Ministry of Environment
and Food of Denmark
Environmental
Protection Agency

Status and trends of the aquatic environment and agricultural practice in Denmark

Report to the European Commission for the period 2012-2015 in accordance with article 10 of the Nitrates Directive (1991/676/EEC)

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1. Introduction

Council Directive 91/676/EEC aims to protect waters against pollution caused or induced by nitrates from agricultural sources.
According to Article 10 in the Nitrates Directive Member States shall, in respect of the four-year period following the notification of this Directive and in respect of each subsequent four-year period, submit a report to the Commission containing the information outlined in the Directives Annex V.

The aim of the present report is to give a status and trend in the aquatic environment and agricultural practice, compared to previous reporting period and as well evaluate the impact of the action programme.

On the basis of the information received pursuant to Article 10, the Commission shall publish summary reports and shall inform the European Parliament and the Council on the state of the implementation of the Nitrates Directive, in accordance with article 11. The summery report will be based on the information submitted by Member States referring to the period 2012-2015 and is accompanied by aggregated maps of nutrient pressures from agricultural sources, of water quality and of designated nitrate vulnerable zones.

2. Summary

Water courses

Long-term time series and statistical trend tests show that there have been significant reductions in both flow-weighted nitrate and total nitrogen concentrations since 1989.

Changes in flow-weighted nitrate concentrations between the previous period (2008-2011) and current period (2012-2015) show that in 28 % of the watercourses, there has been a weak or strong reduction in the flow-weighted annual average NO_3-concentration. Similarly, there has been an increase in 25 % of the watercourses, and in 47 % of the watercourses, the concentrations are unchanged.

In the previous reporting, most monitoring stations had reduced nitrate concentrations compared to the previous period. In the 6th reporting, changes have been smaller and in both directions. This should primarily be seen as random effects.

Lakes

In general, annual average nitrate concentrations in Danish lakes are low, compared to the Nitrates Directive limit of 50 mg/l. Less than 8 % of the lakes had an annual average nitrate concentration above 2 mg/l (18 % above 1 mg/l).

Average winter nitrate concentrations are generally higher than annual mean concentrations (in 83 % of the lakes). But only 9 % of the lakes have an average winter nitrate concentrations above 2 mg/l (24 % above 1 mg/l).

Also maximum nitrate concentrations are far below the 50 mg/l with the highest absolute nitrate concentration measured being 9.2 mg/l.

Despite the nitrate concentrations are influenced by climatic conditions (such as precipitation), there are no changes from the 5th and 6th period. The concentration levels are stable in all monitored lakes.

Estuarine, coastal and marine waters

During the 6th period (2012-2015) the highest average NO_3^- winter concentrations were observed in the estuaries with a maximum average concentration of 6.97 mg NO_3^-/l and with the lowest concentrations monitored in the marine open waters, where the average NO_3^- concentration did not exceed 1.42 mg NO_3^-/l.

Surface water nitrate concentrations in estuarine, coastal and marine open waters are generally much lower than observed in groundwater and fresh water systems. Therefore trends between previous monitoring periods (i.e. 2nd and 5th period) and this 6th period have been estimated by a statistical approach rather than by use of absolute concentrations.

Based on this statistical approach, NO_3^- winter surface concentration remained stable at all 59 monitoring stations from the 5th period (2008-2011) to the 6th period (2012-2015). However, assessed across a 16 years' time span (i.e. from the 2nd period to the 6th period) significant NO_3^- winter concentrations decreases were observed at 16 of 59 stations and with only one station showing a significant increase by 0.22 mg NO_3^-/l in marine open waters, which would - according to the reporting guidelines - be categorized as *stable*.

As was seen in winter concentrations, the annual NO_3^- concentrations were stable at all stations from the 5th period (2008-2011) to the 6th period (2012-2015). However, compared to the 2nd period (1996-1999), the annual NO_3^- concentrations decreased significantly across the 16 years' time span at 28 of 44 stations with 22 stations being estuarine or coastal and 6 stations located in marine open waters.

A decreasing trend in chlorophyll *a* concentration was observed at about 25 – 30 % of all stations monitored in Danish estuarine, coastal and marine open waters between the 5th period and the 6th period. This decreasing trend was even more pronounced in estuarine and coastal waters between the 2nd period (1996-1999) and the 6th period, when significant decreases in

chlorophyll *a* were observed at two thirds of these stations.

Groundwater
The groundwater-monitoring programme is designed to monitor recent groundwater recharged after approx. 1940. Implementation of the Water Framework Directive has required adjustments of the groundwater-monitoring network and thus some monitoring points used for previous reporting period were closed and new were established in the last reporting period. The adjustment of the monitoring network is expected to be finalised in 2016. Of approximately 1.200 monitoring points, approximately 1.000 points are common for the two periods.

When comparing the monitoring points that are common for the two last reporting periods, decreasing groundwater nitrate concentrations can be found in more monitoring points than increasing concentrations. The major part - about 75 % - of the monitoring points has an average nitrate concentration below 40 mg/l. In general, both upward and downward trends are to be found all over the country.

Groundwater from a large number of monitoring points has been dated with CFC (chlorofluorocarbon) and tritium/helium, where possible, indicating an overall deceasing nitrate trend in Danish oxic groundwater during the last almost 30 years, which can be assigned to reduced nitrate leaching from Danish agricultural activities since the 1980ies. Based on the latest national "GRUMO report", we conclude that the overall trend with regard to reducing the groundwater nitrate content is generally positive, but several locations still record increases. This includes some of the most recently created groundwater, which was formed after the water environment action plans came into force. The latest data on the development of nitrate in oxic groundwater and the most recent dating in the groundwater monitoring initiative indicate that the nitrate content in the youngest groundwater remains stable.

Nitrate Vulnerable Zones
Denmark is, according to Article 3 (5), exempt from the obligation to identify specific vulnerable zones, as Denmark has established and applied the action programme throughout the whole national territory.

Code of good practice
Measures according to code of good practice pursuant to the Nitrates Directive, annex II, are included in the Nitrate Action Programme as mandatory measures equivalent to the measures included in the programme pursuant to the directive, annex III. Description of the measures according to code of good practice is therefore included in the description of the Nitrates Action Programme.

Nitrates Action Programme
An overview of the implementation of Annex II and Annex III of the Nitrates Directive as mandatory measures in the Danish Nitrate Action Programme in 2015 is given in chapter 6 of this report. The specific measures are described for each litra in the directive, annex II and annex III and measures according to the directive art. 5 (5), respectively.

The overview of the implementation of the Nitrates Directive as described in the Nitrates Action Programme is given of the legal texts valid by the end of 2015. Changes in the implementation of the directive during the reporting period are described for each element in the overview. In general, it has primarily been technical changes that have been amended to the programme during 2012-2015.

Evaluation of the implementation and impact of the action programmes' measures

The amount of Nitrogen, which has been discharged to the sea in the years 2012 to 2014, was within a similar range as in the previous reporting period. The modelled nitrate leaching was reduced by 43% during the period 1991 to 2003, due to the general improvement in agriculture and fertilisation practices, while it remained at a more stable level in the following years up to 2014, where the nitrate leaching was estimated to be 43 and 81 kg N/ha for loamy and sandy soils, respectively.

From the Agricultural Catchment Monitoring Programme (LOOP), it can generally be concluded that the Nitrate concentrations in root zone soil water have remained almost constant since 2004, approaching the ground water limit of 50 mg nitrate/l, though with yearly variations. Nitrate concentrations in the upper oxic groundwater within LOOP decreased to a level below the limit of 50 mg NO3/l for loamy catchments and to a level between 52 and 65 mg NO3/l for the sandy catchments in the period 2009/10-2013/14.

Fertilizer usage has during the years of the current reporting remained at a relatively low level as in the years before (2007 and onwards), compared to the early 1990's, resulting in an more or less unchanged national surplus

Control and inspection

In 2014, the Danish AgriFish Agency carried out 751 inspections on the spot, regarding the orders mentioned above, corresponding to approx. 1.9 % of all agricultural holdings. In 2014, 445 inspections of fertilizer accounts were carried out. 9.6 % were reported to the police for severe violations of the provisions on rational fertilizer use, which indicates an increase compared to 2010, but can most probably be assigned to a more risk-based selection of farms for control. In 2014, 257 on-site inspections on catch crops were carried out with 3.1 % being reported to the police and 4.7 % receiving an enforcement notice. The vast majority of all Danish farmers (38,550 in 2014) must submit data to the Fertilizer Accounting system each year, which are all automatically checked at submission by the IT-system. During the administrative control of fertilization status accounts from year 2012/2013, a number of farms, corresponding to 0.11 % of all farms exceeded the farm nitrogen quota by up to 9 kg N per hectare and 0.08 % by more than 9 kg N per hectare.

Cost effectiveness

The River Basement Management Plans (RBMP) represent the effort to ensure the required status of the water bodies according to the Water Framework Directive. The first RBMP from 2011 included measures suggested by the so called "Committee for Measures II". The expected costs from 2011 and from the re-estimation in 2012 were included in the last report from 2013. The costs of measures in the RBMPs for the agricultural sector was after the exclusion of targeted catch crops around 9 million € per year. The economic costs of the measures have later been estimated to 13.5 million € per year by the Nature Agency when the national target of 60,000 ha catch crops was included. The costs-efficiency for most of the measures is roughly the same as estimated earlier and the overall cost is expected to be close to the 2014 estimate.

Future Evolution of the water body quality

The efforts in the River Basin Management Plans (RBMPs) for 2015-2021 are focused on reducing the nitrogen loads to coastal waters. Measures to achieve good environmental status in the Danish water bodies are implemented until 2027 and internationally measures against waterborne as well as airborne nitrogen emissions towards 2027 are also implemented.

For ground water, it is presupposed that on a long term basis the new targeted regulation along with the baseline 2021 and the existing general regulation will meet the need of measures for groundwater bodies, as proposed in the river basin management plans 2015-2021.

Regarding lakes, new measures as improved wastewater treatment and constructed wetland/mini-wetlands will reduce the discharges of phosphorus in the catchment areas to lakes.

3. Water quality: assessment and maps

3.1 Surface water: Water courses

Jens Bøgestrand, DCE – Danish Centre for Environment and Energy, Aarhus University

In Denmark, watercourses are dominated by numerous small streams and only very few larger rivers, which still – on a European scale – have relatively short distance between source and outlet. Therefore, Danish streams are generally not liable to eutrophication, and nitrate constitutes a major part of total nitrogen during all seasons.

3.1.1 Presentation of monitoring stations

The maps are based on flow-weighted annual mean concentrations at 111 stream sampling stations representing streams draining both smaller and larger catchments. Only stream sampling stations monitored every year since 1991 have been included except for a few reference stations that are only monitored every third year since 2007. The catchments cover a range of nutrient sources, some of them being only affected by losses from agricultural activities in the catchment, others also by point sources.

3.1.2 Status for nitrate concentrations

Flow-weighted mean nitrate concentrations in streams during the period 2012-2015 are shown on the map in Figure 3.1, and the maximum observed nitrate concentrations in watercourses during the period 2012-2015 are shown in Figure 3.2.

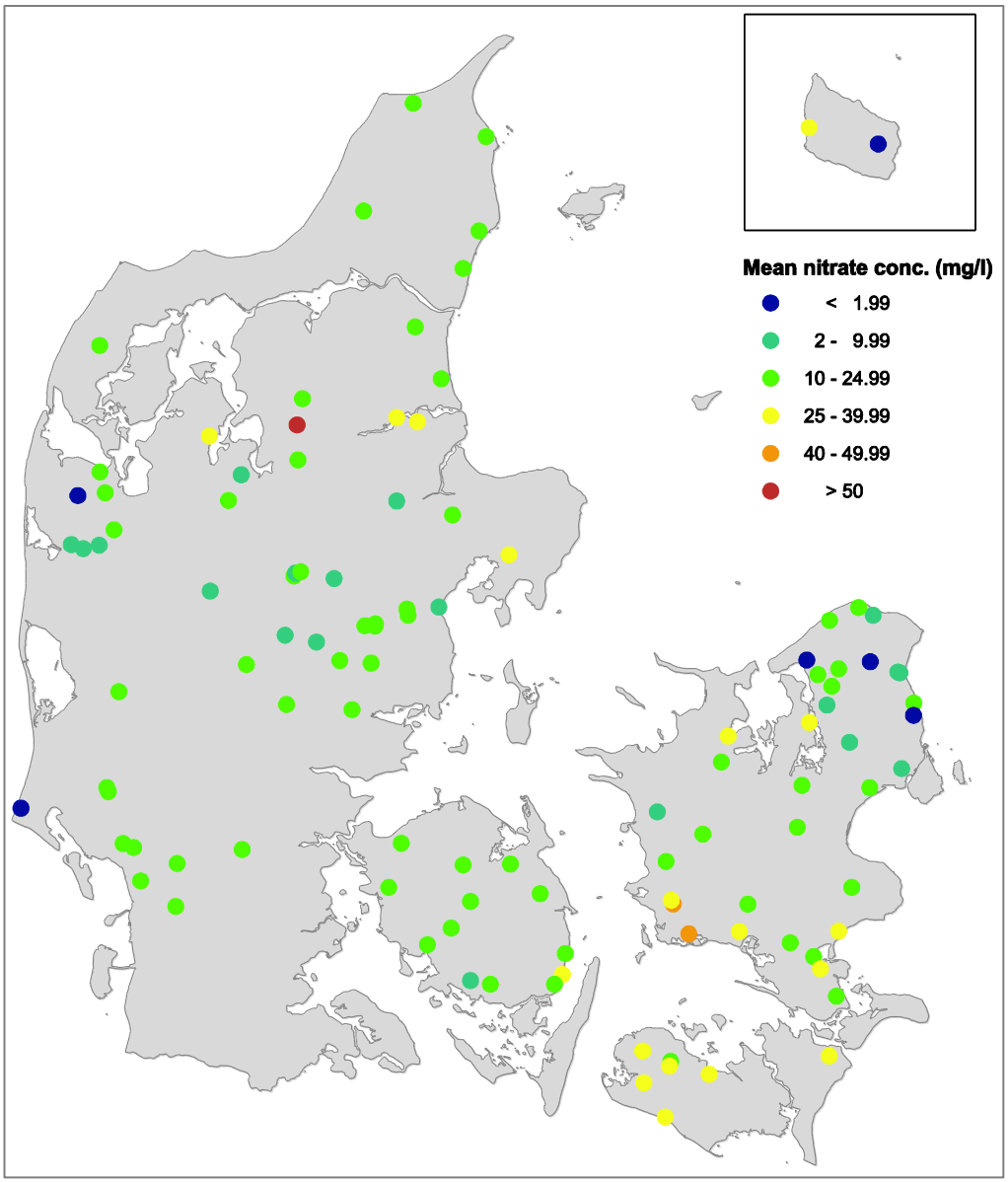

Figure 3.1 Mean NO_3 concentrations in water courses during the current reporting period (2012-2015)

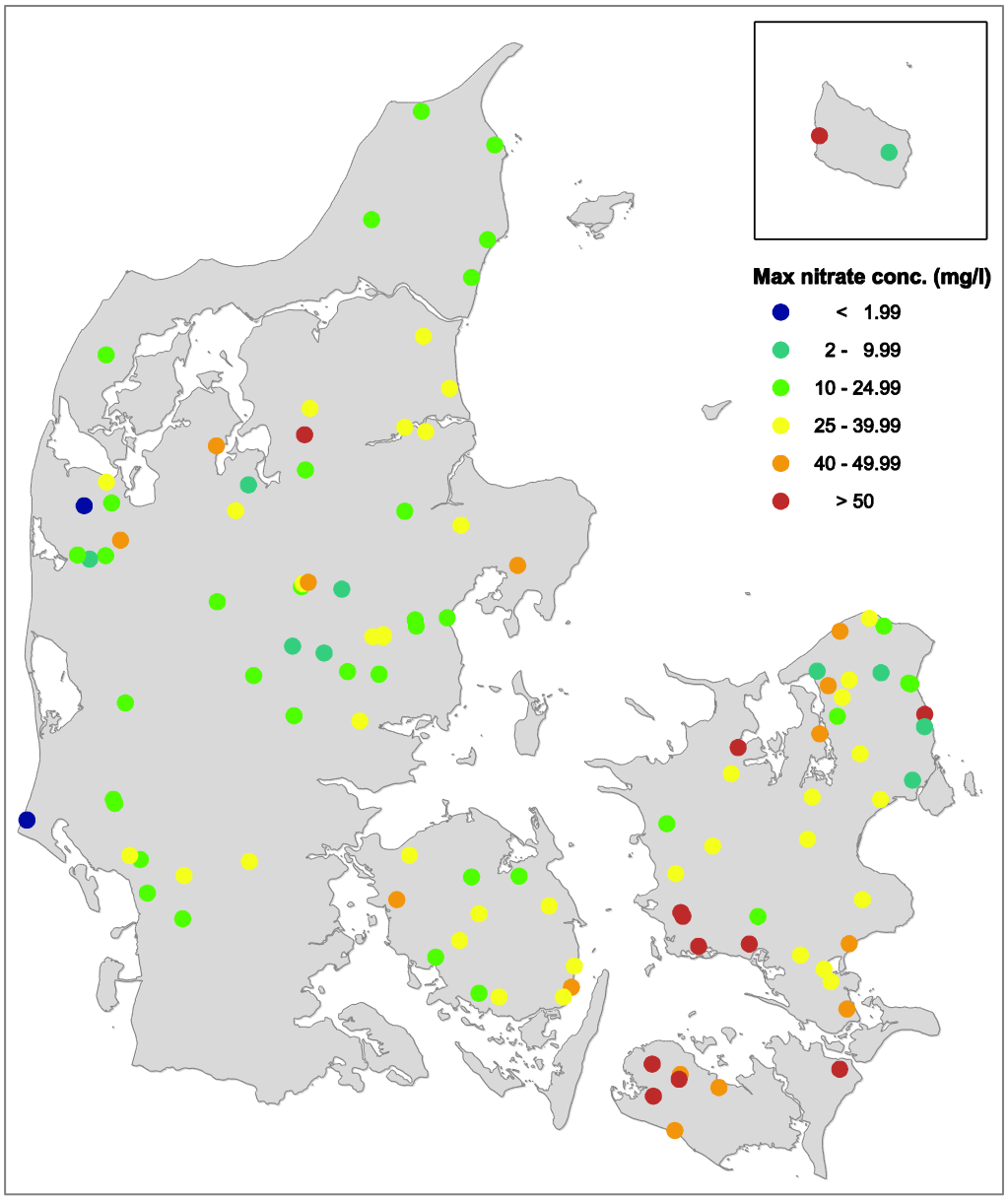

Figure 3.2 Max NO_3 concentrations in water courses during the current reporting period (2012-2015)

3.1.3 Trend in nitrate concentrations

As nitrate concentrations are very dependent on precipitation and run-off, conclusions regarding changes between to specific periods should be drawn with caution. However, the use of flow-weighted annual mean concentrations reduces the climate dependency, but does not completely eliminate it.

In the previous reporting, most monitoring stations had reduced nitrate concentrations compared to the previous period. In the current reporting, changes have been smaller and in both directions. This should primarily be seen as random effects.

Long-term time-series and statistical tests on flow-weighed concentrations show that there have been significant reductions in both nitrate and total nitrogen concentrations since the implementation of the nationwide Danish monitoring programme in 1989. Change in nitrate concentrations between the two periods 2008-2011 and 2012-2015 are shown in Table 3.1.

Table 3.1 Changes in annual average NO_3 concentration in streams from the previous period (2008-2011) to the current period (2012-2015)

Trend	Percentage of water courses
Increasing	
Strongly (>+5 mg/l)	2 %
Weakly (+1 to +5 mg/l)	23 %
Stable	
(±1 mg/l)	47 %
Decreasing	
Weakly (-1 to -5 mg/l)	25 %
Strongly (<-5 mg/l)	3 %

The results on watercourses are based on 111 stream sampling stations representing streams draining both smaller and larger catchments.

Long-term time series and statistical trend tests show that there have been significant reductions in both flow-weighted nitrate and total nitrogen concentrations since 1989.

Changes in flow-weighted nitrate concentrations between the previous period (2008-2011) and current period (2012-2015) show that in 28 % of the watercourses, there has been a weak or strong reduction in the flow-weighted annual average NO_3-concentration. Similarly, there has been an increase in 25 % of the watercourses, and in 47 % of the watercourses, the concentrations are unchanged.

Changes in mean nitrate concentrations in watercourses between the previous and current period (2008-2011 and 2012-2015) are shown in Figure 3.3.

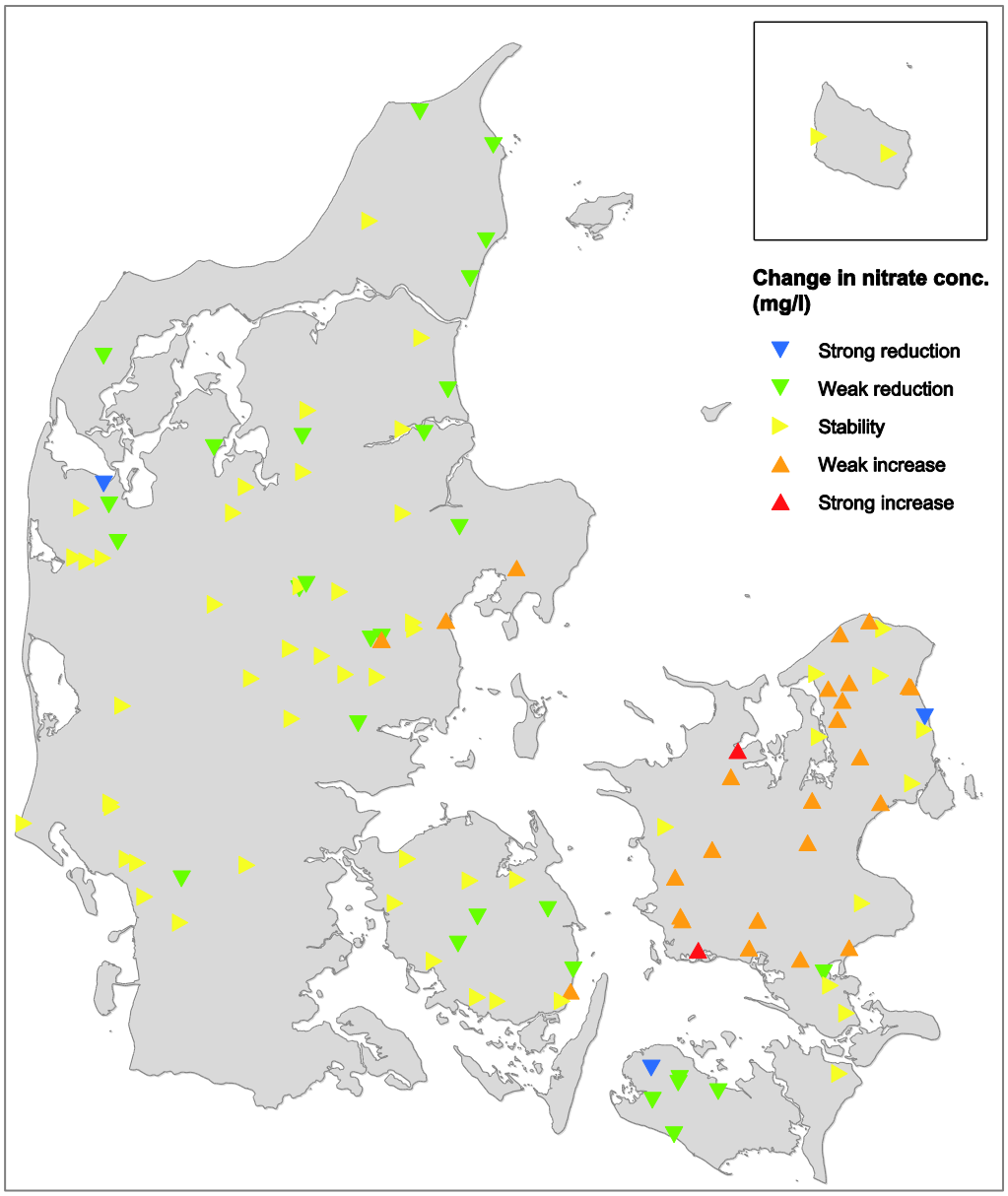

Figure 3.3 Changes in mean nitrate concentration in water courses from the previous to the current period (2008-2011 to 2012-2015)

3.1.4 Indicators for eutrophication in Danish water courses?

Eutrophication caused by excess amounts of nutrients is mainly a problem in lakes and marine waters, and large or slowly flowing rivers. In Danish streams, the residence time is too small for planktonic algae to become a problem. Thus, monitoring of eutrophication indicators such as chlorophyll a concentration is only relevant in lakes, coastal waters and large rivers. Dissolved nutrients may have an effect on benthic algae and macrophytes in streams, but Denmark has not yet established a classification scheme for this kind of nutrient enrichment effects in water-courses.

The main problem with water quality in Danish streams during many years has been pollution with organic matter. Denmark is a country with very short distances from any point on land to the coast. Only very few larger rivers (with a maximum length from source to outlet of approx. 150 km) can be found, while the majority of the area is drained by numerous small streams. Danish streams are generally too small for planktonic algae to become very abundant. Therefore, Denmark has focused its environmental monitoring in streams on organic matter indicators

such as BOD, and there is no monitoring of secchi depth, chlorophyll a or similar eutrophication indicators. Moreover, the Danish monitoring of nutrients in streams is targeted towards the load to nutrient vulnerable surface waters, that is, lakes and coastal waters.

3.2 Surface water: Lakes

Frank Landkildehus, DCE – Danish Centre for Environment and Energy, Aarhus University

3.2.1 Presentation of monitoring stations

Danish lake monitoring stations for the 6th period (2012-2015) are shown in Figure 3.4.

The lakes included are a selection of Danish lakes > 5 hectares with respect to lake area, depth and nutrient levels. Data from the 6th reporting period of the Nitrates Directive (2012-2015) include 66 lakes with analysis of lake water for nitrate concentration and 196 lakes with measurements of Chl *a*.

