

Annual Report for 2002.

Consequences of weather and climate changes for marine and freshwater ecosystems –Conceptual and operational forecasting of the aquatic environment

Jour. no: 2052-01-0034

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Partners

Freshwater Biological Laboratory, University of Copenhagen (FBL)
Danish Climate Centre, Danish Meteorological Institute (DMI),
DHI-Water & Environment (DHI),
National Environmental Research Institute, Dept. of Lakes and Estuaries (NERI),
The Danish Institute for Fisheries Research (DFU),
Department of Marine Ecology, Aarhus University (AU)
Institute of Geography, University of Copenhagen (GI),
Geographical Resource Analysis & Science A/S (GRAS),
Department of maritime and regional history, Southern Denmark University (SDU).

Prepared by Morten Søndergaard, the partners and the Executive Committee.
May 2003

1. Executive summary

The project was officially started June 1, 2002. In May all partners joined a “kick-off” meeting in Salten Skov (a field laboratory) for two days and the agreements concerning cooperation among partners in the different Workpackages (WP) were confirmed. Furthermore, we decided on a homepage, an acronym and that each WP leader at due time should organise WP specific workshops with the purpose of detailed planning and to get the different groups to work together and take responsibility. Such workshops have been organised according to plans.

The Executive Committees’ first meeting was in December in Silkeborg. The most important decisions were: (1) to go ahead with the announcement of the Ph.D. scholarships and a postdoc position at DFU, (2) acceptance of a minor redistribution between the costs of salary and consumables by GRAS, and (3) acceptance of a delay at DMI due to severe sickness of a prospect postdoc. This problem has now been solved (April 2003). The Committee concluded that momentum had been found by those groups supposed to be active according to plans.

The first annual meeting with presence of the External Board (all five) was held at Vilvorde KursusCenter, May 13 -14, 2003. About 35 participants were present and presented progress reports, both with overviews from WP-leaders and specific research. The External Board was very active and their evaluation at the end of the meeting was positive. They suggested that we should adopt a data handling procedure and also encouraged to take more advantage of historic records and use these in hind cast mode and models.

From the progress reports presented at the meeting and the written reports we conclude that all planned activities are on schedule. The participants have been active in promoting the project and even have prepared publications and seminar/workshop talks under the CONWOY umbrella.

The purposes of the project are:

- To develop a conceptual understanding on how the present and future climate will interact with fundamental ecological processes in aquatic systems ranging from rivers, over lakes to coastal areas and more open seas
- To translate and develop the conceptual understanding to an operational modelling capacity with the perspective to quantify the impacts over both short (decades) and long (century) time scales

2. Management

Members of the Executive Committee:

Karen Edelvang, DHI
 Erik Jeppsen, NERI
 Jens Hesselbjerg Christensen, DMI
 Brian MacKenzie, DFU
 Morten Søndergaard, KU (chair)

The External Board:

Job Baretta,
 Wilhelm Granéli
 Michael Heath
 Hans von Storch
 David Patterson

Project meetings

“Kick-off” meeting for all participants, May 16-17, 2002, Silkeborg
 WP-4: The experimental “lake-area” facility: July 2002 and April 2003. Silkeborg
 WP-1: History of Marine Animal Populations in the North Sea, September, 2002, Esbjerg.
 Executive Committee, December 12, 2002, Silkeborg
 WP-2: Time series and intensive work areas, Copenhagen
 WP-3 and 5: Climatic parameters; what is needed? February, Copenhagen.
 First Annual Meeting, May 13-14, 2003, Copenhagen

Home page

The homepage has been set up and maintained by GRAS (Lotte Nyborg). Lotte has developed a scheme on how to keep it active. Her plan was endorsed at the Annual meeting. She was given good credits for the job done. Here is the report from GRAS on this activity:

Structure of www.conwoy.ku.dk

The overall objective of the Conway web is to

- Present the Conway project to the public and researchers
- Operate as a platform for the Conway partners to share data and information, make the work package minutes and working papers accessible and maintain a calendar indicating all Conway meetings and related activities.

It has been intended to design a website which is user friendly to navigate with a straightforward hierarchical structure. Each page is designed with similar graphic and colours and with the Conway logo on the top of each page. The page has the following main pages:

Main pages	Contents
<i>Home</i>	Front page with a very short appetizer to the Conway project
<i>Project</i>	Background, Objectives, Work packages, Funding and Project management
<i>Activities</i>	Selected ongoing activities in Conway – here it is expected to have more contents during the second year of Conway
<i>Dissemination</i>	Dissemination of papers, reports and other public documentation of the Conway project
<i>Participants</i>	Links to partners pages and contact information
<i>Contact</i>	Contact information to the project leader
<i>Links</i>	Links to Conway related activities and relevant scientific projects
*****	*****
<i>Calendar</i>	Mainly internal meetings in Conway are posted here
<i>Jobs</i>	During the first year of the project period five vacant positions have been available and posted here
<i>Login</i>	Login page to the internal Conway platform where minutes and working papers are posted

Maintenance of the Conway web in the future

The website is updated when new information is available from the Conway partners or if information is outdated e.g. vacant position notices and links. During the second year of Conway it is aimed at getting the Conway partners to use the web more actively. Generally more information about research activities has to be communicated out to the public. This requires each partner to consider the website every now and then, when activities e.g. meetings, experiments, writing of reports, speeches are being carried out. To ensure a continuously flow of information and news from the partners to the web master, one web responsible person from each participating institution has been chosen.

Personnel

Three Ph.D. scholarships and one postdoc position have been advertised nationally and exposed on international homepages. We got an overwhelming response, also from outside Denmark. The Ph.D. scholarships are filled and currently the postdoc applicants are evaluated. All evaluation committees have had external members.

