Eutrophication and agriculture in Denmark: 20 years of experience and prospects for the future

Niels Peter Nørring · Erik Jørgensen

Originally published in the journal Hydrobiologia, Volume 629, No. 1, 65–70.
DOI: 10.1007/s10750-009-9772-2

Abstract During the past two decades there has been growing public and political awareness of the consequences of eutrophication in Denmark. By the mid-1980s, the environmental status of inland and coastal waters had deteriorated due to high nutrient loads. Consequently, a number of different Action Plans against water pollution were introduced. In the agricultural sector, focus has been on reductions in nitrogen leaching obtained by the introduction of various measures: a maximum limit to the density of livestock, 9 months' storage capacity for manure, catch crops for at least 6% of the land, enhanced utilization (up to 75%) of nitrogen in manure, etc. The agricultural sector in Denmark has implemented all of these measures, and as a result of the effort, the target for reductions in nitrogen leaching will be reached. Currently, the total loss of nitrogen from farmland is likely to be reduced by approximately 50% compared to the level in the mid-1980s. Some of the measures have been fair and based on sound arguments, and have been implemented with only minor difficulties, whereas others have proved troublesome and in our opinion disproportionately expensive. Today, further general regulation with equal restrictions toward all farmers regardless of differences in environmental impacts is no longer an acceptable path to follow. In the future, it will be necessary to pinpoint new measures in the most sensitive areas, where the potential for further reductions in nutrient loads is large. Danish Agriculture calls for specific actions—and consequently a shift in environmental management and policy making. Such a revised management strategy is the only path to follow in order to obtain further improvements in environmental conditions. Meanwhile, future development in the agricultural sector will be possible and a win–win situation can be reached.

Keywords Agriculture · Eutrophication · Nutrient reductions · Trend reversal · Needs for specific measures · Management

Guest editors: J. H. Andersen & D. J. Conley
Eutrophication in Coastal Ecosystems: Selected papers from the Second International Symposium on Research and Management of Eutrophication in Coastal Ecosystems, 20–23 June 2006, Nyborg, Denmark

N. P. Nørring · E. Jørgensen (✉)
Danish Agriculture (Dansk Landbrug), Vesterbrogade 4A, 1620 Copenhagen, Denmark
e-mail: ejo@dansklandbrug.dk

Introduction

Eutrophication is not a new phenomenon in Denmark. Inland and coastal waters have been under the influence of human activities during thousands of years, in some cases leading to nutrient enrichment and changes in ecosystem structure, functioning and stability (Conley et al., 2002; Ærtebjerg et al., 2003). During the past century, eutrophication processes were enhanced due to changes in social structures. The discharge of urban and industrial wastewater directly to watercourses, lakes, and coastal areas increased, and agriculture became more and more intensive, with increasing inputs of nutrients from fertilizers and manure. Gradually, many aquatic habitats deteriorated, and in the 1970s and 1980s public and subsequently political concern arose (Danish Environmental Protection Agency, 1991).

Historically, agriculture has always played an important role in Denmark. Even though its importance is decreasing in terms of employment, the agricultural sector still plays a major role in society. More than 60% of the total area of Denmark is cultivated (Statistics Denmark, 2005) and livestock production and density are high, although with large geographical differences. In some parts of the country, animal density is very close to the upper limit allowed according to national legislation. The environmental impact is, however, not only linked to the use of fertilizer and manure, but it is also—among others—a function of soil characteristics, crop rotation, precipitation, temperature, and vulnerability of the affected aquatic environment (Knudsen et al., 2000).

To understand the reasons and mechanisms behind the structure and behavior in the agricultural sector, it is necessary to focus on the fact that policies covering the sector agriculture—in Denmark as well as in the European Union as a whole—are largely influenced by the Common Agricultural Policy (CAP). The common policy of today is very different from that of 33 years ago, when Denmark joined the EEC. Back then there was price support, inducing a high production with little or no focus on correlated issues such as environmental conditions. In 1992 a shift toward direct payment was introduced with the MacSharry reform, and direct payments without demands for production rates were further enhanced with the Agenda 2000.

In 2003, the CAP reform introduced a decoupling between payments and land use and cross-compliance was introduced. Cross-compliance is used as a tool to ensure that the individual farmer meets certain demands—including some of which are environmentally supportive—before he or she can receive the full payment from the EU. The changes in agricultural policy during the past 15 years have already led to the improvements in environmental conditions, not least in aquatic ecosystems, and it is likely that the improvements will continue (e.g., Ærtebjerg et al., 2005; Carstensen et al., 2006).

