Denmark

Implementation of the Water Framework Directive in the Limfjorden - How to reach Good Ecological Status

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watersketch

Content

Abstract

According to the Water Framework Directive Programmes of Measures must be produced by 2009 for all water bodies failing to meet the ecological objectives (WFD Art. 11). As a case study of Watersketch a Programme of Measures will be developed for the catchment area of the Limfjorden four years ahead of schedule. Emphasis will be placed on the eutrophication of the fjord, public involvement, and spatial planning.

The figures and photos shown in this report are all produced by the County of North Jutland unless stated otherwise.

1 Introduction

The aim of this case study is to find a way to achieve Good ecological status in the Limfjorden according to the Water Framework Directive. An equation between the loading from land and the status of the fiord should be established. Furthermore, measures to obtain good ecological status should be identified. This will be the basis for a political discussion and decisions following which measures should be applied accordingly in order to reach good ecological status.

The main problem in the fjord is eutrophication due to large loadings of nutrients from the catchment area. In this project impact and pressures from different activities have been identified. The loadings from the arable land are the most significant source for any single contributor.

An empirical modelling has been carried out in order to establish how the basis for Good ecological status can be expressed in operational objectives. Additionally, the spatial distribution of the leaching from the arable land has been mapped out.

Future work will thus concentrate on finding possible measures followed by a process including public participation and a political debate. The River Basin Management Plans will be developed in the new Regional Environmental Centres and under the responsibility of the Environmental Protection Agency. Until the coming New Year the quantitative impact studies, part of the management plans, are being carried out by the counties.

According to amendments to the law, municipalities are obliged to produce an action plan for follow up on the RBMP within a 6 months period after the acceptance of the RBMP, which is to be put into force one year after the passing of the RBMP.

2 Background information

2.1 General characteristics of the Limfjorden

The Limfjorden is a fjord located in the North of Jutland. It is connected to the North Sea in the western part around Thybyrøn and to the Kattegat in the eastern part close to Hals. The overall flow pattern has largely been stable since 1875 when the present conditions were established after some big storms in 1825 and 1862 caused a breakthrough between the fjord and the North Sea.

The surface area of the Limfjorden is around 1470 km^2 – the marked navigation route through the fjord from the West to the East is 170 km. The volume of the fjord is approx. 7.1 km^3 and the average depth of the fjord is 4.3 metres, with a maximum depth of 28 metres. Salinity varies typically from 20 to 30 psu.

The catchment area covers 7608 km^2 in total, which is one sixth of the total area of Denmark. The fresh water run-off from the catchment area comes mainly via water courses.

The soil conditions in the catchment area of the Limfjorden vary a lot due to the geological history. During the ice age the eastern and northern parts of the catchment area were covered with ice while large amounts of melting water ran out on the south-western part of the area.

The landscape in the eastern part consists mainly of hills on the inside of the countryside and more flat areas along the coast. The hills are mainly composed of a layer of melt-water sand and clayey sand upon a bedrock of limestone. The flat areas are made up of marine sediments including sand and clay.

The soil in the north-western part consists mainly of clay. In the south-western part the country is flat with the soil mainly made up of melt-water sand.

The catchment area is distributed over 4 counties. 44 % of the catchment area is located in the County of North Jutland. Around 65 % of the area is arable land with a high density of livestock. 15 % is covered by forest with the remainder being nature and urban areas.

Large areas in the Limfjorden and in the catchment area are designated NATURA 2000 areas, protected habitats and resting areas for birds.

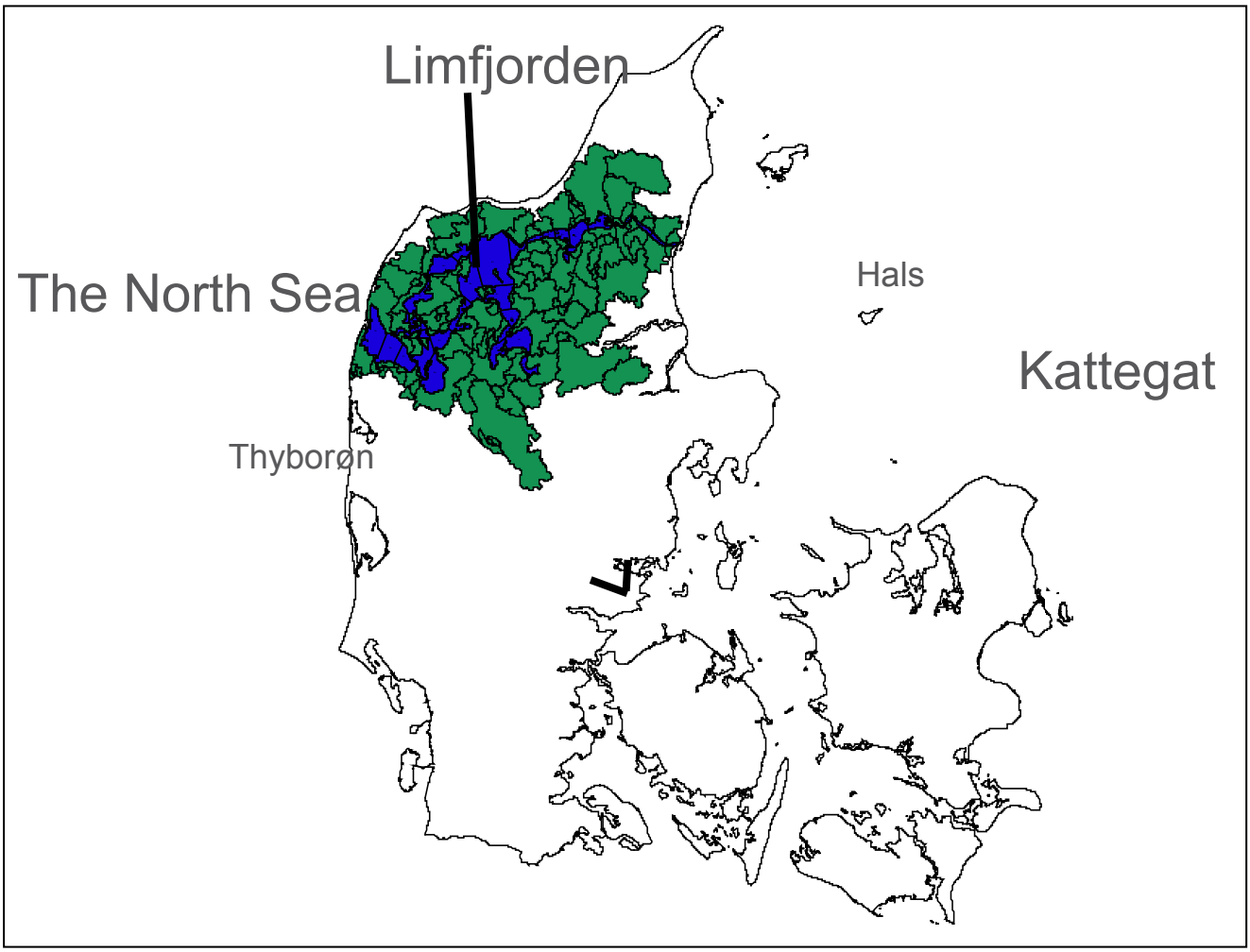


Fig. 1: Limfjorden and catchment area.

2.1.1 Conflicting functions of the Limfjorden

Because the Limfjorden covers such a large area, this results in conflicts for different uses. Figure 2 gives a list of these conflicting issues.

