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REPORT OF THE

WORKING GROUP ON SHELF SEAS OCEANOGRAPHY

Barcelona, Spain
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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 WELCOME AND OPENING

Dr Elisa Berdalet welcomed the Working Group on Shelf Seas Oceanography (WGSSO) on the behalf of Institut de Ciences del Mar. The meeting is chaired by Björn Sjöberg from the Swedish Meteorological and Hydrological Institute. The list of participants is given in Appendix I.

2 APPOINTMENT OF RAPPORTEUR

WGSSO will report to ACME before its May/June 2000 meeting and to the Oceanography Committee at the 2000 Annual Science Conference. François Saucier is elected as rapporteur.

3 APPROVAL OF THE AGENDA

The Chair presented the Terms of Reference (TORs) as described in Appendix II from the 1999 Meeting Resolution 2C05 from the Oceanography Committee. The agenda is presented by the Chair (Appendix III) and is approved.

During the second and third days of the meeting, the WGSSO joins the Working Group on Harmful Algal Bloom Dynamics (WGHABD), chaired by Dr Kaisa Kononen, to address the terms of reference *d* and *e*. The list of the participants from WGHABD is given in Appendix I.

4 INFORMATION FROM ICES

A new formal procedure is adopted in the definition of the Terms of Reference. There have been some problems in the past concluding TORS; some reoccur every year without a clear end or definite objective. The WG should now try to associate specific goals and deadlines for TORs, and move the work on specific TORs into sub-groups when possible. The Chair recalls that the Terms of reference *a* and *c* must be finalised with this year. He also suggested that TOR *f* be on the agenda for the last time this year since there is an ICES/IOC GOOS Steering Group now in place.

The Chair informed the group of a letter to the WG issued from the Oceanography Committee (Harald Loeng) dated 13 March 2000. This letter requested that the WG reviewed its objectives and purpose with the goal of addressing the needs, benefits and disadvantages of merging WGs and forming new ones.

The letter as well as the enclosed ICES Scientific objectives and activities were analysed. The following was noted:

- there are difficulties in communicating among WGs;
- there is a need for joint sessions and inter-annual joint seminars, but the WG deplores that it is hard to find additional funding for these;
- the WG and ICES should continue focussing on human impacts on the environment, and sustainable growth;
- the WG feels it needs to continue advising management toward the better use of the resources;
- the WG agrees with the need for more progressive themes that are topic-oriented rather than disciplinary;
- the WG feels it must focus more on themes that are generic to shelf seas and not area-specific (e.g., Nordic Seas);
- the WG needs to define TORs with better-defined objectives and a clear end;
- one new working group could be created to address one TOR and be dismantled after reaching the objectives;
- the WG recognised that its basic agenda has focussed on ecosystem modelling, monitoring and operational oceanography over the past few years; Prior to this, the work was more focussed on co-ordination in ICES;
- The basic objective of the WG remains unique, highly relevant to the ICES Strategic Plan, and stronger than before, that is to evaluate and promote ecosystem modelling and analyses;
- The WG lacks specialists in the areas of chemistry and biology.

The WG agreed that it needs to blend modellers and observers, disciplines, and to focus on bio-geo-chemical or ecosystem modelling and analyses. It is a unique ICES focus on the development of systems with predictive potential that involve physics, biology, chemistry, and advanced techniques such as data assimilation.

The WG recommends that the WGSSO aims the following new **scientific objective:**

- *To critically review advances of monitoring and modelling systems to describe, understand and quantify the state and variability of the shelf seas physical, biological and chemical processes;*
- *To promote the capability to hindcast, nowcast and forecast natural and anthropogenic impacts, and to promote the capability of observing systems in providing relevant information on key processes and for the initialisation, forcing and validation of modelling systems.*

In order to reach these objectives, the WG recommends the following **Strategy:**

- *Build on analyses of case studies on specific topics (e.g., harmful algal blooms), or of theories and methods (e.g., data assimilation and model parameterisation), in shelf seas ecosystem dynamic;*
- *Identify a key subject for the annual meeting and, as appropriate, review key papers and invite key specialists, or initiate joint sessions with other ICES Working Groups;*
- *Produce co-authored reviews.*

In addition to lessen some of the difficulties listed above, the new objective along with the strategy insure the implementation of the ICES Scientific Objectives from the ICES Strategic Plan, in particular under terms relating operational oceanography, recruitment studies, contaminant fluxes, eutrophication, GOOS, and scenarios for development.

A further analysis of the WG structure is found in Section 13 below.

5 ASSESSMENT OF NUTRIENT MONITORING PROGRAMMES (TERM OF REFERENCE A)

The WG discussed the difficulties in assessing the quality of nutrient monitoring programmes. The statistical approaches vary widely. The WG has previously studied several monitoring programmes, as well as reviews of, from e.g., Canada, Norway, Sweden and Germany. The WG agreed on the following remarks and recommendations - The programmes should focus on fluxes rather than levels, the sources and sinks, and on estimating the variability in frequencies and scales. -The programmes should, increasingly, use models as a support when designing programmes but also when interpreting the results.

- The programmes should in general favour high frequent measurements before high spatial resolution.

- The WG felt that it is important to measure nutrients. Long time series have sometime shown trends (e.g., in the Baltic), as related to human activities (e.g., sewage), periods of no biological activities, etc. However, it is important to correctly sample and target precise indices such as winter or yearly-averaged values. The inorganic components need be monitored as well. The Baltic Sea is rather well mixed laterally in wintertime, and good relationships exist between oxygen consumption and organic nutrients in coastal waters.

The WG recognise that there essentially can be two different kind of strategies for a monitoring programme; to detect trends against a background of natural variations and/ or to classify the environmental state by using prescribed classes (i.e., contaminated or not contaminated). (ACME 1998 Sections 4.7.1 and 4.8 and ACME 1999 Section 5.6.1). Which strategy to choose is related to existing knowledge, secondary aims etc.

When designing a monitoring program, independent of the strategy chosen, one has to:

- Specify the aim (identify relevant environmental threats, for example eutrophication, define requirements (how small a trend should the programme be able to detect)
- Identify relevant variables (nutrient content, type of annual value etc..) from knowledge about the general conditions in the area of concern (temporal and spatial variability etc. ,)
- Evaluate their usefulness (detectable trend) in relation to expected change. Specify requirements and strategy (power, correlation and use of possible co-variables (Hirch, R. M. & Slack, J. R., 1984. A Nonparametric Trend Test for Seasonal Data with Serial Dependence, Water Resources Research, 20(6), p. 727-732.Kendall, Sir M. & Ord, J. K., 1990. Time series (3rd edition), Edward Arnold, London). The WG recognise the possible use of so called fuzzy logic in developing management tools. (This was very well illustrated during the joint meeting with WGHABD were fuzzy logic approach was presented)). (ACME 1998, Sections 4.7.1 and 4.8 and ACME 1999 Section 5.6.1).

6 TIME SERIES FROM THE SKAGERRAK (TERM OF REFERENCE C)

Long term climate monitoring by the Institute of Marine Research in Norway between Denmark and Norway clearly demonstrates that the 1990's at all depths were roughly 1 K warmer than the previous 50 years. This anomaly started in 1988/89 and is highly coupled to increased westerly wind events and, through the use of numerical modelling, to a corresponding increase of about 30% in the inflow of Atlantic waters to the northern North Sea. This inflow is clearly coupled to fish migration, and there are indications that this climatic anomaly has caused significant changes in the ecosystem dynamics relevant for fisheries recruitment in the North Sea (Svendsen, pers. comm.).

Compared with the period 1971 to 1999, the North Sea SST in the year 1999 was on the second place after the year 1990. The nineties contain six of the seven warmest years since 1971. The whole year 1999 was warmer than normal, however, the SST anomaly – compared with the average 1971 to 1990 – were small (about 0.5 K) until June. The following strong SST increase in July (about 3.2 K) caused an area mean temperature of the North Sea of 15.5 ^{o}C, which caused the second warmest month after 1997.

Normally, the seasonal cooling starts in the North Sea in the second half of August. In 1999, the SST stagnated at high temperatures at about 16 ^{o}C until the end of September, 2 K above the long term mean in the North Sea and more than 3 K in the German Bight, set new records for September. This extreme warm anomaly of the whole North Sea decreased only slightly at the end of 1999.

It was reported from the time series in the Skagerrak area that both the surface as well as in the deeper part (about 300 m depth) showed a significant increase, or shift, in the water temperature during late 1980s, highly noticeable in winter and spring time with near 2 K increase, and small increase in the autumn. The WG noted that the winter and spring climate is most important to fisheries.

In summary, increased inflow of Atlantic water combined with a warm summer and autumn lead to temperatures above normal in the eastern Norwegian Sea, in the North Sea and in the Barents Sea in 1999. The central and western parts of the Norwegian Sea are dominated by relatively rich inflow of Arctic water with low temperatures and salinity.

