Ministry of Environment
of Denmark

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

Report to the European Commission for the period 2016-2019 in accordance with article 10 of the Nitrates Directive (1991/676/EEC)

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Authors/responsible institutions of the different chapters of this report can be found under the heading to the respective sections. Where no one is mentioned it is the Ministry of Environment of Denmark

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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 2016-2019 and is accompanied by aggregated maps of nutrient pressures from agricultural sources, of water quality and of designated nitrate vulnerable zones.

2. Summary

Watercourses
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 (2012-2015) and current period (2016-2019) show that in 60 % of the watercourses, the concentrations are unchanged, there is an increase in 31 % of the watercourses, and in 9 % of the watercourses shows a weak or strong reduction in the flow-weighted annual average NO_3-concentration. In the previous reporting, most monitoring stations had reduced nitrate concentrations compared to the previous period. In the 7th reporting, changes have been smaller and in both directions. This should primarily be seen as random effects.

Lakes
In general, annual average nitrate concentrations are low – compared to the Nitrates Directive limit on 50 mg/l: 65% of the lakes have an annual mean concentration less than 2 mg NO_3^-/l.
Despite the nitrate concentrations are influenced by climatic conditions (such as precipitation), there are no changes from the 6th and 7th period for the majority of lakes. The concentration levels are stable in 75% of the monitored lakes. The annual average nitrate concentrations in the 7th period (2016-2019) in Danish lakes range from 0.14-19.0 mg NO_3^-/l with an average of 3.2 mg NO_3^-/l.

Winter average concentrations are generally higher than the annual average concentrations (19 out of 20 lakes) and vary between 0.1 and 30.5 mg NO_3^-/l with an average of 4.3 mg NO_3^-/l. This is due to higher loading, low primary production and less denitrification during winter. The maximum concentrations varies between 0.2 and 70.8 mg NO_3^-/l. One lake had a maximum concentration above 50 mg NO_3^-/l.

Estuarine, coastal and marine waters
During the 7th period (2016-2019) the highest average NO_3^- winter concentrations were observed in the estuaries with a maximum average concentration of 12.2 mg NO_3^-/l and with the lowest concentrations monitored in the marine open waters, where the average NO_3^- concentration did not exceed 1.0 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 6th period) and this 7th period have been estimated by a statistical approach rather than by use of absolute concentrations.

For annual averages, long-term trends (difference between 2016-2019 and 1996-1999) and short-term trends (difference between 2016-2019 and 2012-2015) can be calculated for 37 and 51 stations, respectively. For long-term trends (annual averages), concentrations are stable at 27 stations and significantly decrease at 10 stations. For short-term trends (annual averages), the concentrations are stable at 47 stations, significantly decreasing at 2 stations and very significantly decreasing at 2 stations.

For winter averages, long-term trends and short-term trends can be calculated for 55 and 69 stations, respectively. For long-term trends (winter averages), concentrations are stable at 38 stations, significantly decreasing at 5 stations, very significantly decreasing at 4 stations, significantly increasing at 6 stations and very significantly increasing at 2 stations. For short-term trends (winter averages), concentrations are stable at 63 stations, significantly decreasing at 3 stations and very significantly decreasing at 3 stations, and there are no stations with significant increases

Groundwater

The Danish groundwater-monitoring programme was originally 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 are closed and new established during the last reporting periods. The adjustment of the monitoring network was finalised in 2019. Over the last 12 years, i.e. over the last three reporting periods, groundwater from in total 1.623 monitoring points have been analysed for nitrate over time and of those 929 points are common for the three periods (2008-2011, 2012-2015 & 2016-2019).

When comparing the average nitrate concentrations of 1105 monitoring points that are common for the latest two reporting periods (2012-2015 & 2016-2019), decreasing groundwater nitrate concentrations (31.3 %) can be found in more monitoring points than increasing concentrations (18.3 %) while no trend can be observed at 50.4 % of the monitoring points. The major part (about 80 %) of the monitoring points have an average nitrate concentration below 40 mg/l, as shown in figure 3.18, where the distribution of the average nitrate concentrations in all monitoring points (2016-2019) is illustrated. In general, both increasing and decreasing trends can 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. These data have been used to assess the general nitrate trend in oxic groundwater in Denmark (Figure 3.23, Hansen et al., 2017). The results indicate an overall decreasing 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. The overall trend in regard to reducing the groundwater nitrate content is generally positive, but several locations still record increases (Figure 8, Hansen et al., 2017). This includes some of the most recently created groundwater, which was formed after the water environment action plans came into force. The latest monitoring data on the development of nitrate in oxic groundwater indicate that the nitrate content in the youngest groundwater remains stable. (Thorling et al, 2019).

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 2019 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 2019. 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 2016-2019. In

2017 the “targeted catch crops scheme” was introduced to reduce N-losses through promoting the establishment of additional catch crops for the years 2017-2019. The scheme was designed to protect both groundwater bodies and coastal waters.

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 2016 to 2018, was within a similar range as in the previous reporting period. Seen relative to the distribution of the main soil types in Denmark, the modelled nitrate leaching decreased by 43% during the period 1991 to 2003 due to the general improvement in agriculture and fertilization practises. After 2003, there was a small increase in nitrate leaching, particularly on sandy soils, probably caused by suspension of the set aside obligation. For the loamy catchments, the modelled annual nitrate leaching was less affected by the change in set aside. The nitrate leaching was relatively stable around 50 kg N ha^{-1} during 2003-2013, decreasing with app. 8 kg N ha^{-1} in 2014 and 2015 and increasing again to the level of 2003-2013 in 2016-2018. For the sandy catchments, the annual leaching of 81 kg N ha^{-1} in 2003 was relatively low. After this year, the leaching increased to an interval of 83-93 kg N ha^{-1} in the period 2004-2014, but decreased to a lower level than in 2003, being in the interval of 77-79 kg N ha^{-1} in 2015-2018.

In the Agricultural Catchment Monitoring Programme (LOOP) on loamy catchments, the measured nitrate concentrations in the upper oxic groundwater decreased from 41-46 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 28-31 mg NO_3 l^{-1} in the 5-year period 2013/14-2017/18. On sandy catchments, the nitrate concentration decreased from 87-110 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 58-77 mg NO_3 l^{-1} in the 5-year period 2013/14-2017/18.

The annual nitrogen surplus in the national field balance (added minus harvested) has fallen: from approx. 405.000 tons N in 1990 to 265.400 tons N in 2018, which corresponds to a reduction by 34%. In 2018, the surplus is higher than normal because of the drought causing low yield. The most significant reduction could be observed until 2003

Control and inspection
In the planning period 2016/2017, the Danish Agricultural Agency carried out 121 inspections on the spot, 1.7 % were reported to the police for severe violations and 0.8 % receives an administrative fine for a severe violation of the provisions on rational fertilizer use. This share illustrates a decrease in farms with severe violations, compared to the previous data from 2014 (9.6 %).

The vast majority of all Danish farmers must submit data to the Fertilizer Accounting system each year, which is administrated by the Danish Agricultural Agency. For the planning period 2016/2017, 35.866 farmers were obliged to submit a fertilizer account. The administrative control of 586 fertilization accounts showed that 5.8 % exceeded the farms nitrogen quota by up to 6 kg N per hectare and they received a recommendation. 6.1 % exceeded the farms nitrogen quota from 6 kg N and up to 9 kg N per hectare and they received a reprimand. 2.6 % exceeded the farms nitrogen quota by 9 kg N or more per hectare and they received an administrative fine. 2.0 % exceeded the farms nitrogen quota by 9 kg N or more per hectare and they were reported to the police. The same 586 farms were also controlled regarding the amount of livestock manure applied to land each year (harmony rules). 4.1 % were reported to the police for severe violations of the harmony rules. 3.8% are still under investigation.

In 2017 the “targeted catch crops scheme” was introduced to reduce N-losses through promoting the establishment of additional catch crops for the years 2017-2019. In 2019 a total of 235 on-site inspections on catch crops was carried out involving three national schemes on catch crops: Mandatory catch crops, livestock catch crops and the targeted nitrogen regulation (targeted catch crops). In the non compensated national schemes of mandatory general and livestock catch crops 12.8 % were reported to the police and 7.4 % received an enforcement notice for non-compliance with the requirements for the establishment of catch crops. This share on the national scheme illustrates an increase in farms with violations, compared to the previous data from 2014 (3.1 % and 4.7 %, respectively). Nevertheless, it is important to highlight that since 2014 two new schemes for catch crops has been introduced (livestock and targeted catch crops), the rules for e.g. reporting and control of catch crops have been changed and the rules of sanctioning has been tightened.

The Danish Agriculture Agency continuously focuses on how to improve and streamline the control of catch crops, and in recent years a significant proportion of the inspections of the targeted catch crops are designated using satellite-based screening (e.g. including analysis of specific risk factors), which is very effective compared to other methods of designating farms to control. In 2019, there were 87 inspections of the targeted catch crops. Approximately 60 % of the farms designated using satellite-based screening were sanctioned, however less than 5 % of the inspections of targeted catch crops resulted in a sanction, if one disregard the cases that were selected for inspections using satellite-based screening. For the targeted catch crops non-compliance is sanctioned with both a reduction in the subsidy and a reduction of the fertilizer nitrogen quota for the farm corresponding to the non-compliance.

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 higher N-quota has increased income and N-losses, but in both cases less so than expected. The increased income is likely to be around 400-600 million DKK. The increased use of nitrogen has been around 30-35.000 tones N.

The period from 2015 to 2019 has seen a transition towards more targeted measures and this has insured that the implementation has become more flexible and cheaper to implement. At the same time, it has only been a first step towards targeting as the variation in the measures efficiency across soils and the nitrogen retention map has not been fully used in the targeting. The increased flexibility was a process that was already started before 2016 allowing farmers to replace catch crops with other measures if the measures had the same environmental effect. The targets regarding collective measures have been ambitious and especially the creation of mini wet lands, which in 2015 was a new measure. It is not uncommon that new measures are faced with implementation challenges, which also happened in this case despite a large effort to get farmers on board

Future evolution of the water body quality
The efforts in the River Basin Management Plans (RBMPs) for 2021-2027 are expected to be focused on a significant reduction of the nitrogen loads to **coastal waters**. 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. In the 3rd RBMP it will also be investigated whether there also is a need for further reduction of phosphorous in some of the marine waterbodies where such a reduction will have a substantial impact on the relevant quality elements. In the draft river basin management plans for the period 2021-2027, the assessment of chemical status for groundwater bodies is based on groundwater quality standards and threshold values for pollutants. The assessment of significant and sustained upward trend in the concentrations of pollutants has yet to be completed. A potential need for supplementary measures will be investigated further during the third plan period. 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. 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 etc. can reduce the discharges of phosphorus in the catchment areas to lakes. New target loads are expected to be published in connection with the 6 month hearing of the draft 3rd RMBMs.

3. Water quality: assessment and maps

3.1 Surface water: watercourses

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 210 stream sampling stations, representing streams draining both smaller and larger catchments. With 111 stream sampling stations in the period 2012-15, the number of sampling stations has increased significantly since the previous period. Removed stations are listed in appendix 1. The catchments cover a range of nutrient sources, some of them only affected by losses from agricultural activities in the catchment, others also by point sources.

3.1.2 Status for nitrate concentrations

Data for nitrate are extracted from the “ODA database”,a database holding monitoring data from watercourses, lakes and marine areas. The extract is made by selecting all watercourse stations in the relevant periods with data for nitrate. Data from analyses marked as "under control" or "academic reservation" are not included. Subsequently, a selection of relevant stations has taken place, which has continuous sampling. A few (about 19 stations) do not have sampling every year, but every three years. Unfortunately, the ODA database contains some redundant data for watercourse analyses. That is, for some stations, analyses for nitrate are available on the same date, time, and with the same result. This is an error when loading data, and thus this redundant data is deleted manually in data extracts.

Flow-weighted mean nitrate concentrations (annual and winter value) and max value in streams for the period 2016-2019 shown in table 3.1 and in figure 3.1 and 3.2.

Table 3.1 Annual and winter average NO3 concentration as well as max NO3 concentration for the period 2016-2019

	No of Samples	Avg. Annual Value (mg/l)	Avg. Winter Value (mg/l)	Max Value (mg/l)
Minimum	**12**	**0,08**	**0,1**	**0,44**
Mean	61	14,3	17,7	33,4
Median	55	13,9	16,9	29,2
Maximum	**107**	**52,2**	**51,17**	**146**

In freshwater, the analytical technique used as determined by the method data sheets, and the analysis result is stated as nitrite + nitrate-N. In the vast majority and normal cases, it can be assumed that the concentration of nitrite is vanishingly small, and therefore nitrate-N can be converted via this formula: Nitrate-NO3 (mg / L) = 4.4268 x nitrite + nitrate-N (mg / L).

Average annual value are calculated as the average of all nitrate analyses for each measuring station for each year in the period. However, there is only calculated an average annual value if at least 7 samples have been taken per. year. This number of 7 samples has been chosen based on an analysis that found that a few more stations were included, which had fewer samples than the other stations due to dehydration.

Average winter values are the average of all nitrate analyses for each station for each year in the period, in which the sample was taken, from and including first of October and up to and including 30-31st of March (winter). After this an averages has been calculated. This method are used to avoid that individual analyses are included with different weightings in relation to the average, if the sampling frequency has varied within the 4-year period.

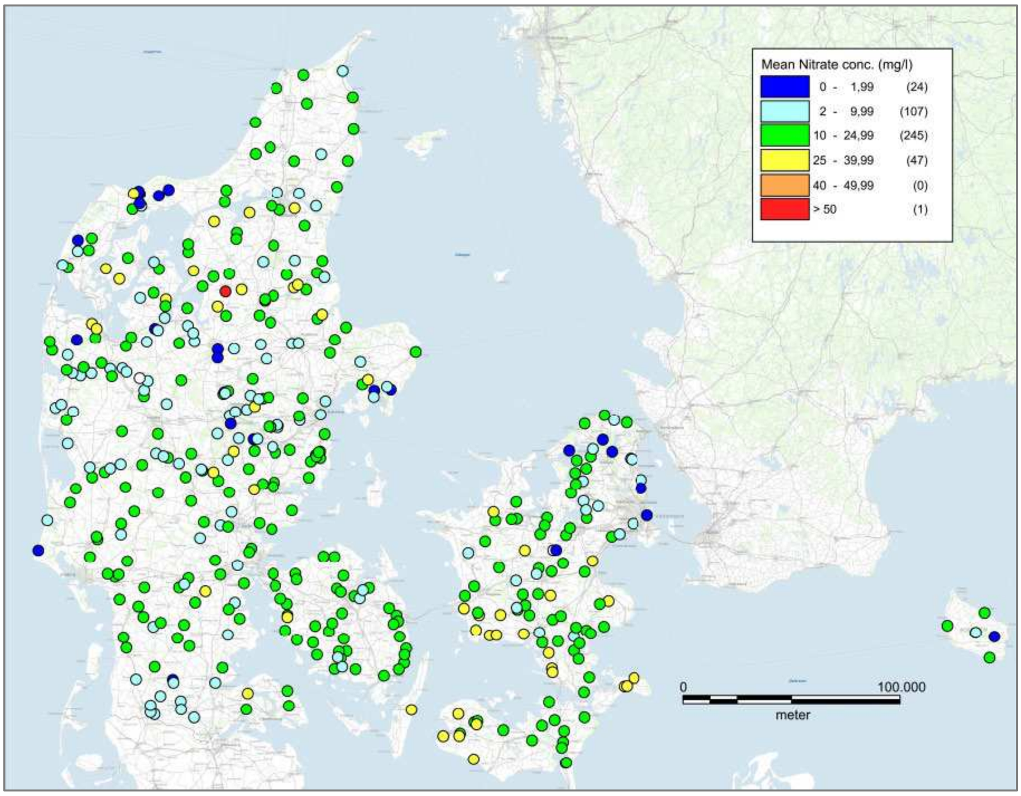

Figure 3.1 Mean nitrate concentration in watercourses during the current reporting period (2016-2019)

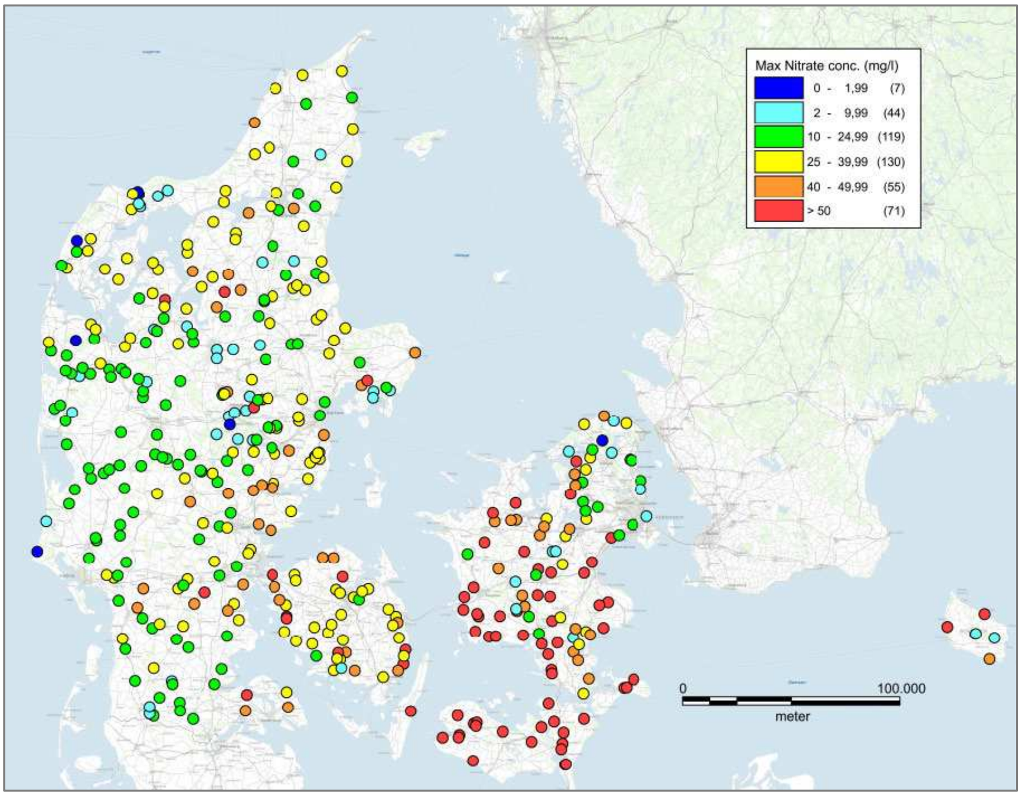

Figure 3.2 Max nitrate concentration in watercourses during the current reporting period (2016-2019)

3.1.3 Trend in nitrate concentrations

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

In the 2008-2011 reporting, most monitoring stations displayed lower nitrate concentrations compared to the previous period. In the 2012-2015 reporting, changes were smaller and in both directions. In the current reporting (2016-2019), nitrate concentrations are stable for most stations although there seems to be an increasing trend of in some monitoring stations.

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. Table 3.2 shows changes in nitrate concentrations between the two periods 2012-2015 and 2016-2019.

(NO_3) Trend		Change in nitrate	Numbers annual average	Percentage (%) annual average	Numbers winter average	Percentage (%) winter average
Increasing	Strong	*> + 5 mg/l*	7	3,3%	15	7,1%
	Weak	>+1 and ≤+5 mg/l	59	28,1%	69	32,9%

Stable		≥– 1 and ≤ + 1 mg/l	126	60,0%	100	47,6%
Decreasing	Weak	>+1 and ≤ –5 mg/l	15	7,1%	24	11,4%
	Strong	< – 5 mg/l	3	1,4%	2	1,0%

Table 3.2 Changes in annual and winter average NO3 concentration in streams from the previous period (2012-2015) to the current period (2016-2019)

The results on watercourses are based on 210 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 (2012-2015) and current period (2016-2019) show that in 8.5 % of the watercourses, there has been a weak or strong reduction in the flow-weighted annual average NO3-concentration. The percentage is a little bit higher (12.4 %) regarding winter average.

There has been an increase in 31.4% of the watercourses (40% for the winter average), and in 60 % of the watercourses, the concentrations are unchanged (47.6 % for winter average).

Changes in mean nitrate and winter average concentrations in watercourses between the previous and current period (2012-2015 and 2016-2019) are shown in Figure 3.3 and 3.4.

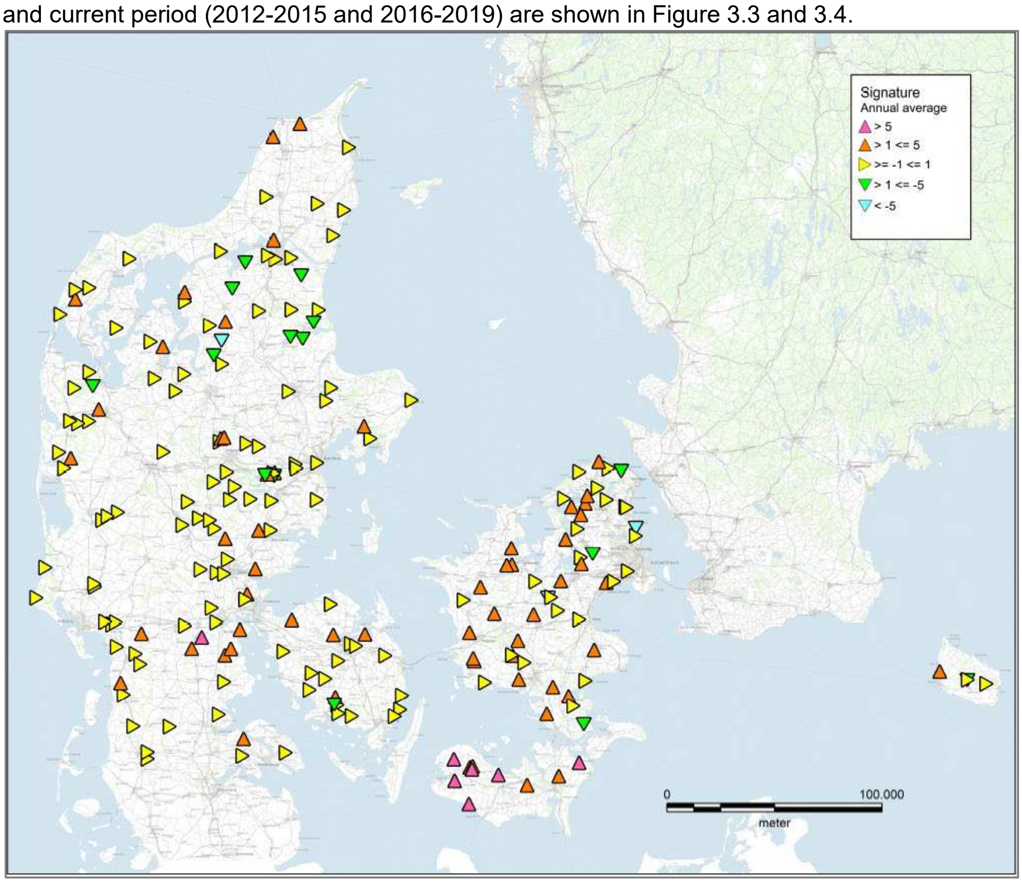

Figure 3.3 Changes in mean nitrate concentration in watercourses from the previous to the current period (2012-2015 to 2016-2019)

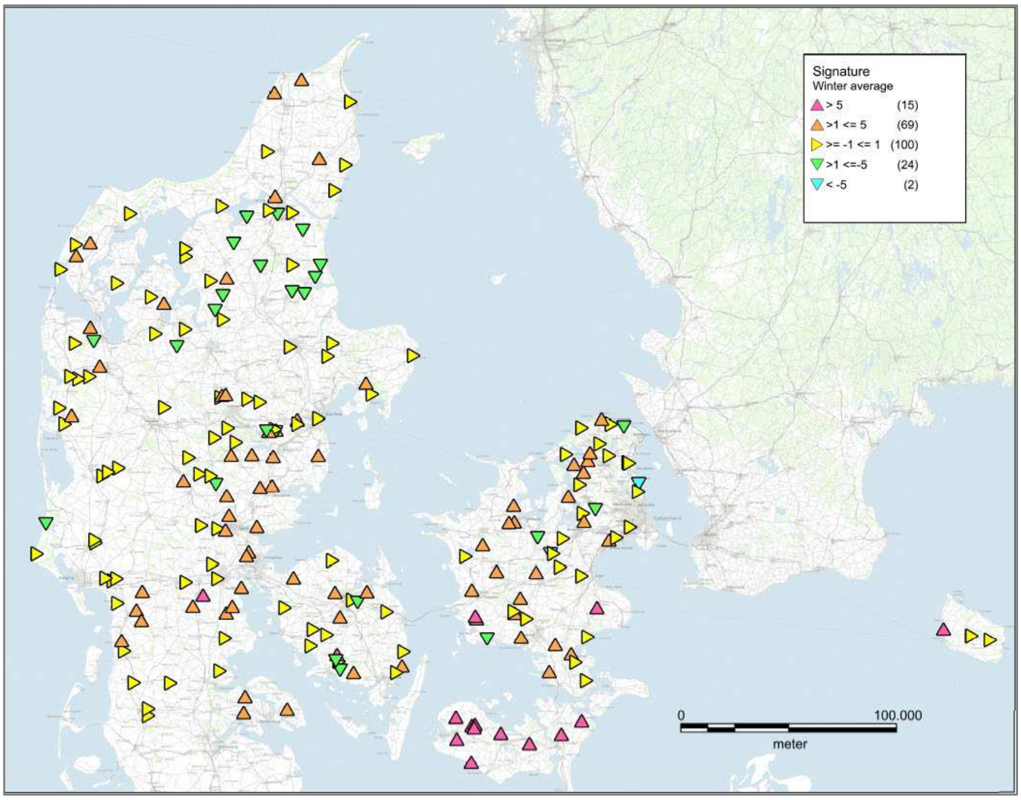

Figure 3.4 Changes in winter average nitrate concentration in watercourses from the previous to the current period (2012-2015 to 2016-2019)

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 short 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 watercourses.

