ICES Oceanography Committee
ICES CM 2004/C:02

Report of the Workshop on Future Directions in Modelling Physical-Biological Interactions (WKFDPBI)

8–9 March 2004
Barcelona, Catalonia, Spain

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Contents

1 Background to the workshop

The ICES Study Group on Modelling Physical-Biological Interactions (SGPBI) at its annual meeting (March 2003) in Chapel Hill, USA, decided to apply for a Working Group (WGPBI) status. As part of the continuing effort in the field of physical-biological interactions a Workshop was decided to be spun off to help identify key areas where existing techniques for modelling physical-biological interactions needed to be improved. F. Peters took the lead in this action and it was decided to convene a Workshop in Barcelona (Catalonia, Spain) in March 2004, immediately before the annual Working Group Meeting, with the title "Workshop on Future Directions in Modelling Physical-Biological Interactions [WKFDPBI]". The findings of the Workshop would be reviewed and considered for incorporation into the strategic plan for the WG.

2 Objectives

The terms of reference for the Workshop were:

A **Workshop on Future Directions in Modelling Physical-Biological Interactions** [WKFDPBI] (Co-Chairs: F. Peters, Spain, and C. Hannah, Canada) will be held in Barcelona, Spain, from 8–9 March 2004 to:

a) review the current state of the art in several fields that require modelling physical-biological interactions and are relevant to ICES, e.g., fisheries recruitment, harmful algal blooms, eutrophication;
b) identify the key areas where model improvements are required.

WKFDPBI will report by 15 May 2004 for the attention of the Oceanography Committee.

The objectives of the Workshop were stated as follows:

The purpose of this Workshop is to identify key areas where existing techniques for modelling physical-biological interactions need to be improved or addressed. The Workshop should attract 25–40 participants. We will invite participation from different ICES Working Groups with an interest in physical-biological interactions (e.g., WGPE, WGZE, WGHABD, WGCCC, WKHABWATCH, PGNSP, and SGGOOS) and from groups such as GLOBEC, PICES and others. The Workshop will also promote lines of communication with modelling communities throughout the ICES Member Countries.

The findings will be reviewed and considered for incorporation into the strategic plan for the WGPBI, ensuring that the workplan is consistent with the needs of the community.

The workshop is aimed at a forum as open as possible to discuss the modelling of physical-biological interactions, with a special emphasis on the interactions. Target aspects include the interaction of planktonic organisms and processes with light, temperature, nutrient or food particle fields and hydrodynamics. Questions on how to address physical-biological interactions that occur over a range of spatial and temporal scales in models that have a regional/annual scope are greatly welcome as are modelling approaches to such issues (Eulerian versus Lagrangian, IBMs, inverse modelling, network analysis, statistical models, etc.).

3 Organisation of the meeting

The organisation of the Workshop started in May 2003. At the same time, the European Union project NTAP (EVK3-CT-2000-00022; Nutrient dynamics mediated through turbulence and plankton interactions; Coordinator: Cèlia Marrasé) was preparing a modelling workshop for sometime in early 2004 and it was agreed to merge the meetings.

The members of the Scientific Advisory Committee for the Workshop were:

- Wolfgang Fennel (Institut für Ostseeforschung, Warnemünde, Germany);
- Charles Hannah (Bedford Institute of Oceanography, Dartmouth, Canada), co-Chair;
- Cèlia Marrasé (Institut de Ciències del Mar, Barcelona, Spain) ;
- Tom Osborn (The Johns Hopkins University, Baltimore, USA);
- Francesc Peters (Institut de Ciències del Mar, Barcelona, Spain), co-Chair;
- Einar Svendsen (Institut of Marine Research, Bergen, Norway);
- Cisco Werner (University of North Carolina, Chapel Hill, USA).

Four themes were proposed for the Workshop:

- Session 1. Harmful algal blooms/Eutrophication;
- Session 2. Ecosystem Integration and questions of scale;
- Session 3. Fish stock recruitment;
- Session 4. Modelling approaches.

Each session would have a chair person and a Rapporteur who would moderate the session and spark discussion if needed.

We wanted to:

1) Have a short workshop; two to three days at most
2) Have as many invited speakers as we could
3) Have at length discussions for each session
4) Have no parallel sessions

These constrains resulted in a two-day Workshop, where each session would last for half a day and consisted of 3–4 invited talks of 30 min. each and a one-hour discussion. All participants were invited to contribute posters. We allocated some time to view the posters and poster presentations were discussed along with the oral presentations during their corresponding discussion session.

In order to have a successful workshop, leading scientists in the field of physical-biological interactions should be invited.

The main criteria for invited speakers were their scientific excellence in the area of physical-biological interactions. We included experimentalists as well as modellers, and biologists as well as physicists. There was a preference for speakers from outside ICES and WGPBI since we wanted a broad spectrum of viewpoints. These criteria were modulated by secondary criteria such as gender balance and country representation. A prioritised list of speakers was completed by the Scientific Advisory Committee in September 2004 and the first round of letters of invitation were sent out by e-mail on 14 October 2004. A sample copy of the invitation letter can be found in Annex 1.

After the ICES 91st Statutory Meeting we received notification on 17 November 2003 that the meeting was approved as an ICES Workshop (C.Res. 2003/2C02).

Logistics (travel arrangements, meeting rooms, bags, badges, coffee breaks, conference dinner, e-mail room, abstract book, etc.) were most heavily dealt with starting December 2003.

See further details of the meeting program, speakers, abstracts, list of participants, etc., in Annex 6.

4 Funding

F. Peters together with other Spanish scientists asked for support from the MCYT (Spanish Ministry of Science and Technology) to the CIRIT (Catalan Government Interdepartmental Commission on Research and Technology) and to the CSIC (Spanish Research Council). The CIRIT application did not come through. Dr Dolors Blasco, the director of the host institution ICM, CMIMA (Institut de Ciències del Mar, Centre Mediterrani d'Investigacions Marines i Ambientals), agreed to provide support in terms of facilities, meeting rooms, computer services and administrative issues. In addition, support was provided by the EU project NTAP.

5 Workshop website

Francesc Peters set up a Workshop website (http://www.icm.csic.es/wkpbi), hosted at the Institut de Ciències del Mar (ICM). The website included the aims of the workshop, the meeting program with the list of invited speakers, information on the meeting venue and accommodation, forms to register for the Workshop and to submit abstracts, and other information. Abstracts were posted on the web as they became available. Registrations and abstract submissions were automatically entered into a database, which, for instance, allowed for immediate updates of the list of participants. The website is being maintained after the Workshop and information of the publication of the proceedings can be found there. A current view of the website can be seen in Annex 2.

6 Scientific presentations and discussion

Session 1. Harmful algal blooms/Eutrophication. Rapporteur: Tom Osborn

The first session examined the dynamics of harmful algal blooms and eutrophication. Dr Ted Smayda reviewed the evidence for increasing bloom frequency and coastal nutrient increases. He raised the questions of structural changes in the community, changes in stability of the community, and whether we are using the species information adequately. This latter point was reinforced by Dr Marta Estrada. She suggested that separating plankton into different types of 'strategies' and functional groups will allow more successful prediction than trying to get the individual species. One important strategy is how plankton responds to the turbulence in the flow field. The difficulties of adequately sampling and describing the in-situ life cycle of the plankton were demonstrated by Dr Percy Donaghay. The thin layers of plankton, predators and prey, nutrients, and other parameters are a formidable challenge to sample. Without an accurate and appropriate description of the relation between predator and prey fields we cannot understand the processes and predict the population dynamics. Dr Paul Tett emphasised the intertwining of the physical and biological aspect of the problem. Model solutions require an integrated approach rather than a combination of two separate – biological and physical - models.

Session 2. Ecosystem integration and questions of scale. Rapporteur: Wolfgang Fennel

The talk of Dr J. Dippner dealt with the problem of how relatively simple cause-effect relationships between system properties (e.g., productivity) and climate variability (e.g., expressed by the NAO index) can be established to understand first order effects. While ecosystems obey intrinsically non-linear dynamics, which obscures predictability, there are apparently simple linear cause-effect chains, which can be expressed by mediators. However, it can be shown that for such simple explanations there are several causal pathways to relate effects to causes. Advanced three-dimensional model systems can be used to shed light on the responses of marine ecosystems to climate variability. As a central recommendation it was stressed that existing models should intensely be used to address such questions. The talk of Dr J.L. Pelegrí examined how diffusive fluxes occur through a variety of processes at many spatial/temporal scales. He pointed out that the basic kinematic mechanisms are diapycnal transfer, epipycnal mixing, and epipycnal pumping, and emphasised that a proper understanding of these processes is necessary for predictive purposes. The contribution of Dr T. Neumann et al. showed applications of three-dimensional coupled physical-biological models of the Baltic Sea at different time scales, ranging from events (several days) to decades. It was shown that temporarily increased nutrient loads over a period of weeks can be described with simple NPZD-models, while decadal simulations require more sophisticated biogeochemical models. The great potential of such advanced model systems to conduct numerical experiments was demonstrated for the case of load reduction scenarios.

During the general discussion a question was raised on the role biological oceanography will have in the process. The type of model system presented by Neumann et al. can serve as an interdisciplinary communication tool to develop common views between experimentalists and modellers and to identify the strengths and weaknesses of the models as more research needs are identified to fill knowledge gaps and support model improvements. It was stressed that the history of the development of such community models (i.e., models shared and jointly developed further by a community of scientists) highlights the significant potential of the step-by-step development of 'community models'.

Session 3. Fish stock recruitment. Rapporteur: Charles Hannah

Dr Pepin opened the session with a talk that focused on understanding the implications of the uncertainty in both models and data for interpreting the results of coupled biological-circulation models applied to larval fish growth and survival. As an example of the uncertainty in the data, in Trinity Bay (Newfoundland) sampling at 8 km intervals only captured 50% of the environmental variance. A key question is: Given the variability of prey concentration, what is the likelihood of observing a relationship between growth and prey availability? The models need estimates of the true probability distribution function (PDF) of all the variables that influence larval fish growth and survival. Dr Pepin also demonstrated from the observations that low mean growth rates were associated with high variance in growth and high mean growth rates were associated with low variance. This is in contrast to the common assumption that encounter rates follow Poisson statistics where the mean and variance are equal. Dr Pepin proposed three possible explanations:

1) Patchiness is not random.
2) Physiological buffering, i.e., growth has both an intrinsic component and a component subject to environmental variability.
3) Differential saturation of the functional feeding response.

At present it is not possible to distinguish between the possibilities. Dr Pepin recommended the development of data assimilation techniques for larval fish modelling and development of PDFs for the mean, median, and variance of the variables in the larval fish growth equations.