The production of zooplankton was relatively low in the Barents Sea while is high in the central parts of the Norwegian Sea. The production of herring larvae seems to be average, the production of capelin larvae, however, at present seems to be very good. In the Skagerrak and along the coast the algae situation was normal in 1999 with only few blooms of harmful algae and algae toxins.

The marine environment is an important ecological factor that influences the biological condition of the ocean. Environmental variability and fluctuations in ocean climate have a strong impact on the distribution, growth and recruitment of fish. The North Sea fish stocks usually have the best conditions for feeding and produce the best year-classes in years with strong inflow of Atlantic water and high temperatures in the sea.

In the Atlantic water flowing into the Norwegian Sea through the Faroe – Shetland Channel the temperature has gradually increased since 1995. In 1999 the average temperature was about 0.4 ^{o}C above normal, which is the highest registered since the beginning of the 1980's. In the core of the Atlantic water off the Norwegian coast the temperature decreased to around normal in 1999. In the northwestern areas of the Norwegian Sea, Southwest form Svalbard, the temperature in the Atlantic water has been nearly normal since 1996. The warm summer and autumn of 1999 the led to abnormal high temperatures in the upper layer in the eastern and central parts of the Norwegian Sea north of Lofoten. The temperatures in the upper layers of the coastal water also stayed above normal. During the unusually warm autumn of 1999 the temperature reached up to 2 ^{o}C above normal for the season. In the deeper layers of the coastal water, the temperatures were 1 to 2 ^{o}C above the long-term normal in the coastal area between Lofoten and Finnmark. IN the central and western parts of the Norwegian Sea, a trend towards less saline water and lower temperatures has been observed over the past few years. This is due to the increased inflow of less saline Atlantic water from the Polar Sea via East-Icelandic Currents. The area is still dominated by Arctic water.

In the western and central parts of the Barents Sea, the temperature has gradually decreased after the warm period around 1990. From 1995 to the beginning of 1998 the temperatures were below the long-term average. During 1998 they gradually increased, and from October 1998 to January 1999, a marked increase took place in the western part of the Barents Sea. Throughout the spring and summer of 1999 the temperature decreased to about 0.3 ^{o}C above normal before it increased again during the autumn. At the turn of the year 1999/2000 the temperature had increased to 1.1 ^{o}C above the long-term average, the highest observed since 1983. In the central parts of the Barents Sea the temperature increased to around 0.5 ^{o}C above long-term normal in 1999, while it stayed 0.2 to 0.3 ^{o}C above normal in the southeast areas between the Kola peninsula and the Sem islands. During the winter 1999 and at the turn of the year 1999/2000 there were much less ice in the Barents Sea than in 1998. We expect the temperatures to stay above normal in the Barents Sea during the winter and spring 2000.

The temperature in the upper layers of the Skagerrak and in great parts of the North Sea stayed between 0.5 and 2.0 ^{o}C above long-term average during 1999. In the autumn 1999, the temperatures were particularly high because of the warmest autumn in 100 years. In the period after 1995 the temperature and the salinity have gradually increased in the layers nearer to the bottom in he northern parts of the North Sea and in the inflowing Atlantic water in the western part of the Norway Channel. The temperature was 0.6 to 0.8 ^{o}C above normal in 1999. IN the northwestern part of the North Sea one must get back to around 1990 to find temperatures at the water, the temperature in 1999 was the highest ever observed since measurements started in 1970.

The WG has asked that ICES produce an inventory of compiled data for the Skagerrak. There has been a shift in the ocean climate throughout the North Sea and the Northwest Atlantic, related both to the local weather and to remote events in the North Atlantic and Arctic oceans. Current monitoring should keep pace with these changes as no other direct evidence of such shift may be presented.

7 NEWS FROM THE SHELF SEAS

Gerd Becker. The Federal Maritime and Hydrographic Agency (Hamburg and Rostock) concentrates its activities mainly on monitoring and environmental investigations. Additionally several marine services are supplied. In 1999 a new WWW-service was installed (Baden & Meer under www.bsh.de). This daily several times updated information service for the German Bight and western Baltic contains actual measurements (SST, waves, sea level, meteorological parameters) and forecasts for the next 48 hours using all available information and the operational models of the BSH.

The monitoring on fixed positions in the North Sea (German Bight) and the western Baltic continued. Due to extreme weather conditions in 1999 several stations (e.g., LV "Elbe 1") were heavily damaged or destroyed.

As in 1998 a towfish (Delphin) survey in the North Sea was carried out in summer (RV Gauss, cruise 335). In total 2255 nautical miles have been towed with the Delphin and temperature, salinity, oxygen, turbidity and chlorophyll-a data between surface and about 100 m depths gained. In general the hydrographic situation of the North Sea in summer of 1999 regarding the temperature and salinity distribution as well as stratification was within the standard range of variability. The oxygen saturation in the water masses below the seasonal thermocline in the central North Sea and also the German Bight showed values between 70 and 80 percent.

A cruise to investigate the oceanographic conditions (currents, waves, resuspension/erosion) near the gas pipeline EUROPIPE I (54° 22’ N) was carried out from 15 June to 24 June 1999.

During November/December 1999 current meters (ADCP) and turbidity/fluorescence meters (BackScat I) were deployed in the mud-area southeast of Helgoland and in the deep hole south of Helgoland. CTD-observations (General Oceanics Mk IIIc with BackScat I) with multisampler employed on up-casts were carried out to calibrate the instruments and to obtain vertical profiles. Objective was research work on deposition and resuspension of suspended particulate matter in these areas during stormy events.

The synthesis and new conception of North Sea Research (SYCON), an interdisciplinary program supported by the German Ministry of Education, Science, Research and Technology continued. The central objective is a comprehensive inventory and critical evaluation of our present knowledge of the North Sea system. A preliminary list of special deficits in different disciplines has been summarised. The synthesis has to be finished within the year 2000. Now, the work focuses on the evaluation and understanding of key process complexes.

The scientific work of the centre of marine and climate research (ZMK) in the field of shelf sea research is mainly focused on deterministic and statistic modelling of shelf sea and shelf break processes, including sea ice development and convective processes. The basic tool for the deterministic modelling is the coupled ice/ocean model HAMSOM (Hamburg Shelf Sea Model; Harms, 1994; Schrum and Backhaus, 1999), which has been validated in detail with respect to modelling inter-annual variability (Schrum *et al.*, 2000). This model is used to study the influence of shelf sea dynamics on environmental processes in the frame of different national and international research projects, e.g., the influence of circulation and turbulence processes on *Calanus finmarchicus* (EU-TASC) and on fish recruitment (EU-STEREO) in the Greenland Sea, Iceland Sea, Norwegian Sea and the Northern North Sea. To investigate pollution pathways and sea ice drift, the model is applied to the Barents Sea/Kara Sea region (Harms, 1997; Harms and Karcher, 1999; national BMBF projects). Furthermore the HAMSOM is used to investigate the influence of climatic induced variability on shelf seas and to assess their role in the climate system (KLINO, national BMBF project, SFB 512, German Research Foundation, Schrum *et al.*, 2000). These investigations are focused on the Northwest European Shelf and on the Arctic Shelf region. Further regions of interest are the Caspian Sea and the Black Sea.

Literature

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Wolfgang Fennel. The first generation of the IOW-Ecosystem model, named ERGOM, was implemented in 1998/99. Based on the ocean model MOM2.3, the 10-component ecosystem model, with consistent forcing data including ambient input from rivers and the atmosphere, was run for 10 years 1980-1989. A standard run as well as scenarios for river load reduction and enhancement were carried out. This work is underway and will be developed further (e.g., within GLOBEC). The IOW is now migrating to the new ocean model version MOM3.0.

Several projects are currently running in the Baltic in the framework of BALTEX: (1) looking at inertial and internal wave forcing and propagation and their role in the generation of small-scale turbulence; (2) the propagation of salt water tongues in the entrance area, and (3) the mesoscale current patterns in the basins of the Baltic Proper and in particular the deep circulation in the Gotland basins.

The IMR in Norway (Einar Svendsen) is actively involved in developing a community model for algae in the North Sea.

8 JOINT SESSION WITH WGHABD (TERMS OF REFERENCE D AND E).

The WGSSO joined the WGHABD for a two-day joint session on the following terms of reference:

- *d.* assess current knowledge on the importance of physics in relation to harmful algal blooms as well as possible implications of modelling input on pelagic biological monitoring programmes (with WGHABD);
- *e.* compare model parameterisations for growth rates, nutrient uptake rates, nutrient limitation, predation rates, re-mineralisation rates and the physics of the turbulent fluxes and stresses (with WGHABD);

The session was comprised of an introduction, a series of scientific presentations, and a special session investigating two aspects: (1) The improvements in our understanding of HABs since the last joint session in Vigo, Spain, in 1994, and (2) The model parameters of relevance to modelling HABs. The following presents the agenda of the session.