For many years, the main problem with water quality in Danish streams 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 focus on the resulting nutrient loadings in vulnerable surface waters, that is, lakes and coastal waters.

In this reporting for the 7th period (2016-2019) we have included data for eutrophication indicators as phosphorous, total-P, orthophosphate-P and nitrogen, total N, but the data can not be used to describe status for eutrophication in the light of the above mentioned contexts.

3.1.5 Ecological state

The classification of ecological state are based on data from the third RBMP in line with the Guidelines. According to these it´s proposed, that the term “non-eutrophic” of the Nitrates Directive relates to the WFD high and good status, and the term "eutrophic" of the Nitrates Directive relates to situations where undesirable disturbances are common or severe and equates to moderate, poor or bad status. The same approach for classification of ecological state are used for watercourses, lakes and Estuarine, coastal and marine waters.

The classification of ecological state of the 426 monitoring station in watercourses in connection with the latest RBMP can be found in table 3.3. The ecological state at 28 percent of the 392 monitoring station in watercourses with known status are non-eutrophic.

If a similar approach as in table 3.3 is used on all waterbodies in WFD with an ecological classification in the third RBMP then 71 % will be categorized as non-eutrophic and 29 % will be categorized as eutrophic

Table 3.3 Distribution of the 426 monitoring stations in watercourses monitored for the parameters nitrate during the 7th reporting period with respect to ecological state in the third river basin management plan

River type	Eutrophic	Non-eutrophic	Unknown	Total
1 (small)	45	14	2	**61**
2 (medium)	201	70	19	**290**
3 (large)	38	24	2	**64**
Unknown			11	**11**
Total	**284**	**108**	**34**	**426**
Percentage of total with known status (392)	**72 %**	**28 %**		

The classification “Unknown” is either monitoring stations placed in watercourses not included in the RBMP or there is not sufficient data to make a classification at the specific monitoring station.

3.2 Surface water: Lakes

3.2.1 Presentation of monitoring stations

Danish lake monitoring stations for the 7th period (2016-2019) are shown in Figure 3.5 .

The lakes included are a selection of Danish lakes > 5 hectares covered by the Water Framework Directive. Data from the 7th reporting period of the Nitrates Directive (2016-2019) include 20 lakes with analysis of lake water for nitrate concentration and 447 lakes with measurements of Chl a. Removed stations are listed in appendix 2.

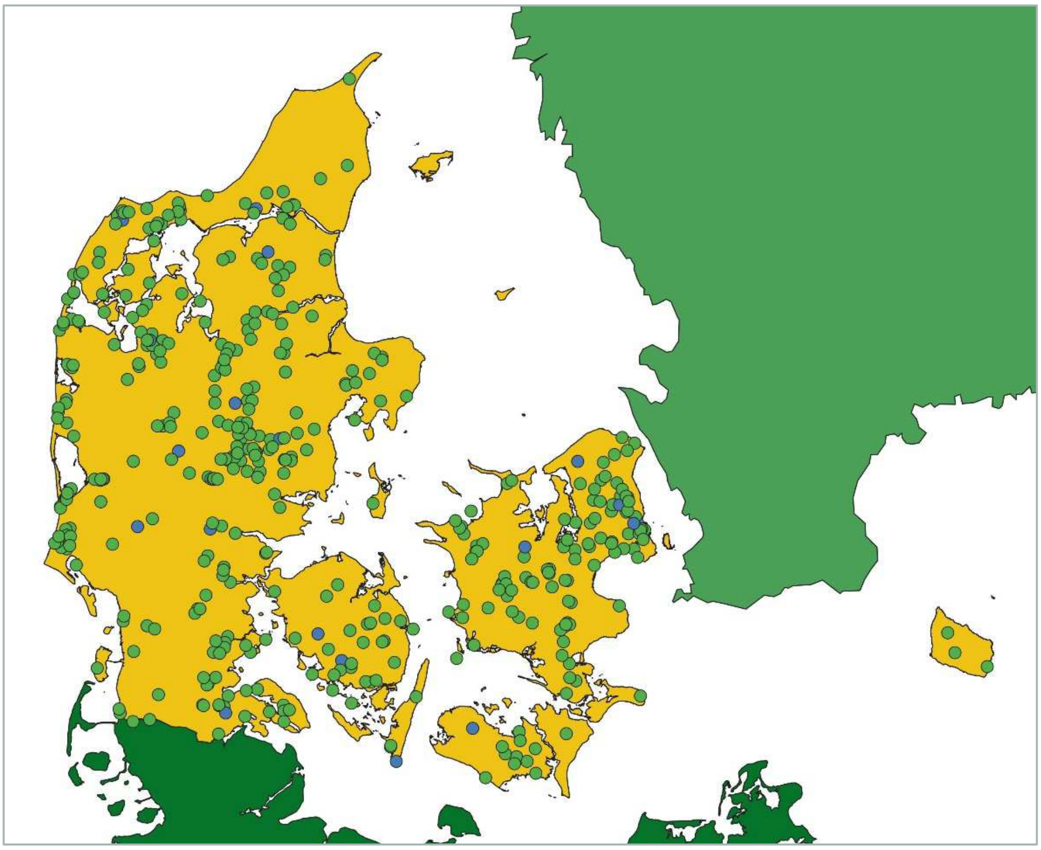

Figure 3.5 The location of 447 Danish lake monitoring stations used to measure the concentrations of nitrate and/or Chlorophyll a in the lake water. Nitrate stations are indicated by blue dots.

Nitrate concentration were monitored ones during the period in two lakes, while the other 18 lakes were monitored every second year during the period and thus two years of data are included. Sampling frequency for nitrate concentration was 18-19 times in the period 1. January to 31. December for the 18 lakes. The other two lakes were measured 6 times in the period 1. April – 30. September and once in the period October-December. Nitrate concentrations are given as time-weighted annual and time-weighted winter averages (January to February and October to December). For the lakes measured biannually, the nitrate concentrations represents simple averages of the time-weighted annual averages and winter averages for the period.

Chlorophyll a concentration were measured ones during the period in 371 of the lakes, while the other 76 lakes were measured twice during the period. Sampling frequency for Chlorophyll a concentration during the summer (1 April - 30 September) was 3-11 times during the summer. For lakes measured biannual the Chlorophyll a concentration are given as a simple average of the time-weighted summer average for the period.

The number of lakes monitored for the parameters nitrate and Chlorophyll a during either the 6th, 7th or both reporting periods can be found in Table 3.4.

Table 3.4. Number of lakes monitored in the 6th and 7th monitoring period for nitrate (NO_3) and Chlorophyll a (Chl a) in lake water.

Number of lakes	6th period	7th period	Common lakes
NO_3	66	20	20
Chl *a*	196	447	158

For the classification of ecological state of the lakes, an approach, including a larger number of lakes and parameters has been used in this 7th reporting period, as described in detail in section 3.2.4.1.

3.2.2 Status for nitrate concentrations

The number of Danish lakes within different classes of nitrate concentrations in the 7th period (2016-2019) with respect to annual average, winter average and maximum nitrate concentrations are shown in table 3.5. The annual average nitrate concentrations in the 7th period (2016-2019) in Danish lakes range from 0.14-19.0 mg NO_3^-/l with an average of 3.2 mg NO_3^-/l.

Winter average concentrations are generally higher than the annual average concentrations (19 out of 20 lakes) and vary between 0.1 and 30.5 mg NO_3^-/l with an average of 4.3 mg NO_3^-/l. This is due to higher loading, low primary production and less denitrification during winter.

In general, annual average nitrate concentrations are low – compared to the Nitrates Directive limit on 50 mg/l 65% of the lakes have an annual mean concentration less than 2 mg NO_3^-/l. The maximum concentrations varies between 0.2 and 70.8 mg NO_3^-/l. One lake had a maximum concentration above 50 mg NO_3^-/l.

Table 3.5: The number of lakes within a certain class of nitrate concentration (annual average, winter average and maximum, respectively)

NO_3^- (mg/l)	Annual average – number of lakes	Winther average – number of lakes	Maximum – number of lakes
0 – 1.99	13	11	7
2 – 9.99	5	7	8
10–24.99	2	1	4
25–39.99	0	1	0
40–49.99	0	0	0
≥ 50	0	0	1

3.2.3 Trend in nitrate concentrations

Table 3.6 and the maps in Figure 3.6 and Figure 3.7 show the development in nitrate concentrations in the lake water in the 20 common monitored lakes between the 6th period (2012-2015) and the 7th period (2016-2019) 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").

The nitrate concentrations are cf. the Nitrates Directive, stated as mg NO_3^-/l, while in the reporting for the 5th and 6th reporting period the unit mg N/l has been used. Previously reported nitrate values have therefore been converted to mg NO_3^-/l in order to determine development trends for the nitrate concentrations in Danish lakes

Table 3.6 Change in annual average and winter average NO_3 concentration in the lake water (mg/l) from 6th to 7th period

Trend in NO_3 (mg NO_3^-/l)	Annual average NO_3		Winter average NO_3	
	Number of lakes	Percentage of lakes (%)	Number of lakes	Percentage of lakes (%)
Strong increase (>5)	1	5	1	5
Increase (>+1 and ≤5)	2	10	2	10
Stability (≥ -1 and ≤1)	15	75	10	50
Decrease (>-1 and ≤ -5)	2	10	7	35
Strong decrease (<-5)	0	0	0	0

In the reporting from the 6th period 2012-2015, no changes were registered in relation to the period 2008-2011. This is because data were reported as mg N/l. If data had been reported in accordance with the Directive's indications for this in the form of mg NO_3^-/l rather than mg N/l, then previous reporting would also have shown that the nitrate content was not stable in all lakes.

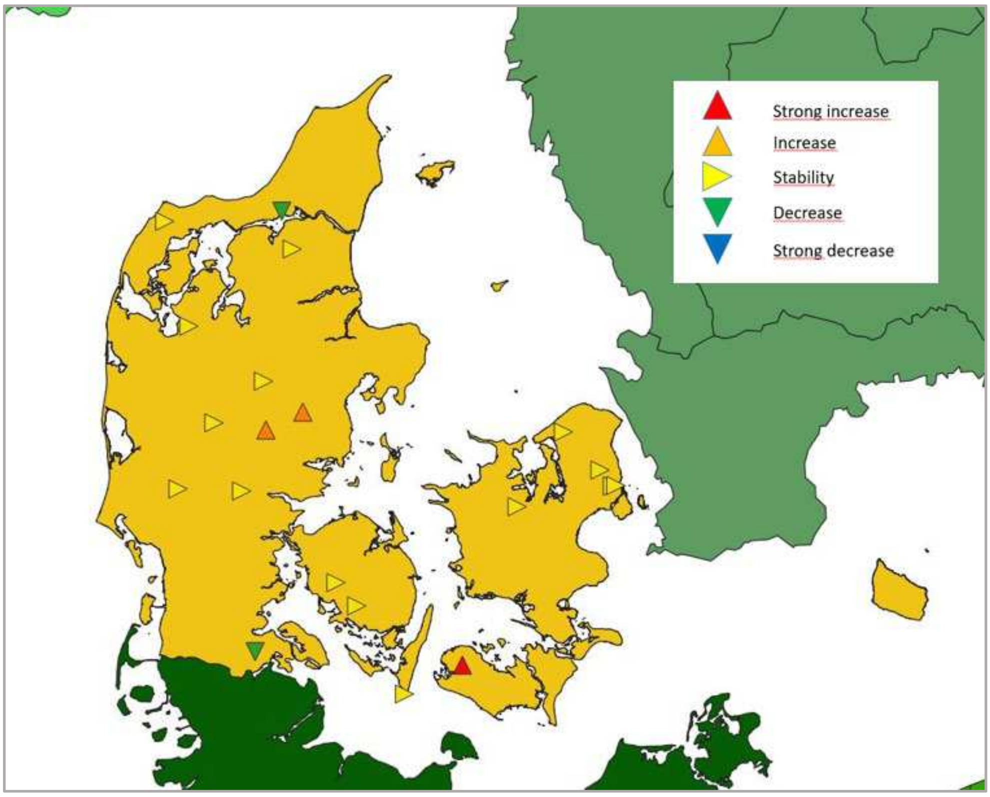

Figure 3.6 Change in annual average nitrate concentration in the lake water (mg/l) from 6th (2012-2015) to the 7th (2016-2019) period.

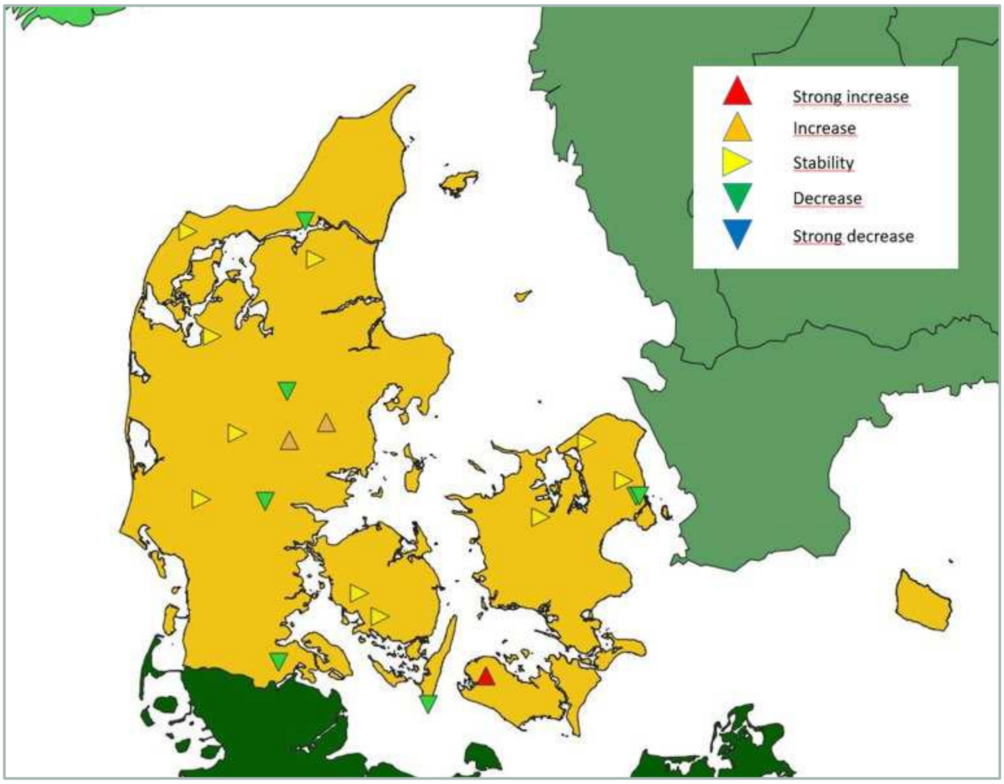

Figure 3.7 Change in winter average nitrate concentration in the lake water (mg/l) from 6th (2012-2015) to the 7th (2016-2019) period.

3.2.4 Eutrophication status and trend

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

The classification of the ecological state of the 447[1] lakes monitored for the parameters nitrate and/or Chlorophyll a during the 7th reporting period is based on monitoring data from the third river basin management plan (RBMP) for the biological elements (chlorophyll a[2], phytoplankton[3], other aquatic flora[4], macrophytes[5], benthic invertebrates [6]and fish[7]) and chemical and physio-chemical elements supporting the biological elements (transparency, oxygenation conditions, nutrient conditions and river basin specific pollutants) sampled during the period 2014-2019. If there are no data from this period, data dating back until 2008 may have been used in the classification of the ecological state of a lake.

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[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] Other aquatic flora can only be included as a quality element in the classification of the ecological state in lakes of the Danish typology 9 and 10.

[5] 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, 10 and 13.

[6] Benthic invertebrates can only be included as a quality element in the classification of the ecological state in lakes of the Danish typology 9 and 10.

[7] Fish can only be included as a quality element in the classification of the ecological state in lakes of the Danish typology 1, 9, 10, 11 and 13.

Data include 287 lakes with measurements of chlorophyll a, 159 lakes of measurement of phytoplankton, 123 lakes of measurement of other aquatic flora, 233 lakes of measurements of macrophytes, 42 lakes of measurement of benthic invertebrates, 193 lakes with measurements of fish fauna, 409 lakes of measurement of transparency, 445 lakes with measurement of oxygenation conditions, 410 lakes of measurement of phosphorus conditions, 406 lakes of measurement of nitrogen conditions and 152 lakes of measurement of river basin specific pollutants.

3.2.4.2 Ecological state

The classification of ecological state of the 447 monitoring lakes in connection with the latest RBMP can be found in table 3.7. Fifteen percent of the 447 lakes are non-eutrophic. If a similar approach as in table 3.7 is used on all 737[8] lakes with an ecological classification in the third RBMP then 21 % will be categorized as non-eutrophic and 79 % will be categorized as eutrophic.

Table 3.7 Distribution of the 447 lakes monitored for the parameters nitrate and/or Chlorophyll a during the 7th reporting period with respect to ecological state in the third river basin management plan

Ecological state	Non-eutrophic	Eutrophic
Low alkaline lakes	4	30
Shallow alkaline lakes	40	272
Deep alkaline lakes	21	80
Percentage of total lakes	**15**	**85**

3.2.4.3 Development in ecological state

The development in ecological state of the lakes is based on a comparison of the ecological state presented in in the second (2015-2021) and the third (2021-2027) river basin management plans. Lakes measured for the parameters nitrate and/or Chlorophyll a during the 7th reporting period are selected. 405 of the 447 lakes have been monitored in both river basin plan periods. The development in ecological state of these lakes is shown in table 3.8. Generally, most lakes has been stable over the course of the two river plan periods and only a minor fraction has increased (5%) or decreased (9%).

Table 3.8 Development in ecological state in the 405 lakes monitored in both the second river basin management plan and the third river basin management plan

Trend in ecological state		Number of lakes	Percentage of lakes
Increase	Eutrophic → Non-eutrophic	25	6
Stable		345	85
Decrease	Non-eutrophic → Eutrophic	35	9

8 Lakes established for the purpose of nutrient retention or lakes with less stringent environmental objectives are not included

3.3 Surface water: Estuarine, coastal and marine waters

3.3.1 Presentation of monitoring stations

The presented nitrate (NO_3^-) concentrations, status and trends are based on data from a total of 79 stations, which is 22 stations more than in the 6th reporting (2012-2015) (Figure 3.8).

Based on analysis of the available data it is assessed that that the 7th reporting can include 22 stations that were not covered by the last report plus 57 out of the 59 stations covered in the 6th reporting. Monitoring has ceased on two out of the 59 stations covered in the 6th reporting. On the 22 new stations there is sufficient data from both the 7th reporting period (2016-2019) and the 6th reporting period (2012-2015) to calculate reliable averages for annual and winter averages and perform trend analysis. The “new” stations are mostly stations which have for various reasons not been monitored for longer periods before 2012. However, sampling at the "new" stations has been resumed since 2012, so that sufficient data are available to include them in this reporting. The 7th reporting (2016-2019) thus comprises a total of 79 stations compared to 59 stations in the 6th reporting.

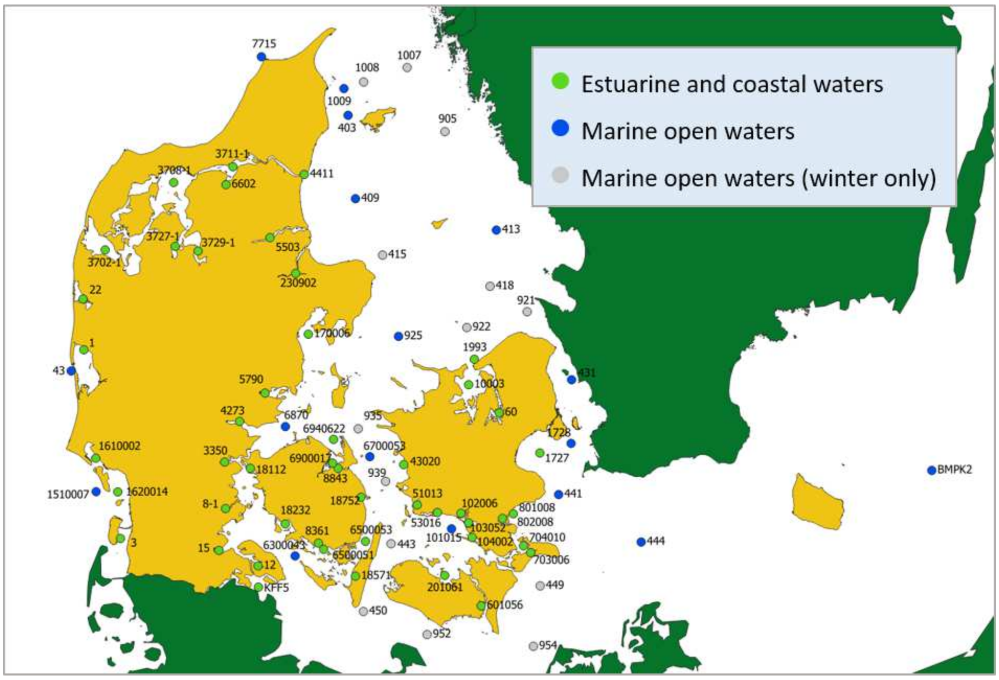

Figure 3.8 Stations with NO_3^- concentrations being monitored every year during the 7th reporting period 2016 – 2019. Out of the 79 stations shown, 48 stations represent estuarine and coastal waters and 31 stations represent marine open waters. Out of the 31 stations representing marine open waters, 17 stations have data for both annual and winter NO_3^-, while 14 stations only have data for winter NO_3^-. Stations where chlorophyll *a* is monitored are shown in Figure 3.16.