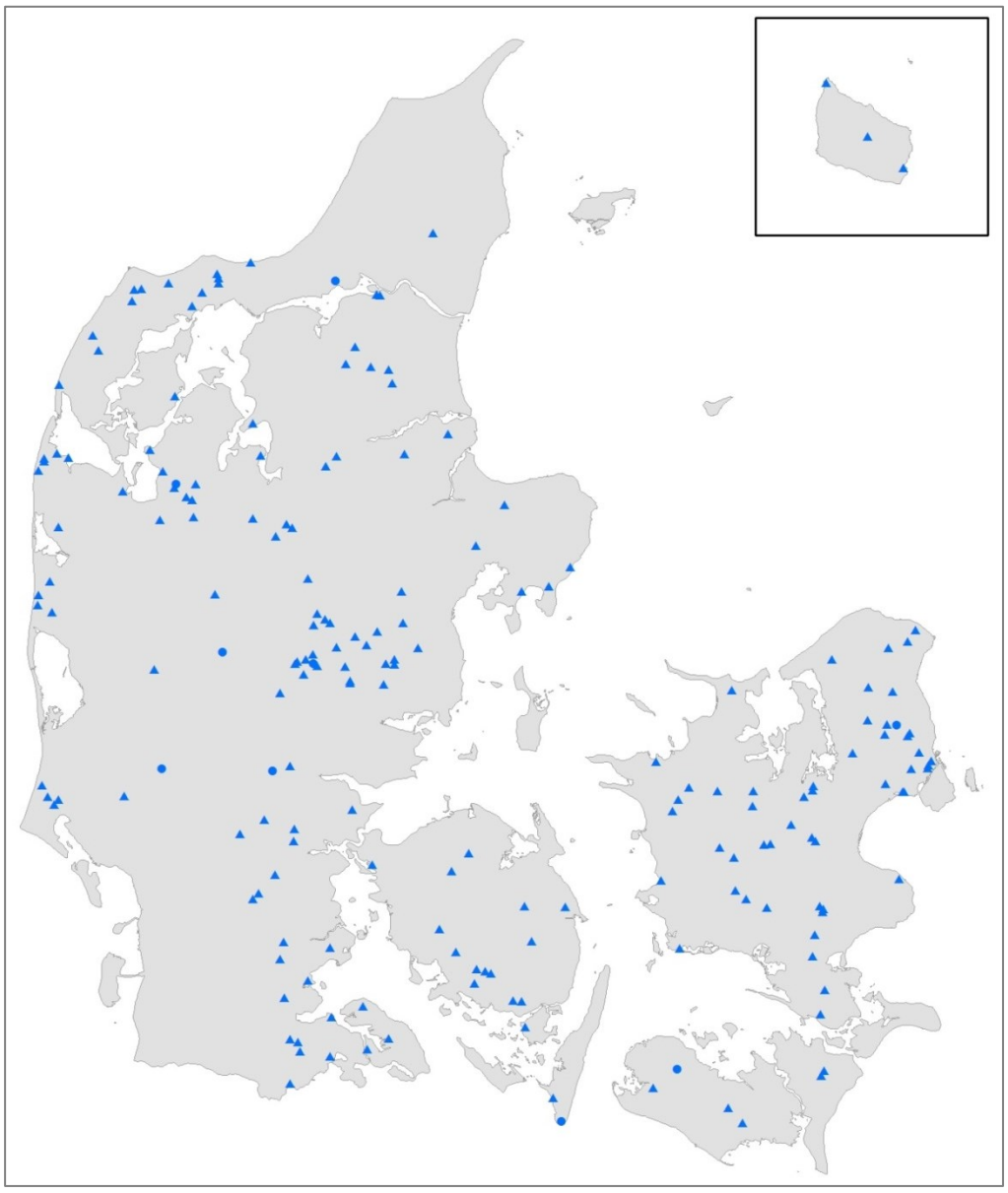

Figure 3.4 The location of 196 Danish lake monitoring stations used to measure the concentrations of nitrate and/or Chlorophyll a in the lake water. Triangles and circles represent 187 lakes monitored in 2012-2015 and the 9 lakes monitored 2012-2014, respectively.

Sampling frequency is 7 samples per year (for one or more years) for 178 lakes, and 19 samples per year for 18 lakes in the period 2012-2014 and only 9 lakes in 2015. Separate calcula-

tions are made for the data from the 9 lakes not measured in 2015, because the 3 years of data not are comparable with the 4 years of data from the majority of the lakes.

The number of lakes monitored for the parameters nitrate and Chlorophyll a respectively during either the 5th, 6th or both reporting periods can be found in Table 3.2.

Table 3.2 Number of lakes monitored in the 5th and 6th monitoring period for nitrate (NO_3) and Chlorophyll a (Chl a) in lake water

Number of lakes	5th period	6th period	Common lakes
NO_3	50	66	27
Chl *a*	200	196	196

For the classification of ecological state of the lakes, a different approach, including a larger number of lakes and parameters has been used in this 6th reporting period, as described in detail in section 3.2.4.1.

3.2.2 Status for nitrate concentrations

Danish nitrate concentrations in the 6th period (2012-2015) in Danish lakes are shown in maps from Figure 3.5 to Figure 3.7. The annual average nitrate concentration can be found in Figure 3.5, the winter average nitrate concentrations in Figure 3.6, as well as the maximum nitrate concentrations in lake water in Figure 3.7.

Average values are based on time-weighted averages to compensate for non-time-equidistant sampling. Summer averages include sampling from May to September (both inclusive) and winter averages include samples from October to February (both inclusive).

In general, annual average nitrate concentrations are low – compared to the Nitrates Directive limit on 50 mg/l - in the 66 monitored Danish lakes (Figure 3.5), which are sampled throughout the whole year. Less than 8 % of the lakes had an annual average nitrate concentration above 2 mg L^{-1} (18 % above 1 mg/l). This is due to low loading/inflow concentrations and efficient removal of nitrate by phytoplankton growth as well as denitrification in deoxygenated areas at the bottom of the lake during summer.

Average winter nitrate concentrations are generally higher (Figure 3.6) than annual mean concentrations (in 83 % of the lakes). But only 9 % of the lakes have an average winter nitrate concentrations above 2 mg/l (24 % above 1 mg/l). This is due to higher loading, low primary production and less denitrification during winter.

Also maximum nitrate concentrations (Figure 3.7) are far below the Nitrates Directives limit with the highest absolute nitrate concentration measured being 9.2 mg/l, whereas the average of the maximum concentration for all monitored lakes is as low as 1.3 mg/l.

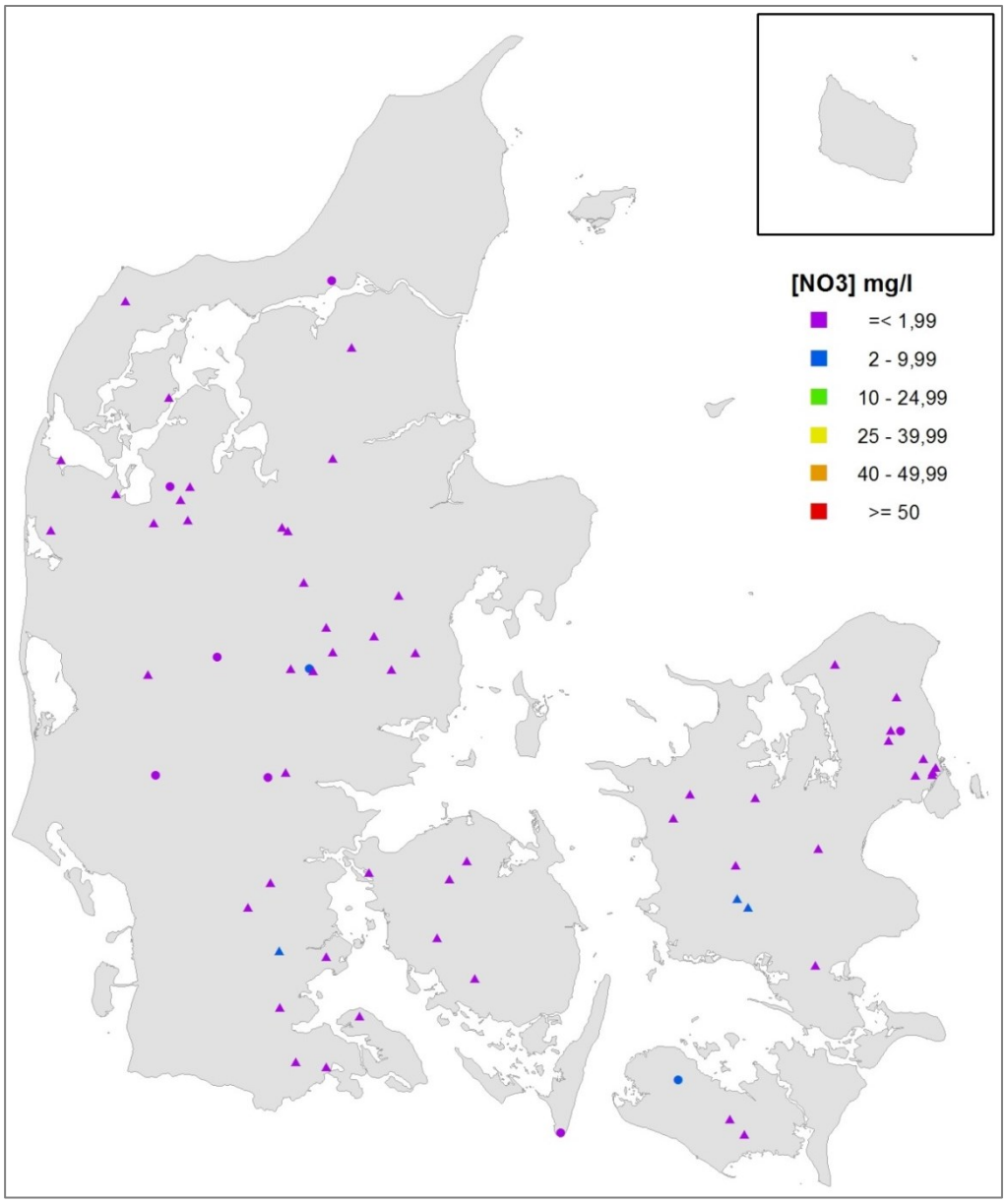

Figure 3.5 Annual average nitrate concentrations in the lake water (mg/l) in the 6th period (2012-2015).
Triangles and circles represent 57 lakes monitored in 2012-2015 and the 9 lakes monitored 2012-2014, respectively

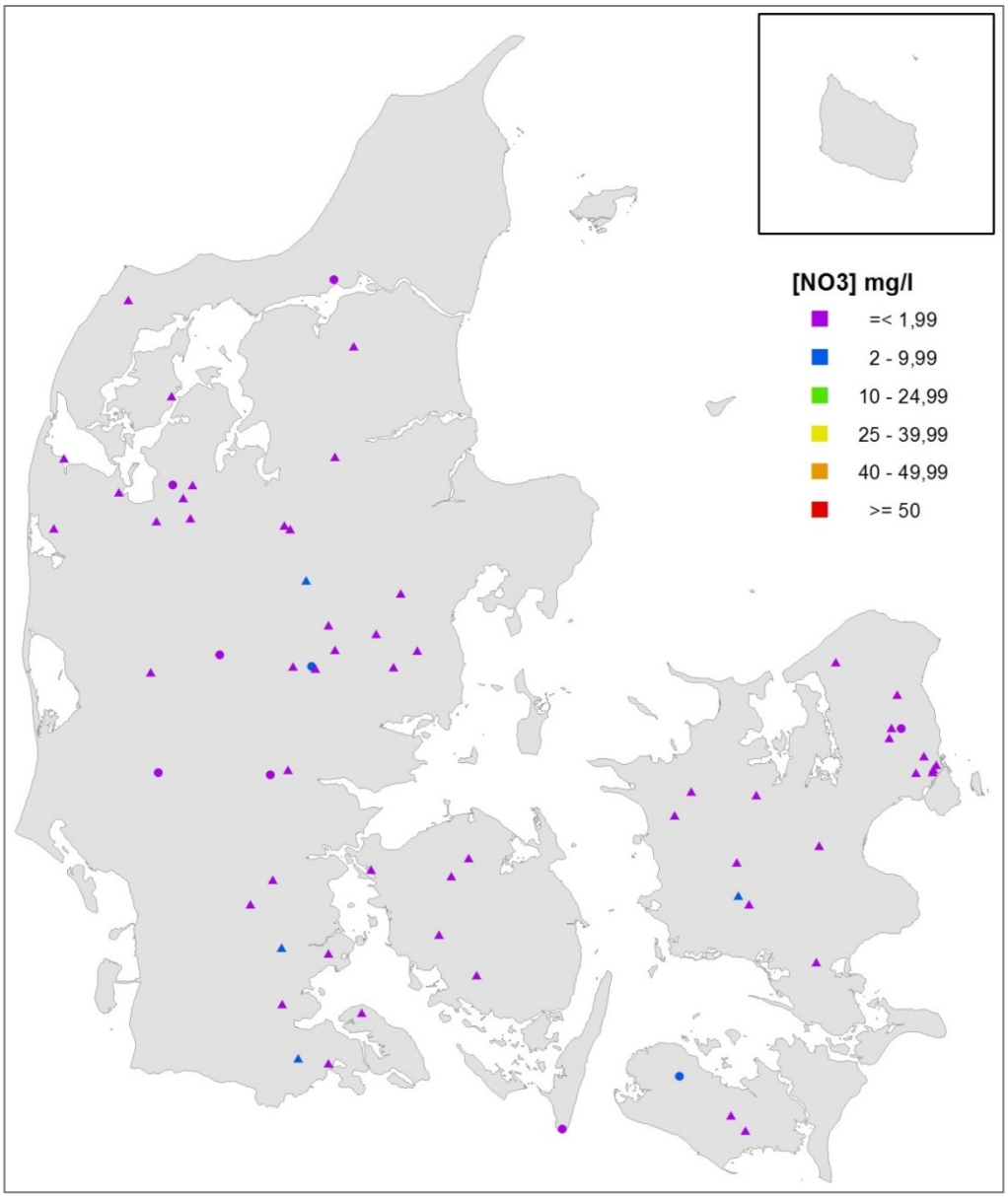

Figure 3.6 Winter average nitrate concentrations in the lake water (mg/l) in 6th period (2012-2015).
Triangles and circles represent 57 lakes monitored in 2012-2015 and the 9 lakes monitored 2012-2014, respectively

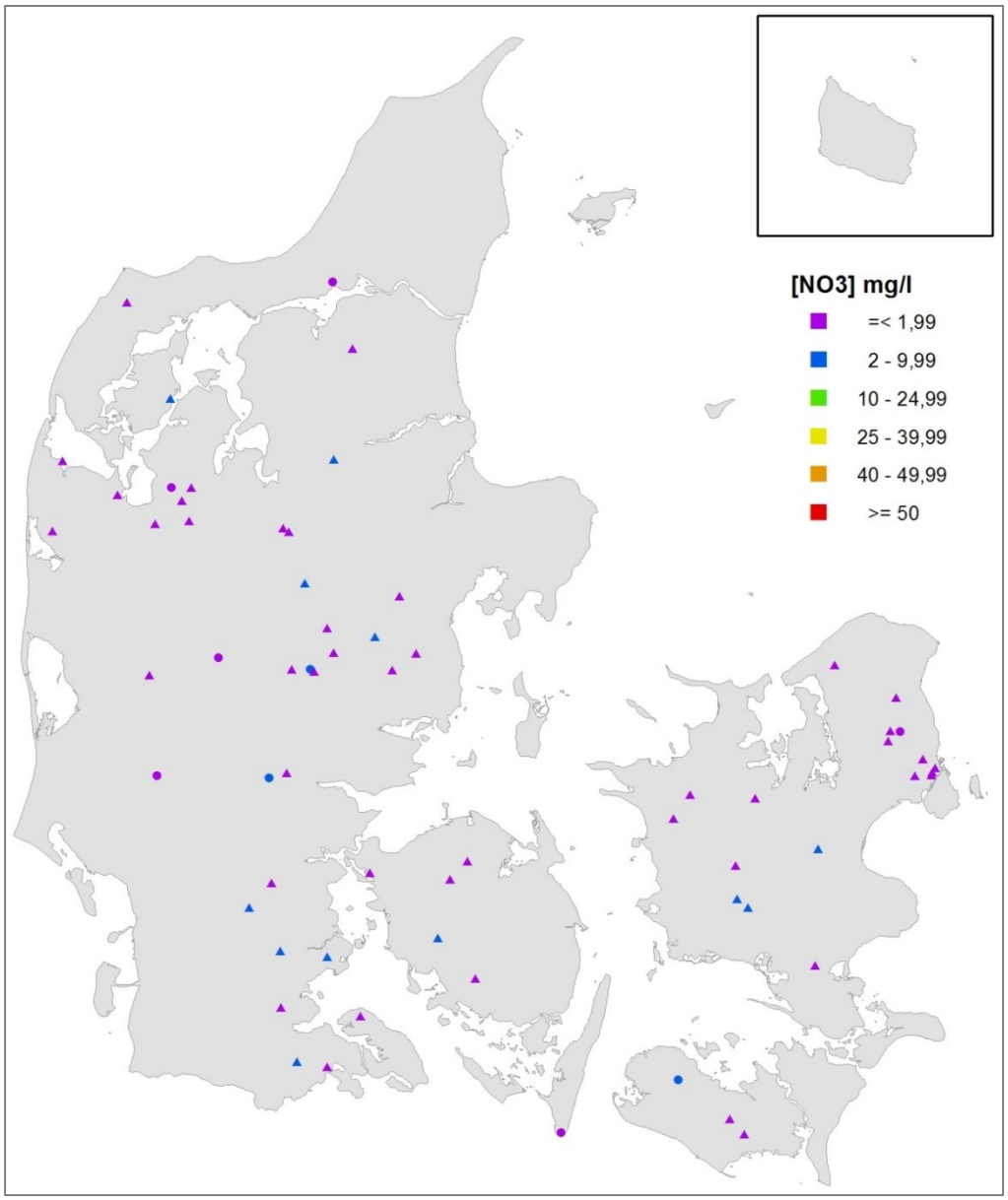

Figure 3.7 Maximum nitrate concentrations in the lake water (mg/l) in the 6th period (2012-2015).
Triangles and circles represent 57 lakes monitored in 2012-2015 and the 9 lakes monitored 2012-2014, respectively

3.2.3 Trend in nitrate concentrations

Table 3.3 and the maps in Figure 3.8 and Figure 3.9 show the development in nitrate concentrations in the lake water in the 27 common monitored lakes between the 5th period (2008-2011) and the 6th period (2012-2015) with respect to annual average and winter average nitrate concentrations, based on the intervals/thresholds given in the reporting guidelines ("Nitrates Directive (91/676/CEE) – 'Status and trends in aquatic environment and agricultural practice - Development guide for Member States' reports").

Despite the nitrate concentrations are influenced by climatic conditions (such as precipitation), there are no changes from the 5th and 6th period. The concentration levels are stable in all monitored lakes.

Table 3.3 Change in annual average and winter average NO_3 concentration in the lake water (mg/l) from 5th to 6th period

Trend	Annual average NO_3		Winter average NO_3	
	Number of lakes	Percentage of lakes (%)	Number of lakes	Percentage of lakes (%)
Increase	0		0	
Stable (± 1mg/l)	27	100	27	100
Decrease	0		0	

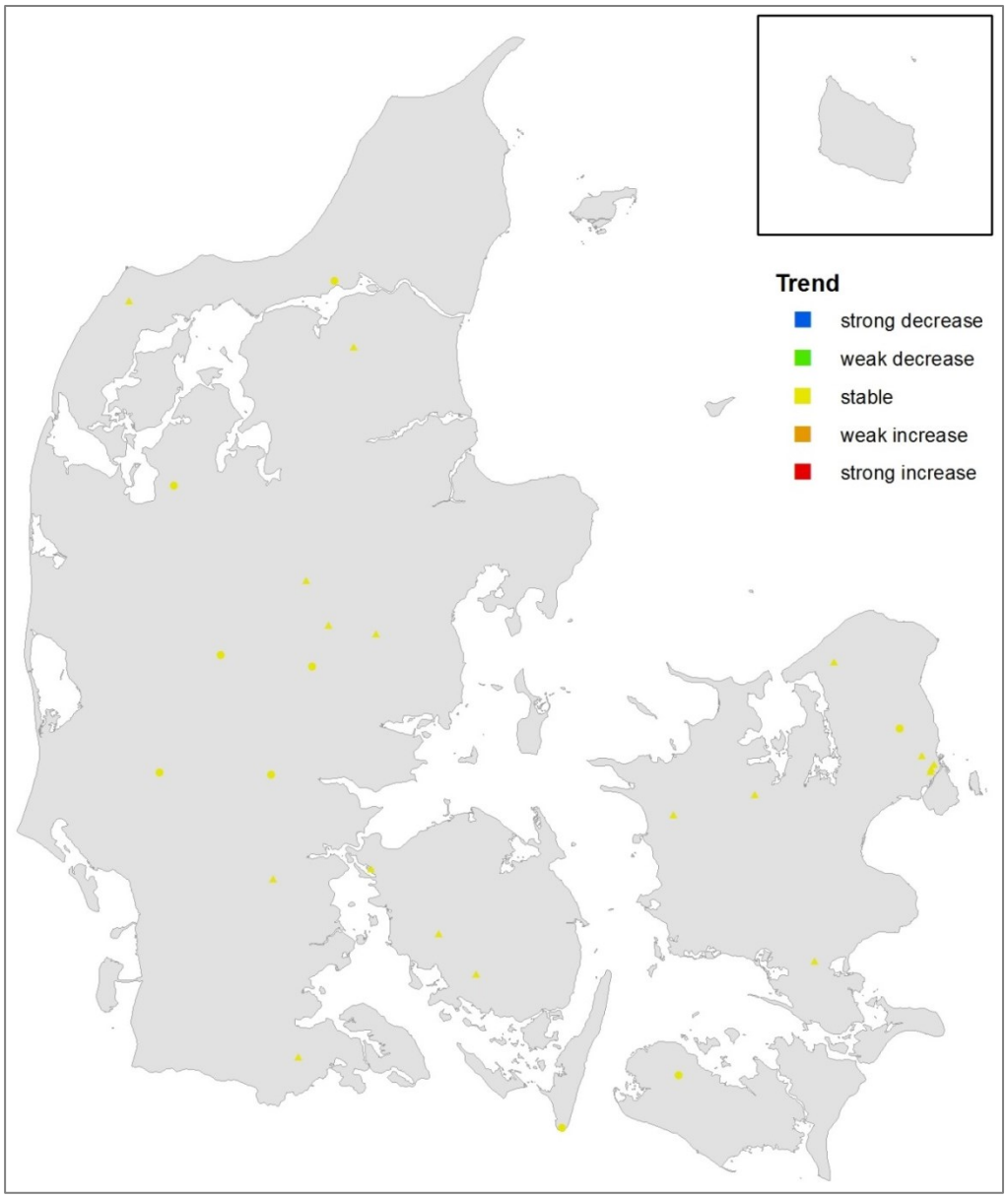

Figure 3.8 Change in annual average nitrate concentration in the lake water (mg/l) from 5th (2008-2011) to the 6th (2012-2015) period. Triangles and circles represent 18 lakes monitored in 2012-2015 and the 9 lakes monitored 2012-2014, respectively

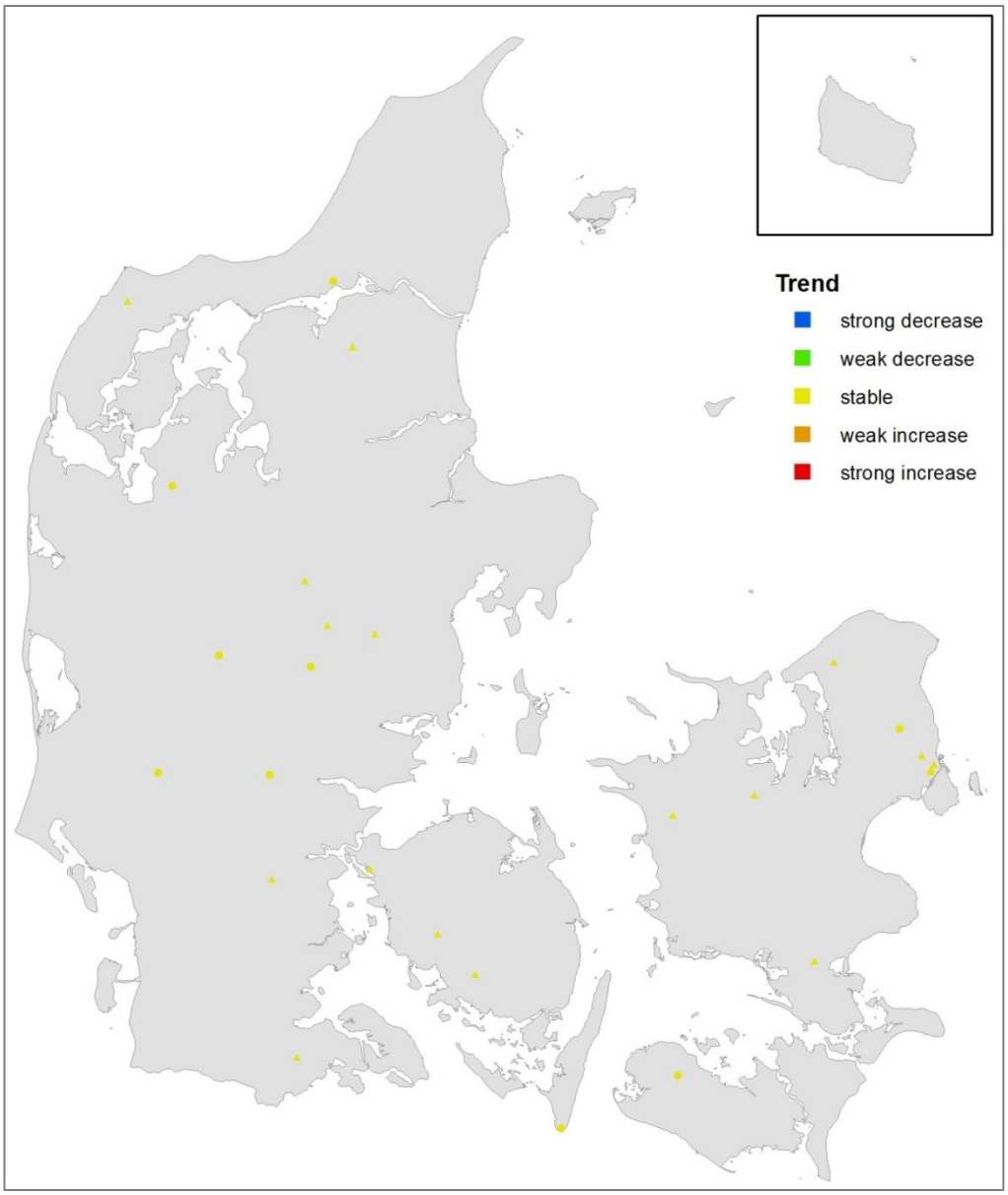

Figure 3.9 Change in winter average nitrate concentration in the lake water (mg/l) from 5th (2008-2011) to the 6th (2012-2015) period. Triangles and circles represent 18 lakes monitored in 2012-2015 and the 9 lakes monitored 2012-2014, respectively

3.2.4 Eutrophication status and trend

Danish Nature Agency, Ministry of Environment and Food of Denmark

3.2.4.1 Data used for the classification of the ecological state of lakes

The classification of the ecological state of the 662[1] lakes from the second river basin management plan (RBMP) is based on monitoring data for the quality elements chlorophyll a[2], phytoplankton[3], macrophytes[4] and fish[5] sampled during the period 2007-2013 (chlorophyll) or 2008-2013 (phytoplankton, machropytes and fish). If there are no data from these periods, data dating back until 2001 (chlorophyll and phytoplankton) or 2004 (macrophytes and fish) may have been used in the classification of the ecological state of a lake.