Physical Limnology: Rikke M. Closter. FBL/DMI
 Sediment transport: Hans Thodsen. DHI/GI
 Fisheries history: Christine R. Overgaard. SDU/DFU
 Winter phytoplankton: To be concluded. AU/FBL

Participating scientists:

FBL
 Morten Søndergaard, Project coordinator
 Lars Kamp Nielsen,
 Kirsten Christoffersen,
 Kaj Sand-Jensen

Peter A. Stæhr
Niels Kongshøj, Conway postdoc
Ursula Friberg, Conway postdoc

DMI
Jens Hesselbjerg Christensen, DMI project coordinator
Annette Guldborg, Conway postdoc
Ole Bøssing Christensen

GRAS a/s
Lotte Nyborg, Homepage coordinator
Michael Schultz Rasmussen, GRAS project co-ordinator

GI
Morten Pejrup, GI project coordinator
Thorbjørn Andersen,
Bent Hasholt,
Ulrik Lumborg

DHI
Anders Erichsen,
Flemming Møhlenberg,
Karen Edelvang, DHI project coordinator
Kristine Garde,
Peter Rasch,
Erik Kock Rasmussen

NERI
Martin Søndergaard,
Erik Jeppesen, DMU project coordinator
Lone Liboriussen,
Jens Peder Jensen,
Brian Kronvang

DFU
Brian MacKenzie, DFU project coordinator
Andy Visser,

SDU
Bo Poulsen,
Rene Taudal Poulsen,
Poul Holm, SDU project coordinator
Majbrit Bager

AU
Katherine Richardson, AU project coordinator

3. Reports by Workpackages.

WP 1. Establishing empirical relationships between climate and long-term dynamics of aquatic ecosystems.

The main activities in WP1 are the following:

i) data retrieval, recovery and compilation. Data are being assembled from diverse sources including lake sediments (paleoecology), written archives in maritime and fisheries history museums, monitoring programmes, research surveys and commercial fisheries records (retained and discarded landings). Data being recovered include biotic and abiotic variables (e. g., cladoceran remains in lake sediments, fisheries landings and effort data).

ii) data analysis and interpretation. Statistical analyses of factors affecting changes in biotic variables and ecosystem structure and function will be conducted using the newly constructed time series. Variables and processes to be investigated include climatic effects (e.g., temperature, precipitation/runoff, ice cover), species interactions (e. g., predation), and socio-economic factors (e. g., demand for fish products, changes in fishing effort).

iii) dissemination. Results from the task will be presented in manuscripts submitted to international peer-reviewed journals and will be presented at national and international meetings and conferences. Results will also be presented on the project homepage.

Task 1.1. Multi-annual effects of climate on lake ecology

Task 1.2. Paleolimnological/historical evidence of plankton, fish and plant abundances in lakes and rivers.

The activities by NERI to Tasks 1.1 and 1.2. have included:

Contemporary data:

1. Begun cross-analysis of data from 30 Danish lakes followed intensively since 1989 in order to evaluate the relations to NAO (NERI, AAU)
2. Begun space for time study on data from European lakes (Finland to Spain) and a cross-comparison of data from Florida and Danish lakes. (NERI, AAU et al.)
3. Written two book chapters on oligotrophication and lake restoration with focus on the role of climate differences (2003 and in press) (NERI, AAU et al.)
4. Written a paper on top-down control in lakes related to variation in nutrient state, depth and climate based on data from 466 lakes from Greenland to New Zealand (NERI, FBL, AAU et al.)
5. Conducted a cross-system analyses of the relative contribution of benthic and pelagic primary production along a nutrient gradient (NERI, FBL, AAU et al.)

Sediment data

1. Conducted analyses of sub-fossils of cladocerans in 150 lakes (Greenland to New Zealand) as indicator of top-down control and temperature in lakes (NERI, FBL, AAU et al.)
2. Conducted an analysis of a 9000-year core from western Greenland to elucidate the effects of change in climate on the trophic structure and dynamics and an analysis of a 7000-year core from Lake Dallund, Denmark, to elucidate the effects of change in land-use and climate (GEUS, NERI, AAU).

Plan for next year:

- Continue the work on disentangling a climate and eutrophication-oligotrophication signal in long-term contemporary data series from Danish lakes.
- Continue the work on an international data set in order to elucidate the role of differences in climate on trophics structure and dynamics (space-for-time).
- Continue the work on counting cladoceran remains in surface sediment from areas with contrasting climate (Europe, Canada, South America, Greenland, the Faroe Islands and New Zealand) and compiling and analyzing data with the same purpose as above.
- Undertake detailed studies of cladoceran remains in laminated sediments (6-monthly dissolution) from two Danish lakes and not least the period around year 8200 where dramatic climatic changes occurred.
- Start (in April 2004) on the comparison of historical changes in fish abundance in lakes reconstructed from the sediment with historical records of catches based on taxes (fish to species level) to the crown (1600-1800?).

Task 1.3. Recovery and assembly of historical landing data

Participants: SDU, DFU

Establish historical catch records (300 - 500 years) for a number of major commercial species of the North Sea, Kattegat and Limfjord (northern Denmark) based on archival research (e. g., customs records, individual fishermen's accounts) in all North Sea countries and in particular the Danish, Dutch and British archives.

A Ph. d. student specializing in archival research and partly supported by the project was employed May 1, 2003 at SDU. The student will be jointly supervised by SDU and DIFRES. The student will investigate archives in Denmark and abroad (e. g., Netherlands, UK) for data relating to the North Sea cod fisheries (e. g., landings, effort).

The task will also be supported by two additional Ph. D. students at SDU who are funded outside of Conway. One student is investigating herring fisheries in the North Sea during 1600-1850, primarily on the basis of Dutch archives, which are believed to be the richest archival fisheries data for this period in the North Sea area. A second student is investigating changes in the exploitation of all marine resources, including herring, in the North Sea during 1850-1914.

All of these student projects have recently started and no quantitative results are available yet. Some initial data series may be available by end of the next reporting period.

In addition, an international workshop on the History of Marine Animal Populations in the North Sea (North Sea HMAP, Census of Marine Life) was organized by SDU, DIFRES and International Council for the Exploration of the Sea (ICES) in September, 2002. This workshop attracted maritime historians, fisheries/benthic/seabird ecologists and oceanographers, and identified some key areas for research of long-term ecological changes, including fisheries, in the North Sea (see <http://www.hmap.cmrs.dk/> for details). Several participants from Conway subtasks 1.3 and 1.4 participated in the workshop.