From the 2nd period (1996-1999) until present, i.e. the 7th period (2016-2019), the total number of monitoring stations has been reduced as shown in table 3.9. However, the number of monitoring stations has increased markedly since the last reporting period.

In estuarine and coastal waters, the number of monitoring stations decreased by 29 from 56 to 27 stations between the 2nd and 6th reporting period, but 21 more stations was included in the 7th reporting (Table 3.9). For marine open water stations, 55 stations were abolished from the 2nd to the 6th period (Table 3.10), mainly because of a stop in North Sea/Skagerrak monitoring between the 4th and 5th period, when 48 stations were abandoned. Monitoring on some of these stations has been reintroduced from 2015/2016 and the 7th reporting includes data from 31 open water stations. In the 7th reporting summer chlorophyll is only reported for stations with a minimum of 7 measurements in the period May to September for 3 out of four years in both the 6th and 7th reporting periods. This corresponds to the minimum requirements for calculating the summer-chlorophyll indicator used in the Danish implementation of the WFD. This change means that summer chlorophyll can only be reported for 10 stations representing marine open waters.

Table 3.9 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	**7th period 2016-2019**
Winter NO_3	56	54	51	36	27	48
Annual NO_3	56	54	51	36	27	48
Summer chlorophyll	55	56	48	36	27	39

Table 3.10 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	**7th period 2016-2019**
Winter NO_3	87	87	82	34	32	31
Annual NO_3	87	87	82	34	17	17
Summer chlorophyll	84	81	37	34	31	10

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 7th 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 3.10).

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 6th and 7th period and (2) eastern Kattegat, the Belt Sea, and southern Baltic Sea, where summer concentrations of nitrate were not monitored during the 7th 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 7th period (2016-2019) the highest average NO_3^- winter (October – March) surface (0-10 m) concentrations were observed in the estuaries with a maximum average concentration of 12.2 mg

NO_3^-/l (± 2.56 mg NO_3^-/l standard deviation) at Station 18752 and with the lowest concentrations monitored in the marine open waters (i.e. Kattegat, the Belt Sea, and Arkona Basin) (Figure 3.9) where the average winter NO_3^- concentration did not exceed 1.0 mg NO_3^-/l. The NO_3^- concentration decreased during the summer half at all stations (data not shown), thus lower annual average concentration (Figure 3.10) was seen for the 7th period compared to the winter concentrations of the same period.

Annual means are only reported when it can be calculated – i.e. an annual average value is not reported for stations with only 1-3 measurements in winter (corresponding to the stations marked marine open water (winter only) in Fig. 3.6).

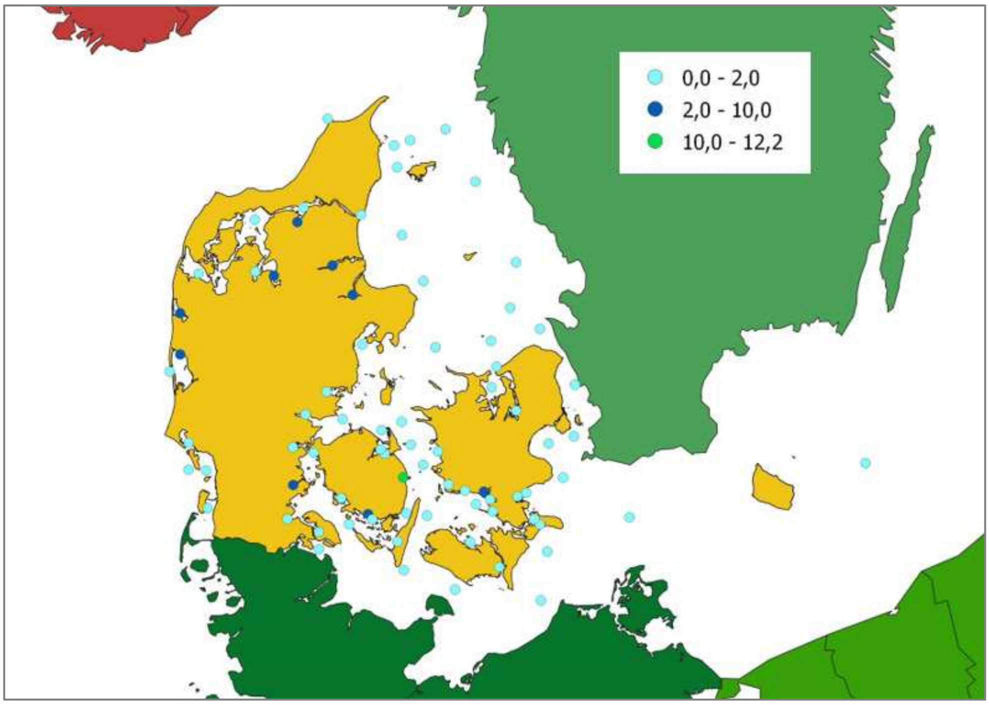

Figure 3.9 Average surface (0-10 m) winter (October – March) NO_{3-} concentrations in mg NO_{3-}/l for the 7th monitoring period (2016 – 2019) at 79 stations in Danish estuarine, coastal and marine open waters.

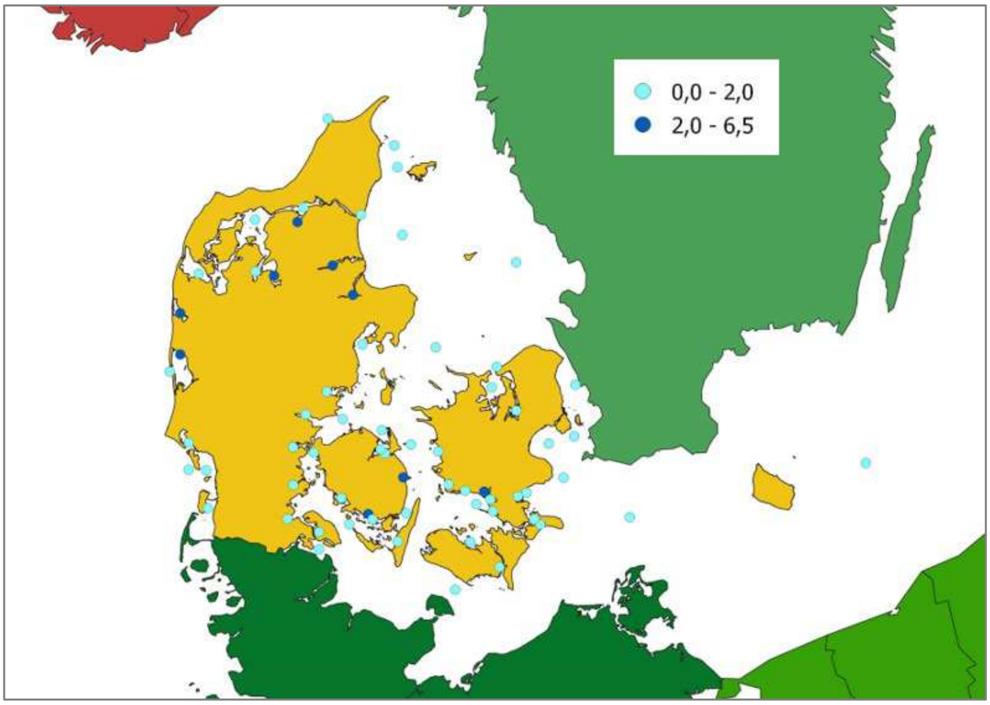

Figure 3.10 Average surface (0-10 m) annual NO_3^- concentrations in mg NO_3^-/l for the 7th monitoring period (2016 – 2019) at 65 stations in Danish estuarine, coastal and marine open waters.

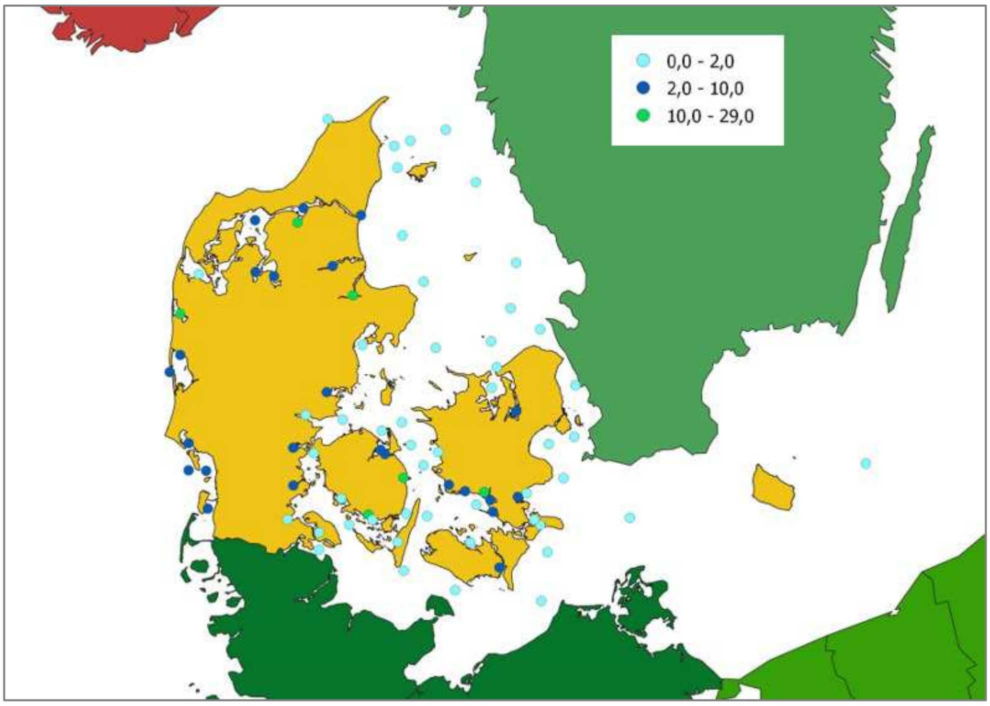

Figure 3.11 Maximum surface (0-10 m) NO_3^- concentrations in mg NO_3^-/l for the 7th monitoring period (2016 – 2019) at 78 stations in Danish estuarine, coastal and marine open waters.

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 6th period) and this 7th period have been estimated by a statistical approach rather than using absolute concentration changes, since the proposed concentration changes to detect change are too large for a marine context (i.e. changes >± 1 mg NO_3^-/l). That means that the trend analysis is carried out in the same way as in the last report. The trend analysis has been carried out as a paired comparison with t-tests on log-transformed mean values, for stations with at least 3 data points within each 4-year reporting period.

Criteria for the trend analysis are: for p-values> 0.05 there is no significant trend, for p-values <= 0.05 and > 0.01 the trend is described as significant, and for p-values <= 0.01 the trend is designated as very significant. The P-value can be interpreted as the certainty that there is a real, significant difference between the two periods being compared. At p = 0.01, there is thus a 99% probability that there is a real significant difference, while correspondingly there is only an 80% probability that there is a real difference when p = 0.2. The limit for when a difference between two periods is described as significant is set to p = 0.05

Table 3.11 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 39 stations for short term trends (diff. between 6th and 7th period) and 26 stations for long term trends (diff. between 2nd and 7th period, Figure 3.12 and Figure 3.13), 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 3.8)

Trend	Significance	6th period to 7th period 2012-2015 to 2016-2019		2nd period to 7th period 1996-1999 to 2016-2019	
Increasing	**strongly** (p<0.01)	0%		0%	
	weakly (p<0.05)	0%		3,8%	(+0.4 mg/l; +130%)[5]
Stable	(p>0.05)	94,2%	(-2.19 mg/l; -20.0%)[1]	73,2%	(-6.5 mg/l; -58.0%)[6]
Decreasing	**weakly** (p<0.05)	2,6%	(-0.31 mg/l; -18.3%)[3]	11,5%	(-3.5 mg/l; -38.9%)[7]
	strongly (p<0.01)	2,6%	(-0.29 mg/l; -28.6%)[4]	11,5%	(-0.61 mg/l; -30.5%)[8]

[1]St. 3729-1, [2]St. 3729-1, [3]St 3727-1, [4]St 3708-1, , [5]St 51013, [6]St 3729-1, [7]St 230902, [8]St 3727-1

Table 3.12 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 30 stations for short term trends (diff. between 6th and 7th period) and 29 stations for long term trends (diff. between 2nd and 7th period, Figure 3.12 and Figure 3.13), 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 3.8).

Trend	Significance	6th period to 7th period 2012-2015 to 2016-2019		2nd period to 7th period 1996-1999 to 2016-2019	
Increasing	**strongly** (p<0.01)	0%		6.9%	(+0,26 mg/l; +204%)[4]
	weakly (p<0.05)	0%		17.2%	(+0,18 mg/l; +121%)[5]

Stable	(p>0.05)	86.6%	(-0.28 mg/l; -29.1%)[1]	65.6%	(-0.64 mg/l; -40.1%)[6]
Decreas-ing	**weakly** (p<0.05)	6.7%	(-0.46 mg/l; -32.3%)[2]	6.9%	(-0.41 mg/l; -36.8%)[1]
	strongly (p<0.01)	6.7%	(-0.06 mg/l; -31.1%)[3]	3.4%	(-0.13 mg/l; -58.2%)[7]

[1]St. 43, [2]St 1510007, **[3]**St 6700053, **[4]**St 1008, [5]St 905, [6]St 1510007, [7]St 6300043

For annual averages, long-term trends (difference between 2016-2019 and 1996-1999) and short-term trends (difference between 2016-2019 and 2012-2015) can be calculated for 37 and 51 stations, respectively. For long-term trends (annual averages), concentrations are stable at 27 stations and significantly decrease at 10 stations. For short-term trends (annual averages), the concentrations are stable at 47 stations, significantly decreasing at 2 stations and very significantly decreasing at 2 stations.

For winter averages, long-term trends and short-term trends can be calculated for 55 and 69 stations, respectively. For long-term trends (winter averages), concentrations are stable at 38 stations, significantly decreasing at 5 stations, very significantly decreasing at 4 stations, significantly increasing at 6 stations and very significantly increasing at 2 stations.

For short-term trends (winter averages), concentrations are stable at 63 stations, significantly decreasing at 3 stations and very significantly decreasing at 3 stations, and there are no stations with significant increases

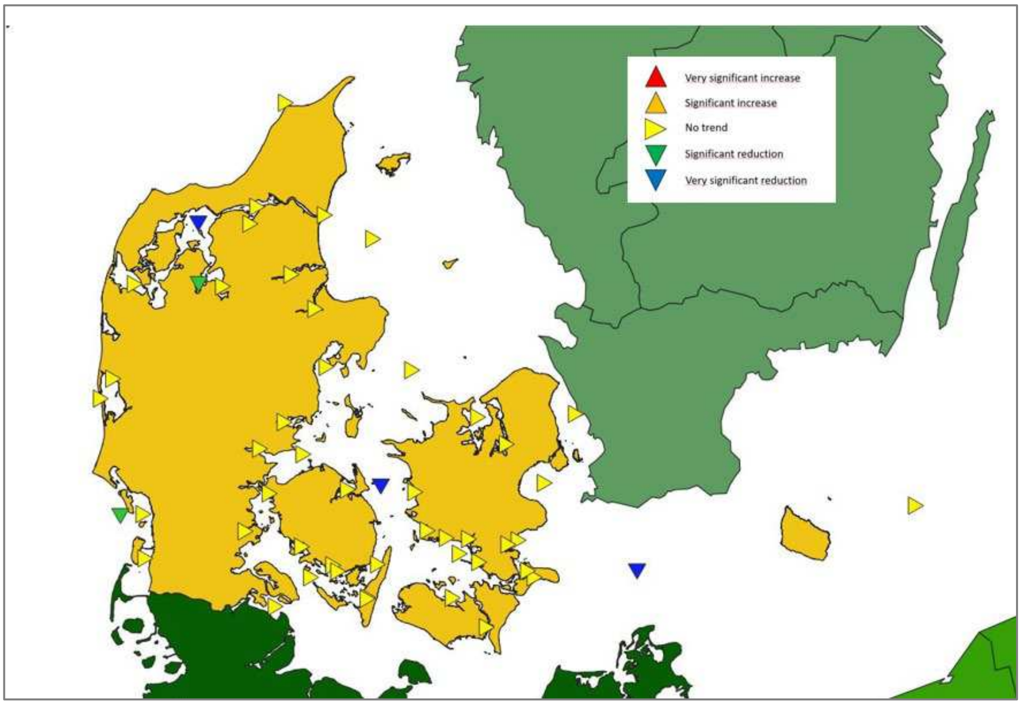

Figure 3.12 <u>Trends</u> in average surface (0-10 m) <u>winter</u> (October – March) <u>NO_3^-</u> concentrations <u>between the 6th</u> reporting period (2012-2015) <u>and the 7th period</u> (2016-2019) at 69 stations in Danish estuarine, coastal and marine open waters.

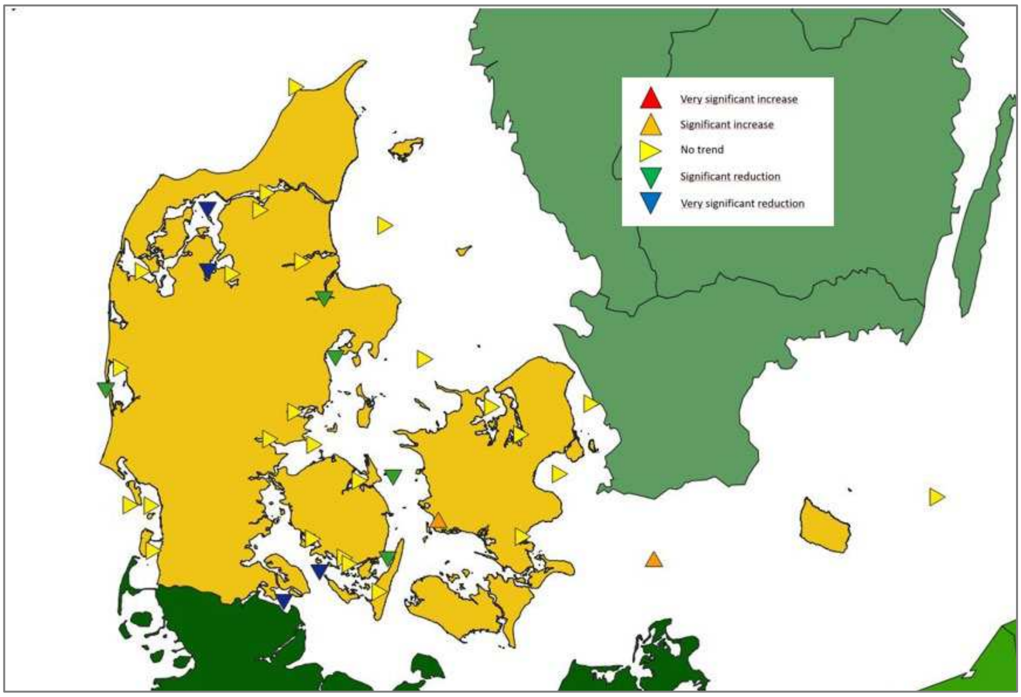

Figure 3.13 Trends in average surface (0-10 m) winter (October – March) NO_3^- concentrations between the 2nd reporting period (1996-1999) and the 7th period (2016-2019) at 55 stations in Danish estuarine, coastal and marine open waters.

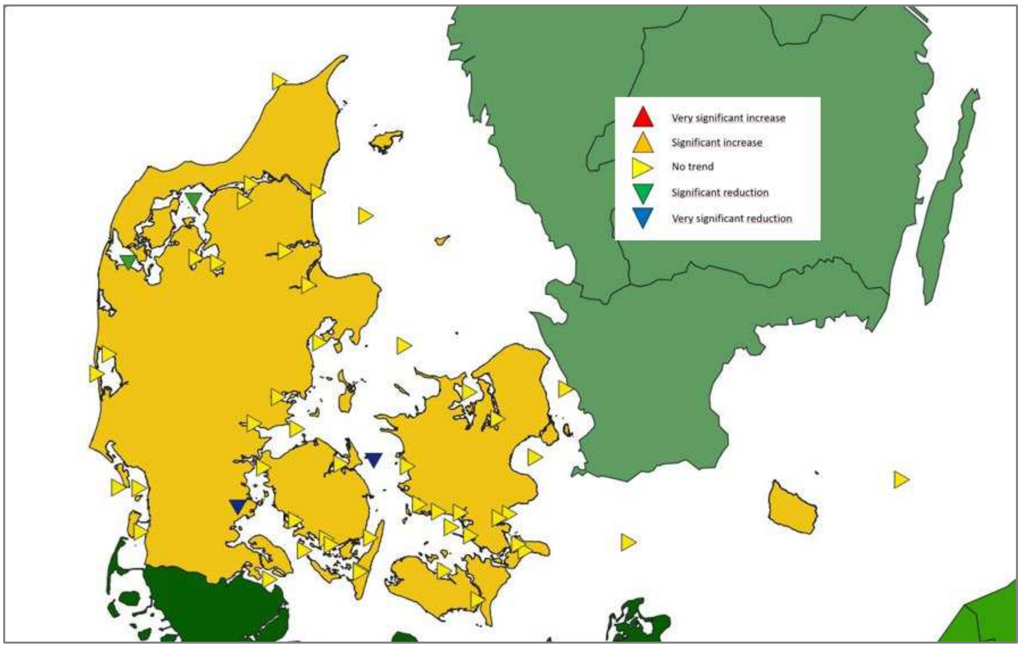

Figure 3.14 Trends in average surface (0-10 m) annual NO_3^- concentrations between the 6th reporting period (2012-2015) and the 7th period (2016-2019) at 51 stations in Danish estuarine, coastal and marine open waters.

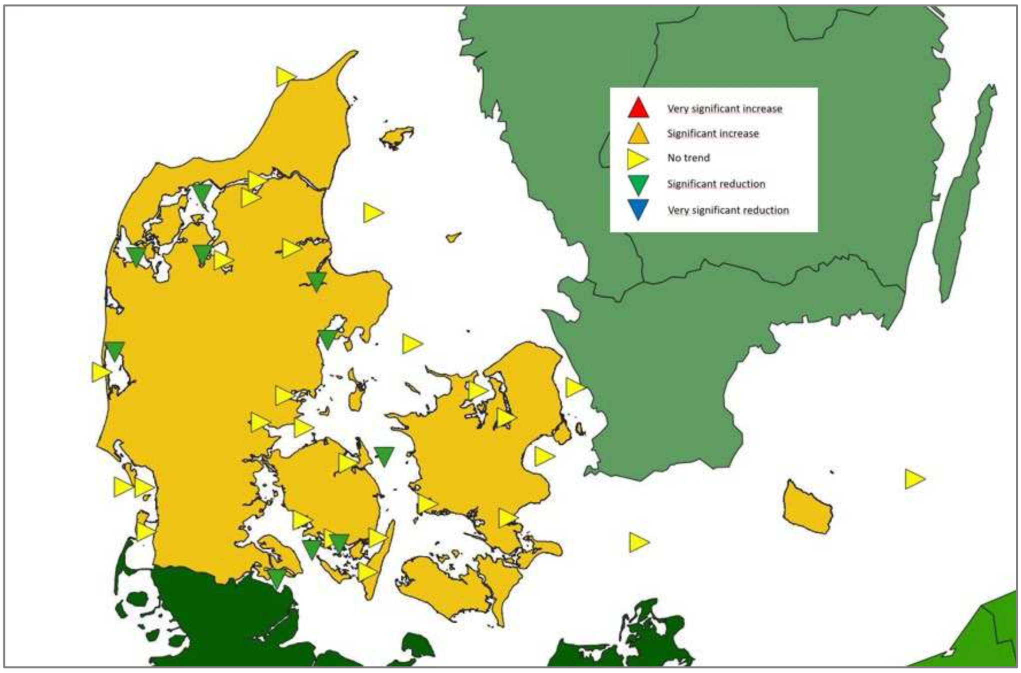

Figure 3.15 Trends in average surface (0-10 m) annual NO_3^- concentrations between the 2nd reporting period (1996-1999) and the 7th period (2016-2019) at 37 stations in Danish estuarine, coastal and marine open waters.