- Welcome by Kaisa Kononen and Björn Sjöberg;
- Wolfgang Fennel, Introduction: Physics, models and harmful algal blooms;
- Percy Donaghay, The importance of microstructure, turbulence and mixing in relation to algal blooms;
- Patrick Gentien, On the importance of thin layers;
- Oleg Savchuk, Aspects of different bio-geo-chemical models as applied in the Baltic;
- Kai Myrberg, The role of atmospheric forcing for ocean model resolution in the Gulf of Finland;
- François Saucier, Ice-ocean modelling in the Gulf of St. Lawrence with applications to biology;
- Eleonor Marmefeldt, SCOBI-3D biogeochemical model;
- Einar Svendsen, NORWECOM – Norwegian Ecological Model System;

- Anouk Blauw, Modelling blue-green algae dynamics in Lake Ijssel: biomass and flotation;
- Donald M. Anderson, A coupled physical-biological model of toxic Alexendrium dynamics in the Gulf of Maine;
- Hermann-J. Lenhart, Effects of river nutrient load reductions on the eutrophication of the North Sea, simulated with ecosystem model ERSEM;
- Odd Lindahl, Changes in the plankton community passing a *Mytilus edulis* mussel bed;
- Juliette Fauchot, Modelling of HABs in the context of regional climate models;
- Kai Myrberg, Larval drift experiments in the Baltic sea, model results and measurements;
- Oleg Savchuk, Parameterisation of phytoplancton groups and communities in the Baltic sea biogeochemical models;
- Sub-group meetings: (1) Forward from the 1994 Joint Vigo meeting and (2) Parameterisation of HAB.

The abstracts made available by the authors are included in Appendix IV. The report from the sub-group meeting on HAB modelling parameters, led by F. Saucier, is presented in Appendix V.

9 REVIEW CURRENT DEVELOPMENTS IN OPERATIONAL OCEANOGRAPHY, ESPECIALLY REGIONAL GOOS PROJECTS (TERM OF REFERENCE F)

The term of reference was introduced and documented by Roald Seatre.

The Global Ocean Observing System (GOOS) is an international program preparing a permanent global framework of observations; modelling and analyses of ocean variables needed to support operational ocean services. GOOS is sponsored by several United Nations agencies. All the necessary information on the nature of GOOS, strategic guidance, principles and framework are reviewed in "The Global Ocean Observing System (GOOS) – Prospectus 1998" GOOS Publication No. 42.

EuroGOOS, the European Association for he GOOS was founded in 1994. EuroGOOS is a European regional component of GOOS, and consists presently of 28 national agencies working together to foster European participation in GOOS and the development of operational oceanography. EuroGOOS have established task teams for the following areas: Baltic, North West European Shelf, Atlantic, Arctic and the Mediterranean. EuroGOOS have initiated a number of development projects both technological and scientific, to promote operational oceanography in Europe.

The approach towards an operational system is most developed in the Baltic. The Baltic Operational Oceanographic System (BOOS) constitutes a close co-operation between national governmental agencies in the countries surrounding the Baltic Sea responsible for the collection of observations, model operations and production of forecasts, services and information for the marine industry, the public and other end users. BOOS is being built on existing systems and will develop mainly through commitments from the participating agencies. Already at present most of the components for an operational system are available within national or international programs. A BOOS plan 1999 – 2003 has been published (EuroGOOS, Publication No. 14, Jan 2000). The premier task for the period 1999-2003 is therefore to integrate the existing systems into a uniform entity in order to meet the users' demands for a high quality operational oceanographic service.

Within the ICES system GOOS was on the agenda for the first meeting of Advisory Committee on Marine Environment (ACME) in 1993 as well as on some of the subsequent ACME meetings. In 1997 ICES established a Steering Group on the Global Ocean Observing System (SGGOOS) with the TOR to "prepare an action plan for how ICES should take an active and leading role in the further development and implementation of GOOS at a North-Atlantic regional level." SGGOOS reported to the ASC in 1998 and one of its accepted recommendations was to organise an ICES – GOOS workshop as an important step towards meeting the ICES ambitions in relation to GOOS. The workshop took place in Bergen in March 1999 with the aim to propose a possible design for an ICES regional GOOS component and to develop a draft implementation plan for ICES-GOOS.

The workshop identified three main elements of an implementation plan for ICES-GOOS:

- The global and regional linkage. To encourage and improve the co-operation with IOC, EuroGOOS and other relevant GOOS regional programs,
- The ICES Ocean Observing System. An Atlantic component focusing on ocean climate consisting of an enhanced ICES standard section and station climate data base, and a climate summary publication such as the Ocean Climate Status Report as a cooperation between the ICES member states and EuroGOOS,

- A regional component for the North Sea. An ICES regional GOOS system on appropriate time scale for the North Sea focussing on ecosystem dynamics with special emphasis on the need for improving the management of fish stocks.

The workshop also proposed to offer the ICES International Bottom Trawl Survey (IBTS) in the North Sea as an ICES contribution to GOOS Initial Observing System (GOOS-IOC) and IOC later approved this.

In 1999 ICES decided that SGGOOS to be renamed the ICES-IOC Steering Group for GOOS with joint Chairs (R. Saetre, ICES, and M. Sinclair, IOC). This group was supposed to meet in Southampton 21 – 23 February 2000 to further develop the ICES-GOOS implementation plan described in the report from the 1999 WGSSO in Bergen. In order to facilitate more preparations the time for the meeting was postponed to 23 – 25 October 2000. The term of reference for the group is to:

a) Develop the ICES-GOOS Implementation plan described in the report of WKGOOS (CM 1999/C:14);
b) Advise and support the Secretariat on GOOS related matters;
c) Promote the role of ICES taking into accounts inputs from ICES Advisory and Scientific Committees;
d) Identify a program of workshops to facilitate the implementation of ICES-GOOS and to improve awareness of GOOS in ICES, including special sessions at the ICES Annual Science Conference;
e) Identify those IOC-GOOS design panels and committees of relevance to ICES-GOOS with the view to proposing the appropriate ICES representatives at these meetings, with the approval of the ICES Council, and to prepare the briefs for these representatives.

During it's meeting the WGSSO discussed the proposal of an ICES Ocean Observing System (I-OOS) and the establishment of a coordinated and harmonised observing network and design a system for operational oceanography on appropriate time scale for the North Sea. The WG recognises that many countries run operational models and observing systems. The WGSSO concluded this discussion with the following recommendation:

> The WGSSO feels a need for co-ordination and harmonisation of the national monitoring activities in the North Sea. Therefore, the WG strongly supports the proposal from the SGGGOS to establish a regional ICES-GOOS system focussing on seasonal to decadal time scales for this area. In the future work with ICES-GOOS all relevant parties should be included, such as EuroGOOS, OSPAR, and EEA in addition to the governmental institutes in the North Sea countries, which have the responsibility of the long-term environmental monitoring of the area. The WGSSO recommends further support for a scientific program to investigate the feasibility of quantifying the inflows to the North Sea.

Canada has submitted a statement at the last IOC meeting in Paris (see Appendix VI). Mike Sinclair plays a leading role in LMR GOOS, and has just completed a WS in March 2000, mainly to develop a template for LMR-GOOS in Canada, which may be used as a template elsewhere also. Savi Narayanan represents Canada at the I-GOOS, and in that capacity will be attending the ICES-GOOS meeting scheduled for October 2000.

10 TRANSPORT PROCESSES INFLUENCING TRACE METAL DISTRIBUTIONS IN ESTUARIES (TOR G)

This term of reference was added to the TOR by the ACME on a suggestion from MCWG. Feeling the need for additional information on what was expected from WGSSO the Chair contacted the ACME and was directed to MCWG who's chairmen refereed to Dr Chiffoleau, a member of WGMC, who originally had formulated the problem. The Chair of the WGSSO wrote a letter to Dr Chiffoleau in order to obtain more details on the specific issues that needed to be dealt with. Unfortunately, no answer was received. Under these circumstances, lacking expertise and information about the problem in question, the WG felt that the question was so broad and ill-focussed that it could not engage in discussing the problem and concluded that this was indeed a formidable problem because of the lack of knowledge about basic processes for sinking, biological loops, etc. in estuaries.

11 USE OF CHEMICAL DATA IN NUMERICAL MODELLING (TOR H)

This term of reference was put forward to the WGSSO from the Marine Chemistry Working Group through ACME. The WGSSO finds it difficult to provide a general review on the topic, and that the question should be more directed at specific ecosystem problems. However, given more time and discussions within and among the WGs, the subject was deemed an important one.