Dr St. John motivated his talk with a brief review that demonstrated that all statistical relationships between recruitment and environment fail after publication. The key point was that most statistical relationships only consider 1 or 2 controlling mechanisms and that recruitment, and groundfish recruitment in particular, has multiple controlling factors and big recruitment events occur 10-20 years apart. Thus there are very few events on which to base a statistical model. A second theme in the talk was that the 'Mean larvae is a dead larvae' and therefore one needs to focus on the 'characteristics of survivors'. Dr St. John then laid out a vision for the use of coupled physical-biological models in recruitment prediction. A crucial part of the vision was an ambitious observation program to collect the data required for validation of the circulation models and the biological models.

The problem of simulating the transport of *Calanus finmarchicus* from the Norwegian Sea into the Barents Sea was addressed by Dr Slagstaad. The study was motivated by the observation that the import of *Calanus* into the Barents is 4 times the local production. The study used a circulation model, an ecosystem model (NPZ type) and a *Calanus* population model. A key feature of the model was the ability to start with an overwintering population of *Calanus*, have them exit diapause, reproduce and have the next overwintering population grow and develop in the virtual environment. The results showed large overwintering populations along the Norwegian Shelf break with the potential to be advected into the Barents. The transport into the Barents was controlled by the circulation, in particular the pressure gradient between the Barents and Norwegian Seas. The results also showed that strong coupling between the shelf and slope populations was an important factor in the *Calanus* life cycle.

Dr Boyra discussed the problem of estimating the vertical distribution of anchovy and sardine eggs in the Bay of Biscay. This is important for fisheries management because of the proposed change in sampling of egg concentration from vertical sampling to continuous horizontal sampling at a fixed depth. The 1-d modelling has confirmed the importance of the adaptability of the egg buoyancy to the local environment. Comparison with vertical distribution data showed some improvement over the previous model and highlighted the difficulties modelling subsurface maximum in some environments. The importance of the work was reinforced by the poster by Magri et al., which addressed the same problem independently.

There was a wide-ranging discussion of the implications of the statement that the average larva is a dead larvae, or equivalently that survival is a rare event. An important point was that fast growth does not imply survival. Ecological theory suggests that as food abundance increases animals will spend more energy on predator avoidance (and thus increase survival). Thus there is likely a trade off between survival and growth that confounds the search for simple relationships between growth rates and prey concentration. There is also the question of food abundance versus food quality. It was noted that in general, food quality dominates when food abundance is low. In addition, there is evidence for a relationship between food quality, as measured by essential fatty acids, and *Calanus* growth.

On a more general note, it was remarked that rare events are not ergodic (i.e., one cannot replace ensemble averages with time averages). This reinforces Dr Pepin's call to re-examine the statistical assumptions in many models.

A second lively topic of discussion centred around three related questions: 1) Given that the system will always be under sampled in space, time, and trophic structure, what is the best way to proceed?; 2) What measurements do the modellers need? [to solve a particular problem]; and 3) Are there key observations that need to be made or should we focus on high density sampling in key areas to validate the models and then let the models do the extrapolation? There was no general resolution to these issues. However, it was clear that describing the space and time variability at scales smaller than those of even a highly focussed field program will be a key area of research. This issue was a common feature of talks in other sessions as well (e.g., Donaghay, Woods, Metcalfe).

Session 4. Modelling approaches. Rapporteur: Cisco Werner

Three modelling studies were presented. Dr John Woods discussed a "Virtual Ecology Workbench" (VEW3) wherein using a Lagrangian ensemble method, ecosystem levels can be addressed by examining individual-based formulations. The aim is to develop a modelling tool that is flexible, portable and allows researchers to ask questions about marine ecosystems within realistic physical environments. At present the model is one-dimensional in space, and is in the process of being extended to three-dimensions. Examples were shown of the importance to capture the interaction of individual life histories with the (physical and chemical/nutrient) environment. Dr Aisling Metcalfe presented results of a joint mesocosm-modelling research effort (NTAP). The results showed the response of the mesocosm to varying levels of nutrient enrichment and turbulence. It was found that increases in turbulence increased nutrient uptake rates by diatoms, decreased sedimentation of diatoms and increased the rate of consumption by meso-zooplankton. In the experiments and models the increases in diatom peaks outpaced the increase in zooplankton grazing suggesting a bottom-up control of the systems considered. Dr Christiane Lancelot discussed modelling approaches used in the study of harmful algal blooms (HABs) and coastal eutrophication in response to environmental changes (anthropogenic and climate induced). Results examining interannual blooms of *Phaeocystis* in the North Sea and particularly in response to river/nutrient discharges along the French and Belgian coasts were presented. Formal adjoint approaches were used to determine the model's sensitivity to the (over 100) parameters and/or "weak points" and it was found that no parameters could be eliminated. In order to make additional advances, a plea was made for enhanced interactions with experimentalists and observationalists.

There was general and strong enthusiasm for the advances made by modelling community. Models now are able to represent quite complex processes quite realistically. At the same time, the discussion also noted that there was a need for establishing methods for validating model results in general. Specifically, given the complexity of models, the need to collaborate with experimentalists and the mining of existing data sets was reinforced. Similarly, as models are now able to integrate over longer time scales (interannual and longer) the need to quantitatively couple with basin-scale models was expressed. The ability to quantify nutrient and species to-and-from the deep ocean onto the shelf was identified as needing to be studied.

7 Publication of workshop proceedings

The Scientific Advisory Committee for the Workshop on Future Directions in Modelling Physical-Biological Interactions has chosen to publish the proceedings of the workshop in a special issue of the Journal of Marine Systems. The idea is to have contributions from the invited speakers, the poster presenters, and one or two papers arising from the discussions at the meeting. All manuscripts should contain some new work and look into the future of the field. All manuscripts will go through the standard peer review process. The deadline for manuscript submissions is 31 August 2004. The letter of invitation that was used to solicit contributions to the special volume is in Annex 3.

8 Summation

There are several general scientific points that can be drawn from the Workshop.

1) There is an urgent need for experimentalists to provide guidance on how to organise organisms and groups of organisms into meaningful characteristic "organisms" amenable to parameterisation and incorporation into models. This includes information on when individuals rather than species need to be modelled and, extends the concept of functional groups to account for the fact that as the bio physical environment changes, the relative abundance of the species in the group may change and this will change the aggregated rate parameters.
2) The need for a constant flux of information and feedback between experimentalists and modellers can not be stressed enough.
3) The physical and biological aspects of environmental issues need to be addressed jointly, not separately.
4) As more and more data is gathered world-wide, there is a growing need to have this data easily accessible through networked databases. At the same time the modelling community needs to further take advantage of already existing databases.

5) Over large time scales, such as in climate change modelling, some ecosystem behaviour may be simplified into linear cause-effect relationships.
6) Fisheries oceanographers are showing the importance of considering ecosystem factors dynamically to predict recruitment.
7) Some issues such as thin layers, small-scale turbulence, and others, clearly require addressing time and space variability at much smaller scales than it is done today.
8) Many researchers feel the need for a greater biological complexity in models. This is a serious logistical problem for models that aim at a global scale or even for models aimed at regional and annual scales. Similarly to physical adaptive grids, an Adaptive Biological Complexity (ABC) grid concept is proposed to collapse the biological complexity when it is not needed and expand it at locations and times where it becomes relevant. Determining of the triggers for the automated collapse and expansion of the complexity should be an active area of research and development.
9) As ecosystem models that include physical-biological interactions, become reasonably complex, they are starting to be used operationally. In order to make predictions with a higher certainly, the community should learn from meteorologists and use predictions from different models and model resolutions as part of an ensemble, or probabilistic, approach to prediction.
10) There is a need to validate model results with observations, in both hindcast and forecast mode. Since there is little hope to exactly match observations with model output, probability distribution functions may be a way to quantify the agreement between models and observations.
11) There is a need to be able to compare different models. A large effort should be made to establish standardised datasets (real or artificial) that models can use and results be compared.

The response of the scientific community to the Workshop in terms of the number and quality of participants went well beyond the organisers' expectations. Feedback from the participants (see web page) shows they found the meeting very useful in advancing science and the discussions thought provoking. This is a success in itself. The main motivation of WGPBI for proposing this Workshop was that the quality and spectrum of presentations and the discussions would help identify key issues to be incorporated into the strategic plan of the WG. An additional benefit has been that, through the Workshop, WGPBI has gained more international exposure and awareness and membership has increased. The WG is now better prepared to continue its task of recommending further work and sponsoring actions in the field of modelling physical-biological interactions.

9 Annexes

Annex 1 Sample of letter for invited speakers

Barcelona, 14/10/2003

Dear Dr. Smayda,

The ICES Working Group on Modelling Physical-Biological Interactions (WGMPBI) is organizing a workshop on Future Directions in Modelling Physical-Biological Interactions (WKPBI) in Barcelona, Spain (March 8-9, 2004). This workshop will provide a forum for the discussion of the current generation of models and their strengths and weaknesses in addressing such interactions. The organizers are actively seeking the assistance of researchers from other ICES groups and beyond.

The goals of the workshop are to:
a) Review the current state of the art in several fields that require modelling physical-biological interactions and are relevant to ICES: e.g. fisheries recruitment, harmful algal blooms, eutrophication.
b) Identify the key areas where model improvements are desired.

You have been proposed by a scientific advisory committee as an invited speaker on the topic **Harmful algal blooms-Eutrophication** (please visit our website at www.icm.csic.es/wkpbi). With this letter we would like to invite you to this workshop and ask you to give a 30 min. talk on the above topic

If you accept this invitation, we will cover an inexpensive roundtrip airline ticket, lodging for 4 nights in Barcelona and a per diem of ca. 50 euro/day. Unfortunately, our funding is not yet absolutely secured. In case our funding would not come through (although this is quite unlikely), please understand that we would not be able to cover your travel and lodging expenses and of course, you would not be bound to attend the workshop. The reason to contact invited speakers before we have a confirmation on funding is to allow for time to make travel plans in advance.

We are looking forward to hear from you and to have you in Barcelona.

Francesc Peters and Charles Hannah
Chairmen of WKPBI

Annex 2 Workshop website

WORKSHOP ON PHYSICAL BIOLOGICAL INTERACTIONS - Netscape

WKFDPBI

ICES Workshop on Future Directions in Modelling Physical-Biological Interactions

Barcelona, 7-9 March 2004

- Sessions
- Schedule and abstracts
- Organizing committee
- Venue
- Accomodation
- Registration
- Abstract submission
- Presentation information
- Special volume
- Logo contest
- List of participants
- Abstract book
- Mail bonding
- Job announcements

This workshop is organized under the auspices of ICES (The international Council for the Exploration of the Sea) as a spin off from the Working Group on Modelling of Physical-Biological Interactions (WGPBI).

The purpose of this Workshop is to identify key areas where existing techniques for modelling physical-biological interactions need to be improved or addressed. The Workshop should attract 25-40 participants. We will invite participation from different ICES Working Groups with an interest in physical-biological interactions (e.g., WGPE, WGZE, WGHABD, WGCCC, WKHABWATCH, PGNSP, SGGOOS) and from groups such as GLOBEC, PICES and others. The workshop will also promote lines of communication with modelling communities throughout ICES member countries.