Danish agriculture and environmental policies

A large number of EU Directives, international obligations and the subsequent national legislation have an influence on agricultural practice and production with regard to eutrophication. As an example, the Nitrates Directive contains general definitions as well as specific targets and measures. In addition, Denmark has ratified the OSPAR and Helsinki Conventions, thereby committing the country to specific environmental objectives. In the future, the EU Water Framework Directive (European Communities, 2000) is likely to be the most important legislation concerning the aquatic environment.

EU Directives and international political agreements (e.g., HELCOM, OSPAR, and North Sea Conferences) have influenced a number of national Action Plans on the Aquatic Environment, introduced between 1985 and 2004. The plans and their most important objectives and measures are listed briefly in Table 1. In general, the political focus has been on losses from the root zone, whereas agriculture has always argued that attention should instead be paid to the nutrient load that actually reaches the aquatic environment. Model results from Ringkøbing Fjord and Nissum Fjord suggest that on average 60–70% of the nitrogen leaking through the root zone at field scale is removed before reaching the coastal water, with significant spatial variation throughout the river basins (Ringkøbing County, 2004).

Results from efforts in agriculture: lower nitrogen leaching—mission completed

The various action plans introduced a variety of measures, all of which were supposed to add to the targeted reduction in nitrogen leaching, set by the first Action Plan (1987) to a maximum loss of 145,000 tons of nitrogen per year. In the evaluation of Action Plan II in 2003, it was concluded that the objective in terms of changes in agricultural practices was finally reached (Grant et al., 2006). Consequently, the nitrogen load from agriculture was reduced by 48%. The phosphorus load was more

Table 1 National action plans enacted in Denmark since 1985

Year	Plan	Objectives	Measures
1985	NPo Plan		Regulation of animal density
			Manure: minimum storage capacity
1987	Action Plan I	145,000 t reduction of N-loss (50%)	50% reduction in N-leaching
		15,000 t reduction of P (80%, primarily WTP)	Winter plant cover
			Compulsory plans on N-use
1991	Sustainable agriculture	Same as Action Plan I	Improved utilization of manure
			Maximum N-standards for crops
			Fertilizer plans/accounts
1998	Action Plan II	Same as Action Plan I	Further improved utilization of manure
			Reduced N-quota (10% below economic optimum)
			Conversion of cultivated soil to wetlands and forests
2004	Action Plan III	Further 13% reduction in N-leaching	Further improved utilization of manure
		50% reduction of P-surplus in cultivated soils	Increased catch crops demands
			Additional wetlands

Some important objectives and measures concerning agriculture are listed
WTP wastewater treatment plant

than 80% lower than that before 1984 primarily due to improved wastewater treatment. The objectives set in the Action Plans by politicians and water managers were met by the Danish farmers and improvements in wastewater treatment.

Figure 1 shows the development in annual nitrogen surplus from agriculture (please note that only part of the surplus will actually enter the aquatic recipients because of removal by the denitrification process in the soil). Figure 2 shows the changes in nitrogen leaching from cultivated soils in Denmark since 1985, with a prognosis of the development until 2012 when the last measures are fully implemented. After a maximum surplus was reached during the 1980s, the surplus has decreased to the same level as in the early 1970s. The observed reduction in nitrogen surplus (Fig. 1) and leaching (Fig. 2) is due to a combination of improved utilization of animal manure (demands today are up to 75% utilization compared to no requirements just 20 years ago) and a reduction in the use of artificial fertilizer. The amount of nitrogen from artificial fertilizer in Denmark was almost halved between 1990 and 2002 (The Danish Plant Directorate, 2003). In the same period, average reductions in EU were only around 10% (The Danish Plant Directorate, 2003).

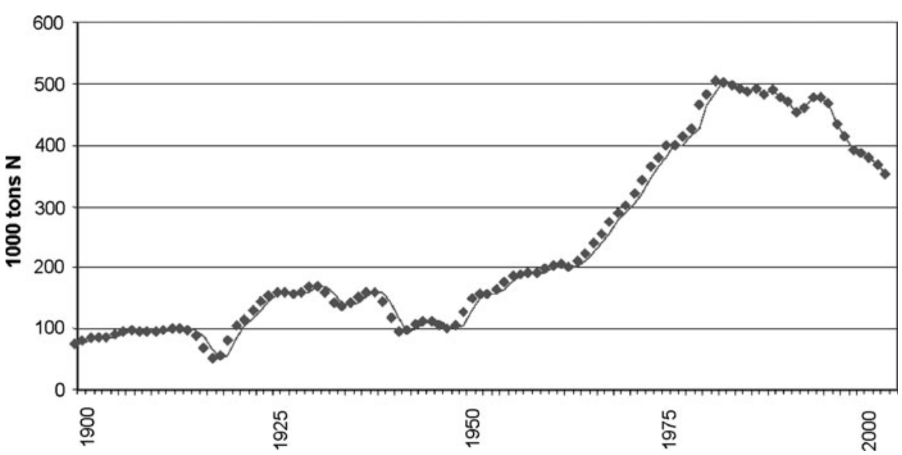

Fig. 1 Changes in the annual nitrogen surplus from Danish agriculture in the period 1900–2003 (based on data from The Danish Plant Directorate, 2003)