Coupled physical-chemical-biological models are increasingly being used for environmental research and management. The best progress is made in relation to eutrophication issues and transports of nutrients. However, there are still important lacks of knowledge on processes, e.g., in relation to harmful algal blooms, or of the sources, e.g., rivers, atmosphere, diffuse.

The report from OSPAR/ASMO workshop on eutrophication modelling, held at The Hague in 1997, gives a review on the status of such modelling. However, some improvements have been made since then.

The report from OSPAR/ASMO workshop held on the modelling of contaminants, held at The Hague in 1997, concludes that there is a great lack of bio-chemical process knowledge with respect to individual heavy metals organic contaminants and radio nuclides. The dispersion of such contaminant is being modelled but there exists a lack of relevant source data, and data for validating results, particularly through the water column.

The WGSSO agrees with the MCWG to "continue the communication between modellers and chemical oceanographers", but, when relevant, biological oceanographers need also be included. The WG also agrees that we need to "define more clearly the problems for what models are needed for and to define clearly the data needs in relation to space and time". In this respect, the WG invites biological and chemical oceanographers at the next year's annual WGSSO meeting to improve communication on this issue and to define the most urgent problems where models can contribute significantly (see TORs).

12 DATA PRODUCTS AND SUMMARIES VIA THE ICES WEBSITE (TOR I)

The WG understands that ICES must increase its presence on Internet. Many ICES-related activities and web sites are being deployed among the member countries (e.g., see Section 7, News from the shelf seas), but the links with ICES are not always clear.

The WGSSO recommends that ICES establish a web site entitled " Environmental Status Report of ICES ". This web site should give some general information on ICES, environmental monitoring, include the ICES Ocean Climate Status Report, and other ICES data collection programmes, such as IBTS. The web site should further have direct links and guidance to the national websites presenting data and products from the national monitoring activities.

13 REVIEW OF THE 1999 OCEANOGRAPHY COMMITTEE WORKING GROUP REPORTS (TOR J)

The WG examined its links with other WGs. For Seabird Ecology and Recruitment Processes, the WG felt that there were no more need for coordination. With respect to HABD, the WG felt that the current level of coordination is useful, that more work need be done with scenarios for management, and that the WG should keep abreast of the development in modelling HABs.

The WG feels it can contribute more than at present and expand on the ICES Ocean Climate Status Report, and that such report should perhaps be issued from the Oceanography Committee and not the Oceanic Hydrography Working Group. Indeed much of the material currently produced in the report is highly relevant to shelf seas.

The WG discussed the interest of examining the relations between regional and global GOOS.

The WG discussed the pertinence of having a TOR on new technologies for the WGOH.

Regarding data management, the WG concluded that (1) The ICES services for data are recognised for their quality; (2) It is still very difficult to find more than roughly 25% of data through ICES, and (3) It is the member countries delegates' responsibilities to make sure their country contributes. It is proposed that the WG looks more closely into the marine data management WG report and examines how it can help through specific items.

Regarding the WGs on Zooplankton and Phytoplankton Ecology, the WG recommends a joint workshop in 2001 on coupled bio-physical modelling.

14 INITIALISATION AND VALIDATION OF NUMERICAL MODELS (TOR B)

Gerd Becker announces that a report was prepared for T-S data in grid forms for the North Sea, at 10 km horizontal resolution and 10 m in the vertical. Similar reports have been published for ice and T-S conditions for the Canadian East

Coast (Drinkwater *et al.*, 1999, Petrie *et al.*, 1996ab, Tang, 1997). These data sets are being used in many agencies to initialise and validate numerical models.

Björn Sjobërg introduces the WG to a difficult validation problem regarding the capability to correctly model the changes in circulation anticipated from the construction of a new bridge. Given similar sets of calibration and validation data, and similar physical parameters, a model was calibrated, using only three variable parameters, and evaluated on the basis of correlation coefficients calculated over a validation period.

The WG suggested that the correlation coefficient is not always the correct way to measure the fit or misfit. In particular, it is important to normalise the error by the variance of the data in order to get a meaningful figure. Also, it was noted that although the correlation between the observed and modelled currents is high on average, it is significantly poorer if estimated only for the extreme events, or during periods of maximum currents. Indeed such comparison suggests that the model underestimate significantly the peak values in the current. This casts some doubts on the capability of the model to reproduce extreme events, and the WG suggests that more appropriate statistics be used concerning these extreme observed and case scenarios.

15 ELECTION OF A NEW CHAIR

Björn Sjöberg presented his resignation as the Chair of the Working Group on Shelf Seas Oceanography, a position he held since 1998. The participants noted this and also the great contributions made by the Chair during the past two years.

The Chair proposed that the WG recommend François J. Saucier for the next term in office as the Chair of the WGSSO. This proposal was endorsed unanimously.

16 PLACE, DATE AND TOPIC OF NEXT MEETING

The WG suggest that a meeting will be held next year discussing the items (i)-(v) below. The WG further suggest that the meeting, if possible, will be arranged as a back to back meeting with WGPE discussing item (i) and (ii) leaving the place of the meeting open for now.

The WG proposed that the WGSSO meet during 2001 to:

(i) Develop proposals for a workshop on biophysical ecosystem modelling with emphasis on the importance of anthropogenic forcing in plankton ecosystem change.

(ii) Prepare for a joint session with WGPE and WGZE in 2001 on the development of improved understanding of phytoplankton-zooplankton interaction. The Chair will contact the other Working Groups to arrange for the place and date of the next meeting in this context.

(iii) Review the shortcomings of the data management within ICES, by examining the latest reports from MDM, in relation to the needs within current shelf sea research.

(iv) Prepare a review of the current status of regional operational oceanographic systems (e.g., GOOS) for the North Sea and the Canadian East Coast and their implementation plans.

(v) The WG recommends that a major question of interest to Marine Chemistry and SSO be formulated in order to promote the better use of modelling and observing systems in this field.

(vi) Review the advances in the capability to model HABs with support of an invited specialist in biological modelling

17 CLOSING OF THE MEETING

APPENDIX I – LIST OF PARTICIPANTS TO THE WGSSO

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List of participants from the WGHABD in the joint session with WGSSO

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APPENDIX II – TERMS OF REFERENCE

Following the meeting resolution 2C05 from the Oceanography Committee, the Working Group on Shelf Seas Oceanography [WGSSO] will meet in Barcelona, Spain, from 20–25 March 2000 to:

a) complete the assessment of the relevance and the effectiveness of nutrient monitoring programmes, especially in relation to statistical aspects, such as statistical power, statistical significance and statistical independence;

b) review current methods and principles for initialisation and validation of numerical models;

c) finalise the compilation, and assess the value of, available time series from the Skagerrak;

d) assess current knowledge on the importance of physics in relation to harmful algal blooms as well as possible implications of modelling input on pelagic biological monitoring programmes (with WGHABD);

e) compare model parameterisations for growth rates, nutrient uptake rates, nutrient limitation, predation rates, re-mineralisation rates and the physics of the turbulent fluxes and stresses (with WGHABD);

f) review current developments in operational oceanography, especially regional GOOS projects;

g) elucidate physical transport processes influencing trace metal distributions in estuaries in collaboration with MCWG;

h) review the use of chemical data in numerical modelling and the possible implications for future work in modelling and in field sampling programmes, including the preparation of a workshop or joint session with the MCWG in 2001;

i) consider, and where feasible, develop data products and summaries that can be provided on a routine basis to the ICES community via the ICES website;

j) examine the 1999 Oceanography Committee Working Group reports and the Terms of Reference for 2000 to identify where inter-group input could be provided or required with the view to formulating key questions requiring inter-disciplinary dialogue during concurrent meetings of the Committee's Working Groups in 2002.

Justification

a) It is important to evaluate individual monitoring programmes to determine possible trends against natural variability. A number of programmes have been discussed during previous WGSSO meetings. Now we will try to compile some general remarks and recommendations. ACME asks that reference should be made to the ACME 1998 report Section 4.7.1 and 4.8 and the 1999 report, Section 5.6.1.

b) This item will explore whether or not initialisation and validation studies in intensively studied areas can be generalised to other areas.

c) A first overview of long time series from Skagerrak has been collated to provide a useful set of data to investigate ecosystem variability in the region. These different time series must be brought together to form a coherent dataset.

d) Recent developments and status of physical models for coastal circulation will be reviewed to understand the inherent accuracy, resolution, assumptions and parameterisations etc. in relation to biological parameterisations. This is necessary to appropriately couple physics and population dynamics to provide meaningful calculations of population development.

e) In order to compare model parameterisations for growth rates, nutrient uptake rates, nutrient limitation, predation rates, demineralisation rates and the physics of the turbulent fluxes and stresses, it was felt necessary that a joint session of the WGHABD and WGSSO be held. On the basis of case examples such as the Baltic, the Gulf of Maine, the estuary of Saint Laurence, the Bay of Biscay, etc., it should be possible to compare and discuss implications of the different biological processes formulations.