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.

Maximum chlorophyll *a* concentrations during the 7th period (2016-2019) were observed in estuaries with concentrations up to 41.5 ± 10.6 µg/l at Station 6602 (Halkær Bredning) but with decreasing concentrations towards marine open waters and lowest chlorophyll *a* concentrations in Kattegat ranging from 1.3 to 1.4 µg/l at Stations 925 and 409, respectively (Figure 3.16).

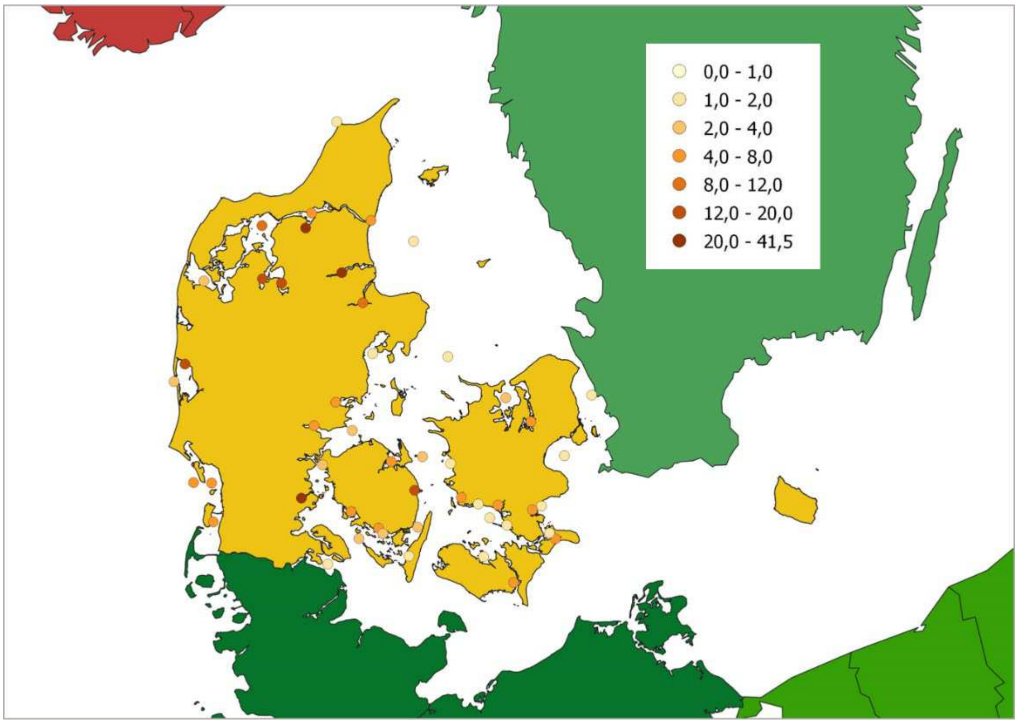

Figure 3.16 <u>Average</u> surface (0-10 m) summer (May – September) <u>chlorophyll *a*</u> concentrations (µg/l) for the 7th monitoring period (2016 – 2019) at 49 stations in Danish estuarine, coastal and marine open waters. The average concentration is expressed at each station as a simple mean i.e. $\frac{1}{n}\sum_{i=1}^{n}[\text{chlorophyll a}]$. The highest value shown in the legend corresponds to the highest concentration on the map.

While significant reductions in chlorophyll was reported for both short and long-term trends in the 6th reporting (2012-2015), no significant reductions were found in the 7th reporting. In contrast, an increasing trend in chlorophyll *a* concentration was observed at about 14 % of all stations monitored in Danish estuarine, coastal and marine open waters between the 6th period (2012-2015) and the 7th period (2016-2019; Figure 3.17, Table 3,13 and Table 3.14), and no long term trend in chlorophyll a between the 2nd period (1996-1999) and the 7th period (2016-2019) was detected (Figure 3.18, Table 3.13 and Table 3.14).

Table 3.13 <u>Trends</u> in average surface (0-10 m) summer (May – September) <u>chlorophyll *a*</u> concentrations in Danish <u>estuaries and coastal waters</u>. Percentage of points (i.e. stations) with increasing, stable or decreasing average concentrations of chlorophyll *a* at 39 stations for short term trends (diff. between 6th and 7th period) and 26 stations for long term trends (diff. between 2nd and 6th period, Figure 3.17 and Figure 3.18), 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 (se 3.8).

Trend	Significance	6th period to 7th period 2012-2015 to 2016-2019		2nd period to 7th period 1996-1999 to 2016-2019	
Increasing	**strongly** (p<0.01)	2.6%	(+0.93 µg/l; -90.3%)[1]	0%	
	weakly (p<0.05)	10.2%	(+3.93 µg/l; -121.1%)[2]	0%	
Stable	(p>0.05)	87.2%	(-16.02 µg/l; -46.8%)[3]	100%	(-24.70 µg/l; -72.2%)[3]
Decreasing	**weakly** (p<0.05)	0%		0%	
	strongly (p<0.01)	0%		0%	

[1]St. 1727, [2]St 4411, [3]St. 3729-1

Table 3.14 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 10 stations (diff. between 6th and 7th period) and 8 stations for long term trends (diff. between 2nd and 7th period, Figure 3.15 and Figure 3.16), 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 (se figure 3.8)

Trend	Significance	6th period to 7th period 2012-2015 to 2016-2019		2nd period to 7th period 1996-1999 to 2016-2019	
Increasing	**strongly** (p<0.01)	10%	(+0.75 µg/l; +77.3%)[1]	0%	
	weakly (p<0.05)	10%	(+0.61 µg/l; +82.6%)[2]	0%	
Stable	(p>0.05)	80%	(+0.66 µg/l; +58.3%)[3]	100%	(-3.78 µg/l; -48.1%)[4]
Decreasing	**weakly** (p<0.05)	0%		0%	
	strongly (p<0.01)	0%		0%	

[1]St. 431, [2]St. 925, [3]St. 101015, [4]St. 1510007

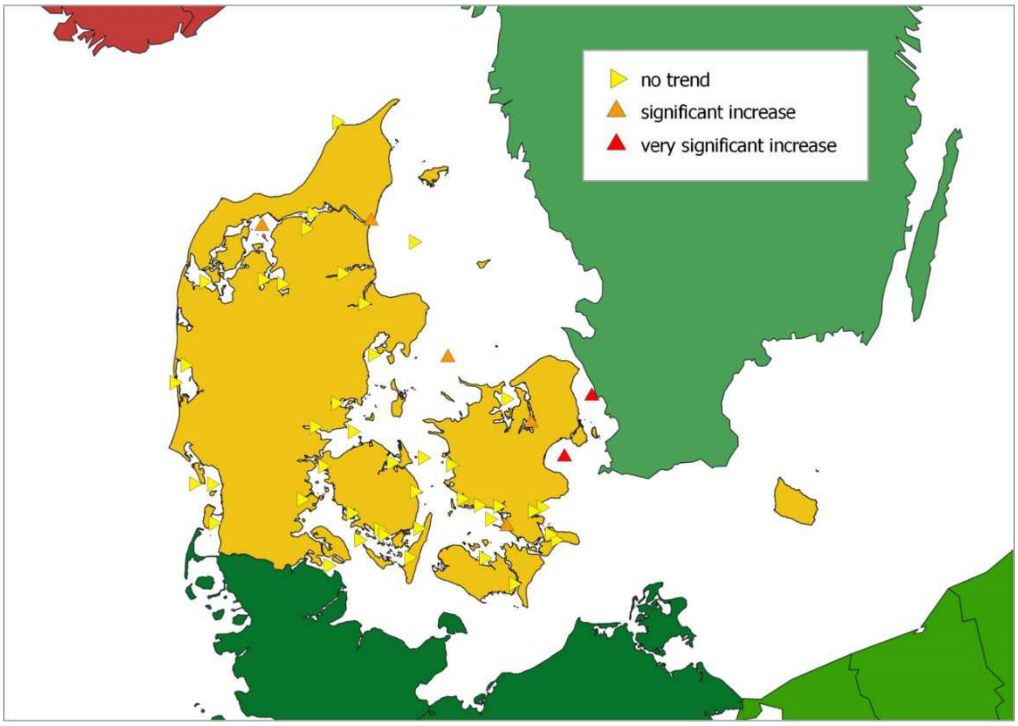

Figure 3.17 Trends in average surface (0-10 m) summer (May – September) chlorophyll *a* concentrations between the 6th reporting period (2012-2015) and the 7th period (2016-2019) at 49 stations in Danish estuarine, coastal and marine open waters. Trends are based on statistical analyses as explained in the text and shown in Table 3.13 and Table 3.14.

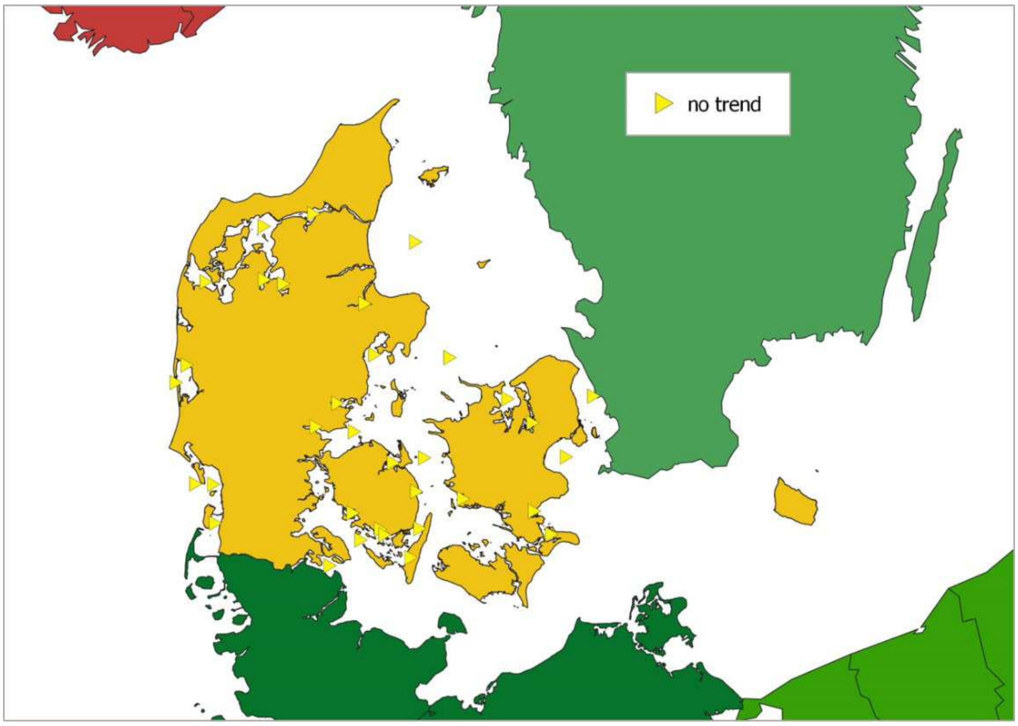

Figure 3.18 Trends in average surface (0-10 m) summer (May – September) chlorophyll *a* concentrations between the 2nd reporting period (1996-1999) and the 7th period (2016-2019) at 36 stations in Danish estuarine, coastal and marine open waters.
Trends are based on statistical analyses as explained in the text and shown in Table 3.13 and Table 3.14.

3.3.5 Ecological State

A total of 79 Danish monitoring stations are included in the 7th reporting for the Nitrates Directive covering the period 2016-2019, and 55 out of the 79 stations are located in 55 coastal water bodies administered in the Danish River Basin Management Plans (RBMP). The 24 remaining stations are open water stations located more than 12 nautical miles from the coast, where ecological status is not assessed, The 55 stations in coastal water bodies represent more than half of the 109 coastal water bodies included in the Danish RBMP.

The ecological status of the 55 coastal water bodies represented by the 55 monitoring stations included in the 7th Nitrates directive reporting was recently assessed in relation to the 3rd generation RBMP (2022-2027). The 6-year data period used for the assessment of ecological status was 2014-2019.

Based on nutrient sensitive BQE's, 52 out of the 55 coastal water bodies containing the stations reported in the 7th reporting are classified as 'Eutrophic', while the remaining stations are classified as 'non-eutrophic' (Table 3.15).

Since the basic typology of Danish water bodies, and reference conditions and environmental targets for key nutrient sensitive BQE's was adjusted in preparation for the 3rd generation RBMP, it is not meaningful to compare the trophic status presented in Table 3.15 to previous assessments.

Table 3.15 Trophic status of the 55 coastal water bodies containing 55 of the monitoring stations included in the 7th Nitrates directive reporting. The classification of water bodies is a translation of the ecological status assessment made for the 3rd generation RBMP (2022-2027) based on nutrient sensitive Biological Quality Elements.

	Non-Eutrophic	Eutrophic
Number of water bodies	3 (5.5 %)	52 (94,5 %)

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 Groundwater

Lærke Thorling and Ingelise Møller, Geological Survey of Denmark and Greenland

3.4.1 Presentation of monitoring network

In Denmark, the monitoring network, which is used for meeting the monitoring requirements according to the Nitrates Directive, ND, also serves to assess groundwater quality according to the Water Framework Directive, WFD. Implementation of the WFD has required large 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. (Jørgensen and Stockmarr, 2009). The major adjustments took place in the period 2010-17, and involved establishment of new monitoring wells as well as closure of existing monitoring wells (Thorling et al. 2019). Due to timing of the registrations of new wells etc. the number of monitoring wells in the recent reports may differ slightly from the present e.g., we here report data from 1210 monitoring points in the 2012-2015 period in contrast to the 1204 reported monitoring points from the same period in the ND report from 2016.

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 are thus 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 3.19 shows the location of the 1623 groundwater monitoring points in Denmark available for this reporting. Due to the clustered character of the monitoring network, it is not possible to show the closed monitoring wells on the same map.

Due to the mentioned adjustments of the groundwater-monitoring network in line with the requirements in the EU Water Framework Directive, some monitoring points used for previous reporting periods were closed and new ones were established elsewhere. As the monitoring network originally was clustered, 90 monitoring points have each been replaced by one other monitoring point within the same location, 12 monitoring points have been replaced by six monitoring points and three monitoring points have been replaced by just one monitoring point. New monitoring points were established at completely different locations in order to monitor more groundwater bodies and increase groundwater monitoring network density in other parts of the country.

A detailed overview on the removed points and their respective replacement points are given in *Appendix 3* to this report. In this overview, closed monitoring points have been categorized by the character of their respective replacement point, which can either be found in close proximity, within the same groundwater body or even within the same groundwater monitoring well (in cases where one well contains several screens).

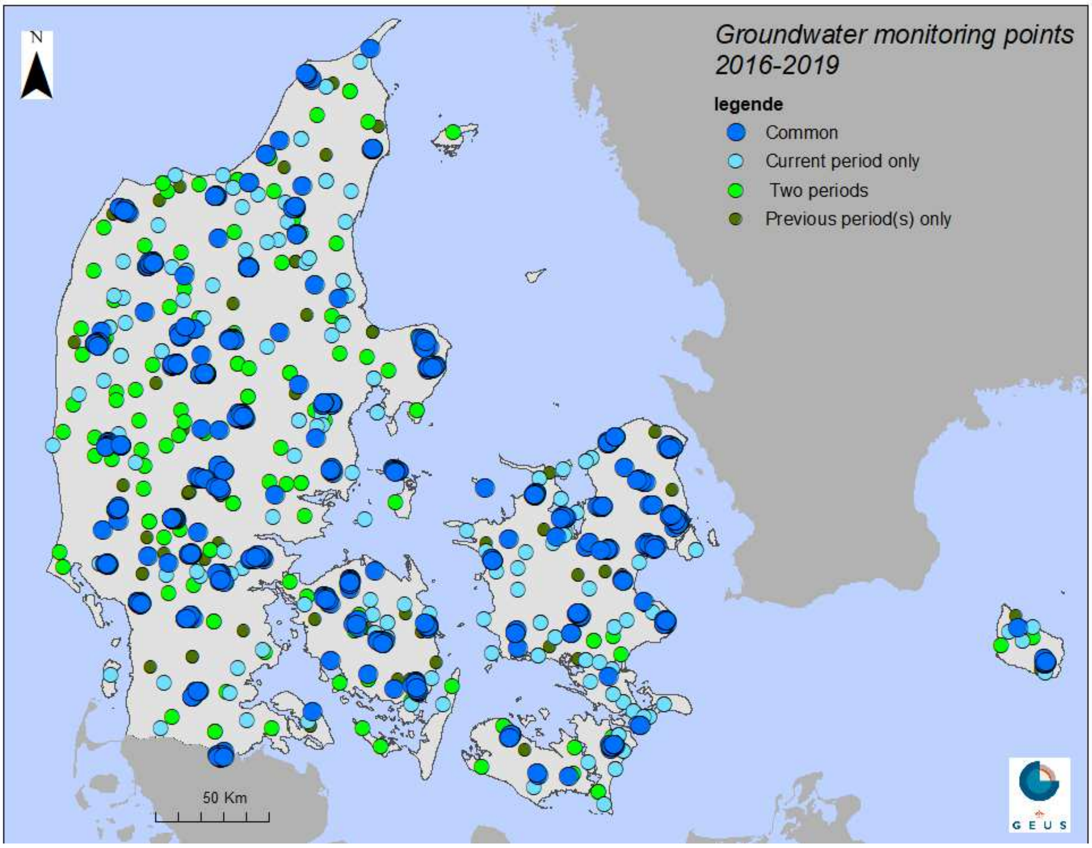


Figure 3.19 The location of the 1623 groundwater monitoring points in Denmark available for this reporting. The large blue signature shows the 929 common monitoring points for the last three periods (2008-2019). Light blue signature shows monitoring points only available for the 7th reporting period (2016-2019). Monitoring points used in the current period and one of the previous periods in this report (2008-2011 or 2012-2015) are shown in light green. Finally, the dark green signature shows monitoring points with data from one or both of the previous periods (2008-2011 / 2012-2015).

The number of groundwater monitoring points for the current and previous reporting period is shown in table 3.16. A total of 1623 monitoring points have been used at some stage in the monitoring network in the period 2008-2019.

Table 3.16 Number of groundwater monitoring points (screens in monitoring wells) for the current (2016-2019) and the two previous reporting periods.

	2008-2011 5th reporting period	2012-2015 6th reporting period	2016-2019 7th reporting period	common points all 3 periods	common points 6th and 7th period
number of points	1256	1210	1275	929	1105

The national groundwater monitoring programme has been designed to monitor groundwater recharged after approx. 1940. The monitoring wells are either placed in quaternary glacial deposits, in underlying tertiary fluvial deposits or in underlying cretaceous limestone. Many monitoring points are placed in partly artesian aquifers, due to hydraulic inactive clay layers, but most 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 the karstic properties of the limestone aquifers are considered insignificant and the typical captive groundwaters have a natural quality unsuitable for drinking water, due to salt, fluoride etc.Tables with nitrate content in the current reporting period and trends since the previous period subdivided according to depth can be found in Appendix 4.

3.4.2 Status for nitrate concentrations

Nitrate data for 2016-2019 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. For comparison the same aggregation is done for the two previous periods 2008-2011 and 2012-2015. Due to the revision of the monitoring network data is aggregated not only for all the monitoring data from each year, as described in the guidelines, but also for the common monitoring points only.

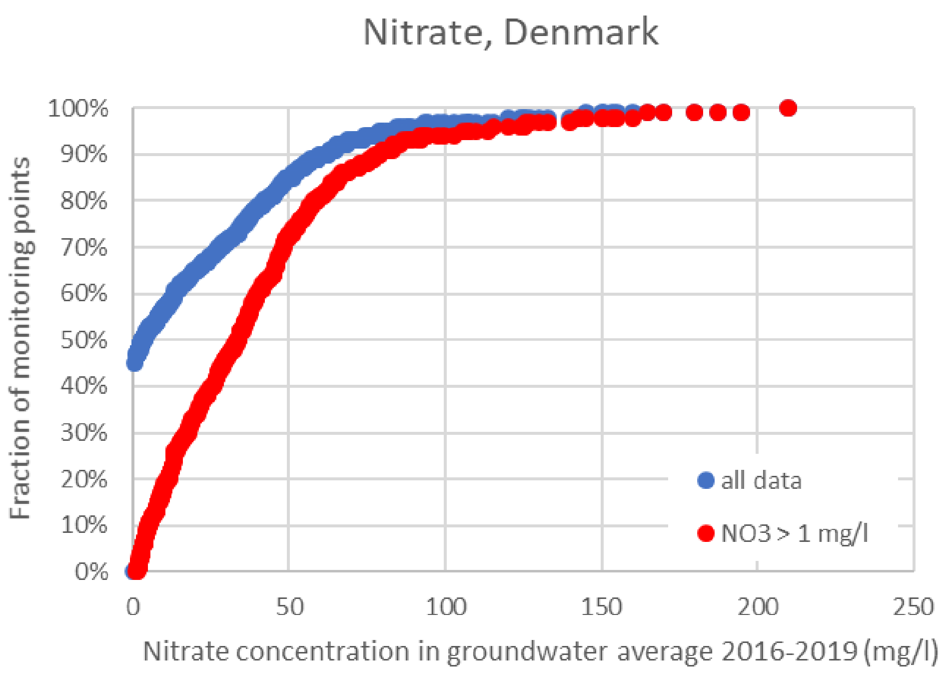


Figure 3.20 The distribution of the average nitrate concentrations of the individual monitoring points 2016-2019. The distribution is shown for all monitoring points and monitoring points with an average nitrate concentration above 1 mg/l.

Figure 3.20 shows the distribution of nitrate in all the monitoring points from the current period 2016-2019. As groundwater from approximately 45 % of the monitoring points does not contain any nitrate (or concentrations below 1 mg/L), the blue data series for all data does not start in the point of origin in the diagram. 14% of all the monitoring points had a mean nitrate concentration above 50 mg/l nitrate. As also shown in figure 3.20 approximately 30 % of the monitoring points with > 1 mg/l nitrate, exceed 50 mg/l. 55 % of the monitoring points had an average nitrate concentration above 1 mg/l, and around 40 % of all the monitoring points did hold nitrate contents between 1 and 50 mg/l.

The aggregated data is found in table 3.17 and 3.18. 18.9 % of all the monitoring points had a maximum nitrate concentration ≥ 50 mg/l and 14.3 % of the monitoring points had an average nitrate concentration ≥ 50 mg/l nitrate in the reporting period 2016-2019. The percentage of monitoring points ≥ 40 mg/l nitrate is for the maximum and average concentrations 25.3 % and 20.9 % respectively.