Lakes missing one or more quality elements (phytoplankton, macrophytes or fish) are downgraded from high/good to moderate ecological state, if summer mean nutrient levels exceed 0,080 mg P/l and 0,95 mg N/l (shallow lakes) or 0,042 mg P/l and 0,90 mg N/l (deep lakes)

The lakes included are a representative selection of the total Danish lakes with respect to lake area, depth and nutrient levels. Data include 510 lakes with measurements of chlorophyll a, 123 lakes of measurement of phytoplankton, 393 lakes of measurements of macrophytes and 189 lakes with measurements of fish fauna.

3.2.4.2 Development in ecological state

The development in ecological state of the lakes is based on a comparison of the ecological state of the lakes monitored in both the first (2009-2015) and the second (2015-2021) river basin management plan.

The classification of the ecological state of the lakes monitored in the first RBMP is based on monitoring data for chlorophyll a from the period 2005-2010. If there are no data from the period 2008-2010, the ecological state of the lakes is based on data from 2002-2007.The classification of the ecological state of the lakes monitored in the second RBMP is described in section 3.2.4.1. The classification of ecological state of the monitoring lakes in connection with the latest RBMP can be found in Table 3.4

Table 3.4 Distribution of the 662 monitoring lakes in the second river basin management plan with respect to ecological state

Ecological state	High/good	Moderate/bad/poor
Low alkaline lakes	31	47
Shallow alkaline lakes	107	372
Deep alkaline lakes	26	79
Percentage of total lakes	**25**	**75**

[1] Lakes established for the purpose of nutrient retention or lakes with less stringent environmental objectives are not included.

[2] Chlorophyll a is only used as an element for the classification of ecological status of a lake, when there exists no measurements of the quality element phytoplankton

[3] Phytoplankton can only be included as a quality element in the classification of the ecological state in lakes of the Danish typology 1, 5, 9, 10 and 11.

[4] Macrophytes can only be included as a quality element in the classification of the ecological state in lakes of the Danish typology 1, 5, 9 and 10.

[5] Fish can only be included as a quality element in the classification of the ecological state in lakes of the Danish typology 9, 10 and 13.

If a similar approach as in the previous reporting periods, i.e. classifying eutrophication status in Danish lakes based on thresholds for chlorophyll a concentration, had been used again, the distribution of all (196, see Table 3.2) lakes into the state classes, would have shown a comparable distribution as in the 5th reporting period with 35.2 % being categorized as "high/good" and 64.8 % as "moderate/bad/poor", respectively. This assessment (performed by DCE, Aarhus University) illustrates the overall stability of the eutrophication status of the Danish lakes, when comparing the data from the 5th and 6th reporting period.

The development in ecological state in the lakes, monitored in both the first and second RBMP is shown in Table 3.5

Table 3.5 Development in ecological state in the 552 lakes monitored in both the first river basin management plan and the second river basin management plan

Trend in ecological state		Number of lakes	Percentage of lakes
Increase	Moderate/bad/poor → High/good	20	4
Stable		454	82
Decrease	High/good → moderate/bad/poor	78	14

The apparent general deterioration of the lakes from the first river basin management plan to the second river basin management plan can mainly be explained by the fact, that inclusion of up to three quality elements (chlorophyll a/phytoplankton, macrophytes and fish) in the classification of the ecological state of lakes in the second river basin management plan compared to the inclusion of only one quality element (chlorophyll a) in the classification of the ecological state of lakes in the first river basin management plan, makes it more difficult for the lakes in the second river basin management plan to be classified as having a high/good state, because of the "one-out, all out" principle.

3.3 Surface water: Estuarine, coastal and marine waters

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3.3.1 Presentation of monitoring stations

The presented nitrate (NO_3^-) and chlorophyll a concentrations, status and trends are based on data from the same 59 stations (in total) monitored every year in Danish estuarine, coastal and marine open waters during the reporting period 1996 – 2015 (Figure 3.10).

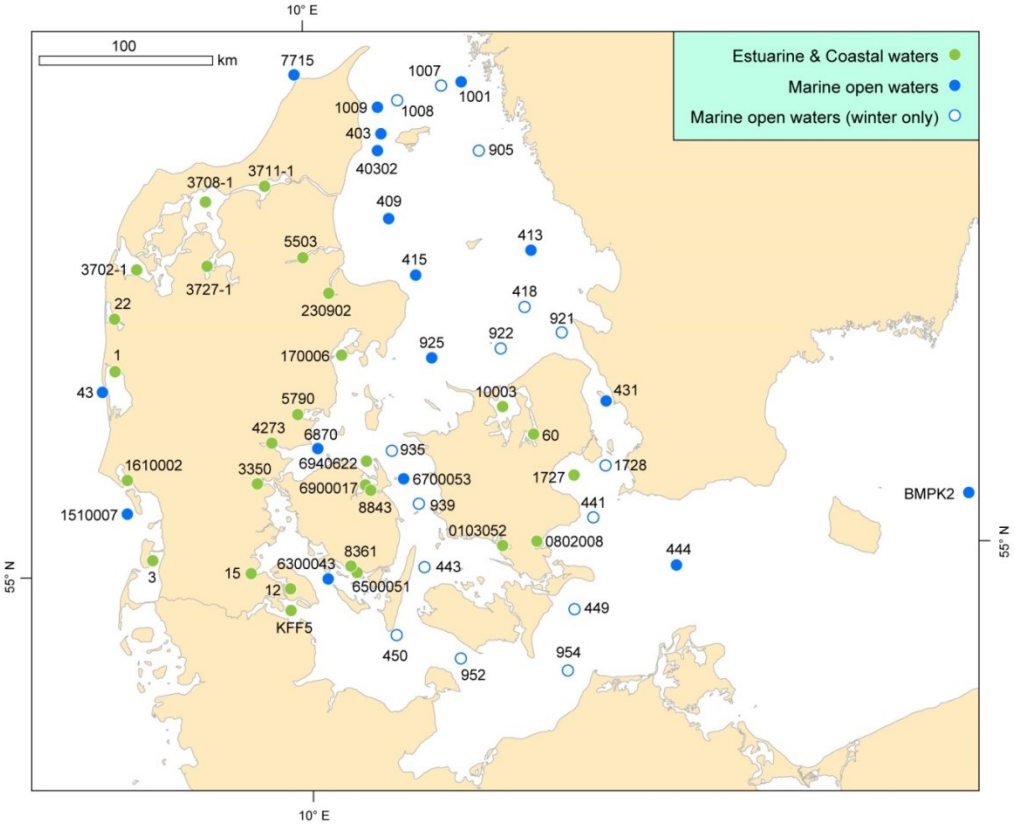

Figure 3.10 Stations with NO_3^- concentrations being monitored every year during the reporting period 1996 – 2015 comprising 27 estuarine and coastal stations, 15 marine open water stations with both winter and summer monitoring, and 17 marine open water stations with winter monitoring only.
Stations where chlorophyll *a* is monitored are shown in Figure 3.18.

However, from the 2nd period (1996-1999) until today, i.e. the 6th period (2012-2015), the total number of monitoring stations has been reduced by 84 stations and the annual monitoring frequency on many stations has also been reduced.

In estuarine and coastal waters the number of monitoring stations has decreased by 29 from 56 to 27 stations (Table 3.6), whereas 55 marine open water stations were abolished from the 2nd to the 6th period (Table 3.7), mainly because of a stop in North Sea/Skagerrak monitoring between the 4th and 5th period, when 48 stations were abandoned (this monitoring is reintroduced from 2015/16 at 20 stations, see below).

Table 3.6 Monitoring points (i.e. number of stations) for Danish estuaries and coastal waters

Number of monitoring points	2nd period 1996-1999	3rd period 2000-2003	4th period 2004-2007	5th period 2008-2011	**6th period 2012-2015**	**Common points 5th and 6th period**
Winter NO_3	56	54	51	36	27	27
Annual NO_3	56	54	51	36	27	27
Summer chlorophyll	55	56	48	36	27	27

Table 3.7 Monitoring points (i.e. number of stations) for Danish marine open waters

Number of monitoring points	2nd period 1996-1999	3rd period 2000-2003	4th period 2004-2007	5th period 2008-2011	**6th period 2012-2015**	**Common points 5th and 6th period**
Winter NO_3	87	87	82	34	32	32
Annual NO_3	87	87	82	34	17	17
Summer chlorophyll	84	81	37	34	31	31

Additionally, at 15 marine open water stations, the NO_3^- concentration was not measured in the summer months (i.e. between April – September) during the 6th period allowing only 17 stations to be included in the calculated average annual NO_3^- concentration opposite to 87 stations in the 2nd period, i.e. a reduction in station number by 80% (Table 3.7).

The estuarine and coastal water monitoring stations abolished since the 2nd reporting period have been carefully singled out to secure an adequate, though less dense, coverage of Danish estuarine and coastal waters. Thus the reported data are still expected to be sufficient to give a true and fair view of nitrate and chlorophyll a concentrations in estuarine and coastal waters. The same counts for Danish marine open water with the exceptions of (1) the North Sea where no monitoring was conducted during the 5th and 6th period and (2) eastern Kattegat, the Belt Sea, and southern Baltic Sea, where summer concentrations of nitrate were not monitored during the 6th period and thus preclude calculation of a sufficient coverage of annual average NO_3^- concentrations in these water bodies. However, monitoring of the North Sea was reintroduced in 2015/16 along with the implementation of the Marine Strategy Framework Directive and will continue in the new monitoring program for 2017-21, presently being worked out (20 stations).

3.3.2 Status for nitrate concentrations

During the 6th period (2012-2015) the highest average NO_3^- winter (October – March) surface (0-10 m) concentrations were observed in the estuaries with a maximum average concentration of 6.97 mg NO_3^-/l (± 2.56 mg NO_3^-/l standard deviation) at Station 22 and with the lowest concentrations monitored in the marine open waters (i.e. Kattegat, the Belt Sea, and Arkona Basin) (Figure 3.11) where the average NO_3^- concentration did not exceed 1.42 mg NO_3^-/l. The NO_3^- concentration decreased during the summer half at all stations (data not shown), thus lower annual average concentrations (Figure 3.12) was seen for the 6th period compared to the winter concentrations of the same period. Because the highest NO_3^- concentrations were observed during the winter there was a certain similarity between Figure 3.11 and Figure 3.13, the latter showing the highest NO_3^- concentration measured at each station during the 6th period, e.g. Station 8361 where the annual average was 2.65 ± 4.87 mg NO_3^-/l, covering a concentration range from 0.003 to 23.03 mg NO_3^-/l.

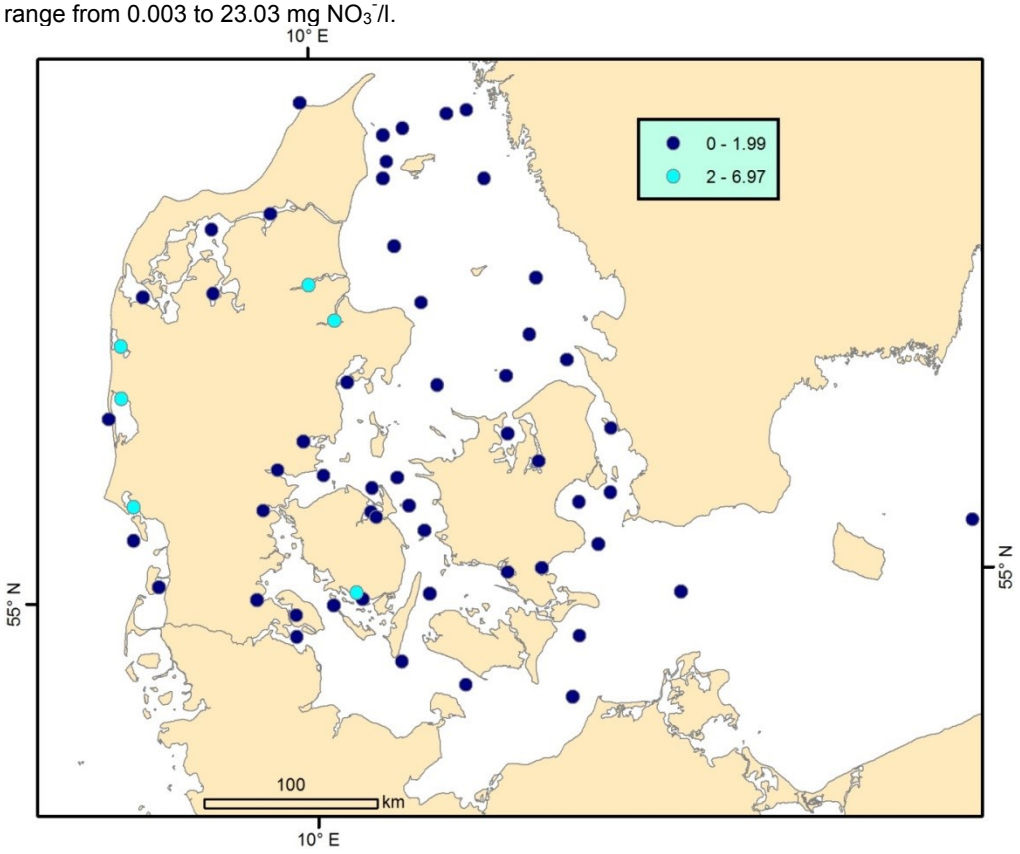

Figure 3.11 Average surface (0-10 m) winter (October – March) NO_3^- concentrations in mg NO_3^-/l for the 6th monitoring period (2012 – 2015) at 59 stations in Danish estuarine, coastal and marine open waters. The average concentration is expressed at each station as a simple mean, i.e. $\frac{1}{n}\sum_{i=1}^{n}\left[NO_3^-\right]$. Note that all average NO_3^- concentrations are <7 mg NO_3^-/l and therefore shown in the blue colour range, subdivided into 2 classes showing oligotrophic and mesotrophic conditions in accordance with the reporting guidelines. The boundary between the two classes is 2 mg NO_3^-/l. The highest value shown in the legend corresponds to the highest concentration on the map.

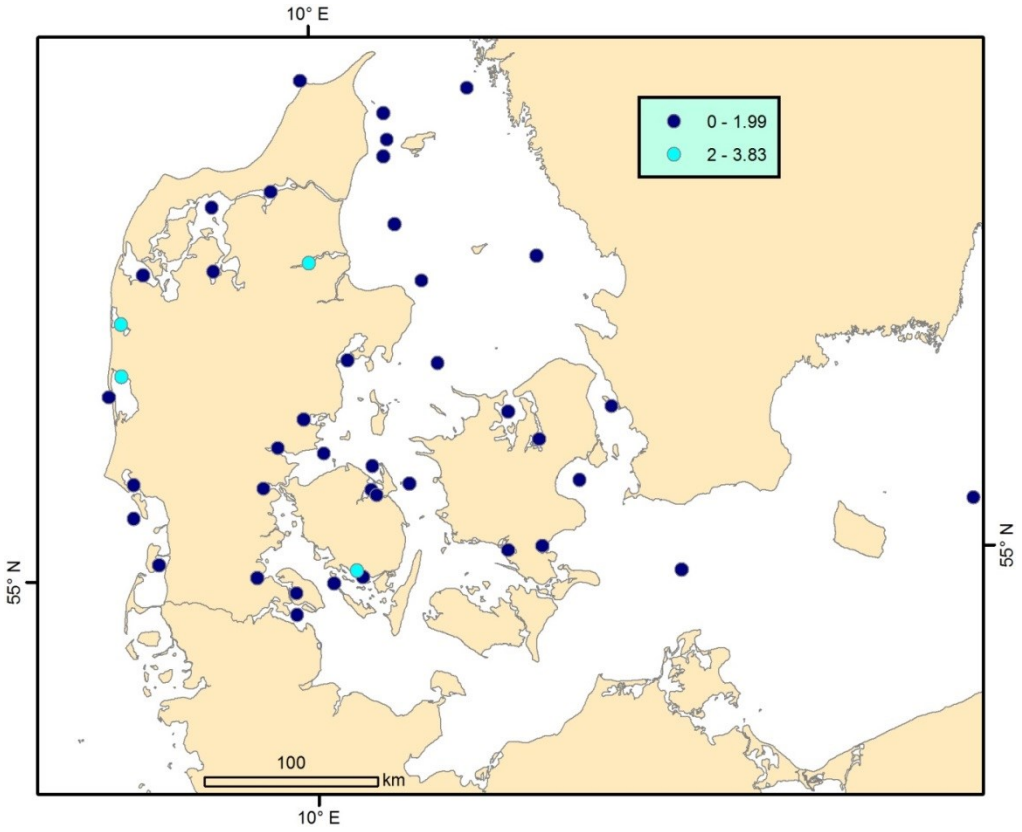

Figure 3.12 Average surface (0-10 m) annual NO_3^- concentrations in mg NO_3^-/l for the 6th monitoring period (2012 – 2015) at 44 stations in Danish estuarine, coastal and marine open waters. The average concentration is expressed at each station as a simple mean i.e. $\frac{1}{n}\sum_{i=1}^{n}\left[NO_3^-\right]$. Note that all average NO_3^- concentrations are <4 mg NO_3^-/l and therefore shown in the blue colour range subdivided into 2 classes showing oligotrophic and mesotrophic conditions in accordance with the reporting guidelines. The boundary between the two classes is 2 mg NO_3^-/l. The highest value shown in the legend corresponds to the highest concentration on the map.

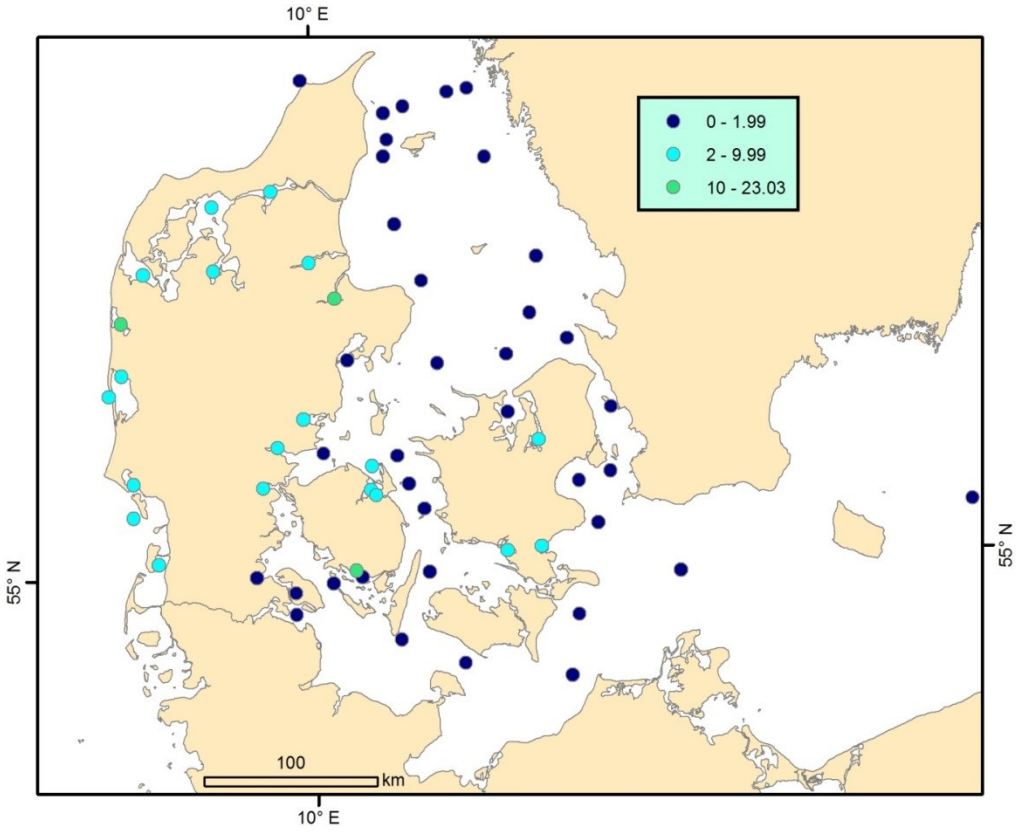

Figure 3.13 Maximum surface (0-10 m) NO_3^- concentrations in mg NO_3^-/l for the 6th monitoring period (2012 – 2015) at 58 stations in Danish estuarine, coastal and marine open waters. Nitrate concentrations <10 mg NO_3^-/l are shown in the blue colour range subdivided into 2 classes showing oligotrophic and mesotrophic conditions in accordance with the reporting guidelines. The boundary between these two classes is 2 mg NO_3^-/l. Stations with maximum NO_3^- concentrations in the range from 10 to 24.99 NO_3^-/l are shown in green (i.e. the eutrophic class). The highest value shown in the legend corresponds to the highest concentration on the map.

3.3.3 Trend in nitrate concentrations

Surface water nitrate concentrations in estuarine, coastal and marine open waters are generally much lower than observed in groundwater and fresh water systems. Therefore trends between previous monitoring periods (i.e. 2nd and 5th period) and this 6th period have been estimated by a statistical approach rather than by use of absolute concentrations changes as such changes must be relatively large in a marine context (i.e. >± 1 mg NO_3^-/l) before even a weak in- or decrease is acknowledged.

Hence our statistical approach tested, whether the average concentrations for two periods were significantly different. Since the distributions of nutrient and chlorophyll *a* concentrations are right-skewed and their variation scales with the mean (Riemann et al. 2015), the test was performed using log-transformed values. Where the p-value for the difference in means of log-transformed concentration was greater than 0.05 then '*no trend*' was reported. If the p-value was less than 0.05, the trend was considered '*significant*' and if less than 0.01, '*very significant*'. Whilst the significance of trends in concentrations are tested using log-transformed data, the absolute and percentage changes in average values reported in Table 3.8 to Table 3.11 are based on the averages of untransformed data, as required by the reporting guidelines.

Table 3.8 Trends in average surface (0-10 m) winter (October – March) NO_3^- concentrations in Danish estuaries and coastal waters. Percentage of points (i.e. stations) with increasing, stable or decreasing average concentrations of nitrate at 27 stations, i.e. one station ~3.7% (Figure 3.14 and Figure 3.16), based on statistical significance. In brackets: Maximum absolute concentration changes (mg/l) and relative (%), digit sign shows increasing (+) or decreasing (-) value. Footnotes refer to station numbers (see Figure 3.10)

Trend	Significance	5th period to 6th period 2008-2011 to 2012-2015		2nd period to 6th period 1996-1999 to 2012-2015	
Increasing	**strongly** (p<0.01)	0%		0%	
	weakly (p<0.05)	0%		0%	
Stable	(p>0.05)	100%	(-0.50 mg/l; -25.6%)[1]	52%	(-0.98 mg/l; -56.7%)[2]
Decreasing	**weakly** (p<0.05)	0%		15%	(-1.07 mg/l; -42.5%)[3]
	strongly (p<0.01)	0%		33%	(-3.26 mg/l; -35.3%)[4]

[1]St. 3350, [2]St. 0103052, [3]St. 3350, [4]St. 230902

Table 3.9 Trends in average surface (0-10 m) winter (October – March) NO_3^- concentrations in Danish marine open waters. Percentage of points (i.e. stations) with increasing, stable or decreasing average concentrations of nitrate at 32 stations i.e. one station ~3.1% (Fig. 5 and 7), based on statistical significance In brackets: Maximum absolute concentration changes (mg/l) and relative (%), digit sign shows increasing (+) or decreasing (-) value. Footnotes refer to station numbers (see Figure 3.10).

Trend	Significance	5th period to 6th period 2008-2011 to 2012-2015		2nd period to 6th period 1996-1999 to 2012-2015	
Increasing	**strongly** (p<0.01)	0%		0%	
	weakly (p<0.05)	0%		3%	(+0,22 mg/l; +174%)[2]
Stable	(p>0.05)	100%	(-0.21mg/l; -50.7%)[1]	88%	(-0.27 mg/l; -16.2%)[3]
Decreasing	**weakly** (p<0.05)	0%		0%	
	strongly (p<0.01)	0%		9%	(-0.11 mg/l; -29.2%)[4]

[1]St. 403, [2]St. 921, [3]St. 1510007, [4]St. 6870

Based on the statistical approach, NO_3^- winter surface concentration remained stable at all 59 monitoring stations from the 5th period (2008-2011) to the 6th period (2012-2015) (Figure 3.14, Table 3.8, Table 3.9). However, assessed across a 16 years' time span (i.e. from the 2nd period to the 6th period) significant NO_3^- winter concentrations decreases were observed at 16 of 59 stations (Figure 3.15) and with only one station (Station 921, marine open waters) showing a significant increase by 0.22 mg NO_3^-/l (from 0.12 ± 0.15 to 0.34 ± 0.08 mg NO_3^-/l) (Table 3.9), which would - according to the reporting guidelines - be categorized as *stable*. Of the 16 stations with significant decreases in winter NO_3^- concentration, 13 stations were estuarine or coastal, with the most significant NO_3^- concentration decrease being observed at Station 230902, where the winter NO_3^- concentration decreased by 3.26 mg NO_3^-/l (from 9.24 ± 3.99 to 5.98 ± 2.69 mg NO_3^-/l) (Table 3.8).

