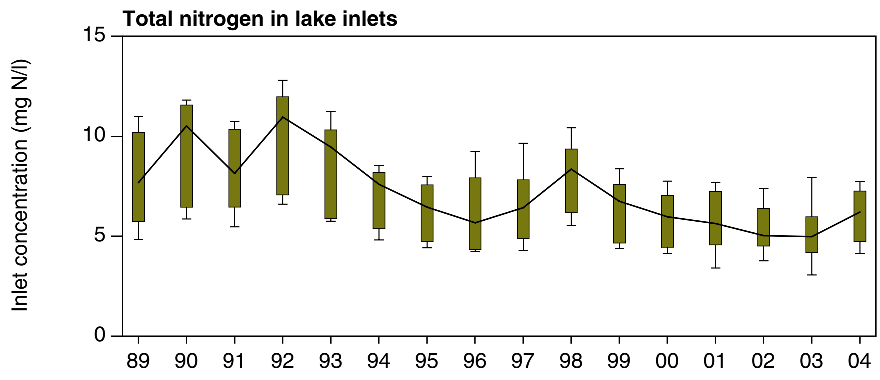


Figure 8.7 Trend in annual mean nitrogen concentration in the water that runs into the intensively monitored lakes (*Lauridsen et al., 2005*).

Nitrogen concentration

As was the case with phosphorus, the nitrogen concentration is higher in the small lakes than in the large lakes, including the intensively monitored lakes (Figure 8.8). The proportion of small lakes in which the whole catchment is cultivated is probably greater, and this considerably influences nitrogen loading.

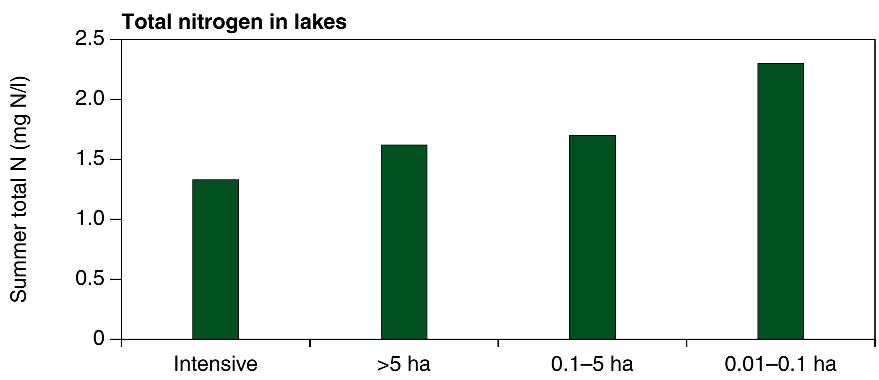


Figure 8.8 Median summer total nitrogen concentration in the intensively monitored lakes and the three sizes of extensively monitored lakes in 2004 (*Lauridsen et al., 2005*).

The trend in nitrogen concentration in the intensively monitored lakes roughly follows the trend in nitrogen loading (Figure 8.9). Compared with phosphorus, changes in the lake water nitrogen concentration will take place more rapidly when loading is changed because the lake sediment does not act as a buffer for the nitrogen concentration in the same way as for the phosphorus concentration.

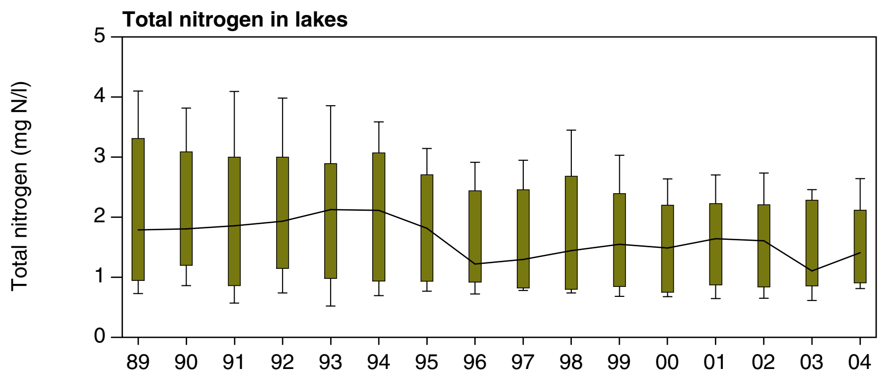


Figure 8.9 Trend in summer mean total nitrogen concentration in the intensively monitored lakes (*Lauridsen et al., 2005*).

8.4 Phytoplankton, Secchi depth and chlorophyll

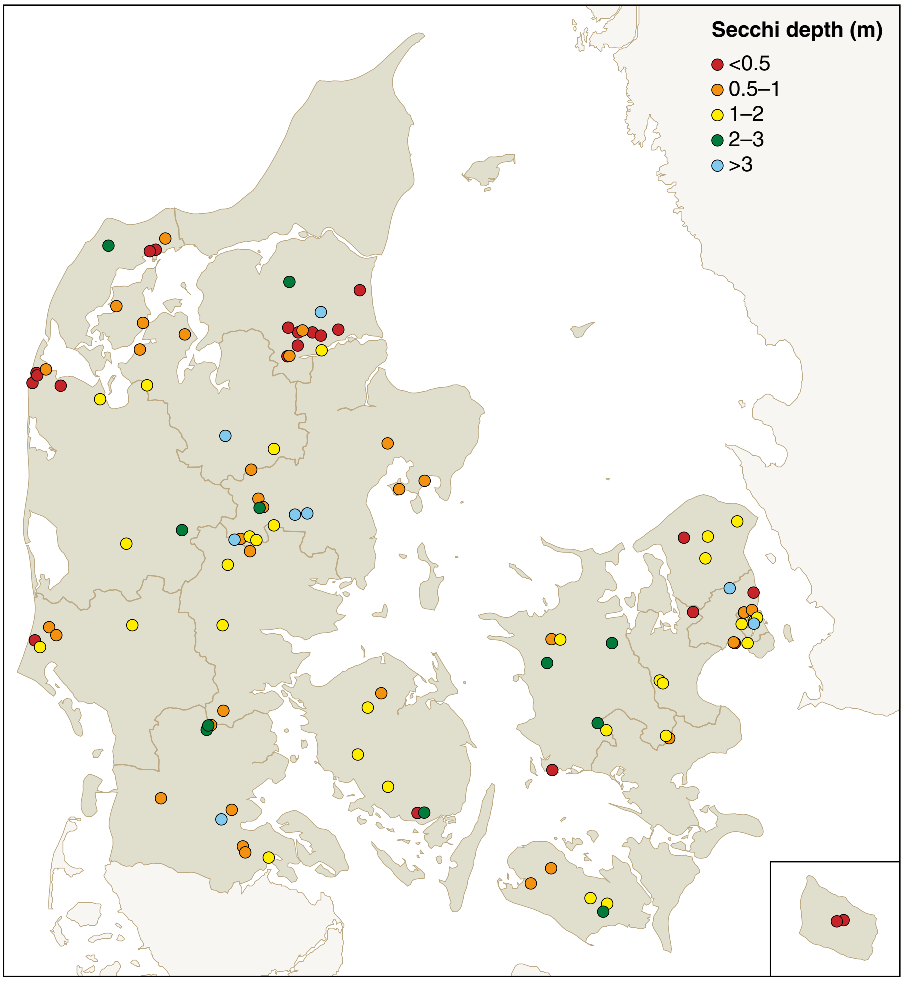
The primary effect of enhanced nutrient loading of lakes is an increase in phytoplankton biomass. The latter is normally determined by measuring the concentration of chlorophyll, the green pigment responsible for photosynthesis in plants. Secchi depth, which is the depth at which a white plate can just be glimpsed, often provides a good measure of the amount of algae and the quality of the water.

Algal biomass and Secchi depth in 2004

The mean Secchi depth during the summer is shown for all the lakes in Figure 8.10. The Secchi depth is generally poor in that approximately half of the lakes have a summer Secchi depth of less than 1 m.

Figure 8.10 Mean Secchi depth for all the monitored lakes in 2004 (after *Lauridsen et al., 2005*).

Secchi depth in lakes in 2004



As is the case with phosphorus, the environmental quality expressed in terms of Secchi depth generally decreases with decreasing lake size, and in the very small lakes (>0.1 ha) is only approx. 0.6 m as compared with approx. 1.4 m in the intensively monitored lakes (Figure 8.11). A corresponding distribution according to lake size is not seen for the lake water chlorophyll concentration, however (Figure 8.11).

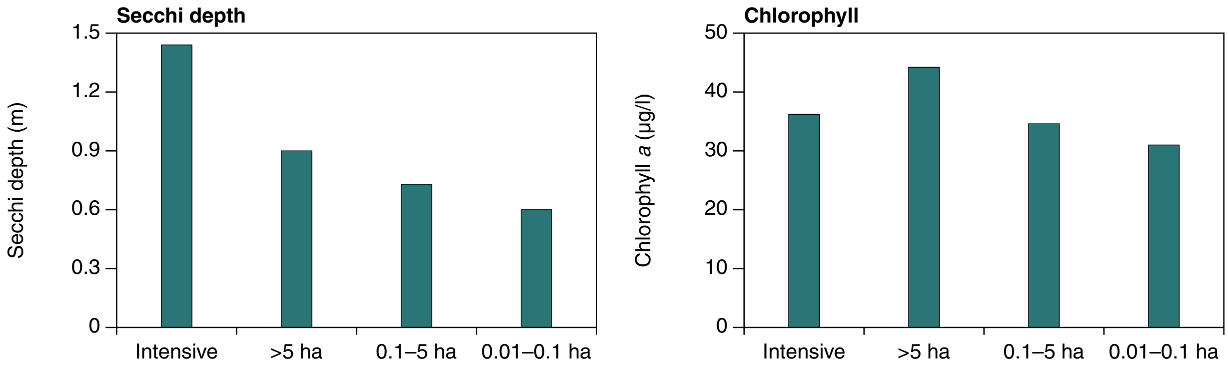


Figure 8.11 Median summer Secchi depth and chlorophyll concentration in 2004 in the intensively monitored lakes and in the three sizes of extensively monitored lakes (*Lauridsen et al., 2005*).

Trend in lake water quality

The chlorophyll concentration in the 20 lakes for which measurements are available since 1989 is largely unchanged compared to the level in recent years (Figure 8.12). Since 1989 the chlorophyll concentration has decreased in the most polluted lakes, whereas the median concentration has remained largely unchanged. The annual mean chlorophyll concentration has decreased in 10 of the 20 lakes and increased in 1 (Lake Nors), and the summer mean chlorophyll concentration has decreased in 7 of the lakes.

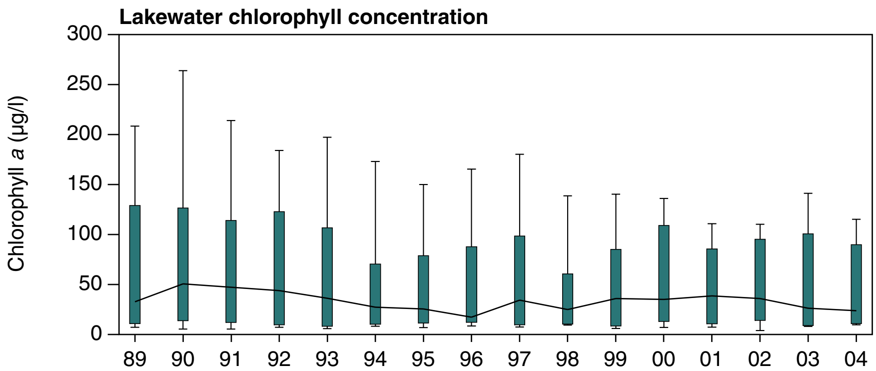


Figure 8.12 Trend in surface water chlorophyll concentration in 20 intensively monitored lakes. The curve connects the median values (*Lauridsen et al., 2005*).

The Secchi depth often reflects the amount of algae and chlorophyll in the water. Secchi depth in the 20 intensively monitored lakes has generally tended to increase since 1989, median Secchi depth having increased from 1.1 m in 1989 to 1.45 m in 2004 (Figure 8.13). The general decrease in lake water nutrient concentrations since monitoring started in 1989 has thus led to an increase in Secchi depth. Annual mean Secchi depth has increased in 10 of the 20 lakes while summer mean Secchi depth has increased in 7 of the lakes and decreased in 1.

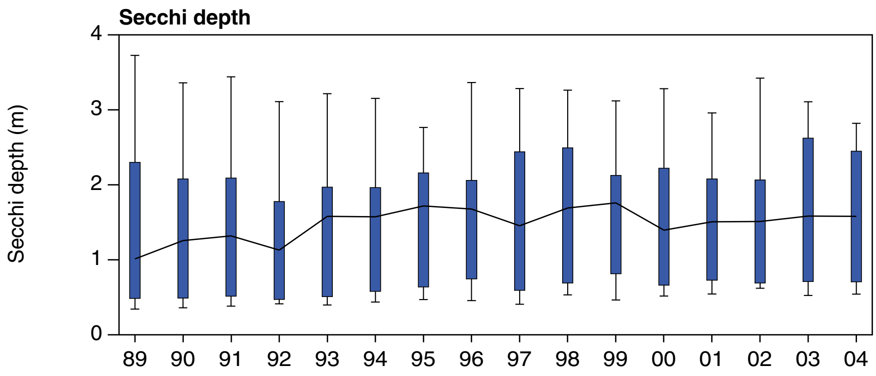


Figure 8.13 Trend in summer mean Secchi depth in 20 intensively monitored lakes. The curve connects the median values (*Lauridsen et al., 2005*).

9 Marine waters

9.1 Marine waters

The main impact of pollution on Danish marine waters is the eutrophication (nutrient enrichment) resulting from the fact that nitrogen and phosphorus loading from land, via the air and with sea currents exceeds the natural levels. The most polluted marine waters are the fjords with high nutrient loading from land. The more open parts of the Danish inner marine waters are also affected by the high nutrient loading. The impact is enhanced by the fact that the water in the shallow Danish marine waters is often stratified, which increases the risk of poor oxygen conditions at the seabed.

Nutrient concentrations have decreased in most marine waters, but no significant, general improvements have yet occurred in the flora and fauna.

Monitoring programme

The aim of the marine monitoring is to describe the status of Danish marine waters and the trend therein, including the impact of sources of pollution and transport of pollutants. The programme is designed to reveal the effects of efforts to curtail pollution and whether the quality objectives have been met, to help meet international obligations and to serve as part of the decision-making basis for initiatives to meet the environmental objectives.

The subprogramme for marine waters is subdivided into three programme areas:

- Eutrophication, incl. physical conditions and modelling. Monitoring is performed in 34 representative coastal waters and at 14 intensive and 100 extensive marine stations.
- Biodiversity and natural habitat types. Monitoring is performed at 51 reefs, seven fish locations and 845 benthic fauna stations, although not at all locations every year.
- Hazardous substances and biological effect monitoring. Sediment is monitored at 50 locations, mussels at 57 locations, fish at five locations and biological effects at 33 locations, although not at all locations every year.

As an example of station distribution, Figure 9.1 shows where samples are collected in the water column.

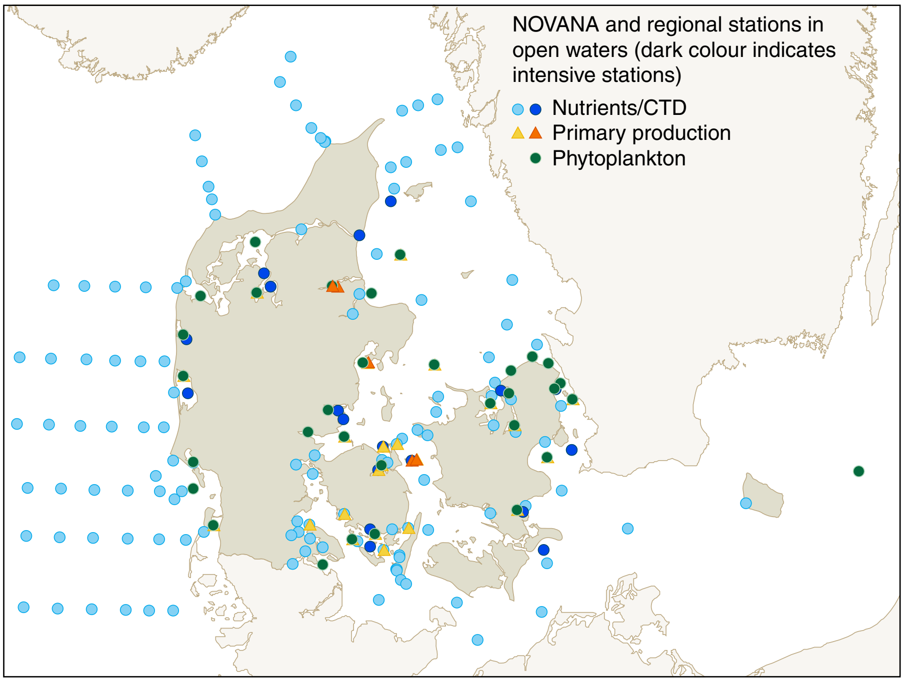


Figure 9.1 Nutrient and plankton sampling stations. From *Ærtebjerg et al. (2005)*, where corresponding charts are provided for benthic invertebrates, submerged aquatic vegetation and hazardous substances.