While the geographic focus of this subtask is on the North Sea-Kattegat-Limfjord, the partners are involved in other projects which are supporting archival work related to historical fisheries in other

geographic areas (i. e., Baltic Sea). These data will be analysed in relation to climate variability in future years and will contribute to Conway's overall goals.

Some preliminary results have been disseminated within the scientific community (MacKenzie et al 2002) and to the general public (Holm and MacKenzie 2003).

Task 1.4. Analysis and interpretation of marine fisheries data

Participants: DFU, SDU

Use the new documentation of historical fisheries and other contemporary data to test possible linkages of fish distribution and abundance to major climatological factors, hydrographic changes and socio-economic influences.

Climate change will have several impacts on fish populations and the marine ecosystems in which they live around Denmark. These impacts will include changes in:

- production and survival of individual fish species;
- species composition (biodiversity) of fish communities;
- migration patterns (seasonal arrival and departure times of migratory species);
- ecosystem structure and function (e. g., plankton production rates and species composition, timing of plankton production peaks; ocean circulation) that affect growth and survival of different lifehistory stages.
- lifehistory (e. g., growth rates, time and location of spawning, maturity ogives)

The main activity in Year 1 has been the identification of suitable species, areas and data sets for analysis. In addition, two manuscripts partly based on Conway and other project work related to fish production and distribution in relation to climate variability (Brander et al 2003; MacKenzie and Köster 2003) have been submitted to international journals for review and publication.

Statistical analyses involving historical data for cod and herring in the North Sea will begin in years 2 and 3 when data series become available from subtask 1.3.

Fisheries data sets based on 20th century data are being identified and compiled from fisheries institute sources (e. g., research surveys, retained and discarded Danish commercial fisheries landings data). These data will be used to investigate how some individual species and the fish fauna have reacted to climate variability in the past. Some candidate species and populations have been identified for analysis (Table 1.1).

Table 1.1. Species, regions and variables to be considered in analyses of impacts of climate change on fish populations around Denmark.

Species	Region	Variables to be investigated
sprat	Baltic Sea	temperature, NAO, ice cover, exploitation
cod	Baltic Sea	salinity, oxygen, temperature, exploitation
cod	North Sea	temperature, NAO, predation, exploitation
herring	North Sea	temperature, NAO, predation, exploitation
sole	Kattegat-Skagerrak	temperature, salinity, NAO, exploitation
"southern" species (e.	North Sea-Skagerrak-	temperature, NAO, exploitation

g., red and thicklip mullets, sardine, anchovies)	Kattegat-Baltic Sea	
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Some key environmental data sets (e. g., sea temperatures, NAO) are being compiled from various sources (e. g., internet, ICES). Other data sets are being constructed from scratch. For example, one variable that significantly affects reproduction and recruitment of cod in the eastern Baltic Sea is a volume of water (“reproductive volume”) that has high enough salinity and oxygen concentration to allow cod eggs to be successfully fertilized and to hatch (Jarre-Teichmann et al 2000). Existing time series (MacKenzie et al 2000) are based on direct hydrographic measurements from research cruises. However, a collaboration between DHI and DIFRES is investigating whether an ecosystem model of lower trophic level processes (e. g., primary production, grazing, sedimentation, remineralization) coupled to a 3D ocean circulation model forced by regional climate can produce new process-based time series of reproductive volume. Should the new model estimates of reproductive volume also explain significant variation in the historical cod recruitment time series, then this model could potentially be used in scenario studies (WP 5) of the impacts of climate change on cod reproductive habitat and reproduction in the Baltic Sea. This issue will be investigated in subsequent years of Conway.

Activities in Year 1 are summarized in Table 1.2. Activities in Year 2 will continue to recover and compile data sets. Some data analyses will begin as data series become available. The collaboration between DIFRES and DHI regarding process-based modelling of reproductive volume will continue.

Table 1.2. Summary of activities and status of Subtasks 1.3 and 1.4

Subtask	Status
1.3	One Ph. D. student employed to investigate historical cod fisheries in the North Sea.
	Archival sources for historical herring fisheries (1600-1850) identified and some initial investigations have been started.
	Sources for historical fisheries including herring in North Sea during 1850-1914 identified and some initial investigations have been started.
	One international workshop on long-term ecological change in the North Sea organized together with International Council for the Exploration of the Sea (ICES).
1.4	Several candidate fish species and populations have been identified for analysis later in project (see table above).
	Some late 20 th century fisheries datasets have been identified.
	Recovery and updating of some 20 th century data sets has begun (e.g., sole in Kattegat-Skagerrak).
	Development/extension of historical time series of model outputs of key environmental variables has begun together with project partners (DHI).

WP 2: Hind- and forecast of weather induced changes in hydrology, sediment and nutrient transfer in the interconnected river, lake and estuarine system.

The overall objectives of WP 2 are to evaluate how changes in weather and climate potentially influence the transfer for sediment and nutrients from land to lakes and the near coastal estuarine system.

The fresh water runoff will be analysed and modelled on a decadal time scale and the future transport of sediment and nutrients will be assessed. Finally, this will be used to evaluate the future stability of coastal lagoons and salt marsh areas.

Five sub-tasks have been defined to address the overall objective of WP2.

Task 2.1: Discharge in a climate change perspective

Seventeen Danish watercourses have been analysed with respect to change in average, minimum and maximum runoff. It was found that there was a significant increase in western Jutland and at the western part of Zealand, whereas the rest of the country did show any significant change in runoff at the $p > 0.05$ level. Based on this analysis 5 catchments have been selected as future test areas. The selected river basins are: Skjern å, Varde å, Gudenå, Odense å and Suså. Besides a Swedish catchment (Emån) have been selected as future test area.

At the same time the spatial distribution in precipitation have been established for the period 1961 – 1990 in a grid of 50 x 50 Km. This spatial precipitation has been modelled for the same period using the output from an atmospheric GCM model (general circulation model) as input to the HIRHAM model. The measured and modelled precipitation compares well with respect to spatial variation and fairly well with respect to absolute values of precipitation.

The participation of NERI in WP2 has included the following activities:

1. Collection and inspection (quality assurance) of long-term data on river runoff from 17 Danish catchments.
2. Collection and inspection (quality assurance) of longer-term data on sediment and water chemistry from different Danish rivers.
3. Statistical analysis of monthly and annual runoff data for trends in mean, minimum and maximum.
4. Initiating a collection of information on changes in land use in the 17 catchments during the last 80-100 year period.