As was seen in winter concentrations, the annual NO_3^- concentrations were stable at all stations from the 5th period (2008-2011) to the 6th period (2012-2015) (Figure 3.16). However, compared to the 2nd period (1996-1999), the annual NO_3^- concentrations decreased significantly across the 16 years' time span at 28 of 44 stations with 22 stations being estuarine or coastal and 6 stations located in marine open waters (Figure 3.17). In other words, the number of stations in Danish waters with significant decreasing NO_3^- concentrations does increase from 16 to 28 stations from the 2nd to the 6th period when trends are calculated from annual values rather that winter concentrations. However, because Station 921 was included in the 15 marine open water stations that were not monitored during summer of the 6th reporting period, it is not possible to

validate whether the significant increase in winter NO_3^- concentration at Station 921 (Figure 3.15) would have been confirmed also from an annual approach.

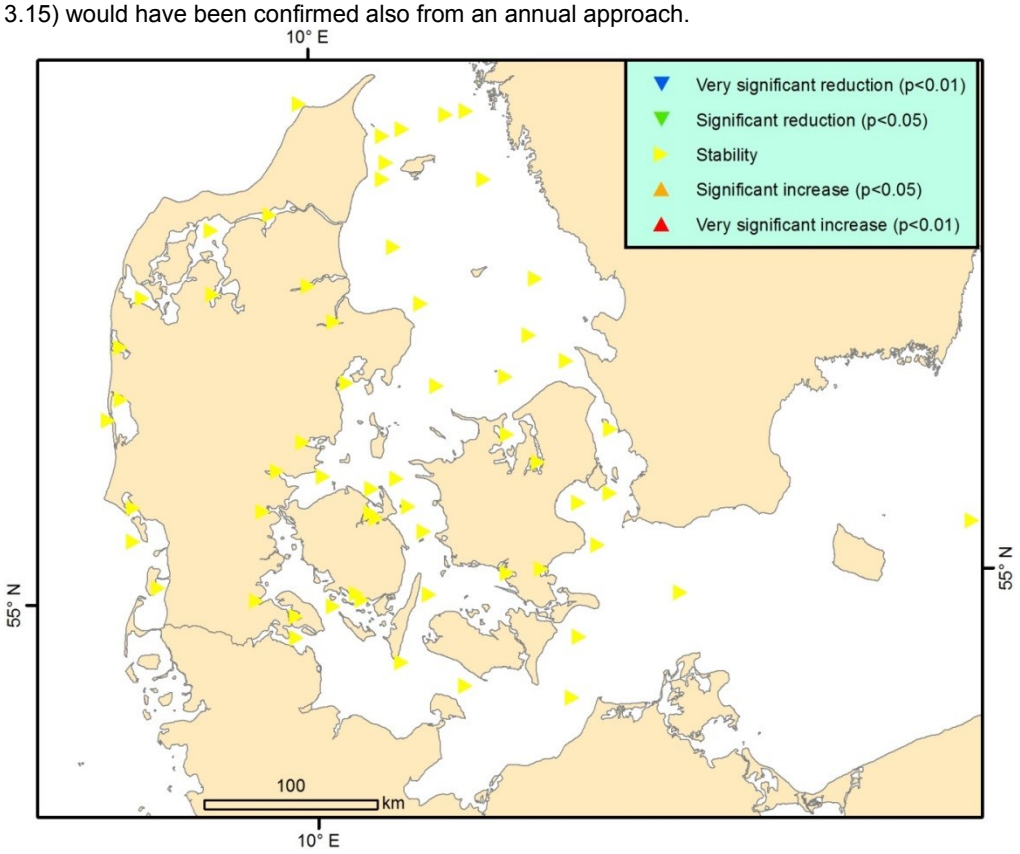

Figure 3.14 Trends in average surface (0-10 m) winter (October – March) NO_3^- concentrations between the 5th reporting period (2008-2011) and the 6th period (2012-2015) at 59 stations in Danish estuarine, coastal and marine open waters. Trends are based on statistical analyses as explained in the text and shown in Table 3.8 and Table 3.9.

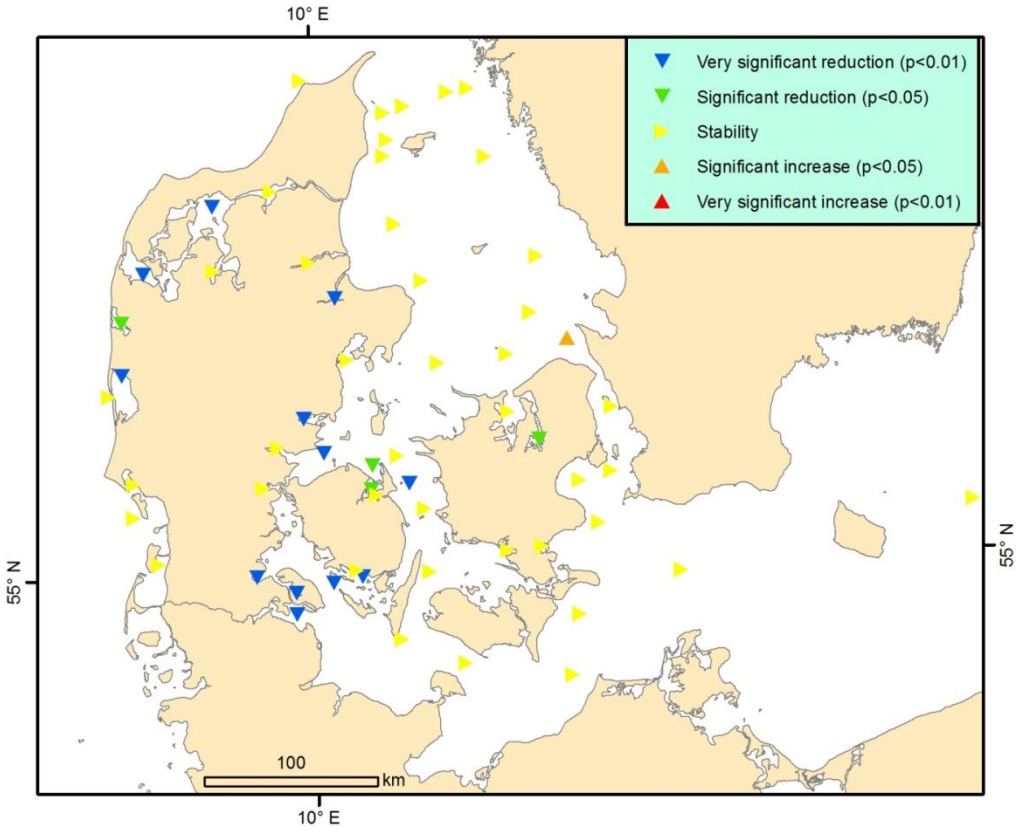

Figure 3.15 Trends in average surface (0-10 m) winter (October – March) NO_3^- concentrations between the 2nd reporting period (1996-1999) and the 6th period (2012-2015) at 59 stations in Danish estuarine, coastal and marine open waters. Trends are based on statistical analyses as explained in the text and shown in Table 3.8 and Table 3.9.

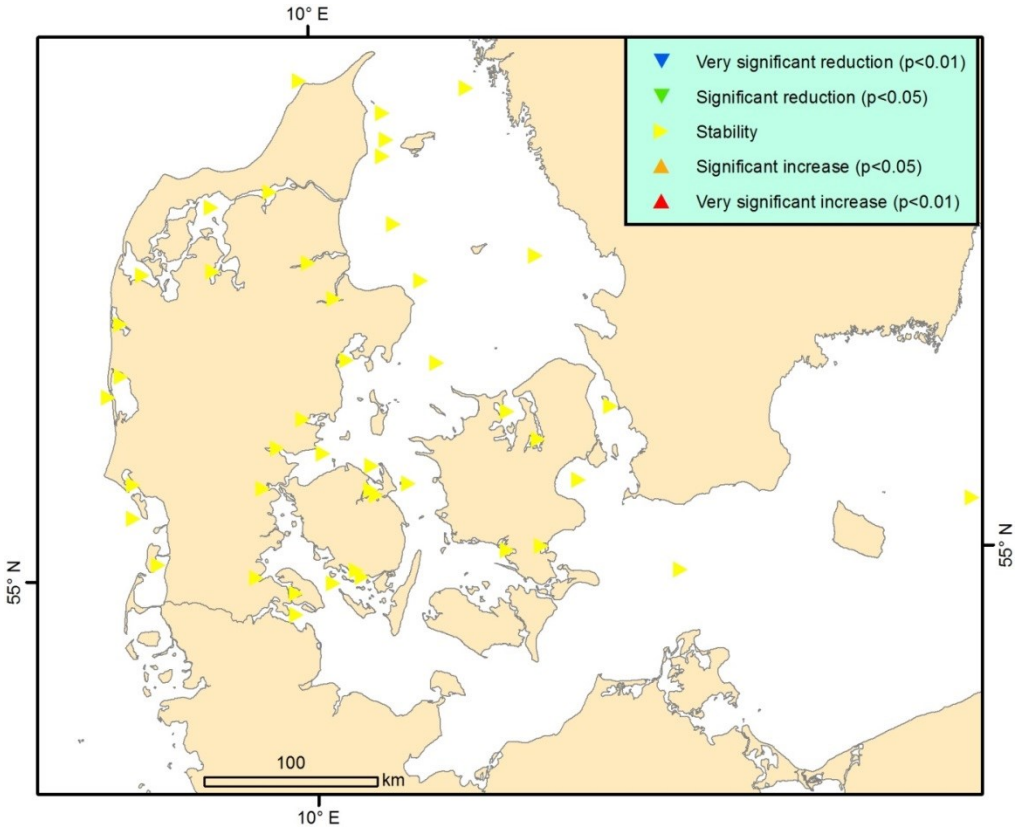

Figure 3.16 Trends in average surface (0-10 m) annual NO_3^- concentrations between the 5th reporting period (2008-2011) and the 6th period (2012-2015) at 44 stations in Danish estuarine, coastal and marine open waters. Trends are based on statistical analyses as explained in the text and shown in Table 3.8 and Table 3.9.

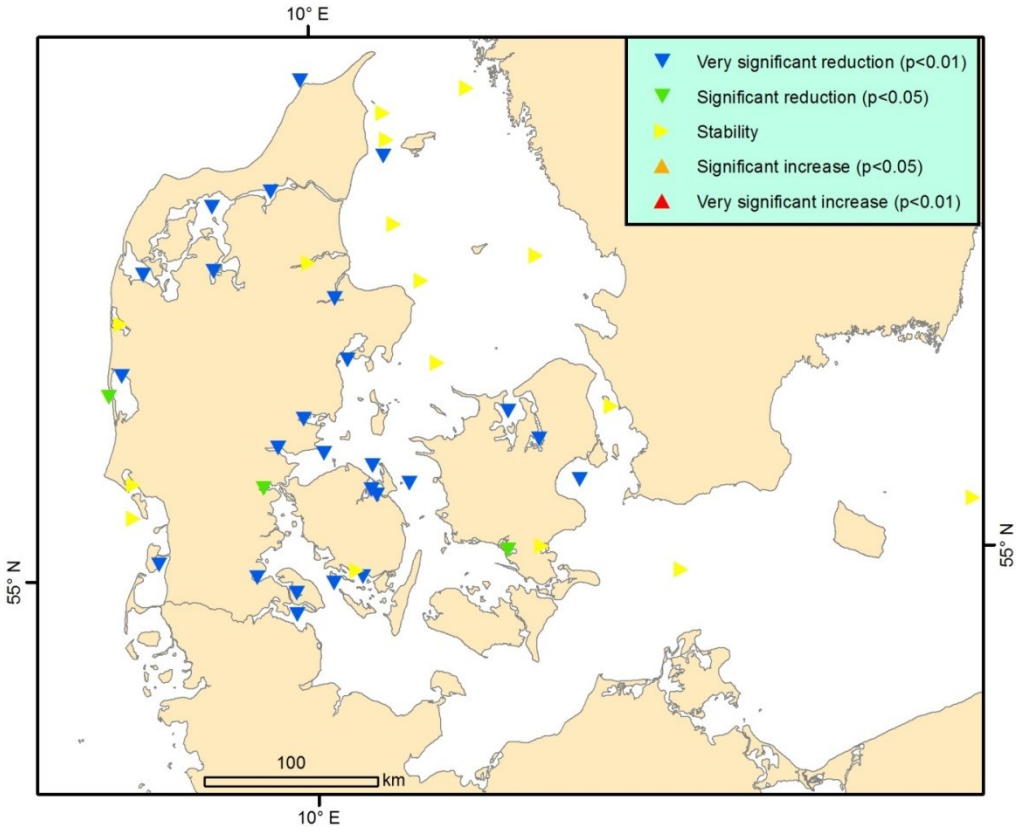

Figure 3.17 Trends in average surface (0-10 m) annual NO_3^- concentrations between the 2nd reporting period (1996-1999) and the 6th period (2012-2015) at 44 stations in Danish estuarine, coastal and marine open waters. Trends are based on statistical analyses as explained in the text and shown in Table 3.8 and Table 3.9.

3.3.4 Eutrophication status and development

In this report we use the average summer (May – September) concentrations of chlorophyll *a* in surface waters (0-10 m) as a proxy for eutrophication in Danish estuarine, coastal and marine open waters. Chlorophyll *a* has been chosen in order to provide consistency with previous reports.

During the 6th period (2012-2015) maximum chlorophyll *a* concentrations were observed in estuaries with concentrations up to 17.9 ± 12.1 µg/l at Station 5503 but with decreasing concentrations towards marine open waters and lowest chlorophyll *a* concentrations in Kattegat ranging from 0.74 to 1.46 µg/l at Stations 925 and 409, respectively (Figure 3.18).

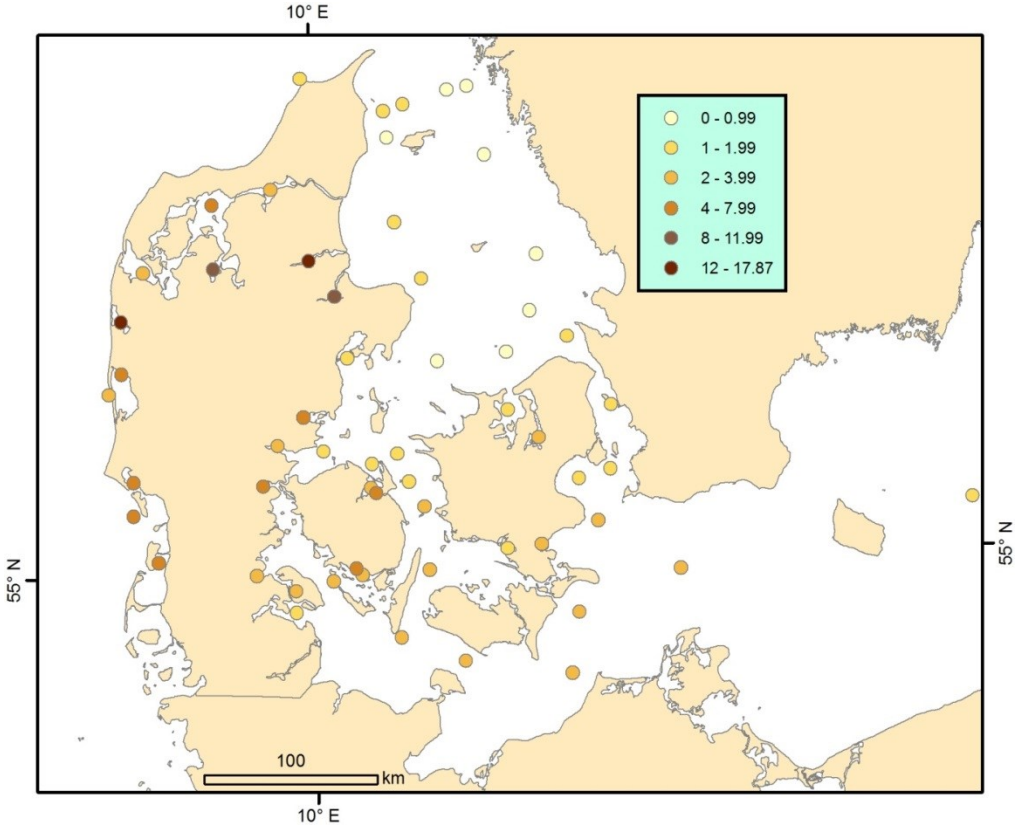

Figure 3.18 Average surface (0-10 m) summer (May – September) chlorophyll *a* concentrations in µg/l for the 6th monitoring period (2012 – 2015) at 58 stations in Danish estuarine, coastal and marine open waters. The average concentration is expressed at each station as a simple mean i.e. $\frac{1}{n}\sum_{i=1}^{n}[\text{chlorophyll a}]$. The highest value shown in the legend corresponds to the highest concentration on the map.

A decreasing trend in chlorophyll *a* concentration was observed at about 25 – 30 % of all stations monitored in Danish estuarine, coastal and marine open waters between the 5th period (2008-2011) and the 6th period (Figure 3.19, Table 3.10 and Table 3.11). This decreasing trend was even more pronounced in estuarine and coastal waters between the 2nd period (1996-1999) and the 6th period, when significant decreases in chlorophyll *a* were observed at two thirds of these stations (Figure 3.20, Table 3.10). At no station did chlorophyll *a* concentration increase at any time – neither from the 5th to the 6th period, nor from the 2nd to the 6th period.

Table 3.10 Trends in average surface (0-10 m) summer (May – September) chlorophyll *a* concentrations in Danish estuaries and coastal waters. Percentage of points (i.e. stations) with increasing, stable or decreasing average concentrations of chlorophyll *a* at 27 stations (5th to 6th period) and 26 stations (2nd to 6th period) stations, i.e. one station ~3.7% (Figure 3.19 and Figure 3.20), based on statistical significance. In brackets: Maximum absolute concentration changes (µg/l) and relative (%), digit sign shows increasing (+) or decreasing (-) value. Footnotes refer to station numbers (see Figure 3.10).

Trend	Significance	5th period to 6th period 2008-2011 to 2012-2015		2nd period to 6th period 1996-1999 to 2012-2015	
Increasing	**strongly** (p<0.01)	0%		0%	
	weakly (p<0.05)	0%		0%	
Stable	(p>0.05)	74%	(-2.33 µg/l; -36.2%)[1]	31%	(-1.70 µg/l; -25.6%)[4]
Decreasing	**weakly** (p<0.05)	4%	(-0.74 µg/l; -17.4%)[2]	27%	(-4.71 µg/l; -39.4%)[5]
	strongly (p<0.01)	22%	(-4.15 µg/l; -42.8%)[3]	42%	(-28.7 µg/l; -67.6%)[6]

[1]St. 8361, [2]St. 4273, [3]St. 3 [4]St. 3708-1, [5]St. 1, [6]St. 22

Table 3.11 Trends in average surface (0-10 m) summer (May – September) chlorophyll *a* concentrations in Danish marine open waters. Percentage of points (i.e. stations) with increasing, stable or decreasing average concentrations of chlorophyll *a* at 31 stations (5th to 6th period) and 30 stations (2nd to 6th period) stations i.e. one station ~3.2% (Figure 3.19 and Figure 3.20), based on statistical significance In brackets: Maximum concentration changes in absolute numbers (µg/l) and relative (%), digit sign shows increasing (+) or decreasing (-) value. Footnotes refer to station numbers (see Figure 3.10)

Trend	Significance	5th period to 6th period 2008-2011 to 2012-2015		2nd period to 6th period 1996-1999 to 2012-2015	
Increasing	**strongly** (p<0.01)	0%		0%	
	weakly (p<0.05)	0%		0%	
Stable	(p>0.05)	71%	(-1.35 µg/l; -23.6%)[1]	73%	(-0.87 µg/l; -42.3%)[4]
Decreasing	**weakly** (p<0.05)	10%	(-0.78 µg/l; -34.2%)[2]	10%	(-1.86 µg/l; -34.8%)[5]
	strongly (p<0.01)	19%	(-0.99 µg/l; -52.8%)[3]	17%	(-3.16 µg/l; -42.0%)[6]

[1]St. 22, [2]St. 7715, [3]St. 403, [4]St. 415, [5]St. 43, [6]St. 1510007,

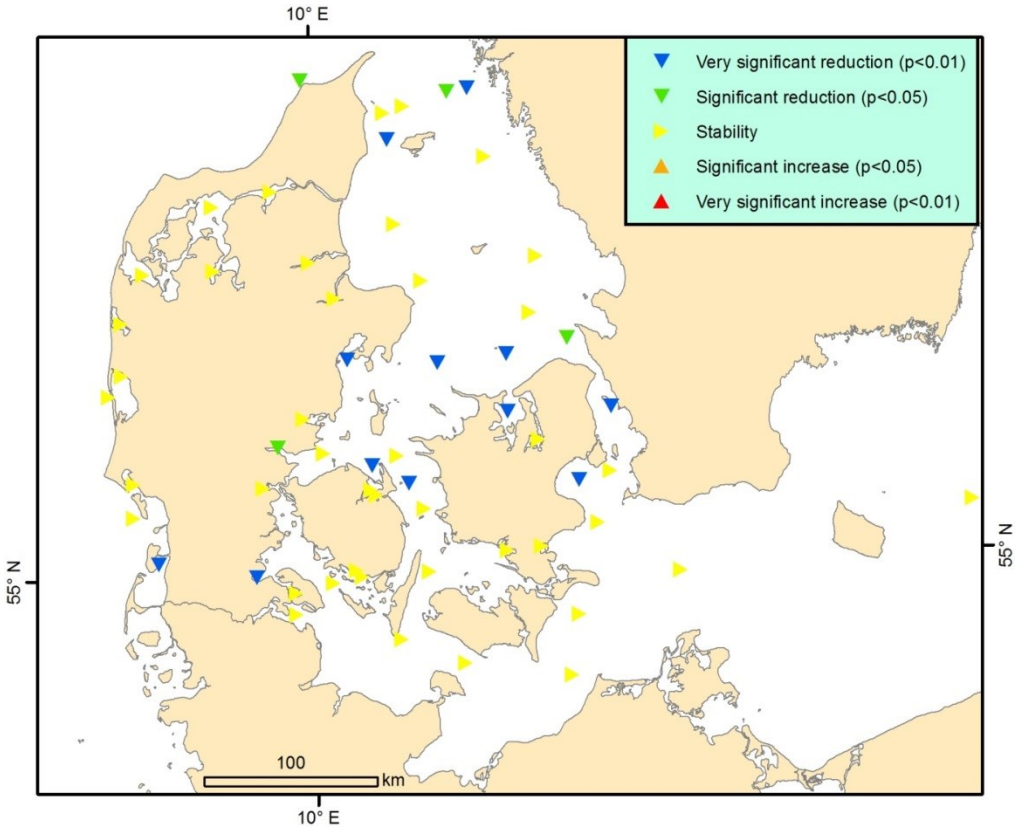

Figure 3.19 Trends in average surface (0-10 m) summer (May – September) chlorophyll *a* concentrations between the 5th reporting period (2008-2011) and the 6th period (2012-2015) at 58 stations in Danish estuarine, coastal and marine open waters. Trends are based on statistical analyses as explained in the text and shown in Table 3.10 and Table 3.11.

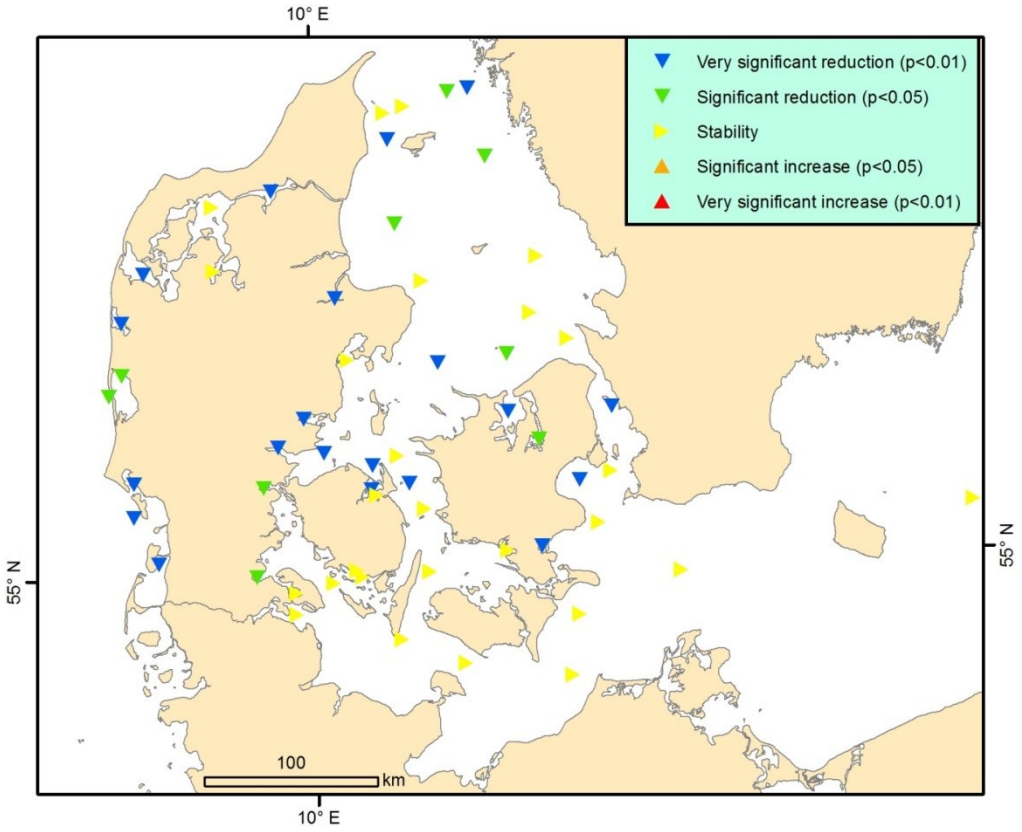

Figure 3.20 Trends in average surface (0-10 m) summer (May – September) chlorophyll *a* concentrations between the 2nd reporting period (1996-1999) and the 6th period (2012-2015) at 58 stations in Danish estuarine, coastal and marine open waters.
Trends are based on statistical analyses as explained in the text and shown in Table 3.10 and Table 3.11.