Climate in 2004

Environmental conditions in the marine waters are highly dependent on the weather, in particular because nutrient loading increases during periods of high precipitation and because wind enhances mixing and exchange of the water masses and hence reduces oxygen deficit. In 2004, precipitation was approx. 15% higher than the normal value and freshwater runoff approx. 6% greater. Wind speed was lower than normal, and there were fewer strong winds than normal.

Quality objectives and compliance

The quality objective for Danish marine waters is that the flora and fauna should at most be only slightly affected by man's activities.

This objective is generally considered to be met in the Skagerrak and in the open parts of the North Sea, and close to being met in the open northern and central Kattegat. In the remaining Danish marine waters the quality objective is not met. This is primarily due to nutrient loading, which has resulted in increased phytoplankton biomass, unwanted growth of annual eutrophication-dependent macroalgae, shadowing-out of perennial submerged macrophytes and episodes of oxygen deficit.

With most fjords and coastal waters that fail to meet their quality objectives the regional authorities also state the presence of hazardous substances as a contributory factor, in particular raised concentrations of tributyl tin (TBT) and in certain cases also of organochlorines and certain hydrocarbons (PAH). Several regional authorities also state the presence of heavy metals as a reason for marine waters failing to meet their quality objectives.

The degree of compliance with quality objectives has not changed since 1989. If the marine waters are to meet their quality objective that the flora and fauna should at most be only slightly affected by pollution it will be necessary to further reduce inputs of nitrogen and phosphorus, and in certain marine waters also inputs of TBT and other hazardous substances.

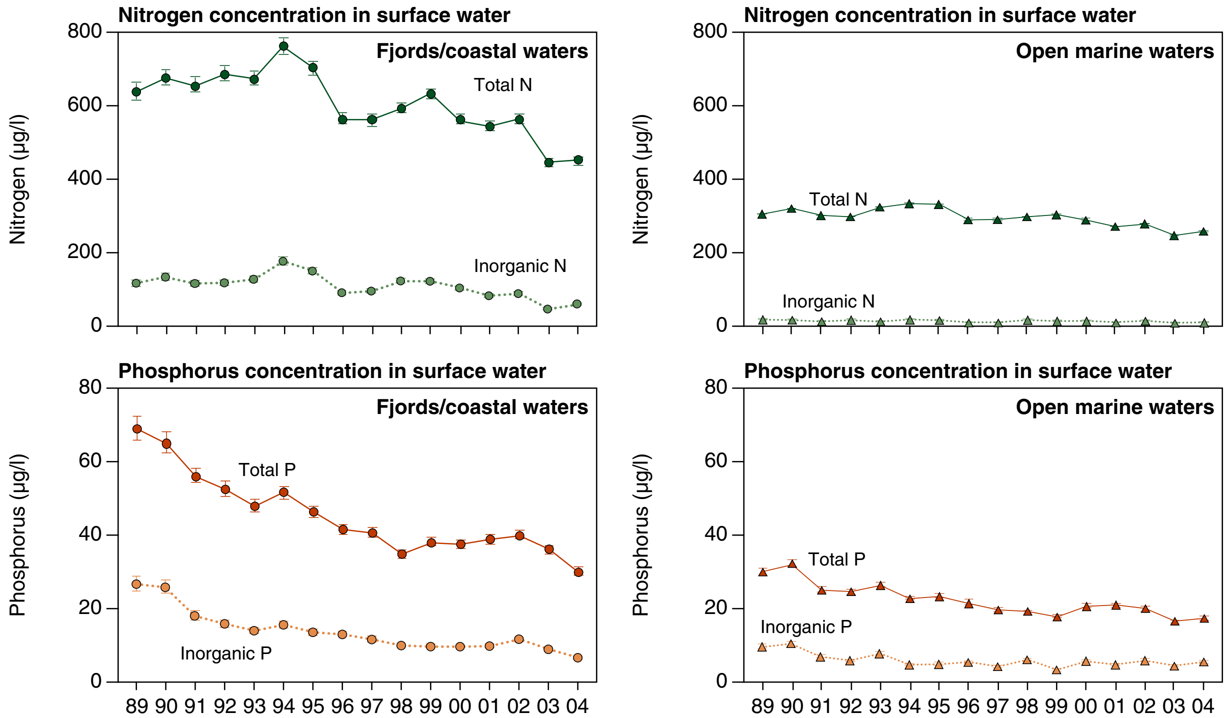
9.2 Nitrogen and phosphorus in marine waters

Water nutrient concentrations are greatest in fjords that receive a lot of fresh water because the nitrogen and phosphorus concentrations are far higher in freshwater runoff than in seawater (see the figures in *Andersen et al., 2004*). The fjords are therefore generally the most strongly polluted marine waters. At the same time the fjords are also the group of marine waters in which the effect of the reduction in nutrient loading from land is most apparent as by far the majority of freshwater runoff in Denmark flows into the fjords. The following description of the trend in nitrogen and phosphorus concentrations is therefore subdivided into two groups: The open marine waters and the fjords/coastal waters.

Trend in nutrient concentrations in the surface water

The phosphorus concentration in fjords/coastal waters has decreased, especially in the early 1990s (Figure 9.2) as a result of phosphorus removal from wastewater. The reductions have been marked, the concentration of inorganic plant-available phosphorus having decreased from approx. 25 µg/l to approx 10 µg/l. The total phosphorus concentration has also decreased by more than half.

Figure 9.2 Measured annual mean concentration of inorganic nitrogen, total nitrogen, inorganic phosphorus and total phosphorus in the surface water (0–10 m) in fjords/coastal waters and in open marine waters. 95% confidence intervals are also shown (*Ærtebjerg et al., 2005*).



The reduction in the nitrogen concentration mainly took place around and after 2000 (Figure 9.2). The concentration of inorganic nitrogen has halved on average, whereas the reduction in the concentration of total nitrogen is somewhat less. The reduction is mainly attributable to the reduction in leaching from cultivated land.

Nutrient limitation of phytoplankton growth

As a result of the lower nutrient concentrations in the marine waters, phytoplankton growth is potentially limited by a lack of nitrogen and/or phosphorus to a greater degree than was previously the case. The most marked change is the increased potential phosphorus limitation in fjords, where phosphorus can be limiting in approx. 50% of the growth season as compared to only approx. 20% around 1990 (Figure 9.3). In the open marine waters, phosphorus limitation has increased from approx. 40% of the time to approx. 80%. In recent years the extent of potential nitrogen limitation has also increased.

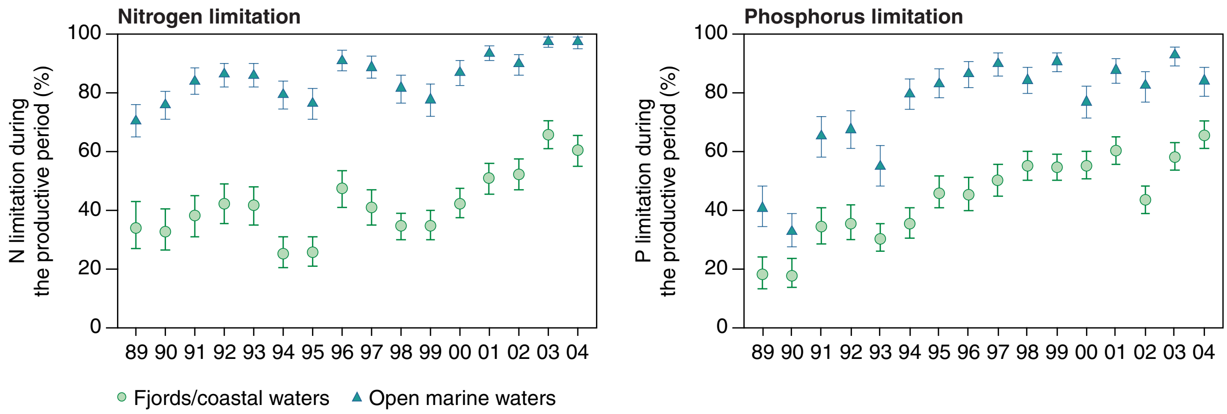


Figure 9.3 Potential nitrogen and phosphorus limitation calculated as the probability that measurements during the productive period from March to September inclusive lie under the value for potential limitation of primary production (28 µg/l for inorganic N and 6.2 µg/l for inorganic P) in the surface water (0–10 m) (*Ærtebjerg et al., 2005*).

The monitoring results indicate that the amount of phytoplankton in fjords/coastal waters can be reduced both by reducing nitrogen inputs and by reducing phosphorus inputs. In the open marine waters it is doubtful whether a further reduction in phosphorus loading will have any effect, in part because nitrogen is usually the most limiting of the two nutrients and in part because inputs of phosphorus from the marine sediment and with sea currents are considerable relative to loading from land. Even when the nutrient concentrations are so low as to indicate growth limitation it remains uncertain whether growth is actually limited as the assessment is based on measurements of the concentrations and not on the rate at which the nutrients are cycled and become available for the phytoplankton growth.

9.3 Phytoplankton

Secchi depth and chlorophyll

Based on the measurements of Secchi depth and chlorophyll concentration the environmental status was generally poorer in 2004 than in the preceding five years, especially in the Belt Sea and the Kattegat, despite the relatively low nutrient concentrations. The reason was an unusual bloom in April–June of the silicoflagellate *Dictyocha specu-*

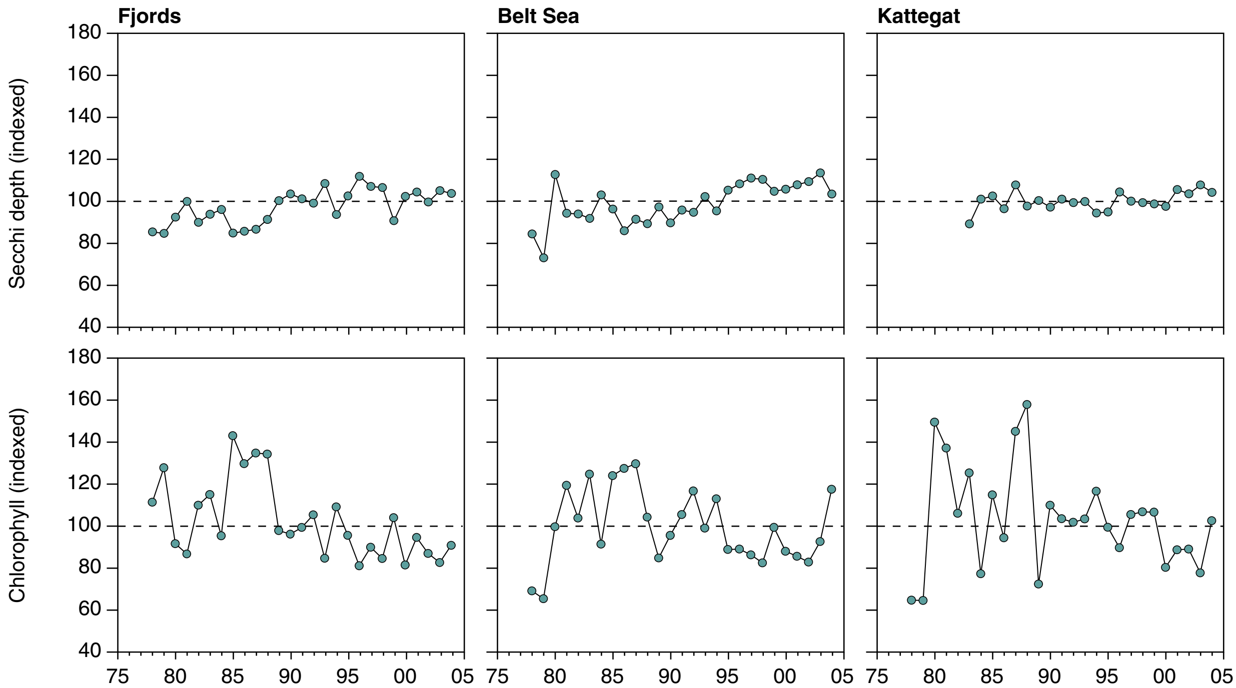
lum, which probably obtained nutrients from the bottom water. The bloom started in the boundary between the surface water and the nutrient-rich bottom water, which lay very close to the water surface.

Trend in indexed Secchi depth and chlorophyll concentration

In order to illustrate the trend, each of these parameters is expressed in terms of an index. The index value for each year is calculated as a percentage of the mean value for all the years. Thereafter the mean of the index values is calculated for all the water bodies.

The trend in the fjords is positive in that the Secchi depth is greater and the chlorophyll concentration lower after 1993 than in the period 1980–1993. Since 1993 there has been little change in the chlorophyll concentration, however, while the Secchi depth has decreased slightly. In the Kattegat and the Belt Sea the positive trend in Secchi depth and chlorophyll concentration is clearer (Figure 9.4).

Figure 9.4 Indexed trend in Secchi depth and chlorophyll concentration in fjords, the Belt Sea and the Kattegat (After *Ærtebjerg et al., 2005*).



The decrease in nutrient concentrations has been somewhat greater than the changes in Secchi depth and chlorophyll concentration. In the fjords the difference between pre- and post-1993 values corresponds to the trend in loading, especially the trend in phosphorus loading from wastewater treatment plants, where the reduction in discharges took place until 1993. Thereafter total phosphorus loading from the landmass has remained almost constant, whereas the nitrogen load has varied considerably from year to year depending on the precipitation. The amount of algae is probably also affected by the after-effects of the oxygen deficit in 2002.

9.4 Oxygen conditions in the marine waters

The year gone by

The oxygen deficit in Danish marine waters was less extensive and shorter in 2004 than in the two preceding years. This is despite the fact that unexpectedly early, widespread and severe oxygen deficit occurred in the Belt Sea from July to September, probably due to a combination of an unusually great phytoplankton bloom in May–June, a lack of wind to mix and exchange the bottom water and the after-effects of the extreme oxygen deficit in 2002 and the oxygen deficit in 2003.

The extent of oxygen deficit peaked in mid September 2004, when the area affected by severe oxygen deficit was of the same size as in 2003, particularly encompassing the southern Little Belt, Kiel Bay and Mecklenburg Bight (Figure 9.5).

Oxygen concentration in the bottom water in 2004

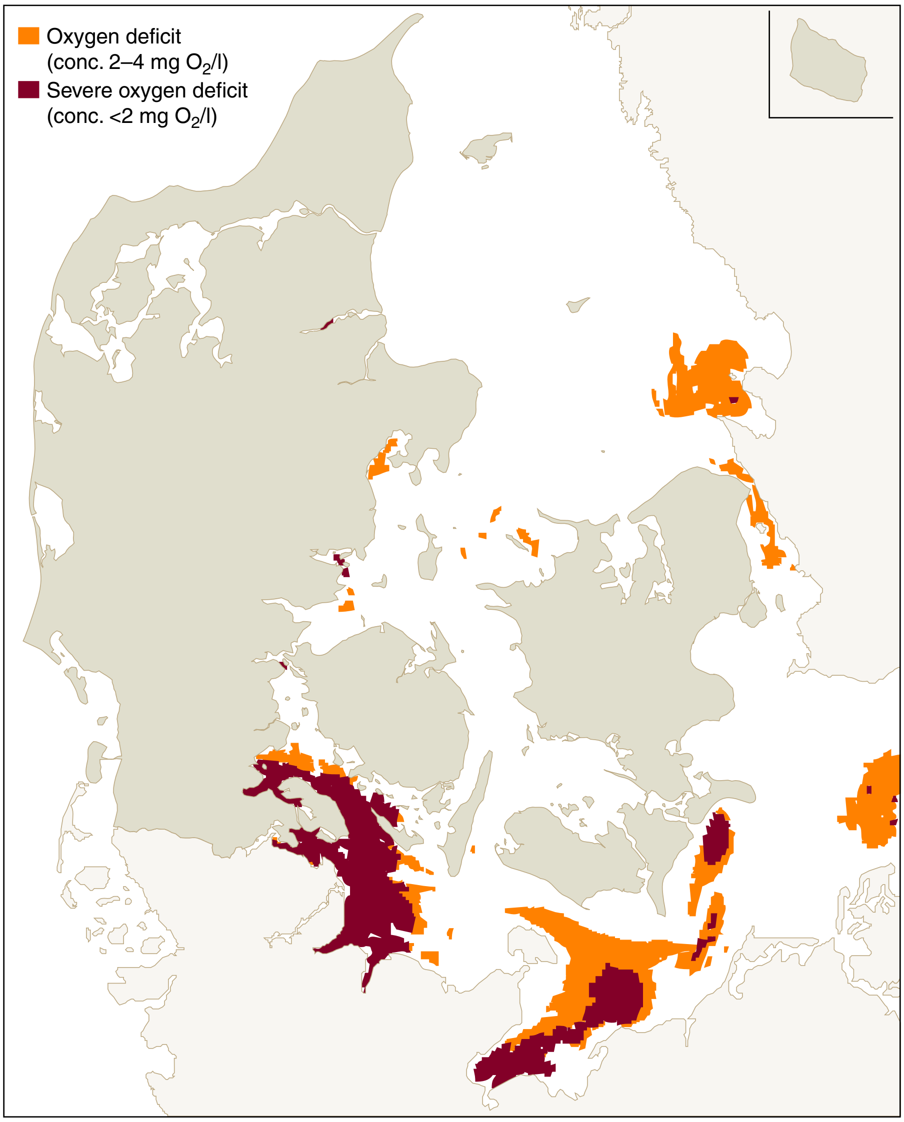


Figure 9.5 The extent of oxygen deficit in 2004 peaked in week 37 (6–12 September) when an area of approx. 5,000 km^2 was affected by oxygen deficit and approx. 2,200 km^2 by severe oxygen deficit (*Ærtebjerg et al., 2005*).