DMI has participated in work package meetings with the aim to distribute data from observational stations as well as from numerical climate models to the investigations of WP2. Currently, it is decided which precipitation stations are relevant for the statistical treatment of measured runoff performed by NERI.

Next year precipitation data from observation stations will be extracted and delivered to NERI in order to facilitate a distinction between anthropogenic and climatic effects on the variations of measured runoff data.

Task 2.2: Soil erosion and climate change

Preliminary studies of soil erosion potential have been carried in the catchment areas of Varde å and Vejle å by use of RUSLE (Revised Universal Soil Loss Equation). The results will be used to establish test sites where soil erosion will be measured.

Task 2.3: Modelling of future leaching scenarios

The work on this task has not yet been started. It is planned to start in the second year of the project.

Task 2.4: Algorithm development to describe the stability of intertidal mudflats and salt marshes.

Shear strength of intertidal mudflat sediments have been measured in situ. Based on this a relationship between chlorophyll *a* contents and sediment shear strength have been established. It has been shown that shear strength of the bottom sediment shows a seasonal as well as a spatial variation. This has been incorporated into the numerical hydrodynamic model MIKE 21 MT.

DHI has participated in two meetings in WP2. 5 catchments were selected for analyses. DHI has given overview of existing models in the relevant rivers/estuaries.

Catchment	MIKE 3	MIKE 21	MIKE 11	MIKE 12	NAM	SHE
Odense å	x ¹		x			x
Varde å						
Skjern å	x ²	x	x			
Gudenå			x	x ³		
Suså			x ⁴	x ⁵		

DHI has just started on improving the combined hydrodynamic-ecological model, set up on Ringkøbing Fjord. in order to use the evolved model system to analyse the potential future effects on the ecology on a changing climate with emphasise on effects of increased discharge and load of fine sediment and nutrients.

Focus next year:

Development of the combined mud transport and eutrophication model with regard to describing the nutrient cycling in mud beds.

Setting up models in the above mentioned areas Odense Fjord, Ringkøbing Fjord, Randers Fjord in order to have them ready for climate scenario simulations in WP 3 and WP 5.

Task 2.5: Sedimentation, climate signals and sediment transport.

MIKE 21 MT has been used to simulate sediment accumulation during a 9 months period for the Lister Dyb tidal area. It was found that the intertidal mudflats would accumulate some 14 mm of sediment in month. This result is preliminary but it compares well with direct measurement of sediment accumulation in the area. Furthermore, the spatial distribution of sediment accumulation compares well with monitoring of the area.

Around 1. May the work with settling up the hydrodynamic MIKE 11 model for the 5 selected rivers was initiated.

Accumulation rates of mud based on the gamma-dating technique have been measured at several locations in both the Grådyb tidal area and the Lister dyb tidal area. The measured values will be used to evaluate both recent and historical accumulation rates.

Finally, a new technique to date recent sediment has been tested. It is the OSL method (Optical Stimulated Luminescence). This work has been carried out in corporation with Nordic Centre for Luminescence Research at Risø. The results look very promising and the new method has potential for dating sediment from a few years of age to thousands of years. When the method is fully established it will give quite new possibilities of detecting changes in sedimentation in the estuarine environment. It will be tested if the method can be used for dating lake sediments as well.

WP 3 Coupling between physical forcing and ecology

This WP seeks to define the linkage between climate (physical forcing), physical conditions of marine and freshwater environments, and the subsequent ecological impacts on these ecosystems.

Task 3.1: Present day climate simulations and their verification

Ongoing activities

DMI has hosted a meeting (5/2/2003) with the aim of giving an overview of available data from the institute. Observational data have largely been published in DMI reports and put online for public download. Output from numerical models is generally available in its native format (GRIB) on a typical temporal scale of 3 hours. Postprocessed daily data in a common data format (netCDF) is becoming available at present for download. This database will grow to contain all simulations of the EU project PRUDENCE, more than 50 30-year long experiments.

At the meeting held at DMI to initiate the collaboration on climate model verification it was understood to concentrate on year 2000. DHI has data from Farvandsmodellen, satellite images may be supplied by GRAS. DHI has suggested that DMI re-simulate year 2000 using measurements as boundary conditions. The results are to be used in Farvandsmodellen to check the response of the model comparing measured weather year 2000 with modelled weather year 2000. This will allow us to evaluate whether this is a feasible method.

Focus next year

Evaluation of the feasibility of the above suggested method for comparison of the hydrodynamic and climate models in order to give an overall evaluation.

An inter-comparison will be performed between specific parameters such as heat exchange between water/atmosphere interaction both modelled in the climate model and “Farvandsmodellen”.

In collaboration between DMI and DHI climate model data will be delivered as input to the marine impact model for a one-year experiment. Initially the effect of model deficiencies on the output of “Farvandsmodellen” will be investigated. Subsequently, regional model output corresponding to a future scenario will be fed to the marine impact model.

Task 3.2: Simulation of nowcast scenarios and their verification

Ongoing activities

DHI is in the process of operating Farvandsmodellen in nowcast and forecast in order to optimise the parameter description of selected ecological and hydrodynamic features such as thermoclines, haloclines, primary production, algae bloom etc. Verification is ongoing using measured data and satellite images.

During the first year of Conway the activities at GRAS have been concentrated on setting up a system for semi-automatic processing of Sea Surface Temperature (SST) maps using NOAA AVHRR satellite data.

Processing system for mapping Sea Surface Temperature from NOAA AVHRR data

A large number of Sea Surface Temperature (SST) and Chlorophyll a (Chl-a) maps will be processed from NOAA AVHRR and SeaWiFS satellite data. This is a part of WP 3. The data are primarily intended to be used for data assimilation in the “Farvandsmodel” and as input data to the “Hirham model”. Together with DHI it has been decided to process selected periods in 2000 and 2001 as a function of the number of available *in situ* measurements from DHI. Until now GRAS has concentrated on setting up a system for semi-automatic processing of the NOAA AVHRR data to processed SST maps. The NOAA AVHRR data processed are from the Archive at the Institute of Geography, University of Copenhagen, whereas the SeaWiFS images will be purchased at Dundee Satellite Receiving Station.