3.3.5 Overall assessment

In order to bring the above nitrate and chlorophyll *a* concentrations and their concomitant status and trends into perspective we introduce the annual average concentrations (adjusted for annual variations in freshwater discharge) of DIN (i.e. Dissolved Inorganic Nitrogen = nitrate + nitrite + ammonium), DIP (i.e. Dissolved Inorganic Phosphorous = phosphate) and chlorophyll *a* in Danish waters (Figure 3.21). Through the named adjustment, trends in concentration changes become clearer as pronounced impact from annual variations in precipitation and related river runoff from land are markedly reduced (Hansen, 2014).

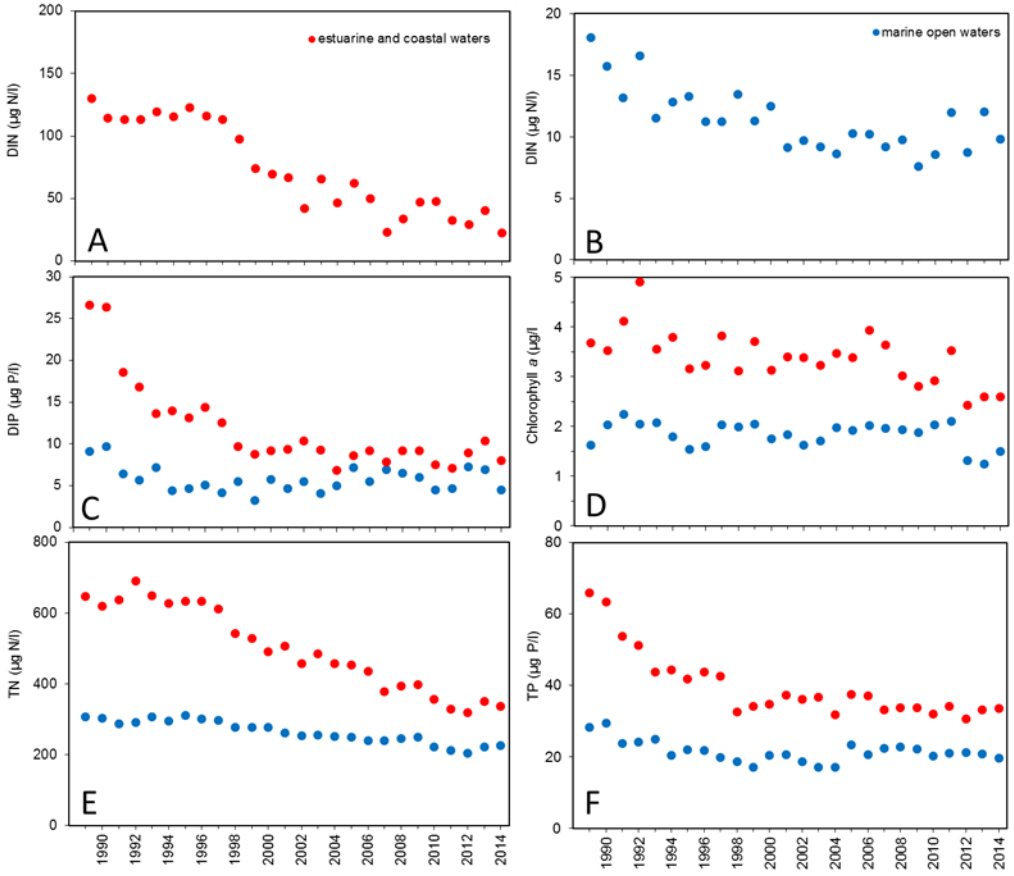

Figure 3.21 Annual average concentrations adjusted for annual variations in freshwater discharge of Dissolved Inorganic Nitrogen (DIN = nitrate + nitrite + ammonium; µg N/l) in estuarine and coastal waters (A) and marine open waters (B), Dissolved Inorganic Phosphorous (DIP = phosphate; µg P/l) (C), Chlorophyll *a* (µg/l) (D), Total Nitrogen (TN; µg N/l) (E) and Total Phosphate (TP; µg P/l) (F).
Red filled circles show estuarine and coastal waters, blue filled circles show marine open waters. (Redrawn after Hansen, 2015)

The significant decline in the annual average DIN concentrations particularly observed in estuarine and coastal waters from the late 1990'ies (Figure 3.21A) – most pronounced during the 2nd period (1996-1999) – is in accordance with the declining NO_3^- concentration trends shown on Figure 3.17 and in Table 3.8, the latter however based on winter concentrations only. Also in agreement with Figure 3.16 are observations that DIN concentrations since 2008 (i.e. start of the 5th period) have been fairly stable around 40 µg N/l.

Marine open water stations are much lower in DIN concentrations (Figure 3.21B) than observed in estuarine and coastal waters. Generally spoken, DIN concentrations in marine open waters have remained fairly stable around 10 µg N/l since 2000, corresponding to a level approx. 25% of the current DIN concentration in estuarine and coastal waters (Figure 3.21A). Therefore, the

majority of stations (i.e. 22 out of 28) with significant NO_3^- concentrations reductions between the 2nd and 6th period were estuarine and coastal (Figure 3.17). It should, however, be noted that the significant NO_3^- concentration decrease at all marine open water stations was <1 mg/l and therefore shows '*no trend*' according to the reporting guidelines.

In this report chlorophyll *a* is used as a proxy for eutrophication, but it does not necessarily respond (immediately) to changes in nitrate concentration but rather to total nitrogen (TN) concentrations (Riemann et al. 2015). This becomes evident by comparing Figure 3.21A, B, D and E. Nevertheless the observed decrease in NO_3^- concentrations from the 2nd period (1996-1999) to the 6th period (2012-2015) (Figure 3.15 and Figure 3.17) was accompanied by significant decreases in chlorophyll *a* (Figure 3.20) but whereas the DIN concentration became more or less stable 'years ago' (Figure 3.21A and B) TN concentration has continued the decrease until today (Figure 3.21E), particularly in estuarine and coastal waters, accompanied by a similar decrease in chlorophyll *a* concentration. This suggests that reductions in internal nitrogen pools are ongoing, because nitrogen released from sediments, mainly during summer, is immediately assimilated by phytoplankton and therefore not affecting DIN concentrations in the water.

Concurrently with decreasing inorganic nitrogen concentrations this nutrient became increasingly more limiting to phytoplankton growth and thus chlorophyll *a* production (Figure 3.22A) and during the latest years (2012-2014) DIN has been potentially limiting for about 75 % of the productive period (March – September) in estuarine and coastal waters and in marine open waters for nearly 95 % of the time since 2000.

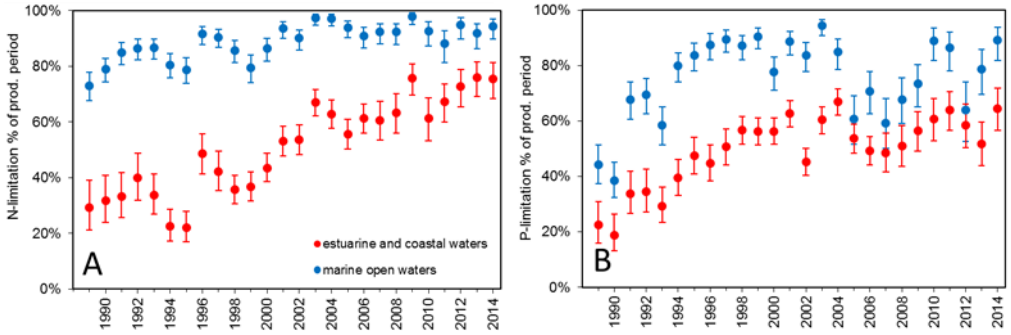

Figure 3.22 Percentage of productive period (March – September) when nitrogen (A) and phosphorous (B) are potential limiting to phytoplankton growth and thus chlorophyll *a* production in estuarine and coastal waters (red filled circles) and marine open waters (blue filled circles). Calculations are based on 28 µg DIN/l and 6.2 mg/l DIP as limiting to phytoplankton growth with annual average shown ± 95% confidence limits. (Redrawn after Hansen, 2015)

The decreasing nitrogen concentrations in Danish marine waters were also accompanied by a decrease in DIP and TP concentrations (Figure 3.21C and F), which accordingly limit P-dependent primary production by up to 75 % and 60 % of the productive period in marine open waters and estuarine/ coastal waters, respectively (Figure 3.22B). Primary production and hence chlorophyll *a* concentration can be limited by phosphorus, particularly in estuaries in spring.

As discussed, chlorophyll *a* should not necessarily be the only proxy for eutrophication, as also ecologically induced changes of parameters like e.g. Secchi-depth, bottom water oxygen concentration, eelgrass cover and/ or fauna biomass add to the interpretation, how reduced nutrient loading to marine waters affect eutrophication (Riemann et al. 2015).

Literature

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Riemann, B., J. Carstensen, K. Dahl, H. Fossing, J. W. Hansen, H. H. Jakobsen, A. B. Josefson, D. Krause-Jensen, S. Markager, P. a. Stæhr, K. Timmermann, J. Windolf, and J. H. Andersen (2015) Recovery of Danish Coastal Ecosystems After Reductions in Nutrient Loading: A Holistic Ecosystem Approach. Estuaries and Coasts, doi:10.1007/s12237-015-9980-0

3.4 Ground water

Lærke Thorling, Geological Survey of Denmark and Greenland (GEUS)

The groundwater-monitoring programme is designed to monitor recent groundwater recharged after approx. 1940. Implementation of the Water Framework Directive has required adjustments of the groundwater-monitoring network and thus some monitoring points used for previous reporting period were closed and new were established in the last reporting period. The adjustment of the monitoring network is expected to be finalised in 2016. Of approximately 1.200 monitoring points, approximately 1.000 points are common for the two periods.

When comparing the monitoring points that are common for the two last reporting periods, decreasing groundwater nitrate concentrations can be found in more monitoring points than increasing concentrations. The major part - about 75 % - of the monitoring points has an average nitrate concentration below 40 mg/l, as shown in Figure 3.24, where the distribution of the average nitrate concentrations in all monitoring points (2012-2015) is illustrated. In general, both upward and downward trends are to be found all over the country.

Groundwater from a large number of monitoring points has been dated with CFC (chlorofluorocarbon) and tritium/helium, where possible, indicating an overall deceasing nitrate trend in Danish oxic groundwater during the last almost 30 years, which can be assigned to reduced nitrate leaching from Danish agricultural activities since the 1980ies. Based on the latest GRUMO report, we conclude that the overall trend with regard to reducing the groundwater nitrate content is generally positive, but several locations still record increases. This includes some of the most recently created groundwater, which was formed after the water environment action plans came into force. The latest data on the development of nitrate in oxic groundwater and the most recent dating in the groundwater monitoring initiative indicate that the nitrate content in the youngest groundwater remains stable. (Thorling et al, 2016)

3.4.1 Presentation of monitoring stations

Groundwater monitoring in Denmark has until 2007 been based on information from up to 75 groundwater monitoring areas, each equipped with a number of monitoring wells with 20-25 monitoring screens, 5 agricultural watersheds and about 5500 water supply wells (Jørgensen and Stockmarr, 2009).

Implementation of the Water Framework Directive has required adjustments of the groundwater monitoring network, in order to obtain a geographically more distributed monitoring network, representing the Danish groundwater bodies, instead of the previous clustered network. The mayor adjustment is taking place in the period 2010-16, and involves establishment of new monitoring wells as well as closure of existing monitoring wells/screens and some monitoring areas. Many monitoring wells have several screens in different depths; the term “monitoring point” is used in the following, when referring to samples from individual monitoring screens. Different concentrations of nitrate can thus be found at the same geographical point. To handle this, maps are shown in two versions: with either the highest or the lowest concentrations drawn last / uppermost at each geographical point.

Figure 3.23 shows the location of the 1002 common monitoring points (blue) for the current (2012-2015) and the last (2008-2011) reporting period as well as the new monitoring points, added for status assessment during this reporting period (green). Thus, the map only shows monitoring wells used for the current reporting period. Due to the clustered character of the hitherto monitoring network, it would not be possible to show the closed monitoring wells on the same map.

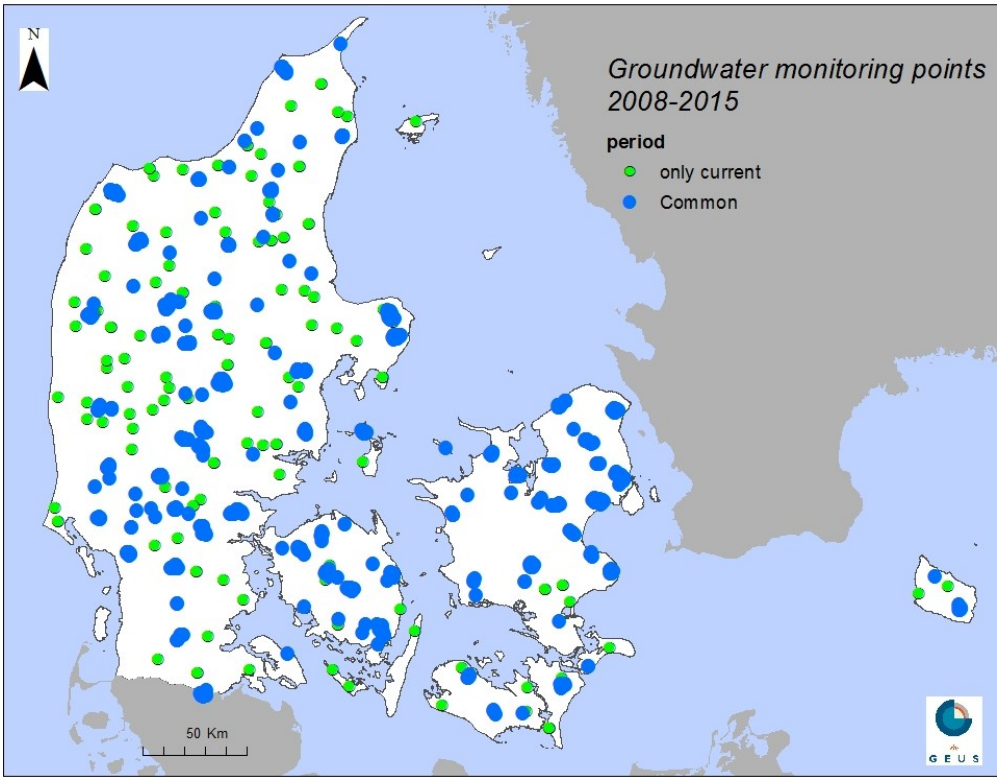

Figure 3.23 The location of the 1002 common groundwater monitoring wells in Denmark covering the period 2008 - 2015. Green signature shows monitoring wells only available for the 6th reporting period (2012-2015), while all monitoring wells with large blue signature have been in use for both reporting periods.

The number of groundwater monitoring points for the current and previous reporting period is shown in Table 3.12.

Table 3.12 Number of groundwater monitoring points (screens in monitoring wells) for the current (2012-2015) and previous (2008-2011) reporting period

	Previous reporting period (2008-2011)	Current reporting period (2012-2015)	Common points for both periods
number	1259	1204	1002

The groundwater-monitoring programme is designed to monitor groundwater recharged after approx. 1940. The monitoring wells are either placed in quaternary glacial deposits, in underlaying tertiary fluvial deposits or in underlaying cretaceous limestone. Many monitoring points are placed in artesian aquifers, due to hydraulic inactive clay layers, but all monitored aquifers are characterised as having a significant flowrate and groundwater with a residence time below 60-70 years. There is no monitoring of captive or karstic groundwater, as karstic groundwater does not exist and far the most captive groundwater has a natural quality unsuitable for drinking water, due to salt, fluoride etc. Due to the heterogeneity of the quaternary geological layers and very large variation in the depth to groundwater table, no classification of the groundwater monitoring points due to depth or other criteria is introduced. This procedure was also followed in the latest 5th reporting for the nitrates directive.

3.4.2 Status for nitrate concentrations

Nitrate data for 2012-2015 have been aggregated and the average value and the maximum value for each monitoring point was calculated, as the average/max of the annual average/max, respectively. The distribution of the monitoring points according to nitrate concentration is presented in four quality classes: < 25, [25-40[, [40-50] and > 50 mg/l nitrate. This was done for all monitoring points as well as for the common monitoring points used in both reporting periods, only (Table 2 and table 3).

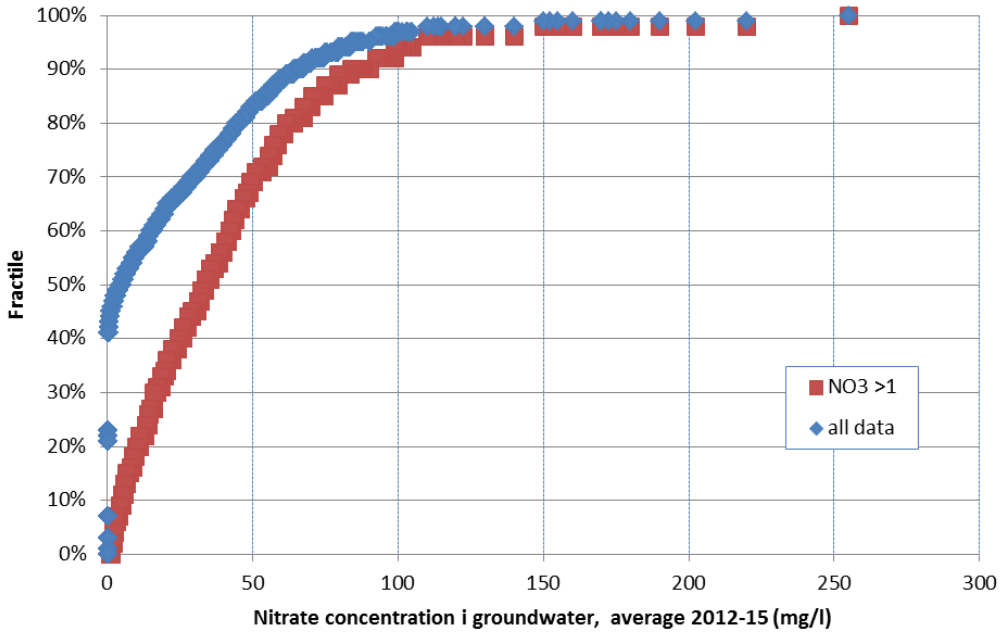

Figure 3.24 The distribution of the average nitrate concentrations of the individual monitoring points 2012-2015. The distribution is shown for all monitoring points and monitoring points with an average nitrate concentration above 1 mg/l.

20 % of the monitoring points had a maximum nitrate concentration above 50 mg/l nitrate, and 16 % of the monitoring points had an average nitrate concentration above 50 mg/l nitrate in the reporting period 2012-2015, see Figure 3.24. 55 % of the monitoring points had an average nitrate concentration above 1 mg/l,), and 40 % of the monitoring points did hold nitrate contents between 1 and 50 mg/l. As also shown in Figure 3.24 approximately 30 % of the monitoring points with > 1 mg/l nitrate, exceed 50 mg/l.

The major part, about 75 % of the monitoring points thus has an average nitrate concentration below 40 mg/l (Figure 3.24). The share of monitoring points with high nitrate concentrations is only a few percentages higher when comparing the maximum values to the average values. This is due to the relative stable nitrate content in most monitoring points.
A comparison between Table 3.13 and Table 3.14 indicates that a higher percentage of wells with nitrate above 40 and 50 mg/l is monitored in the new adjusted network used in the current reporting period, giving a larger share of monitoring points with high nitrate in Table 3.14. This explains why the overall tendency of decreasing nitrate concentrations in the groundwater only is reflected in Table 3.14, when comparing the current to previous reporting period. The missing indication of a trend in Table 3.13 is caused by the overruling effect of the adjustments of the monitoring network.

Table 3.13 Distribution of average and maximum nitrate concentration, for the previous (2008-2011) and current (2012-2015) reporting period. All monitoring points in each period are used.
NB: The networks for the reporting periods are not identical. See Table 3.14 for common monitoring points only.

Percentage of all points	previous reporting period	current reporting period
exceeding > 50 mg/l		
on max. values NO_3	20 %	20 %
on avg. values NO_3	16 %	16 %
exceeding > 40 mg/l		
on max. values NO_3	25 %	25 %
on avg. values NO_3	22 %	23 %

Table 3.14 Distribution of average and maximum nitrate concentration, for the previous 2008-2011 and current reporting period 2012-2015. Only common monitoring points are used.

Percentage of common points	previous reporting period	current reporting period
exceeding > 50 mg/l		
on max. values NO_3	23 %	21 %
on avg. values NO_3	18 %	17 %
exceeding > 40 mg/l		
on max. values NO_3	30 %	28 %
on avg. values NO_3	25 %	25 %

The spatial distribution of nitrate in the groundwater reflects the importance and regional differences of natural nitrate reduction processes in the aquifers and spatial distribution of clayey layers covering the deeper parts of the groundwater (Figure 3.25). High concentrations of nitrate in the deeper aquifers are mainly found in the western part of Denmark, whereas high nitrate concentrations are found in the upper groundwater in all parts of Denmark (Hansen et al, 2012).

The geographical distribution of nitrate in the current reporting period is shown in Figure 3.26 and Figure 3.27.

The average nitrate content from the 6th reporting period (2012-2015), is illustrated in Figure 3.26 (top and bottom), where the monitoring points are drawn in both ascending and descending order, and thus resulting in different monitoring points, on top of the other signatures. It is evident that it is possible to make two very different maps. Figure 3.26 (top) gives an impression of an geographic widespread occurrence of nitrate in Danish groundwater, whereas Figure 3.26 (bottom) indicates that nitrate problems only can be found at a very limited number of locations within the country. If no active choice of drawing order for the monitoring points was taken, any possible combination of the map in the Figure 3.26 (top and bottom) would have been the result with a risk for very different conclusions to be drawn.
In general, nitrate can be found in all oxic groundwater layers in most of Denmark, due to intensive agriculture, but the penetration depths of nitrate varies widely, and primarily gives rise to problems for drinking water abstraction in the western parts of the country. On the other hand,

nitrate present in the very shallow ground waters in the eastern part of Denmark, where clay layers promote surface near runoff, often finds a way to surface waters, and hence contributes to problems with eutrophication.

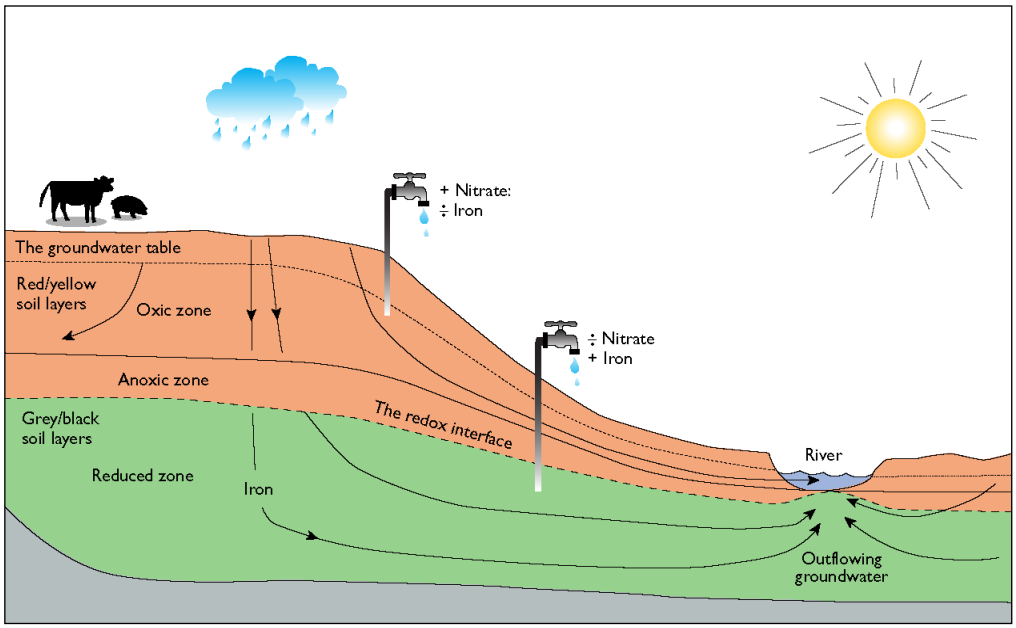

Figure 3.25 Principle for spatial nitrate distribution in an aquifer

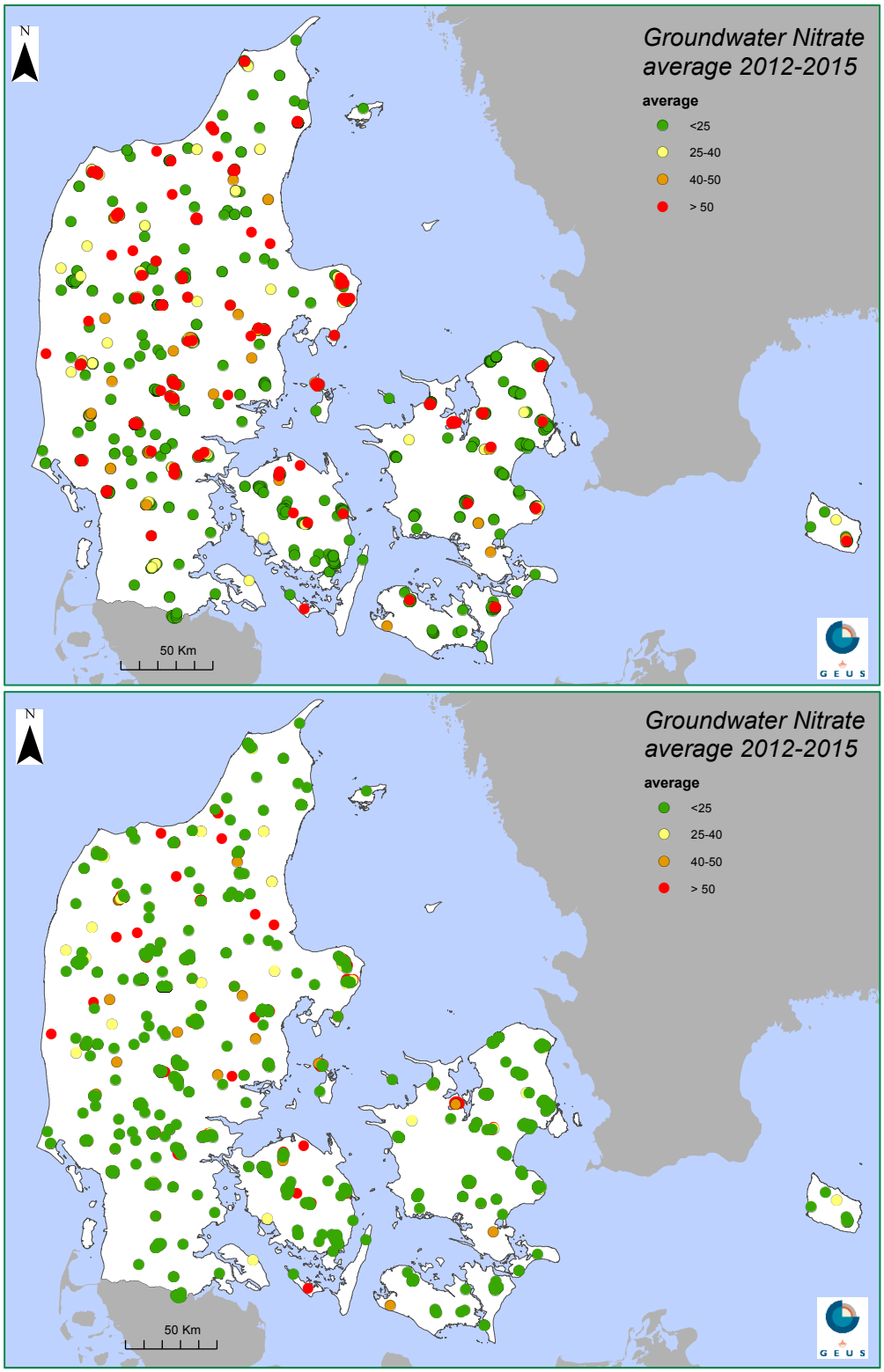

Figure 3.26 Status for the average nitrate concentration 2012-2015 in all monitoring points. The same dataset is shown in two GIS presentations: on the top map, nitrate is drawn in ascending order (above 50 mg/l are drawn last), on the bottom map, nitrate is drawn in descending order (values below 25 mg/l are drawn last).

