



## **Application of a 3D bio-chemical model for Norsminde Fjord Part of task 1.1 of the EU-LIFE project AGWAPLAN**

LIFE05 ENV/DK/000155: Integrated Protection of Surface and Groundwater in Agricultural Regions (AGWAPLAN)

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## SUMMARY

### Conclusions

A bio-chemical model has been set up for the waters of Norsminde Fjord. The model describes temporal variations in nutrient concentrations, oxygen conditions and growth of phytoplankton and benthic vegetation due to nutrient loads from the surrounding catchment area. The model provides an excellent tool for simulations of the environmental effects of reduced nutrient loads to the fjord, which will subsequently enable us to find the measures necessary to protect the aquatic environment.

The model has been set up based on surveys of the bathymetry of the fjord and a large number of meteorological, physical, biological and chemical data recorded during an extensive 2 year field campaign from 2005 to 2006.

The model shows very good results on the reproduction of physical parameters, temperature, salinity and water level as well as bio-chemical parameters, nutrients, oxygen concentrations and phytoplankton. The description of macro algae and rooted vegetation is more complicated since the model describes possible growth areas and rates. The model does not take into account grazing by swans or the wind induced transport of floating macro algae. This means that it may not be possible to reproduce the exact distribution of the vegetation. However the potential growth can be modelled and compared for various scenarios of nutrient (phosphorus and nitrogen) loads from the catchment area.

The model set up is described in more detail in “**Modelanalyse af den fremtidige vandkvalitet i Norsminde Fjord**”, **Kalibrering & validering (DHI, 2007)**.

The work has been carried out by the Environmental Centre Aarhus and the consultancy DHI as part of task 1.1 of AGWAPLAN.

### Description of Norsminde Fjord

Initially the factors and processes of importance for the ecosystem of Norsminde Fjord were analysed in order to choose a suitable model set up.

The physical environment is of significant importance for the variability of the flora and fauna in the fjord. The fjord receives substantial amounts of fresh water from the catchment area. The largest fresh water source is Rævs Å, discharging to the inner part of the fjord. The fresh water mixes with salt water from the southern part of the bay of Århus entering through the gate thereby creating a highly dynamical brackish and some times stratified environment (Århus Amt, 1994). The mean retention time of water in the fjord is between 2 and 3 weeks, but with large seasonal variations. Spring has the shortest retention time due to the large run offs during this period, figure 1.

Biological factors of special importance in the Norsminde Fjord ecosystem are the grazing of swans on rooted vegetation, filtration of phytoplankton caused by mussels especially in the inner part of the fjord and light extinction caused by suspended solids in the water originating from streams or sediment in the fjord.

Between 85 and 90 % of the nutrient load to the fjord is discharged through Rævs Å. Compared to nitrogen a larger part of the phosphorus (P) is bound to particles.

Analysis of the sediment show that the sediment pool of N in the fjord is 51 ton corresponding to half of the annual load and the sediment pool of P is 4,6 ton. P has a longer retention time in the fjord than N due to the exchange with the sediment. Comparisons between results from the investigations in 1992-93 and recent data from 2005/2006 show that the sediment pool of P has been reduced to 1/3 during the last 14 years.