The findings will be reviewed and considered for incorporation into the strategic plan for the WGMPBI, ensuring that the workplan is consistent with the needs of the community.

WKFDPBI

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Pages last updated 7/5/2004

Web pages checked with NS 7.02 and IE 5.1
Webmaster

Annex 3 Copy of letter to invite contributions to the special volume

Dear all,

As some of you know, the Workshop on Future Directions in Modelling Physical-Biological Interactions (http://www.icm.csic.es/wkpbi) that was held in Barcelona (Spain) during March 7-9, 2004, was a participation and discussion success. We will now put together a Special Volume in the Journal of Marine Systems. You are invited to contribute to this special volume either because you gave a presentation (oral or poster) at the workshop, you are one of the rapporteurs or you had been contacted to be an invited speaker but could not make it for one reason or another.

If you wish to contribute to the Special Volume you should know that:
1. The manuscript should contain a significant percentage of new results.
2. The manuscript will be peer reviewed.
3. The manuscript should address all 3 aspects of the title of the Workshop, namely it should deal with 1) modelling issues of 2) physical-biological interactions and it should address 3) future directions in the field. Reviewers will be asked to make sure these aspects are addressed.
4. The manuscript should adhere to the guidelines of JMS. See http://www.elsevier.com/locate/jmarsys
5. The guest editors will be Charles Hannah (Bedford Institute of Oceanography, Canada) and Francesc Peters (Institut de Ciències del Mar, Spain).
6. The deadline for submission of manuscripts is August 31, 2004.

Please send manuscripts to either Charles Hannah or myself.

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Annex 4 Meeting statistics

The meeting had a registration of 88 people, of which 3 did not show up. Twenty participants were from the host institution. Participants represented institutions from 15 different countries, plus two more nations (Catalonia and Scotland). Nine participants were from North America.

There were 15 invited speakers, although Dr Laurent Seuront had to cancel at the last minute owing to family health reasons. The travel and lodging expenses of 9 speakers were covered by the organisation. Three invited speakers were female. There were 30 contributed poster presentations.

Four computers (mainly for e-mail) were available exclusively for WKFDPBI participants.

Annex 5 Report writing

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Annex 6 Workshop program and abstract book

Workshop on Future Directions in Modelling Physical–Biological Interactions

International Council for the Exploration of the Sea

WKFDPBI

Institut de Ciències del Mar, CMIMA (CSIC)
Barcelona, Catalunya (Spain)

March 7–9, 2004

WKFDPBI

ICES Workshop on Future Directions in Modelling Physical-Biological Interactions

Barcelona, March 7-9, 2004

This workshop is organized under the auspices of ICES (The international Council for the Exploration of the Seas) as a spin off from the Working Group on Modelling of Physical-Biological Interactions (WGPBI). It is financed by the Spanish Ministry of Science and Technology (MCYT), the Spanish Research Council (CSIC) and the European Union project NTAP. The meeting venue is the Centre Mediterrani d'Investigacions Marines i Ambientals (CMIMA, CSIC) in Barcelona, Catalunya, Spain.

The purpose of this Workshop is to identify key areas where existing techniques for modelling physical-biological interactions in oceanography need to be improved or addressed. Target aspects include the interaction of planktonic organisms and processes with light, temperature, nutrient or food particle fields and hydrodynamics. Questions on how to address physical-biological interactions that occur over a range of spatial and temporal scales in models that have a regional/annual scope are greatly welcome as are modelling approaches to such issues (Eulerian versus Lagrangian, IBMs, inverse modelling, network analysis, statistical models, etc.).

The Workshop is aimed as an open forum and we invite participation from different ICES Working Groups with an interest in physical-biological interactions (e.g., WGPE, WGZE, WGHABD, WGCCC, WKHABWATCH, PGNSP, SGGOOS) and from groups such as GLOBEC, PICES and others. The workshop will also promote lines of communication with modelling communities throughout ICES member countries.

The findings will be reviewed and considered for incorporation into the strategic plan for the WGPBI, ensuring that the workplan is consistent with the needs of the community.

Contents

Organization

Scientific Advisory Committee

Charles Hannah (Chairperson)
Bedford Institute of Oceanography, Dartmouth, Canada

Francesc Peters (Chairperson)
Institut de Ciències del Mar, Barcelona, Spain

Wolfgang Fennel
Institut für Ostseeforschung, Warnemünde, Germany

Cèlia Marrasé
Institut de Ciències del Mar, Barcelona, Spain

Tom Osborn
The Johns Hopkins University, Baltimore, U.S.A.

Einar Svendsen
Institut of Marine Research, Bergen, Norway

Cisco Werner
University of North Carolina, Chapel Hill, U.S.A.

Local Executive Committee

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Institut de Ciències del Mar, Barcelona, Spain

Meeting Program at a Glance

	Sunday 7	Monday 8	Tuesday 9
08:30		REGISTRATION	
09:00			*Session 3: Fish stock recruitment*
09:30		OPENING ADDRESSES	
10:00		*Session 1: Harmful algal blooms / Eutrophication*	
10:30			
11:00		COFFEE BREAK	COFFEE BREAK
11:30		*Session 1 cont'd*	*Session 3 cont'd*
12:00			
12:30			TOUR OF CMIMA
13:00			
13:30		LUNCH BREAK	LUNCH BREAK
14:00			
14:30			
15:00	REGISTRATION		*Session 4: Modelling approaches*
15:30		*Session 2: Ecosystem integration and questions of scales*	
16:00			
16:30		COFFEE BREAK	COFFEE BREAK
17:00		*Session 2 cont'd*	*Session 4 cont'd*
17:30			
18:00			
18:30		*Poster Session*	CLOSING ADDRESSES
19:00			
19:30			
20:00			
20:30			
21:00		WORKSHOP BANQUET	

4

Session Information

Monday morning

08:30 REGISTRATION

09:30 OPENING ADDRESSES

Dr. Dolors Blasco, director of the Centre Mediterrani d'Investigacions Marines i Ambientals, CSIC (Spain)
Dr. Francesc Peters, Co-chairperson of the Workshop
Dr. Charles Hannah, Co-chairperson of the Workshop

Session 1: Harmful algal blooms / Eutrophication.

Chairperson: [1]C. Marrasé, Institut de Ciències del Mar, CSIC (Spain)
Rapporteur: T. Osborn, Johns Hopkins University (USA)

10:00 Harmful algal blooms and eutrophication: Is there a linkage?

T.J. Smayda

10:30 Eutrophication and the state of marine pelagic systems.

P. Tett

11:00 COFFEE BREAK

11:30 Phytoplankton strategies in a turbulent environment.

M. Estrada

12:00 The role of finescale physical-biological interactions in controlling the dynamics and impacts of thin layers of harmful algal in stratified coastal waters.

P.L. Donaghay

12:30 DISCUSSION

[1] Substituting Dr. Elisa Berdalet

Monday afternoon

Session: Ecosystem Integration and questions of scale.

Chairperson: M.A. Rodríguez, Universitat de Barcelona (Spain)
Rapporteur: W. Fennel, Institut für Ostseeforschung (Germany)

15:30 Climate variability and marine ecosystems - identification of mediators and predictability.

J.W. Dippner

16:00 Key oceanic physical mechanisms controlling fluxes at different scales.

J.L Pelegrí

16:30 COFFEE BREAK

17:00 Modelling the Baltic Sea ecosystem - from simple approaches to complex models.

T. Neumann, W. Fennel & C. Kremp

17:30 DISCUSSION

18:30 POSTER SESSION

21:00 WORKSHOP BANQUET

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Tuesday morning

Session: Fish stock recruitment.

Chairperson: [1]A. Gordoa, Institut d'Estudis Avançats de Blanes, CSIC (Spain)
Rapporteur: C. Hannah, Bedford Institute of Oceanography (Canada)

09:00 Uncertainty in model-data interplay for coupled biological-circulation models.

P. Pepin

09:30 Coupled physical biological modeling in recruitment prediction: Where we are and how to get there from here…

M. St. John, H.H. Hinrichsen

10:00 Oceanic overwintering of *Calanus* and nauplii production on the shelf the following spring. A model study.

D. Slagstad

10:30 Simulating the adaptive buoyancy and vertical distribution of anchovy and sardine eggs.

G. Boyra, S. Coombs, L. Rueda, M. Santos & A. Uriarte

11:00 COFFEE BREAK

11:30 DISCUSSION

12:30 TOUR OF CMIMA

[1] Substituting Dr. Francesc Maynou

Tuesday afternoon

Session: Modelling approaches.

Chairperson: J. Solé, Institut de Ciències del Mar, CSIC (Spain)

Rapporteur: F. Werner, University of North Carolina (USA)

15:00 The Virtual Ecology Workbench - VEW3

J. Woods, T. Field

15:30 Modelling plankton communities subject to turbulence.

A.M. Metcalfe

16:00 Modelling approaches for predicting HABS and coastal eutrophication in response to anthropogenic and climate changes: plea for an integrated research methodology.

C. Lancelot

16:30 COFFEE BREAK

17:00 DISCUSSION

18:30 WORKSHOP CLOSING
Dr. Charles Hannah, Co-chairperson of theWorkshop

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Abstracts

Invited Oral Presentations

SS1 Monday 10:00

Harmful algal blooms and eutrophication: Is there a linkage?

Smayda, T.J.

Graduate School of Oceanography, University of Rhode Island, Kingston, RI 02881 U.S.A.

Four primary causation theories have been advanced to explain the global epidemic in harmful algal blooms (HAB): increased cultural eutrophication, aquacultural initiatives, and unusual climatological conditions ('changing environment' theories). The 'emigration theory' holds that the dispersal of species in ballast water is a major driver of the HAB epidemic. Quantification of the eutrophication-HAB linkage has been compromised by inexact definition of eutrophication; failure to view eutrophication as a process; HAB occurrences in oligotrophic waters; the role of phosphorus during HAB events in coastal waters traditionally considered to be nitrogen-limited systems, and the incorrect view that HAB species have high nutrient uptake efficiency (low Ks). These issues and eutrophication as a process and its influence on HABs are discussed. The view that HABs occur within a common ecological zone of high watermass stabilty, low nutrients and high irradiance is refuted. Physiological data suggest that HAB species generally require high nutrient levels because of their inefficient nutrient uptake. HABs are often stimulated by high levels of nutrients from domestic and agro-industrial sources. However, it is hypothesized that the grazer community then determines whether a HAB develops and the HAB species selected. That is, eutrophication leads to prey-predator mismatches, with the observed HAB response primarily the result of failure of, or altered grazing processes and, secondarily, a result of nutrification. Local and global scale evidence shows that cultural eutrophication can stimulate HABs. However, HAB are also induced by the various combinations of nutrient-mixing-irradiance-grazing that accompany natural variability and other 'changing environment' triggers. Time allowing, the types of HAB cellular and population models needed and some unique features of dinoflagellate autecology relative to diatoms that complicate HAB model building will be discussed.