Large amounts of leaching of nutrients from agriculture cause the main conflict with fisheries, angling, bathing and NATURA 2000 areas. Second to that mussel dredging and mussel farming cause serious conflict.

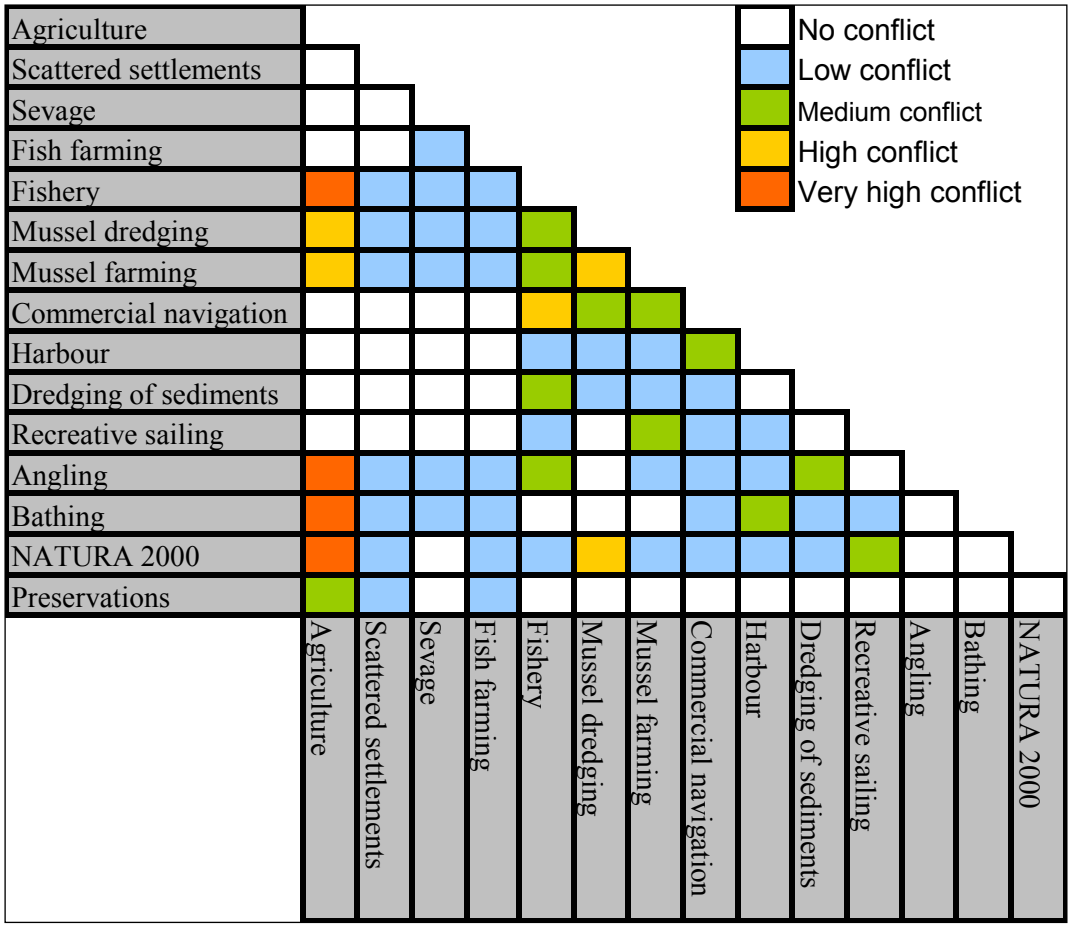


Fig. 2: Conflict issues in the Limfjorden.

2.1.2 Ecological status of the Limfjorden

The main problem of the fjord is the eutrophication due to large loadings of nitrogen and phosphorus from the catchment area. The loadings result in a state for the fjord that is quite far from the Good ecological status that is the goal of the WFD.

The climate is also of great importance for the physical and biological condition of the Limfjorden.

The amount of fresh water run-off and nutrients from the catchment area is very dependent on precipitation. The wind is of crucial importance for the exchange of water between North Sea and Kattegat, as it is in certain parts of the fjord. Finally, the temperature of the wind and the radiation from sun are crucial to the warming of the water, and the radiation from the sun is crucial as a source of energy to the biological system.

The loading of nutrients to the fjord results in an increased production of phytoplankton which causes the secchi depth to decrease, and thereby decreasing the depth limit of the submerged macrophytes, e.g. eelgrass. The biological degradation of the increased amount of phytoplankton leads to severe oxygen deficiency for quite big areas. For a climatically normal year it is estimated that around 20 % of the bottom area can be suffering from severe oxygen deficiency. During the last two decades the area suffering from oxygen deficiency has varied from 5 to 35% mostly due to climate conditions, see Figure 3. The oxygen deficiency essentially has a negative impact on the state of the benthic fauna.

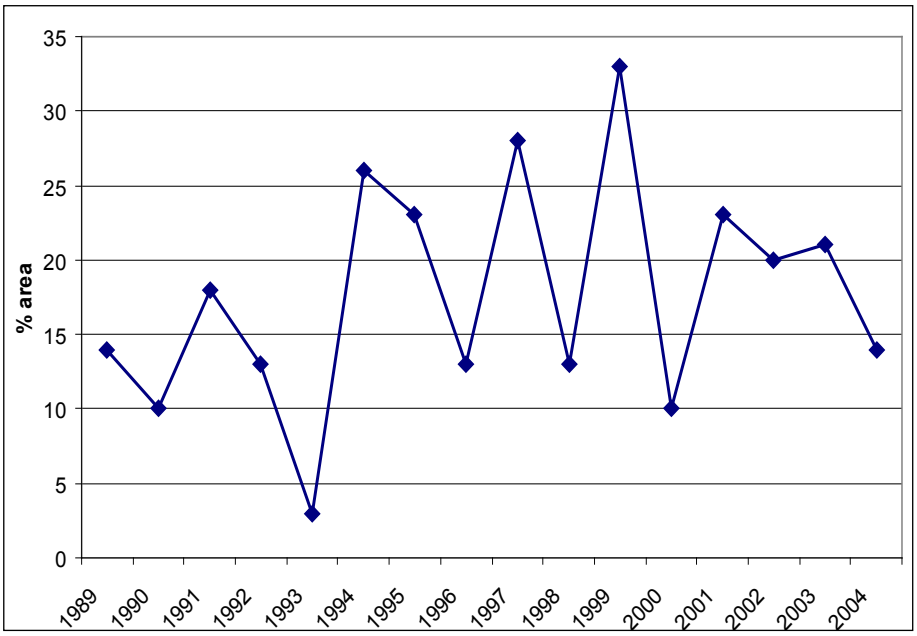


Fig.3: Percentage of the area of the Limfjorden showing severe oxygen deficiency (less than 2 mg O2/l) in the period 1989 through 2004.

Furthermore, mussel dredging has a negative impact on the fauna and flora that are using rocks and mussel shell as a substrate, due partly because of the dredging itself, and partly because the substrate (rocks/shells) is being removed due to the catching method. The bottom of the fjord has thus become much more homogeneous, which reduces the availability of diverse habitats for the benthic fauna and fish.

Over the years there has been a decrease in the loadings of nitrogen and phosphorus to the fjord. Figures 4 and 5 show annual loadings since the mid 1980s and in 1973. Estimates of the loadings have been made for 1950.