Processing and Method

The processing is performed using the image processing software WinChips. The images are automatically rectified. Using a set of geometrically rectified reference images from different seasons up to 74 Ground Control Points are automatically located using cross correlation techniques. The number of GCP’s used in the final rectification is a function of the cloud cover. Extensive cloud cover in the image results in a low number of GCP’s whereas a cloud free image will have a large number of GCP’s available in the final rectification. Furthermore, an automatic cloud mask is applied.

After the automatic rectification has been performed the rectification accuracy is manually checked. If the error in rectification exceeds 1 pixel (1 km) the image will be discarded or manually rectified. Furthermore, a manually check of the cloud mask is performed and if needed adjusted manually.

The SST is calculated using the last updated/used operational algorithms by NOAA/NESDIS, see example of the day-algorithm in the box. The algorithms are tuned to return the Temperature at 1 meters depth and the accuracy is approximately 0.5 degree.

Day NLSST Split - OPERATIONAL DAYTIME EQUATION

Operational algorithms by NOAA/NESDIS

Day NLSST Split: $A1 * T4 + A2 * Tsfc * (T4 - T5) + A3 * (T4 - T5) * (\sec(\text{sat_Angle}) - 1) + A4$

T4= Channel 4 calibrated temperature

T5= Channel 5 calibrated temperature

Tsfc = an priory estimate of SST obtained from analysis of past satellite data (In Conway we use the MCSST Split algorithm to make this estimate, see below)

A1-A4= Constants dependent on the Satellite number

MCSST Split: $A1 * T4 + A2 * (T4 - T5) + A3 * (T4 - T5) * (\sec(\text{sat_Angle}) - 1) + A4$

An example of a final SST map is shown in figure 1.

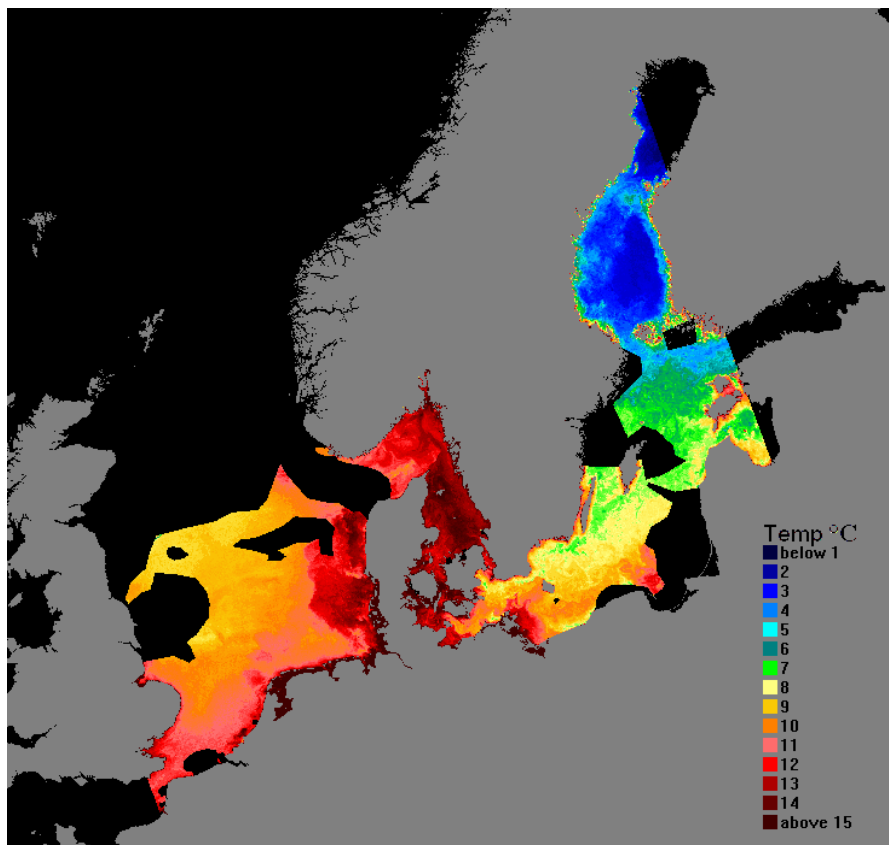


Figure 1. SST map from May 6, 2000. The study area covers 2100*2000 km. The projection is UTM zone 32, Datum WGS 84. (Upper left corner: E= -400000, N= 7500000).

Future processing

The processing system for SST has been finished and tested and the data from 2000 and 2001 has to be processed in the near future. Later processing of a number of Chlorophyll a maps will be performed.

Task 3.3 Climatic forcing and biological structure in lakes

The newly appointed PhD-student in Physical Limnology will be working with an investigation of climatic effects on the ecology of Danish lakes based on the available regional model output data and new model data with higher spatial resolution. Furthermore, an investigation of feasibility and usefulness of a possible coupling of the regional model with a lake model will be performed.

DMI activities have included the delivery of measured temperature data from North Zealand for an ongoing investigation described below:

Temperature dependence of net ecosystem production

A sub-project at FBL

Background:

Production and transformation of organic matter are generally found to be temperature dependent processes. A rise in water temperature is expected to increase the rate of primary production as well as the microbial activity in aquatic ecosystems. The question remains however, whether oxygen producing and consuming processes will be stimulated similarly. It has been suggested that microbial activity is stimulated more by increasing temperature than primary production. Substrate

availability may however, impede the temperature dependence of both primary - and bacterial production.

The main objective of this study is to examine basic relations between temperature and rates of primary production and system respiration. As a part of this we want to investigate the extent to which temperature controls the seasonal changes in phytoplankton production and transformation of organic material, and determine at what time of the year will a rise in temperature have the greatest impact.