SS1 Monday 10:30

Eutrophication and the state of marine pelagic systems.

Tett, P.

School of Life Sciences, Napier University, Edinburgh EH10 5DT, Scotland

Marine pelagic ecosystems are characterised by spatial and temporal variability. The latter includes high-frequency semi-random variation, seasonal change, interannual variation, and long-term trends ascribed to changes in climate and the effect of fisheries, nutrient enrichment, and chemical pollution. A general scientific problem is thus to detect major ecosystem changes against a background of 'random' variability, explaining them in terms of significant drivers, and assess these changes in relation to ecosystem function and human interests. In the case of the undesirable consequences of eutrophication, the problem is also to distinguish changes driven by nutrient enrichment from those due to other drivers.

This paper explores an approach to this problem using mathematical models and the concept of ecosystem state. In thermodynamics, the state of a system is defined by the values of state variable, such as the temperature, pressure and volume of a perfect gas. An ecosystem is more complicated than such a gas and hence may need many more state variables. To be practically useful, however, the full set must be reduced to smaller sets conveying most of the relevant variation. Ecosystem models, exemplified by ERSEM and PROWQM exhibit one level of reduction; screening models, such as that of the CSTT reduce the system to a small handful of state variables. The paper will draw on work from the EC FP5 OAERRE project to show how model-defined trajectories through a phase space defined by pairs of state variables, or their functions, can be used to help understand eutrophication.

Reference: Tett, P., Gilpin, L., Svendsen, H., Erlandsson, C. P., Larsson, U., Kratzer, S., Fouilland, E., Janzen, C., Lee, J.-Y., Grenz, C., Newton, A., Ferreira, J. G., Fernandes, T. & Scory, S. (2003). Eutrophication and some European waters of restricted exchange. Continental Shelf Research, 23, 1635-1671.

SS1 Monday 11:30

Phytoplankton strategies in a turbulent environment.

Estrada, M.

Institut de Ciències del Mar, CMIMA (CSIC), Passeig marítim de la Barceloneta, 37-49, 08003 Barcelona, Spain

Turbulent water motion at a wide range of spatio-temporal scales is a key property of the aquatic ecosystem and interacts with biological factors to produce a highly dynamic variety of ecological niches. Phytoplankton organisms exploit the spectrum of environmental variability through a large array of morphological, ecophysiological, life-history and behavioural features. The functional group approach, based on the grouping of species showing similar responses to patterns of environmental conditions, provides a way of simplifying the diversity of the real world and may be useful in the context of modelling applications. This communication presents some examples, based on laboratory experiments and field surveys, of the use of statistical approximations in highlighting groups of species with common strategies.

SS1 Monday 12:00

The role of finescale physical-biological interactions in controlling the dynamics and impacts of thin layers of harmful algal in stratified coastal waters.

Donaghay, P.L.

Graduate School of Oceanography, University of rhode Island, Narragansett, RI, U.S.A.

One of the major challenges in modeling the dynamics and impacts of harmful algal blooms is to determine the scales that control critical physical-biological interactions, and then develop techniques to measure those processes and incorporate them into numerical models. This problem is particularly challenging for harmful algae that form layers that are substantially thinner than the multi-meter scales that are typically resolved in physical models or easily sampled from ships. Herein we will first use field data to evaluate the vertical sampling scales needed to resolve the finescale biological, chemical and physical structure of thin layers, and then use those data to evaluate the importance of finescale physical-biological interactions in controlling the dynamics and impacts of such layers. In a final section we will consider how these processes might be incorporated into models.

SS2 Monday 15:00

[1]Elucidating large-scale patterns and processes from understanding biophysical properties and interactions at micro-scale in the marine environment?

Seuront, L.(1,2), Waters, R.L.(2), Seymour, J.R.(2), Mitchell, J.G.(2,3)

(1) Ecosystem Complexity Research Group, Station Marine de Wimereux, CNRS UMR 8013 ELICO, Université des Sciences et Technologies de Lille, 28 avenue Foch, 62930 Wimereux, France
(2) School of Biological Sciences, The Flinders University of South Australia, GPO Box 2100, Adelaide 5001 South Australia
(3) Marine Ecosystems Dynamics, Marine Microbiology, Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo 164-8639, Japan

The central tenet of ecology is the elucidation of the spatio-temporal organization of community structure and dynamics. In particular, spatial ecology investigate how physical and biological processes interact through their spatial and temporal scales, and influence population and community dynamics. Theoretical studies have suggested that biotic properties of individuals and populations interact to produce spatio-temporal complexity in otherwise homogeneous environments. Environmental complexity interacts with biotic processes and further influences spatial patterns. Biomass and species are thus rarely dispersed uniformly. Instead patchiness (also referred to as 'spatial heterogeneity') is the norm, and ecological field studies and environmental monitoring programs must be designed accordingly. However, in aquatic ecology conventional sampling still implicitly assumes a steady state, especially at the microscale. From a series of one-, two- and three-dimensional high-resolution (millimetre to centimetre) empirical data sets we will qualitatively and quantitatively demonstrate that the seldom addressed hypothesis that two nearby drops of water could be regarded as two different ecosystems (Azam 1998, Science 280,694) must be regarded as the rule rather than the exception in planktonic ecosystems. Specifically, we will show different levels of spatial complexity in the abundance and activity of bacterial populations, and the abundance of phytoplankton taxonomic groups suggesting spatial niche separation and ultimately deeply questioned the relevance of any single point sampling. We will subsequently use the observed distributions to numerically investigate their potential impact on higher trophic levels, namely protozooplankton and mesozooplankton trophodynamics. Finally, we will use numerical and empirical arguments to address the effects of the intrinsic, but seldom investigated, intermittent property of microscale turbulence on the planktonic microenvironment.

SS2 Monday 15:30

Climate variability and marine ecosystems – identification of mediators and predictability.

Dippner, J.W.

Baltic Sea Research Institute, Warnemünde, Germany

Many authors have shown correlations between climate variability and the variability of marine organisms such as phytoplankton, zooplankton, benthos or fish recruitment in different parts of the world ocean. The mechanisms how marine organisms react to climate variability are not understood. Often a phase lag exist between climate variability and the reaction of organisms. Therefore it is not clear who plays the role of mediator between climate and biology. As mediators are considered all possible physicochemical mechanisms having a direct or indirect influence on the variability of marine organisms.
The understanding of the reason of the phase lag, which possibly implies a "biological memory", and the identification of possible mediators are necessary to predict the response of marine organisms to climate variability. The future direction of forecast marine ecosystems is discussed.

[1] This presentation was not given

SS2 Monday 16:00

Key oceanic physical mechanisms controlling fluxes at different scales.

Pelegrí, J.L.

Institut de Ciències del Mar, CMIMA-CSIC, Passeig Marítim de la Barceloneta, 08003 Barcelona, Spain

Diffusive transport in the ocean is an artificial concept because it depends on the spatial and temporal scales under consideration, advection at one scale becoming diffusion at a larger/longer scale. Models, however, do incorporate this distinction so their transport predictive skill relies on a truthful representation of the mechanisms operating at small/short scales. This is only possible if the physical mechanisms that cause these fluctuations are thoroughly understood.

Our objective here is to discuss physical variability at different spatial and temporal scales, and to examine how it results in the redistribution and net transport of physical and biological properties. With this purpose we first examine the different ways in which fluctuations may produce diffusive-type processes that lead to mean distributions at larger/longer scales: diapycnal transformations, downgradient epipycnal diffusion, and down or upgradient epypicnal pumping.

Next we examine some of the principal physical mechanisms responsible for those fluctuations at a range of spatial and temporal scales, and discuss which are the key processes for transporting properties. The examples discussed include gyre (nutrient irrigation) and regional circulation (coupling between open ocean and coastal upwelling region), mesoscale features (eddies and meanders), mixed boundary layers (upper and bottom), and fine structure (heat and nutrient exchange).

SS2 Monday 17:00

Modelling the Baltic Sea ecosystem – from simple approaches to complex models.

Neumann, T., Fennel, W., Kremp, C.

Baltic Sea Research Institute, Warnemünde, Germany

The Baltic Sea is one of the largest brackish water systems. Due to restricted water exchange with the North Sea the residence time is about 20 years, implying serious impacts of nutrient loading and slow responses of the ecosystem to long term changes.

Different, partly conflicting interests have an impact on the quality of the environment of the Baltic Sea. Industry and agriculture of riparian countries with dense population generate industrial and municipal waste as well as nutrient loads, while beaches are recreation areas and tourism is an important factor for local income and last not least fishery benefits from the healthy Baltic Sea. The varying emphasis of the stakeholders forces the need for an appropriate management based on a sound understanding of the systems functioning that in turn requires basic and applied research.

Appropriate tools for synthesizing our understanding of complex systems like the Baltic Sea are ecosystem models. While on shorter time scales simpler models can be used for short term simulations of events, for changes on longer time scales, e.g. decadal simulations, advanced coupled model systems are required. Models aiming at on higher trophic levels have to resolve live cycles of animals.

The talk discusses models of increasing complexity and their applicability to different scientific questions. Examples of model simulations of a flood event, nutrient load reduction scenarios and stage resolving zooplankton developments are given and discussed.

SS3 Tuesday 9:00

Uncertainty in model-data interplay for coupled biological-circulation models.

Pepin, P.

Northwest Atlantic Fisheries Centre Fisheries and Oceans Canada, St. John's, Newfoundland, Canada

Individual-based models of biological processes coupled with local or regional circulation models are increasingly being used to study the dynamics of larval fish populations. Forward projections are used to predict patterns of mortality while backward projections enable environmental reconstruction to be contrasted with growth histories. In all instances, there are uncertainties in the projected conditions due to dispersion of organisms, the accuracy of our representation of environmental variability and model structure. The consequences of the former two sources of uncertainty on our ability to detect environment-fish relationships (i.e. growth or mortality) are discussed in relation to the implementation of stochastic models of prey-predator interactions. In the end, it is the accuracy of our representation of environmental structure and stochasticity in prey-predator encounters between sampling locations that may place the most serious limits on detecting environmental effects on early life stages of fish.

SS3 Tuesday 9:30

Coupled physical biological modeling in recruitment prediction: Where we are and how to get there from here...

St. John, M.(1), Hinrichsen, H.-H.(2)

(1) Institute of Hydrobiology and Fishery Sciences, University of Hamburg, Germany
(2) IfM-GEOMAR, Fishery Biology,

The justification for coupled modeling approaches in the study of larval fish is the refinement of recruitment predictions to encompass the effects of environmental processes. Modeling approaches focus on classic recruitment hypotheses, these being the match and mismatch of larvae and their prey and the transport and or retention of larvae in or to critical refuges from predators or optimal prey conditions. At present two approaches are employed for developing recruitment relationships, both employing state of the art hydrodynamic models. The first approach is based on the seeding of a flow field with a population of eggs and larvae in known spawning locations and through the use of flow fields generated by the hydrodynamic model and Individual based models of larval feeding and growth, predictions of larval size and destination is simulated. The second approach is based on the "characteristics of survivors". This approach uses sequential sampling of the population and the examination of phenotypic and genotypic characteristics of individuals before and after experiencing an event to resolve traits and processes influencing survival success. Here using hydrodynamics models in a "back track" mode researchers can identify critical abiotic and biotic processes. Time series of these key processes are then developed for inclusion in, models to predict recruitment dynamics. The utility and future directions for both approaches will be presented and discussed.