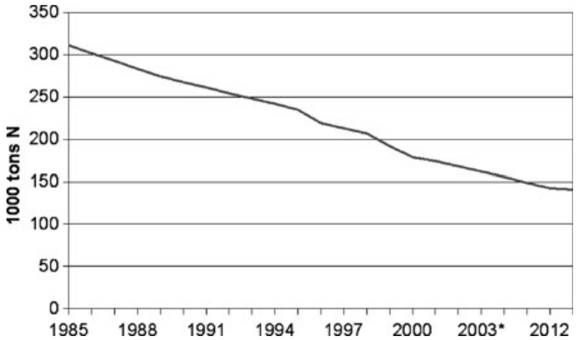

Fig. 2 Development in modeled nitrate leaching from the root zone in cultivated catchments in Denmark, 1985–2003, with prognosis until 2012 [based on data from Grant et al. (2006) and the expected further reduction until 2012 (Action Plan III)]

The large reduction in nitrogen leaching from cultivated soils has induced significant improvements in the nutrient status of lakes, watercourses, and coastal waters (Andersen et al., 2004; Lauridsen et al., 2005; Carstensen et al., 2006).

Nitrogen concentrations in watercourses with a high degree of cultivated soils in their catchments were reduced by about 29% from 1989 to 2003, and there has been a significant decrease in nitrogen concentrations at 50 out of 63 monitoring stations (Andersen et al., 2004). The lower nitrogen concentrations have subsequently led to reduced loads of nitrogen to lakes.

The nitrogen load to the marine environment decreased 43% in the period 1989–2003 (corrected for annual differences in runoff) (Andersen et al., 2004). In addition, Carstensen et al. (2006) showed that the positive changes in nutrient status in the Danish marine areas are statistically significant.

The observed and statistically verified reductions in nitrogen and phosphorus concentrations have led to only minor improvements at the ecosystem level (Andersen et al., 2004; Carstensen et al., 2006). Possible suggested explanations for the limited impact on biota are time lags, changes in basic physical and/or chemical conditions (nutrient pools, sediment texture, and hypoxia), as well as alternative steady-states in ecosystem structures (Scheffer, 1998).

Benefits have not been without costs

The agricultural sector in Denmark has contributed to the reversal of eutrophication in Danish waters during the past 20 years. By changing their practice, individual farmers have contributed to the decrease in nutrient loads, which has proved to be a success in what is visible to the eye as well as to the statistical experts. Many of the measures introduced have been based on sound science and understanding—improved utilization of nitrogen in manure and requirements for a certain storage capacity for slurry, to mention just a few. However, the use of general regulations applied equally to all farmers regardless of their actual environmental impact has reached its limits—and in some cases well exceeded them.

The second Action Plan from 1998 introduced a fixed reduction in the nitrogen quota that each farmer can apply to their fields of 10% below the economic optimum in terms of yield without any compensation to the farmer. This new national quota of nitrogen was fixed with regard to the existing types and distribution of crops in 1998. Changes in crop distribution since 1998 toward improved breeds with higher yields and larger nitrogen demands have caused the gap between the allowed and optimal yield to grow from 10% up to almost 15%. This restriction is not only expensive in terms of low yields compared to farmers in other countries, but is also resulting in poor quality crops (low protein content due to a lack of nitrogen). This is surely not a strategy to be recommended in the future, neither in Denmark nor in other countries that are about to reduce nutrient losses from agriculture.

Future management of aquatic habitats—an urgent need for re-thinking

As mentioned in the previous section, general regulation is only feasible and acceptable to a certain extent. In Denmark, the usefulness of this approach is outdated as the simple solutions have already been used. Environmental managers must put their habitual thinking aside and look ahead for new options. With the Water Framework Directive, we are facing new challenges and possibilities. Hopefully, a new approach will replace the present old-fashioned strategy with equal rules and requirements for all areas, regardless of their individual impact on the environment. It does, however, require the ability to quantify environmental impacts on a smaller scale with reasonable certainty, which is by no means a trivial task.

Danish Agriculture calls for the allocation of efforts in the right areas, both regarding sectors and on a geographical (micro-) scale. In addition, it is very important to have a holistic view, with focus on a wider range of measures than today and inclusion of cumulative effects (one measure in one specific area will often add to improvements in other areas).