Areal distribution of oxygen deficit 2001–2004

The areal distribution of oxygen deficit varies considerably from year to year depending on the weather conditions, including wind and precipitation, and on the leaching of nutrients from the catchment. The size of the areas affected by severe oxygen deficit is shown for each of the years 2001–2004 in Figure 9.6. It can be seen that the oxygen deficit peaked earlier in 2003 and 2004 than in the other years and was of roughly the same level as in 2001 and 2003, but far less widespread than in 2002.

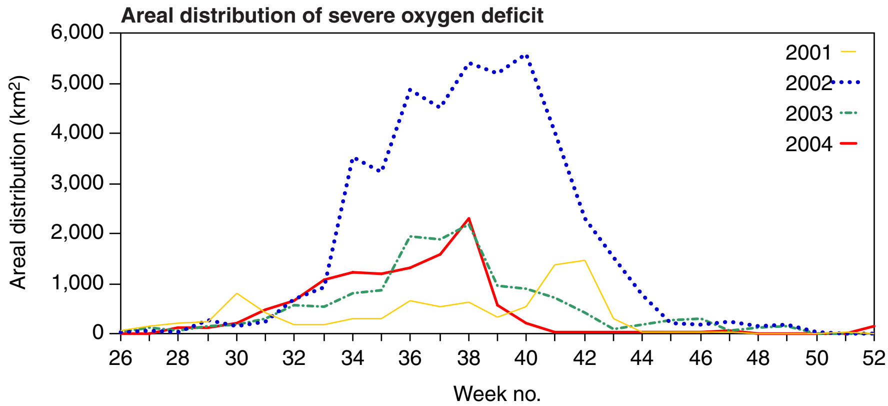


Figure 9.6 Areal distribution of severe oxygen deficit (<2 mg O_2/l) each week during the second half of each of the years 2001 to 2004 (*Ærtebjerg et al., 2005*).

Trend in oxygen deficit

No clear trend in oxygen deficit is apparent in the fjords and coastal waters over the period 1981–2004, although the mean oxygen concentration has been relatively low over the past six years (Figure 9.7).

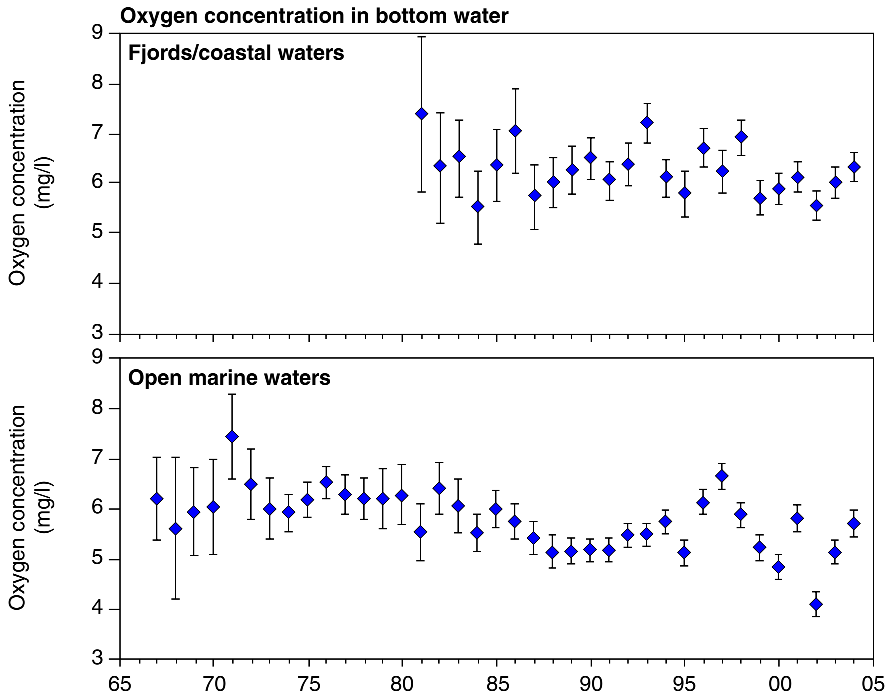


Figure 9.7 Mean bottom water oxygen concentration in fjords/coastal waters and in open marine waters. The deviation around the mean value has fallen over the years due to an increase in the number of measurement points and frequency of measurement (*Ærtebjerg et al., 2005*).

In the open marine waters the mean oxygen concentration in July–November was low around 1990. During the first half of the 1990s the oxygen concentration generally increased to the level in the 1970s in the dry years 1996–1997, thereafter to generally decrease again. The mean value in 2004 was at the same level as in the mid 1980s.

Analysis of the data shows that the oxygen concentration under stratified conditions in July–November correlates to the preceding input of nitrogen and to the wind strength in July–September the same year. In the open inner marine waters, in addition, correlations have been found to the inflow of bottom water in May–September and to the temperature of the water flowing in from the Skagerrak in January–April.

9.5 Submerged macrophytes

The submerged macrophytes in the sea around Denmark consist both of angiosperms such as eelgrass and widgeon grass and of macroalgae such as bladderwrack and sugar kelp, which grow anchored to stones. Some large algae are freely floating in the water, e.g. sea lettuce.

Submerged macrophytes are important indicators of the environmental state because they are affected differently by eutrophication, which can for example lead to the mass occurrence of sea lettuce, and because the depth distribution of the plants is an indicator of water quality. The depth distribution of eelgrass is particularly suitable as an indicator.

A decrease in nutrient loading is expected to lead to improved light conditions and consequently to an increase in the depth distribution and coverage of the vegetation in deep water.

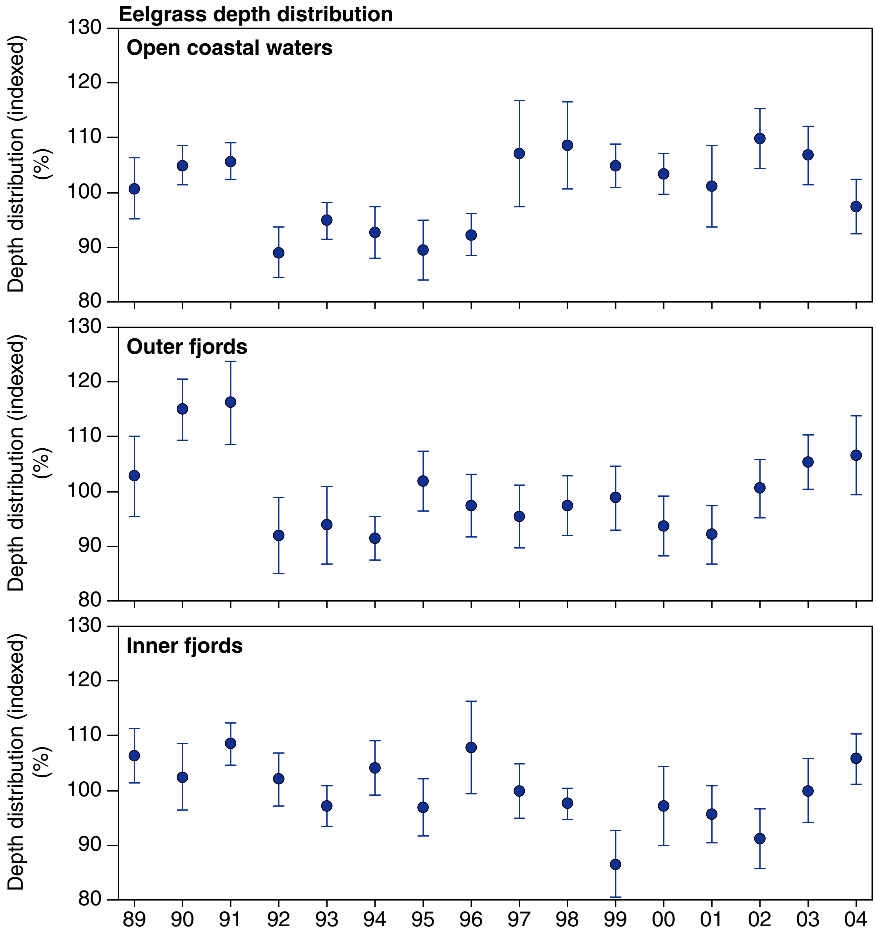
Eelgrass

Over the period 1989–2004 the maximum depth distribution of eelgrass was greatest along the open coasts (4.9–6.7 m), slightly less in the outer fjords (3.3–4.3 m) and least in the inner fjords (2.5–3.4 m).

The trend in indexed eelgrass maximum depth distribution is shown for the three types of coastal water in Figure 9.8. The index value for each year is expressed as a percentage of the mean for the whole period, thus indicating the deviation around the mean. The maximum depth distribution of eelgrass has varied considerably during the period, although no systematic changes seem to have taken place that could be explained by changes in nutrient concentrations.

Eelgrass coverage has also been analysed for the depth intervals 1–2, 2–4 and 4–6 m in the three types of coastal water. Taken together the analyses showed that eelgrass maximum depth distribution and coverage decreased in the outer fjords over the period 1989–2004. The populations in the inner parts of the fjords and along the open coasts generally remained unchanged during the period.

Figure 9.8 Trend in indexed eelgrass maximum depth distribution over the period 1989–2004 in open coastal waters, outer fjords and inner fjords. A high index value indicates that the eelgrass is found at greater depths than in an average year (*Ærtebjerg et al., 2005*).

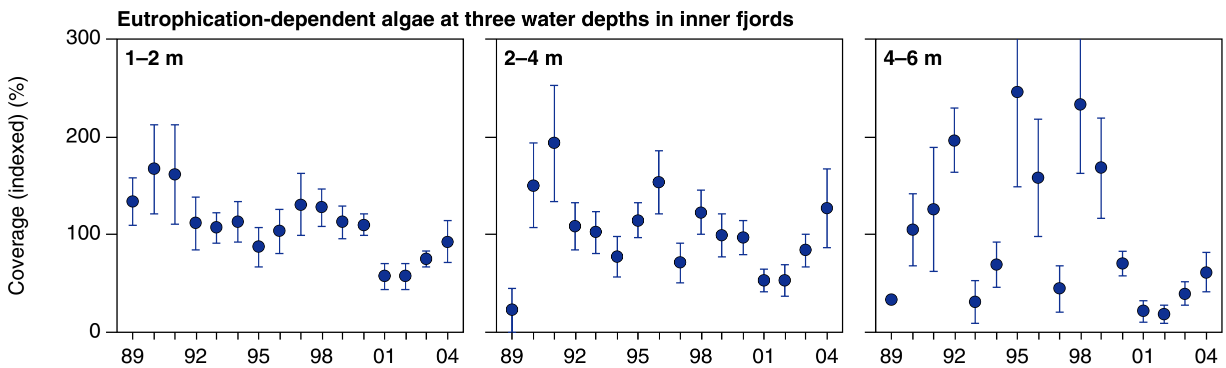


One of the reasons for this in the fjords could be that Secchi depth has decreased slightly and the chlorophyll concentration has been unchanged since 1993. There are many examples of the maximum depth distribution in individual fjords/coastal waters not following Secchi depth, however. Factors other than light may therefore also play an important role in regulating the eelgrass. One important factor seems to be that oxygen deficit is harmful to eelgrass (*Ærtebjerg et al., 2005*).

Eutrophication-dependent algae

Eutrophication-dependent algae is the term for algae that are favoured by high nutrient loading. High coverage with such algae should therefore indicate high nutrient loading.

Figure 9.9 Trend in indexed coverage of eutrophication-dependent algae over the period 1989–2004. The trend is shown for three water depth intervals in the inner fjords. A high index value indicates that the amount of algae is greater than in an average year (*Ærtebjerg et al., 2005*).



No overall trend was detectable in coverage with eutrophication-dependent algae over the period 1989–2004, although coverage decreased at the 1–2 m depth interval in the inner fjords (Figure 9.9).

Macroalgae on stone reefs in open marine waters

The investigations of stone reefs performed in 2004 showed that the vegetation on the stone reefs in the inner open marine waters consists of multilayered red and brown algae, which completely cover the solid seabed down to a depth of 10–12 m. At greater depths total coverage by the algae decreases to a single layer of upright algae that does not cover the whole reef. Coverage with the upright algae decreases with increasing depth, whereas coverage with crust-like algal growths remains high down to a depth of 24 m. A number of stone reefs were investigated for the first time in 2004. In the Skagerrak, algal coverage of the suitable solid seabed was poor relative to the depth. In the Arkona Sea off Møns Klint, in contrast, it was very well developed.

9.6 Benthic invertebrates

The animals that inhabit the seabed are affected by the surrounding environmental conditions, irrespective of whether these are determined by man's activities or natural processes. The majority of benthic invertebrates live for more than one year and their occurrence therefore reflects habitat conditions over several years. Eutrophication particularly affects the benthic fauna by increasing the amount of food available to them, but also increases oxygen consumption at the seabed and thereby the risk of oxygen deficit.

Benthic invertebrates in the open marine waters

The benthic invertebrate fauna was investigated at 22 stations in the open inner marine waters in 2004. All the variables investigated (biomass, abundance and species diversity) showed that the benthic invertebrate fauna was very impoverished in 2004 (Figure 9.10). This is a continuation of the general decrease that started in the mid 1990s (Figure 9.11).

Figure 9.10 Trend in the total biomass and abundance of the main taxonomic groups of benthic invertebrates at the 22 stations in the open Danish marine waters (*Ærtebjerg et al., 2005*).

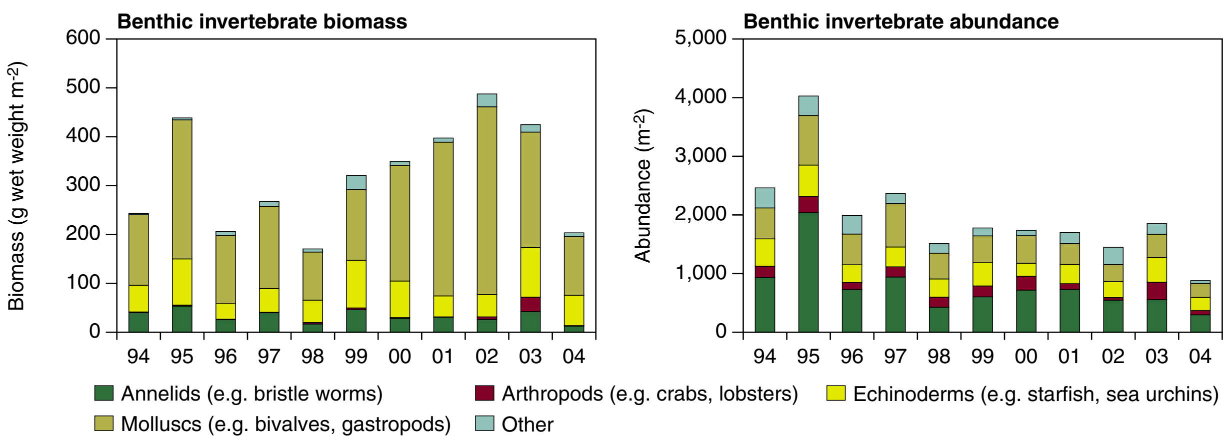
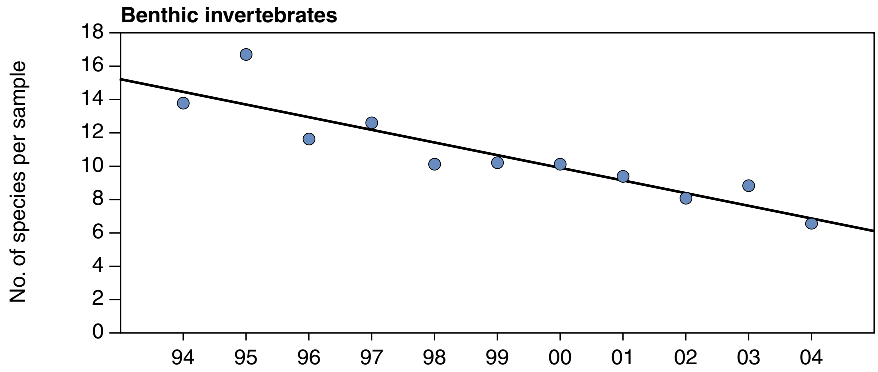


Figure 9.11 Trend in number of benthic invertebrate species detected per sample at 20 stations in the Kattegat and the Belt Sea over the period 1994–2004 (*Ærtebjerg et al., 2005*).