SS3 Tuesday 10:00

Oceanic overwintering of *Calanus* and nauplii production on the shelf the following spring. A model study.

Slagstad, D.

SINTEF Fisheries and Aquaculture, Norway

Very high concentrations of overwintering *Calanus finmarchicus* was found in the eastern Lofoten basin close to the shelf break. A coupled hydrodynamic and ecological model has been used to study the dynamics formation of the overwintering distribution and its stability during the winter months when *C. finmarchicus* stay at the overwintering depth. In late summer high concentration of overwintering animals were found near the shelf break north of the North Sea, North eastern part of the Vøring Plateau and in the eastern part of the Lofoten Basin just outside slope of the Barents Sea shelf. Particle tracking experiments showed that most of the particles were drained out from the shelf in late summer. The particles are more or less kept in these positions due to a southward current at the overwintering depths. These current is not continuous along the shelf break, but interrupted at topographic structures. At the interruption points the current make a turn west and create an anticyclonic gyre. The average residence time is 3 to 4 months, but as much as 30 to 60% of animals entering the gyre in late summer my still be kept inside the eddy after 7 months. There is large interannual variability. Particle tracking experiments further shows the high overwintering areas on the Vøring Plateau Gyre and the East Lofoten Basin Gyre that are the major contributors to the imported Barents Sea stock of *Calanus* the following spring.

SS3 Tuesday 10:30

Simulating the adaptive buoyancy and vertical distribution of anchovy and sardine eggs.

Boyra, G., Coombs, S., Rueda, L., Santos, M., Uriarte, A.

AZTI Foundation, Spain

Biomass estimations of pelagic fish species in the Bay of Biscay are usually carried out using the Daily Egg Production Method, in which adult abundance is estimated from fish egg concentration. The change from vertical to continuous samplers (as estimators of the total egg abundance per sea surface unit) reduces the sampling time but limits the sample collection to a fixed depth. Therefore, a vertical distribution model of eggs was needed to extrapolate the egg abundance at a fixed depth to the total abundance.

We developed a 1D stationary model of vertical distribution of anchovy and sardine eggs, taking as starting point the Sundby model (1983), improved through some modifications in the turbulence parameterisation and adaptability of egg buoyancy to the environment.

In order to study more precisely the adaptability, we also developed a 1D transient model, that included the permeability of the external membrane (or chorion) of the eggs, to simulate the movement of sardine eggs released at the top of a density gradient column. The permeability of the chorion would permit the flow of salted water inside or outside the egg, provoking the adaptation of egg density to the medium (specially for species of large perivitelline space, as sardine), this affecting to their actual vertical distribution. Experimental measures of settling velocity of eggs in a density gradient column were performed and compared to the modelled ones. The results of the comparison clearly confirmed the adaptive behaviour of sardine eggs and allowed to infer an optimum value for the permeability of their chorion.

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SS4 Tuesday 15:00

The Virtual Ecology Workbench - VEW3.

Woods, J., Field, T.

Imperial College, London, U.K.

We want a magic box that allows us marine ecologists without software engineering skills to create and analyse mathematical simulations of the plankton ecosystem with our own choice of species and at a location of our choice, with forcing that creates realistic physical, chemical and biological environment. We want it to be easy to use, so that we can quickly explore different assumptions about the biology and environment. But we do not want it to compromise on realism in physical-biological interactions. Ideally it should combine individual-based modelling with accurate demography of each population and accurate biofeedback to the environment. It should provide explicit quality control.

The Virtual Ecology Workbench does all that. VEW3 allows you to choose any combination of plankton species defined by biological primitive equations. And it is global: you can create a scenario using OCCAM circulation and ERA weather for the last 45 years, plus any special events such as climate change or pollution. VEW3 has a user-friendly graphical interface. It codes the model-plus-scenario automatically in Java so the simulation can be created on your own computer, even an AppleMac. It uses Lagrangian Ensemble integration to produce life histories of individual plankton lineages, demographic histories of populations, and time series of the synoptic environment. VEWdata provides powerful tools to simplify diagnosis of these large data sets.

I shall demonstrate the prototype of VEW3. And I shall show how it is used to investigate biological-physical interactions in the plankton ecosystem by simulating the plankton ecosystem one-dimensionally in a virtual water column drifting with the mean circulation. It is now being beta tested.

SS4 Tuesday 15:30

Modelling plankton communities subject to turbulence.

Metcalfe, A.M.

Department of Applied Mathematics and Theoretical Physics, University of Cambridge, U.K.

I will describe the modelling of enclosure experiments which investigated the effect of small-scale turbulence on plankton communities as part of the project NTAP (nutrient dynamics mediated through turbulence and plankton interactions).

In the experiments natural plankton assemblages, taken from waters off the Norwegian coast, were subjected to various levels of turbulence and initial nutrient enrichment.

The model groups the plankton population as bacteria, autotrophic flagellates, diatoms, heterotrophic flagellates, ciliates and meso-zooplankton. Theory predicts that turbulence will increase the rate of nutrient uptake by diatoms and that low and moderate levels of turbulence will increase the rate of predation by meso-zooplankton but that high levels of turbulence will decrease it. In the experiments turbulence also decreased the amount of sedimentation by diatoms. These three different effects of turbulence have been incorporated into our model. The model results show that the dominant effects of turbulence are the increase in diatom nutrient uptake and the reduction in diatom sedimentation, both of which lead to an increase in diatom concentration with turbulence, a result which agrees with experiment.

SS4 Tuesday 16:00

Modelling approaches for predicting HABS and coastal eutrophication in response to anthropogenic and climate changes: plea for an integrated research methodology.

Lancelot, C.

Université Libre de Bruxelles, Ecologie des Système aquatiques, Boulevard du Triomphe, CP-221, B-1050, Brussels, Belgium

Eutrophication and climate change are assumed to affect the dynamics of potentially harmful algal species, as nutrients, light and temperature affect the growth rate of all phytoplankton species. Therefore one key to the long term sustainability of coastal marine systems is to understand how natural and human-induced changes in ecosystems interact. Complex models based on physical and biological principles and integrating the current knowledge of ecosystem functioning constitute valuable tools to identifying and understanding the climatic and human-induced drivers of ecosystem structure and function in coastal seas. Such models do exist for predicting HABS but most of them are species- and area-specific. Based on a review of existing models we identify strength and weakness of these coupled physical-biological models in term of their skill at (i) defining properly plankton functional groups; (ii) conceptualising key processes at a mechanistic level; (iii) reproducing coastal sea physics; (iv) validating model behaviour throughout model-data comparison and (v) understanding the prediction capability of these non linear systems. Making use of our own experience gained from the Belgian AMORE project on predicting and mitigating *Phaeocystis* blooms in the North Sea we then discuss advantages of conducting an integrated research methodology that combines in an interactive and iterative way different modelling (Eulerian and inverse models, statistical and network analysis) and experimental (traditional monitoring, remote sensing and process level studies) approaches. Installing such a sustained dialogue between different communities of modellers and experimentalists warrants the implementation of a conceptual approach and cross combination of expertise in ecophysiology and modelling, the identification of new research requirement, the design of monitoring strategies and mathematical tools for guiding environmental management.

Poster Presentations

PS1.1

Plankton community level responses to turbulence and nutrient load: experimental results.

Peters, F.(1), Marrasé, C.(1), Alcaraz, M.(1), Dolan, J.(2), Egge, J.(3) Guadayol, O.(1), Havskum, H.(4), Jacobsen, A.(3), Stiansen, J.E.(5), Vidal, M.(6)

(1) Institut de Ciències del Mar (CSIC), Barcelona, Spain
(2) Laboratoire d'Oceanologie de Villefranche (CNRS), Villefranche-sur-Mer, France
(3) Dept. of Fisheries and Marine Biology, University of Bergen, Bergen, Norway
(4) University of Copenhagen, Copenhagen, Denmark
(5) Institute of Marine Research, Bergen, Norway
(6) Vidal, M., Dept. d'Ecologia, Universitat de Barcelona, Barcelona, Spain

There is evidence that turbulence affects plankton community metabolism differently depending on nutrient load. We examined the combination of turbulence and nutrient enrichment in mesocosms in Espegrend, Norway and in Barcelona, Spain. Mesocosms of 2.6 cubic meters were placed onshore allowing for proper control of turbulence by means of vertically-oscillating grids.
Turbulence levels spanned 4.7 orders of magnitude in energy dissipation rate while nutrient load ranged from 0 to 24 µM in terms of nitrate. Phosphate was added in Redfield ratio and silicate at the same molarity as nitrate.
Nutrient load increases the proportion of autotrophic biomass and of total living particulate organic carbon. Turbulence also increases autotrophic biomass but not always total carbon. Sedimentation appears to be an important factor. We will discuss these results in the framework of coastal zones addressing the fate of organic carbon based on the timing of turbulence with nutrient load events and the presence of a population of zooplankton.

PS1.2

Using the 3D coupled physical-biological model MIRO&CO-3D to assess diatom-*Phaeocystis* colony blooms in the Southern Bight of the North Sea and the response to short-term climatic and nutrient changes.

Lacroix, G.(1), Lancelot, C.(2), Ruddick, K.(1), Spitz, Y.(3), Gypens, N.(2)

(1) Management Unit of the North Sea Mathematical Models, Gulledelle 100, 1200 Brussels, Belgium
(2) Ecologie des systèmes aquatiques, Université Libre de Bruxelles, Campus de la Plaine - CP 221, Boulevard du Triomphe, 1050 Bruxelles, Belgium
(3) Oregon State University/COAS, 103 Ocean Admin. Bldg, Corvallis, OR 97331, U.S.A.

There is evidence that the North Atlantic Oscillation (NAO) has a substantial impact on phytoplankton bloom dynamics and species dominance in the NW European shelf seas. However mechanisms are still poorly understood and the added influence of human activity needs to be assessed. Such is the case in the Southern Bight of the North Sea, a highly dynamic system with water masses resulting from the variable mixing between the in-flowing southwest Atlantic waters through the Strait of Dover and freshwater and nutrient inputs from mainly the Scheldt, Rhine-Meuse, Seine and Thames rivers. Here we developed a 3D coupled physical-biological model (MIRO&CO-3D) to explore the dual role of short-term climate variability and nutrients of anthropogenic origin on the magnitude and extent of diatom-*Phaeocystis* bloom in the Southern Bight of the North Sea during the last decade. MIRO&CO-3D results from the online coupling of the COHERENS 3D hydrodynamic model and the complex ecological model MIRO. This coupled model allows to resolve the changing nutrient loads, the complex biology and hydrodynamics and the strong coupling between the benthic and pelagic realm that characterises the coastal shelf ecosystem. The model has been set up for the region between 48.5°N and 52.5°N. The MIRO&CO-3D model has been run to simulate the annual cycle of inorganic and organic nutrients, phytoplankton (diatoms & *Phaeocystis*), bacteria and zooplankton (microzooplankton & copepods) in the Southern Bight of the North Sea under real forcing (meteorological and river loads) for the period 1991-2000. These model runs give a general view of the seasonal and geographical spreading of blooms within the domain. Model results also show significant variability in bloom timing, magnitude and geographical extension for years characterised by contrasted NAO.