The loadings of nitrogen and phosphorus have been reduced during the period, mostly because of stronger requirements to the sewage treatment plants, but there has also been a minor reduction from the arable land. The reduction from the arable land has somewhat been counteracted due to the bigger precipitation that has been observed during the 1990s.

70 % of the loading with nitrogen and 37 % of phosphorus originates from agriculture. For the present it has been deemed impossible to reduce the amount coming from the sewage treatment plants much more and that any further reduction of nitrogen and phosphorus must come from the rural areas.

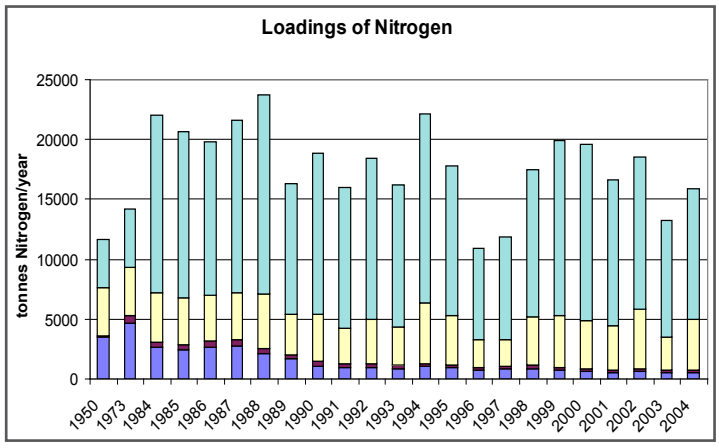


Fig. 4: Annual loadings of nitrogen from the catchment area to the Limfjorden.

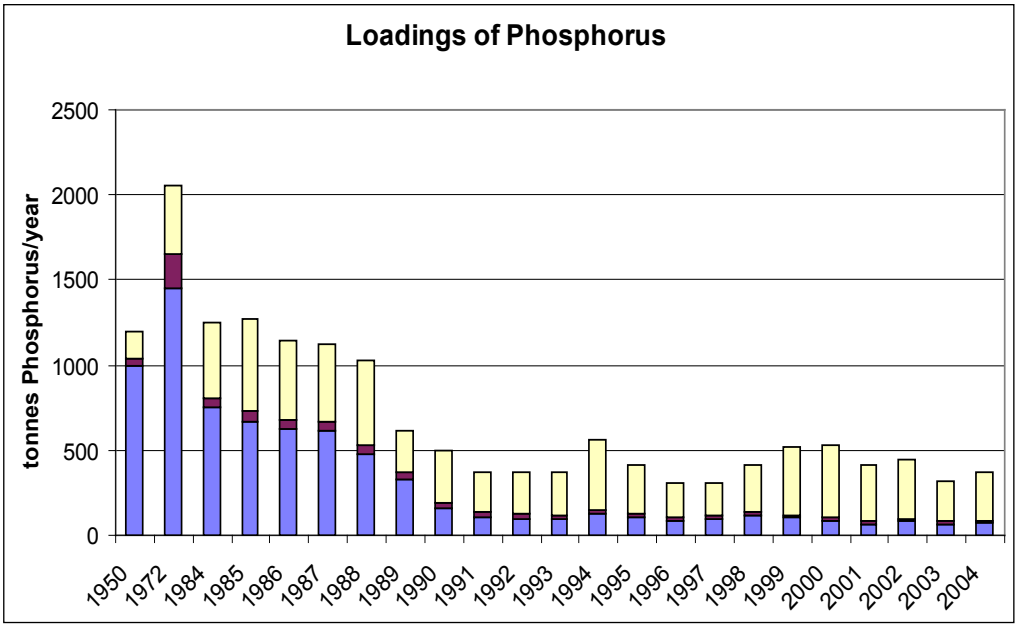


Fig.5: Annual loadings of phosphorus from the catchment area to the Limfjorden.

The status of the fjord today therefore is considerably altered from its status before human activities increased the loadings of nutrients and changed the state of the bottom. In the beginning of the 20th century the eelgrass on average grew down to 5.7 metres depth. At present it only grows down to 2 metres, see Figure 6.

The transparency of the water was considerably better a hundred years ago. The benthic fauna therefore had a much higher biodiversity, and the individual species had a normal distribution of age and size. Today a lot of species is dominated by small individuals because already the young fish are exposed to oxygen deficiency and die.

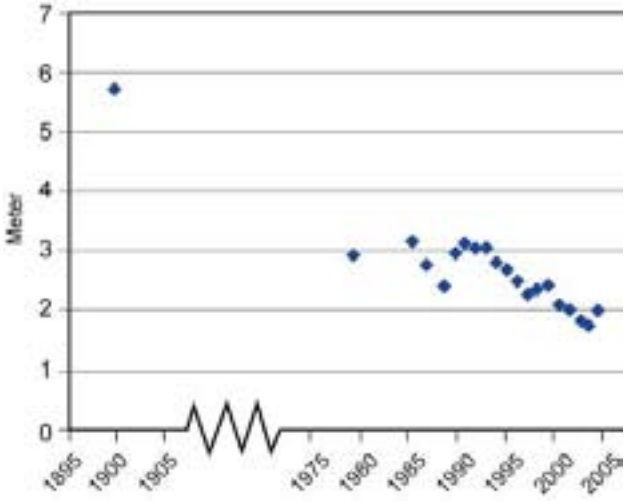


Fig. 6: Maximum depth limit of eelgrass as an average for the whole of the Limfjorden.

In previous years many people's livelihoods depended on fishery but the fish stocks have declined significantly. As a result, fish catches have declined (Figure 7) and nowadays commercial fishing consists only of a large fishery for mussels (dredging) and oysters. In addition, there is a fishery for herring (consumption) which enter the fjord during the spawning period, and for sprat (industry).

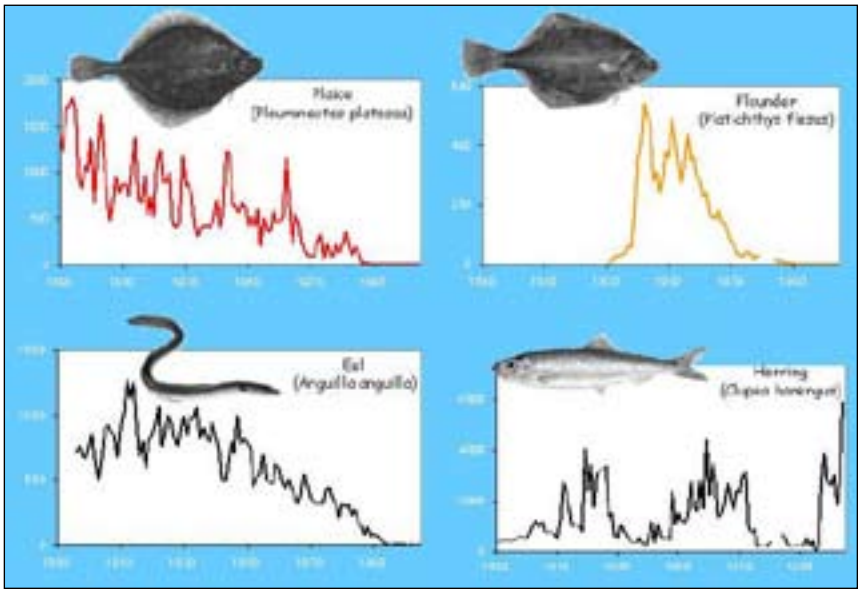


Fig. 7: Catches of plaice, flounder, eel and herring in the Limfjorden since the beginning of the 20th century.