As a baseline, dissolved oxygen data will be used to calculate primary production, respiration and NEP in Frederiksborg Slotssø, a shallow eutrophic lake. Seasonal variations in these parameters will be related to environmental factors (temperature, irradiance, nutrients) and biological pools (phytoplankton and bacterial biomass). High frequent measurements of temperature (air and water), irradiance (above and below surface), O₂ and wind speed will be collected from a monitoring buoy

A factorial laboratory experiment will be conducted on water from Frederiksborg Slotssø. The experiment will test the effect of increasing temperature and substrate (inorganic nutrients and glucose) availability on rates of primary and bacterial production. Furthermore, temperature optimum for rates of primary and bacterial production will be determined using a temperature bench.

Time schedule:

The monitoring buoy has been launched in May 2003 and will be operated for one year. Through out this period, frequent (every week) sampling of organic pools and nutrients will be conducted. Laboratory experiments are intended to be conducted 7 times within this period, starting May 2003.

Work package 3.4: Dynamics of biological systems along the thermocline

Participants DFU, AU, DHI, DMI

Within this work package we have conducted 1 cruise on board the RV DANA to the Dogger Bank in August 2002. Hydrographic as well as biological data was gathered along 5, 120 km long transects perpendicular to the Dogger Bank bottom front over a 10 day period. This is part of a campaign sponsored by DFU and in collaboration with AU to build up a time series of the physical and biological parameters in the central North Sea in summer. A similar cruise is planned for 2003. It is hypothesised that subsurface production along the flanks of the Dogger Bank lends significantly to the annual primary production of the area (Richardson et al. 2000), and it is the objective of this section to determine

1. the physical processes that control the 1° production, and
2. how expected climate change will affect the timing, duration strength and location of production cycles.

The results from the 2002 cruise are currently being written up in 3 manuscripts. The first concerns the observed photosynthetic state of the subsurface chlorophyll peak (*Katherine should have a few sentences about this*) revealed by the fast tracker (Richardson and Visser). A second manuscript concerns an inter-comparison of the bio-physical state of the Dogger Bank front over the last 10 years of observations (Visser and Richardson). A final manuscript, that is at an advanced stage

concerns an analytic model of the cross frontal circulation along the Dogger Bank summer front, and a comparison with the processes expected to supply nutrients across the thermocline (Visser). This latter allows heuristic climate scenarios to be tested. For instance, a 2°C warming of winter temperatures will decrease cross frontal summer circulation by about 40%, thus reducing the potential new 1° production fuelled during the summer. In the coming year, the dynamics of these processes will be studied using more sophisticated numerical models forced by weather (wind, air temperature, solar radiation) time series under different climate change scenarios.

WP4. Influence of temperature and nutrients on biological structures and processes: an experimental approach.

This workpackage covers a number of experiments focusing on the impact of changing temperatures on trophic structure and dynamics and nutrient cycling in both lakes and marine areas. The most pronounced climate changes are predicted during winter. It is hypothesised that these changes will have cascading effects on the structure and function of the food web also during summer. A multi-faceted approach ranging from small scale laboratory experiments to *in situ* enclosure studies and intensive *in situ* measurements under natural winter conditions will be used.

4.1 Mesocosms experiments in Lemming

Mesocosm experiments will be conducted to study the role of interactions between simulated climate warming and eutrophication for shallow lake functioning. The experiments consist of 24 enclosures (2-m diameter) in which flow-through heated systems (electric power) will be used to mimic the predicted seasonal variation in temperature for 2071-2100 in Denmark. The IPCC A2 scenario and A2+50%, respectively, downgraded to local Danish level by the Danish Meteorological Institute (DMI), will be employed. And a set act as control. The experiment is conducted by the National Environmental Research Institute (NERI) and the universities of Aarhus and Copenhagen in co-operation. The temperature will be regulated automatically and is expected to deviate at maximum 0.3°C. Half of the enclosures will be subject to high nutrient concentrations mimicking a turbid shallow lake (250 µg TP l⁻¹), while the other half will receive a low input (25 µg TP l⁻¹, clear water). Fish (male three-spined-stickleback *Gasterosteus aculeatus*) will be added to all enclosures: two to the low TP treatments and 12 individuals to the high TP treatments. All enclosures (1 fish x 2 nutrients x 3 temperatures x 4 replicates) will include sediment from many lakes to assure plant establishment and a mixed plankton inoculum from many lakes.

Hypotheses to be tested

We expect:

- higher internal P-loading - lower net retention of P;
- lower N loss in the turbid state and higher loss in the clear state;
- higher risk of dominance by filamentous algae in the ponds in summer and better survival of macrophytes during winter (if ice cover occurs naturally for prolonged periods during the study period);
- higher phytoplankton biomass and more cyanobacteria/green algae in the turbid ponds - higher risk of clear ponds to become turbid during summer;
- more benthic grazers in the clear state;
- reduced top-down control on algae in turbid ponds, as we expect comparatively higher production of phytoplankton than of grazers and less benthic facilitation of grazers. Higher top-down control in the clear state for several reasons: more plants, more refuges for grazers, higher benthic facilitation, higher growth and abundance of large grazers like snails.

Strategy

- Short-term effect of warming (1 month before to 2 months after);

- “longer term effects” (≥ 1.5 year);
Recovery after termination of heating (several months).

The study includes:

- nutrient and carbon mass balances, sediment-water exchange;
- community production and respiration (oxygen and pH probes, corrected for exchange at the air-water interface);
- community structure in the pelagic, macrophytes and sediment;
- production of selected functional groups;
- stable isotopes (including addition of ^{15}N the second year);
- benthic-pelagic, top-down versus bottom-up, facilitation;
- Genetic analyses of *Daphnia*;
- *Daphnia*-parasite interactions.

Status

The enclosures were established in the winter 2002-2003 and run well. We have some minor problems with the flow, but expect them to be solved soon. Nutrients were added on May 15, fish shall be added on June 1. In June, heating of equipment and oxygen/pH probes and data storing will be tested. We expect to be ready to start the heating system, as planned, on September 1.

Task 4.3: Light, temperature and marine microbial food webs

Ongoing activities

DHI has participated in the mesocosm experiment with temperature manipulations carried out during Jan - Feb 2003. DHI was responsible for measuring the response in phytoplankton and bacterioplankton to changing temperature conditions.

Focus next year

Update temperature relation for biological processes (nitrification, denitrification ...) according to findings of the experiments performed in this WP.