   Recent developments and the status of physical models for coastal circulation will be reviewed to understand the inherent accuracy, resolution, assumptions and parameterisations, etc. This understanding and interaction is necessary to appropriately incorporate the details of the population dynamics (bloom initiation, growth, and mortality...) to provide meaningful calculations of the population development.

   During this joint meeting, physicists could also provide advice to some biologists regarding design of oceanographic investigations.

f) Operational oceanography is becoming increasingly important as a tool for getting appropriate data available in time but also as a platform for an integrated approach involving observations and remote sensing as well as models.

g) This is a request from ACME 1999. An improved understanding of the behaviour of trace metals in estuaries is a prerequisite for the estimation of net riverine trace metal fluxes to the coastal zone. The WG should review information regarding the distribution of the trace metals in different model estuaries, their chemical speciation, laboratory experiments, and thermodynamic calculations, as well as the work done on chemical- and hydrosedimentary modelling.

h) This is a request from ACME 1999. Nutrient input with freshwater into estuaries and coastal water can be estimated by combination of use of hydrodynamical models and measurements of nutrient concentrations. However, the quality and quantity of data sets available for calibration and validation of models are crucial. The future work should concentrate on special study areas, e.g., the German Bight; the Danish estuaries and/or the Norwegian coast where it is known that work is already taken place.

i) and j) were formulated during discussions of WG Chairs at the 1999 ASC.

APPENDIX III – AGENDA OF THE WGSSO 2000 MEETING

i) Welcome and opening
ii) Appointment of rapporteur
iii) Approval of agenda
iv) Information about new ICES guidelines from the Chair
v) Assessment of nutrient monitoring programmes (term of reference a)
vi) Time series from the Skagerrak (term of reference c)
vii) News from the shelf seas
viii) Joint session with WGHABD
- Welcome by Kaisa Kononen and Björn Sjöberg
- Wolfgang Fennel, Physics, models and harmful algal blooms
- Percy Donaghay, The importance of microstructure, turbulence and mixing in relation to algal blooms
- Patrick Gentien, On the importance of thin layers
- Oleg Savchuk, Aspects of different bio-geo-chemical models as applied in the Baltic
- Kai Myrberg, The role of atmospheric forcing for ocean model resolution in the Gulf of Finland
- François Saucier, Ice-ocean modelling in the Gulf of St. Lawrence with applications to biology
- Eleonor Marmefeldt, SCOBI-3D biogeochemical model
- Einar Svendsen, NORWECOM – Norwegian Ecological Model System
- Anouk Blauw, Modelling blue-green algae dynamics in Lake Ijssel: biomass and flotation
- A coupled physical-biological model of toxic Alexendrium dynamics in the Gulf of Maine
- Hermann-J. Lenhart, Effects of river nutrient load reductions on the eutrophication of the North Sea, simulated with ecosystem model ERSEM
- Odd Lindahl, Changes in the plankton community passing a *Mytilus edulis* mussel bed
- Juliette Fauchot, Modelling of HABs in the context of regional climate models
- Kai Myrberg, Larval drift experiments in the Baltic sea, model results and measurements
- Oleg Savchuk, Parameterisation of phytoplankton groups and communities in the Baltic sea biogeochemical models
- Sub-group meetings: (1) Forward from the 1994 Joint Vigo meeting and (2) Parameterisation of HAB

ix) Current developments in operational oceanography (TOR f)
x) Transport processes influencing trace metal distributions in estuaries (TOR g)
xi) Use of chemical data in numerical modelling (TOR h)
xii) Data products and summaries via the ICES website (TOR i)
xiii) Review the 1999 Oceanography Committee Working Group reports (TOR j)
xiv) Initialisation and validation of numerical models (TOR b)
xv) Election of a new Chair
xvi) Place, date and topic for the next meeting
xvii) Closing of the meeting

APPENDIX IV – ABSTRACTS OF PRESENTATIONS MADE DURING THE JOINT SESSION WITH WGHABD

Modelling blue-green algae dynamics in Lake Ijssel: biomass and flotation

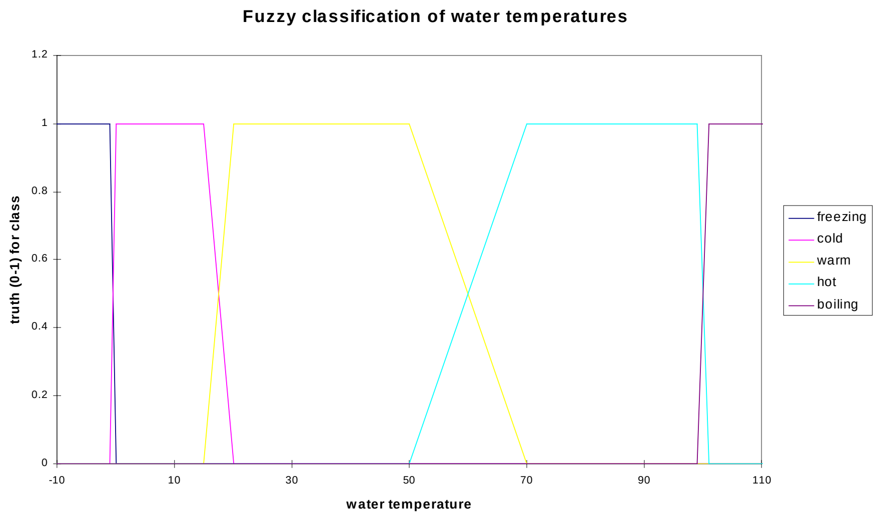
Anouk Blauw

Goal of the study. Scums of floating algal biomass, consisting of blue-green algae are a nuisance in many water systems, Lake IJssel, a big fresh water lake in the Netherlands is one of these systems. The scums cause bad odour, toxins and oxygen depletion in many harbours and recreational areas on the lakeshore. An early warning system is needed to give a warning when problems (could) arise, so mitigating measures can be taken in time. WL| Delft Hydraulics has worked on an early warning system for Lake IJssel, together with the research department for fresh water of the Dutch government.

Model set-up. The formation of scums of blue-green algae is the result of two processes: the growth of blue-green algae and their upward migration towards the water surface. The amount of biomass of blue-green algae varies largely over the years. Measurements of blue-green algae biomasses are not done frequently enough to base the early warning system upon measurements. The biomass is determined on the one hand by the amount of nutrients and light available for growth and on the other hand by the competition by other algae. These processes could be modelled using the model DBS, containing transport, nutrients and algae kinetics. The results of this model were used as a starting point for a predictive model on where scums of blue-green algae would appear.

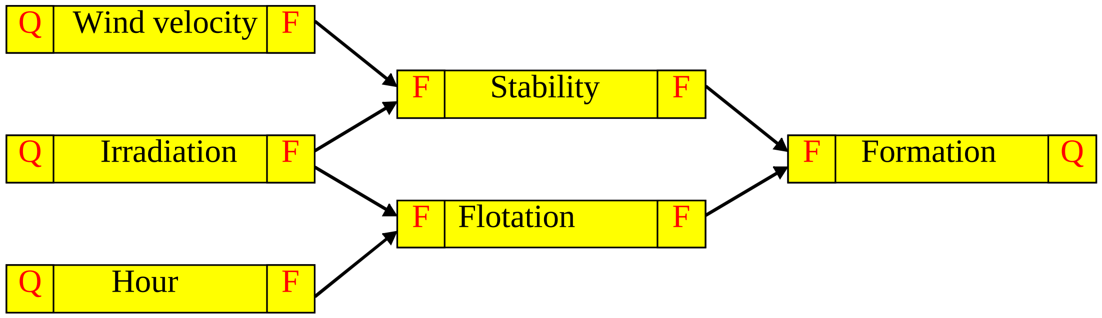
The upward migration of blue-green algae is determined by a complex interaction of physiological processes within the algae and the measure of turbulence/ stability in the water column. These are hard to quantify in a deterministic model like DBS. Therefore the fuzzy-logic approach was chosen to describe in a coarse way the result of the various factors determining the vertical transport of the algae.

Fuzzy logic is often applied in several engineering techniques, but it can also be used for the modelling of physical biological coupling in algae modelling. The essence of fuzzy logic is that quantitative values of factors involved in a process are translated to more abstract parameters that correspond with the measure of understanding available on the process. In the figure below a fuzzy classification of water temperatures is shown as an example.