Dredging of mussels is regulated, and there are 51 licence holders. Mussel catches have been stable at approx. 75,000 tonnes per year for the last 10 years, see Figure 8.

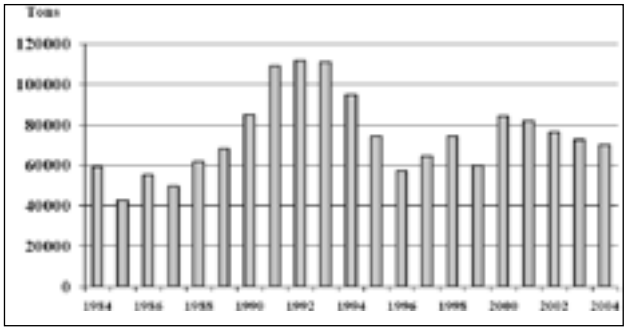


Fig. 8: Catches of mussels 1984 – 2004 in tonnes. Since 1994 methods of recording catches have changed, which means that only live mussel catched have been recorded. Therefore, the values before 1994 are around 15 – 20 % higher than in later years.

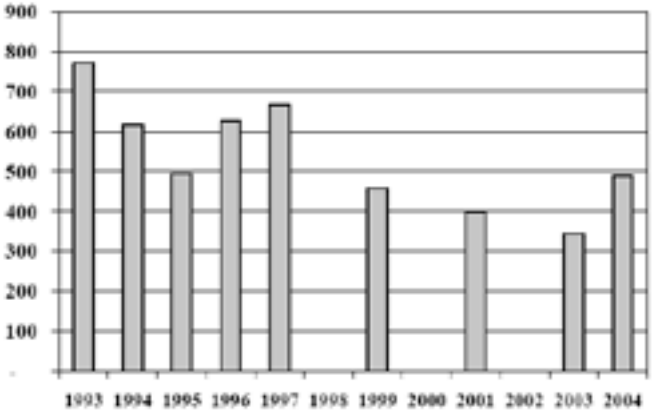


Fig. 9: Size of mussel stock in tonnes in the Limfjorden.

The total bio-mass of mussels in the fjord has been estimated for the period 1993 - 2004, see Figure 9. During this period there was a reduction in the mussel stock from approx. 800,000 tonnes to approx. 400,000 tonnes – however, the bio-mass seems to be increasing again in 2004. The decline is not necessarily disastrous but if it continues the fishery could be considered not sustainable. The cause for the decline is a combination of lacking recruitment, oxygen deficiency, and fishery. As the annual fishery normally only takes out approx. 10 – 15 % of the stock it should not aggravate the situation, whereas severe oxygen deficiency for large areas results in a very serious situation. In 1997 around 350,000 tonnes of mussels died due to oxygen deficiency.

Parallel to the mussel fishery mussel farming is being established – in 2004 approx. 30 authorizations were given for mussel and oysters farming in the fjord. In well suited places mussels can be harvested after approx. one year's growth. The quality of mussels is very good.

2.2 Description of significant pressures

As described in the previous chapters the main problem is the eutrophication of the fiord with reduced transparency of the water, reduced depth limit of eelgrass and decreased fish stocks as a consequence.

Regarding the nitrogen loading the main source is the arable land. Therefore, a main task will be to find methods to reduce the loading from agriculture. Nitrogen is leached from the fields as nitrate dissolved in water – therefore the leaching is also dependent on precipitation.

Regarding phosphorus the point sources have been reduced to a low level – therefore, the main target area to reduce phosphorus will be the arable land. Phosphorus is leached to the surface waters in two forms, dissolved phosphorus (mostly inorganic) and particulate phosphorus. The dissolved phosphorus follows the water through the root zone. The particulate phosphorus mostly originates from erosion. Thus, a method to reduce the loading of particulate phosphorus could be to secure areas with great risk of erosion. Dissolved phosphorus leached through the root zone is difficult to avoid.

Therefore, for the present it seems that the best solution would be only to allocate the amount of phosphorus to the fields that is necessary for the plants to grow. Thereby it can be prevented that a pool of phosphorus is being built up in the soil.

The County of North Jutland does not have tools to regulate the farmers in general. Only when a farmer wants to extend his live stock is it possible for the County to regulate him through an EIA (environmental impact assessment) procedure.

2.3 Analysis of impact and pressures

In general the point sources are very well regulated and the impacts limited. Sewage and fish farms are of significance only in some rivers. The main problem in the Limfjorden is eutrophication due to the high loading with nutrients mainly from agriculture.

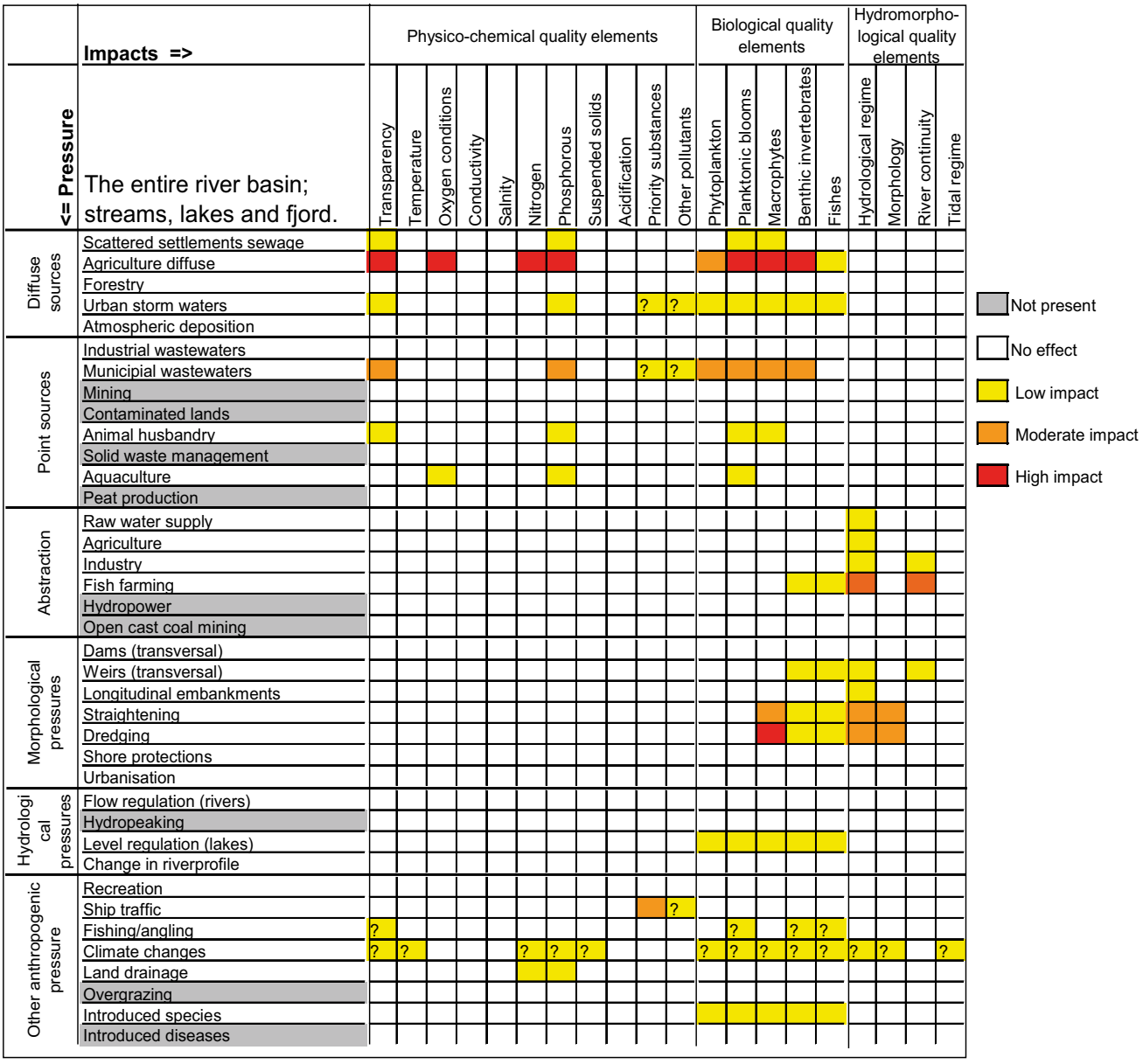


Fig. 10: Impact matrix for the Limfjorden.