The major part, about 80 % of the monitoring points has an average nitrate concentration below 40 mg/l (figure 3.20). The share of monitoring points with nitrate concentrations above 40 mg/l 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.
In both table 3.17 and 3.18 a decreasing percentage of monitoring points ≥40 mg/l and ≥50 mg/l can be found for the maximum values as well as the average values of nitrate over the succession of the latest reporting periods.

A comparison between table 3.17 and 3.18 indicates that a higher percentage of wells with nitrate concentrations above 40 and 50 mg/l, respectively, is monitored in the new adjusted network used in the current reporting period, giving a larger share of monitoring points with nitrate concentrations above these levels in table 3.18. This explains why the overall tendency of decreasing nitrate concentrations in the groundwater is only weakly reflected in table 3.17, when comparing the current two previous reporting periods. The weaker indication of a trend in table 3.17 is caused by the overruling effect of the adjustments of the monitoring network.

Trend between 5th and 7th monitoring period

Table 3.17 Distribution of average and maximum nitrate concentration, for the previous (2008-2011 and 2012-2015) and current (2016-2019) reporting period. All monitoring points in each period are used.
NB: The networks for the reporting periods are not identical. See table 3.16 for common monitoring points only

Percentage of all points	2008 - 2011	2012-2015	2016-2019
≥ 50 mg/l			
on max. values NO_3	20.4	19.8	18.9
on avg. values NO_3	16.2	16.4	14.3
≥ 40 mg/l			
on max. values NO_3	26.1	26.3	25.3
on avg. values NO_3	22.0	23.1	20.9

Table 3.18 Distribution of average and maximum nitrate concentration, for the previous (2008-2011 and 2012-2015) and current reporting period 2016-2019. Only common monitoring points (n=929) are used.

Percentage of common points	2008 - 2011	2012-2015	2016-2019
≥ 50 mg/l			
on max. values NO_3	25.3	22.9	21.9
on avg. values NO_3	20.0	18.9	16.7
≥ 40 mg/l			
on max. values NO_3	32.5	30.5	29.5
on avg. values NO_3	27.1	26.6	24.8

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 3.21). In the deeper aquifers, elevated concentrations of nitrate are mainly found in the western part of Denmark, whereas upper groundwater can contain elevated nitrate concentrations in all parts of Denmark (Hansen et al, 2012).

The geographical distribution of nitrate concentration levels in the current reporting period is shown in figure 3.22 and 3.23 for the average and maximum values respectively. On the maps, 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, for the recent reporting period.

The average nitrate content from the 7th reporting period (2016-2019), is illustrated in figure 3.22 (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 3.22 (top) gives an impression of a geographic widespread occurrence of nitrate in Danish groundwater, whereas figure 3.22 (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 figures 3.22 (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, but the infiltration 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 is 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 3.21., The highest concentrations can generally be found below intensive agricultural areal that comprise approx. 63% of the land use. Nitrate leached from gardens, forest and natural areas generally results in concentrations below 50 mg/l.

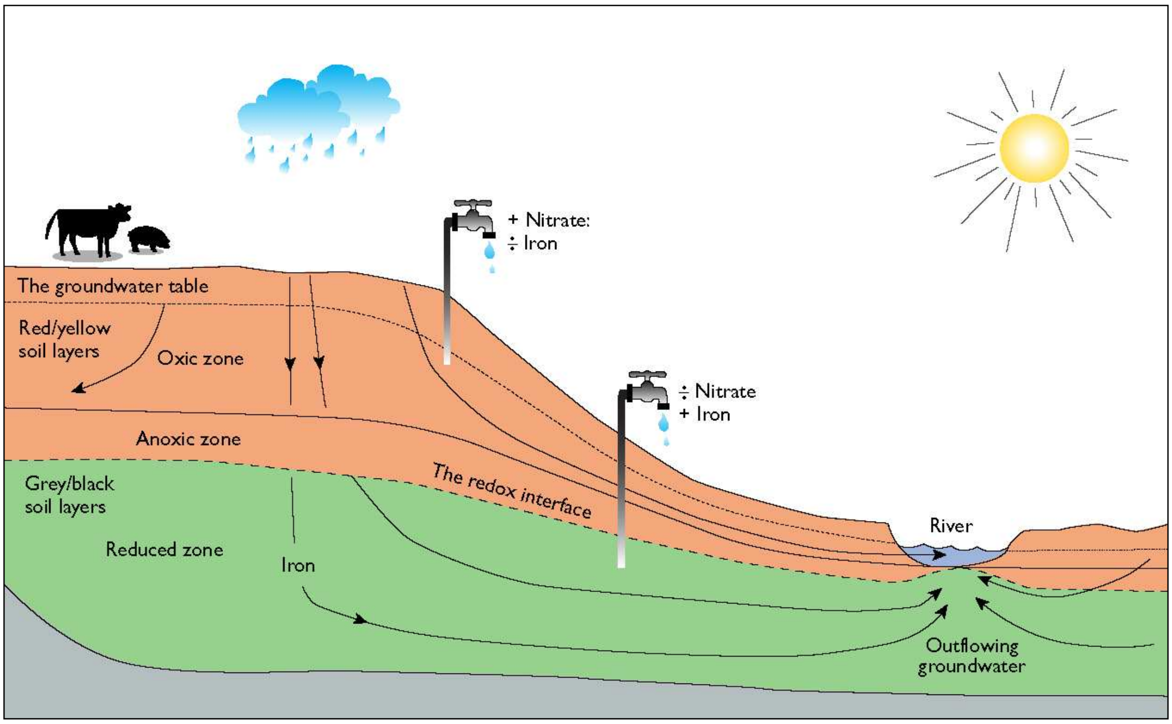
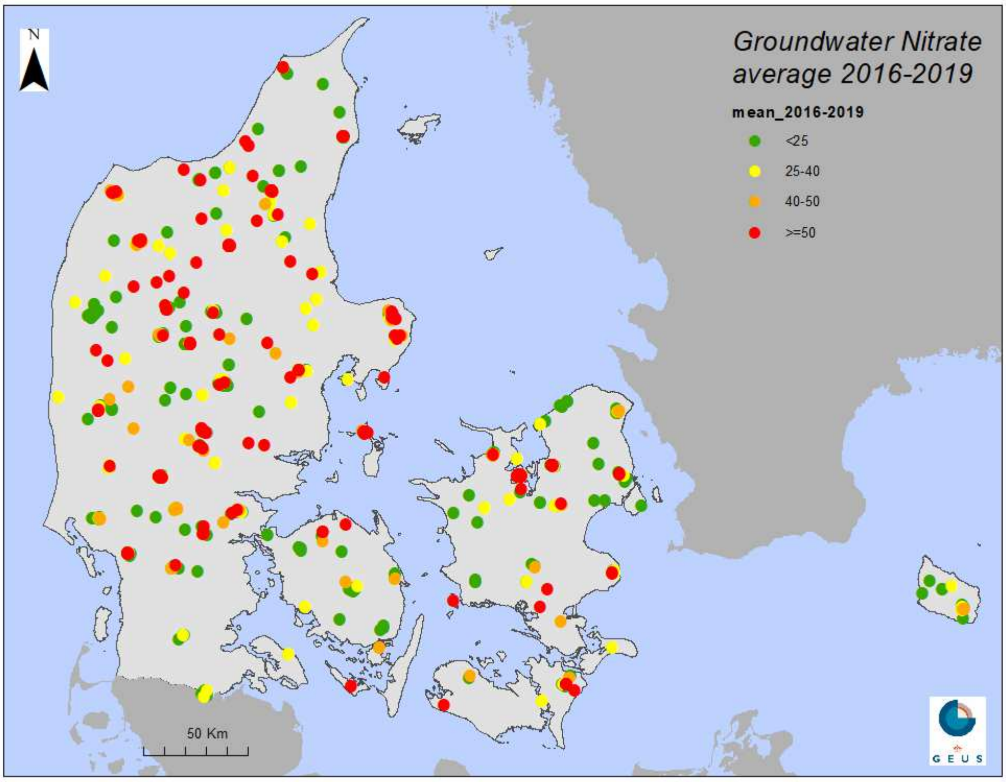


Figure 3.21 Principle for spatial nitrate distribution in an aquifer.



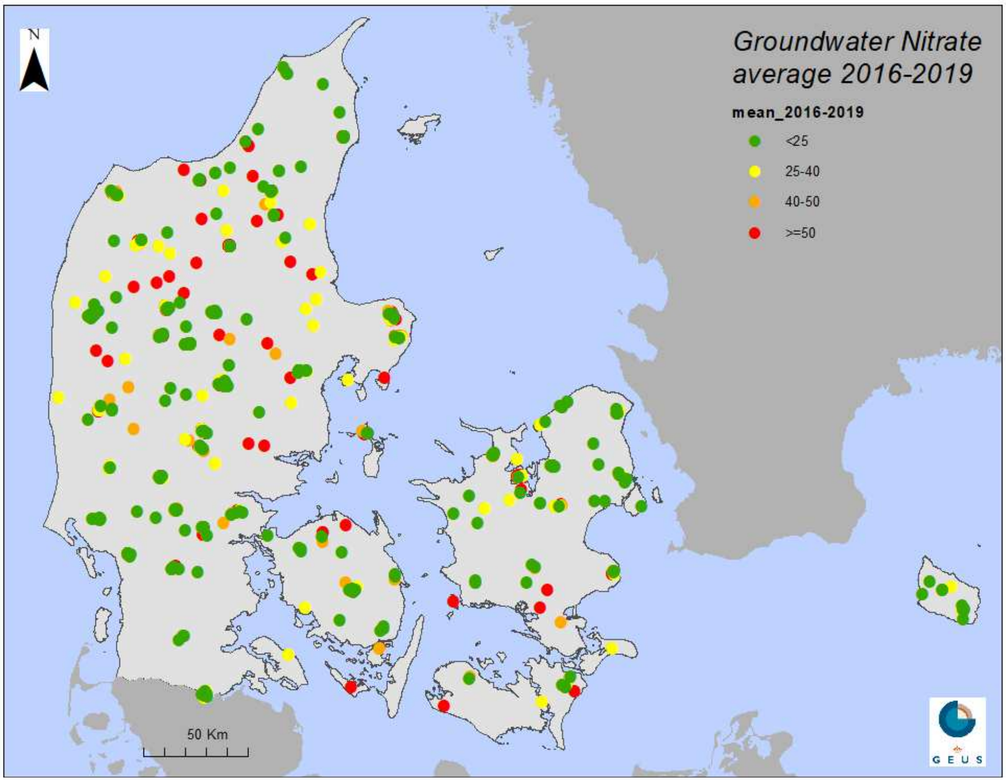


Figure 3.22 Status for the average nitrate concentration 2016-2019 in all 1275 monitoring points. The same dataset is shown in two GIS presentations: on the top map, nitrate is drawn in ascending order (above 50 mg/l are drawn last), on the bottom map, nitrate is drawn in descending order (values below 25 mg/l are drawn last).

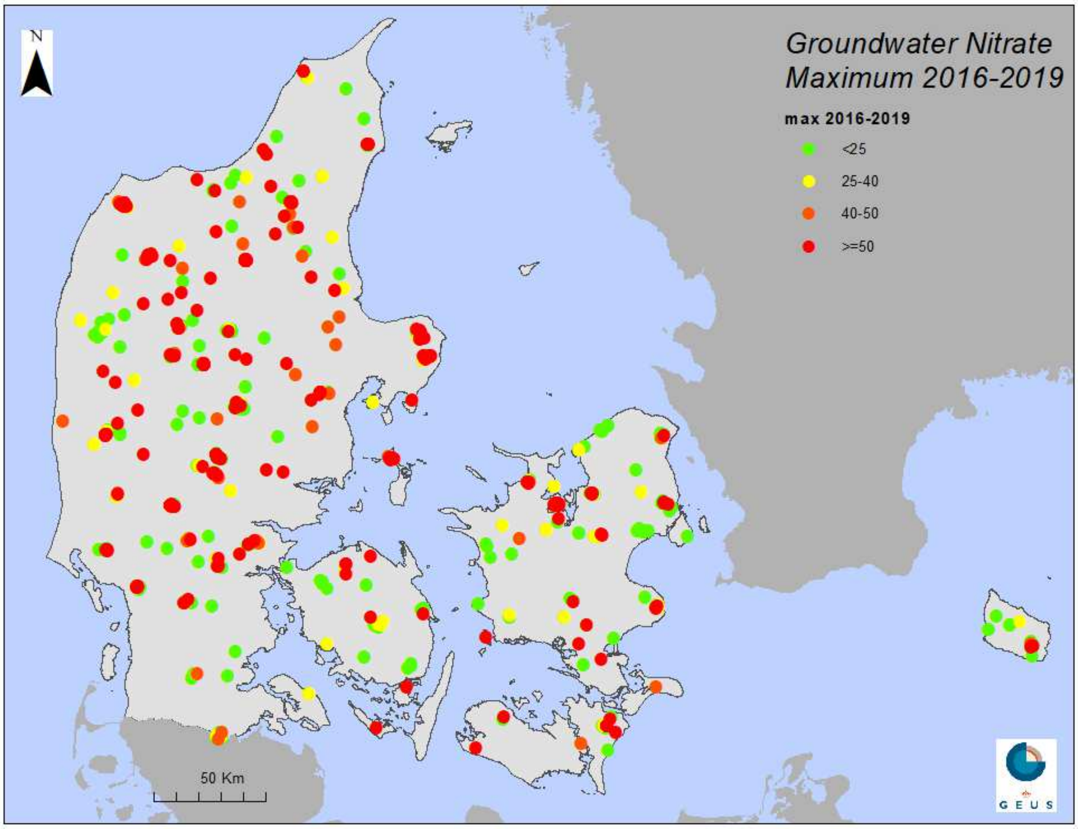


Figure 3.23 Status for the maximum nitrate concentration 2016-2019 in all 1275 monitoring points. Nitrate concentrations drawn in ascending order, values above 50 mg/l are drawn last.

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 the 1105 common monitoring point between the previous (2012-2015) and the current (2016-2019) reporting period. This procedure was also followed in the previous reportings. The results are grouped in five classes, as shown in table 3.19.

Table 3.19 Trend in average and maximum nitrate concentrations in 1105 common monitoring points between the previous period 2012-2015 and the current reporting period 2016-2019.

Percentage of common points	On max. NO_3	**On average**
Increasing	Nitrate mg/l-4years	Nitrate mg/l-4years
Strongly >+5 mg/l	12,9	10,7
Weakly >+1 to +5 mg/l	7,9	7,6
Stable		
±1 mg/l	50,1	50,4
Decreasing		
Strongly <-5 mg/l	18,1	18,9
Weakly <-1 to -5 mg/l	11,0	12,4

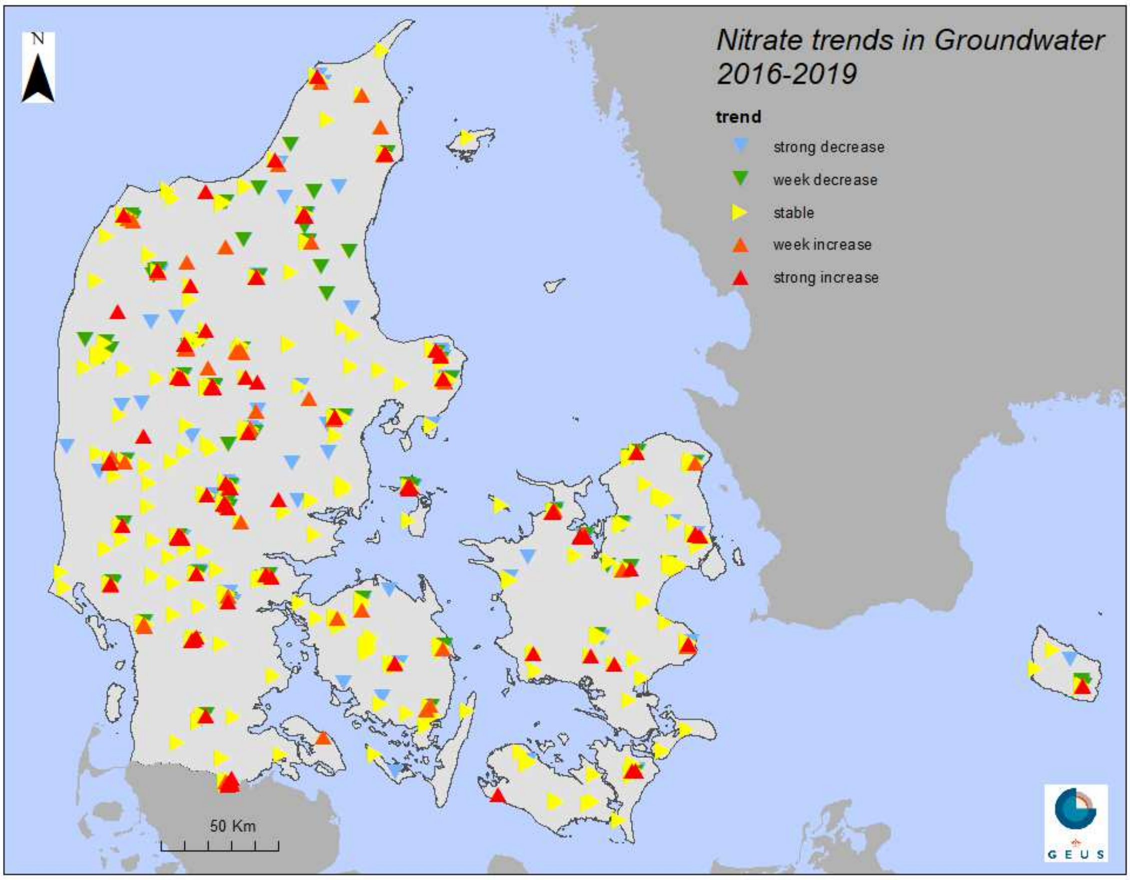
The major part of the monitoring points has trends in nitrate concentration of -1 to 1 mg/l from 6th to 7th reporting period. For obvious reasons this holds for groundwater where nitrate concentrations are below 1 mg/l, which accounts for about 45 % of the monitoring points, the stable fraction in table 3.19.

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 3.19 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 3.17 and 3.18) that a larger fraction of monitoring points has decreasing nitrate content than the fraction with increasing content. With respect to the average nitrate concentration, 31.3 % of the monitoring points are decreasing whereas 18.3 % are increasing. Looking at the maximum nitrate concentration, 29.1 % of the monitoring points are decreasing and 20.8 % are increasing.

Figure 3.24 shows a map of the spatial distribution of the trends in average nitrate of the monitoring wells from the 6th to the 7th reporting period. As for the status in figure 3.22 and 3.23, the overall trend shows very different pictures, depending on the drawing order. At the top of figure 3.24 the trends are drawn in ascending order (strongly increasing nitrate > 5 mg/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 3.24 shows that both increasing and decreasing trends can be found all over the country, as one would expect due to groundwater of different age having different distributions of trends, figure 3.24. 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 to explain the increasing trends, in spite of 30 years of action plans.



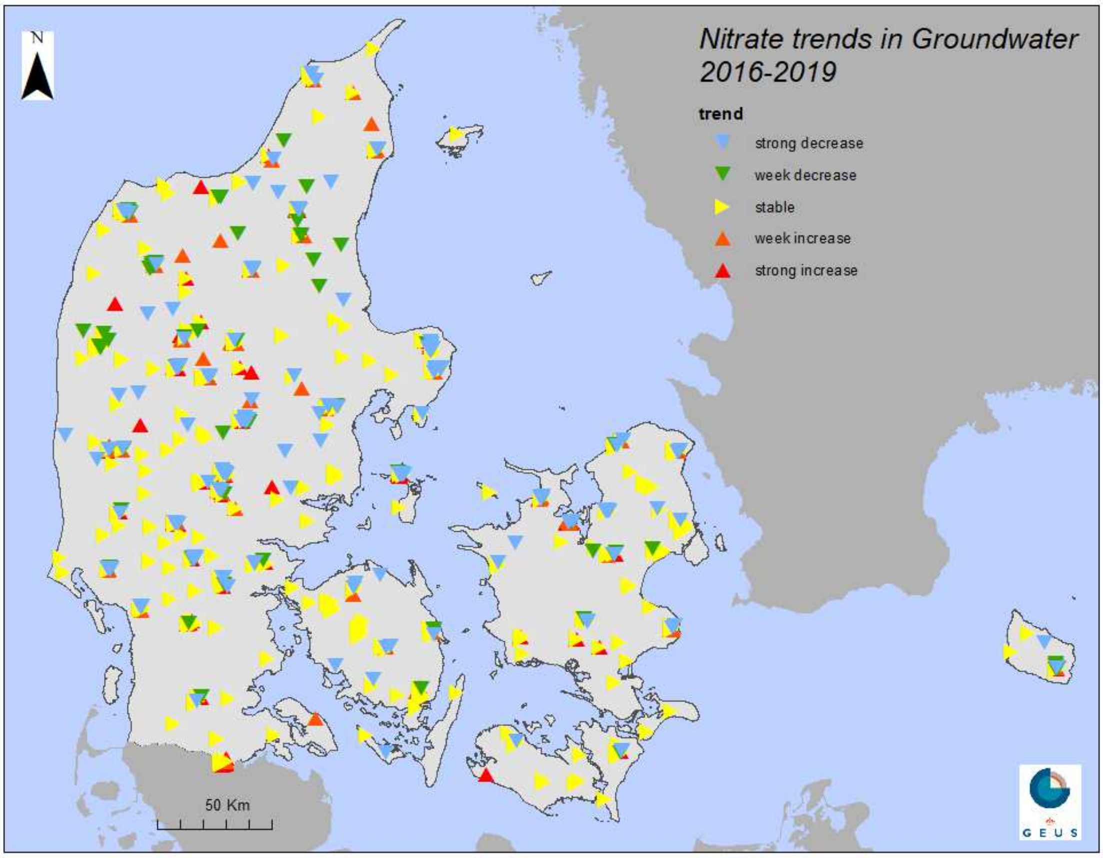


Figure 3.24 Trend of average nitrate content in 1105 common monitoring points from the 6th to the 7th reporting period. (2012-2015 and 2016-2019). Note: On the top map, trends are drawn in ascending order; the bottom map shows trends drawn in descending order.

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 the groundwater age and infiltration time has not been taken into account.

Statistical nitrate trend analyses at a national level using CFC dating gave a strong indication of a trend reversal of nitrate in Danish oxic groundwater in the beginning of the 1980'ies due to reduced nitrogen leaching in Danish agriculture (Hansen et al., 2011). A recent assessment by Hansen & Larsen (2016) and Hansen et al. (2017) using both CFC and tritium/helium dating, support these earlier findings showing significant correlation between nitrate in oxic groundwater and nitrogen surplus in agriculture at the overall Danish national level (Figure 3.25). 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 3.25).

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.