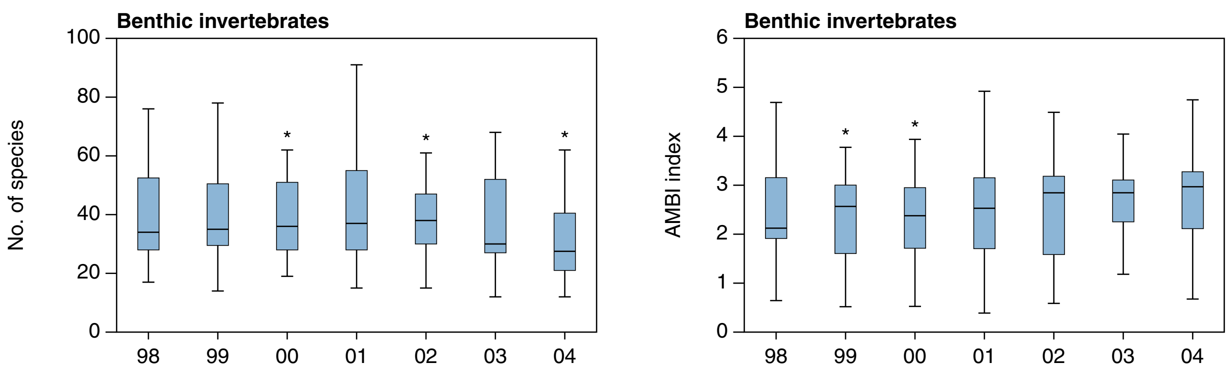
The reason for the general impoverishment in the Belt Sea is the extreme oxygen deficit in 2002 and the oxygen deficit in 2003, while the reason it occurred in the Kattegat is unknown. By far the majority of the stations in the Kattegat are only slightly affected by oxygen deficit. The decreasing nutrient concentrations in the open marine waters are hardly likely to be the underlying cause. In this case it would be expected that a lack of food due to lower productivity in the water column could initially lead to reduction in biomass, but not to a reduction in the number of species.

Benthic invertebrates in coastal waters

Investigations at 29 stations in the coastal waters in 2004 also revealed impoverishment of the benthic invertebrate fauna. The trend over the period 1998–2004 in the coastal waters is illustrated both by the number of species detected and the so-called AMBI index, the value of which is high when there are relatively many pollution-tolerant species present and low when many pollution-sensitive species are present.

Figure 9.12 indicates a tendency towards a reduction in the number of species and an increase in the number of pollution-tolerant species in the past few years. The decreasing species diversity and environmental quality of the coastal waters are probably attributable to the severe oxygen deficit in autumn 2002 and to the fact that re-establishment of the benthic fauna after such extensive oxygen deficit takes many years.

Figure 9.12 Trend in number of benthic invertebrate species and AMBI index (which is low for pollution-sensitive species) at the coastal benthic fauna stations over the period 1998–2004. The median values and deviation are shown (*Ærtebjerg et al., 2005*).



9.7 Heavy metals in marine waters

Heavy metals are naturally occurring in the marine environment. Concentrations exceeding the background level are normally attributable to wastewater discharges or the input of heavy metals from the atmosphere.

Monitoring of heavy metals in the marine environment in 2004 encompassed measurements in mussels and fish. Mussels are used as a general indicator of heavy metal loading of the marine environment. Samples were collected at approx. 38 stations in Danish fjords and inner marine waters for measurement of zinc, copper, nickel, lead, cadmium and mercury.

Objective

Heavy metals in the marine environment are encompassed by international marine conventions, e.g. HELCOM, OSPAR and the North Sea Conferences. Limit values or quality criteria have not yet been set in any of these contexts, however. The Norwegian Pollution Control Authority has published a guideline system for classifying the degree of pollution (*Norwegian Pollution Control Authority (SFT), 1997*).

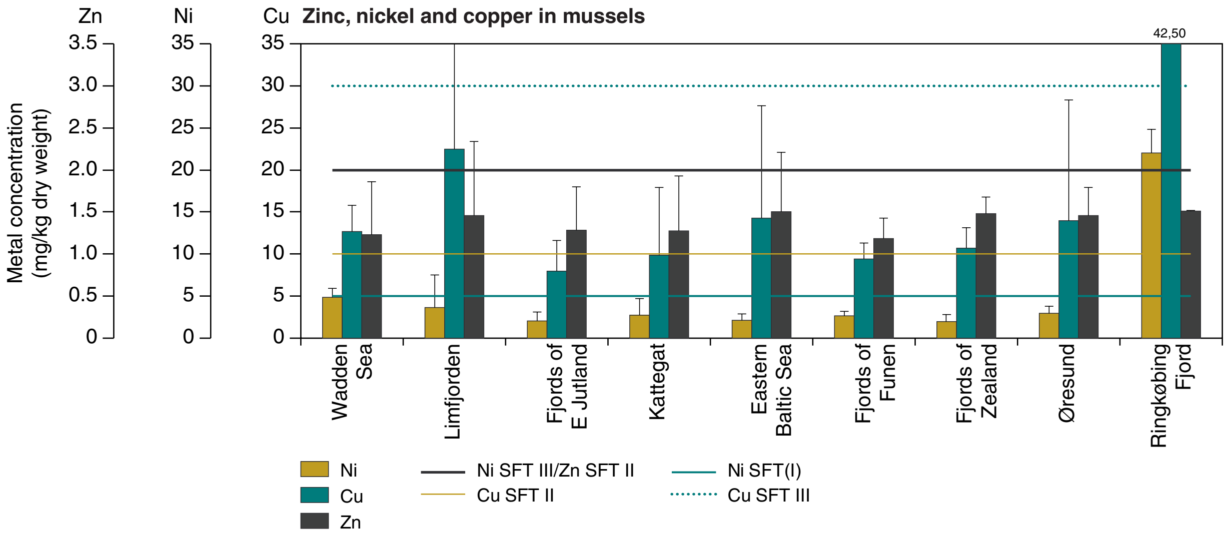
The Danish Veterinary and Food Administration has set limit values for the heavy metal content of fish and mussels used in the manufacture of foods (*Danish Veterinary and Food Administration, 2005*).

Heavy metals in mussels/clams

In general, Danish marine waters are only slightly to moderately polluted by heavy metals (Figure 9.13).

The highest concentrations of the harmful metals lead, cadmium and mercury are found in the Wadden Sea and Øresund. The mercury concentration in mussels from the Wadden Sea and Øresund corresponds to the classification "moderately polluted" under the Norwegian classification system (I: Slightly to moderately polluted, II: Moderately polluted, III: Strongly polluted, IV: Severely polluted, V: Very severely polluted).

The highest concentrations of the less harmful metals zinc and copper in common mussels are found in Limfjorden. The copper concentration is higher in Ringkøbing Fjord than in Limfjorden. It should be noted, though, that the measurements in Ringkøbing Fjord were made on the soft-shelled clam as there are no common mussels in the fjord. These measurements are therefore not completely comparable with the other measurements. The levels of nickel and copper in Ringkøbing Fjord correspond to the classification "strongly polluted". This might possibly be due to the fact that they were measured in soft-shelled clams, which live buried in the seabed, instead of in common mussels, which live in the water above the seabed.



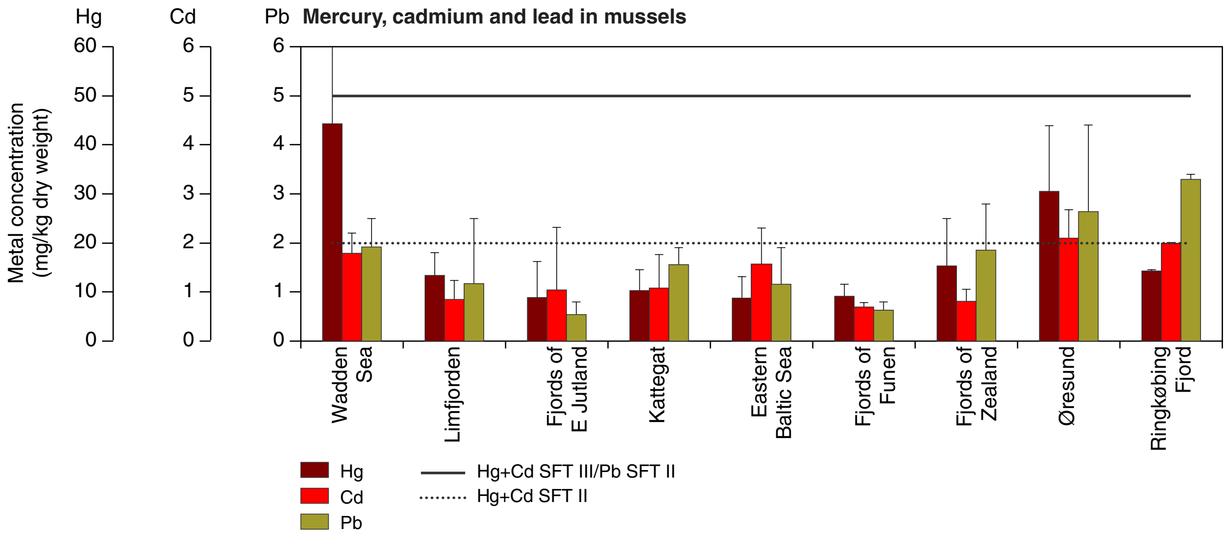


Figure 9.13 Metal concentrations in mussels shown as the mean and maximum of 1–5 stations per area with 1–3 replicates per station. The limit values for moderate (class I/II), marked (II/III) and severe contamination (III/IV) used by the Norwegian Pollution Control Authority (SFT) are indicated (*Ærtebjerg et al., 2005*).

Assessment of the measured concentrations

Assessment of the results of the fish and mussel/clam studies shows that the lead and cadmium concentrations do not exceed the limit values for these metals in fish and mussels intended for the manufacture of foods. Two fish liver samples from Nivå Bay exceeded the limit value of 0.5 mg Cd/kg wet weight, whereas no mussels exceeded the limit value of 1.0 mg Cd/kg wet weight. The mean value for Nivå Bay was 0.41 mg Cd/kg wet weight.

9.8 Hazardous substances in marine waters

Hazardous substances are measured in the marine environment in common mussels collected in the fjords and inner Danish marine waters. The concentrations of heavy metals and hazardous substances in common mussels are generally used as an indicator of pollution with these substances, both internationally and nationally. Common mussels are found throughout Denmark except in Ringkøbing Fjord, where the measurements are instead made on the soft-shelled clam. The measurements typically encompass substances that are persistent and which have a tendency to accumulate in the sediment or marine organisms.

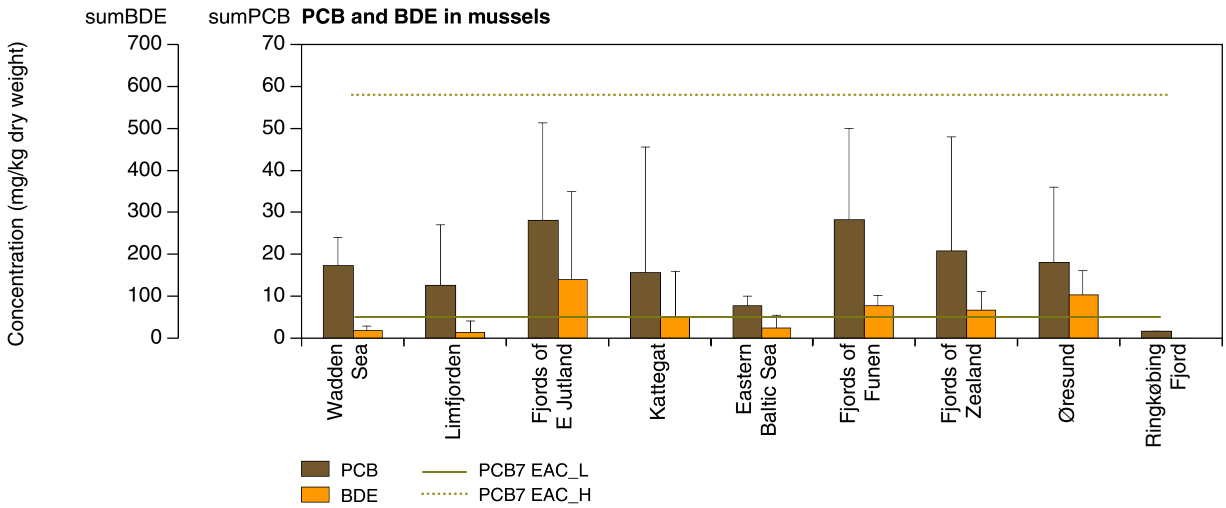
Objective

A number of hazardous substances in the marine environment are encompassed by international marine conventions, e.g. HELCOM, OSPAR and the North Sea Conferences. In this context, OSPAR has drawn up ecotoxicological assessment criteria (EACs) (*OSPAR, 1998*). The EACs are expressed as concentration intervals. The upper limit (EAC_H) is set such as to indicate that exceedances of this limit entails the risk that long-term exposure could have effects on the most sensitive species in the ecosystem. If the concentration lies within the interval the possibility of effects cannot be excluded. If the concentration lies below the lower limit (EAC_L) it is probable that harmful effects on the environment will not occur.

Hazardous substances in mussels/clams

In most areas PCB was detected in concentrations such that the possibility of effects on the environment cannot be excluded (Figure 9.14). This assessment is based on the fact that apart from in Ringkøbing Fjord, PCB has been detected in concentrations exceeding the OSPAR ecotoxicological assessment criterion EAC_L (low) (*OSPAR, 1998*).

Figure 9.14 Concentration of sum PCB and sum BDE in mussels (mean and maximum) compared with the OSPAR ecotoxicological assessment criteria EAC_L (low) and EAC-H (high) for sum PCB (*Ærtebjerg et al., 2005*).



Brominated flame retardants of the BDE type were included in the monitoring for the first time in 2004. The concentration exceeded the detection limit in 75% of the samples and was 10-fold greater than the detection limit in 30% of the samples (Figure 9.14). The highest concentrations were detected in fjords of eastern Jutland (Vejle Fjord) and in Øresund. In general, though, the BDE concentration is more than 10-fold lower than the PCB concentration. No quality criteria have yet been set for brominated flame retardants.

Tributyl tin (TBT) was generally detected in lower concentrations in 2004 than in 2003. Nevertheless, the concentration level in all the areas investigated was such as to pose a considerable risk of causing adverse effects in animals. The highest concentrations were found in Randers Fjord and in the fjords on Funen, which are characterized by a high level of shipping and related activities.

PAHs in the marine environment can mainly be attributed to combustion products from biomass/coal or fossil oils. They reach the marine environment via the air or through direct discharges. Of the PAHs monitored in 2004, only anthracene was detected in concentrations considered capable of having adverse effects.

9.9 Biological effects in eelpout and mussels

Biological effects of hazardous substances have been investigated in fish and mussels in coastal waters. The effect studies encompassed eelpout fry, detoxification enzyme activity in eelpout and lysosomal stability in mussels (see box). The effects are not substance-specific and should therefore be considered as general markers for the overall pressure. The pressure can come from hazardous substances, but other stress factors could also play a role.

Eelpout fry	**Detoxification enzyme activity**	**Lysosomal stability**
Eelpout fry are investigated for deformities. The investigations of the adults include length and the liver and gonad somatic index.	CP450-mediated enzyme activity is measured in eelpout liver. Increased activity indicates that the fish's metabolic detoxification system has been activated. High enzyme activity indicates that the fish are affected. The activity of the detoxification enzyme is often termed EROD activity.	Lysosomal stability is investigated by measuring the time it takes to destabilize the membranes of cells in the hæmolymph (the blood fluid in animals with an open circulation). A rapid destabilization time indicates that the mussels are affected.

Eelpout investigations

Eelpout are used for biological effect studies because:

- They are sedentary
- The fry are live-born, with up to 200 per brood
- They are widespread in coastal waters.

The frequency of malformed eelpout fry is greatest in Vejle Fjord (Figure 9.15). In 2004, 13% of the investigated broods from the inner fjord and 11% from the outer fjord contained more than 5% malformed fry.

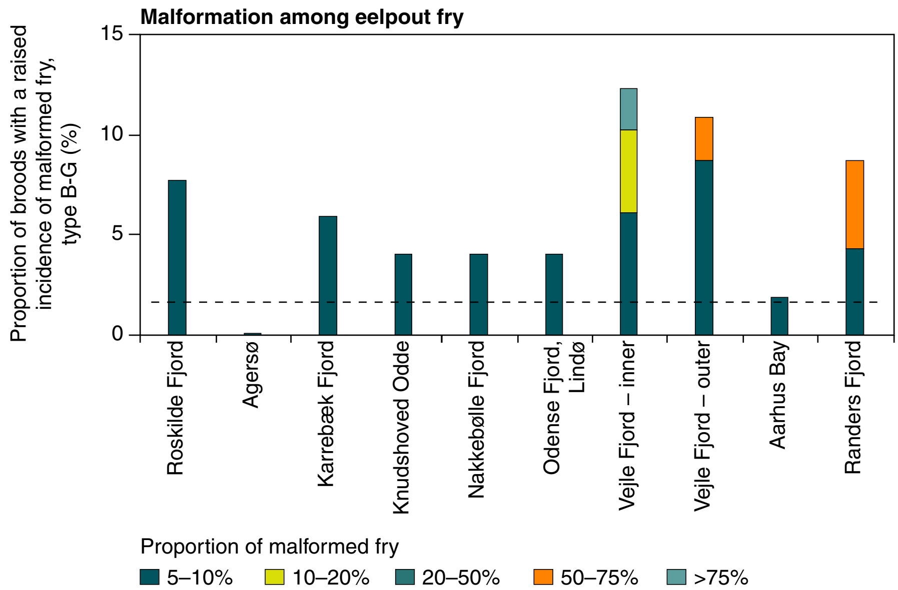


Figure 9.15 Proportion of eelpout (*Zoarces viviparous*) broods with a raised incidence (>5%) of malformed live-born fry. The broken line indicates the background level for unpolluted areas (After *Ærtebjerg et al., 2005*).

Supplementary investigations of the gender distribution of the fry have revealed an even gender distribution. An uneven gender distribution could indicate pressure from endocrine disruptors.

Detoxifying enzyme activity was greatest in eelpout from Odense Fjord and Vejle Fjord (Figure 9.16).