2.4 Protected areas

Around 60% of the surface area of the fjord is designated Natura 2000 sites, including Sites of Community Importance (SCI) according to the Habitats Directive and Special Protection Areas (SPA) according to the Birds Directive. In the overall catchment area 10% of the area is designated Natura 2000 sites, see Figure 11.

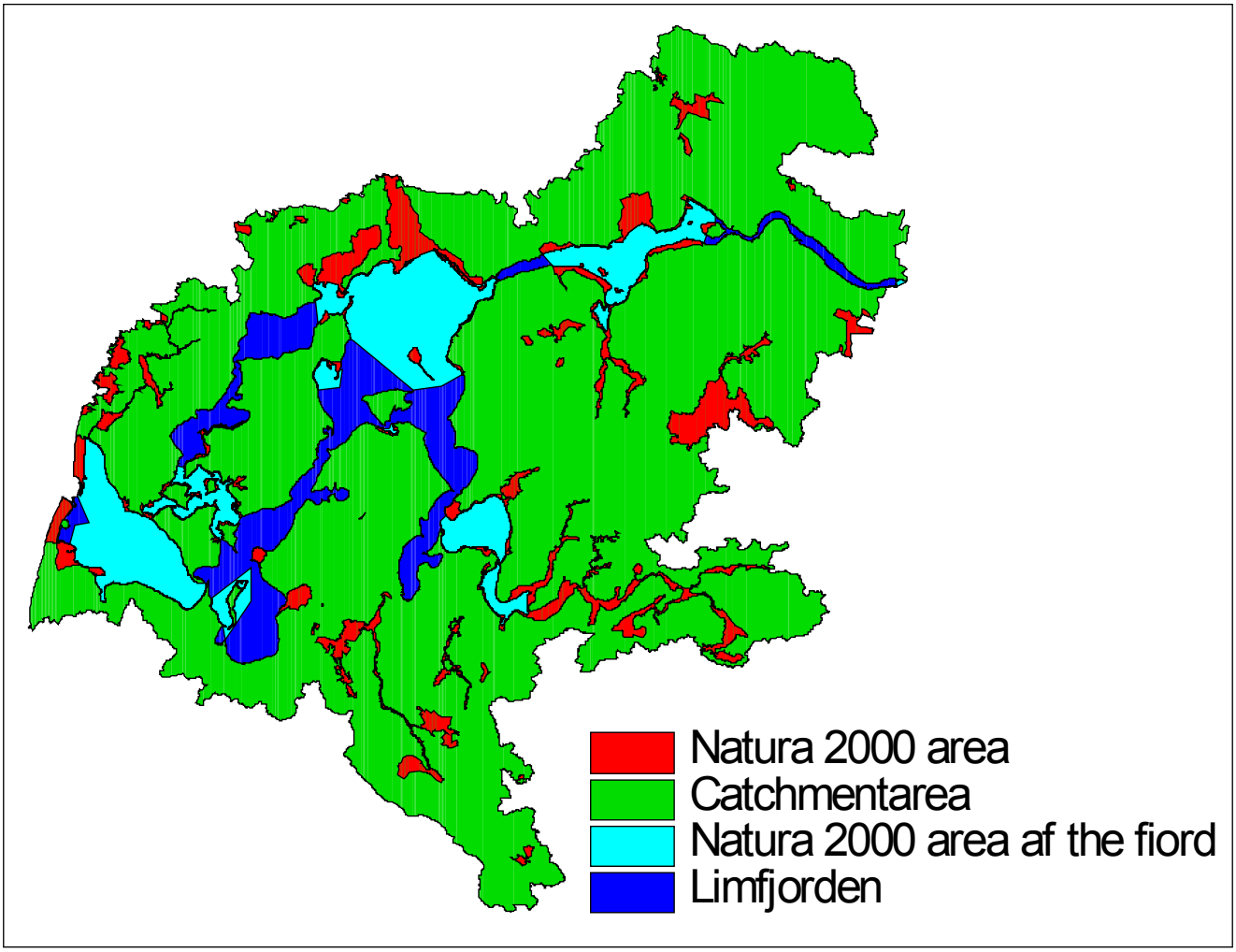


Fig. 11: Natura 2000 sites in the fjord and in the catchment area of the Limfjorden.

3 Problems relating to the WFD implementation

3.1 Conflicting Directives and national legislation

The political and administrative structure in Denmark is changing due to a structural reform, which will be put into force by 2007. That means big changes in the spatial planning system, which previously involved the implementation of the Water Frame Directive as well as the Habitats Directive.

In this context a review of the current planning system, which will be revoked in the near future, seems valuable.

3.1.1 The Planning Act (in force until 2007)

(from the website of Ministry of the Environmental Spatial Planning Department)

Denmark has a simple and clear spatial planning system that strongly decentralizes the delegation of responsibility. The municipal councils are responsible for comprehensive municipal planning, detailed local planning and permits for construction and changes in land use in rural zones. The 12 regional planning authorities are responsible for regional planning. The Minister for the Environment may influence decentralized planning through national planning initiatives. The State may veto the planning of municipalities and regional planning authorities to uphold national interests. Planning decisions may be appealed to the Nature Protection Board of Appeal. Only the legal issues in planning decisions may be appealed.

3.1.2 Purpose of the Act

The Planning Act ensures that the overall planning synthesizes the interests of society with respect to land use and contributes to protecting the country's nature and environment, so that sustainable development of society with respect for people's living conditions and for the conservation of wildlife and vegetation is secured.

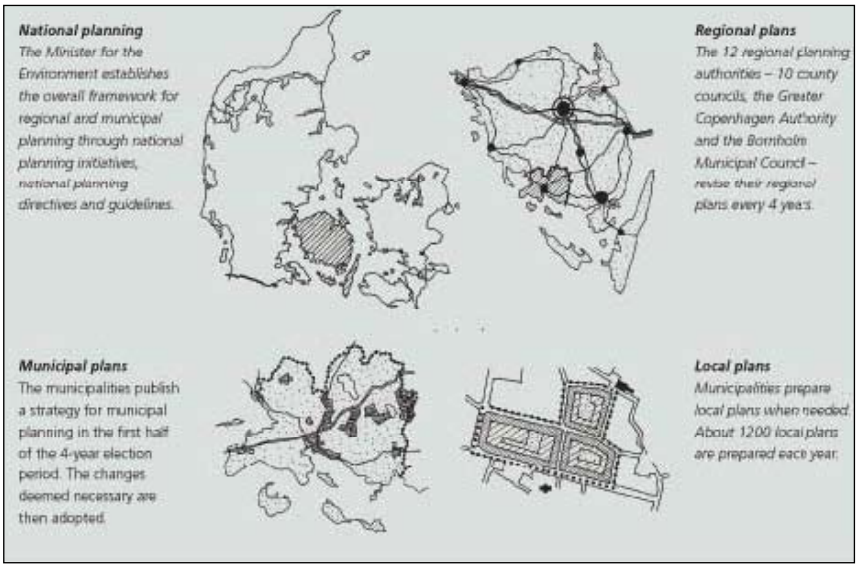


Fig. 12: Levels in the Danish Spatial Planning System.