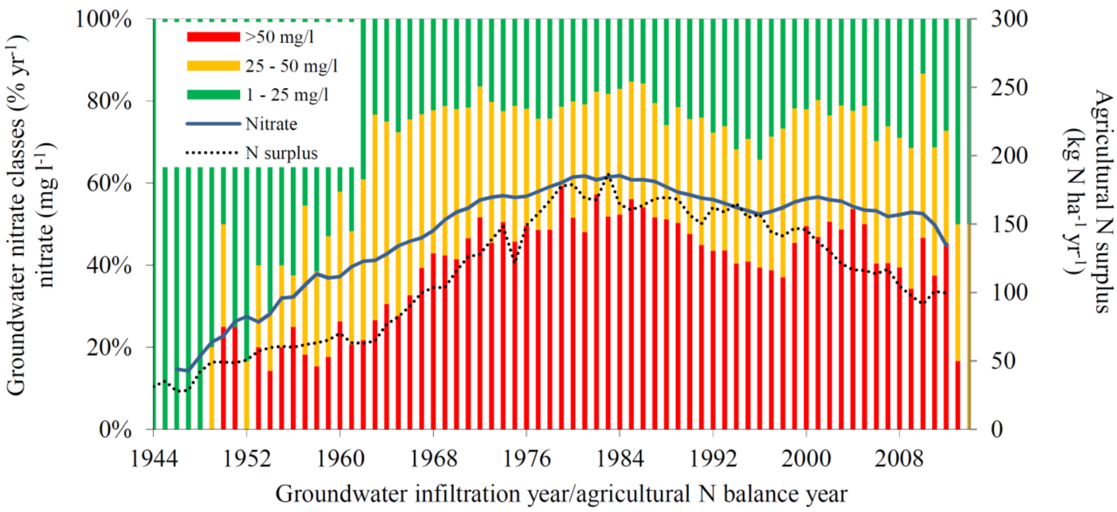


Figure 3.25 Concentrations of nitrate in oxic groundwater (5-years moving average) as a function of infiltration year for dated groundwater, and nitrogen surplus in agriculture. Nitrate concentration classes are also shown for the intervals: >50 mg/l, 25-50 mg/l, and 1-25 mg/l. A total of 5,506 nitrate samples from 340 oxic monitoring points are shown.

To underpin these conclusions, the development in the nitrate concentration in individual monitoring points, i.e. screens, in the national groundwater monitoring network (“GRUMO”) with oxic groundwater has been investigated with a linear regression analysis of nitrate time series from the individual monitoring points, as published in Hansen et al. (2017). The analysis includes a total of 3,233 samples from 250 points, where the time series cover at least eight years in the individual sub-periods. A total of 303 time series are included in the four sub-periods in Figure 3.26 (1940-75, 1975-85, 1985-1998 and 1998-2014), which means that some of the 250 intakes are repeated in several sub-periods.

A nitrate trend is interpreted as increasing if the slope coefficient of the regression line through the monitoring points is positive, and decreasing if it is negative. Figure 3.26 shows the accumulated result of the 303 calculated nitrate trends for the individual monitoring points distributed over the four periods with both statistically significant and non-significant trends at a 95% confidence level.

Figure 3.26 shows a clear trend towards a declining nitrate content in oxic groundwater, both when only the development in the statistically significant trends is considered and when both significant and non-significant trends are examined. It can be seen that the number of samples for the last period (1998-2014) provides a slimmer data basis (41 monitoring points) than, for example, the period 1975-1985 (135 monitoring points).

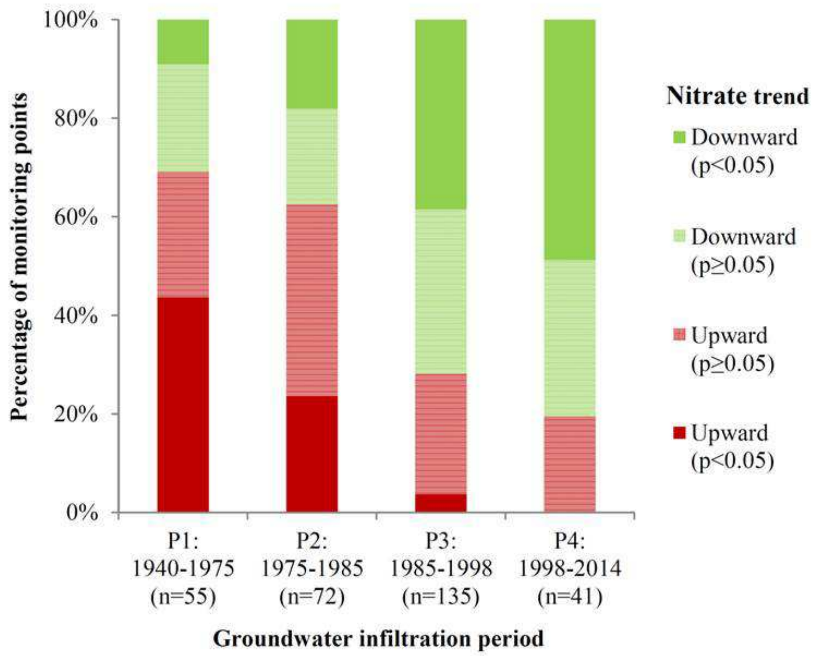


Figure 3.26 National groundwater monitoring network "GRUMO": Oxic groundwater only: nitrate trends in 303 monitoring points in oxic groundwater for 4 periods based on the year of groundwater formation. The analysis includes a total of 3,233 samples from 250 screens, where the time series cover at least 8 years. The numbers in brackets shoes the number of monitoring points. Both statistically significant and non-significant nitrate trends are shown at 95% confidence levels. The figure is based on data collected from 1988-2014 (Hansen et al., 2017).

References:

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.

Hansen, B., Thorling, L., Dalgaard, T. og Erlandsen, M., 2011: Trend Reversal of Nitrate in Danish Goundwater – a Reflection of Agricultural Practices and Nitrogen Surpluses since 1950. Environmental Science and Technology, vol. 45 nr. 1 pp 228-234.

Hansen, B., Dalgaard, T., Thorling, L., Sørensen, B., Erlandsen, M., 2012: Regional analysis of groundwater nitrate concentrations and trends in Denmark in regard to agricultural influence. Biogeosciendes Disucssion paper, 9, 5321-5346, 2012. http://www.biogeosciences-discuss.net/9/5321/2012/bgd-9-5321-2012.html

Hansen, B., Thorling, L., Schullehner, J., Termansen, M. & Dalgaard, T., 2017: Groundwater nitrate response to sustainable nitrogen management. Scientific Reports, 7, 8566. DOI: 10.1038/s41598-017-07147-2.

Jørgensen, L.F.; Stockmarr, J., 2009: Groundwater monitoring in Denmark: characteristics, perspectives and comparison with other countries. *Hydrogeology Journal* 2009, 17, 827-842

Thorling**, L**., Ditlefsen, C., Ernstsen, V., Hansen, B., Johnsen, A.R., og Troldborg, L. 2019: Grundvand. Status og udvikling 1989 – 2018. Teknisk rapport, GEUS 2019.

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

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 2016 to 2019 (both years included) and the promotion of the elements in the programme.

6. Principle measures applied in the Action programme

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. References of executive orders etc., which may be regularly updated, will be the version of the order that was active on December 31st of 2019.

At present, the Nitrates Directive is implemented in the following legislation as part of the Danish Action programme or as additional measures according to Article 5, paragraph 5:

- Act on Environmental protection cf. Executive Order no. 1218 (25/11/2019) with subsequent amendments.,"Lov om miljøbeskyttelse, jf. lovbekendtgørelse nr. 1218 af lov af 25. november 2019 med senere ændringer.", see link: https://www.retsinformation.dk/eli/lta/2019/1218
- Act on agricultural use of fertilizer and plant cover. "Lov nr. 338 af 2. april 2019 om jordbrugets anvendelse af gødning og om næringsstofreducerende tiltag", see link: https://www.retsinformation.dk/eli/lta/2019/338
- Act No 256 of 21 March 2017 on Livestock Husbandry and Use of Fertilizers with subsequent amendments, "Lov om husdyrbrug og anvendelse af gødning, jf. lovbekendtgørelse nr.520 af 1. Maj 2019, see link https://www.retsinformation.dk/eli/lta/2019/520
- Executive Order No 1176 of 23 July 2020 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers," Bekendtgørelse om miljøregulering af dyrehold og om opbevaring og anvendelse af gødning" See link: https://www.retsinformation.dk/eli/lta/2020/1176 .
- Executive Order No 1166 of 13 July 2020 on Agricultural Use of Fertilisers in the planning period 2020/2021, "Bekendtgørelse om jordbrugets anvendelse af gødning i planperioden 2020/2021". See link: https://www.retsinformation.dk/eli/lta/2020/1166. The Order is re-issued yearly and the fertilization standards are re-calculated regularly.
- Executive Order No 66 of 28 January 2020 on Nutrient-Reducing Measures and Cultivation-Related Measures in Agriculture for the planning period 2020/2021, " Bekendtgørelse om næringsstofreducerende tiltag og dyrkningsrelaterede tiltag i jordbruget for planperioden 2020/2021". See link: https://www.retsinformation.dk/eli/lta/2020/66. The Order is re-issued yearly.
- Consolidated Act on Water extraction no 118 of 22 February 2018

Other regulation is currently under preparation.

From 2016-2019 the Nitrate Directive was implemented in the following legislation as part of the Danish Action programme or as additional measures according to Article 5, paragraph 5:

- Act on Environmental protection cf. Executive Order no. 1218 (25/11/2019) with subsequent amendments.,"Lov om miljøbeskyttelse, jf. lovbekendtgørelse nr. 1218 af lov af 25. november 2019 med senere ændringer.", see link: https://www.retsinformation.dk/eli/lta/2019/1218
- Act No 388 of 2 April 2019 on agricultural use of fertilizer and plant cover. "Lov nr. 338 af 2. april 2019 om jordbrugets anvendelse af gødning og om næringsstofreducerende tiltag" , see link: https://www.retsinformation.dk/eli/lta/2019/338 Previously: Act No 433 og 3 may 2017 on agricultural use of fertiliser and on plant cover.
- Act No 256 of 21 March 2017 on Livestock Husbandry and Use of Fertilizers with subsequent amendments, "Lov om husdyrbrug og anvendelse af gødning, jf. lovbekendtgørelse nr. 520 af 1. Maj 2019, see link https://www.retsinformation.dk/eli/lta/2019/520

- Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers," Bekendtgørelse om miljøregulering af dyrehold og om opbevaring og anvendelse af gødning" See link: https://www.retsinformation.dk/eli/lta/2019/760 Previously: Order on commercial livestock, livestock manure, silage, etc. The Order is re-issued yearly
- Executive Order No 762 of 29 July 2019 on Agricultural Use of Fertilisers in the planning period 2019/2020, "Bekendtgørelse om jordbrugets anvendelse af gødning i planperioden 2019/2020". See link: https://www.retsinformation.dk/eli/lta/2019/762 The Order is re-issued yearly and the fertilization standards are re-calculated regularly.
- Executive Order No 759 of 29 July 2019 on Nutrient-Reducing Measures and Cultivation-Related Measures in Agriculture for the planning period 2019/2020, " Bekendtgørelse om næringsstofreducerende tiltag og dyrkningsrelaterede tiltag i jordbruget for planperioden 2019/2020". See link: https://www.retsinformation.dk/eli/lta/2019/759 The Order is re-issued yearly.
- Executive Order No 739 of 12 July 2019 on national subsidy for nitrogen-reducing measures (voluntary targeted regulation), "Bekendtgørelse om nationalt tilskud til kvælstofreducerende virkemidler". See link: https://www.retsinformation.dk/eli/lta/2019/739
- Consolidated Act on Water extraction no 118 of 22 February 2018. In Danish "Bekendtgørelse af lov om vandforsyning m.v." link: https://www.retsinformation.dk/eli/lta/2018/118

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 2019 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 2019. Changes in the implementation are described for each element in the overview in Table 6.1. Changes in the legal texts in effect in 2020 are not included in the legal references in the overview.

The exact text of the orders, as they were in 2019, 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 2016-2019 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 2019 Indication of changes during the period 2016-2019
Annex II A 1. Periods when the land application of fertilizer is inappropriate	§ 28 of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers ***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.***
	Changes compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 1318 of /06/2015: Special rules for application of root vegetable washing water and vegetable juices.
Annex II A 2. The land application of fertilizer to steeply sloping ground	§ 29 (6) (7) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers ***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. 1318 of /06/2015..
Annex II A 3. The land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground	§ 29 (5) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers ***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. 1318 of /06/2015.
Annex II A 4. The conditions for land application of fertilizer near water courses	§ 29 (5) (8) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers ***Manure, digestate, silage effluent, residual water and mineral fertilizer must not be applied 2 m from watercourses.***
	No change compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 1318 of /06/2015.
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.***
	No changes compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 1318 of /06/2015.
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.	§ 27 (2) , 29 (1) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers ***Application of liquid manure and digestate may only be carried out by means of trailing hoses, trailing foot/shoe applicators or by injection.***
	Changes compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 1318 of /06/2015: Clarification of how deposition should take place.
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;	§ 41 (1), Act No. 338 of 2. April 2019 on agricultural use of fertilizer and plant cover (Fertilizer Act) § 11 (1) and (5), Executive Order No. 762 of 29. July 2019 on Agricultural Use of Fertilisers in the planning period 2019/2020***Farms subject to registration in the Fertilizer Register pursuant to the Fertilizer Act must report a fertilizer plan in a dedicated template with a field map showing all cultivated and uncultivated areas and the field crops. The farms must do this no later than 10 September after the planning period. The farms must submit the plans electronically using a self-service IT facility on the Danish Agricultural Agency website.***

	Change compared to previous Order: With the new Fertilizer Act, farms were obliged to submit their fertilizer planning to the Agency, and not only to prepare the plan and keep it on-farm. The plan should be prepared in a dedicated template with a field map showing all cultivated and uncultivated areas and the field crops. In addition, the deadline for submission of the final plan was moved forward to 10 September from a previous deadline for preparation of the plan in April the year after. These changes contributed with greater transparency and a better overview of commitments for the farmer as well as improved conditions for control by the Agency of farm compliance with the commitments.
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;	§ 3 (1)- (4) in Executive Order No 759 of 29 July 2019 on Nutrient-Reducing Measures and Cultivation-Related Measures in Agriculture for the planning period 2019/2020 § 38 in Act No 338 of 2. April 2019 on agricultural use of fertilizer and plant cover. ***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 The new executive order included provisions on the reporting of catch crops with requirement to report at field level and to enclose a field map, provisions for mandatory reporting of changes between planned and actually laid out catch crops. Also, new flexible sowing deadlines for catch crops were introduced, where postponement of the sowing is accepted at the expense of a lower farm nitrogen quota in the planning period. Requirements for livestock catch crops and associated rules were transferred from the Livestock Manure Order to the Nutrient-reducing Measures Order in order to streamline regulation concerning commitments on catch crops. The order also introduced a new sanctioning practice (fines rather than quota reduction).On 22 December 2015, the Danish government and supporting political parties in the Danish Parliament reached an agreement on a Food and Agricultural Package. The agreement included a diverse package of measures, initiating a shift in environmental regulation of the agricultural sector from a general regulation to a more targeted approach. One central element in the agreement was to roll back the percentage reduction of the annual nitrogen application standards for farming, which had previously been applied. The standards had previously been reduced by approximately 20% compared to the economically optimal standard level. In order to avoid an increase in nitrate leaching due to this adjustment, the Danish government in 2017 introduced a number of measures, including an intermediate N reduction initiative to promote the targeted sowing of additional catch crops. The targeted scheme comprised of a de-minimis aid scheme for voluntary establishment of additional catch crops combined with an additional obligatory N-reduction requirement on farmers, in case the voluntary

	scheme did not reach its targets. The scheme contributed with N effect to Denmark's continued fulfilment of the objectives of the Directive in 2017-2019. Also during the period, a number of amendments to provisions on compulsory catch crops were made, including changes in the conversion factors between catch crops and alternative nitrates-reducing actions and adding new plants species to the list of plants allowed for the compulsory catch crops.
Annex II B 9. The establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer Use	§ 25 and § 42 (1), Act No. 338 of 2. April 2019 on agricultural use of fertilizer and plant cover. § 11 (1) and (5), § 12 (1) and § 14 (5) in Executive Order No. 762 of 29 July 2019 on Agricultural Use of Fertilisers in the planning period 2019/2020. ***Requirement to prepare a fertilizer plan and a fertilizer account for each holding.*** ***Farms subject to registration in the Fertilizer Register pursuant to the Fertilizers Act must report a fertilizer plan in a dedicated template showing all cultivated and uncultivated areas, a field map and the field crops. The farms must do this no later than 10 September after the end of the planning period. The farms must submit the plan electronically using a self-service IT facility on the Danish Agricultural Agency website.*** ***By the end of March each year, farmers are obliged to submit their farm fertilization account containing information on the previous cropping season (planning period August-July) to the Danish Agricultural Agency for registration and control.***
	Change: Previously, the farms were not obliged to submit the fertilizer plan to the Agency, only to prepare it and keep it on-farm.
Annex II B 10. The prevention of water pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems	§ 22 Consolidated Act on Water extraction no 118 of 22 January 2018 ***Farmers need permission for water intake for irrigation. Permissions are issued for a limited period.*** ***In addition, the need for irrigation is included when calculating nitrogen fertilizer 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 § 28 (1-6) (9-13) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers
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	See Annex II A 5 above.

actual storage capacity will be disposed of in a manner which will not cause harm to the environment;	
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 […]	§ 12 and § 13 (1), Act No. 338 of 2. April 2019 on agricultural use of fertilizer and plant cover § 1 bkg. nr. 210 af 17. marts 2020 om om kvælstofprognosen for planperioden 2019/2020 § 29 (6) , § 26 (1) (2) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers **Application of fertilizers** § 12 of Act No. 338 of 2. April 2019 on agricultural use of fertilizer and plant cover ***In each plan period, farms subject to registration in the Fertilizer Register pursuant to the Act must not apply more nitrogen for fertilizer purposes than the fertilizer quota calculated for the farm.*** ***For each plan period, a farm's total fertilizer quota for nitrogen must be calculated as the sum of the quotas for each farm field. For each field the quota must be calculated on basis of the size of the field, the crop, the pre-crop and the nitrogen standard of the crop.*** § 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.*** § 3-9 of Executive Order No. 762 of 29. July 2019 on Agricultural Use of Fertilisers in the planning period 2019/2020 ***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 nitrogen standards for each crop are determined and updated regularly. 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 for each crop.*** ***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.***

	The fertilizing content of nitrogen in the livestock manure must be calculated using stipulated standards. Standards are set for different types of livestock and with respect to the housing system. If the production deviates from standard, e.g. slaughter weight, the standard figures must be corrected, using standard corrections formulas. A large percentage of the nitrogen contents of applied livestock manure must be included in the accounting of overall application of nitrogen fertilizer on the farm. Minimum application efficiency rates are imposed on each type of manure. Thus, the possibility to use additional mineral fertilizer up to the fertilizer quota is restricted. § 29 (6) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers - See under Annex II A2 § 26 (1) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers
	Changes: Act No. 338 of 2. April 2019 on agricultural use of fertilizer and plant cover was a continuation of the previous fertilizer Act on agricultural use of fertilizer and plant cover no. 500 (12/05/2013) as amended by Act no 576 (04/05/2015). The new Act also mandated the shift in fertilizer regulation from general regulation to a more targeted regulation. The 22nd 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. A central element of the agreement was to roll back the general percentage reduction of nitrogen fertilizer standards from economically optimal levels, which had previously been applied. In order to avoid an increase in nitrate leaching due to this adjustment, a number of compensatory measures were established. Among these, a targeted nitrates-reducing obligatory scheme was designed. It consisted of a first round with a de-minimis aid scheme for voluntary targeted establishment of additional catch crops followed by an obligatory targeted N-reduction requirement on farmers, in case the voluntary scheme did not reach its targets (see Annex II B8). Also in 2017, a revised regulation addressing phosphorus was introduced. Until then the Danish harmony rules had regulated the application of phosphorus in an indirect way: by setting limitations based on the amount of manure-N applied to the field. As the N/P-ratio is different for the various livestock types, the level of indirect P limitation varied correspondingly. Instead was introduced direct P application ceilings at different levels throughout the country, depending on geographical location and livestock manure type.

	§ 26 (1) of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers: Clarification with requirements that crops are covered by nitrogen norm in Act No. 338 of 2. April 2019 on agricultural use of fertilizer and plant cover
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.	§ 26 (1) § 34 (1), (2) and (4) and § 41 of Executive Order No 760 of 30 June 2019 on Environmental Regulation of Animal Husbandry and the Storage and Use of Fertilisers ***A maximum of 170 kg N per hectare (previously 1.4 livestock units per hectare equivalent to 140 kg N pr. Ha) 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 new specified methods where a holding may apply up to 170 kg. N. pr. from livestock manure on a harmony area. 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.*** ***General rules has been introduces to counteract the increased risk to phosphorus loss to the aquatic environment.*** ***Derogation (Commission decision of December 6th 2018): On agricultural holdings with a yearly production of nitrogen in livestock manure above 300 kg of which at least two thirds are from cattle, can apply livestock manure containing up to 230 kg nitrogen per hectare per planning period when in compliance with certain conditions.***
	Change compared to previous Order on commercial livestock, livestock manure, silage, etc. no. 1318 of /06/2015 regarding calculation method. See above.
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 watercourses.*** ***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 programme's measures

7.1 Data concerning the territory of Denmark

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

	Reporting Period	
	Previous period Average of 2012-2015	**Current period Average of 2016-2019**
Total land area[1)] hectare (ha)		4,309,800
Agricultural land, 1000 ha	2,648	2,615[4]
Agricultural land available for application of manure, 1000 ha	2,460	2,507[4]
Permanent grass, 1000 ha	211	220[5]
Perennial crops[2)] (fruit trees, bushes and energy crops), 1000 ha	14	14[5, 6]
Annual use of organic N from livestock manure[3)], 1000 tons	217	220[4]
Annual use of organic N from other sources than livestock manure, 1000 tons	7	8[4]
Annual use of N from fertilizer (mineral N), 1000 tons	202	232[4]
Number of farms	40,400	34,400[4]
Number of farms with livestock	21,800	13,400[5]
Dairy cattle, 1000 heads	568	573[5]
Cattle, million heads	1.52	1.54[5]
Slaughter Pigs, million/year	20.1	17[7]
Poultry, million heads	18.6	20.8[5]
Fur, million heads	2.78	3.14[5]
Other (horse, sheep), 1000 heads	147	148[5]
Manure N excretion per livestock category, 1000 tons/year		
Cattle	113	117[4]
Pigs	84	83[4]
Others	20	21[4]

[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)

Sources: The AgriFish Agency[4], Statistics Denmark[5], Aarhus University[6], Danish Agriculture and Food Council[7]

7.2 Nitrogen discharges to the aquatic environment

The amount of Nitrogen, which has been discharged to the sea in the years 2016 to 2018, was within a similar range as in the previous reporting period (Table 7.2). The discharges are recalculated every year for each year. The discharges from previously reported years are lower in the latest discharge due to a change in the modelling of the unmeasured areas[9].

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

	4th period (2004-2007)		5th period (2008-2011)		6th period (2012-2015)		7th period (2016-2019)	
	2004	2007	2008	2011	2012	2015	2016	2018[1]
Total N discharge (tons N)	66,000	78,000	60,000	55,000	54,000	67,000	57,000	50,000
Water-discharge-normalized N discharge (tons N)[2]	67,000	61,000	58,000	53,000	52,000	53,000	55,000	55,000

1) Data for 2019 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.