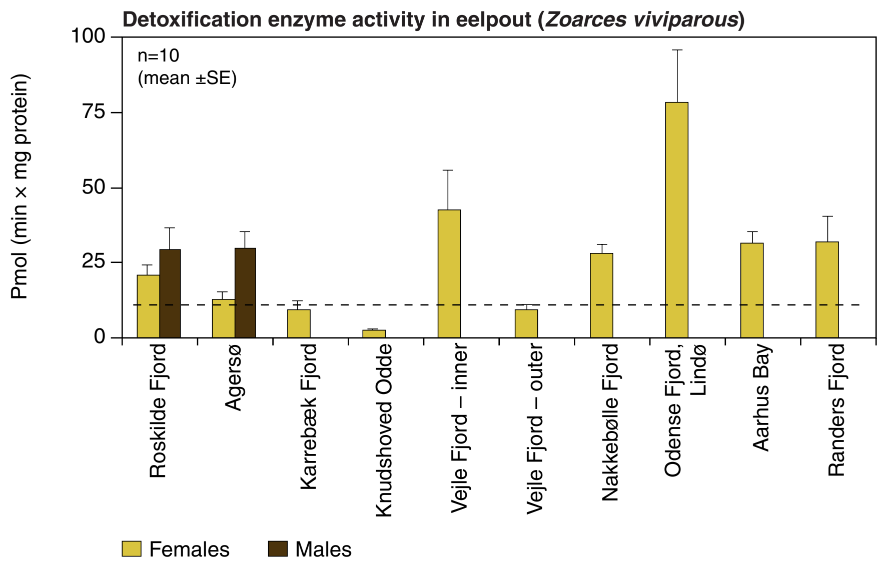


Figure 9.16 Detoxification enzyme activity (EROD activity) in eelpout (*Zoarces viviparous*) liver (*Ærtebjerg et al., 2005*).

Mussel investigations

The lysosomal stability studies do not indicate any evidence of mussels being affected (Figure 9.17). Significantly rapid destabilization times were only found in mussels from Odense Fjord and the Wadden Sea.

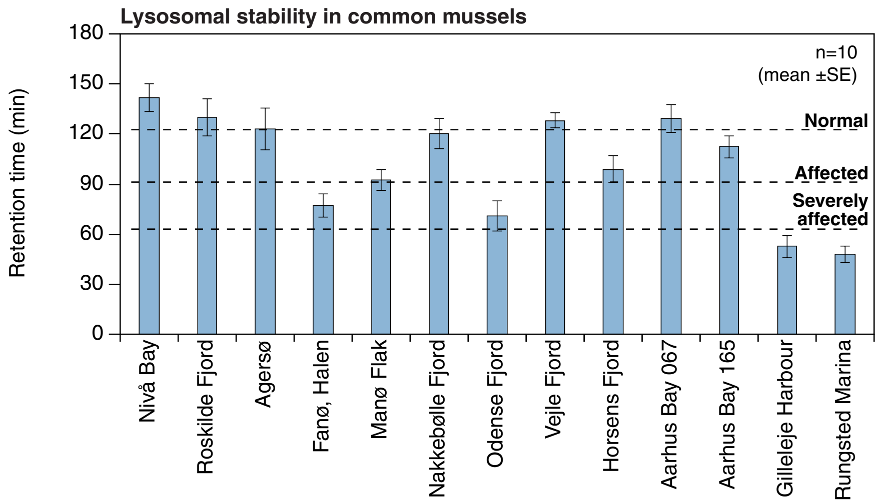


Figure 9.17 Lysosomal stability in common mussels. Severely affected mussels from Gilleleje Harbour and Rungsted Marina have been investigated for comparison (*Ærtebjerg et al., 2005*).

Indications have thus been found that fish and mussels in certain coastal waters are affected by hazardous substances in the form of effects on fry, raised detoxification enzyme activity and reduced lysosomal stability. This is the first time that these biological effect studies are included in the monitoring programme. Future monitoring will reveal whether the effects detected are permanent.

10 Terrestrial natural habitats

10.1 Background and purpose of monitoring terrestrial natural habitats

With the implementation of the NOVANA integrated programme for monitoring of the aquatic and terrestrial environments in 2004, systematic national monitoring of the Danish terrestrial environment became a reality for the first time. International obligations with the main emphasis on EU directives, including the Habitats Directive, have been accorded particularly high priority in the programme.

The primary aim of the Habitats Directive is to ensure biological diversity through the conservation of natural habitats and species. A number of Special Areas of Conservation (SACs) have been designated that together with the Special Protection Areas (SPAs) established pursuant to the Birds Directive comprise part of the European Natura 2000 network of conservation-worthy sites. The Danish Natura 2000 sites also encompass sites designated pursuant to the Ramsar Convention. The Natura 2000 sites include natural habitats and species whose conservation is considered to be threatened and of great significance to the European Community.

Terrestrial natural habitat types

The terrestrial natural habitat types in Denmark have developed on the basis of the natural growth and habitat conditions such as climate, soil type, invading species, etc. Part of the terrestrial environment has been subjected to exploitation in the form of grazing, haymaking and felling. Over the past approx. 100 years the terrestrial environment has been affected by drainage, fertilization, eutrophication from the air and the spread of introduced species, especially mountain pine and common spruce, and shrubs such as broom and rugosa rose.

The Danish natural habitat types belong to two of the northwestern European biogeographic regions – the Continental and the Atlantic Zones. The natural habitat types encompassed by NOVANA are described in more detail in *Strandberg et al. (2005)*.

Monitoring of terrestrial natural habitats under NOVANA

The NOVANA monitoring programme for terrestrial natural habitats aims to provide a representative picture of the status and trend for the Danish terrestrial natural habitats included in Annex I of the Habitats Directive. The monitoring is designed to determine the status of the natural habitats and to describe the relationship between pressures, status and trend. Of the 35 types of non-forest natural habitat found in Denmark, 18 are monitored under NOVANA. Many of the remaining 17 types of non-forest natural habitat occur as a natural mosaic among the primarily monitored natural habitats and will therefore also be encompassed by the results to some extent.

The monitoring is carried out at a network of intensive monitoring stations where monitoring is performed annually. These are mainly located in Natura 2000 SACs, as well as at a network of extensive stations located both inside and outside these SACs. In 2004, monitoring was only performed at the intensive monitoring stations.

The distribution of the 202 intensive monitoring stations among the natural habitat types encompassed by the programme is shown in Table 10.1. The number of stations per habitat type varies from 7 to 19.

Table 10.1 Number of natural habitat types and intensive stations. Each habitat type is identified by its Natura 2000 code (Habitats Directive Annex 1).

Code	Habitat type	No. of intensive stations
1330/ 1340	Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) Inland salt meadows	19
2130	Fixed coastal dunes with herbaceous vegetation (”grey dunes”)	16
2140	Decalcified fixed dunes with *Empetrum nigrum*	11
2190	Humid dune slacks	10
2250	Coastal dunes with *Juniperus* spp.	7
4010	Northern Atlantic wet heaths with *Erica tetralix*	9
4030	European dry heaths	18
6120	Xeric sand calcareous grasslands	6
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*)	16
6230	Species-rich *Nardus* grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)	15
6410	*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	11
7110*	Active raised bogs	11
7140	Transition mires and quaking bogs	9
7150	Depressions on peat substrates of the *Rhynchosporion*	7
7210	Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*	8
7220	Petrifying springs with tufa formation (*Cratoneurion*)	11
7230	Alkaline fens	18

Much of the work performed under the subprogramme by the regional authorities in 2004 and 2005 concerned charting the occurrence and baseline status of the habitat types inside and outside the Natura 2000 SACs in order to facilitate the establishment of a representative network of stations before extensive monitoring is initiated in 2006. The results of the habitat charting are not included in this year’s report.

A nationwide assessment of the status of natural habitats both inside and outside the Natura 2000 SACs will gradually be built up as the results of the intensive and extensive monitoring become available. The extensive monitoring will not be complete until 2009. From 2007 onwards, monitoring of forest habitats will be included in NOVANA.

Strategy for monitoring of natural habitats

The monitoring is based on the operational criteria for favourable conservation status of terrestrial natural habitats and species (*Søgaard et al., 2003*). Favourable conservation status entails that a natural habitat type or species can be conserved within the foreseeable future. General knowledge of the habitats will be considerably enhanced by the monitoring programme as systematic monitoring of terrestrial natural habitats has not previously been performed in Denmark. One of the aims of NOVANA is to gather data to facilitate a concrete assessment of conservation status. When Natura 2000 plans are drawn up in 2009, a political decision will be made setting specific quality objectives for the terrestrial natural habitat types. NOVANA data will play a central role here, both in establishing the quality objectives and in the follow-up on the Natura 2000 plans.

Favourable conservation status – operational criteria

The operational criteria for favourable conservation status are taken into account when describing and assessing the monitoring results for the individual natural habitat types. The choice of criteria is based on investigations of concrete, measurable variables that have proven useful as status indicators for the habitat type in question. The criteria cannot stand alone, though, but must be part of an overall assessment of the conservation status of the individual natural habitat types at the local and national levels. Based on the monitoring results for this and the coming years, methods will be developed to weight the individual indicators against each other and in relation to supplementary information about each habitat type in order to facilitate an overall assessment of their status.

With some of the criteria, knowledge is limited or insufficient to be able to set a specific indicator threshold, e.g. the maximum permissible nitrogen concentration in moss, the maximum permissible coverage by woody plants, etc. In these cases, establishment of the indicator threshold must await the new knowledge that is expected to be gained through the monitoring programme. In the case of some natural habitat types the continued accumulation of knowledge could lead to changes or adjustments to the indicator thresholds. Thus the operational criteria will initially be used as indicators when assessing the monitoring results.

Monitoring activities in 2004

The monitoring stations for the individual natural habitat types are delimited such that the habitat type that the station is intended to monitor occupies at least 50% of the monitored area. A broad definition of the habitat types is employed so as to ensure the monitoring of test plots at the monitoring station having both potentially favourable and potentially unfavourable status. The monitoring typically encompasses 40 randomly located test plots depending on the station's size and complexity, with some small stations having only 20 test plots and some large stations having 60 test plots.

Vegetation studies

Each test plot consists of a 0.5 x 0.5 m quadrant. A 5-m radius circle is drawn centred on the test plot. Vegetation coverage and height are measured in the test plot. In the surrounding circle data are collected on supplementary species, including invasive and character species, and on a number of other variables such as invasion by woody plants, wind breaches, damage caused by insect attacks, etc.

Chemical investigations

A number of measurable indicators have been selected that describe physical/chemical and biological conditions and relationships between pressures and the status of the habitat type. The indicators have been selected so as to enable description of the effects of pressures such as eutrophication, acidification, changes in management practice, changes in hydrology and habitat fragmentation.

The selected monitoring variables differ from habitat type to habitat type, but encompass measurement of a number of nutrient-related variables, including the C:N ratio in the soil, nitrate in the water, nitrogen in lichen and moss, phosphorus in the soil, the pH and, in the wetter terrestrial habitat types, conductivity and water table level.

10.2 Water nitrate concentration

The water nitrate concentration is measured in raised bogs and transition mires.

Relevance

In nutrient-poor habitats such as raised bogs and transition mires the pool of available nitrogen is maintained by input from the atmosphere and release from degrading organic matter. The occurrence of nitrate in the water in these types of natural habitat indicates changes in the processes that normally ensure almost complete binding of the nitrogen. The occurrence of nitrate in raised bogs in concentrations exceeding 0.03 mg nitrate-N/l can result in invasion by grasses.

Indicator threshold

The indicator threshold for nitrate in the water of raised bogs has been set at 0.03 mg nitrate-N/l. The level has to be stable or declining.

Assessment of status

The nitrate concentration in water samples from the raised bog and transition mire stations is shown in Figure 10.1. The figure shows the mean value for each station together with the 5% and 95% percentiles. The interval between these percentiles encompasses 90% of all the measured values. The measured mean concentrations are low compared with the indicator threshold of 0.03 mg nitrate-N/l at six of the eight raised bog stations and higher than the indicator threshold at one station.

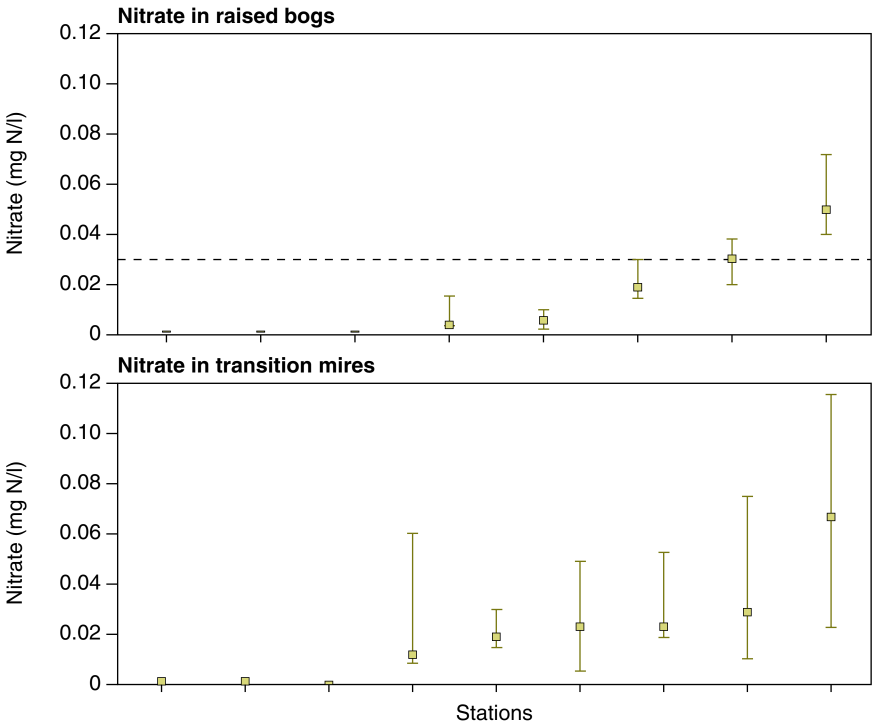


Figure 10.1 Nitrate concentration in raised bogs and transition mires at the intensive stations. The indicator threshold for nitrate in raised bogs has been set at 0.03 mg nitrate-N/l.

10.3 Nitrogen in lichen and moss

The nitrogen content of lichen and moss is measured on dune heaths and dune slacks, heaths, raised bogs and transition mires, as well as in springs and alkaline fens. The dune landscape encompasses several different natural habitat types, with grey dunes being the naturally most nutrient-rich and least acidic type of dune. In dune heaths (decalcified fixed dunes) the limestone has been washed out of the sand, and the pH of the soil is generally less than 4. Dry heath is the traditional inland heath dominated by heather. Wet heath will often be dominated by cross-leaved heath.

Relevance

The nitrogen content of lichen and moss is an indicator of nitrogen status and hence of nitrogen deposition from the atmosphere. In Denmark the nitrogen content of lichen ranges from 0.4% to 1.3% of dry matter and is typically lowest in the coastal regions and highest in the inner parts of the country. Studies show that the nitrogen content of mosses and lichen from northern Scandinavia lies in the range

0.2–0.4% (*Strandberg et al., 2005*). Increasing nitrogen deposition on these natural habitat types will lead to changes in the plant communities and the disappearance of sensitive lichens and mosses.

Indicator threshold

The indicator threshold for lichen and moss in grey dunes is 6 mg N/g plant dry matter, i.e. 0.6%. Indicator thresholds for lichen and moss have not been set for the other types of dune and heath. An indicator threshold of 1.0% has been set for the nitrogen content in peat mosses in raised bogs (Figure 10.2).