Spatial planning is especially intended to ensure that:

- the whole country and the individual counties and municipalities develop appropriately, based on overall planning and economic considerations;
- valuable buildings, settlements, urban environments and landscapes are created and conserved;
- the open coasts continue to comprise an important natural and landscape resource;
- air, water, soil and noise pollution are prevented; and
- the public is involved in the planning process as much as possible.

3.1.3 Decentralization of responsibility

The municipal councils, county councils and the Greater Copenhagen Authority have substantial responsibility for spatial planning. During each 4-year election period, the regional planning authorities revise the regional plan. During the first half of the election period, each municipal council publishes a political strategy for municipal planning and determines the extent to which the municipal plan should be changed.

Local plans are prepared when needed. Large development projects require a local plan before being initiated.

3.1.4 Public participation

One of the basic aspects of the Planning Act is that the citizens are encouraged to be involved in the planning process before the plan is adopted. A plan proposal and a report on the premises of the plan are therefore published before the proposal is adopted. The municipal council establishes a deadline of at least 8 weeks during which property owners, neighbours, Non-Governmental Organizations, public authorities and others may submit their proposals or objections.

Substantial changes in a regional or municipal plan require a period of public comment before the planning authority starts to prepare a specific plan proposal. Many counties and municipalities use the Internet to publish plan proposals and adopted plans.

Special rules for coastal zones and retail trade

The Planning Act contains special rules for planning in coastal zones and for planning for retail trade.

The aim is to keep Denmark's coastal areas as free as possible of development and installations that do not need to be located near the coast.

Planning for retail trade is intended to promote a diverse supply of retail shops in Denmark's numerous small and medium-sized towns.

3.1.5 Local Agenda 21

During the first half of the election period, Denmark's county and municipal councils publish a strategy for their contribution to sustainable development in the twenty-first century: a Local Agenda 21 strategy. The Minister for the Environment submits a report to the Folketing (parliament) every 4 years on the Local Agenda 21 work.

3.1.6 Environmental impact assessment

Large development projects that are likely to have significant effects on the environment are subject to environmental impact assessment and a public hearing before being initiated. The rules on environmental impact assessment in the Planning Act comprise Denmark's implementation of a European Union Directive. The regional planning authority usually conducts the assessment and prepares a supplement to the regional plan with an accompanying environmental impact assessment statement.

3.1.7 The upcoming Planning Acts

The change of the political and administrative structure from 2007 onwards means larger municipalities and the exit of the county based local government structure, which will be replaced by larger regions. At the same time the reform of structure contains changes in the distribution of assignments between the municipalities and the new regions.

The new Planning Act transfers most of the spatial planning formerly done by the counties (called regional planning) to municipalities. Some overriding objectives and guidance responsibilities are moved to three new national environmental centres. The state control of spatial planning is brought to a higher level through nationwide statements, Directives, and guidance notes.

Currently one of the main issues in the regional planning process is the need to state the scope of the municipal plans related to the government's spatial planning announcements. In total, the fourteen regional plans constitute a national plan based on a decentralized democratic elected system.

Fig. 13: River Basin Districts in Denmark.

According to the new structure the democratic element of the counties is removed and the cooperation now will be between the municipalities with a democratic elected leadership and an administrative level, the state. As a consequence, this will mean that the impact from the state on spatial planning will increase on the one hand, and on the other, that the democratic and decentralized element of the Danish spatial planning will become weak.

The implementation of the Water Frame Directive as well as the Habitats Directive in Denmark is enforced by the new Law on Environmental Objectives (2003).

The implications are, among others, that the former 13 River Basin Districts (to a large extent following county borders) will be reduced to 4, of which Bornholm (a small island) is the smallest RBD in Europe (587 km2), and one is international. The largest will then be 33132 km2, covering the most of Jutland and the island of Funen, see Figure 13.

Other legislation, such as the Environment Protection Act and the Planning Act has subsequently been amended.

The Ministry of the Environment is the competent authority, but while responsibility for the management plans was previously allocated to the counties, the structure is being centralized with the structural reform. The RBMPs will now be produced in the new Regional Environmental Centres, under the responsibility of the Environmental Protection Agency. Until the coming New Year the quantitative impact studies, part of the management plans, are being carried out by the counties.

According to the amendments to the law, municipalities are obliged to produce an action plan for follow up on the RBMP within a 6 months period after the acceptance of the RBMP, which is to be put into force one year after the passing of the RBMP.

3.2 Spatial Planning dimension

Spatial Planning has been carried out at county and municipality level, as well as through local plans, but with the recent structural changes the municipality will be the central planning unit and the new regions will be in a coordinating role. The planning period is 12 years with an update every 4 years. Amendments to the Spatial Planning Act provide for municipality planning to be carried out within the framework given by the action plans relating to water, Natura 2000, forests and other resource plans. RBMPs will therefore play an important role for the spatial plans, and the interactions between national environmental centres and municipality planning units will be crucial.

3.3 Public Participation

At this point in time there has been no clarification of how the public will be involved in the process. However, it is difficult to establish how public involvement should take place in a process where politicians are not required to make decisions following public consultations of the two public phases: the Idea Phase and the Proposal Phase. There is a missing link in the RBMP-process.

Nonetheless, the case study is an individual project outside the WFD and it is expected that following the political processing two public consultations will go ahead. The political process will take place after a political conference at the start of June 2006.

The first phase - the idea phase lasting 4 weeks - will include public meetings to inform the public about the action plan and the background. Workgroups will be established geographically and topically with stakeholders primarily representing agriculture and fish farming enterprises. The aim is to involve the stakeholders early in the process before the idea phase to give them opportunities to contribute ideas and interests to the phase.

In the second phase - the proposal phase lasting 8 weeks - the action plan will be presented to the public, followed by a public consultation with opportunities for making contributions, which the County Council will handle.

The schedule of the public phases has not yet been drawn up.

4 Implemented solutions – Programme of Measures

4.1 Monitoring programme

The four counties in the catchment area of the Limfjorden are responsible for monitoring of the environmental quality of the Limfjorden. The first extensive monitoring programme leading to a general management plan was carried out in 1973/74. Monitoring of the environmental quality has been carried out on an annual basis since 1983. Since 1988 the monitoring programme has been part of the Danish nationwide monitoring programme for the quality of water and nature (NOVANA). The current programme is running from 2004 to 2009 and consists of 8 main stations in the Limfjorden and of 32 in the larger water courses. Besides the annual monitoring, the counties, universities, fisheries department etc. carry out various supplementary investigations that vary from year to year. A short presentation of the NOVANA programme for the fjord and supplementary investigation in 2005 can be found on. http:// www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR532.PDF.

An in depth description of the NOVANA programme is accessible at: http:// www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR537.PDF

The monitoring programme has 8 main stations in the Limfjorden as illustrated in the map (Figure 14), also indicating the subject under investigation, e.g. water chemistry, plankton, sediment chemistry or benthic fauna.