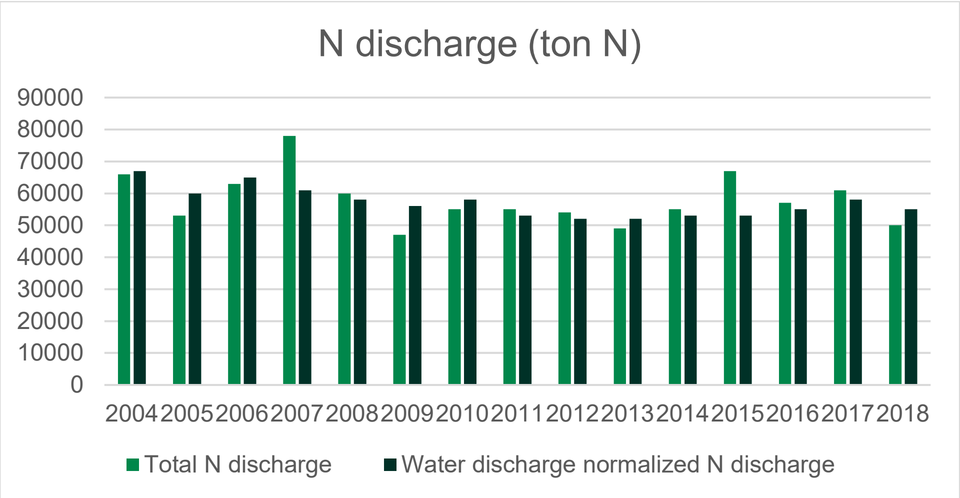


Figure 7.1: Total nitrogen discharges from the Danish territory to the sea from 2004 to 2018 (both diffuse pollution and point sources) (Source: NOVANA)

9 https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notatet_2020/N2020_8.pdf

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 52,000 to 58,000 tons N/year in all the years 2008 to 2018 (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 (Boutrup, S. et al. 2019[10]), which has been in operation since 1989. During this 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 watercourse station network and thus the measured catchment area (the area upstream of a watercourse station) has been increased as a result of the political Agreement of Food and Agriculture. Measured N load from 237 stations is included in the estimated load when modelling the total diffuse N load in 2018[11]. The measured catchment area (the area upstream of stations) has been expanded from approx. 55% to cover approx. 61% of the total area. This expansion of the station network has increased the measured catchment area in general, and in some coastal waters the proportion of measured catchment area has increased considerably. At the same time, the uncertainty in the measures has diminished, as a larger share of the area is measured instead of modelled. For the unmeasured catchments, the N load is calculated using empirical /statistical models for the quantity and conversion of nitrogen in the surface water system, based on the DK-QNP model_v2, Windolf et al. (2011b).

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 app. 55,000 N/year in the years 2016 to 2018. 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. However there are regional differences according to the land use e.g. in the Sound (Øresund) where the contribution from wastewater is higher than the national average due to the urban land use.

In the year 2018, 35 of the largest (> 50.000 PE) waste water treatment plants treated 50% 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 wastewater (Source: NOVANA)

Source[1]	**4th period (2004-2007)**		**5th period (2008-2011)**		**6th period (2012-2015)**		**7th period (2016-2019)**	
	2004	2007	2008	2011	2012	2015	2016	2018[2]
Urban waste water	4 030	3 620	3 500	3 900	3 800	3 800	3 400	3 130
Industrial waste water	500	500	400	310	220	330	340	370

1) This is a non-exhaustive list - there are more point sources than urban and industrial wastewater.

2) Data for 2019 not yet available

10 https://dce2.au.dk/pub/SR356.pdf

11 https://dce2.au.dk/pub/SR353.pdf

Additionally, the N discharge to the aquatic environment from households in rural areas, storm water, storm water overflows and aquaculture sums up to circa 2,249 tons N/year in 2018. Two thirds are discharged from fresh water plants and one third from plants in salty waters.

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

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

7.3.1 Nitrates in water leaving the root zone

This section deals with the general development in nitrate leaching from 1990 to 2018. Data for 2019 is not yet available. Information on agricultural practises is provided by Gitte Blicher-Mathiesen, Tina Houlborg and Helle Holm (Department of Bioscience, Aarhus University), and is based on the annual derogation report to the EU Commission for 2019.

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), 1990-2018

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 2018 (representing the hydrological years 1990/91 to 2017/18) is shown in Figure 7.2 as an average for sandy and loamy catchments, respectively.

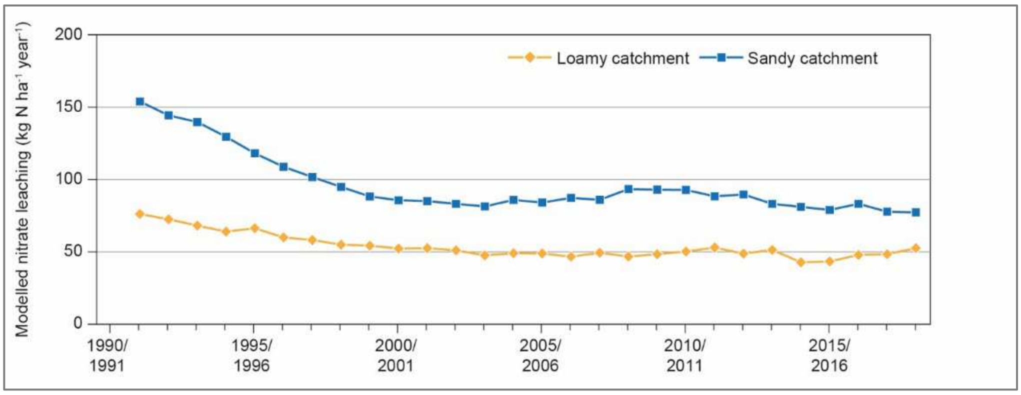


Figure 7.2 Modelled nitrate leaching in a standard climate for the fields of the Agricultural Catchment Monitoring Programme, 1990/91-2017/2018 (Source: Danish Derogation Report 2019)

Seen relative to the distribution of the main soil types in Denmark, the modelled nitrate leaching decreased by 43% during the period 1991 to 2003 due to the general improvement in agriculture and fertilization practises. After 2003, there was a small increase in nitrate leaching, particularly on sandy soils, probably caused by suspension of the set aside obligation. For the loamy catchments, the modelled annual nitrate leaching was less affected by the change in set aside. The nitrate leaching was relatively stable around 50 kg N ha^{-1} during 2003-2013, decreasing with app. 8 kg N ha^{-1} in 2014 and 2015 and increasing again to the level of 2003-2013 in 2016-2018. For the sandy catchments, the annual leaching of 81 kg N ha^{-1} in 2003 was relatively low. After this year, the leaching increased to an interval of 83-93 kg N ha^{-1} in the period 2004-2014, but decreased to a lower level than in 2003, being in the interval of 77-79 kg N ha^{-1} in 2015-2018.

The purpose of the root zone modelling is to show the effects of measures introduced to mitigate nutrient losses from agriculture. The modelling is therefore carried out for normalised growth conditions, i.e. averaging the model output for a 20-year period: The model is run for each year in the 20-year period and model outputs are then averaged for the period. The climatic data used cover the period 1990-2010. Actual measurements of nitrate leaching will show higher annual variations than the climatic average of the modelled values as the measurements depend on the actual climate.

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 (approx. 1 m depth – 30 samples per year) and the upper oxic groundwater (1.5-5 m depth – 6 samples per year). The measured concentrations are shown as annual average values for loamy and sandy soils, respectively, for the period 1990/91-2017/18 (Figure 7.3).

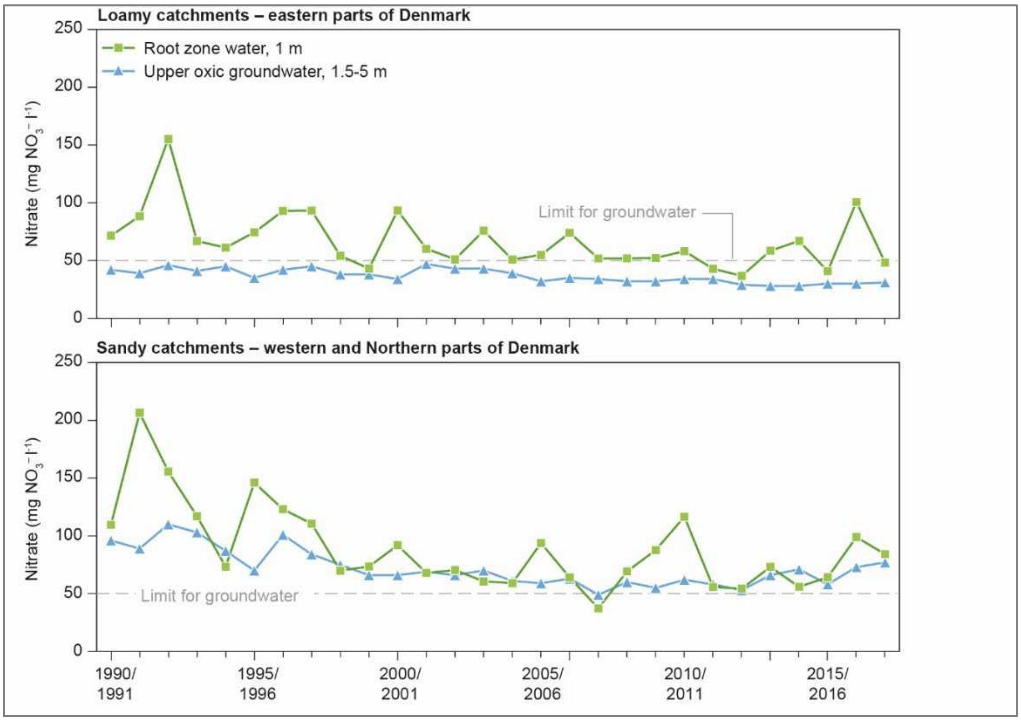


Figure 7.3 Annual flow-weighted nitrate concentrations measured in root zone water and annual average nitrate concentrations measured in upper oxic groundwater, the Agricultural Catchment Monitoring Programme (LOOP) 1990/91-2017/18 (Source: Danish Derogation Report 2019)

There is a strong inter-annual variation in the measured nitrate concentrations due to differences in rainfall and temperature. Therefore, a long time series and a large number of measuring points are necessary to detect any statistically significant trend. Such data series are available from the Danish Monitoring Programme. A statistical trend analysis – a Mann-Kendall test, incorporating annual variations in the mean annual flow-weighted nitrate concentrations for water leaving the root zone – showed that concentrations decreased significantly by 1.2 and 2.6 mg NO_3 l^{-1} a^{-1} for the measured sites on loamy and sandy soils, respectively, and for the whole 26-year monitoring period from 1990/91 to 2015/16.

On loamy catchments, the measured nitrate concentrations in root zone water decreased from 61-155 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 37-66 mg NO_3 l^{-1} in the 5-year period 2011/12-2015/16 and increased to 101 and 48 mg NO_3 l^{-1} in the two years 2016/17 and 2017/18, respectively. The high nitrate concentrations are seen in years with low percolation as observed on loamy soils in 2004/05, 2010/11 and in 2016/17. On sandy catchments, the nitrate concentration decreased from 73-207 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 54-73 mg NO_3 l^{-1} in the 5-year period 2011/12-2015/16 and increased to 99 and 84 mg NO_3 l^{-1} in the two years 2016/17 and 2017/18, respectively (Figure 7.3.).

After 2003/04, no statistically significant change in measured nitrate concentrations in soil water leaving the root zone has been recorded. However, before 2011/12, high concentrations were temporarily observed for sandy soils. This is most likely due to growth of crops with high leaching potential on these fields, such as turnover 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 sampling stations (27 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 induce higher inter-annual variations than seen in the modelled nitrate leaching, which covers a larger area including approx. 126 farms.

In the upper groundwater (1.5-5.0 m below ground level), nitrate concentrations were lower than in the root zone water, indicating nitrate reduction in the aquifer sediment between the bottom of the root zone and the uppermost groundwater (Figure 7.3).

On loamy catchments, the measured nitrate concentrations in the upper oxic groundwater decreased from 41-46 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 28-31 mg NO_3 l^{-1} in the 5-year period 2013/14-2017/18. On sandy catchments, the nitrate concentration decreased from 87-110 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 58-77 mg NO_3 l^{-1} in the 5-year period 2013/14-2017/18.

7.3.2 Difference between input and output of nitrogen

In the annual reports of the national monitoring programme for the aquatic environment and nature (NOVANA) is published the national usage of commercial fertilizer, which has decreased from 394,000 tons N in 1990 to 265,400 tons N in 2018. The data for 2019 is not yet available. Nitrogen input in form of livestock manure has decreased from ca. 244,000 tons N in 1990 to approx. 224,000 tons N in 2018. 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 inter-annual variations, especially in the early years and again from 2007 onwards. In 2018, a generally relatively low yield because of the drought has increased the N balance.

The annual surplus in the national field balance has fallen: from approx. 405,000 tons N in 1990 to 265,400 tons N in 2018, which corresponds to a reduction by 34%. There appears to be a slight increase in N-balance in the last years as presented in Fig. 7.4. The Food and Agriculture Package of 2015 removed the general nitrogen quota reduction and hence permitted farmers to fertilize according the economic optimum from 2016 and on. Following an anticipation that this could lead to an increase in nitrogen loss from the root zone, regulation to target root zone loss was implemented. The effects of the targeted regulation are unlikely to show on a graph of N-balance representing N-application and N-harvest. The weather's influence on yields is showing in the N-balances of for example 2018, where the N-surplus is higher than normal because of the drought causing low yield. However, 2018 was an unusually dry year resulting in a poor harvest.

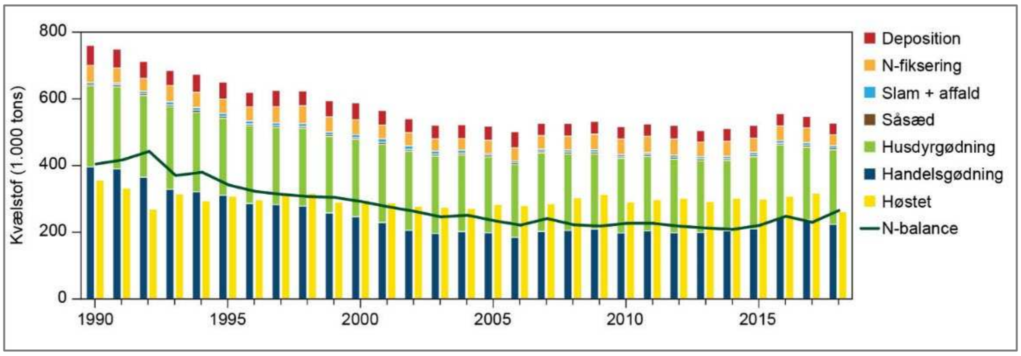


Figure 7.4 Danish field balances for nitrogen (green line) (Source: NOVANA LOOP 2018[12])

Since 1990, the utilization of nitrogen in animal slurry has 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 of development in key parameters concerning the use of animal slurry within the LOOP-monitoring programme in 1990 and during the reporting period (2016-2018, data for 2019 not yet available) (Source: NOVANA LOOP 2018)

Parameter	1990	2016	2017	2018
Storage capacity for liquid animal slurry, corresponding to 9 months' production (% of LU)	38	91	84	81
For the different farm types:				
Pigs		100	100	100
Cattle		100	100	100
Other		70	77	80
Spreading of liquid slurry during spring & summer (% of LU)	55	90	91	92
Slurry application with trail hose or injection (% of total N in liquid animal slurry applied)	8	100	100	100
Percentage applied by trail hose (%)		39	42	39
Percentage injected (%)		61	58	61

Broadspreading of animal slurry has been banned since 2003. Since 2011, farmers are obliged to inject slurry on grass or bare soil. Probably because slurry acidification was accepted as an alternative to injection since 2012, followed by trail hose application.

More detailed field balances, given in kg N per hectare, can be found in Table 7.5. Table 7.5 also shows a significant decrease in application of commercial fertilizer since the 1990's. While keeping the amount of harvested N relatively constant since the late 1990's, the N balance has, therefore, decreased since the late 1990's.

[12] https://dce2.au.dk/pub/SR352.pdf

Table 7.5 Data on field balances for whole territory (kg N/ha) cultivated area until 2018 (Source: NOVANA LOOP 2018)

Year	1990[1]	1998[1]	2007[2]	2011[2]	2015[2]	2016[2]	2017[2]	2018[2]
Inorganic Fertilizer	142	104	73	76	79	92	92	86
Livestock manure[3]	88	87	87	85	82	83	84	86
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	2
N-fixation	18	20	15	18	16	17	17	13
N-deposition[4]	39	30	26	25	25	25	24	24
Applied[5]	273	233	194	198	196	211	211	202
Harvested	145	115	107	113	114	117	122	100
N balance	**128**	**118**	**87**	**85**	**82**	**94**	**89**	**102**
Cultivated area (1000 ha)	2788	2672	2744	2693	2663	2634	2593	2602

[1] data for mineral fertiliser based on information from “Danmarks Statistik”

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

[3] data for livestock manure based on the Fertilizer Accounting System (2015-2018), earlier data on livestock from Aarhus University (LOOP, 2018)

[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 (2016-2019, data for 2019 not yet available) remained at the same relatively low level from 2007 and onwards (Table 7.6). The data from year 2015 was not available during the last reporting period, and is included here.

Table 7.6 Development in fertilizer usage until 2018, the year refers to the year of harvest (Source: NOVANA LOOP 2018)

Year	1990	1998	2007	2011	2015	2016	2017	2018
Nitrogen (1000 tons N)								
Mineral fertilizer	400	283	202	204	210	242	237	224
Livestock manure	244	278	238	228	216	219	218	224
Total N[1]	760	623	530	530	520	555	546	527
Phosphorus (1000 tons P)								
Mineral fertilizer	40.4	20.7	13.4	10.8	13.3	13.3	20.8	14.8
Livestock manure	54.6	55.9	45.9	41.3	46.1	44.3	43.0	43.9
Total P[1]	98.5	84.0	66.1	58.9	66.2	64.4	70.5	65.0

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

Literature:

Blicher-Mathiesen, G., Holm, H., Houlborg, T., Rolighed, J., Andersen, H.E., Carstensen, M.V., Jensen, P.G., Wienke, J., Hansen, B. & Thorling, L. 2019. Landovervågningsoplande 2018. NOVANA. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 241 s. - Videnskabelig rapport nr. 352 http://dce2.au.dk/pub/SR352.pdf

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

The Danish Agricultural Agency, Ministry of Food, Agriculture and Fisheries 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 Danish Act 338/2019 on the “Farms’ use of Manure and on Plant Cover”, including the annually revised “Statutory Order on Nutrient-reducing Actions and Cultivation-related measures in the planning period”, “Statutory Order on agricultural use of fertilizer in the planning period” and “Statutory Order on Nitrogen Prognosis”.

Administrative staff of the Danish Agricultural Agency control the provisions in the mentioned acts and orders. Besides the administrative control, they also inspect farm compliance of the rules 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 66/2020 and 1176/2020, respectively.

In the planning period 2016/2017, the Danish Agricultural Agency carried out 121 inspections on the spot and for the planning period 2016/2017, the Danish Agricultural Agency carried out 586 administrative control of submitted fertilizer accounts, regarding the orders mentioned above, corresponding to approx. 2.0 % of all agricultural holdings obliged to submit a fertilizer account.

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 the planning period 2016/2017, 121 inspections of fertilizer accounts were carried out. 2 of these (1.7 %) were reported to the police for severe violations and 1 of these (0.8 %) have received an administrative fine for a severe violation of the provisions on rational fertilizer use. This share illustrates a decrease in farms with severe violations, compared to the previous data from 2014 (9.6 %). Additionally one (0.8 %) farmer was given an enforcement notice for a minor violation. The same 121 inspected farms were also controlled regarding the amount of livestock manure applied to land each year (harmony rules). Two of these farmers (1.7 %) were reported to the police for severe violations of the harmony rules.

The vast majority of all Danish farmers must submit data to the Fertilizer Accounting system each year, which is administrated by the Danish Agricultural Agency. For the planning period 2016/2017, 35.866 farmers were obliged to submit a fertilizer account. All submitted fertilizer accounts ware automatically checked at submission by the IT-system, according to a set of previously defined risk criteria. The administrative control of these 586 fertilization accounts showed that 34 farms (5.8 %) exceeded the farms' nitrogen quota by up to 6 kg N per hectare and they received a notification and recommendation (minor violation). 36 farms (6.1 %) exceeded the farms nitrogen quota from 6 kg N and up to 9 kg N per hectare and they received a warning (minor violation). 15 farms (2.6 %) exceeded the farms nitrogen quota by 9 kg N or more per hectare and they received an administrative fine. 12 farms (2.0 %) exceeded the farms nitrogen quota by 9 kg N or more per hectare and they were reported to the police. The same 586 farms were also controlled regarding the amount of livestock manure applied to land each year (harmony rules). 24 farms (4.1 %) were reported to the police for severe violations of the harmony rules. 22 farms (3.8%) are still under investigation.

In 2017 a new scheme on live stock catch crops were introduced. The individual requirement to establish catch crops for holdings using organic manure such as livestock manure were aimed at ensuring the sufficient protection towards nitrogen leaching to sensitive Natura 2000-areas in catchment areas, where the amount of applied organic manure has increased since 2007 and at contributing to the reduction of nitrogen leaching to coastal water bodies, where a reduction of nitrate leaching is necessary in order to obtain the environmental objective according to the River Basin Management Plans (RBMP).

As part of the political agreement on the Food and Agricultural Package of December 2015, the reduction of the nitrogen application standards was removed. It was also agreed to develop a new nitrogen regulation, the "targeted nitrogen regulation", which was to be implemented in 2019. The Danish government introduced an intermediate initiative, the "targeted catch crops scheme", to reduce N-losses through promoting the establishment of additional catch crops in 2017 and 2018. The scheme was designed to protect both groundwater bodies and coastal waters. The scheme was designed as a de minimis aid scheme for voluntary establishment of additional catch crops. The targeted regulation of nitrogen has contributed to the Danish implementation of the Nitrate Directive in the period 2017 to 2019. From 2020, the regulation contributes to the implementation of the Water Framework Directive.

In 2019, the Danish Agriculture Agency carried out a total of 235 on-site inspections on catch crops involving three national schemes on catch crops: Mandatory catch crops, livestock catch crops and the targeted nitrogen regulation (targeted catch crops). The mandatory catch crops has a requirements on 10.7 % or 14.7%, respectively of the area to be covered with catch crops. In 2019, livestock catch crops included in total around 27,500 ha and the targeted nitrogen regulation included in total around 138,000 ha of catch crops.

The farmer may use alternative measures instead of catch crops in order to minimize the leaching of nutrients e.g. establishing energy crops, early sowing of winter crops, reduction of the farms nitrogen quota. Conversion factors are used to secure that the alternatives have the same nitrogen reduction effect as catch crop.

In the non-compensated national schemes of mandatory general and livestock catch crops 19 of the 148 inspections (12.8 %) on crop rotation planning were reported to the police and 11 farmers (7.4 %) received an enforcement notice for non-compliance with the requirements for the establishment of catch crops.

This share on the national scheme illustrates an increase in farms with violations, compared to the previous data from 2014 (3.1 % and 4.7 %, respectively). Nevertheless, it is important to highlight that since 2014 two new schemes for catch crops has been introduced (livestock and targeted catch crops), the rules for e.g. reporting and control of catch crops have been changed and the rules of sanctioning has been tightened. The new rules came into force shortly before the beginning of inspections and it is expected that the infringement rate will be lowering as farmers adjust to the rules.

The Danish Agriculture Agency continuously focuses on how to improve and streamline the control of catch crops, and in recent years a significant proportion of the inspections of the targeted catch crops are designated using satellite-based screening (e.g. including analysis of specific risk factors), which is very effective compared to other methods of designating farms to control. In 2019, there were 87 inspections of the targeted catch crops. Approximately 60 % of the farms designated using satellite-based screening were sanctioned, however less than 5 % of the inspections of targeted catch crops resulted in a sanction, if one disregard the cases that were selected for inspections using satellite-based screening. For the targeted catch crops, non-compliance is sanctioned with both a reduction in the subsidy and a reduction of the fertilizer nitrogen quota for the farm corresponding to the non-compliance.