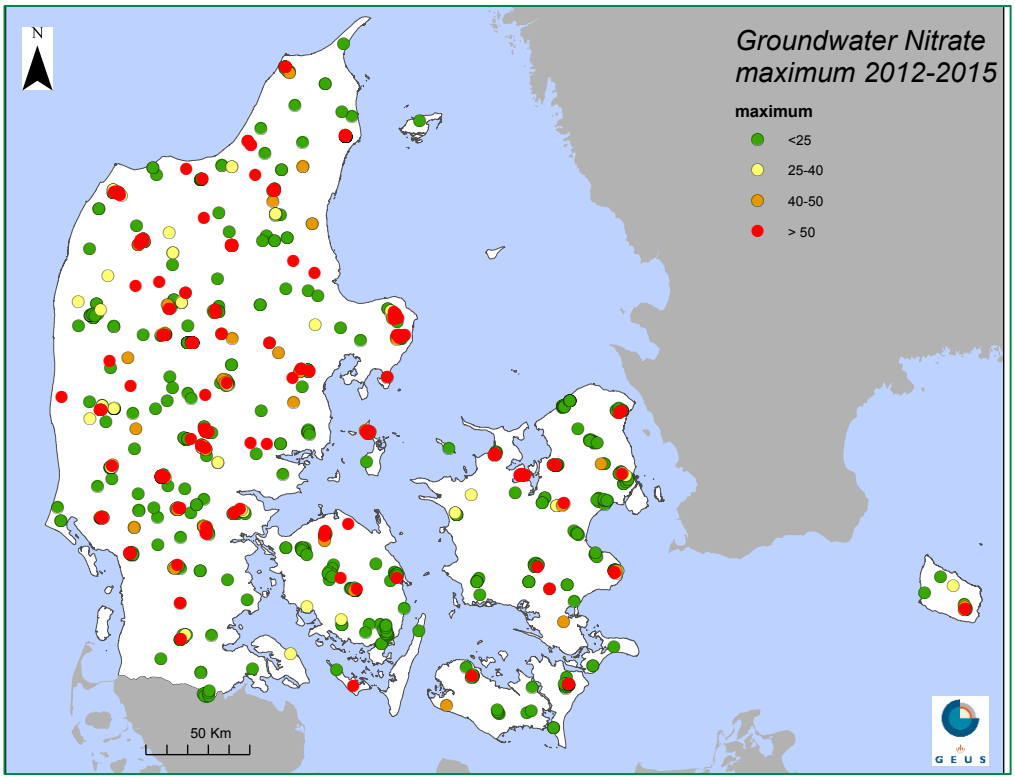

Figure 3.27 Status for the maximum nitrate concentration 2012-2015 in all monitoring points. Nitrate concentrations drawn in ascending order, values above 50 mg/l are drawn last.

3.4.3 Trend in nitrate concentrations

Trend in this reporting setup is defined as the difference of the average or maximum nitrate values, respectively for each monitoring point between the previous (2008-2011) or (1990-1993) and the current (2012-2015) reporting period. This procedure was also followed in the previous reportings. The results are grouped in five classes, as shown in Table 3.15.

Table 3.15 Trend in average and maximum nitrate concentrations in common ground water monitoring points between the previous period (2008-2011) and the current monitoring reporting period (2012-2015).

Percentage of common points	On max. NO_3 concentration	On average NO_3 concentration
Increasing		
Strongly (>+5 mg/l)	13.7 %	14.2 %
Weakly (+1 to +5 mg/l)	8.1 %	8.9 %
Stable		
±1 mg/l	45.0 %	47.1 %
Decreasing		
Weakly (-1 to -5 mg/l)	9.7 %	9.6 %
Strongly (<-5 mg/l)	23.6 %	20.3 %

The major part of the monitoring points has trends in nitrate concentration of -1 to 1 mg/l from 5th to 6th reporting period. For obvious reasons this holds for groundwater where nitrate concentrations are below 1 mg/l, which accounts for about 45 % of the monitoring points, the stable fraction in Table 3.15. The fluctuations from one year to another in the nitrate content in the

monitoring wells with contents above 25 mg/l are often more than 5-10 mg/l/year (measured as standard deviations). This is reflected in table 4 as the large fraction of wells, with increasing and decreasing nitrate contents from one reporting period to another. It is notable and in line with the decreasing fractions of monitoring points with high nitrate (Table 3.13 and Table 3.14) that a larger fraction of monitoring points has decreasing nitrate content than the fraction with increasing content. With respect to the average nitrate concentration, 29.9 % of the monitoring points are decreasing whereas 23.1 % are increasing. Looking at the maximum nitrate concentration, 33.3 % of the monitoring points are decreasing and 21.8 % are increasing, which is an even stronger tendency, reflecting the decrease in very high nitrate concentrations.

Figure 3.28 shows a map of the spatial distribution of the trends in average nitrate of the monitoring wells from the 5th to the 6th reporting period. As for the status in Figure 3.26 and Figure 3.27, the overall trend shows very different pictures, depending on the drawing order. At the top of Figure 3.28 the trends are drawn in ascending order (strongly increasing nitrate > 5mg/l per reporting period drawn last) and in the bottom in descending order (decreases in nitrate > 5 mg/l per reporting period drawn last).

The same picture would be found, if maps, showing the trend for the maximum nitrate contents, were presented.

Figure 3.28 shows that both upwards and downward trends can be found all over the country, as one would expect due to groundwater of different age having different distributions of trends. The map gives no information on the level of nitrate in groundwater with increasing nitrate content, or the age of the groundwater, which could help explain the upward trends, in spite of 30 years of action plans.

Figure 3.29 shows the trends between the 1st and the 6th reporting period, where 488 common monitoring points are available. The tendency of decreasing nitrate concentrations in some parts of the Danish groundwater is visible, but still some points have increasing nitrate. The figure gives no indication of the starting level of nitrate concentration in the 1990s, e.g. a 5 mg/l increase over 30 years from e.g.10 to 16 mg/l nitrate shows up as a red signature.

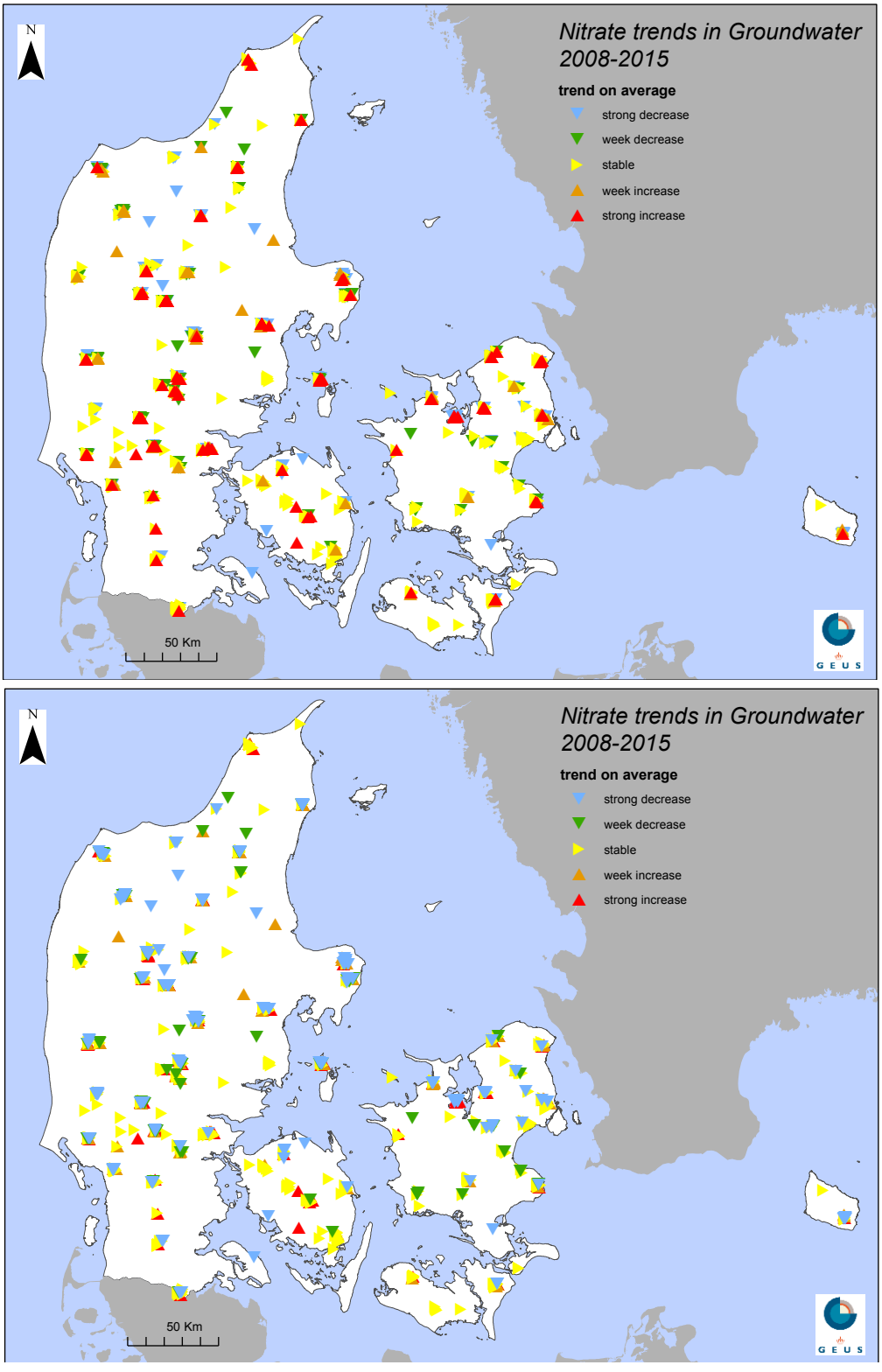

Figure 3.28 Trend of average nitrate content in common monitoring points from the 5th to the 6th reporting period. (2008-2011 and 2012-2015), 1002 common monitoring points
Note: On upper map, trends are drawn in descending order; bottom map shows trends drawn in ascending order.

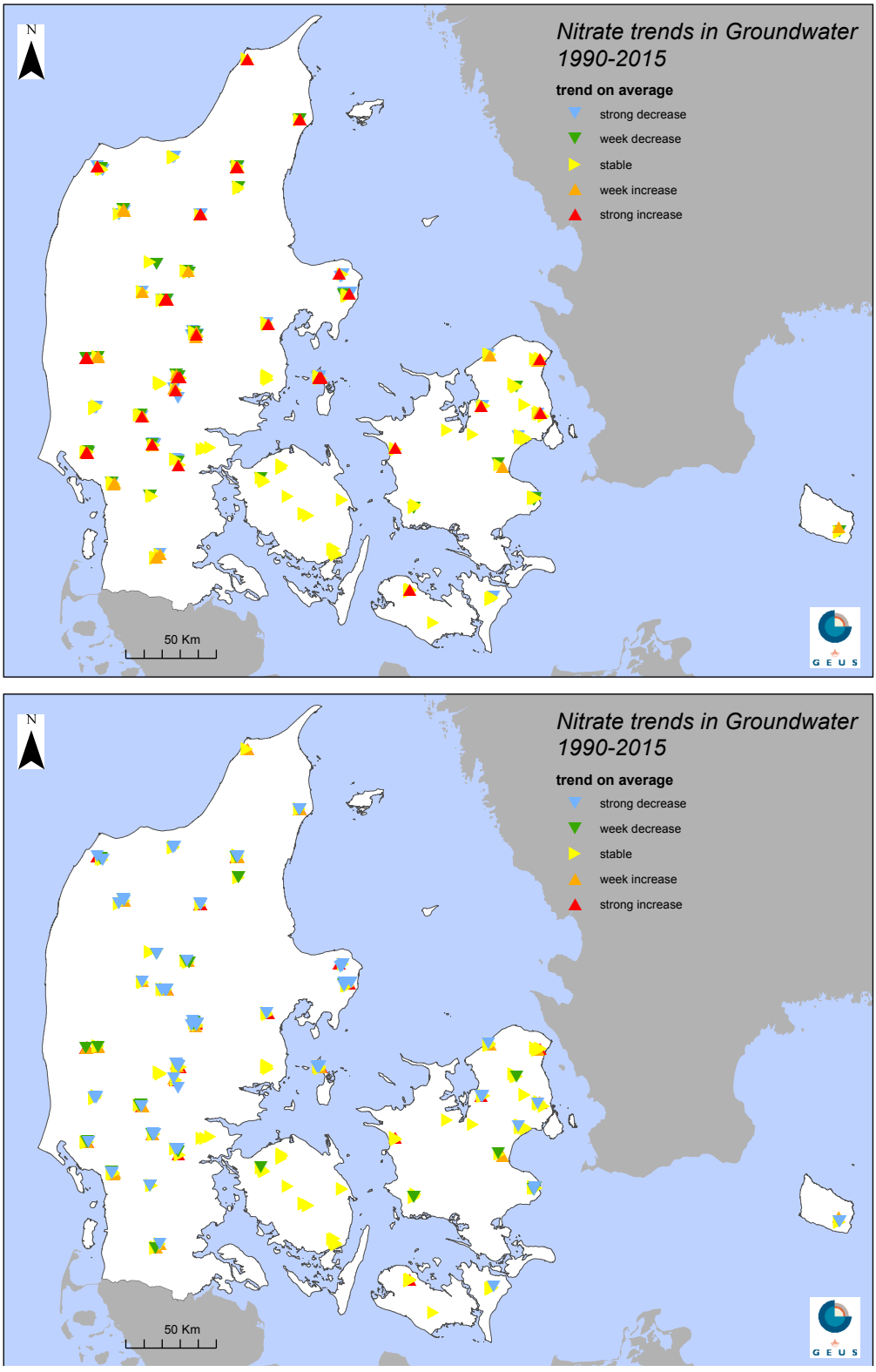

Figure 3.29 Trend of average nitrate concentration of common monitoring points from the 1st to the 6th reporting period - based on data from 488 common monitoring points (1990-1993 to 2012-15).
Note: Trends in the upper figure are drawn in descending order; trends on bottom map are drawn in ascending order.

3.4.4 Improved interpretation of nitrate concentration trends by groundwater dating

Groundwater age determination allows a relationship to concentrations of nitrate with “time of recharge” instead of “time of sampling”. In this way direct comparison between nitrate in groundwater and N loss from agriculture is possible.

The data analysis in this report only vaguely shows that the nitrate content of Danish groundwater has been improving through the reporting periods. This might be due to the fact that we are not taking the groundwater age and infiltration time into account.

Statistical nitrate trend analyses at a national level using CFC dating has given a strong indication of a trend reversal of nitrate in Danish oxic groundwater due to reduced nitrogen leaching in Danish agriculture since the 1980ies (Hansen et al., 2011). A recent assessment by Hansen & Larsen (2016) supports these earlier findings showing significant correlation between nitrate in oxic groundwater and nitrogen surplus in agriculture at the overall Danish national level (see Figure 3.30). In the last century, nitrate concentrations in groundwater was increasing in wells monitoring groundwater recharged in the period from approximately 1940-1985 due to the development of Danish agriculture with increasing input of N fertilizers and N surplus. A decreasing trend in the nitrate content of oxic groundwater has been observed from 1985 – 2012 (see Figure 3.30).

The age of the groundwater in oxic groundwater monitoring points is up to 50 years. Thus, an increase in nitrate concentrations still takes place in many monitoring points due to the high input of nitrogen in agriculture in the period from 1940-1985.

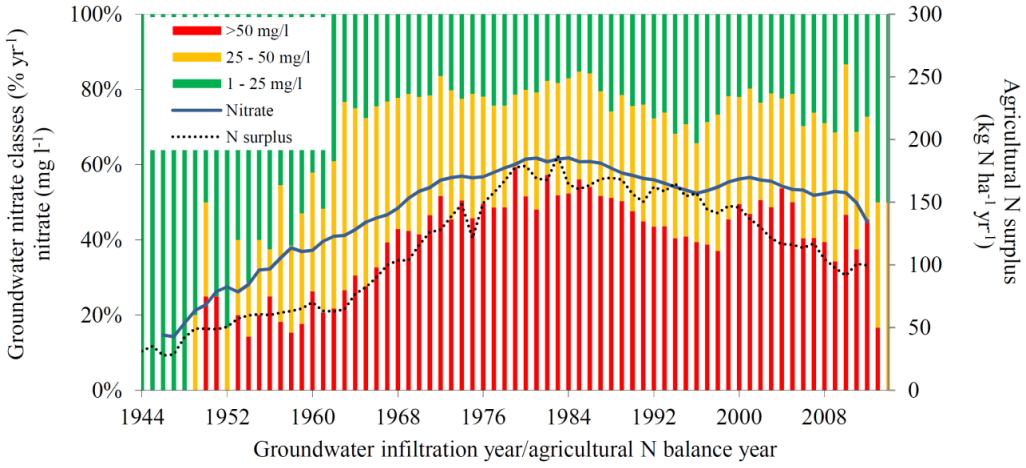

Figure 3.30 Concentrations of nitrate in oxic groundwater (5-years moving average) as a function of infiltration year for dated groundwater, and nitrogen surplus in agriculture. Nitrate concentration classes are also shown for the intervals: > 50 mg/l, 25-50 mg/l, and 1-25 mg/l. A total of 5506 nitrate samples from 340 oxic monitoring points are shown. The broken line shows number of nitrate samples per year of groundwater infiltration.

Literature

Hansen, B. & Larsen, F. 2016: Faglig vurdering af nitratpåvirkningen af iltet grundvand ved udfasning af normreduktionen for kvælstof i 2016-18. Danmarks og Grønlands Geologiske Undersøgelse Rapport. 2016/04. GEUS, 22 pp.

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4. Revision of the Vulnerable Zones

According to Article 3 (5) in the Nitrates Directive (1991/676/EEC), member states shall be exempt from the obligation to identify specific vulnerable zones, if they establish and apply action programmes, referred to in Article 5 in accordance with this Directive throughout their national territory.

Denmark has established and applied action programmes for the whole territory since the first Action Plans in the 1980's.

5. Development, promotion and implementation of code of good practice

Danish Environmental Protection Agency, Ministry of Environment and Food of Denmark

According to article 3 (5) in the Nitrates Directive the Danish Nitrates Action Programme applies to the whole national territory. The Danish Nitrates Action Programme consists of the measures in annex III and the measures in the code of good agricultural practice in annex II.

Measures according to code of good practice pursuant to the Nitrates Directive, annex II, are included in the Nitrate Action Programme as mandatory measures equivalent to the measures included in the programme pursuant to the directive, annex III. Description of the measures, according to code of good practice, is therefore included in the following chapter.

In the following chapter 6, the principle measures in the Nitrate Action programme are described along with the specific implementation, changes in the regulation effected during the period 2012 to 2015 (both years included) and the promotion of the elements in the programme.

6. Principle measures applied in the Action programme

Danish Environmental Protection Agency, Ministry of Environment and Food of Denmark

In this chapter the principle measures in the Nitrate Action programme are described along with the specific implementation, changes in the regulation effected during the programme period and the promotion of the elements in the programme.

At present, the Nitrates Directive is implemented in the following legislation:

- Act on Environmental protection no. 1317 (19/11/2015)
- Order on commercial livestock, livestock manure, silage, etc. no. 1318 (26/11/15)
- Act on agricultural use of fertilizer an plant cover no. 388 (27/04/16)
- Order on agricultural use of fertilizer in the planning period 2016/2017 no.1055 (01/07/2016)
- Order on plant cover and cultivation-related measures no. 1056 (01/07/2016)

Legal implementation of the Nitrates Directive by the end of 2015 consisted of the following Acts and Orders:

- Act on Environmental protection no. 1317 (19/11/2015), in Danish “Bekendtgørelse af lov om miljøbeskyttelse”, see link: https://www.retsinformation.dk/forms/R0710.aspx?id=174654
- Order on commercial livestock, livestock manure, silage, etc. no. 1318 (26/11/15), in Danish “Bekendtgørelse om erhvervsmæssigt dyrehold, husdyrgødning, ensilage m.v.“, see link: https://www.retsinformation.dk/forms/R0710.aspx?id=175399
- Act on agricultural use of fertilizer and plant cover no. 500 (12/05/2013), In Danish “Bekendtgørelse af lov om jordbrugets anvendelse af gødning og om plantedække” (see link: https://www.retsinformation.dk/Forms/R0710.aspx?id=146592), as amended by Act no. 576 (04/05/2015), in Danish “Lov om ændring af lov om jordbrugets anvendelse af gødning og om plantedække”, see link: https://www.retsinformation.dk/Forms/R0710.aspx?id=169949
- Order on agricultural use of fertilizer in the planning period 2015/2016 no 929 (29/07/2015), in Danish “Bekendtgørelse om jordbrugets anvendelse af gødning i planperioden 2015/2016”, see link: https://www.retsinformation.dk/Forms/R0710.aspx?id=173478
- Order on plant cover and cultivation-related measures no. 1777 (16/12/2015), in Danish “Bekendtgørelse om plantedække og om dyrkningsrelaterede tiltag”, see link: https://www.retsinformation.dk/Forms/R0710.aspx?id=176420

The titles of the orders at the beginning and by the end of the reporting period were:

- Order on commercial livestock, livestock manure, silage, etc. no. 764 of 28/06/2012: At present the title of the equivalent order is “Order on commercial livestock, livestock manure, silage, etc.” no. 1318 of 26/11/2015.
- Order on agricultural use of fertilizer in the planning period 2011/2012 and on plant cover no. 845 of 12 July 2011: At the end of the period the title of the equivalent orders were “Order on agricultural use of fertilizer in the planning period 2015/2016” no. 929 (29/07/2015) and “Order on plant cover and cultivation-related measures” no. 1777 (16/12/2015).
- The Order on agricultural use of fertilizer is re-issued yearly, as the fertilization standards are re-calculated for each planning period.

An overview of the implementation of Annex II and Annex III of the Nitrates Directive as mandatory measures in the Danish Nitrate Action Programme in 2015 is given in Table 6.1. The specific measures are described for each litra in annex II and annex III and measures, according to

art. 5 (5), can be found in text set in bold italic type in Table 6.1.

Note that the overview of the implementation of the programme is given for the legal texts valid by the end of 2015. Changes in the implementation are described for each element in the overview in Table 6.1. Changes in the legal texts in effect in 2016 are not included in the legal references in the overview.

The exact text of the orders, as they were in 2015, can be found in Danish on Legal Information ("Retsinformation", see respective links given in the list above). Only the paragraphs in the overview in Table 6.1 are legal elements, implementing the Nitrates Directive.