PS1.3

Effects of changing nutrient loads to the North Sea.

Skogen, M.D., Søiland, H., Svendsen, E.

Institute of Marine Research, Pb.1870 Nordnes, N-5817 Bergen, Norway

The environmental effects of river nutrient loads to the North Sea have been investigated using a numerical biophysical model, NORWECOM, to perform different reduction scenarios. The simulations demonstrate that the river nutrients have a significant contribution on the annual primary production, both in the southern North Sea, in Skagerrak and along the Norwegian west coast. A 50% reduction in the loads of N and P reduces the primary production with 10-30% in the southern North Sea, and 5-10% in Skagerrak and along the Norwegian west coast. Scandinavian rivers only contribute to the 1-2% level in these reductions, thus continental rivers has the major effect on the environment in all downstream areas. However, it should be noted that this reduction, even in the southern North Sea, is less than the natural variability of the production of phytoplankton. A reduction only in the P values, shows that the production regime in the southern
North Sea is phosphorous limited, while nitrogen is the limiting nutrient in the northern North Sea. Focusing on the N/P ratio as a possible proxy for eutrophication, a reduction in the N and P loads reduces this ratio by a similar factor, while a reduction in the P loads only, increases it. Based on this it is proposed to use the N/P ratio for eutrophication assessment, and this is demonstrated.

PS1.4

A simple assimilative capacity model for fjordic environments.

Laurent, C., Tett, P., Fernandes, T., Gilpin, L.

Napier University, Edinburgh, Scotland

The assimilative capacity of a system was defined by the United Nations Environmental Programme's Group of Experts on Scientific Aspects of Marine Pollution as "its ability to accommodate a particular activity or rate of activity without unacceptable impacts." Unacceptable levels of impact must be set by statutory environment agencies, but simple models for input, conversion and loss of pollutants provide tools which can facilitate the decision-making process.
A simple model was designed by the UK CSTT for predicting the effects of nitrogen and phosphorus in urban wastewater on worst-case chlorophyll concentration scenario in a mixed box. This model has been applied to a number of regions of restricted exchange during the OAERRE project. The present work, aimed at developing a tool to estimate the nutrient assimilative capacity of semi-enclosed coastal waters, uses an improved and dynamic version of the OAERRE-CSTT model. The new model takes account of key Environmental Quality Variables (EQVs) and so it may be called an Environmental State Vector (ESV) model. The variables used in the model include: dissolved inorganic nutrients, particulate organic matter, chlorophyll, flagellate/diatoms ratio (y), dissolved oxygen, temperature and salinity.
Fieldwork to validate the model was carried out in the partly-mixed fjordic Loch Creran, in the Scottish Highlands, in 2003. Within the loch is currently located a large salmon farm and several mussel farms. Present day conditions can be compared with those observed during the 1970s. This poster presents a preliminary three-way comparison between the predicted chlorophyll and nutrients concentrations with the historical data and recently collected data.

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PS1.5

Short-term effects of nutrient reductions in the North Sea and the Baltic Sea as seen by an ensemble of numerical models.

Stipa, T.(1), Skogen, M.D.(2), Sehested Hansen, I.(3), Eriksen, A.(3), Hense, I.(1), Kiiltomäki, A.(1), Søiland, H.(2), Westerlund, A. (1)

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The NO COMMENTS project of the Nordic Council of Ministers (NMR) has pursued to demonstrate that three-dimensional numerical biogeophysical ocean modeling in Nordic sea areas (North Sea, Baltic Sea and their transition area) can provide information on the short-term sensitivity of ecosystem to anthropogenic preturbations. Three different three-dimensional coupled physical-biological ocean models have been applied to study the effects of reduced external nutrient input to the on the development of primary producers. In line with the reductions proposed by e.g. HELCOM and OSPARCOM, scenarios with 30% reductions in dissolved inorganic nutrient input have been carried out. The changes that are visible within one year of four environmental quality indicators - the nitrogen to phosphorus ratio and the vertically integrated phytoplankton biomass in the middle of the summer, the annual maximum of the phytoplankton biomass, and the total annual primary production - have been analysed.
The model results indicate large local and regional differences in the response to nutrient reduction: The largest sensitivities ("hot spots") are found on the west coast of Denmark, the Kattegat area as well as in the Gulf of Riga and the Bay of Bothnia in the Baltic Sea. The effect of the reduction is seen to depend on the initial state of the sea area. However, variations occur between the different models, indicating the need of further validation. In general, the reduction effects on this timescale are relatively small on the modeled time scale, and in many cases constrained into the immediate vicinity of the source. A large-scale, immediate response is found for the direct atmospheric deposition of nitrogen in N-limited sea areas.

PS1.6

Cyanobacterial anomaly in the Gulf of Finland, 2003 - an explanation through a combination of model and field experiment results.

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Late winter phosphate concentrations in the Gulf of Finland were exceptionally high in the year 2003. For decades, such a surplus of phosphate in the pre-bloom period has been conceived as a precondition for extensive cyanobacterial blooms in the summer, and has recently been used to produce graphical maps of the potential for blooms. However, the observed blooms during July-August were modest at best.
Our data from the pre-bloom period of summer 2003 in the western Gulf of Finland show that nutrient conditions were favourable for the formation of cyanobacterial blooms still close to the bloom season. In May and June of 2003, PO4 concentrations in the western Gulf of Finland varied between 0.2 and 0.5 μM, and were higher than in the previous years. In addition, our results on phosphate stress studies of cyanobacteria expressed by ELF labelling (Enzyme Labelled Fluorescence) showed that the July populations of cyanobacteria only locally suffered from phosphate starvation, and an intense heatwave in July provided the suitable environmental conditions for growth. Yet despite the favorable physiological indicators and environmental conditions, the observed cyanobacterial biomasses were low.
An explanation for the discrepancy between the indicators for cyanobacterial blooms and the realised situation is found by analysing forecast results from the FIMR operational 3D ecosystem model, and the hindcasts from a fuzzy logic -based cyanobacterial model. The atmospheric circulation pattern led to a mean upwelling circulation in the Gulf, which in combination with the cold temperatures in the early summer results in a scenario for the cyanobacterial development that is consistent with observations. The results call for improvements in the seasonal forecasting of Baltic HAB bloom potential.

PS1.7

A parameterization of temperature- and salinity-dependent growth rates for two harmful brackish water cyanobacteria (*Nodularia* and *Aphanizomenon*).

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Growth rates for two dominant cyanobacterial species in the Baltic Sea (*Nodularia* and *Aphanizomenon*) at varying salinity and temperature values are modeled on the basis of previous laboratory experiments. The model of temperature-dependent growth is based on highly non-linear, physiology-based functions, which are extended to the salinity-dependent growth parameterization. The parameter values for the model are then derived by inverting the biomass increase experimentally observed in different salinity and temperature conditions, subject to the model functions. The parameterization results in functional groups that are separable in their temperature and salinity preferences, and are likely to appear in different geographical areas and different hydrodynamic conditions. The growth rate maxima in the parameterization correspond to the range of salinity and temperature values, where *Nodularia* and *Aphanizomenon* blooms have been observed to occur in the Baltic.
Sensitivity of the parameterization to the sparsity of experimental data is analyzed. Focal areas in future experiments are found to include the low temperature behavior of *Aphanizomenon* and growth of *Nodularia* in low salinities, as well as in high temperatures.

PS2.1

An operational SPM transport model for the North Sea and the Baltic.

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(2) GKSS Forschungszentrum Geesthacht, Germany

Knowledge of the distribution of suspended particulate matter (SPM) is indispensable for the description of the ecological status of a sea area as well as for predictions of its future development. The SPM concentration in water affects the penetration depth of light and is thus a parameter which has a major influence on primary production. Sediments, on the other hand, have a buffer function with respect to nutrient dynamics and act both as a source and sink of nutrients.
Therefore, an operational three-dimensional SPM transport model for the North Sea and Baltic Sea has been developed at Bundesamt für Seeschifffahrt und Hydrographie (BSH), in co-operation with the GKSS Research Centre, Geesthacht. Besides transports and horizontal diffusion, the Eulerian SPM dispersion model simulates vertical mixing in the water column caused by current shear and wave orbital velocities, sinking of the SPM particles, sedimentation, resuspension, erosion, as well as diffusion and sediment bioturbation. The SPM transport model is an important component of the BSH's operational model system and a basis for an ecological model of the North and Baltic Seas, which is presently being developed at the BSH.
Several hindcast scenarios have been computed to calibrate and validate the model. Model results were compared to satellite imagery and in-situ SPM measurements. The SPM transport model is capable of reproducing SPM concentrations not only during periods of calm weather but also in storm periods. A MOS satellite image taken after a storm in the winter of 2000 agrees quite well with the computed surface SPM distribution.

PS2.2

Plankton-benthos interactions: the study of the main factors affecting uptake rate constants.

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(3) Hawaii Institute of Marine Biology. Kaneohe, Hawaii. U.S.A.

Interactions between plankton and benthos include complex transfer of matter and energy between both ecosystems. The quantification of nutrient fluxes among water column and seafloor and the way they interact with the physical environment is of crucial importance to understand the regulation of these transfers. We have focus our attention to measure uptake of dissolved nutrient and sestonic particles by benthic coral reef substrates under different water motion situations using an experimental flume. Mass-transfer theory (indicating that nutrient uptake is limited by their transport from a high concentration layer to a depleted layer) has been examined to explain different pattern observed in the uptake of dissolved nutrients and particles. Calculation of the Stanton number (a dimensionless number giving the ratio of uptake rate to the rate of advection of the substance past the uptake surface) let us to discuss under what situations nutrient uptake by benthos would be limited by physical (mass-transfer) or biological processes. We propose a parameterization of Stanton number to predict and modeling mass-transfer and/or biological control of nutrients fluxes between plankton and benthos.

PS2.3

Growth and grazing of the dinoflagellate *Fragilidium subglobosum* in patchy and even distributions of its prey *Ceratium tripos* caused by different levels of small-scale turbulence.