Cause-effect relationships can than be modelled using the abstract (fuzzy) parameters. For example:

When there is <u>little wind</u> and <u>high solar irradiation</u> the <u>stability of the water column is high</u>.
(The fuzzy parameters used in this logic reasoning are underlined).
In this way the factors determining the vertical transport of the algae are modelled with the following relations:



The quantitative 'measure of upward migration' is multiplied with the maximum upward velocity to estimate the actual upward migration at the actual wind velocity, irradiation and hour of the day. Combined with the estimate of the blue-green algae biomass in the water column, an upward flux of algae reaching the water surface and forming a scum could be calculated at each model segment.

Once the scums have been formed they are transported by the wind. This could be modelled, assuming transport in the wind direction with a velocity proportional to the wind velocity. At high wind velocities the scums disappear again. This was also modelled using the fuzzy logic approach.

Results

This combination of techniques resulted in a model describing the formation and transport of scums of blue-green algae:

- numerical transport and water quality and algae model to calculate biomasses of blue-green algae;
- fuzzy logic for the modelling of formation and disappearance of scums;
- transport modelling using the numerical transport model mentioned before and the wind.

The results were compared to remote sensing pictures taken from Lake IJssel. The occurrence of scums could be modelled reasonably well as is shown in the table below.

Total	Satelite picture without scum	Satelite picture with scum
Model result without scum	266	4
Model result with scum	20	19
percentage correct	93%	83%

Conclusions

- Fuzzy logic is a good way to overcome the difficulties in deterministic modelling of the coupling of physics and biology.
- The fuzzy logic approach is a robust way to reason and predict from available knowledge on cause-effect relations, with less sensitivity to unknown parameters.
- The combined effect of more parameters cannot be calculated; all outcomes of the model need to be explicitly added to the model. The model is just a reflection of existing knowledge.

A coupled physical-biological model of toxic *Alexandrium* dynamics in the Gulf of Maine: progress to date

Donald M. Anderson, Biology Department, MS # 32, Woods Hole Oceanographic Institution, Woods Hole MA 02543 USA

A five-year program called ECOHAB-GOM was initiated to address several fundamental issues regarding *Alexandrium* blooms in the Gulf of Maine: 1) the source of the *Alexandrium* cells that appear in the fresh water plumes in the western Maine coastal current (WMCC); 2) *Alexandrium* cell distribution and dynamics in the eastern Maine coastal current (EMCC); and 3) linkages among blooms in the WMCC and the EMCC. Utilising a combination of numerical modelling, hydrographic, chemical, and biological measurements, moored and drifting current measurements, and satellite imagery, a team of 14 investigators from 9 institutions is attempting to characterise the structure, variability and autecology of the major *Alexandrium* habitats in the Gulf of Maine. This talk focussed on the modelling efforts that have been undertaken, with special emphasis on bloom initiation in the western Maine region.

In the western Gulf, *Alexandrium* blooms and patterns of PSP have been linked to a coastal current or plume of low salinity river outflow (the WMCC). One major project goal has been to investigate an area near Casco Bay implicated as the major "source region" for the toxic cells that populate that coastal current. Intensive, small-vessel field surveys in 1998 demonstrated that there might well be an offshore source of cells, possibly from cysts germinating from the deeper basins. A hierarchy of numerical models was described that are guiding project activities. These are based on a three-dimensional coupled physical-biological model of the regional circulation. The domain of that model is presently from Cape Cod to Penobscot Bay, but this is now being expanded up to the Bay of Fundy. This is a Blumberg and Mellor 3-dimensional primitive equation model, fully non-linear, with 12 vertical layers. Vertical mixing is internally generated from the Mellor-Yamada 2.5 turbulence closure model. The model is forced by various modelled inputs as well as land-based and shipboard observations.

Initial model results with *Alexandrium* populations originating in various “source” regions suggested that uniform cell input throughout the domain (i.e., cysts evenly distributed, with uniform germination) gave unrealistic results compared to cruise data, and shellfish toxicity patterns. Likewise, cell input only in the vicinity of major river/estuarine systems also gave unrealistic results. However, continuous cell input near Casco Bay gave results in excellent agreement with cruise and shellfish toxicity observations for 1993, but <u>not</u> for 1994. The latter discrepancy argues that cyst germination is not continuous throughout the bloom season, and that modelling efforts cannot proceed without better parameterisation of the cell input function (i.e., <u>where</u>, <u>when</u>, and <u>at what rate</u> are cysts germinating). As a result, a cyst germination model was developed that is based on laboratory-derived germination rates and cyst distributions mapped during survey cruises. Data from this model are being incorporated into the three-dimensional model of the regional circulation in 1993. Initial conclusions from these simulations are that: 1) germination of cysts from deep waters is quantitatively more important than germination from shallow areas; 2) newly germinated cells in deeper, offshore waters can become entrained into the coastal current when the buoyant coastal current is pushed offshore by upwelling winds, then returned to shore by downwelling winds; 3) the westernmost cyst seedbed used in the simulations is too far south and west to account for blooms and toxicity in Casco Bay, or the offshore origin of the bloom observed in 1998; and 4) further refinement of the model is clearly needed (e.g., expanded domain, sensitivity analysis, grazing dynamics, nutrient effects, migration behaviour, encystment).

ECOHAB-GOM is thus a combined modelling/observational program following an approach commensurate with the multiple scales and oceanographic complexity of paralytic shellfish poisoning phenomena in the Gulf of Maine. More details on this project, including an update of cruise activities and results can be found at the project web page at: http://crusty.er.usgs.gov/ecohab/

First steps in the modelling of *Alexandrium* bloom dynamics in the St. Lawrence Estuary, Canada.

Juliette Fauchot, Maurice Levasseur and François Saucier.

In July 1998, a red tide developed in the St. Lawrence Estuary (SLE). The causative organism was *Alexandrium tamarense*, a dinoflagellate known to cause PSP outbreaks in the SLE. Over a three day period, the red tide spread along the south shore of the estuary, with *A. tamarense* concentrations reaching $2.3 \cdot 10^6$ cells L^{-1}. The highest concentrations of *A. tamarense* were found in waters of lower salinity and higher temperature. Environmental data indicate that the development of the red tide occurred during a period of increased stratification of the water column due to reduced vertical mixing and warming of the surface layer. The surface water circulation, the distribution of surface salinities and the transport of passive tracers in the surface layer were simulated with the ice-ocean model of the Gulf of St. Lawrence developed at the Maurice-Lamontagne Institute (Canada). The results of the model simulations indicate that the red tide developed during a ca. 1 week-period of retention of surface waters in the estuary that allowed the accumulation of the growing biomass. Therefore, the red tide observed on the south shore of the estuary resulted from in situ growth and biomass accumulation close to the north shore followed by a north-south cross-estuary transport. Our results show that, during the red tide formation, a particular climatic condition prevailed in which the retention period coincided with a northeasterly wind.

In order to understand the dynamics of red tides in the SLE better, the development of a biological model of *A. tamarense* bloom dynamics, coupled with a circulation model of the SLE, is in progress. This model will take into account the growth rate of *A. tamarense* cells, the different stages of their life cycle (permanent cysts, vegetative cells), their behaviour (vertical migrations) and community interactions (grazing).

Effects of river nutrient load reductions on the eutrophication of the North Sea, simulated with the ecosystem model ERSEM

Hermann-J. Lenhart

The results of the reduction scenarios with the ecosystem model ERSEM by Lenhart (1999) and Lenhart *et al.* (1997) are in good accordance to the conclusions from the ASMO modelling workshop on eutrophication (OSPAR, 1998). In the ERSEM studies the simulation of a standard year was compared with the one of a reduction scenario, where the river nutrient load of the anorganic and organic load was reduced by 50 %. The result of the ERSEM studies supported the ASMO conclusion, that a reduction of the river nutrient load by 50 % in N and P can not be linearly transferred to a 50 % reduction in the resulting net primary production. While the reduction scenario revealed a decreased winter concentrations of nitrogen and phosphorous up to 40%, the decrease in net primary production was clearly lower. Reducing the anorganic and organic the river loads in ERSEM by 50%, the largest effect on the net primary production was observed in the coastal zone with a reduction of about 20 %. Phytoplankton groups in ERSEM showed different reactions to the changed nutrient availability. While the biomass and production of diatoms did not show any effect to the river load reductions, small changes could be observed for the flagellates. However, these changes did also include an increased biomass of flagellates for some time in summer. This result is severe because the increase in algal biomass due to eutrophication was related mainly to an increase in flagellates, which are not decreasing accordingly in the reduction scenario. Generally all changes in the time series of the modelled phytoplankton concentration occurred after the spring bloom._Also regional differences between primary production and nutrient uptake of algae were indicated between the standard run and the reduction scenario. Greatest differences with regard to primary production were found downstream of the river Rhine and the Elbe. This is matched by the uptake of ammonium, while the uptake of nitrate and especially phosphorus showed its greatest differences in the river mouth of Rhine and Elbe.