Table 6.1 Implementation of the Nitrates Directive in national orders during the period 2012-2015 for each litra in the Annex II and III of the Directive and art. 5(5), and changes of the implementation during the same period

Nitrates Directive, annex II and III, art. 5(5).	Implementation in national order by 2015 Indication of changes during the period 2012-2015
Annex II A 1. Periods when the land application of fertilizer is inappropriate	§ 29 of Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015. ***In the period from harvest, though no later than 1. October, to 1. February, liquid manure or digestate from vegetable biomass may not be applied – with exemptions.***
	No changes compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 764 of 28/06/2012[1].
Annex II A 2. The land application of fertilizer to steeply sloping ground	§ 30 (3) and (4) of Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015 ***Manure, degassed plant biomass, and mineral fertilizer must not be applied on sloping areas.***
	No changes compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 764 of 28/06/2012[1].
Annex II A 3. The land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground	§ 30 (2) Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015 ***Manure, digestate from plant biomass, silage effluent, residual water and mineral fertilizer must not be applied in a manner with risk of run-off, including water-saturated, flooded, frozen or snow-covered soil.***
	No changes compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 764 of 28/06/2012[1].
Annex II A 4. The conditions for land application of fertilizer near water courses	§ 30 (5) of Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015 ***Manure, digestate, silage effluent, residual water and mineral fertilizer must not be applied 2 m from water courses.***
	Change in Order on commercial livestock, livestock manure, silage, etc. no. 594 (04/05/2015): Ensuring precise regulation on prohibition to spread any kind of fertilizer within 2 meters from water courses
Annex II A 5. The capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage.	§ 8 (1), § 9, § 11, § 12, § 13 (1) and (2), § 14 (1) and (3), § 15, § 16, § 18 (1), § 19 (1), (2), (4) and (7), § 22, § 23, § 24 (1), § 25, § 26 of Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015 ***Stables, stalls, etc. shall be designed in such a way that groundwater and surface water is not polluted.*** ***Capacity of storage facilities for manure must be adequate (specified). Adequate storage capacity may be satisfied by storage on other property or delivery to the biogas plant, manure treatment plant or manure storage facility.*** ***Solid manure must be stored in accordance with the correct***

	provisions. When storing manure it must be ensured that surface water from the surrounding areas cannot seap into the manure storage. Compost with a dry matter content of at least 30% may be stored in the field, if complying with certain requirements. ***Manure stored in the field, deep litter and processed manure, compost with a dry matter percentage greater than or equal to 12 must be covered with waterproof material.*** ***Silage must be stored in a silage storage facility or wrapped in waterproof material. Silage effluent must be discharged through purpose-designed drainage.*** ***Storage vessels for liquid manure, silage effluent, digestate and residual water must be constructed of materials which are resistant, impermeable to moisture. The vessels must be dimensioned in relation to capacity, so that they can withstand the influence, including from stirring, covering and emptying. Drains from stables/stalls, manure yards, silage stocks, cesspools, and pump wells shall be run through impermeable closed pipes and shall lead to liquid manure containers.***
	Change in Order on commercial livestock, livestock manure, silage, etc. no. 1318 (26/11/2015): General exemption from the provision concerning slurry alarm under certain conditions. Ensuring clarification concerning the prohibition against placing silage on the edges of the storage area also applies to silage storage area.
Annex II A 6. Procedures for the land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level.	§ 28 (2) of Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015 ***Application of liquid manure and digestate may only be carried out by means of trailing hoses, trailing foot/shoe applicators or by injection.***
	No changes compared to previous "Order on commercial livestock, livestock manure, silage, etc." no. 764 of 28/06/2012[1].
Annex II B 7. Land use management, including the use of crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops;	§ 21 of Act on agricultural use of fertilizer and plant cover no. 500 (12/05/2013) as amended by Act no. 576 of 04/05/2015. ***Farms subject to registration in the Fertilizer Register pursuant to the Act shall for each planning period make a fertilizer plan for cultivated and set-aside areas. The planning must be done before a date determined by the Minister for Environment and Food.*** § 11 in Order on agricultural use of fertilizer in the planning period 2015/2016 no 929 (29/07/2015). ***Farms subject to registration in the Fertilizer Register pursuant to the Act must prepare a fertilizer plan showing all cultivated and uncultivated areas, at the latest by the date specified as deadline for application in the Order on field block and electronic Common Application Schedule (the common application for CAP area payments). The fertilizer planning must be done on forms***

	prepared by AgriFish Agency or similar forms approved for fertilizer planning by the agency.
	No change.
Annex II B 8. The maintenance of a minimum quantity of vegetation cover during (rainy) periods that will take up the nitrogen from the soil that could otherwise cause nitrate pollution of water;	§ 18 of Act on agricultural use of fertilizer and plant cover no. 500 of 12/05/2013, as amended by Act no. 576 (04/05/2015). § 2-14 of Order on plant cover and cultivation-related measures no. 1777 of 16/12/2015. ***General requirement for mandatory catch crops on farms nationwide on a certain percentage of the area on the holding.*** ***Agricultural enterprises with crop or livestock or combinations thereof with a certain annual turnover from crops or livestock, or combinations thereof and a total area of 10 hectares or more, shall establish a minimum amount of catch crops.***
	Changes by Act no 576 (04/05/2015) : Act no 576 gave legal basis to reduce the general catch crop requirement at national level by 80,000 ha to 300,000 ha. The catch crops contributed to, respectively the aims of the Nitrates Directive with 240,000 ha and the Water Framework Directive with 60,000 ha. The reduction was decided by Parliament by political agreement on Growth Plan for Food of 2nd April 2014. The resulting increase in the general requirement for catch crops by 60,000 ha was later withdrawn by political agreement of 22nd December 2015 (Food and Agricultural package), resulting in a remaining general catch crop requirement of 240,000 ha contributing to the Nitrates Directive. In addition, Act no. 576 gave a better legal basis to introduce alternative cultivation activities in farming as alternatives to the general requirement for catch crops, at the same time preventing double counting of environmental effects. Changes by Order no 1777 (16/12/2015): The order introduced new possibilities for fulfillment of the catch crops requirement. The list of crops that may be used as catch crops was extended, voluntary set-aside was added to the list of alternative actions to meet the catch crop requirement, and the list of crops that may be used in the alternative action early sowing was extended.
Annex II B 9. The establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use	§§ 11(1), 11a (1), 13(1), 14(1) and 21-23 of Act on agricultural use of fertilizer and plant cover no 500 (12/05/2013). §§ 11, 26 and 27 in Order on agricultural use of fertilizer in the planning period 2015/2016 no 929 (29/07/2015). ***Requirement to prepare a fertilizer account for each holding.***
	Change: An amendment to Act no 415 (03/05/2011) was introduced by § 21a of Act on agricultural use of fertilizer and plant cover no. 500 (12/05/2013) giving authority to require farmers to report their areas with catch crops to the Ministry for each planning period according to the general requirement for catch crops.
Annex II B 10. The prevention of water	***Need for irrigation is included when calculating nitrogen fertilizer***

pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems	***standards***, see Annex III, 1.3.
	No changes.
Annex III, 1, 1. Periods when the land application of certain types of fertilizer is prohibited;	See under Annex II A1 and Annex II A5.
Annex III, 1, 2. The capacity of storage vessels for livestock manure; this capacity must exceed that required for storage throughout the longest period during which land application in the vulnerable zone is prohibited, except where it can be demonstrated to the competent authority that any quantity of manure in excess of the actual storage capacity will be disposed of in a manner which will not cause harm to the environment;	See under Annex II A5.
Annex III, 1, 3. Limitation of the land application of fertilizers, consistent with good agricultural practice and taking into account the characteristics of the vulnerable zone concerned […]	**Application of fertilizers** § 5 of Act on agricultural use of fertilizer and plant cover no. 500 (12/05/2013) as amended by Act no. 576 of 04/05/2015 ***In each plan period, farms subject to registration in the Fertilizer Register pursuant to the Act on agricultural use of fertilizer and plant cover must not apply more nitrogen for fertilizer purposes than the fertilizer quota calculated for the farm.*** § 27 of Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015. ***The nutrients in manure, digestate, silage effluent and residual water may only be applied to crops with a nitrogen standard or a normative standard for phosphorus and potassium.*** Order on agricultural use of fertilizer in the planning period 2015/2016 no. 929 (29/07/2015) ***The yearly amount of nitrogen permitted at farm level is calculated taking into account the characteristics of the area and is based on a balance between the foreseeable nitrogen requirement of the crops and the nitrogen supply to the crops from the soil and from fertilization.*** ***The optimal relationship between the nitrogen requirements of the crops and nitrogen supply is set every year on basis of field trials. This is done for four different soil types and for irrigated sandy soil. In addition, the relationship between prices for nitrogen and crops is taken into account, and the optimal fertilization level is calculated. Subsequently, the allowed amount of N fertilizer per ha was reduced compared to the economic optimum.*** ***Due to the varying abilities to retain nutrients, different soil types are divided into four categories with different nitrogen standards for the same crop. Irrigation is taken into consideration by the***

	authorities when the specific standards are set . Yearly variations in temperature and extent of rainfalls in the wintertime are also taken into account.
	Changes: Act on agricultural use of fertilizer and plant cover no. 500 (12/05/2013) as amended by Act no 576 (04/05/2015). Order on agricultural use of fertilizer in the planning period 2015/2016 no 929 (29/07/2015). On 22 December 2015, the Danish government reached a political agreement in Parliament on different measures to make a shift from general environmental regulation of agriculture to a more targeted approach (Food and Agricultural package). The aim was to improve the ability for farmers to produce at the same time more environmentally and economically sustainably. An element of the agreement was to remove the reduction of nitrogen fertilizer standards.
Annex III, 2 These measures will ensure that, for each farm or livestock unit, the amount of livestock manure applied to the land each year, including by the animals themselves, shall not exceed a specified amount per hectare. *The specified amount per hectare be the amount of manure containing 170 kg N.*	§ 31, § 32, § 33 (1) and (2), § 34 of Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015. ***The total quantity of manure and digestate applied on an agricultural holding shall not exceed an amount corresponding to 1.4 livestock units per hectare per planning period.*** ***Manure produced on agricultural holdings with cattle, sheep, or goats may be applied in quantities corresponding to 1.7 livestock units per hectare per planning period.*** ***A maximum of 170 kg N per hectare per planning period of manure and degassed plant biomass may be applied on agricultural holdings.*** ***The quantities of manure applied to land as well as area for spreading manure (harmony area) are calculated on the basis of further specified methods.*** ***If an agricultural holding has greater quantities of manure available, including manure received from other farms, than what can be applied to spreading area, agreements shall ensure that excess manure is disposed to/for by specified solutions. The operator must be able to document compliance with the harmony rules.*** ***Derogation (Commission decision of October 23rd 2012): On agricultural holdings where at least 2/3 of the livestock are cattle, manure and degassed plant biomass may be applied in quantities corresponding to 2.3 livestock units per hectare per planning period when in compliance with certain conditions.***
	No change.

Additional measures according to Article 5, paragraph 5	§ 11, § 12, § 18, § 23 (2), § 28 (2), § 30 (5), § 31 (1), (3) and (4) in Order on commercial livestock, livestock manure, silage, etc. no. 1318 of 26/11/2015? ***Regulation of storage and spreading of anaerobically digested plant biomass.*** ***Regulation of land application of fertilizer near water courses.*** ***Regulation of storage of washing water.*** ***Reduced harmony rules for manure and degassed plant biomass for farms, producing slaughter pigs, poultry and fur animals to 1.4 LU/ha (instead of 1.7 LU/ha).***

[1] The Order on commercial livestock, livestock manure, silage, etc. no. 764 of 28/06/2012 has been used as reference in the last Danish report according to Article 10 in the Nitrates Directive for the period 2008-2011 (5th period).

7. Evaluation of the implementation and impact of the action programmes' measures

7.1 Data concerning the territory of Denmark

Danish AgriFish Agency, Ministry of Environment and Food of Denmark

Table 7.1 Data concerning the territory of Denmark[1)]

	Reporting Period	
	Previous period Average of 2008-2011	**Current period Average of 2012-2015[4)]**
Total land area[1)] hectare (ha)		4,309,800
Agricultural land, 1000 ha	2,712	2,648
Agricultural land available for application of manure, 1000 ha	2,656	2,460
Permanent grass, 1000 ha	213	211
Perennial crops[2)] (fruit trees, bushes and energy crops), 1000 ha	11	14
Annual use of organic N from livestock manure[3)], 1000 tons	227	217
Annual use of organic N from other sources than livestock manure, 1000 tons	13	7
Annual use of N from fertilizer (mineral N), 1000 tons	197	202
Number of farms	46,000	40,400
Number of farms with livestock	24,700	21,800
Dairy cattle, 1000 heads	563	568
Cattle, million heads	1.56	1.52
Slaughter Pigs, million/a	21.3	20.1
Poultry, million heads	18.3	18.6
Fur, million heads	2.75	2.78
Other (horse, sheep), 1000 heads	196	147
Manure N excretion per livestock category, 1000 tons/a		
Cattle	118	113
Pigs	88	84
Others	20	20

[1)] Without territories which are not part of the European Union (Greenland and the Faroe Islands)

[2)] Does not include data for Christmas trees

[3] This figure refers to Nitrogen in livestock manure (excreted Nitrogen minus losses in housing and storages)

[4] Data are from reporting years 2012-2015 corresponding to the planning periods: 2010/2011, 2011/2012, 2012/2013 and 2013/2014

Sources: The AgriFish Agency, Statistics Denmark

7.2 Nitrogen discharges to the aquatic environment

Danish Environmental Protection Agency, Ministry of Environment and Food of Denmark

The amount of Nitrogen, which has been discharged to the sea in the years 2012 to 2014, was within a similar range as in the previous reporting period (Table 7.2).

Table 7.2 Total Nitrogen discharges from the Danish territory to the sea (both diffuse pollution and point sources) (Source: NOVANA)

	3rd period (2000-2003)		4th period (2004-2007)		5th period (2008-2011)		6th period (2012-2015)	
	2000	2003	2004	2007	2008	2011	2012	2014[1]
Total N discharge (tons N)	80 900	43 600	68 200	81 200	64 900	59 300	59 700	62 800
Water-discharge-normalized N discharge (tons N)[2]	72 800	61 200	68 700	63 800	61 300	55 600	55 400	59 400

[1] Data for 2015 not yet available

[2] For water-discharge normalization, the total N discharge is calculated, corrected by assuming a fixed standard water discharge for each respective year, whereas the actual annual water discharge has varied between approx. 10 000 mio. m^3 (in 2003) and 17 900 mio. m^3 (in 2007) during the presented period 2000-2014

Taking the climatic conditions into account, including especially precipitation, a decrease in annual Nitrogen discharge to the sea from over 100.000 tons N in the early 1990's down to a level ranging from 55.000 to 59.000 tons N/year in all the years 2009 to 2014 (water discharge-normalized, land-based N discharge to the sea) has been observed (Table 7.2).

The total N discharge to the sea, presented in Table 7.2, has been corrected, compared to earlier reports. The estimated land based nutrient load of Danish coastal waters is based on data provided by the national monitoring program NOVANA (Wiberg-Larsen et al., 2015), which has been in operation since 1989. During the period the methods for this estimation have been changed and the adjusted methods have been applied to the full time series. These adjustments have resulted in some changed quantifications of the total annual nutrient load, also for the years before 2012.
The method for estimating Total Nitrogen load is based on the DK-QNP model, (Windolf et al., 2011). Measured N load from 169 streams (near coastal gauging stations) is included together with modelled diffuse N load and sewage outlets in unmonitored catchment. Around 50 of the gauging stations do not hold full time series of measurements and for these years nutrient load is modelled. Hence, in 2014, 130 gauging stations were in operation covering 22.000 km^2 (52%) of the total land area.

Simplified and in rounded numbers, it can be stated that approximately 10% of the climate-normalized N discharge originates from point sources, e.g. waste water treatment plants. The

diffuse, normalized contribution has been within the range of 49.000 to 52.000 tons N/year in the years 2012 to 2014. In connection with the latest River Basin Management Plans, the natural background contribution to N discharge has been estimated – in rounded numbers - to account for approximately 20% of the N discharge to the sea. Consequently, the share of N discharge to the sea, caused directly by agricultural activities within the country can be estimated to round about 70% of the total N discharge.

In the year 2014, the 250 largest waste water treatment plants treated 95% of waste water in Denmark. Table 7.3 gives an overview on the amount of N discharge from waste water.

Table 7.3 Nitrogen discharges to the aquatic environment with waste water (Source: NOVANA)

Source[1]	3rd period (2000-2003)		4th period (2004-2007)		5th period (2008-2011)		6th period (2012-2015)	
	2000	2003	2004	2007	2008	2011	2012	2014[2]
Urban waste water	4 650	4 530	4 030	3 620	3 500	3 900	3 800	3 500
Industrial waste water	900	750	500	500	400	310	220	285

[1)] This is a non-exhaustive list - there are more point sources than urban and industrial waste water.
[2)] Data for 2015 not yet available

Additionally, the N discharge to the aquatic environment from aquaculture sums up to circa 1.040 tons N/year in 2014. Two thirds are discharged from fresh water plants and one third from plants in salty waters. The approximate N amount, discharged from aquaculture has not changed since 2011.

Literature

Windolf, J., Hans Thodsen, Lars Troldborg, Søren E. Larsen, Jens Bøgestrand, Niels B. Ovesen & Brian Kronvang, (2011)b: A distributed modeling system for simulation of monthly runoff and nitrogen sources, loads and sinks for ungauged catchments in Denmark. J. Environ. Monit., 2011, 13, 2645-2658. Kan downloades på http://pubs.rsc.org/en/Content/ArticleLanding/2011/EM/c1em10139k

Wiberg-Larsen, P., Windolf, J., Bøgestrand, J., Larsen, S.E., Tornbjerg, H., Ovesen, N.B., Nielsen, A., Kronvang, B., & Kjeldgaard, A. 2015. Vandløb 2014. NOVANA. Aarhus Universitet, DCE - Nationalt Center for Miljø og Energi, 54 s. - Videnskabelig rapport fra DCE - Nationalt Center for Miljø og Energi nr. 165
http://dce2.au.dk/pub/SR165.pdf (in Danish)

7.3 Evaluation of the implementation and impact of the action programmes' measures

Danish Environmental Protection Agency, Ministry of Environment and Food of Denmark

7.3.1 Nitrates in water leaving the root zone

This section deals with the general development in nitrate leaching from 1990 to 2014. Data for 2015 is not yet available.
Information on agricultural practises is derived from the Agricultural Catchment Monitoring Programme and provided to the Agency by Gitte Blicher-Mathiesen and Jonas Rolighed (Department of Bioscience, Aarhus University). It has also already been reported to the EU Commission in the annual derogation reports.

This Agricultural Catchment Monitoring Programme (Danish abbreviation: LOOP) includes six small agricultural catchments situated in various parts of the country in order to cover the variation in soil type and rainfall and hence in agricultural practises. The farmers are interviewed every year about livestock, crops and fertilisation and cultivation practises.

7.3.1.1 Development in modelled nitrate leaching in the Agricultural Catchment Monitoring Programme (LOOP), 1990-2014

Nitrate leaching is modelled for every field in the LOOP catchments, based on the information provided by the farmers on agricultural practises and standard percolation values (calculated on the basis of the average climate for 1990-2010).

The trend in modelled nitrogen leaching from the agricultural area in the catchments from 1990 to 2014 (representing the hydrological years 1990/91 to 2014/15) is shown in Figure 7.1 as an average for sandy and loamy catchments, respectively.

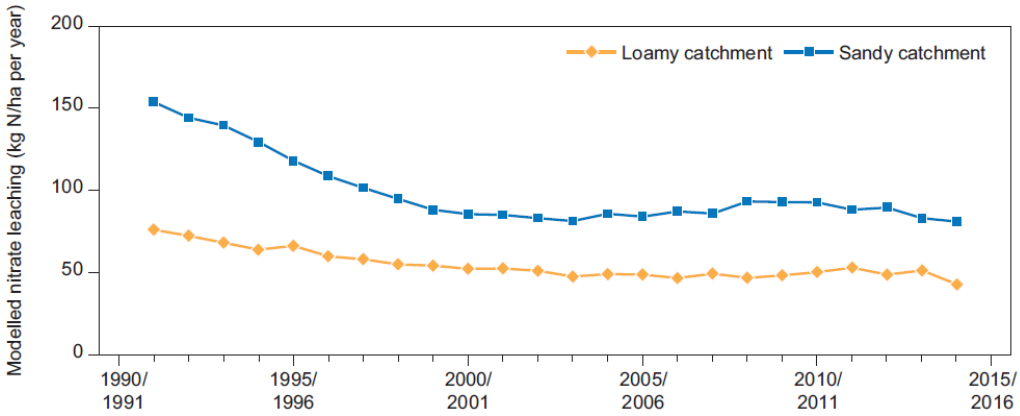

Figure 7.1 Modelled nitrate leaching in a standard climate for the fields of the Agricultural Catchment Monitoring Programme, 1990/91-2014/15 (Source: Danish Derogation Report 2015)

Taking the distribution of the main soil types in Denmark into consideration, it was found that modelled nitrate leaching was reduced by 43% during the period 1991 to 2003, due to the general improvement in agriculture and fertilisation practises. After 2008, there was a small increase in nitrate leaching, particularly on sandy soils, probably caused by suspension of the set-aside obligation. After 2011, the modelled nitrate leaching for the sandy soils again decreased and reached the same level as before 2008. For the loamy soils, modelled nitrate leaching was less affected during the years 2008-2013. For 2014, the nitrate leaching was estimated to be 43 and 81 kg N/ha for loamy and sandy soils, respectively.

The purpose of the root zone modelling is to show the effect of measures introduced in agriculture. The modelling is therefore carried out for normalised growth conditions, i.e. for climatic data representing measurements in 1990-2010 and for average crop yields. Actual measurements (see 7.3.1.2) are expected to show higher annual variations as the measurements depend on the actual climate.

7.3.1.2 Measurements of nitrate in water leaving the root zone

In five out of the six Agricultural Monitoring Catchments (LOOP), water samples are collected regularly at in total 30 sites. The samples represent the root zone water and the upper oxic groundwater (1.5-5 m depth). The measured concentrations are shown as annual average values for loamy and sandy soils, respectively, for the period 1990/91-2013/14 (Figure 7.2).

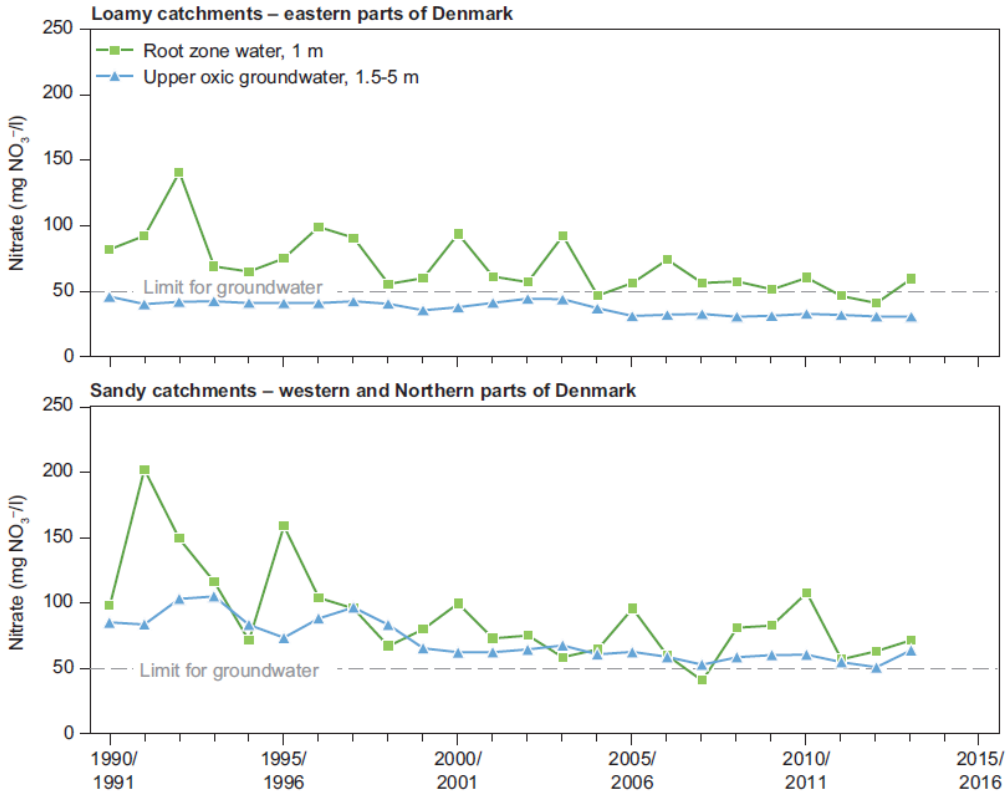

Figure 7.2 Annual flow-weighted nitrate concentrations measured in root zone water and annual average nitrate concentrations measured in upper oxic groundwater, the Agricultural Catchment Monitoring Programme (LOOP) 1990/91-2013/14 (Source: Danish Derogation Report 2015)

There is strong interannual variation in measured nitrate concentrations due to variations in rainfall and temperature. Therefore, a long time series and a large number of measuring points are needed to detect a statistically significant trend. Such data series are available from the Danish Monitoring Programme and a statistical trend analysis showed that the nitrate concentrations in water leaving the root zone, with 95% probability, have decreased by 21 and 67 mg NO_3 l^{-1} for loamy and sandy soils, respectively, during the years 1990/91-2003/04, corresponding to a relative reduction of about 23 % and 48 %, respectively. After 2003/04, no statistically significant change in measured nitrate concentrations in soil water leaving the root zone has been recorded. However, within the past five years, high concentrations have been observed temporarily for sandy soils. This is most likely a coincidence in local farming practice on the specific fields within the catchment during the period, e.g. cultivation of crops with high leaching potential on these fields, such as turn-over of grassland followed by cereals with no catch crops the following years, growing of maize and winter rape etc.

It should be noted that the measurements of nitrate leaching originate from a small number of samplings stations (30 stations). Furthermore, the measurements are affected by high crop yields in particular in 2009 and effects of crop rotation especially of grass in rotation. These conditions contribute to a trend in the measured nitrate concentration in the root zone water, exhibiting higher interannual variations than seen in the modelled nitrate leaching covering a larger area from approx. 120 fields (Figure 7.1).

In the upper groundwater (1.5-5.0 m below surface), nitrate concentrations are lower than in the root zone water, indicating that nitrate reduction occurs in the aquifer sediment between the bottom of the root zone and the uppermost groundwater (Figure 7.2). The annual variations in upper oxic groundwater concentrations follow the same pattern as root zone water, but with a

time lag of about one year. During the years 2003/04 to 2013/14, the annual mean concentrations in upper oxic groundwater varied from 3-44 and 54-68 mg NO_3 l^{-1} for the loamy and sandy sites, respectively. For the five-year period 2009/10 to 2013/14, the upper groundwater concentrations were 31 and 58 mg NO_3 l^{-1} for loamy and sandy sites, respectively.