Fig. 14: Map of NOVANA stations.

The environmental measurements are highly dependend on the current. The current is determined by fixed electrodes in the harbours of Thyborøn and Hals measuring the salinity and temperature of the surface waters at 15 minutes intervals. At the Vilsund Bridge salinity and temperature are measured in 4 different depths 3 times a week.

Thyborøn

Hals

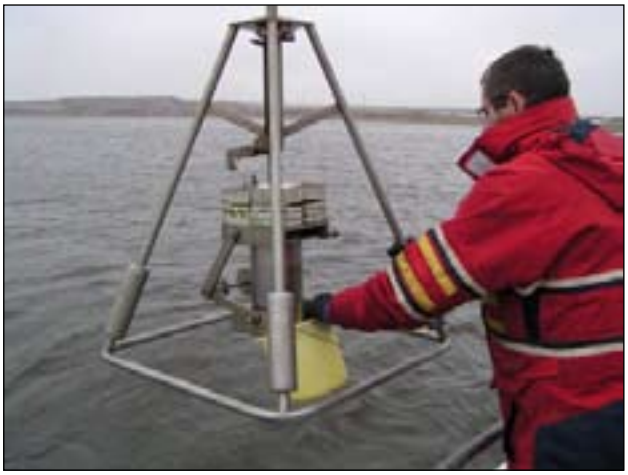
Most of the monitoring is carried out from the counties environmental survey ship "Limgrim". Prior to every sampling a profile monitoring from the surface to the bottom including salinity, temperature, fluorescence (amount of algae) and light are measured by electrodes. Finally, the transparency of the water is visually estimated using a secchi plate.

A schematic presentation of the monitoring programme with the number of samples each year is shown in Figure 15.

Location	Water chemistry	Plankton	Internal loadings	Hazardous substances	Benthic fauna	Vegetation
Skive Fjord	46	24	8		1	X
Lovns Bredning	46					X
Risgårde Bredning	46					X
Nibe Bredning	24			1	1	X
Løgstør Bredning	24	24		1	1	X
Nissum Bredning	24	24		1	1	X
Thyborøn Kanal	12					
Hals Havn	50					

Fig. 15: The monitoring programme in the fjord showing stations and number of samples per year.

Water chemistry: For each location the samples are analysed for nutrients (nitrogen and phosphorus), silicon and chlorophyll (green substance in algae). The analyses from Thyborøn and Hals are used to calculate the transport of nutrients through the Limfjorden.

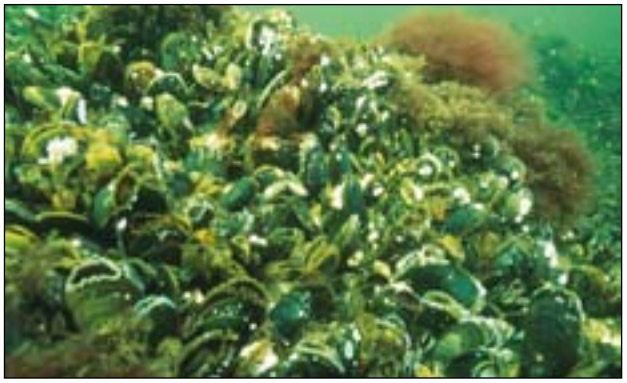


Phytoplankton: The term plankton comprises both microscopic algae (Phytoplankton) and microscopic animals (Zooplankton) living in the free water column. At Nissum and Løgstør only phytoplankton is monitored. In Skive Fjord both phyto- and zooplankton is monitored and the growth of phytoplankton is measured as primary production.

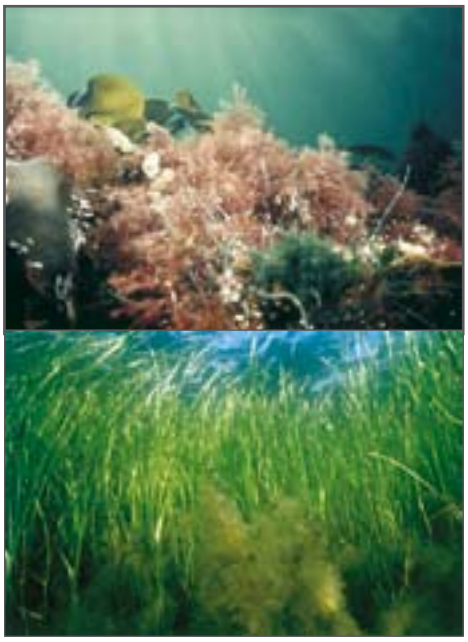
Sediment chemistry: Monitoring of sediment chemistry is only carried out at 3 different locations in Skive Fjord. The programme consists of measuring the exchange of nitrogen and phosphorus between the sediment and the water phase and of the sediment oxygen consumption. The oxygen consumption is caused by the decomposition of dead algae and may cause oxygen deficiency, which is one of the major problems in the fjord.

Hazardous substances: The amount of hazardous substances in blue mussels is measured annually at Nissum Bredning, Løgstør Bredning and Nibe Bredning, and from Aalborg to Hals. At one specific point in the period 2004-2009 this is combined with measurements of the amount of hazardous substances in the sediment. Sexual deviation (imposex) in the snail "Netted Dogwhelk" (Hinia Nassarius) caused by toxic organic tin substances TBT is investigated each year from Løgstør to Hals.

Benthic fauna: Monitoring of the benthic fauna is carried out at 4 locations, each consisting of 50 sub sample areas. Species composition, number and biomass are determined. The population of blue mussels is monitored in great detail in the Skive Fjord each year



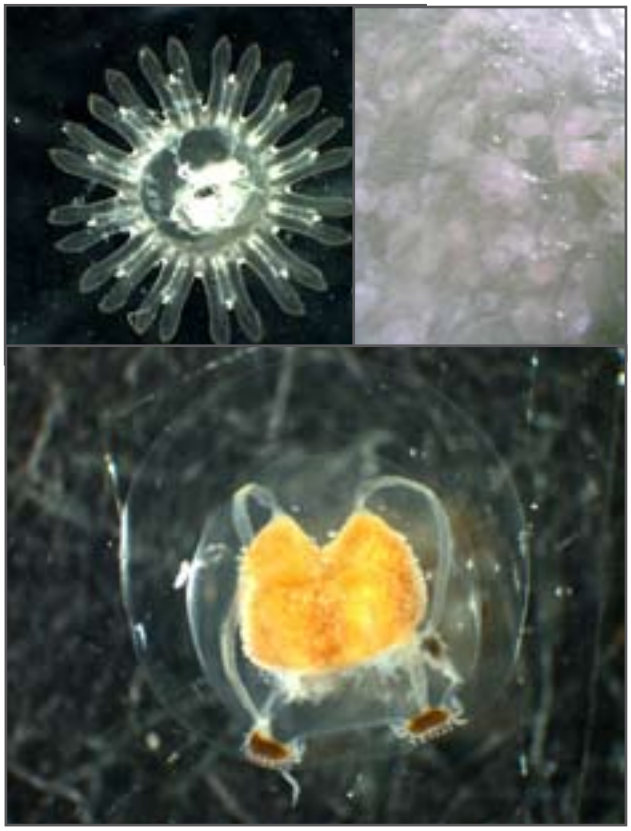
Vegetation: The vegetation on the bottom (seaweed and Eel grass) is monitored at 38 locations once per year. The monitoring is preformed by a scuba diver swimming along a fixed transect from the shore to the maximum depth of the vegetation. Species composition, abundance and depth distribution are determined.