8. Economic analysis with respect to nitrogen reduction in Denmark 2016-2019

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The River Basin Management Plans (RBMP) from 2016 were based on the preliminary RBMPs from December 2014 and the Food and Agricultural Package (FAP) from December 2015. The plans cover the period from 2016-2021. This economic analysis covers four parts where the first part deals with the economic gain from higher nitrogen norms as part of the FAP. This is followed by three sections evaluating the three major parts of the regulation in RBMP regarding surface water quality. The three parts are: 1) Collective measures 2) Environmental Focus Areas and 3) The Targeted Regulation.

8.1 Higher nitrogen norms and economic gains

As part of the FAP, the requirement regarding 60,000 ha of targeted catch crops was no longer required, just as the new Government in 2015 abandoned the requirement regarding riparian zones. Another key part of the FAP was to increase the N-quota to the economic optimum. The N-quota was introduced as a 10% reduction of the quota in 1998, but the reduction increased over time to 18% reduction in 2014/2015 due to the decisions regarding the maximum size of the N-quota made over time and other changes (e.g. reduction of set a side).

With the FAP, the nitrogen application was increased and so the N-quota was 7% under the optimum in 2015/16 and back to the optimal level in 2016/17. The environmental impact of this change was much discussed prior to and after the decision regarding the FAP. It was estimated that the N-application in total increased by around 60,000 tonnes of N as it was expected that some farms (e.g. organic farms) would not increase their application. In total, the average application increased by ca. 20 kg N/ha (14 %) when the application in 2016 and 2017 is compared with the levels in 2015 (according to the annual fertilizer account from all farms). The norms for e.g. winter wheat on clay soils increased by 46 kg N/ha or 28 % from 2015 to 2017. The reason for this higher increase was an increase in the value of protein in the calculations. The overall increase in the total N-quota has been around 30-35,000 tons N when 2017 and 2018 are compared with 2015 (Jacobsen and Ørum, 2021; Blicher-Mathiesen et al., 2019). This is lower than the expected prior to the FAP (Børgesen et al., 2015). The lower increase is partly due to an increase in the area with spring barley which lowers the average N-quota per ha. Also farmers had, in the years before, converted catch crops to higher N-norms and the yearly adjustment made the jump to optimal quotas smaller than expected. Analyses made of the fertiliser accounts show that roughly around 93-95% of the N-quota has been used throughout the whole period 2013-2019 (Blicher-Mathiesen et al., 2019; Jacobsen, 2019). Typically, the organic farms do not use the full quota.

Analyses of the yield indicates an increase of 1.9 hkg/ha in winter wheat and 0.6 hkg/ha in spring barley when yields in 2016, 2017 and 2019 is compared to 2013-2015 (Eriksen et al., 2020). The yields over time are shown in figure 8.1. In 2018, there was a drought and so this year has been left out of the comparison above (Eriksen et al., 2020).

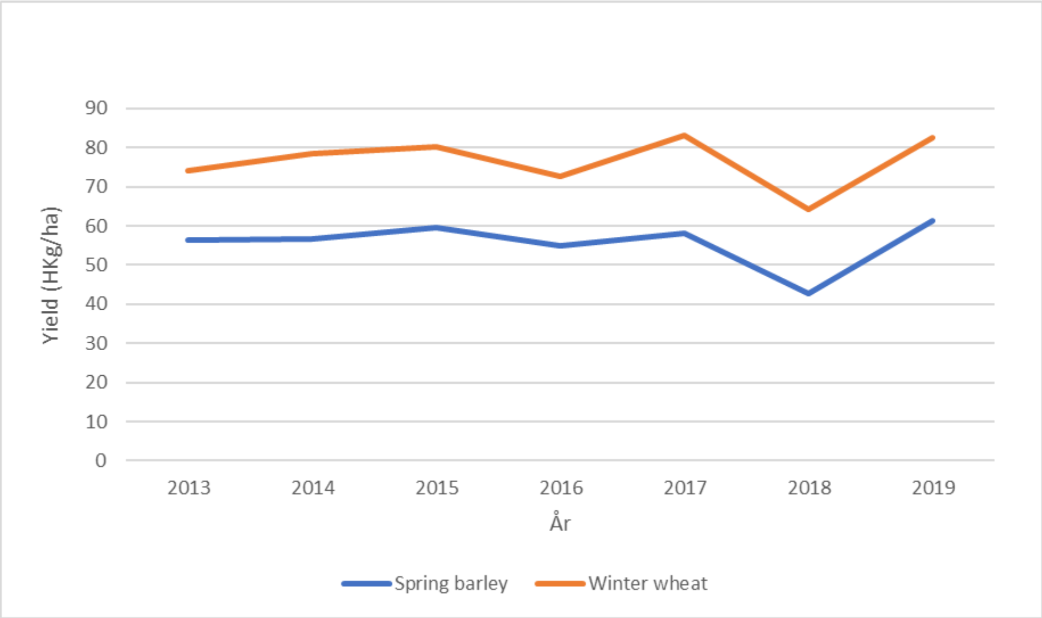

Figure 8.1. Yield in winter wheat and barley for 2013-2019.
Source: Danish Statistics (2020)

The change back to optimal quota also gives an opportunity to compare the effect with the predicted effect based on trials. The latest analyses have shown that a 10% and 20% reduction of the N-quota in winter wheat is expected to reduce yields by 0.6 and 2.3 hkg/ha (Eriksen et al., 2020). The reduction in protein content was expected to be 0.4 and 0.9% respectively and the net cost is 59 and 234 DKK/ha. For spring barley the yield reduction is 0.5 hkg/ha and 1.6 hkg/ha and the net costs are 30 and 120 DKK/ha. Here the reduction from a 10% and 20% decrease in the N-quota on the protein content is expected to be 0.3% and 0.6% units (Eriksen et al., 2020). In other words, the models seem to predict a change which is similar to the observed change in yields until now. With more years, a more precise estimate can be seen of the ex-post yield increase. In genera,l the trials will have a higher yield impact than the average of the national yields. The long term yield reductions are predicted to be lower than in previous analyses, and the losses are estimated to be 6-18 and 23-73 DKK/ha for winter wheat depending on the time horizon used (3 or 100 years) (Eriksen et al., 2020).

The economic value of a higher N-quota due to the FAP was estimated to be around 1200-1800 million DKK per year based on a preliminary assessment of the yield losses with a 21% reduction in the N-quota (6-8 hkg/ha) (Jacobsen, 2016; Jacobsen and Ørum, 2016). The updated estimate of the yield effects are lower and so the economic gain from higher quota is lower than expected in FAP. The calculations would indicate an economic gain from a higher N-quota of around 400 - 600 million DKK (54 - 80 million €/year) or around 150 – 230 DKK/ha (See Jacobsen, 2016; Jacobsen, 2020).

8.2 Collective measures

The collective measures include wetlands, mini-wetlands, afforestation and set-a-side of low-lying areas. For the wetlands, the target was close to 14,500 ha for 5 years which is high compared to around 5,000 ha which has been achieved for the previous 5 years (see table 8.1). It is expected to get gradually more difficult to establish these sites as wetlands have been a part of the planning for 20 years. Mini wetlands was a new measure and an ambitious target of 100,000 ha catchment to the mini wetlands was set as the target in FAP (Graversgaard et al., 2021).

Wetlands often include more farmers, whereas the mini wetlands are decided and created by one farmer. The measures are partly aimed at the same farmers. The measures are perceived as collective measures in that farmers implementing this on one's own farm for the benefit of the catchment, but there is no direct reward such as lower requirements regarding targeted regulation on your own farm which could offer a carrot for participation.

Table 8.1. Expected implementation of collective measures (2016-2021)

	Area (ha)	Reduced N-loss to the sea (tonne N/year)	Total cost (mio. DKK)
Wetlands	14,572	1,253	1,705
Mini wetlands	1,002	900	550
Afforestation	5,000	150	175
Set a side (low areas)	2,955	150	325
Total	20,574	2,452	2,755

Note: Mini wetlands would be 1% of the catchment. A typical catchment related to one mini wetland (one ha) is expected to be 100 ha. Due to reduction in the effects per ha, the catchment area involved has been increased from 100,000 ha to 138,500 ha.
Source: Jacobsen, 2016

As shown in Table 8.2, the targets regarding mini wetlands have been difficult to reach by 2021. Afforestation and set-a-side have reached 54 and 85% respectively of the target. With respect to afforestation the uptake is larger than expected considering that some of the forest is established without subsidy as they are located outside the areas where afforestation is promoted. In general the implementation of the collective measures has been promoted intensively with the use of local catchment officers from the Agricultural Advisory Service (SEGES).

Table 8.2. Ajusted assessment of collective measures and expectations towards 2021

	Ajusted effect (kg N/ha)	Ajusted total effect (tons N)	Ajusted area (ha)	Fulfillment (%)
Wetlands	130	977	7.513	78
Mini wetlands	6,5	332	51.031	37
Afforestation	30	81	2.688	54
Set a side (low areas)	40	128	3.197	85
Total		1.517		62
Reductions still to be achieved		936		

Source: MFVM, 2020

Table 8.3 shows the costs and the cost effectiveness of the measures at the outset. With the lower effect of the mini-wetlands, the costs per kg N increase from 55 to 76 DKK/kg N (in the sea).

Table 8.3. Collective measures and costs per ha and per kg N (2016-2021)

	Efficiency (ton N)	Efficiency (kg N/ha)	Investment (DKK pr. ha)	Yearly cost pr ha based on 20 years (DKK pr. ha)	Cost efficiency (based on 20 years) (DKK/kg N)
Wetlands	1,253	90	123,000	7,860	87
Mini wetlands	900	9	550,000	49,362 *)	55*)
Private afforestation	150	30	35,000	2,352	78
Set a side (low laying fields)	150	40	110,000	7,391	146
I alt	2,453				81

*) For Mini wetlands, a time span of 15 years has been used. The effect has since been reduced to 6.5 kg N/ha which changes the cost effectiveness to 76 DKK/kg N.
Source: Jacobsen, 2016

8.3 Measures related to Greening and the CAP

As part of the FAP, the preliminary plans from 2014 regarding targeted catch crops and 25,000 ha of riparian zones along the streams were removed. So in order to fulfil the requirement regarding 5% Environmental Focus Areas (EFA) farms had to choose more catch crops instead of the riparian zones which farmers disliked (Jacobsen et al., 2017). Due to the exchange rate used in relation to greening one ha of riparian zones requires 5 ha of catch crops. The net effect is a reduction in N-losses as 5 ha catch crops replaced 1 ha riparian zone. As shown in table 8.4 this gave a larger positive environmental effect without direct costs. It also shows that farmers are not keen to use riparian zones as a measure (Jacobsen et al., 2017).

The target for more catch crops was after discussions with the EU commission, set at 145.100 ha in 2017 and 121.600 ha in 2018. This was done in order to to ensure that there was no negative effect of the higher N-quota on especially groundwater and mainly in the southern part of Jutland) (see figure 8.2). This measure was in principle similar to the 123,000 ha targeted catch crops in the draft plans which was removed in 2014. The area involved was very different as it was no longer the northern part of Jutland.

Table 8.4. Measures related to Greening (2016-2021)

	Efficiency (kg N pr. ha)	Compensation (kr. pr. ha)	Costs (mio. kr.)	Effect (tons N)	Cost -eff. DKK/kg N
Environmental Focus Areas (2016-2021)			0	5.532	0
Targeted catch crops (2017-2018)	9,6	700	180	2.467	73
Sum			180	7.999	22

Note: The effect from EFA comes as it replaces 25,000 ha of riparian zones.
Source: Jacobsen, 2016

The increased targeting was based on some new approaches. Firstly, the areas where more catch crops were required were based on the new id15 maps where the retention is given for an area of 1500 ha and for the whole catchment (see figure 8.2). This allowed the measures to be more targeted than the regulation at the catchment level. As the requirements also related to groundwater, an implementation at the catchment level would have been covering far more area than was now the case. Secondly, there was a requirement for each area (id/catchment) not per farm, which meant that some farmers could implement more catch crops than required. This flexibility allowed farmers with more room in their crop rotation to implement more and so farmers with less options could implement less. In total, this reduced the overall costs for the farmers. Furthermore, the application was divided into three rounds to ensure that the area which required the catch crops the most came first. The compensation given was financed using Danish funds (not EU funding) and the compensation was set at 700 DKK/ha.

This approach was very much the front-runner for the approach adopted two years later regarding targeted regulation (see next section). In the first year with targeted catch crops, the full requirement was almost achieved, but in the second year around 10,000 ha was not achieved in the voluntary round, which led to some farms having an obligatory requirement (without compensation) in the catchments where the target was not reached (e.g. northern part of Jutland).

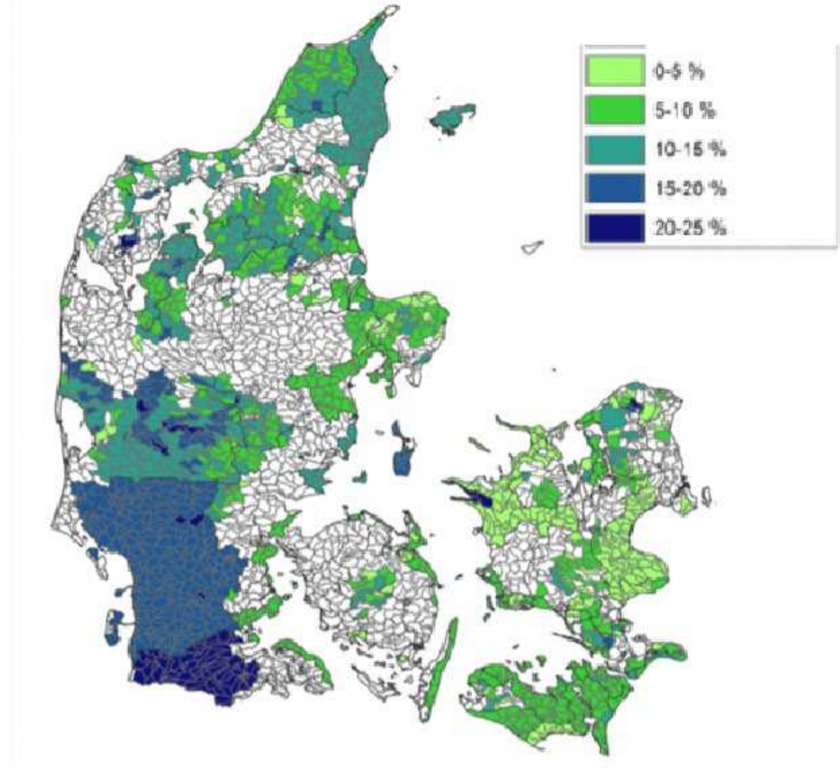

Figure 8.2. Targeted catch crops in 2018
Source: LBST, 2018

8.4 Targeted regulation

Targeted regulation was introduced in 2019 with the aim of reducing N-losses further. The precise nature of the regulation was not clear in the FAP. In the FAP, the implementation was intended to happen over three years where 1/3 of the final target would be reached in 2019, 2/3 in 2020 and full implementation in 2021. It was later changed so full implementation was implemented in 2020. The full requirement was around 380,000 ha of catch crops in 2020 (MFVM, 2019). In 2019, the requirement was 1.167 tonnes N or approximately 120,000 ha catch crops and the compensation was 529 kr. pr. ha (Ørum et al., 2018).

As part of the FAP analyses an analysis was carried out in order estimate which measures would be required to reach the target (Jacobsen, 2016). Again catch crops was a key measure (replacing the targeted catch crops in 2017 and 2018). Furthermore, the model suggested using lower N-quota and early sowing as the cheapest measures in the 90 catchments which were included in the analysis. As mentioned earlier, the remaining 6,200 tonne N was moved to the next planning period (2021-2027). The overall assessment in 2016 can be found in Table 8.5. The costs of targeted regulation were calculated to be around 305 million DKK per year (41 mio. €).

Table 8.5. Measures regarding targeted regulation in order to reach a reduction of 3.640 tons N in 2020.

	Area (ha)	**Efficiency (kg N/ha)**	**Effect (tons N)**	**Costs (1000 DKK)**	**Costs (DKK/ha)**	**Cost efficiency (DKK//kg N)**
Catch crops	155.582	9	1.426	37.783	243	26
N-quota reduction 7 %	1.272.354	1	814	85.248	67	105
N-quota reduction (+3 %)	113.041	0	38	9.043	80	239
N-quota reduction (+4 %)	62	0	0	11	173	1.657

Set-a-side (rotation)	11.661	16	186	44.311	3.800	238
In between crops	175.348	3	600	63.125	360	105
Early seeding	142.630	2	295	0	0	0
Narrow riparian zones	575	12	7	1.669	2.904	249
Broad riparian zones	273	5	1	1.039	3.800	831
Set a side	16.654	16	273	63.284	3.800	232
Sum /average			3.640	305.514		84

Source: Jacobsen, 2016

The basic concept is a flexible implementation at the farm level so that farmers can chose the measures which fit their farm the best. There is a national given exchange rate using the area with catch crops as exchange. Using the same exchange rate across the country meant that the variation in effects of the measures were not as targeted as it could have been. As an example the effect of catch crops on sandy soils and clay soils are very different (12 vs. 45 kg N/ha in the root zone). However, it allowed for an implementation that was understandable and yet flexible. With more detailed levels, the data requirements would have been even greater. The compensation of 529 DKK/ha covers the costs for the average farmer linked to the Rural Development Program, but especially pig farmers might have higher costs as they need the high yields from winter wheat and so there is limited room for catch crops. However, some farms have included more spring crops in the crop rotation as mentioned earlier. The exchange rate in catch crops between the different measures is shown in Table 8.6. This shows that 4 ha of early sowing or 2 ha of in between crops replaces one 1 ha of catch crop.

Looking back at the actual 2019 implementation in Table 8.6, we can see that most of the 350,000 ha catch crops units have been achieved using catch crops (79%). N-quota reductions have been limited and this might be the case if the crop rotation or climate does allow for so many catch crops. There will be some variation in the use of early sowing as this varies with the weather conditions. Many of the other options have not been selected in more than 5% of the cases and so it can be concluded that riparian zones are still not popular!

Table 8.6. Targeted regulation assessment regarding implementation in 2019

	Area (ha)	**Conversion factor**	**Units of catch crops (ha)**	**Share (%)**
Catch crops	274.469	1	274.469	79
Reduction of N-quota (average) Under 80 kg N/ha Over 80 kg N/ha	113.665	122 kg N 93 kg N 150 kg N	15.839	5
Riparian zones	820	1	820	0
Set a side	1.767	1	1.767	1
Early sowing	194.336	0,25	48.584	14
In between crops	14.340	0,5	7.170	2
Energy crops	608	1,25	759	0
Sum	**600.004**		**349.406**	**100**
Environmental effect (ton N)			**3.459**	

Source: MFVM, 2020 and own calculations

8.5 Conclusion

The higher N-quota has increased income and N-losses, but in both cases less so than expected. The increased income is likely to be around 400-600 million DKK. The increased use of nitrogen has been around 30-35.000 tones N.

The period from 2015 to 2019 has seen a transition towards more targeted measures and this has insured that the implementation has become more flexible and cheaper to implement. At the same time, it has only been a first step towards targeting as the variation in the measures efficiency across soils and the nitrogen retention map has not been fully used in the targeting. The increased flexibility was a process that was already started before 2016 allowing farmers to replace catch crops with other measures if the measures had the same environmental effect. The targets regarding collective measures have been ambitious and especially the creation of mini wet lands, which in 2015 was a new measure. It is not uncommon that new measures are faced with implementation challenges, which also happened in this case despite a large effort to get farmers on board

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

Ministry of Environment of Denmark

Nitrogen pressure on coastal Waters
Preliminary assessment in 2020 of the status for the marine coastal waters has shown that only 5 coastal water bodies of the total 109 coastal waters bodies are in good status. The number of marine waterbodies has changed since the 2nd RBMP because of changed delineations of some water bodies. 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 2021-2027 are expected to be focused on a significant reduction of 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 2nd RBMPs for 2015-2021 it was estimated that land-based Danish nitrogen losses to Danish coastal waters should 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. For the 3rd draft RBMP for 2021-2027, the model calculations have been expanded and updated with the most resent monitoring data. New target loads are expected to be published in connection with the 6 month hearing of the draft 3rd RMBMs in the start of 2021.

For approximately 60% of the catchment areas in Denmark, the nitrogen load to the marine waters are monitored (in watercourses). Loads are estimated based on model calculations for the remaining 40% of the catchment where there are no monitoring data. In 2019, the calculation method has been corrected and therefore, the load in the whole dataset from 1990-2018 has been reduced rather significantly. Therefore, the current gap cannot be estimated by comparing current load to the target load in the 2nd RBMP.

The nitrogen load to coastal waters (2018) for the last 5 years has been 52,000 - 58,000 tons N/year. The gap between the current load and the target load (to support achieving good ecological status) will be calculated for each catchment to the 109 marine water bodies for the 3rd RBMP In the 3rd RBMP, it will also be investigated whether there also is a need for further reduction of phosphorous in some of the marine waterbodies where such a reduction will have a .substantial impact on the relevant quality elements.

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 2027
The Danish Government face challenging tasks concerning the fulfillment of objectives for climate change, CO2 emissions, nature and water environment protection. All these objectives are expected to have an impact on the Danish agriculture. Therefore, the Danish Government are planning to make a strategy for the future Danish agriculture. However, due to the special actions needed regarding the

corona situation, the political negotiations for the future of Danish agriculture have only just started on a technical level in February 2021.

This strategy for the future of Danish agriculture is expected to be decided in spring 2021 after political consultations. The framework for the future regulation of the Danish agriculture in order to fulfill the obligation in the WFD are expected to be decided in this strategy. It is expected that measures will also be taken to reduce the discharges of nitrogen and phosphorus from other sources than agriculture, i.e. point sources, depending on the need for reduction to the 109 marine water bodies. Especially in catchments where the contribution from point sources are relatively high and in catchments where the contribution from point sources in the summer period are high. According to the WFD, the draft 3rd River Basin Management Plans is to be published for a 6 month public hearing prior to their finalization.

On this background, it will not be possible to make a forecast for the reductions of nutrients before 2021.

Achievement of environmental objectives in groundwater

In the draft river basin management plans for the period 2021-2027, the assessment of chemical status for groundwater bodies is based on groundwater quality standards and threshold values for pollutants. Currently, 1345 (out of 2050) groundwater bodies are in good chemical status in relation to nitrate, 22 groundwater bodies are in poor chemical status in relation to nitrate, and 683 bodies have unknown chemical status in relation to nitrate. Poor chemical status in relation to nitrate is attributed to a ground water body when one monitoring point or more is assessed to have a nitrate concentration exceeding 50 mg/liter and a conceptual model and expert assessment concludes that the groundwater body has poor chemical status in relation to nitrate. The assessment of significant and sustained upward trend in the concentrations of pollutants has yet to be completed.

It was presupposed in the 2nd RBMP 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. For the 3rd RBMP, this assessment will be reevaluated. A potential need for supplementary measures will be investigated further during the third 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 relatively 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 significantly affected by emissions of nitrogen. Quality elements such as phytobenthos and to some extent macrophytes may be affected by the phosphorus concentration in watercourses. However, it has not yet been possible for Danish researchers to determine at what concentrations phosphorus affects these quality elements in watercourses and streams.

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