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(2) Institute of Marine Sciences (CMIMA-CSIC), Barcelona, Catalunya, Spain

Cultures of the dinoflagellates *Ceratium tripos* and *Fragilidium subglobosum* were exposed to natural levels of small-scale turbulence (dissipation rates between 0.0001 and 1 $cm^2 s^{-3}$). Autotrophic growth of *F. subglobosum* and mixotrophic growth in food-saturated conditions (prey density >>10 *C. tripos* cells mL^{-1}) were not affected by turbulence. At an average prey density of 5 to 8 *C. tripos* cells mL^{-1}, however, growth and ingestion of *F. subglobosum* were significantly higher at the highest turbulence level (1 $cm^2 s^{-3}$) than at the other turbulence levels and close to those measured at food saturation. The growth of the prey, *C. tripos*, decreased at dissipation rates higher than 0.005 $cm^2 s^{-3}$. At low turbulent dissipation rates (0.0001 and 0.005 $cm^2 s^{-3}$) *C. tripos* was evenly distributed in the water column. At 0.05 $cm^2 s^{-3}$ some aggregates of *C. tripos* settled at the bottom of the containers and the density in samples taken from the bottom was significantly higher than those taken from the top of the containers. At 1 $cm^2 s^{-3}$ 80 to 90 % of all *C. tripos* cells were found in aggregates at the bottom of the containers. The patchy distribution of *C. tripos* at high turbulence (1 $cm^2 s^{-3}$) resulted in higher ingestion and growth of *F. subglobosum* at average prey cell densities between 5 and 8 *C. tripos* cells mL^{-1}. When *F. subglobosum* grazed on aggregates of *C. tripos* it was not food-limited. Nutrient transport up the food chain was enhanced when low prey cell densities (food limitation for *F. subglobosum*) were exposed to high turbulence (1 $cm^2 s^{-3}$).

PS2.4

Phytoplankton dynamics at hourly scale: competition between horizontal currents and night penetrative convection.

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Physical processes in many lakes, reservoirs and estuaries are crucial because they affect ecosystem functioning at a range of time and spatial scales. Horizontal circulation and penetrative convection, among other processes determine the paths of suspended particles (from organic or inorganic nature) in aquatic ecosystems, therefore affecting the water quality of them.
In this study measurements of the fluorescence of different phytoplankton populations obtained with an in situ submersible fluorimeter of 5 channels, together with CTD and current velocity profiles, carried out with an acoustic Doppler profiler, are presented. Measurements were taken hourly during a 24 hours cycle at a fixed station in Sau Reservoir, Catalonia, Spain, in July and September 2003. Measurements at a higher time intervals (~ 4 hours) at other stations are presented and compared with the previous results. Comparison of estimates of convective velocities in response to uniform surface heat loss and measured horizontal velocities show that during night time, vertical transport of populations due to convective processes is the main phytoplankton transport mechanism in the water column. However, during day time, wind induced seiching in the reservoir can produce horizontal circulation that dominates phytoplankton dynamics.

PS3.1

A 1-D model for the vertical distribution of fish eggs.

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Modelling the vertical distribution of fish eggs results of prior importance when estimating fish fecundity on various spawning grounds in the context of conservation plans from fast underway continuous samplers, as well as for adequate egg sampling when assessing fish stocks with egg production methods.
Fish eggs are passive particles with constant density during embryonic development. They have in general an ascent vertical velocity due to their lower density relative to that of ambient sea water. The vertical distribution of fish eggs is determined by parameters as density, wind and tidal induced turbulence, or vertical hydrological structure. The study is based on the use of a 1D-vertical physical model in which is parameterised the ascent velocity considering egg and water properties. This model is forced by surface wind, tidal current and a given T-S profile corresponding to the sampling conditions. The turbulence is parameterised by a k-L closure scheme.
The model is able to generate egg sub-surface maxima when hydrological conditions are favourable, i.e. during the presence of river plumes. Focus is put on anchovy and sardine egg distributions in spring on the French shelf. A variety of hydrological conditions occur in spring which have been classified as: low stratification, thermal stratification under seasonal surface heating, haline stratification under river plume influence.
Our goal is to study the response of the model to a variation of the major parameters influencing egg vertical distributions. Parameters retained were wind and tidal turbulent forcing and egg properties. According to forcing conditions, eggs distribution along the water column is different. Wind resulted to be the driving element in changing the vertical distribution in each of the hydrological conditions. The range of variation for the parameters was realistically chosen to reproduce extreme and average spring conditions observed in fisheries surveys across past years.

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PS4.1

Large scale circulation in the Canary Basin.

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We show the mean and seasonal ocean circulation in the Canary basin, as result from an inverse model. For this purpose, a high-quality data set, obtained during the CANIGO (Canary Islands, Azores and Gibraltar Observations) project, has been used. It is composed of CTD casts carried out in four cruises along the four seasons. Basically, mean surface circulation consists of an upwelling jet (UJ) carrying 1.0+/-0.4 Sv, separated from the Canary Current (CC), which carries 3.9+/-0.5 Sv. These two regimes can also be found in the seasonal circulation, obtaining the highest transport in summer (1.9+/-0.5 Sv for the UJ and 5.6+/-0.5 Sv in the CC). Mesoscale structures induced by the presence of the islands are also important in the central waters circulation. The intermediate depth circulation is dominated by the presence of two water masses flowing in opposite directions, AAIW and MW, flowing northward and southward respectively, without a clear seasonal variability. Finally, deep ocean circulation in this basin is featured by its uncertainty, which prevent us to find out a significant circulation for these depths.

PS4.2

A model for the primary production on the Faroe Shelf.

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On the Faroe Shelf there is a high correlation between the primary production and fish production. Observations furthermore show large variations in the total primary production from one year to another and there are indications that grazing by zooplankton is a controlling factor. Here we present preliminary results from a mathematical model for the lowest trophical levels on the Faroe Shelf. We discuss the effects of different exchange rates between shelf and off shelf water and the extent, to which the model supports the hypothesis of zooplankton grazing as a controlling factor for the production.

PS4.3

Building an open source work bench for marine biogeochemical models of the water column.

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It is projected to extend the General Ocean Turbulence Model (GOTM, see http://www.gotm.net), which has recently been equipped with an interface to pelagic biogeochemical models, towards an Open Source work bench for marine biogeochemical models of the water column. This will include a number of Eulerian biogeochemical models, including idealised and realistic test scenarios and documentation of models and test scenarios. Everything will be accessable and downloadable through the internet web site at http://www.gotm.net.
These modelling activities will be closely related to the ICES Working Group on Physical-Biological Interactions.
This poster will present the basic ideas how to build up the model work bench including some preliminary test simulations.

PS4.4

Towards an optimization approach to physical-biological modelling.

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(2) Dalhousie University, Halifax, Canada

Models that couple ocean physics to food web dynamics are an essential tool in understanding and predicting marine ecosystem change. However, capturing complex food web interactions in numerical models is a daunting problem. Current PZND models, which simplify the planktonic ecosystem into a few homogeneous compartments, may be reaching their limits in terms of explanatory and predictive power. Increasing complexity can refine the representation of food-web structure, but generates other problems (many poorly known parameters, lack of stability, etc.). We review approaches proposed recently to increase the realism and generality of food web models while minimizing complexity and maintaining stability. One avenue is to base models on optimization principles that turn hitherto constant model parameters into variables that 'adapt' to changing external or internal conditions. In that context, new concepts that emphasize the critical role of weak food web interactions appear as a promising guide to develop general and robust representations of food web dynamics into physical-biological models.

PS4.5

Effects of small-scale turbulence on the growth of two diatoms of different size in a phosphorus-limited medium.

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The response on the growth of two marine diatoms of different size (*Thalassiosira pseudonana*, 6 µm diameter and *Coscinodiscus* sp., ca. 110 µm diameter) to turbulence was studied in phosphorus-limited cultures. The growth of both algae was followed for ca 5 Days under still and turbulent (epsilon = 4.4×10^{-2} cm^2 s^{-3}) cultures in two independent experiments. In agree with the theory, turbulence enhanced the growth of *Coscinodiscus* sp. but not the growth of *T. pseudonana*. At the end of the experiment there were about 1.7 times more *Coscinodiscus* sp. cells in the turbulent than in the still conditions, while for *T. pseudonana* almost the same cell numbers were found in both conditions. In addition, the *Coscinodiscus* sp. cells growing under still conditions presented a higher specific alkaline phosphatase activity than those growing in turbulent ones which indicates a higher phosphorus limitation of *Coscinodiscus* sp. cells in the still cultures. A dynamical model of phosphorus uptake and cell growth, implemented using literature parameters, fitted experimental results and showed that turbulence increased the growth rates of *Coscinodiscus* sp. and *T. pseudonana* in a 118 % and a 19 %, respectively.

PS4.6

Using the MIRO model to describe the present-day interannual variability of the diatom-*Phaeocystis* blooms in the nutrient enriched Belgian coastal waters.

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Massive blooms of *Phaeocystis* colonies are recorded every spring in the Belgian coastal zone (Southern Bight of the North Sea) submitted to riverine nutrient loads over-enriched in N compared to P and DSi. *Phaeocystis* blooms usually occur between the spring and summer diatom blooms and their relative importance varies between years. The reason for the observed interannual variability is not known yet and no link has been established with changing riverine nutrient loads in spite of a clear decrease in P since the late 80's. Here, we use the complex mechanistic MIRO model to assess and understand the role of nutrient loads variability on the magnitude of the diatom-*Phaeocystis* blooms in the Belgian coastal waters. MIRO includes 32 state variables and describes C, N, P and Si cycling through the planktonic and benthic realm. It is run to simulate the seasonal cycle of inorganic and organic carbon, nutrients, phytoplankton (diatoms and *Phaeocystis*), bacteria and zooplankton. For this application MIRO is implemented in a multi-box frame delineated on the basis of the hydrological regime and river inputs and is run over the 1989-1999 period. The model predictions are compared with monthly-averaged field observations of nutrients and phytoplankton recorded in the central Belgian coastal zone during the simulated period. Model results analysis shows that *Phaeocystis* blooms are sustained by new sources of NO3 but regenerated NH4 and PO4 originated from the organic matter degradation associated with the previous diatom bloom. The height of *Phaeocystis* blooms is therefore indirectly determined by the winter stock of DSi which determines the magnitude of the early-spring diatoms. Overall the predicted annual mean of diatoms and *Phaeocystis* is determined by the annual loads of P and N respectively. Additional MIRO runs are conducted to explore the ecosystem response to several nutrient scenarios under contrasting climate conditions which impact differently on N and P sources.

PS4.7

Open ocean modelling of the carbon cycle using a global Forecasting Ocean Assimilation Model (FOAM).

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(2) Southampton Oceanography Centre, U.K.