Task 4.4: Cycling of C, N and P in sediments

The model set up for Ringkøbing Fjord (WP2) include the following improvements to the existing model:

A description of fine sediment transport and processes for P adsorption/desorption to the fine sediment.

A description of phytobenthic biomass and production.

Nutrient metabolism and temperature models

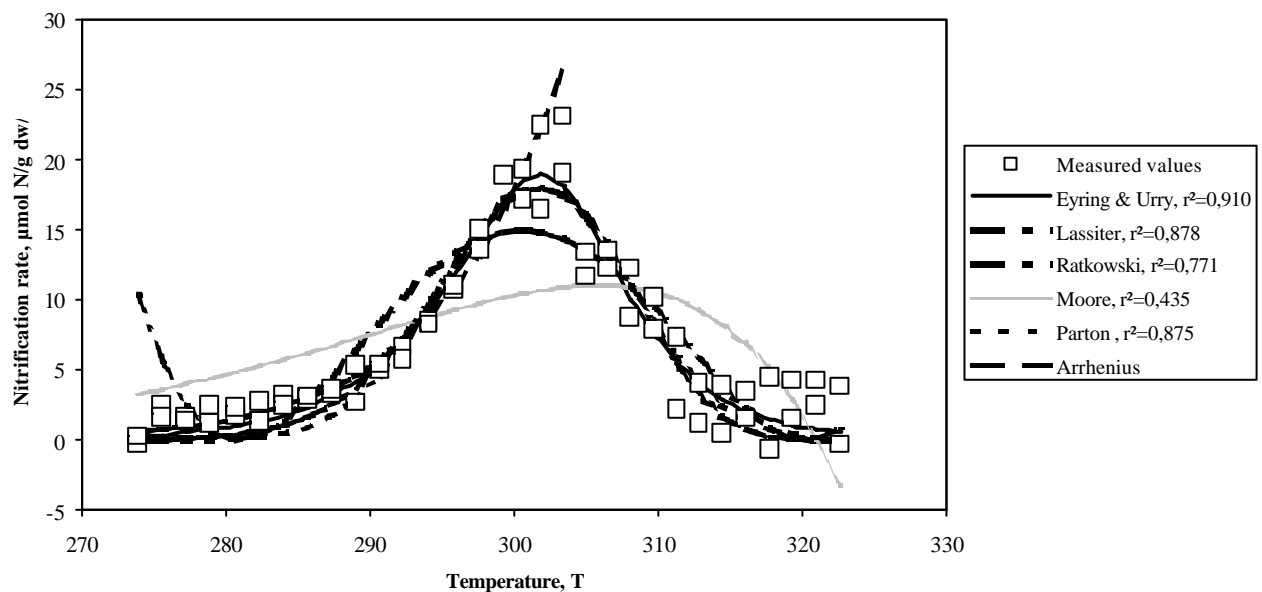
Sensitivity analyses on ecosystem models have documented the importance of correct formulation of the temperature influence on the processes consisting the ecosystems. The temperature models applied for the bio-geochemical processes range from simple, linear models over exponential models as the Van't Hoff-Arrhenius expressions to unimodal models with minimum, optimum and maximum temperatures. In the CONWOY-project are climate scenarios predicting elevated winter

and summer temperatures bringing focus to correct description of temperature dependence in the low end (0-5)^oC and in the high end (20-30 ^oC)

Nitrogen and phosphorus mineralisation, nitrification and denitrification are key processes in nutrient metabolism in freshwater and marine ecosystems. We have studied these processes in surface sediment from Frederiksborg Castle lake in a temperature gradient block made of solid aluminium with cooling down to 0^oC from a cooling bath in one end and heating to 50^oC from a heating bath in the other end. 124 holes in the block allowed us to run 4 replicates at 31 equidistant temperatures over the temperature range 0 - 50^oC. Initially, half saturation constants have been determined for both nitrogen and carbon limitation of nitrification and denitrification for the design of non-substrate limited experiments. For nitrification a thermodynamically based model with enthalpy and entropy as constants appeared to give the best fit over the entire temperature range (see Figure).

Acclimatisation is rarely seen as a part of ecosystem models although it is a well-known process. To study this we use another temperature gradient block allowing us to acclimatise at 8 temperatures over periods of months. Preliminary results suggest that optimum temperature for denitrification increases from 29 to 34^oC when acclimatisation temperature increases from 5 ^oC to 30^oC after 2-4 weeks acclimatisation. Experiments have been done with blocking of cell growth by addition of chloramphenicol and blocking of nitrification with chlorate or nitrapyrin (N-serve) to ensure the correct interpretation of changes in substrate.

Nitrification - measured data and various models



Plan for next year

Acclimatisation experiments for nitrification will be continued and temperature models including acclimatisation will be developed. The models will be applied on the fjord models (Ringkøbing as the first) in collaboration with DHI under WP 6 and later introduced into the "Farvandsmodel". A validation of the model will be done on monthly samples of sediments and water from the experimental set up in Lemming when the heating starts in August.

Task 4.5. Temperature influence on metabolism, growth and distribution of macrophytes in streams

Main research goals:

- To evaluate the importance of temperature for the distribution and seasonal development of macrophytes in streams
- To determine the influence of temperature on morphology, allocation, metabolism and growth on submerged stream macrophytes
- To determine the influence of temperature on light-photosynthesis relationships of individuals and communities of selected macrophyte species.

The first year (June 2003-June 2004):

1. Comparative analysis of temperature influence (10-25°C) on photosynthesis and respiration of macrophyte species from stream localities of different temperature regimes.
2. Growth, morphology and allocation patterns across a temperature range of three species of macrophytes predominantly associated with low (*Callitriche platycarpa/cophocarpa*), intermediate (*Ranunculus peltatus*) and high (*Potamogeton perfoliatus*) temperatures in nature.
3. Photosynthesis-light relationships for individuals and communities of three macrophyte species (ad 2) acclimated to different temperatures across a natural temperature range (ad 1).

The second year (June 2004-June 2005):

4. Continuation of broad-scale comparative analysis (ad 1) and detailed analysis for selected species (ad 2-3).
5. Coupling between macrophyte species distribution in relation to temperature regimes at 200 sites in 44 Danish streams and experimentally determined optimum temperatures for growth and metabolism of selected species.
6. Broad-scale analysis of geographic and seasonal distribution and abundance patterns in relation to field temperatures and established temperature optimum ranges of selected macrophyte species.