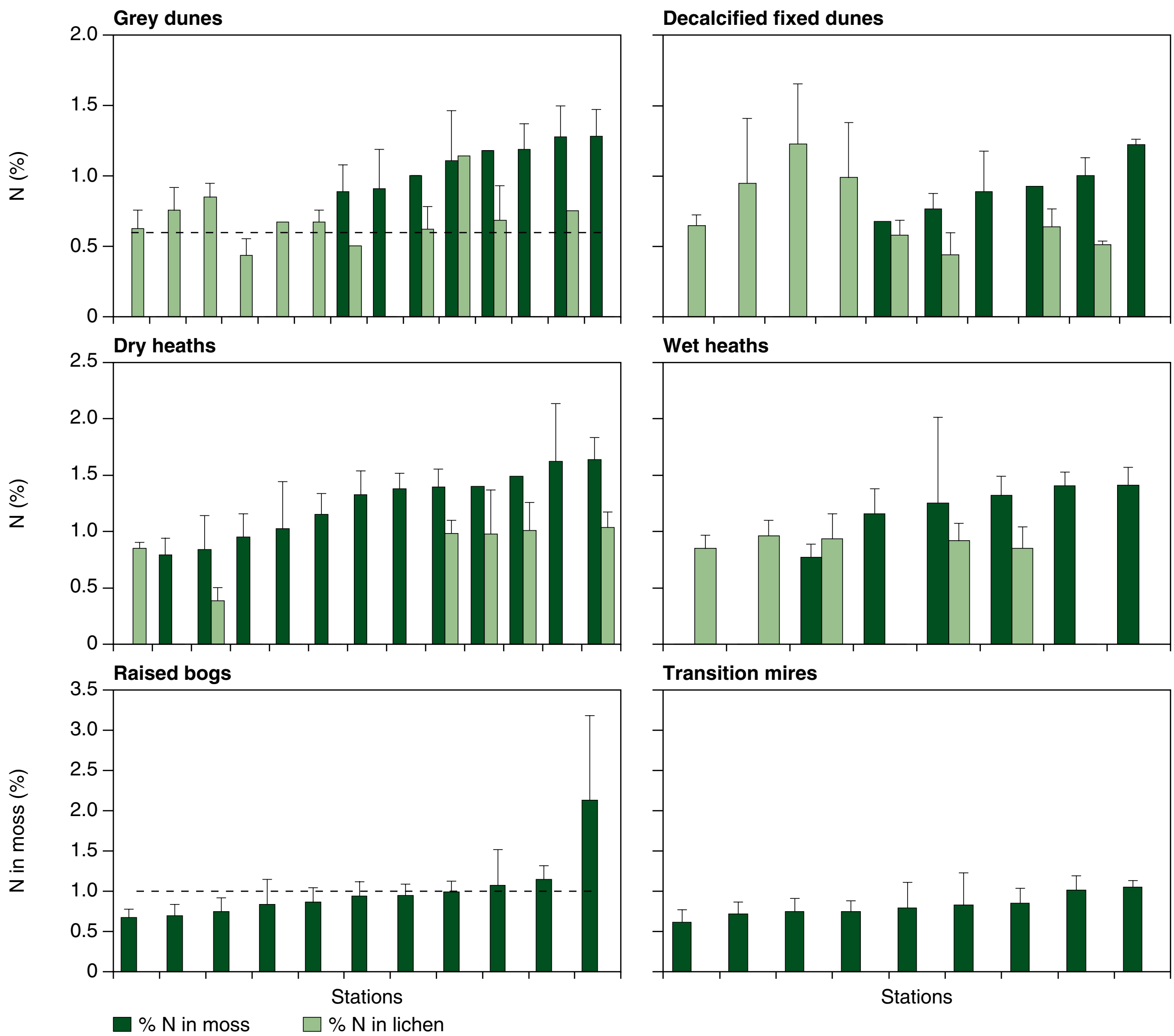


Figure 10.2 Nitrogen content of lichen and moss in percent of plant dry matter in dunes, heaths, raised bogs and transition mires. The bars indicate the standard deviation and the broken lines the indicator threshold.

Status assessment

In general, the nitrogen content of moss is higher than that of lichen irrespective of the type of natural habitat. With the habitat types grey dune, dune heath, dry heath and wet heath, the nitrogen content is monitored in both moss and lichen. The indicator threshold for moss is not met in grey dune – out of the 113 test plots investigated the indicator threshold for the nitrogen content of lichen was only met at 24.

The nitrogen content of moss and lichen in dune heath, dry heath and wet heath is generally high, i.e. on par with that in grey dune.

In raised bogs, where the chemical composition of the peat mosses has been analysed, the indicator threshold of 1.0% is met at 65 of the 110 test plots investigated. The corresponding figure for transition mires is 72 out of 88 test plots.

10.4 Soil C:N ratio

The soil C:N ratio is monitored on dune heath, dune slacks, heaths, dry grasslands, *Molina* meadows, calcareous fens and alkaline fens.

Relevance

The ratio between carbon and nitrogen (C:N) is a measure of the ecosystem's accumulation of nitrogen. A relationship exists between the amount of plant-available nutrients and the C:N ratio of the soil. A decrease in the C:N ratio is an indicator of the formation of nitrate. The amount of plant-available nitrogen is highest in soils with a low C:N ratio. A low C:N ratio thus indicates pollution of natural habitats with nitrogen.

Indicator threshold

With nutrient-poor habitat types such as dune heath and dry and wet heath the indicator threshold for the C:N ratio is >30. With dry grassland the corresponding value is >15.

Status assessment

The results of the C:N ratio monitoring are summarized in Figure 10.3, which shows the mean values for each habitat type at each station together with the indicator threshold.

With dune heaths, the C:N ratio is below the indicator threshold at eight of the nine monitoring stations and the mean ratio is 27. With wet heaths the C:N ratio is below the indicator threshold at five of the eight stations, and the ratio is also 27. At three of the stations the ratio is closer to 20. With dry heaths the threshold is met at one station out of 11. At this dry heath, a traditional inland heath, the mean C:N ratio was 23. At four of the 11 monitoring stations the C:N ratio was just under 20. The low C:N ratio recorded for both wet and dry heaths indicates that the heather turf is unstable and that the plant communities on these heaths could consequently change in the long term.

The C:N ratios at the acidic dry grasslands and calcareous dry grasslands were very similar and lay at or below the indicator threshold of >15. In the long term this could lead to a change in species composition to the benefit of the more nutrient-demanding species.

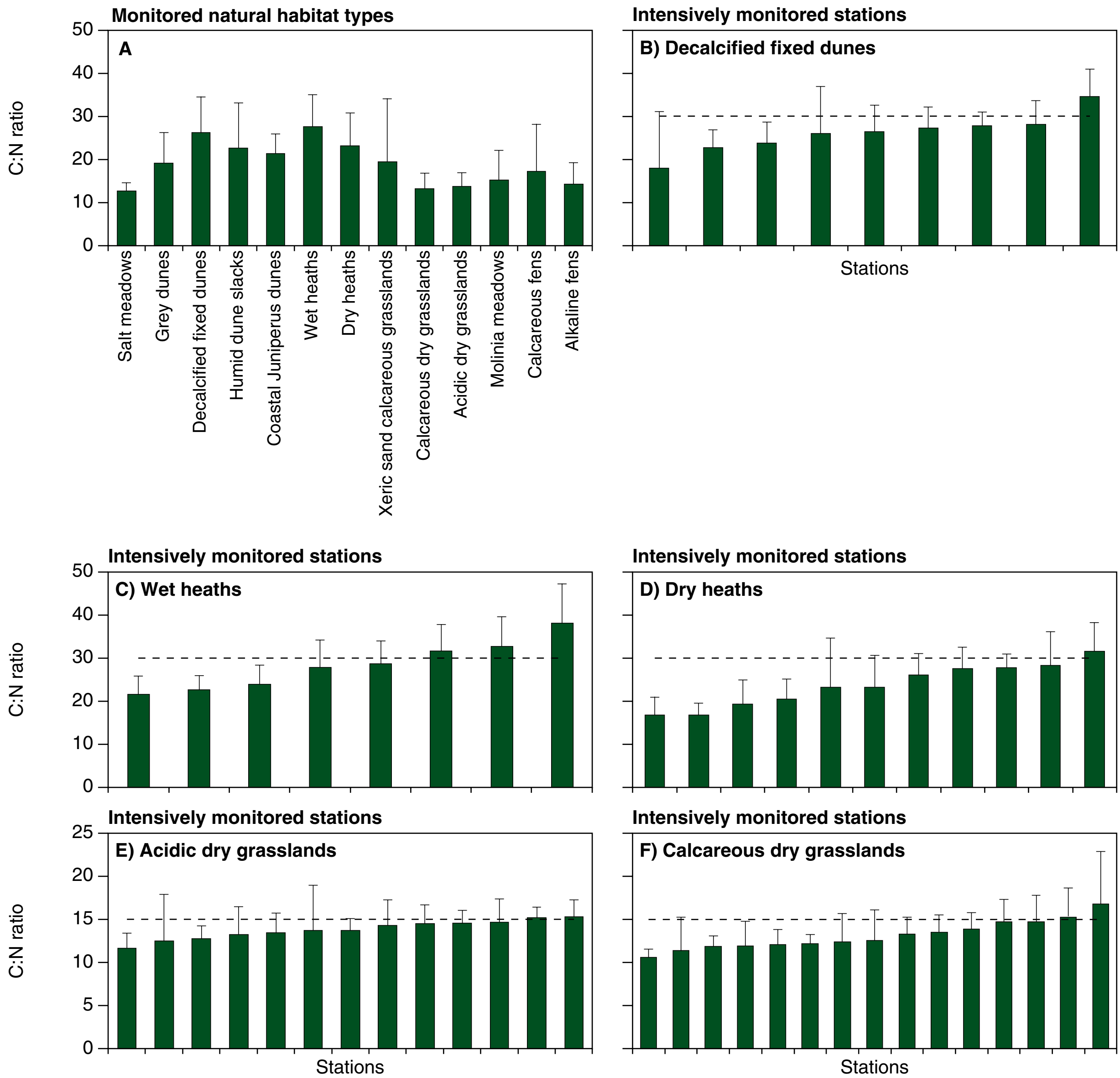


Figure 10.3 Mean C:N ratio in relevant Danish natural habitat types in 2004. A: C:N ratio for the monitored natural habitat types. B-F: C:N ratio for the intensively monitored stations in decalcified fixed dunes, wet heaths, dry heaths, acidic dry grasslands and calcareous dry grasslands. The bars indicate the standard deviation and the broken lines the indicator threshold.

10.5 Grass coverage

Relevance

If the status of a heath is good, the vegetation is dominated by dwarf shrubs.

On wet heaths the dominant species is cross-leaved heath. Grasses can become dominant if the heath receives too much nitrogen, though. Lowering of the water table can also result in purple moor-grass and other grasses becoming dominant.

Dry heaths are naturally low in nitrogen, and several species of dwarf shrubs dominate. In earlier times the heaths were maintained in that state by grazing and other exploitation. Following closure of heath farms it has become necessary to "manage" the heaths if their species composition is to be preserved. A shift can occur from domination by cross-leaved heath to domination by crowberry, and in the case of the more nutrient-rich heaths, a shift towards a grass-dominated community is taking place.

In the case of wet heath, the occurrence of cross-leaved heath and the ratio between coverage by purple moor-grass and cross-leaved heath reflect the status of the habitat. The ratio should be low.

Dry heath should be dominated by heather. The occurrence of heather and the ratios between crowberry and heather and between grass and heather reflect the status of the habitat. Ideally, both ratios should be low.

Indicator threshold

The ratio between coverage by purple moor-grass and cross-leaved heath should be low. Coverage by purple moor-grass should not exceed 30% on wet heath.

Status assessment

Coverage by cross-leaved heath and purple moor-grass is shown in Figure 10.4. As can be seen, there is considerable variation in coverage by both species. In general, coverage by cross-leaved heath is rather low. Thus cross-leaved heath was absent at 46% of the 324 test plots in wet heath, and was only dominant at 30% of the test plots.

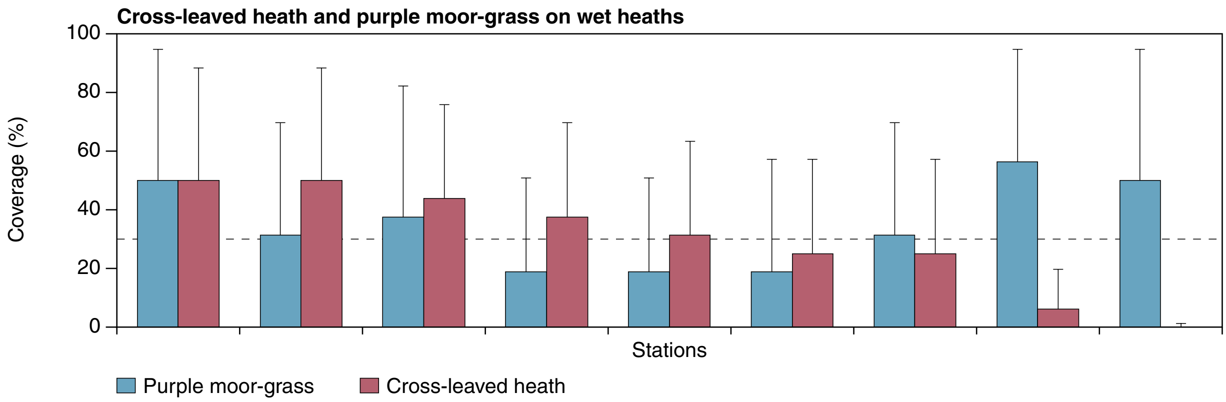


Figure 10.4 Mean coverage (%) of cross-leaved heath and purple moor-grass at nine stations sorted in order of decreasing coverage of cross-leaved heath. The bars indicate the standard deviation and the broken line the indicator threshold for purple moor-grass coverage.

The indicator threshold for coverage by purple moor-grass was exceeded at 2/3 of the stations and at 40% of all the test plots.

Heather was present at all 18 of the dry heath stations. Heather coverage varied considerably, though, and heather was absent at just under half (49%) of the field plots and only covered 50% or more of the area at 28% of the test plots.

The ratios between crowberry and heather and between wavy hair grass and heather are apparent from Figure 10.5. Crowberry coverage exceeded 50% at 18% of the test plots, and wavy hair grass coverage exceeded 50% at 47% of the test plots.

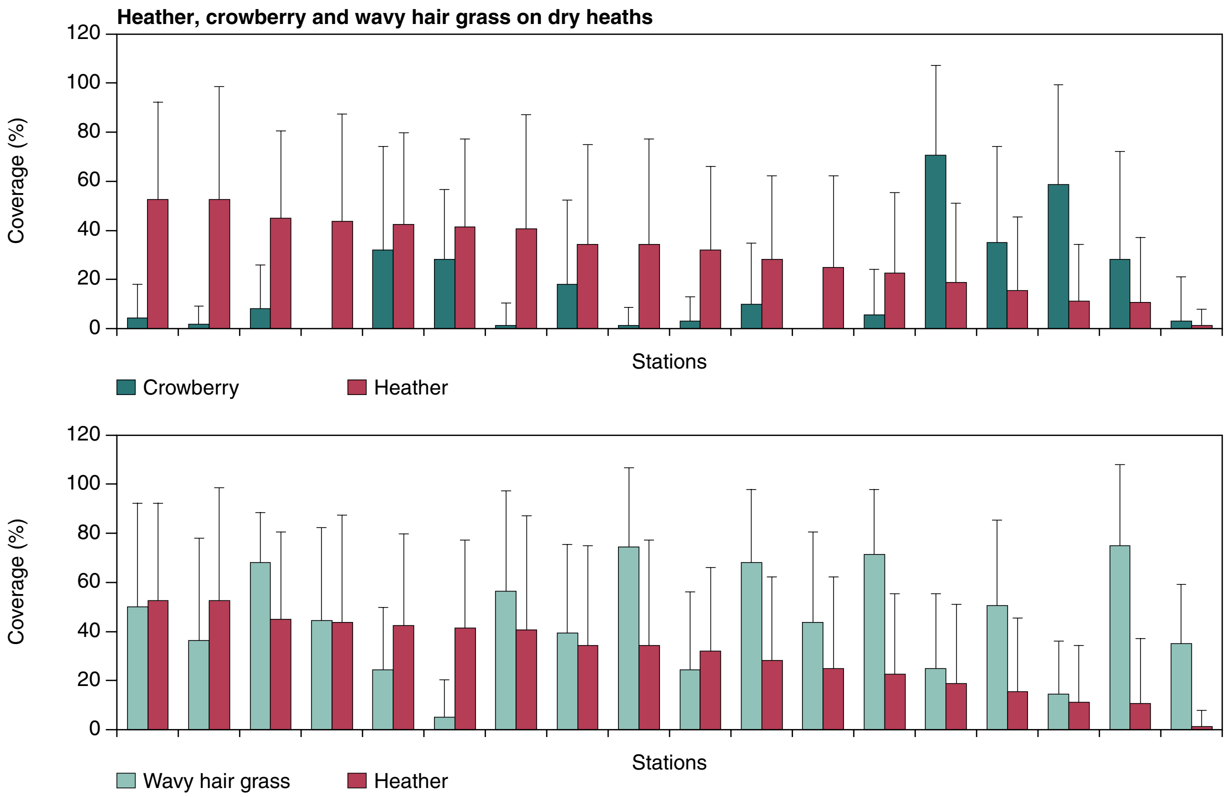


Figure 10.5 Mean coverage (%) of crowberry and heather (upper panel) and wavy hair grass and heather (lower panel) at 25 stations on the natural habitat type dry heath sorted in order of decreasing heather coverage. The bars indicate the standard deviation. Note that crowberry is not present at two of the stations.

10.6 Invasion by woody plants

Monitoring of all natural habitat types included a visual assessment of coverage by woody plants with a height of less than and more than 1 metre, respectively, in a 5-m radius circle around the test plots.

Relevance

At the majority of non-forest habitat types, grazing or other removal of above-ground biomass is an important precondition for conserving the habitat type. The majority of Danish natural habitat types will eventually become invaded by woody plants in the absence of grazing or other forms of ecosystem management.