Lenhart, H.J., Radach, G., Ruardij, P. (1997): The effects of river input on the ecosystem dynamics in the continental coastal zone of the North Sea using ERSEM. J. Sea Res., 38: 249-274.

Lenhart, H.J. (1999): Eutrophierung im kontinentalen Küstenbereich der Nordsee. Reduktionsszenarien der Flußeinträge von Nährstoffen mit dem Ökosystem-Modell ERSEM. Thesis, University Hamburg, 169 pp.

OSPAR 1998. Report of the ASMO Modelling workshop on Eutrophication issues. 5-8 November 1996, The Hague, The Netherlands, OSPAR Commission 1998, 86 pp.

Modelling of Ecosystem Dynamics in the Estuary and Gulf of St. Lawrence

F. J. Saucier

Three-dimensional baroclinic models of the Estuary and Gulf of St. Lawrence are developed to reproduce and investigate the hourly to seasonal variations in the ice-ocean conditions, exchanges with the atmosphere, and plankton dynamics. The Gulf and Estuary models have resolutions of 5 km/73 layers and 400 m/20 layers, respectively. The forcing includes detailed tidal, atmospheric, oceanic and hydrological data, at hourly to daily intervals. The model results are evaluated over hindcast periods in the 1980s using sea surface temperature, salinity-temperature profiles, water levels, and ice charts. The models reproduce well many of the features of the known circulation, transports, and the formation of water masses and sea ice. Tracer experiments aimed at investigating the fate of surface phytoplankton, and zooplankton with diurnal migration, over days to months show that the tidally, wind-driven and density-driven circulation contribute to gulf-wide dispersion. These experiments demonstrate the importance of well-resolved high frequency forcing and currents in order to insure the appropriate precision in carrying tracers in the sea. A study of krill aggregation at the head of the St. Lawrence channel shows that the relatively small changes in the timing of the semi-diurnal tide with respect to the timing of surface excursion at night can lead to very different solutions, either patches of high concentration, or high dispersion and flushing from the system. The models are being applied by Fauchot *et al.* (this joint session) to examine the retention/dispersion process of a HAB that occurred in early July 1998 in the St. Lawrence Estuary.

APPENDIX V – SUMMARY FROM THE JOINT WORKING GROUP ON MODELLING HABS – PARAMETRIZATION MARCH 23, 2000

Chaiman: François Saucier
Rapporteur: Maurice Levasseur

The aim of this subgroup was to list and discuss the parameters required for HABs modelling. State variables and processes were thus determined for the different bloom phases: initiation, development and decline. A summary of the parameters and processes is presented in Table 1. When establishing this list, the participants had mostly planktonic HABs in mind. Although most parameters and processes listed here are applicable to benthic and epiphytic HABs, the modelling of these HABs may require specific parameters not adequately discussed in this report.

HABs initiation phase

A minimum knowledge of the initial field ($N_0(x,y,z)$) is essential. Parameters and processes required to adequately initialise the model runs vary depending if the species is a cyst forming or a non-cyst forming species.

For the cyst forming species, a basic knowledge of the cyst spatial distribution (mapping of 2D cyst concentrations) is crucial. For different reasons, the total number of cysts per square meter may not be a good indicator of the potential cyst population since a significant portion of the cysts may not be able to germinate. Anoxia, for example, has been shown to prevent the germination of *Alexandrium sp*. cysts. It may thus be important to know their exact location (depth) in the sediment. For modelling purposes, cyst concentration in the top 2 cm have been used in the past (Gulf of Maine model – ECOHAB-GOM). The potential presence of cysts in the nepheloid layer (organic matter-rich layer lying on the top of the bottom) has been mentioned as an area for future research. Finally, the distribution of cysts may be very dynamic. For example, they may move with the sediment, especially in estuaries. By redistributing cysts and oxygen in the sediment, the intensity of bioturbation may be important in this matter.

Once the cyst bed has been located, it is important to understand what controls germination. Newly formed cysts go through a mandatory dormancy period during which they cannot germinate. The length of this period, which is temperature dependent for *Alexandrium tamarense*, is a crucial parameter to know. After this period, cysts remain quiescent until their germination is triggered by either an internal or external signal. So far, the existence of an internal clock has been demonstrated for *Alexandrium sp*. cysts. On the other hand, environmental signals, which may initiate germination of mature cysts, are light, temperature, oxygen and bottom shear stress (induced by tidal current, wind, and storm). Temperature may either affect the rate of germination or have a threshold-type effect. On the other hand, a single flash of light has been shown to trigger germination in some species.

The physiological characteristics of the newly germinated cells may also be important to know. Do newly germinated cells need light to divide? How long can they survive in the dark? How fast are they dividing? What is their swimming behaviour? What is their survival rate? These questions remained unanswered.

For non-cyst making species, it would also be useful to know the initial 3D distribution of the founding population. This information may however be difficult to obtain since the over-wintering cells are most often present in extremely low abundance. The geographical limits for potential inoculation should at least be known.

Finally, it may also be important to take into account the physical, chemical and biological characteristics of the body of water receiving (for cyst forming species) or containing the founding population since inappropriate environmental conditions (irradiance, salinity, temperature, nutrients, circulation, co-occurring species, grazing, etc.) may limit cell growth and accumulation. For example, a minimum threshold of irradiance (J/m2/d) has been shown to be important for *Phaeocystis* bloom initiation. Initial nutrients levels are of particular importance when the harmful species represents a large portion of the community and consumes a significant portion of the nutrient pool.

HABs development phase

Temporal changes in the size of a population result from the difference between its gross growth rate (or cellular growth rate) and the sum of the different loss rates. The parameters and processes that are important to model the development of a bloom are those that affect the gross growth rate of the population.

Modelling gross growth rates - For autotrophic species, daily irradiance and factors controlling the light regime of the cells such the water column light attenuation coefficient and the mixed layer depth need to be known. Other factors, which may affect gross population growth rates, are water temperature and nutrient concentrations or regeneration rates.

Algal gross growth rate may also be affected by the bioavailability of trace metals, vitamins and various organic compounds, which in turn may depend on the pre-conditioning influence of previous blooms. The frequent association between HABs and brackish river plumes has been often attributed to the presence of humic substances, which may either detoxify the water mass or serve as a nutrient (nitrogen, iron) source. For many HAB species, cell division may also be suppressed by turbulence. CO_2 concentration has also been shown to limit algal growth and biomass accumulation in colony forming *Phaeocystis* spp. It should be noted that a direct relationship between light, inorganic nutrients and algal growth might be blurred by mixotrophy, a wide spread phenomena in HABs.

Modelling net growth rates – Grazing may be the most important loss term during the bloom development phase. However, the inclusion of a grazing term in models requires an adequate understanding of the food web structure. It is crucial to identify the right grazer(s) (e.g., copepods, ciliates, heterotrophic dinoflagellates, etc.) and to have a basic knowledge of the grazing rate/prey relationship. It is also important to keep in mind that grazing may exert a strong control on population, especially at low cell number (e.g., initiation phase). Grazing by filter feeding organisms (shellfish) may also be important in controlling bloom development. For colony forming species, the rate of colony formation is also important to know since it has repercussions on predation and sinking rate. Aggregation behaviours are also important. Models must also include vertical migration behaviours. To do so, we need to know the triggering factor (nutrients, light, other chemicals) and the vertical swimming speed.

HABs declining phase

HABs enter their declining phase when loss rates overcome their gross growth rates. For non-cyst forming species, bloom development may stop due to a reduced gross growth rate and/or an increase in loss rate. The decrease in gross growth rate may result from a shortage of essential nutrients or light or a change in the physical environment (e.g., increase in turbulence). Natural mortality (i.e., genetically determined mortality) may also be more important than previously thought. However, this mortality rate is not well quantified in any species yet. Harmful algae populations may also collapse due to heavy grazing pressure (grazing rate > algal gross growth rate), parasites, fungi and viruses. A rapid sedimentation of the population may occur if the cells become physiologically stressed (high turbulence, nutrient limitation). This phenomena is often dependent on cell density. The decline of the population may also be physically driven, with dispersion becoming greater than retention for a given area. Finally, the bloom may also collapse if cells enter the sexual cycle. This is of course extremely important for cyst-forming species. For these species, we need to know what triggers cyst formation (nutrient concentration, nutrient quota, population density, etc.). Gamete encounter rate is density dependent and may increase with turbulence. Cyst formation rate may thus vary from high to low from the centre to the edge of the bloom.