WP 5: Prognoses and simulations of aquatic ecosystems in a climate change perspective

This workpackage will combine the results from the other WPs relating historical, experimental and model simulations to reach a better understanding of possible ecological climate change consequences. The overall intention is to provide examples of cause and effect related to the main topics concerning hydrodynamics in freshwater and marine systems, transport of matter from land to the sea, as well as for key biological and ecological processes in Danish aquatic environments.

Task 5.1: Improve the algorithms for climate and ecosystem models

Ongoing activities

DHI has initiated work on improving existing algorithms with respect to algae developing a whole new description of 3 different algae types including flagellates, diatoms and blue-green algae. This new description now includes 22 components.

Focus next year

Hold a workshop to decide relevant scenarios to be run by the various models for the remainder of the project.

Test the validity of the new model, split organic matter into DOM, DON, DOP, include zooplankton and bacteria to improve a better description of selected areas.

Dissemination:

The following contributions have partly or fully been supported by CONWOY resources. Disseminations with CONWOY support have to be acknowledged by reference to SNF No. 2052-01-0034

Papers in refereed journals:

Brander, K. M., G. Blom, M. F. Borges, K. Erzini, G. Henderson, B. R. MacKenzie, H. Mendes, A. M. P. Santos, and P. Toresen. 2003. Changes in fish distribution in the eastern North Atlantic: are we seeing a coherent response to changing temperature? ICES J. Mar. Sci. (in press).

MacKenzie, B. R., and F. W. Köster. 2003. Fish production and climate: sprat in the Baltic Sea. Ecology (submitted).

Christoffersen, E. Jeppesen, P.H. Enckell & D. Block. 2003: Five Faroese lakes. Physico-chemical and biological aspects. *Annales Societatis Færoensis Supplementum XXXVI*: 1-139.

De Eyto, E., K. Irvine, C. Bareiss, E. Gross, S. Cerbin, W. van den Bund, F. G. Criada, M. Gyllström, E. Jeppesen, R. Kornijow, M.R. Miracle, M. Nykanen, J. Salujõe & D. Stephens, 2003: The distribution of chydorids (Branchiopoda, Anomopoda) in European shallow lakes. – *Arch. Hydrobiol.* 156: 181-202.

Jeppesen, E., J.P. Jensen & M. Søndergaard, 2003: Climatic warming and regime shifts in lake food webs - some comments. – *Limnol. Oceanogr* 48: 1346-1349.

Liboriussen, L. & E. Jeppesen, 2003: Comparison of the seasonal production of benthic, periphytic and pelagic microalgae communities in a clearwater and a turbid shallow lake. – *Freshwat. Biol.* 48: 418-431.

Bradshaw, E., N.J. Anderson, J.P. Jensen & E. Jeppesen, 2002: Phosphorus dynamics in Danish lakes and the implications for diatom ecology and palaeoecology. – *Freshwat. Biol.* 47: 1963-1975.

Book chapters:

Jeppesen, E., M. Søndergaard, J.P. Jensen & T. Lauridsen, 2003: Chapter 5.1 “Restoration of eutrophic lakes: a global perspective”. In: M. Kumagai & W.F. Vincent (Eds.), *Freshwater Management – Global Versus Local Perspectives*. Springer, Tokyo: 135-152.

Papers in preparation:

Visser, A.W., Richardson, K. The effect of tidal stage, wind forcing and isolation on the structure and productivity of the Dogger bank front in summer. *in preparation*

Visser, A.W. Cross frontal circulation and primary production: a diagnostic model for the Dogger Bank front in summer. *in preparation*. To be submitted to *J Mar Syst*.

Other scientific reports :

MacKenzie, B. R., K. Awebro, M. Bager, P. Holm, J. Lajus, A. Must, H. Ojaveer, B. Poulsen, and D. Uzars. 2002. Baltic Sea fisheries in previous centuries: development of catch data series and preliminary interpretations of causes of fluctuations. ICES CM 2002/L:02.

Popular science magazines, journals or newspapers:

Dansk Fiskeritidende (Danish Fishermens' Association newspaper) May 1, 2003. Interview with Brian MacKenzie (DIFRES) regarding North Sea fish communities and climate change.

Holm, P. and B. R. MacKenzie. 2003. Østersøens historiske fiskebestande – hvor mange fisk var der i gamle dage? Fisk og Hav 55: 4-10.

Søndergaard, M. Miljøforskning i medvind. Pressemøde, juni 2002.

Oral/Poster contributions

Edelvang, Karen, Anders Erichsen, Kim Gustavson og Karl Iver Dahl-Madsen. 2002. Modelling af de økologiske konsekvenser af vejr- og klimaforandringer i de danske farvande: Præsentation af et koncept baseret på Farvandsmodellen. Præsentation ved DMUs Natur- og Miljøforskningskonference 22. - 23. august 2002 i København.

Edelvang, K. 2002. Modelling sediment and water movement: 2D and 3D cohesive sediment transport models. STRAEE workshop on European coastal research. Ferrara from 9 to 14 of September 2002 arranged by DIPARTIMENTO DI SCIENZE DELLA TERRA UNIVERSITA DI FERRARA.

Søndergaard, M. 2002. Konsekvenser af vejr- og klimaforandringer for vandmiljøet. Et projekt under initiativet: Større Tværgående Forskergrupper. Præsentation ved DMUs Natur- og Miljøforskningskonference 22. - 23. august 2002 i København.

Søndergaard, M. 2002. Dänische Initiative zur Klimafolgenforschung aquatischer Systeme (CONWOY). Deutsche Forschungsgemeinschaft-Rundgespräch, 15 – 17 September, Berlin.

Teaching etc.

By the examinations in the course "Environmental management and technology" at the University of Copenhagen one of the questions we passed to the students was to calculate the losses of nitrogen to the aquatic environment in a climate scenario with 20% increase in runoff and an increase in temperature of 4°C. The correct result was a decreased loss of nitrogen to the marine environment since increased denitrification more than balanced the increased outwash from farmlands.