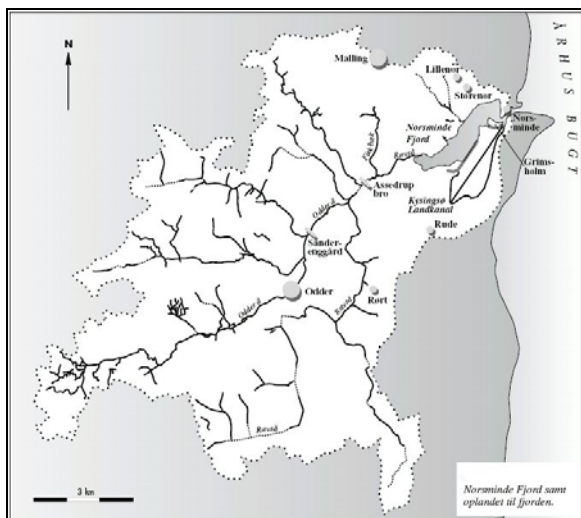


Figure 1 Catchment area and fresh water run off

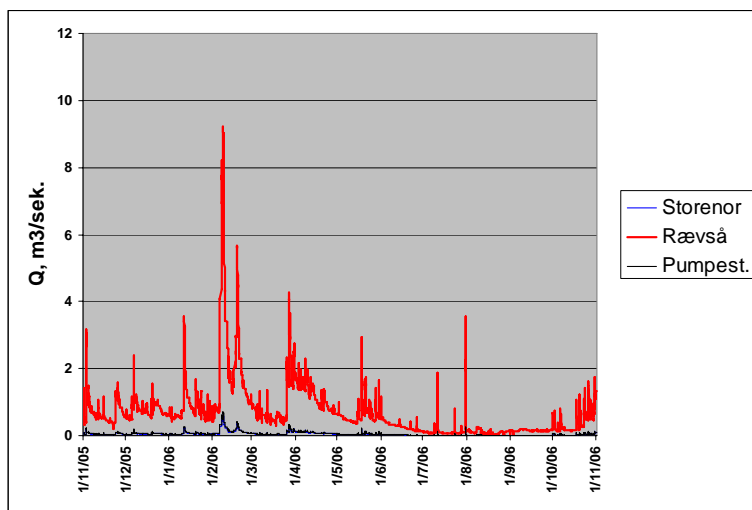


Figure 2 Fresh water run off 2006

### Model system

The Norsminde Fjord model is based on the 3D fully dynamical model MIKE 3 Eco-Lab developed by DHI (DHI, 2005a and b). The model system consists of two modules. The hydrodynamic modules provides the basis for computations performed in the bio-chemical module. It simulates water level variations and flows in response to fresh water discharge, exchange with surrounding waters and meteorology.

The eutrophication module describes chemical, biological, ecological processes and interactions between state variables. State variables included can either be transported by advection-dispersion processes based on the hydrodynamics, or have a more fixed nature, for instance like rooted vegetation or mussels. The model includes the description of nutrient cycling, phytoplankton and zooplankton growth, growth and distribution of rooted vegetation and macro algae in addition to simulation of oxygen conditions. Model results are for example concentrations of phytoplankton, chlorofyll-a, zooplankton, organic matter, nutrients, oxygen and area-based biomass of benthic vegetation over time, primary production and secchi depth. Below a schematic description of the pelagic processes of the model is shown. The pelagic model is dynamically coupled to a complicated sediment model.

C, N & P Stofcyklus i vandfasen  
ink. sandmuslingernes filtration

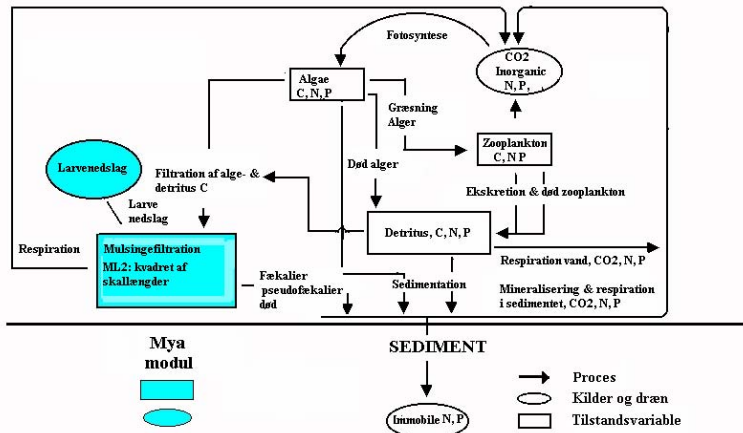


Figure 2 Nutrient cycle included in the bio-geo-chemical model MIKE 3 Eco-Lab.