4.1.1 Supplementary investigations in 2005

Mapping of oxygen deficiency: The spatial distribution of the area exposed to oxygen deficiency is mapped once a week from May to September each year. Oxygen is measured at 25 to 30 locations at a depth exceeding 4 meters.

Jellyfish: Jellyfish are monitored once a week from "Limgrim" as part of an EU research project (EUROGEL) with participation of the University of Southern Denmark and the Danish Fishery Association (DFU). The objective of the project is to investigate the role of jellyfish in the ecosystem and the impact of jellyfish on fish larvae and eggs.**Additional Benthic fauna monitoring:** The benthic fauna was monitored at an additional 4 locations above the requirements of the NOVANA programme. The following locations were monitored in 2005: Visby Bredning, Agerø, Thisted Bredning and Kaas Bredning.



Fish: The Danish Fishery Association monitors species distribution, numbers, length and weight of the fish at 8-10 locations each year. The counties monitor the amount of fish larvae and fry at the same locations.

4.2 Empirical modelling of the fjord

Using the data from the monitoring programme an empirical model for estimating the acceptable loading of nutrients (nitrogen and phosphorus) has been developed in order to obtain the ecological status for fulfilling the goals from the Regional Management Plan of the County of North Jutland.

The model is based on annual values of loadings of nitrogen and phosphorus from the catchment, concentrations of nitrogen and phosphorus in different parts of the fjord, and climatic data.

The studies have shown that the loadings of nitrogen and phosphorus to the fjord should be reduced in order to secure Good Ecological Status. Good Ecological Status can be obtained if the loading is reduced to around 10,000 tonnes of nitrogen per year and 360 tonnes of phosphorus. Phosphorus is the crucial factor for the amount of algae in spring time (March through June) and nitrogen in summer time (July through October). In Figure 16 the concentrations of nitrogen and phosphorus in the Løgstør Bredning are shown for the years 2003, 2004, and 2005. Here it can be seen that the algae are short of phosphorus in the spring time and nitrogen in the summer time.

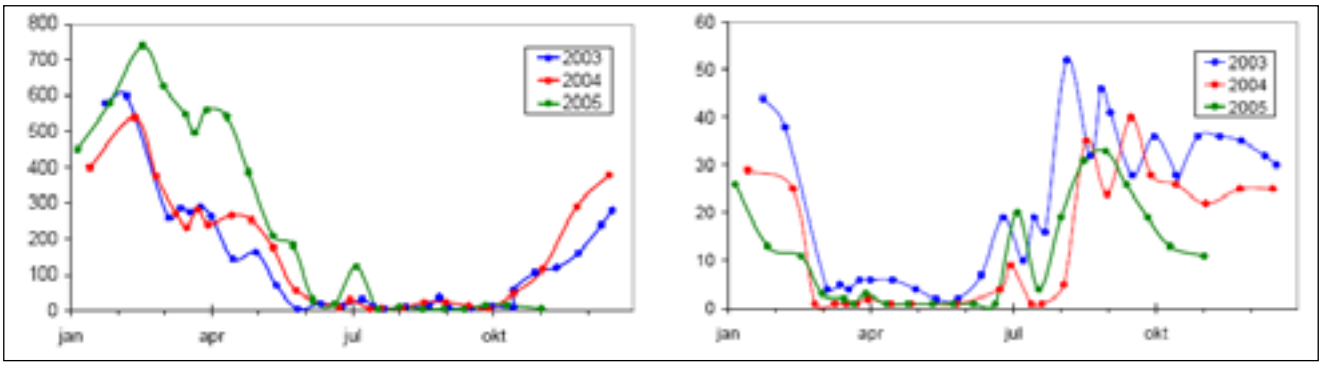


Fig. 16: Concentrations (µg/l) of nitrogen (left) and phosphorus (right) in Løgstør Bredning.

The results from the modelling can be applied to different areas of the fjord with different values for acceptable loadings in order to obtain an improved status for the fjord.

4.3 Model for the catchment area

For the catchment area a database (CTtools) has been developed based on information from the farmers in the area. The information has been collected from three databases in Denmark where farmers have to report annual data concerning crops, use of nitrogen in manure and fertilizers, live stock on their farm etc. These data have been collected in one database, which also has connected GIS facilities.

On the basis of CTtools calculations of balances for nitrogen on the farms/fields in the catchment area have been carried out. From these data, knowledge of nitrogen leaching from the root zone has been gained and the spatial distribution has been mapped in GIS.

As the relation between leaching from the root zone and the run-off of surface waters is known it is possible to implement efficient measures in order to reduce leaching. As at the same time the acceptable loadings to the fjord are known it is possible to ensure that the goals of the fjord are obtained.

4.4 Application of tools from the toolbox

The Public Hearing Database and the Priority Game have been developed and used in the planning process in the County of North Jutland for several years. Web-HIPRE was used during this project in a learning session with planners. The objective of the study was to obtain "a sustainable management of Limfjorden" taking into account economic, social and environmental criteria. Management options studied were a) an overall decrease in fertiliser loadings, b) development of fishing technology c) reduced trawling and d) increased sewage treatment. Results indicated that an overall decrease in fertilizer would be the option with the largest impact, and that it would affect all three main criteria, economic, social and environmental dimensions. RiverLifeGIS was tested in the case study but the extensive GIS analysis was carried out using ArcView.

4.5 Programme of Measures

The acceptable loadings to the fjord are known as well as the spatial distribution of agricultural losses. We are now in a process of creating a Programme of Measures to ensure Good Ecological Status in the fjord in the most cost efficient way.

Which exact measures are going to be used in the future in order to obtain these goals will depend on political willingness and economic possibilities.

5 Experience gained to sustainable river basin management

In Denmark regional planning including goals for the status of e.g Limfjorden has been carried out for the last 30 years. These have been evaluated every four years. The plans have been a very efficient tool to control the point sources such as domestic and industrial sewage. Due to the plans the loadings of nitrogen and phosphorus from the point sources have been reduced. For arable land the plans have not been efficient as the County have no authority to control the farmers in general. The loadings from arable land have, however, been reduced too, but this has been due to the Danish Governments Action Plan for the Environment, which has resulted in a general reduction.

In order to meet the objectives in the WFD it is necessary to make a further reduction in nitrogen and phosphorus loadings of the fjord. The County of North Jutland, however, has not got the tools for handling this for the time present.

6 Conclusions

Through this case study we have been able to determine the connection between the loading from land and the status of the fjord.

Proposals for measures to reduce the loadings from land have been identified.

In August 2006 a political review will take place regarding which measures could be applied in the catchment area of the Limfjorden in order to reduce the loadings. This work will be a very good basis for a thorough solution which will ensure Good Ecological Status in the Limfjorden.

In addition, the management of the work regarding planning and River Basin Management Plans will be taken over by the State from 2007 and the municipalities will be responsible for developing the action plans and ensuring their full implementation.

7 References

Annual reports of the Status of the Limfjorden, 1992 – 2004.
Counties of Ringkjøbing, Viborg and North Jutland

Hoffmann, Erik: Fisk, Fiskeri og Epifauna, Limfjorden 1984 – 2004.
Danmarks Fiskeriundersøgelser, DFU-rapport 147-05, Maj 2005.

A complete list of reports (in Danish) regarding the Limfjorden can be found on the website http://www.limfjord.dk