Conclusions

HABs models may obviously become increasingly complex. In a second step, the group members tried to classify the different models based on their utility, which in turn may help to determine the level of complexity required. In the HABs field, models may be required to predict 1) harmful effects, 2) minimum cell concentrations for harmful effect, 3) initiation time (occurrence), 4) duration, and 5) location (spreading or dispersion). Then, depending on what you need/want to deliver, the models may be grouped in 4 classes:

1) Very complex comprehensive community models (learning tool, long term prediction, exploration of scenarios)
2) Less complex multi-species models (e.g., include algal growth, grazing rates)
3) More simple, single species models (e.g., physical model with algae as passive tracers)
4) Empirical models (e.g., models for statistical forecast)

The participants also tried to rank by importance the parameters, which need to be included in physical-biology models. The ones that came up the most often were: 1) the initial field (N_0 (x,y,z)), 2) the particular behaviour of the targeted species (e.g., swimming dinoflagellate, fast sinking diatoms, etc.), 3) the *in situ* growth rate, and 4) the factor(s) controlling toxicity.

In order to improve our modelling capacity of HABs, the discussion group members concluded that we need to improve data assimilation and real-time observing systems. In poorly known systems, new approaches such as inverse modelling and neural network should also be tested. To the knowledge of the group members, these methods have not yet been applied to the HABs field. The level of definition required for the physical models was discussed and it was concluded that this was species specific. In some cases, physical models clearly require a fine resolution (e.g., eddy resolving models). This is particularly true for species forming micro-layers.

Regarding our predictive capacity, it is important to build on our current capabilities such as 3D currents and temperature forecasts. The value of experience-based relationships was also recognised (e.g., empirical relationships between wind or salinity and HABs). Whatever the level of complexity of the model, there was a general consensus that one should be cautious about the capacity of any model for long-term predictions.

Table 1. Summary of the parameters and processes required to model HABs.

Phases of bloom	Parameters/processes	Remarks
Initiation		
Cyst forming species	2D cyst distribution	May change with time
	Cyst distribution in the sediment	Top 2 cm has been used
	Length of the dormancy period	May bee function of temperature
	Internal/external factors triggering germination	May be an internal clock, a physical cue (light, temperature)
	Germination rate	May bee function of light, temp.
	% of germinating population	
	Behaviour of newly hatched cells	Dark survival, tropisms, etc.
	Division characteristics of newly hatched cells	Rapid initial cell division rate?
Non-cyst forming species	3D distribution of the founding population	May be hard to determine. Geographical limits for cell inoculation may be sufficient.
Development	Irradiance (daily; J/m2/d)	Daily (J/m2/d)
	Water column coefficient of extinction	Will partly control the light regime of the cells
	Mixed layer depth	Will partly control the light regime of the cells
	Growth/irradiance curve	Species-specific
	Nutrient concentrations	Nitrogen, phosphate, silicate
	Nutrient uptake kinetics	Species-specific
	Grazing rates	Macrozooplankton, microzooplankton, shellfish, heterotrophic dinoflagellates, etc.
	Predator/prey relationships	
	Specific behaviours	(e.g., aggregation, vertical migration, etc.)
	Factors triggering aggregation or vertical migration	May be light, nutrient limitation
Decline	Sexual cycle	Production of gametes or cysts
	Grazing rates	
	Parasites	
	Viruses	
	Fungi	

APPENDIX VI – CANADIAN CONTRIBUTIONS TO GOOS

Prepared for the First GOOS Commitments Meeting, Paris, 5-6 July, 1999

Introduction

Canada continues its support of GOOS as the principal international mechanism for obtaining long-term systematic observations of the marine environment, both regionally and globally, to meet a broad range of user requirements. In the past this support has primarily involved Canadian participation in the planning of GOOS through its panels, working groups, I-GOOS and this inaugural GOOS Commitments Meeting, as well as through Canada's support of the infrastructure that are being used to implement GOOS. In the future Canada will contribute more directly to GOOS through the designation of parts of its long-term monitoring effort as contributions to GOOS and do so in a manner that is consistent with the GOOS Principles. The extent of Canadian involvement in GOOS awaits further development of the detail design of the GOOS observing system for all the GOOS modules; especially those that require observations in the Canadian EEZ and which are less developed than the climate module. Another obvious constraint will be the ability to commit long-term funding to GOOS in times of government cutbacks and assessment of priorities. However, given Canadian concerns regarding climate change and the marine environment, the opportunity exists to make a substantial contribution to GOOS.

Canadian GOOS Organisation and Planning

Within Canada the responsibility for the planning and implementation of ocean observing systems rests primarily with the Fisheries and Ocean Sciences Directorate, Department of Fisheries and Oceans (DFO). Collaborations are established with other departments and agencies to include those variables for which the responsibility falls outside DFO. Within this framework, ocean monitoring programs have been developed for the ocean off both the Atlantic and Pacific coasts and to a lessor extent for the Arctic. They have been designed to meet a number of Canadian needs and have elements that span C-GOOS, LMR and HOTO concerns.

More recently, in the post-Kyoto spirit, Canada has been planning its potential contributions to GCOS, including the entire ocean, terrestrial and atmospheric elements. In addition, requirements have been defined for the augmentation of the sparse GCOS global network to provide the climate observing system needed to meet Canadian national interests. While for the atmosphere and land this augmentation primarily increases the density of the observing network, for the ocean it includes climate observations on the continental shelves and the oceans directly off Canada's coasts. Long-term government support for Canadian climate observations for GCOS, and its Canadian augmentation, is being sought. Some elements are however presently being routinely carried out as part existing monitoring or research programs.

Potential Canadian Contributions to GOOS

As just mentioned, serious consideration has been given to what Canada could contribute the GOOS/GCOS common climate module given adequate resources. First priority has been given to (1) five geocentrically positioned tide gauges (2 on the east coast, of which one would be a new gauge on the coast of Labrador, 2 on the west coast and one in the Arctic, also a new gauge); (2) continuation of the research-based time series on Line P and the site of OWS P in the Pacific, at the site of OWS Bravo, and on an annual section across the Labrador Sea; and (3) a substantial contribution of profiling floats to the Argo program that might eventually total about 5 percent of the global array. Regarding profiling floats, Canada would consider providing floats to the global array in regions other than off Canada's coasts should the contributions of other nations provide regional coverage. Slightly lower priority has been given to carrying out one transocean section off both the east and west coasts every eight years for the assessment of the inventories and transports of heat, fresh water and carbon.

This contribution to the global GOOS/GCOS physical ocean observing system would be augmented by (1) seasonal sampling using hydrographic sections and time series stations of the water properties on Canada's continental shelves and adjacent seas including the Arctic (roughly 12 sections and 8 time series stations on the east coast including the Gulf of St Lawrence, 9 sections on the west coast and a moored climate station and annual hydrographic survey in the Beaufort Sea region of the Arctic Ocean; (2) an enhanced tide gauge network, some of which would be geocentrically positioned (roughly 6 gauges on the east coast, 4 gauges on the west coast and one in the Arctic, all of which would be in addition to those contributing to the climate module); (3) direct observation of the transport on the Labrador shelf and through the Canadian Archipelago, (4) observations of sea-ice concentrations, extent and velocity both off the coast of Labrador and in the Canadian Arctic. In the case of limited resources priority will be given to maintaining parts of the hydrographic and tide gauge networks as well as to observations of sea ice. How much of the above observational array would contribute to GOOS depends on the final design of the global C-GOOS observing system. In any event, Canada would be willing to contribute the observations it is taking to GOOS as the evolving GOOS plans indicate is appropriate. Data presently being obtained is already being archived in the international data management system.

Potential Canadian contributions to the HOTO and LMR modules are less clear, partly as the result of the less advanced state of both GOOS and Canadian planning in these areas. On the other hand Canada does have operational programs in these areas, especially as they relate to fisheries. In an effort to evaluate the effectiveness of current monitoring programs to meet Canada' ecosystem objectives for integrated oceans management and conservation as well as the performance measures by which observational tools used to monitor the ocean ecosystem can be assessed, a Canadian workshop will be held in the fall of 1999. It is expected that in addition to addressing Canadian issues this will aid Canada's input to the design of the LMR module and better indicate how Canada could most effectively contribute to this aspect of GOOS.

Canada also contributes to the infrastructure supporting the implementation of GOOS, through its role in the GTSPP, and by collaborating with other countries to develop data management policies and guidelines, as well by providing expertise to the various implementation panels of GOOS modules.

Summary

In general, Canada supports the development of GOOS as a planned observing system to meet specific needs and providing data and products of known quality to the global community. While the boundary between what Canada contributes to GOOS and what should remain in the Canadian context is still to be determined, Canada will support international efforts to make GOOS as broad as possible within the framework of the GOOS Principles of design and involvement. Canada views climate change and marine environmental matters in general as issues requiring an international approach and will support the contribution that GOOS can make to the extent possible and the resources available.