**Set up, calibration and validation of the Norsminde Fjord model**

The application of the model is based on a large number of surveys carried out during the period 2005-2006. Among other things the campaigns included measurements of temperature, salinity, nutrients, oxygen, phytoplankton and zooplankton every second week at stations shown on figure 3. The bathymetry survey was used to produce the model bathymetry illustrated in figure 4.

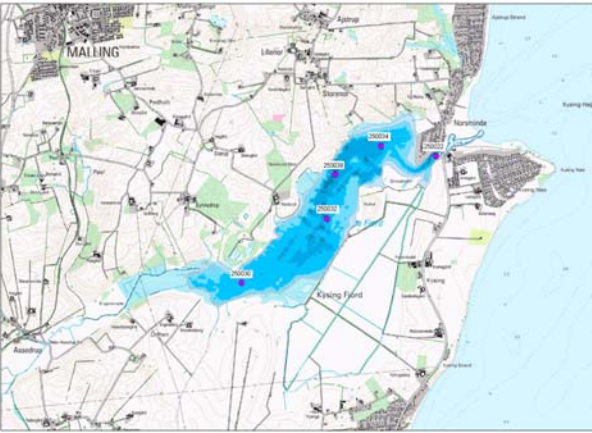
	Station	Parameter	Periode
	120118	Vandføring vandkemi: Total-N, NO <sub>2+3</sub> , NH <sub>3+4</sub> , total-P, ortho-P, temperatur	daglige vandføringer siden 1976 vandkemi ca. hver 14. dag i 1980, 1985 og siden 1989
	120118	Flowproportionale prøver af total-P og ortho-P	september 2006 – juni 2007
	170118	Saltholdighed og temperatur i -4, -8 og -11 m DO og Chl. I -11 m	hvert 30. min jan 2003 – dec 2006
	250022	Vandstand før og efter slusen, sluseaktivitet (åben/lukket) saltholdighed/temperatur 0,5 m over bunden (m o b) og 0,5 m under overfladen (m u o). Den øverste sensor følger vandstanden.	15. dec 2005 – 31. juli 2006
250030, 250034	profiler af saltholdighed, temperatur og ilt vandkemi midt i vandsøjlen: TN, DIN, TP, DIP, DO, silicium, SS og chl-A	11. jan 2005 – 2. november 2006 (reduceret program i 1991- 1993)	
250032	profiler af saltholdighed, temperatur og ilt vandkemi: TN, DIN, TP, DIP, DO, silicium, SS og chl-A fytoplankton og primærproduktion	11. jan 2005 – 2. november 2006 (reduceret program i 1991- 1993)	
250038	Kontinuerte målinger af saltholdighed og temperatur	20. dec 2005 – 1. jan 2007	
250101- 250109	sedimentmålinger: Næringsstofpuljer (TN+TC, TP og Fe-P), densitet, tørstof og glødetab, svovlbrintebufferkapacitet og oxideret jern, bestemmelse af svovlbrintefront ud fra porevandsprofiler og Ag- tråd, iltmedtrængning	6. sep 2005 og 10. april 2006	
9 transekter i fjorden	bundvegetation	1-2 gange i løbet af sommeren i perioden 1989- 2006	
15 stationer 25001- 25015	Bundfauna: artsantal, individtæthed, biomasse	1991, 2003	

Figure 3 Position of monitoring stations used during the campaigns during 2005-2006.

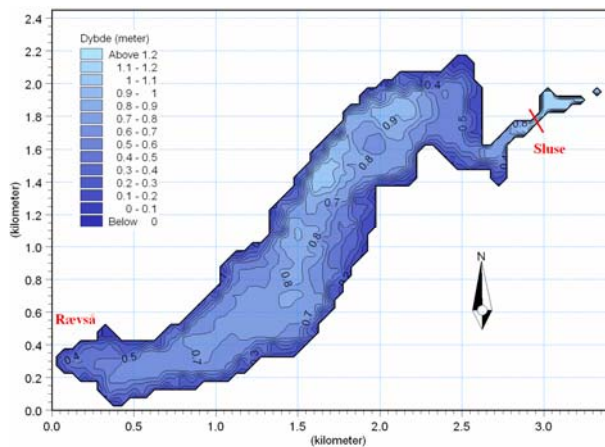


Figure 4 Model bathymetry, based on survey 2005.