Indicator threshold

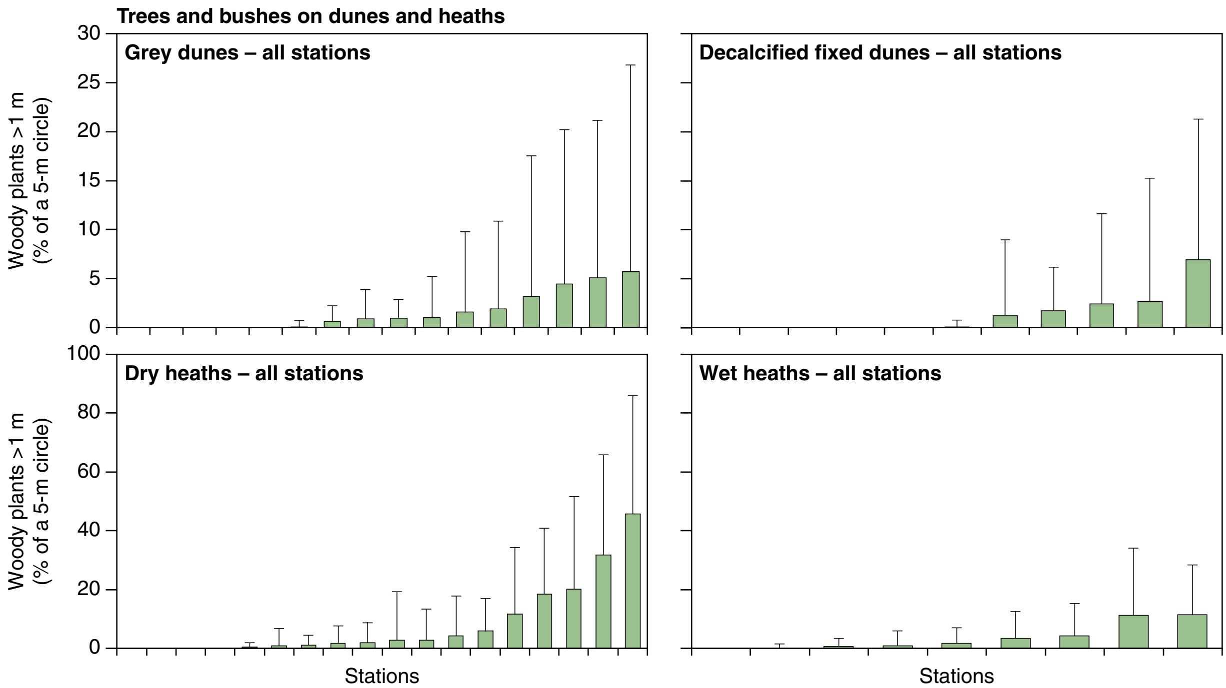
In the case of the non-forest habitat types grey dune, dune heath, wet heath, dry heath, xeric sand calcareous grassland, calcareous dry grassland and *Molina* meadow, the degree of coverage by woody plants higher than 1 m generally has to be stable or decreasing.

In addition, an indicator threshold of 5% at maximum has been set for woody plant coverage of wet heath and 10% at maximum for woody plant coverage of dry heath and *Molina* meadow.

Status assessment for dunes and heaths

Coverage with woody plants higher than 1 m is shown for heath and dune habitat types in Figure 10.6. As can be seen, there is considerable variation, both between stations and within the individual stations. In the dunes and dune heaths, woody plant coverage was 7% at maximum.

Figure 10.6 Coverage of woody plants higher than 1 m expressed in percent of a 5-m circle at the intensive stations on heath and dune habitat types. The columns represent the means for the various stations, and the bars indicate the standard deviation. The data are sorted in order of degree of overgrowth. Note that several stations are not overgrown. Note also the difference in the scale of the y axis.



Woody plant coverage is considerably greater for wet and dry heath than for the dune habitat types. Moreover, dry heath is more overgrown than wet heath as mean coverage exceeded 20% at many stations. Mean coverage on dry heath exceeded the threshold of 10% woody plant coverage at five of the 20 stations, while woody plants were absent at four of the 20 stations. Mean coverage on wet heath exceeded the indicator threshold of 5% woody plant coverage at two of the nine stations, while one station lacked woody plants.

Status assessment for grasslands

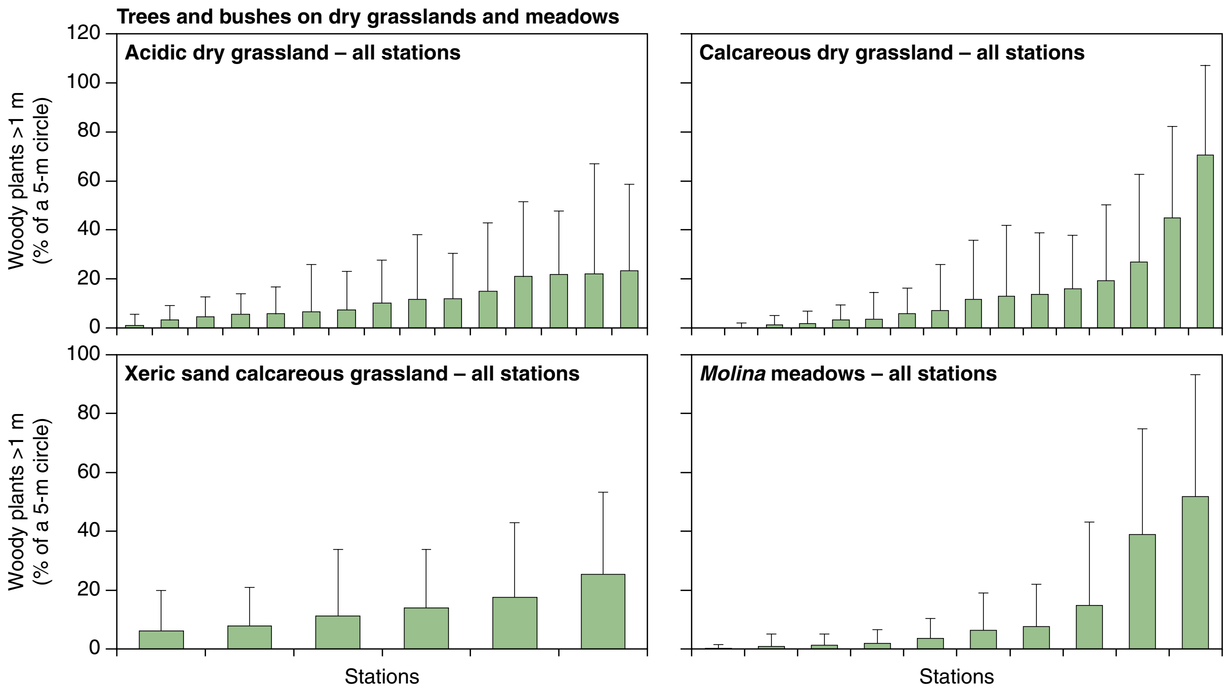
Mean coverage with woody plants higher than 1 m is shown for the intensive monitoring stations on grassland and meadow in Figure

10.7. Coverage exceeded 10% at four of the six stations on xeric sand calcareous grassland.

Figure 10.7 Coverage of woody plants higher than 1 m expressed in percent of a 5-m circle at the intensive stations on dry grasslands and *Molina* meadows. The columns represent the means for the various stations, and the bars indicate the standard deviation.

On calcareous dry grassland, mean woody plant coverage exceeded 10% at half of the eight stations, and woody plants were only absent at one station. The picture is roughly the same for acidic dry grassland in that mean woody plant coverage exceeded 10% at seven of the 15 stations.

On *Molina* meadow, mean woody plant coverage exceeded the 10% threshold at three of the 10 stations.



Overall, the degree of woody plant coverage was high at many of the stations on grasslands, although the variation was considerable. The future monitoring results will reveal whether the trend in woody plant coverage meets the criterion that this should be stable or decreasing.

11 Monitoring of species

11.1 Background and purpose of monitoring species

With implementation of the NOVANA integrated programme for monitoring of the aquatic and terrestrial environments in 2004, systematic monitoring of the Danish terrestrial environment became a reality for the first time. International obligations with the main emphasis on EU directives, including the Habitats Directive, have been accorded particularly high priority in the programme.

The primary aim of the Habitats Directive is to ensure biological diversity through the conservation of natural habitats and species. A number of Special Areas of Conservation have been designated pursuant to the directive that together with Special Protection Areas established pursuant to the Birds Directive and Ramsar sites comprise part of a European network of conservation-worthy sites called Natura 2000 sites.

The purpose of the species monitoring is to procure knowledge about the individual species' range and population size so as to be able to assess conservation status and the need for intervention.

Monitoring of species

The species part of the NOVANA subprogramme for species and terrestrial natural habitats encompasses the following elements:

- Monitoring of the status and trend for selected plant and animal species encompassed by Annexes II and IV of the Habitats Directive
- Monitoring of certain species of national responsibility, i.e. species of which more than 20% of the total population occurs in Denmark (vascular plants, moths)
- Monitoring of birds listed in Annex I of the Birds Directive
- Monitoring of other regularly occurring migratory species
- Monitoring of other selected species.

Favourable conservation status – operational criteria

According to the Habitats Directive the conservation status of a species is considered to be favourable when:

- Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

Pursuant to the Habitats Directive, which among other Danish legislation has been implemented in the "Act on environmental objectives for water bodies and international nature protection sites", EU Member States are required to ensure that the species concerned achieve favourable conservation status.

In the case of species encompassed by the Habitats Directive and the Birds Directive, the monitoring is based on operational criteria for favourable conservation status (*Søgaard et al., 2003*). The criteria are applied when assessing the results of the species monitoring. They are not legally adopted objectives, but are an aid and guideline when assessing the populations.

Strategy for monitoring species

The occurrence of a species can be described through its range and population size, both of which are key elements of the Habitats Directive's definition of favourable conservation status. Population size will typically be monitored intensively, while species range will be monitored extensively.

As a rule, intensive monitoring is carried out annually, but could later be reduced to every 2nd, 3rd or 6th year. Extensive monitoring is carried out in order to establish data material for assessing whether a species' range in Denmark is decreasing, stable or increasing. Extensive monitoring is generally carried out every 6th year. Thus not all the species encompassed by the programme were monitored in 2004. The data are collected in a nationwide 10 x 10 km grid network.

11.2 Monitoring in 2004

Monitoring of species

The Habitats Directive species and species of national responsibility monitored under NOVANA in 2004 comprised 17 species of vascular plants, mosses, insects and mammals (Table 11.1).

With most of these species the 2004 monitoring results will serve as the baseline with which the future monitoring results will be compared. It will eventually become possible to assess the trend in their population size and range.

Monitoring of breeding birds and migratory birds

Of the breeding birds listed in Annex I of the Birds Directive, the regional authorities monitored six species in 2004 (Table 11.2). The snowy plover, gull-billed tern, black tern and tawny pipit are monitored annually, while the dunlin and ruff are monitored every 2nd year.

Table 11.1 Species and species groups (Habitats Directive species and species of national responsibility) monitored under NOVANA in 2004. The number of localities monitored in each county is indicated. NOR: Nordjylland; ARH: Aarhus; VIB: Viborg; RIN: Rinkjøbing; VEJ: Vejle; RIB: Ribe; SØN: Sønderjylland; FUN: Funen; FRE: Frederiksborg; VES: Vestsjælland; CPH: Copenhagen; ROS: Roskilde; STO: Greater Copenhagen; BOR: Bornholm.

Species/County	NOR	ARH	VIB	RIN	VEJ	RIB	SØN	FUN	FRE	VES	CHP	ROS	STO	BOR
Vascular plants:														
Fen orchid (*Liparis loesilii*)	6	1						4	2	6			4	1
Marsch saxifrage (*Saxifraga hirculus*)	5	3	7	2										
Least moonwort (*Botrychium simplex*)	2	1								2			2	
Lady's-slipper orchid (*Cypripedium calceolus*)	3													
Floating water-plantain (*Luronium natans*)				14		2								
Slender naiad (*Najas flexilis*)			2			1								
Mosses:														
Green shield-moss (*Buxbaumia viridis*)	6	2					1	3	5		2			
Insects:														
Marsh fritillary (*Euphydryas aurinia*)	16		7	2		1	1							
Hermit beetle/Pseudoscorpion (*Anthrenochernes stellae*)	2	3			2			2	4	3	3	4	13	
Green club-tailed dragonfly (*Ophiogomphus cecilia*)		16	12	10		6								
Green mosaic dragonfly (*Aeshna viridis*)						2	5	3	8					
Large white-faced darter (*Leucorrhinia pectoralis*)									7				5	
Selected diving beetles (*Dytiscus* spp.)	5	4	3		4	1	3	3	4	3	3	3	3	5
Mammals:														
Common dormouse (*Muscardinus avellanarius*)							13	10				6		
Otter (*Lutra lutra*)	152	135	119	151	86	93	120	116	42	99	3	26	93	

The water bird censuses performed in 2004 encompassed:

- All water birds in January
- Pink-footed geese and barnacle geese in mid March
- Brent geese, knot and bar-tailed godwits in mid May
- Greylag geese in mid September
- Swimming ducks and pochard in the first half of October.

Table 11.2 Bird species listed in Annex 1 of the Birds Directive that were included in the county monitoring of breeding birds in 2004. For an explanation of the county codes see Table 11.1.

Species/County	NOR	ARH	VIB	RIN	VEJ	RIB	SØN	FUN	FRE	VES	CPH	ROS	STO	BOR
Snowy plover (*Charadrius alexandrinus*)						x	x							
Dunlin (*Calidris alpina schinzii*)	x	x	x	x	x	x	x	x	x	x	X	x	x	
Ruff (*Philomachus pugnax*)	x		x	x		x	x	x	x	x	X	x	x	
Gull-billed tern (*Sterna nilotica*)						x	x							
Black tern (*Chlidonias niger*)	x	x	x				x					x		
Tawny pipit (*Anthus campestris*)	x	x												

11.3 Otter

The otter (*Lutra lutra*) lives in close connection with wetlands. It is found in both still and running water and in both seawater and fresh water. Lakes and mires with large reed beds comprise a particularly suitable habitat.

Table 11.3 Number of stations investigated in the individual counties over the period March–May 1996 and 2004 and the number and percentage of positive stations at which signs of otter (*Lutra lutra*) were detected. Only stations that were investigated during the stated period in both years are included.

County	No. of stations	No. of stations in 1996		No. of stations in 2004	
		Positive	%	Positive	%
Nordjylland	150	57	38.0	136	90.1
Viborg	118	92	78.0	109	92.4
Ringkjøbing	149	89	59.7	132	88.6
Aarhus	135	23	17.0	104	77.0
Ribe	93	1	1.1	48	51.6
Vejle	86	1	1.2	38	44.2
Sønderjylland	120	0	0	17	14.2
Funen	116	0	0	0	0
Vestsjælland	99	0	0	0	0
Frederiksborg	42	0	0	0	0
Roskilde	26	0	0	0	0
Copenhagen	3	0	0	0	0
Storstrøm	93	0	0	0	0
Total	1,230	263	21.4	584	47.5

Relevance

At the end of the 1950s the otter was found throughout the country except on a number of islands such as Bornholm, Samsø and Læsø. Despite it being declared a preserved species in 1967, the population declined drastically during the latter half of the 20th Century. Efforts to promote the otter population have been initiated pursuant to the Management Plan for the Otter in Denmark (*Søgaard & Madsen, 1996*).

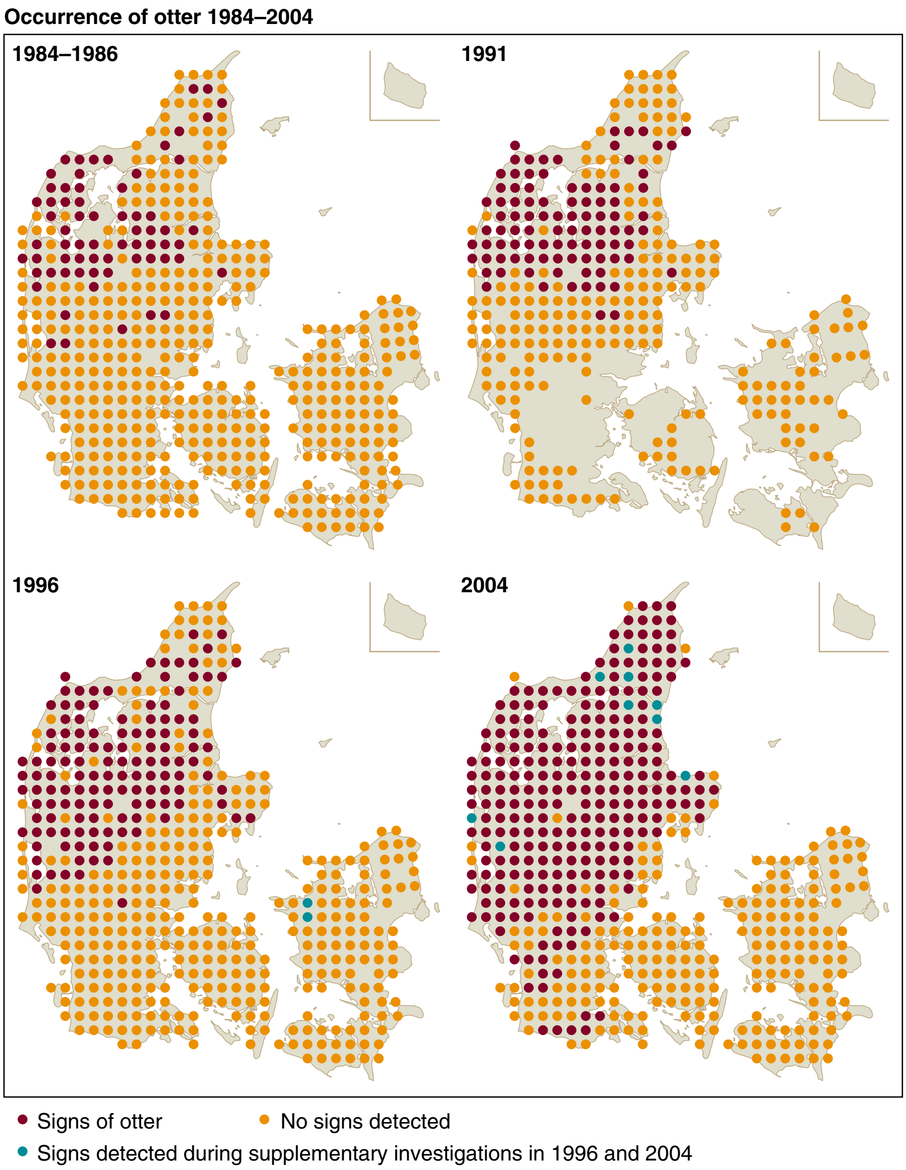
Criteria for favourable conservation status

The criteria for favourable conservation status require the existence of viable otter populations consisting of a stable or increasing number of individuals in the Atlantic and the Continental regions of Jutland (*Søgaard et al., 2003*).