The general conclusions to be drawn from the Agricultural Catchment Monitoring Programme are that:

- Nitrate concentrations in root zone soil water (1.0 m below soil surface) have decreased steadily from 1990 to 2004, approaching the ground water limit of 50 mg nitrate l^{-1}. Since 2004, these concentrations have remained almost constant, with some annual variations, though.
- Nitrate concentrations in the upper oxic groundwater (1.5-5.0 m below soil surface) decreased to a level below the limit of 50 mg NO_3 l^{-1} for loamy catchments and to a level between 52 and 65 mg NO_3 l^{-1} for the two sandy catchments in the period 2009/10-2013/14.

7.3.2 Difference between input and output of nitrogen

As published in the annual reports of the national monitoring programme for the aquatic environment and nature (NOVANA), the national usage of commercial fertilizer has decreased from 394.000 tons N in 1990 to ca. 203.000 tons N in 2014. The data for 2015 is not yet available. Nitrogen input in form of livestock manure has decreased from ca. 244.000 tons N in 1990 to approx. 228.000 tons N in 2011. The overall N-input consists of all sorts of fertilizer, including input from grazing as well as N-fixation and atmospheric deposition. On the output side, the yield has been on a relatively constant level with some interannual variations, especially in the early years and again from 2007 onwards. In 2014, a generally relatively high cereal yield, does not significantly increase the N-output, as the N content in the harvested plant material, including seeds, has been low.

The annual surplus in the national field balance has consequently also fallen: from approx. 405.000 tons N in 1990 to ca. 220.000 tons N in 2014, which corresponds to a reduction by more than 40%. While the most significant reduction could be observed until 2003, a smaller decrease by approx. 10.000 to 25.000 tons N could be observed in the following years (Figure 7.3).

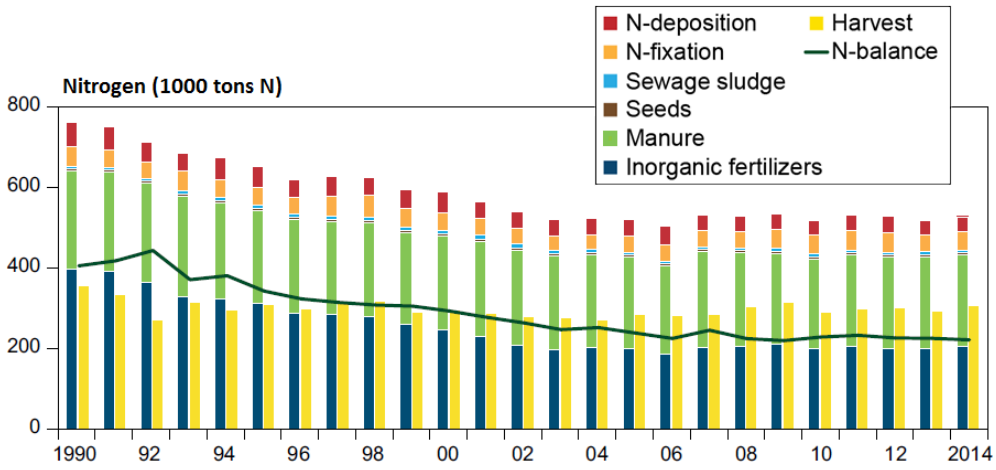

Figure 7.3 Danish field balances for Nitrogen (until 2014) (Source: NOVANA Vandmiljø og Natur 2014)

Since 1990, the utilization of nitrogen in animal slurry has been improved significantly. This can be regarded as a result of binding N-norms, an increase in slurry storage capacity, a higher proportion of slurry being spread during spring and summer and the investment in and use of advanced slurry application techniques (Table 7.4).

Table 7.4 Overview on development of key parameters concerning the use of animal slurry within the LOOP-monitoring programme in 1990 and during the reporting period (2012-2014, data for 2015 not yet available) (Source: NOVANA LOOP 2014)

Parameter	1990	2012	2013	2014
Storage capacity for liquid animal slurry, corresponding to 9 months production (% of LU)	38	86	100	100
For the different farm types:				
Pigs		100	100	
Cattle		71	100	
Other		100	100	
Spreading of liquid slurry[1] during spring & summer (% of LU)	55	94	94	94
Slurry application with trail hose or injection (% of total N in liquid animal slurry applied)	8	100	100	100
Percentage applied by trail hose (%)		40	40	43
Percentage injected (%)		60	60	57

[1] the annual amounts of livestock manure for the year 2011 has also been used for the years 2012-2014

Broadspreading of animal slurry has been banned since 2003. Since 2011, farmers are obliged to inject slurry on grass or bare soil. Most probably because of slurry acidification, followed by trail hose application, being accepted as an alternative to injection since 2012, the share of slurry being injected has slightly decreased in 2014.

More detailed field balances, given in kg N per hectare can be found in Table 7.5. Also there, the significant decrease in application of commercial fertilizer since the 1990's can be found. While keeping the amount of harvested N relatively constant since the late 1990's, the N balance could therefore be decreased substantially, remaining at stable level during the years 2012 to 2014.

Table 7.5 Data on field balances for whole territory (kg N/ha) cultivated area until 2014 (Source: NOVANA LOOP 2014)

Year	1990[1]	1998[1]	2007[2]	2011[2]	2012[2]	2013[2]	2014[2]
Inorganic Fertilizer	142	104	73	76	74	74	76
Livestock manure[3]	88	87	87	85	85	85	85
Sewage sludge	1	1	1	1	1	1	1
Industrial waste	1	2	2	2	2	2	2
Seeds	2	2	2	2	2	2	2
N-fixation	18	20	15	18	18	16	17
N-deposition[4]	39	30	26	25	26	24	25
Applied[4]	273	233	194	198	197	193	197
Harvested	145	115	107	113	114	114	117
N balance[5]	**128**	**118**	**87**	**85**	**83**	**79**	**80**
Cultivated area (1000 ha)	2788	2672	2744	2693	2679	2671	2661

[1] data for mineral fertiliser based on information from "Danmark Statistik"

[2] data for mineral fertiliser based on information from the Fertilizer Accounting System (since 2005)

[3] By the time of the publication of the latest NOVANA LOOP report, the annual amounts of livestock manure had not been updated for the years 2012-2014 yet. Therefore the value for 2011 has been assumed for the following years, too.

[4] data for N-deposition is the sum of natural N-deposition and N-deposition, caused by agricultural activities

[5] since 2005 based on data from Fertilizer Accounting System

Also the fertilizer usage, for both Nitrogen and Phosphorus, has during the years of the current reporting period (2012-2014, data for 2015 not yet available) remained at a relatively low level as in the years before (2007 and onwards), compared to the early 1990's (Table 7.6).

Table 7.6 Development in fertilizer usage until 2014, the year refers to the year of harvest (Source: NOVANA LOOP 2014)

Year	1990	1998	2007	2011	2012	2013	2014
Nitrogen (1000 tons N)							
Mineral fertilizer	400	283	202	204	198	199	203
Livestock manure[2]	244	278	238	228	228	228	228
Total N[1]	760	623	530	530	527	516	526
Phosphorus (1000 tons P)							
Mineral fertilizer	40.4	20.7	13.4	10.8	11.8	11.3	13.0
Livestock manure[2]	54.6	55.9	45.9	41.3	41.3	41.3	41.3
Total P[1]	98.5	84.0	66.1	58.9	59.9	59.4	61.1

[1] incl. other sources: seeds, (sewage) sludge, industrial waste deposition and in the case of N also N-fixation and other organic fertiliser

[2] By the time of the publication of the latest NOVANA LOOP report, the annual amounts of livestock manure had not been updated for the years 2012-2014 yet. Therefore the value for 2011 has been assumed for the following years, too.

Success in maintaining a relatively constant yield level, while cutting the N-input to a great degree, and hence reducing the potential loss of surplus nutrients to the environment has been one of the achievements of Danish agricultural regulation and performance of the farmers in Denmark.

7.4 Percentage of farmers visited each year by the supervising authorities or their delegates

Danish AgriFish Agency, Ministry of Environment and Food of Denmark

Provisions on crop rotation, fertilizer planning and catch crops as well as provisions on rational fertilization use taking into account physical, climatic conditions and irrigation among other parameters are implemented in Act 500/2013 on the “Farms’ use of Manure and on Plant Cover”, including the annually revised “Statutory Order on Farms’ use of Manure and on Plant Cover” and annually revised “Statutory Order on Nitrogen Prognosis”.

Administrative staff of the Danish AgriFish Agency control the provisions of “Act on Farms’ use of Manure and on Plant Cover”, including “Statutory Orders on Farms’ use of Manure and on Plant Cover” and on Nitrogen Prognosis. Besides the administrative control, they also inspect farms on the spot.

Inspection on the spot covers control of crop rotation planning, including plant cover and catch crops, fertilizer planning, fertilizer account, but also the provisions regarding application of the amount of livestock manure to land each year (harmony rules) laid down in Statutory Order 1318/2015.

In 2014, the Danish AgriFish Agency carried out 751 inspections on the spot, regarding the orders mentioned above, corresponding to approx. 1.9 % of all agricultural holdings.

The on-spot inspections regarding fertilizer accounts support the control carried out on basis of the annually submitted data in the fertilizer accounting system. During the on-site inspections, compliance with the requirements of fertilizer accounts and requirements regarding use of fertilizers are controlled. In 2014, 445 inspections of fertilizer accounts were carried out. 43 of these (9.6 %) were reported to the police for severe violations of the provisions on rational fertilizer use. This share illustrates an increase in farms with severe violations, compared to the previous data from 2010 (2.7 %). Nevertheless it is important to highlight that the choice of farms to be inspected in 2014 has been made based on a specific set of risk criteria to a greater extent rather than randomly, which inevitably leads to a higher possibility of finding violations. Additionally 7 (1.6 %) farmers were given an enforcement notice and 2 cases are still under investigation. The same 445 inspected farms were also controlled regarding the amount of livestock manure applied to land each year (harmony rules). 12 of these farmers (2.7 %) were reported to the police for severe violations of the harmony rules, 1 (0.2 %) farm was given an enforcement notice, 1 case is still under investigation.

In 2014 the Danish AgriFish Agency carried out 257 on-site inspections on catch crops. 8 of the 257 inspections (3.1 %) on crop rotation planning were reported to the police and 12 farmers (4.7 %) received an enforcement notice for non-compliance with the requirements on 10 % or 14%, respectively of the area to be covered with catch crops.

The vast majority of all Danish farmers must submit data to the Fertilizer Accounting system each year, which is administrated by the Danish AgriFish Agency. In 2014, 38,550 farmers were obliged to submit a fertilizer account. All submitted fertilizer accounts are automatically checked at submission by the IT-system, according to a set of previously defined risk criteria. An administrative control of fertilization status accounts from year 2012/2013 showed that 42 farms corresponding to 0.11 %, exceeded the farm nitrogen quota by up to 9 kg N per hectare. 29 farms corresponding to 0.08 %, exceeded the farm nitrogen quota by more than 9 kg N per hectare.

8. Economic analysis with respect to nitrogen reduction in Denmark 2012-2015

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The first River Basin Management Plan (RBMP) from 2011 included measures suggested by the so called “Committee for Measures II”. The total effect of the measures was meant to reduce the N-load to the coastal waters by around 9,000 tons N, but this reduction aim was later reduced (see Table 8.1). The expected costs from 2011 and from the re-estimation in 2012 were included in the last reporting (5th period: 2008-2011). The farm measures included in Table 8.1 are reduction in farmland (area used for roads and houses), no tillage in the autumn, no ploughing of grass fields in the autumn and the introduction of more catch crops to replace green crops (winter cereal crops). The N-norms used to increase when area was taken out of production as the same amount of N-norms nationally was distributed over a slightly smaller area. This was changed with the 2011 plans and so the expected increase in N-norms over time does not occur any longer. The next section in Table 8.1 shows measures like wetlands and riparian zones, which are financed by the state, whereas the costs, related to the farm measures, were paid by the farmers.

The economic costs of the measures have later been estimated by the Nature Agency (Nature Agency, 2014). Many of the same measures are included in the national catalogue of measures from 2014 (Eriksen et al., 2014). The costs are more or less on the same level for the measures in Table 8.1, but the costs of no ploughing down grass in the autumn to prevent N-losses has been reduced. Other measures, such as set-a-side (not included in Table 8.1), have increased costs, as the income in the previous years (2011-13) was relatively high. The total costs estimated by the Nature Agency in 2014 including 60,000 ha of catch crops was around 13.5 million € per year.

The riparian zones (or buffer zones) were intended to be 10 meter wide along all streams and small lakes, which is equivalent to 50,000 ha (under 2% of the agricultural area). The compensation was intended to be 282 € per ha for an area in rotation and 161 € for an area with permanent grass. The overall compensation is in line with the expected long term economic losses, but some farms will have higher costs than the compensation, whereas some will have lower costs than the compensation. In the short run some farms will have higher costs related to adjustment of capital, labour costs and other fixed costs. The compensation is slightly higher than the average rent paid when renting farm land.

The area with riparian zones was originally 50,000 ha, but due to several issues it was later reduced to 25,000 ha along targeted streams. Some farms were not able to get compensation in the first year, as they hit the limit for compensation per farm. In the second year (2015) riparian zones became part of the greening requirement in the Common Agricultural Policy (CAP), which meant that no compensation was given directly to riparian zones as they were part of the requirement related to the basic payment (the former single payment scheme) and support cannot be paid twice for the same measure.

Table 8.1 Re-estimated costs for agriculture of RBMP from 2011

			Green Growth[1]		Re-estimation 2012		2014-catalogue[4]
Measure	**Area (ha)**	**N Effect (tons N/a)**	**Cost (million €/a)**	**Cost effect. (€/kg N lost to the sea)**	**Cost (million €/a)**	**Cost effect. (€/kg N lost to the sea)**	**Cost effect. (€/kg N lost to the sea)**
Still active in 2015							
Reduced farmland (average for 5 years)		1.008	0.0	0.0	5	5	
No tillage in autumn	111.000	739	0.1	0.1	0.1	0.1	0.1-0.5
No ploughing of grass fields in the autumn	15.000	230	0.1	0.9	0.9	4.0	6
Catch crops replacing green crops	50.000	690	2.8	4.0	3.2	4.7	2.2-8.5
Sub-total 1		**2.667**	**3.0**	**1.1**	**9.2**	**3.4**	
Riparian zones[2]	25.000	725	0	5	0	6-10	21-42
Wetlands[3]	9.000	920	0	7	0	7	4-5
Sub-total 2		**4.312**					
Later redrawn							
New targeted catch crops	140.000	1.706	7.9	4.0	9.1	5.4	2.2-8.5
In total		**6.018**	**11.0**		**18.3**		

Notes:

[1)] Green Growth is the political agreement on environmental issues from 2009. Green Growth was amongst others implemented via the first River Basement Management Plans (RBMP).

[2)] The costs for riparian zones was 12.8 million €, which is equivalent to 5 € per kg N lost to the sea. The cost is paid by the state, but based on Rural Development program. Due to delays and ceilings with respect to total payment per farm the payment was not carried out as intended. (The riparian zones were finally terminated in the spring 2016.) Riparian zones were firstly assumed to cover 50,000 ha but later reduced to 25,000 ha. Not all farmers received support in 2014 and from 2015 it became part of the green requirement for the new Basic Payment. The costs for 2014 have not been re-estimated. The effect in the 2014 catalogue was 37-74 kg N/ha in the root zone and an estimated effect of 40 kg N/ha has been used in some calculations by University of Aarhus. The loss of income (460 €/ha) is higher in the 2014 catalogue as the income was higher in the period used in the calculations (2011-2013). This also affects the calculations for wetlands in the Catalogue. The Ministry has later in 2016 decided to use an effect of 725 ton or 29 kg N/ha (The Danish AgriFish Agency (NAER), 2016).

[3)] Wetlands cost around 13,400 €/ha or 830 € per ha per year based on 50 years and 6%. With 113 kg N/ha this is equivalent to 7 €/ kg N. The effect in the 2014 catalogue is set at 120-190 kg N/ha, but the Nature Agency has lately reduced the effect to 90 kg N/ha based on the actual effects of wetlands. The costs used in the catalogue is 500-850 €/ha.

[4)] The N-retention used is 70%.

Source: Jacobsen, 2012, Eriksen et al. (2014)[4] and own calculations.

The effect of the riparian zones along streams has been discussed, just as the actual location of streams (not targeted streams) has been a problem. Although this measure has an effect with respect to nitrogen, phosphorus and nature, the implementation issues as well as the uncertainty regarding compensation has meant that the initial riparian zones are not a part of the RBMP in 2016. It is likely that the cost (€/kg N) of this measure will be higher today, as the effect in kg N/ha is lower than in 2011.

As noted in Table 8.1 the targeted catch crops have later been redrawn and both the total effect and the total costs are therefore lower than anticipated in 2011. The costs of the new measures for agriculture are not more expensive per kg N, than the measures, financed by public funding (e.g. wetlands).

Targeted catch crops of 140,000 ha was later changed to 60,000 ha of wetlands, but then later redrawn, partly based on a fear that the costs might be too high. This care was taken so that the total share of catch crops would not be higher than 20% on farms in a given sub-catchment. Catch crops has in this been used by farmers to replace other measures (lower nitrogen) and in connection with approval for a larger livestock production.

Finally the effect of the reduced N-norms has increased over the years and so have the costs. The N-norms were originally reduced by 10%, but over time this has increased to 14-16% under economic optimum in 2010/11 to 2013/14 and 18% in 2014/15. The increased reduction percentage over time is due to many factors. One key factor was the abolishing of set-a-side which, with the same N limit nationally, meant that the norms pr. ha they were reduced. Another issue has been the increase in economic optimal N application over time as new varieties have a higher yield potential. With a fixed national N-norm (the “N-bag”/N-ceiling) this has led to an increase in the percent under the economic optimum, which may be applied. This will led to higher costs related to land taken out of production as the marginal value of nitrogen now is higher.

The higher reduction percent have increased the costs of this measure. The costs of a reduction of around 15% are in 2016 analysis 600 to 1000 million DKK (81 - 134 million €/year), which is slightly higher than previous estimates in 2013 (3-5 hkg/ha). These estimates are based on yield reductions estimated by Aarhus University. Analyses, based on the yield reductions in the annual trails made by IFRO (University of Copenhagen), indicate a cost of 300 - 500 million DKK (40 - 67 million €/year) in case of a 15% N-norm reduction. It is still discussed what the short and long term effects on yields will be and also what the costs of lower N-application actual is. Without the increase in N-reduction percentage over time the N-application (kg N/ha) would have increased over time. This change would on its own have increased the yield and the N-leaching.

In total, the costs for agricultural sector estimated in 2012 was 18 million € per year and around 9 million for the farming measures included in sub-total 1 (Table 8.1). The later re-estimation made by the Nature Agency showed a cost of 13.5 million €/year including 60,000 ha catch crops. It is likely that the actual total costs of the implemented measures (sub-total 1) will not be too different from this estimate.

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9. Forecast of the future evolution of the water body quality

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Nitrogen pressure on coastal Waters
Currently 2 coastal water bodies of the total 119 coastal water bodies in Denmark are in good ecological status. The coastal waters are affected by a number of pressures. However, the primary reason for the missing fulfillment of the environmental objectives is a too high nitrogen load. Therefore, the efforts in the River Basin Management Plans (RBMPs) for 2015-2021 are focused on reducing the nitrogen loads to coastal waters. The all-important anthropogenic source to the nitrogen load to coastal waters is the loss of nitrogen from arable land.

In the RBMPs published in June 2016, it is estimated that the land-based Danish nitrogen losses to Danish coastal waters must be reduced to approximately 44,700 tons N/year (target load) to support the coastal waters to meet good ecological status. In the model calculations it is assumed that other member states reduce their load correspondingly to a level that supports the achievement of the targets (burden-sharing). An effort from the Danish side alone will not bring the more open parts of Danish coastal waters in good status.

Based on the current nitrogen load to coastal waters (2012) of approximately 56,800 tons N/year the nitrogen load reduction needed to support good ecological status of coastal waters is estimated to about 13,100 tons N/year, if based on the target load of 44,700 tons N/year. This corresponds to a reduction of the nitrogen load by 23 % on national level. In 2012 agricultural activities were the cause for about 70 % of the Danish land-based nitrogen load to coastal waters.

Target loads for each coastal water body are "Danish targets loads" and generally based on the premise that measures to achieve good environmental status in the adjacent Danish water bodies are implemented until 2027; and further that internationally measures against waterborne as well as airborne nitrogen emissions towards 2027 are also implemented.

Expected achievement of environmental objectives in coastal waters by 2021
The following three management actions will affect the level of achievement of environmental objectives in coastal waters in 2021:
1) Baseline 2021, which can be characterized as the accumulation of the effect of measures already in place, structural development etc.;
2) Adjustment of general Nitrogen regulation and
3) newly introduced measures for 2015-2021.

These three actions mean that the Danish land-based nitrogen loading of coastal waters in 2021 is expected to be reduced to a level supporting that 50 of 119 coastal water bodies (42%) will meet the objective of good ecological status. Today 2 coastal water bodies are in good ecological status.

Final River Basin Managements Plans 2015-2021 were adopted and publishes on June 27, 2016. Data has been consolidated in the final River Basin Managements Plans for 2015-2021.

The nitrogen loads to coastal waters in the second planning cycle 2015-2021 is thereby expected to be reduced annually by about 7,300 tons of nitrogen (13%), from about 56,800 tons N/year in 2012 to about 49,500 tons N/year in 2021. The reduction in the land-based nitrogen loads to coastal waters until 2021 is a result of the management actions, shown in Table 9.1.

Table 9.1 Effect of Nitrogen load reductions to coastal waters by different management actions until 2021

Management actions	Effect of load reductions of coastal waters (tons N/year)[1]
1. Baseline 2021[2]	5,600
2. Adjustment of general Nitrogen regulation	-5,200
3. Measures 2015-2021	6,900[3]
TOTAL	**7,300**

[1] The scheme is according to the the final RBMPs published in June 2016.

[2] Baseline 2021: is the reduction in nitrogen loads to coastal waters expected as a result of already implemented or planned measures within the river basin districts.

[3] The more different types of measures used, the more likely it is that some of these are implemented in areas/catchments without a nitrogen reduction need. For the specific measure, EFA (ecological focus area), it is not possible to place the effect targeted in areas with a nitrogen reduction need, while this is possible for other measures.

The adjustment of general Nitrogen regulation includes: Lifting the reduced general fertilization standards for nitrogen to the level of economic optimum, a minor adjustment of the prohibition of soil tillage in the autumn, the growth plan for aquaculture, annulment of the statutory buffer strips along lakes and watercourses.

Measures 2015-2021

New initiatives towards 2021, including targeted efforts (nitrogen reduction) from 2019, are expected to reduce discharges to coastal waters with appr. 6,900 tonnes N/year. The effort will be allocated on the following measures (Table 9.2):

Table 9.2 Effect of N load reductions to coastal waters by measures introduced in the years 2015-2021

Measure	Effect of load reductions of coastal waters (tons N/year)[1]
• Establishments of constructed wetlands	1,253
• Establishment of small constructed wetlands (mini-wetlands)	900
• Afforestation (establishing new forest)	150
• Set-aside of farmland on organogenic soils in river valleys	150
• Ecological Focus Area (EFA) - the EFA area can be established by buffer strips, catch crops, fallow land, coppice and GAEC(Good agricultural and environmental conditions) landscape elements	867
• A targeted regulation of nitrogen leaching at farm level	3,500
• Improved wastewater treatment	44
• Reduction of number of fishfarms (acquisition of fishproductions quotas)	84
TOTAL	**Approx. 6,900**[2]

[1] The measures are agreed as part of the Growth and Agricultural packages from December 2015 and the effects are adjusted according to the final RBMPs published in June 2016.[2] The more different types of measures used, the more likely it is that some of these are implemented in areas/catchments

without a nitrogen reduction need. For the specific measure, EFA (ecological focus area), it is not possible to place the effect targeted in areas with a nitrogen reduction need, while this is possible for other measures.

Part of the nitrogen reduction need for coastal waters corresponding to the remaining 6,200 tons N/year approximately is postponed to the 3rd planning cycle.

Achievement of environmental objectives in groundwater

In the draft river basin management plans for the period 2015-2021 the assessment of chemical status for groundwater bodies is based on groundwater quality standards and threshold values for pollutants. Currently, 170 (out of 402) groundwater bodies are in good status, 109 groundwater bodies are in poor status, and 123 bodies have unknown status. Of the 109 groundwater bodies in poor chemical status, 17 have been identified to be in poor chemical status in relation to nitrate, i.e. more than 20% of each of these groundwater bodies is assessed to have a nitrate concentration exceeding 50 mg/liter. In addition, a significant and sustained upward trend in the concentrations of one or more pollutants has been identified in 37 groundwater bodies. Of these 37 groundwater bodies 23 groundwater bodies have been identified with a significant and sustained upwards trend above 75% of the groundwater quality standard with regards to nitrate. Of these 23 groundwater bodies 4 have been identified to be in poor chemical status in relation to nitrate.

The planned targeted regulation is expected to be in effect as of the growing year 2018-2019 and replacing the existing nitrate regulation of agriculture, is also intended to protect the groundwater. It is thus presupposed that on a long term basis the new targeted regulation along with the baseline 2021 and the existing general regulation will meet the need of measures for groundwater bodies as proposed in the draft river basin management plans 2015-2021. Thus groundwater bodies in poor chemical status in general are expected to reach good chemical status after 2021. A potential need for supplementary measures will be investigated further during the second plan period. It should be noted that in general the chemical status of groundwater bodies develops slowly.

Environmental objectives for watercourses and lakes and relevant pressures

In Denmark watercourses and streams are relative short compared to major rivers in Europe. The national monitoring program and the scientific studies indicate that the ecological water quality in Danish rivers and streams is not affected significantly by emissions of nitrogen and phosphorus.

Emissions/discharges of phosphorus are the most important pressures to obtain good ecological water quality in lakes. New measures as improved wastewater treatment and constructed wetland/mini-wetlands will reduce the discharges of phosphorus in the catchment areas to lakes.

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