Table 1 Summary of the 2005-2006 measurements.

The model has been calibrated by comparing monitoring data with model values and tuning model calibration parameters like for example the bed friction or the light extinction coefficient until the best fit is reached. Figures 5 and 6 shows selected results of the calibration. Subsequently the model parameters are kept fixed and the ability of the model to reproduce data is tested on a set of data from another year, 2005. The model of Norsminde Fjord showed equally good results for the calibration and validation periods.

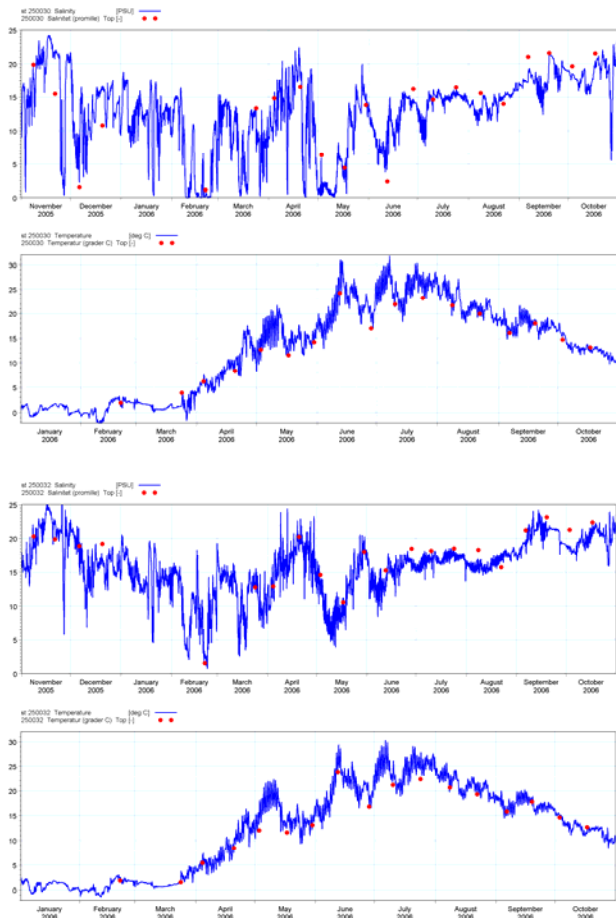


Figure 5 Measured and simulated values of salinity and temperature at stations 250030 and 250032 during calibration period.