2004 monitoring results

The otter's lifestyle makes it impossible to carry out monitoring based on direct observation. The otter monitoring is therefore conducted using an international standardized survey method based on the fact that the otter marks its territory with faeces, which are normally placed at conspicuous locations along watercourses and lakes.

Figure 11.1 Occurrence and range of the otter (*Lutra lutra*) in 10 x 10 km UTM quadrants as revealed by national monitoring in Denmark in 1984–1986, 1991, 1996 and 2004.



Otter monitoring in 1996 and 2004 was performed at 1,230 common stations. Traces of otter were detected at 21.4% and 47.5% of the stations, respectively. The results are shown apportioned by county in Table 11.3 and the trend in geographic distribution since 1984 is shown in Figure 11.1.

Status assessment

The 2004 otter monitoring results show a clear improvement in range compared with the period 1984–1986. The range has been increasing markedly from 28 positive quadrants in 1986–1991 to 37 in the period 1991–1996 and to 121 in the period 1996–2004.

Among other things, the positive development in the population can be attributed to concerted efforts to protect the species through the preparation of a management plan in 1996 (*Søgaard & Madsen, 1996*). Due to the establishment of fauna passages and compulsory use of otter guards on eel traps, fewer otter are lost to road deaths or drowning. At the same time, countryside management by the regional authorities has enhanced the number of otter habitats through nature restoration and the establishment of dispersal corridors.

11.4 Floating water-plantain

Floating water-plantain (*Luronium natans*) grows in slowly flowing watercourses and in small lakes.

Relevance

Floating water-plantain has previously been recorded at approx. 25 localities in western Jutland in the area between Nissum Fjord and Ribe. A survey in 2002 recorded the species at 10 localities in western Jutland near Ringkøbing Fjord and Nissum Fjord.

Criteria for favourable conservation status

The criteria for favourable conservation status require the existence of one or more viable populations of floating water-plantain within the catchment of Nissum Fjord and Ringkøbing Fjord. Viable populations should thus exist in the Skjern, Tim, Falen and Gødelen river systems.

2004 monitoring results

Floating water-plantain is monitored in Ringkjøbing and Ribe Counties at a total of 17 localities. It was detected at 10 localities (Table 11.4 and Figure 11.2), but these are not quite the same localities as in 2002. New localities at which the species was redetected are Lake Husby and the River Skjern, whereas the species was not redetected in Albæk Marsh near the River Skjern and in Stadil Fjord.

Table 11.4 Monitoring results for floating water-plantain (*Luronium natans*) in Ringkjøbing (RIN) and Ribe (RIB) Counties in 2004.

Locality	County	Areal distribution (m^2)	Coverage (%)	Remarks
Albæk Mose	RIN	0	0	Extinct?
Sydlig Parallelkanal	RIN	21,000	50–75	Largest pop. in DK
Skjern Å & Enge	RIN	250	5–25	Viable?
Sønderstrøm	RIN	66	25–50	Viable?
Polderne	RIN	1	0–5	Viable?
Nørre Sø	RIN	1	5–25	Declining
Husby Sø, Nord	RIN	315	5–25	Declining
Stadil Fjord	RIN	0	0	Extinct?
Kimmelkær Vandkanal	RIN	932	25–50	Stable pop.
Felsted Kog	RIN	210	25–50	Stable pop.
Falen Å	RIN	3	5–25	Declining/threatened
Vorgod Å	RIN	0	0	Last reg. in 1938
Bolkvig Gård	RIN	0	0	Last reg. in 1993
Troldhede Brunkulsleje	RIN	0	0	Last reg. in 1938
Hemmet Bæk	RIN	0	0	Last reg. in 1965
Fiil Sø	RIB	0	0	Suitable localities
Gødelen	RIB	18,480	-	Good pop, investigated in transects

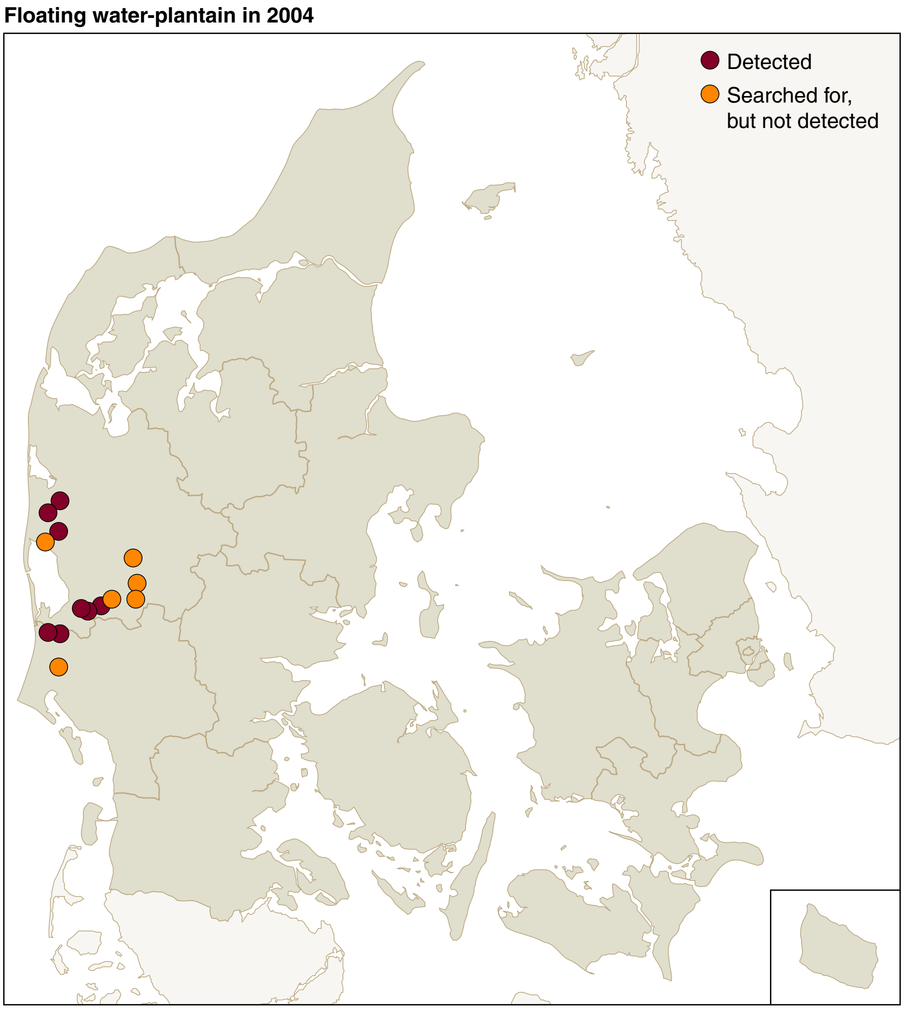
The largest floating water-plantain population in Denmark is found in the southern parallel canal alongside the River Skjern, where coverage is 50–75%. Stable populations are also found in drainage canals at Felsted Polder and Stadil Fjord (Kimmelkær Canal), where coverage is 25–50% in both cases (Table 11.4).

Status assessment

The populations in Lake Husby, Lake Nørre and the River Falen are very small and considered to be on the decline. Time will tell whether the populations in the River Skjern and the polders are viable. It seems that the restoration of the River Skjern has improved conditions for the floating water-plantain in the area. Flooding of the ponds in the riparian areas seems to benefit the floating water-plantain and provide possibilities for the further advance of the species.

In view of the small number of floating water-plantain populations in Denmark there is considered to be a need for active management of both those populations that are on the decline and those populations that are stable and on the advance.

Figure 11.2 Floating water-plantain (*Luronium natans*) detected in 2004.



11.5 Marsh fritillary

The marsh fritillary (*Ephydryas aurinia*) is a butterfly that inhabits humid heaths and unfertilized meadows on poor soil with large amounts of its preferred host plant, devil's-bit scabious.

Relevance

The marsh fritillary used to be widespread in most of the country. The species was last seen outside Jutland in the 1920s and also began to disappear from many localities in Jutland around 1950. In a survey conducted in 2000 the marsh fritillary was found at nine localities in northern Jutland, and it is believed that it may also occur at a further 3–4 localities (*Danish Forest and Nature Agency, 2000*).

Criteria for favourable conservation status

The criteria for favourable conservation status require the existence of one or more viable populations of marsh fritillary in both the Atlantic and Continental regions of Jutland. The number of populations and the range should be on the increase (*Søgaard et al., 2003*).

2004 monitoring results

The occurrence of the marsh fritillary is monitored by recording the adult butterflies and/or larval webs in August–September on the preferred host plant, devil's-bit scabious. Population size is determined by counting larval webs. In addition, various types of habitat information are recorded in May–June, including the occurrence of devil's-bit scabious and flowering herbs (nectar plants).

In 2004, the marsh fritillary was monitored in five counties at a total of 24 localities and was only detected in one county (Table 11.5 and Figure 11.3).

Table 11.5 Monitoring of marsh fritillary (*Euphydryas aurinia*) under NOVANA in 2004.

County	Localities investigated	Localities positive (%)	Remarks
Nordjylland	13	12	Three new localities
Viborg	7	0	Suitable localities
Ringkjøbing	1	0	No devil's-bit scabious
Ribe	2	0	Little devil's-bit scabious
Sønderjylland	1	0	Frøslev Mose

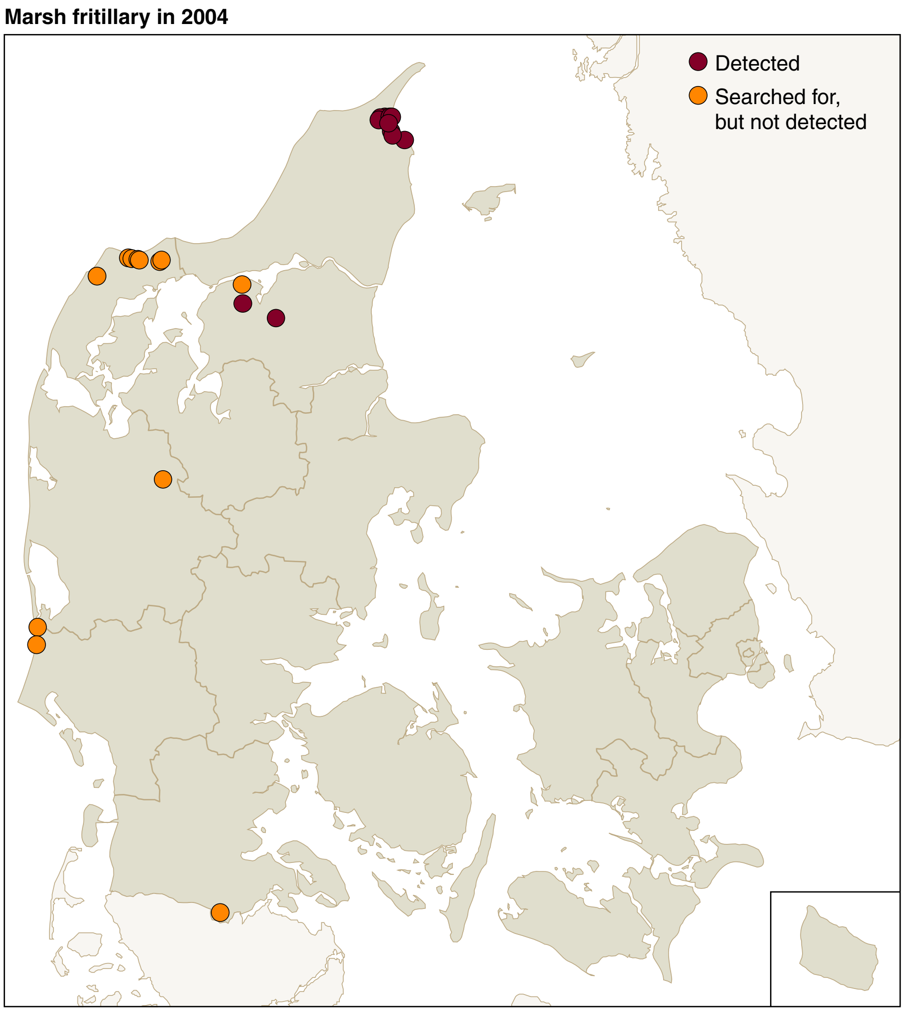


Figure 11.3 Monitoring of the marsh fritillary (*Euphydryas aurinia*) under NOVANA in 2004.

The marsh fritillary was only recorded in Nordjylland County in 2004. Here the species was redetected at nine of the 10 localities where it bred in 2000–2001 and was also detected at three new localities.

Status assessment

The total range of the marsh fritillary in 2004 is estimated to be approx. 150 ha spread over 12 localities. In general, there is no direct correlation between range and population size.

Compared with surveys made in 2000–2001 the marsh fritillary is on the advance at five localities and on the decline at three localities, while it appears to have disappeared at one locality. The host plant devil's-bit scabious was recorded at all the localities except two (Figure 11.3).

The national conservation status of the marsh fritillary is provisionally assessed as being unfavourable due to its limited geographic range.

The populations detected at nearly all localities are so small (under 500 individuals) that they may not be viable unless exchange of individuals takes place between the populations.

11.6 Greylag goose

Relevance

The greylag goose (*Anser anser*) population is monitored twice yearly through international censuses. That the censuses are international entails that the species is counted at all its localities throughout Europe. The census data are used to estimate the size of the greylag goose populations in Europe. These population figures determine how many greylag geese have to be present before an area is considered to be an internationally important greylag goose site and hence qualifies for designation as a Special Protection Area pursuant to the Birds Directive or as a Ramsar site. The latter are sites designated pursuant to the Convention on Wetlands (Ramsar Convention).

Criteria for favourable conservation status

The criteria for favourable conservation status require that the number of greylag geese should be stable or increasing at the national level over a 12-year sliding period. The range should be stable or increasing on the island part of Denmark and in western Jutland.

Censuses in Denmark

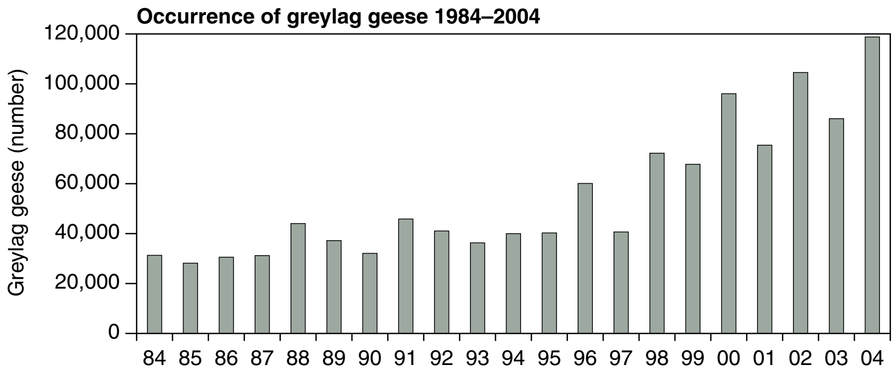
In Denmark, censuses are performed as nationwide censuses and are carried out by a network of volunteers. The censuses are performed in the weekend closest to mid January, when greylag geese are counted together with all other water birds, and in the weekend closest to mid September, when only greylag geese are counted.

All localities at which greylag geese are known to occur are included in the censuses, which are performed as total counts of greylag geese either on the flight path out of their roosting quarters or in their foraging areas. Both the mid winter census and the September census typically cover approx. 150 greylag geese staging areas. The mid winter census of water birds has been carried out in Denmark since 1964, while the September census of greylag geese began in 1984.

2004 monitoring results

The September 2004 census of greylag geese was performed on the weekend of 11–12 September and on the surrounding days. In all, approx. 120,000 greylag geese were counted in the September 2004 census, which is by far the greatest number so far recorded in these censuses (Figure 11.4).

Figure 11.4 Number of greylag geese (*Anser anser*) detected in nationwide censuses in mid September over the period 1984–2004 (from the NERI goose database).



Status assessment

The Danish greylag goose population outside the breeding season fulfils the criteria for favourable conservation status at the national level. The number of greylag geese in Denmark in September increased slowly up to the mid-1990s, whereafter it has increased markedly, tripling over the period 1996–2004. The Danish figures reflect the general increase in the greylag goose population in northwestern Europe. The first population censuses were made in 1967/68, at which time the northwestern European population was estimated to number 30,000 birds. In 2002, the population was estimated to number 400,000 birds (*Delany & Scott, 2002*).

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This report presents the 2004 results of the Danish National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA). 2004 was the first year in which terrestrial nature was included in the monitoring programme. The report reviews the state of the groundwater, watercourses, lakes and marine waters and the pressures upon them and reviews the monitoring of terrestrial natural habitats and selected plants and animals. The report is based on the annual reports prepared for each subprogramme by the Topic Centres. The latter reports are mainly based on data collected and submitted by the regional authorities.

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