The following list contains a set of points that, from our point of view, are very important in future work (the list only contains some suggestions, and is not all-inclusive):

- detailed cost–benefit and cost-effectiveness analyses must be made before measures are selected and implemented;
- measures must be implemented only after very thorough sensitivity mapping and analysis;
- time lags must be taken into account when judging the impact of implemented measures;
- reference conditions should not be the ultimate target—some degree of human activity must be recognized and accepted;
- the fact that conditions are changing continuously (stable baseline conditions do not exist) should be accepted;
- measures should target load and impact; and
- the agricultural sector should be actively involved in the early planning process: win–win situations and ownership will appear.

It is very important to focus on detailed and specific measures. Therefore, sensitivity mapping and precise modeling tools are essential in order to reach the objectives—and to set and adjust the objectives at the right level (e.g., Ringkøbing County, 2004).

The general lack of significant improvements in ecological status after the reductions in nutrient inputs and concentrations that have been observed in most cases (e.g., Ærtebjerg et al., 2005), and discussed on several occasions during the Eutro2006 Symposium in Nyborg in June 2006, is often due to profound changes in a number of basic conditions such as changes in sediment texture, hypoxia, internal loading from nutrient pools in the sediments, changes in hydrology, physical modifications, and climate. The dynamic nature of basic conditions and a need for socio-economic considerations imply that environmental objectives should be set with reference to both the existing and predicted future conditions.

If site-specific environmental impacts are adopted in the WFD implementation, extensive cost–benefit will be needed. Prioritizing between measures considering cost–benefit and environmental impacts at the local scale will be challenging for local administrations, which at present are not equipped to perform such in-depth evaluations. The risk of generalized rules is high if the quality of environmental impact assessment varies significantly.

Finally, Danish Agriculture calls for a close cooperation between managers and the agriculture sector. It is very important to have involvement at early stages in the planning process to ensure the best solutions for all parties. Participation will lead to ownership of the project, and thus create win–win situations.

References

Ærtebjerg, G., J. Bendtsen, J. Carstensen, et al., 2005. Marine områder 2004—tilstand og udvikling i miljø-og naturkvaliteten. National Environmental Research Institute. Report no. 551 (in Danish with English summary).

Ærtebjerg, G., J. H. Andersen & O. S. Hansen (eds), 2003. Nutrients and Eutrophication in Danish Marine Waters. A Challenge for Science and Management. National Environmental Research Institute (Available via http://eutro.dmu.dk).

Andersen, J., M, S. Boutrup, L. M. Svendsen, J. Bøgestrand, R. Grant, J. P. Jensen, T. Ellermann, G. Ærtebjerg, L. F. Jørgensen & M. W. Pedersen, 2004. Vandmiljø 2004. Tilstand og udvikling—faglig sammenfatning. National Environmental Research Institute. Report no. 517 (in Danish).

Carstensen, J., D. J. Conley, J. H. Andersen & G. Ærtebjerg, 2006. Coastal eutrophication and trend reversal: A Danish case study. Limnology and Oceanography 51: 398–408.

Conley, D. J., S. Markager, J. Andersen, T. Ellermann & L. M. Svendsen, 2002. Coastal eutrophication and the Danish National Aquatic Monitoring and Assessment Program. Estuaries 25: 706–719.

Danish Environmental Protection Agency, 1991. Environmental Impacts of Nutrient Emissions in Denmark. Redegørelse fra Miljøstyrelsen, No. 1.

European Communities, 2000. Directive 2000/60/EC of the European Parliament and of the Council of the 23 October 2000 establishing a framework for Community action in the field of water policy.

Grant, R., K. Nielsen & J. Waagepetersen, 2006. Reducing nitrogen loading of inland and marine waters—evaluation of Danish policy measures to reduce nitrogen loss from farmland. Ambio 35: 117–123.

Knudsen, L., H. S. Østergaard & E. Schultz, 2000. Kvælstof—et næringsstof og et miljøproblem. Danish Agricultural Advisory Service (in Danish).

Lauridsen, T. L, J. P. Jensen, M. Søndergaard, E. Jeppesen, A. Strzelczak & L. Sortkjær, 2005. Søer 2004. NOVANA. National Environmental Research Institute. Report no. 533 (in Danish).

Ringkøbing County, 2004. Undersøgelser af Ringkøbing Fjord og opland (in Danish).

Scheffer, M., 1998. Ecology of Shallow Lakes. Chapman & Hall, London.

Statistics Denmark, 2005. Statistical Yearbook.

The Danish Plant Directorate, 2003. Fertilizer Statistics: Consumption of Fertilizer in Denmark 2002/2003.