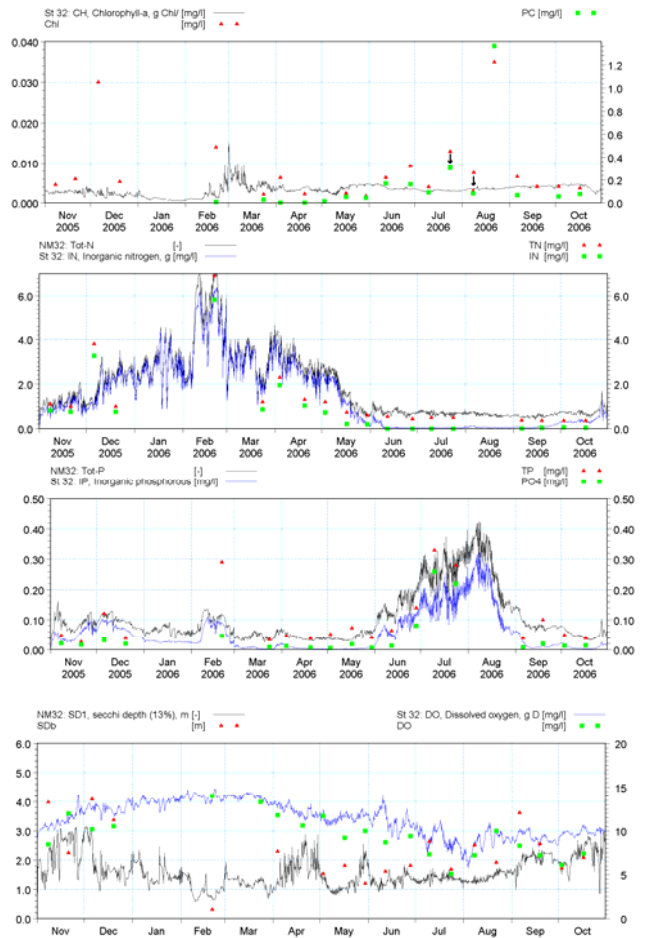


Figure 6 Measured and simulated values of total-nitrogen (TN), inorganic nitrogen (IN), total phosphorus (TP), ortho phosphat (IP), oxygen and sechi depth at station 250032.

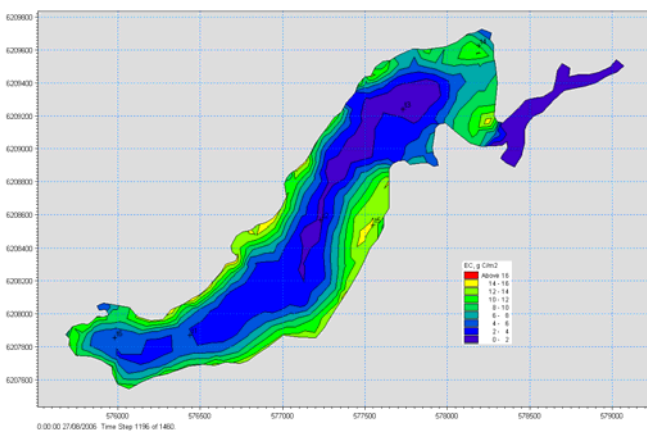


Figure 7 Simulated biomasses ( $g C/m^2$ ) of rooted vegetation on 1. July 2006. The map shows where the growth will take place under the given light-, nutrient- and sediment conditions. Grazing by swans and current is not taken into account.

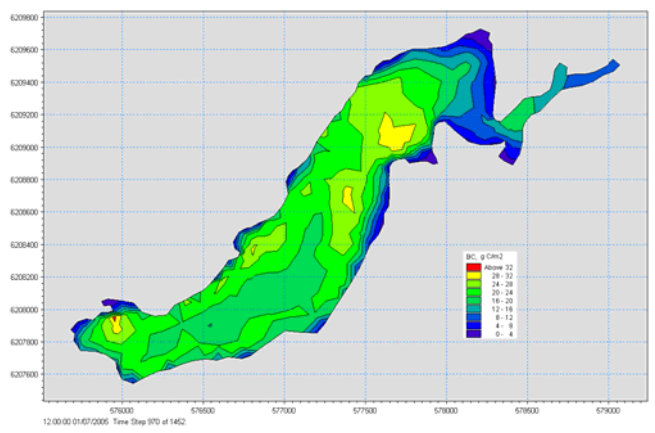


Figure 8 Simulated biomasses ( $g C/m^2$ ) of macroalgae on 1. July 2006. The map shows where the growth will take place under the given light-, nutrient- and sediment conditions.

## References

- DHI, 2005a MIKE 21/3 EU, Eutrophication Module. A scientific description. DHI water and environment Release 2005.
- DHI, 2005b MIKE 21 and MIKE 3 FLOW MODEL, Hydrodynamic and Transport Module. Scientific description. DHI Water & Environment. Release 2005.
- Århus Amt, 1994 Norsminde Fjord 1992. Århus Amt Natur og Miljøkontoret 1994 ISBN: 87-7295-418-3