The Forecasting Ocean Assimilation Model (FOAM) consists of a series of operational ocean models that use data assimilation to produce daily analysis and forecasts of temperature, salinity,ocean currents and mixed layer depth up to five days ahead. The data assimilation component of FOAM is based on in situ as well as satellite observations. FOAM is driven by six-hourly surface fluxes from the Met. Office's operational Numerical Weather Prediction (NWP) system.
The global version of FOAM consists of a 1 x 1 horizontal resolution model and 20 unequally spaced vertical levels. A regional (North Atlantic) version of FOAM, nested within the global model and with 1/3 horizontal grid resolution, is also part of the FOAM suite.
The ecosystem model embedded in FOAM is the Hadley Centre Ocean Carbon Cycle (HadOCC) model. The model consists of four compartments: phytoplankton, zooplankton, nutrient (nitrate and ammonium) and sinking detritus.
The coupled model uses a spectrally averaged light model for phytoplankton photosynthesis and a variable C:Chl ratio.
This presentation will show preliminary results from coupling the HadOCC model to global and 1/3 North Atlantic FOAM. Model results will be compared to satellite (SeaWIFS) and in situ data.

PS4.8

Modelling the DMSP & DMS cycle in the upper mixed, global ocean.

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Oceanic DMS is the most important natural source of sulphur to the atmosphere. DMS is a biogenic substance that results from the breakdown of DMSP. DMSP is produced by
phytoplakcton and transformed into DMS by bacterial and algal enzymatic activity. DMS, once ventilated to the atmosphere, is oxidated to sulfates that are the main contributors to the Cloud Condensation Nuclei (CCN). The cloud optical thickness is a function of CCN: more CCN implies more optically dense clouds and, so, more reflection of incident solar radiation to space. Less solar radiation implies a cooling effect on Earth. It has been hypothesized that, in a Global Warming scenario, the ocean could have an attenuation response through the production of more DMS. Critical to addressing such a hypothesis is the assessment of the relative contribution of oceanic sulphur emissions with respect to antropogenic and volcanic source of sulphate. This requires obtaining a synoptic and seasonal view of oceanic sulphur emission, which can be achieved by global modelling. Processes affecting DMSP and DMS cycles in the upper ocean are very complex. Present models are not able yet to reproduce and predict the variability of DMS at a global scale. Succesful intermediate models have been developed regionally. We are working on a biogeochemical global box model of the DMS cycle, making use of an existing and succesfully validated global ecosystem model. Upon the N/C cycle of the ecosystem model, we have added the sulphur cycle. The main physical forcing that drives biological activity is PAR+ radiation. Preliminary model runs have produced results that are not in agreement with available field data. In sutropical latitudes, the modeled seasonal series of DMS surface concentrations are opposite to the observed pattern of a summer maximum (the so-called DMS summer paradox). At present, we are trying to understand where the model fails and what processes we have missed or have not been able to reproduce properly.

PS4.9

From 'if-then' statements to models of individuals with flexible and variable traits.

Fiksen, Ø.

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One of the major contemporary challenges to modellers is to include long-lived organisms in mass-balanced spatially resolved models of aquatic ecosystems. Existing coupled biological-physical models are naturally biased towards lower trophic levels (nutrients-phytoplankton). Often zooplankton represents the final level in the models, with behavioural traits (spatial distribution) and life history strategies (such as timing of emergence from or transition to hibernation or diapause) defined by the modeller. As models become filled up with 'if-then' statements, they loose their ability to function as tools for studying 'what-if' questions. They become rigid, and are not able to capture the flexibility and variable success that characterise different morphs or genetical variability found in natural organisms. It is also very likely that these imposed schemes of behaviour and schedules of life history traits strongly affect rates of mortality and growth. Here, I discuss some of these problems and suggest a few approximations and methods that may reduce our dependency on 'if-then' statements and increase the consistency of population models.

PS4.10

An object oriented model for the prediction of turbulence effects on plankton.

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Plankton dynamics is related to the auto ecological characteristics of the different populations and their mutual interactions but is also strongly influenced by the fluid motion and the physical structures in the ocean. It is generally believed that micro-turbulence plays a major role in the above scenario, modifying physiological and behavioural responses of small marine organisms as well as the rates and modes of their mutual interactions enhancing, for example, the encounter rate of plankton and fish larvae with their food, thus improving their capture success.
In this work we propose an object-oriented Individual Based Model for the analysis of the effects of turbulence on the interactions and behaviour of planktonic organisms at microscopic scales. We model homogeneous isotropic turbulence by adopting a kinematic simulation of the flow, where the velocity field is prescribed as a combination of a large number of unsteady random Fourier modes. As for the biotic component we use special contact classes to build a "memory" of an individual particle, allowing the storage of frequency, duration and identity of each interaction experienced by the individuals throughout the whole time span of the simulation. This, in turn, allows classifying the different interactions.

PS4.11

[1]Circulation on the Newfoundland and Labrador Shelf.

Han, G.

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Finite element models are developed to investigate monthly-mean circulation over the Newfoundland and Labrador Shelf. Model forcing includes monthly-mean wind stresses at the sea surface computed from the NCEP-NCAR reanalysis data, large-scale sea level setup at the open boundary determined from a North Atlantic model, density gradients in the interior and steric setup at the open boundary from a monthly temperature and salinity climatology. The model solutions are discussed for seasonal changes, for shelf- and bank-scale features, for relative importance of local to remote forcing, and for roles of wind vs. buoyancy forcing.

PS4.12

Merging photophysiological responses of phytoplankton in 1D Lagrangian models.

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(3) IAMC-CNR, Napoli, (4) LISE, Université du Littoral, Italy

The Lagrangian approach, i.e. particle-following, allows tracking the light and nutrient history of individual phytoplankton cells in the mixed layer. This approach was pioneered by different authors in the late eighties. Since then, a large amount of work has been conducted to better characterize the physiological response of phytoplankton to different light and nutrient regimes, on which mechanistic models of phytoplankton photophysiology could be based.
Therefore the impact of time varying mixing on phytoplankton performance can be better anticipated merging the two approaches. Numerical simulations of 1D Lagrangian model with realistic photoacclimation parametrizations are currently conducted to analyze the impact of different parameters and the possible, competitive advantage, of different strategies in responding to light variability.

[1] This presentation was not given

PS4.13

Estimation of wind generated small-scale turbulence: statistical distributions in a coastal area and some implications for the planktonic community

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From laboratory studies, small-scale turbulence is known to have multiple effects on different components of the planktonic community. In order to better understand these effects in a natural system one needs to know the distribution of turbulence in the field. Continuous data about this distribution has been hindered by the difficulties in directly measuring turbulence in the sea under sub-optimal sea conditions.

The main factor in the generation of small-scale turbulence in the upper layers of the ocean is wind stress on the water surface. Both theoretical and empirical models have related turbulent energy dissipation rates (epsilon) to wind speed and depth in the water column. Wind speed follows a two-parameter Weibull distribution in almost all cases. Hence, turbulence distribution is expected to follow also a very regular distribution both in space and time in a wide range of conditions.

We used wind speed data series from six meteorological stations located along the Catalan coast. With a peak threshold approach, we assessed the frequency of wind events, as well as their persistency statistics for each station. Frequency was related to the threshold values following a negative exponential function in all cases. Persistency of events was found, in general, to follow an exponential distribution for all thresholds. Finally we converted these wind speed data series into turbulent energy dissipation rate series using published models, and we determined the general distribution of turbulence in the Catalan coast.

We will show the results of a mesocosm experiment (2.6 m^3 tanks) where we subjected a planktonic community to 4 different levels of turbulence. We will discuss the results in terms of understanding the level at which turbulence becomes an important factor in the dynamics of plankton and its relevance for the coastal ocean.

PS4.14

Using a random displacement model to simulate turbulent particle motion in a baroclinic frontal zone: a new implementation scheme and model performance tests

North, E.W., Hood, R.R., Chao, S.-Y., Sanford, L.P.

University of Maryland Center for Environmental Science, Horn Point Laboratory

Numerical artifacts can limit accurate simulation of turbulent particle motion when Lagrangian particle-tracking models are implemented in hydrodynamic models with stratified conditions like fronts. Yet, modeling of particle motion in frontal regions is critical for understanding sediment dynamics and the transport of planktonic organisms. Our objective was to develop a numerical technique to accurately simulate turbulent particle motion in a frontal zone model. A new interpolation scheme, the 'water column profile' (WCP) scheme, was developed and used to implement a random displacement model (Visser 1997) for turbulent particle motions. A new interpolation scheme was necessary because linear interpolation caused artificial aggregation of particles where abrupt changes in vertical diffusivity occurred. The new WCP scheme fit a continuous function to a smoothed profile of vertical diffusivities at the x-y particle location. The new implementation scheme was checked for artifacts and compared with a standard random walk model using 1) Well Mixed Condition tests, and 2) dye-release experiments. The Well Mixed Condition tests confirmed that the random displacement model with the new interpolation scheme significantly reduced numerical artifacts. In dye-release experiments, high concentrations of Eulerian tracer and Lagrangian particles were released at the same location and tracked for 4 days. After small differences in initial dispersal rates, tracer and particle distributions remained highly correlated ($r = 0.84$ to 0.99) when a random displacement model was implemented. In contrast, correlation coefficients were substantially lower ($r = 0.07$ to 0.58) when a random walk model was implemented. In general, model performance tests indicated that the WCP scheme was an effective technique for implementing a random displacement model, and both could be used to accurately simulate diffusion in a highly baroclinic frontal region.

PS4.15

[1]The Virtual Ecology Workbench - VEW3.

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We want a magic box that allows us marine ecologists without software engineering skills to create and analyse mathematical simulations of the plankton ecosystem with our own choice of species and at a location of our choice, with forcing that creates realistic physical, chemical and biological environment. We want it to be easy to use, so that we can quickly explore different assumptions about the biology and environment. But we do not want it to compromise on realism in physical-biological interactions. Ideally it should combine individual-based modelling with accurate demography of each population and accurate biofeedback to the environment. It should provide explicit quality control.

The Virtual Ecology Workbench does all that. VEW3 allows you to choose any combination of plankton species defined by biological primitive equations. And it is global: you can create a scenario using OCCAM circulation and ERA weather for the last 45 years, plus any special events such as climate change or pollution. VEW3 has a user-friendly graphical interface. It codes the model-plus-scenario automatically in Java so the simulation can be created on your own computer, even an AppleMac. It uses Lagrangian Ensemble integration to produce life histories of individual plankton lineages, demographic histories of populations, and time series of the synoptic environment. VEWdata provides powerful tools to simplify diagnosis of these large data sets.

I shall demonstrate the prototype of VEW3. And I shall show how it is used to investigate biological-physical interactions in the plankton ecosystem by simulating the plankton ecosystem one-dimensionally in a virtual water column drifting with the mean circulation. It is now being beta tested.

PS4.16

Non-local turbulent mixing models: empirical parameterization and potential applications for modelling.

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Non-local mixing models provide an improved theoretical framework for evaluating the effects of mixing. By using non-local models, for example, it is possible to evaluate the effects of anisotropic mixing, which can be especially important when considering the effects at the ecosystem level. Although non-local mixing models have apparent advantages, they have not been widely used because the high complexity and the difficulty for obtaining reliable parameterization. In this study, a new parameterization of non-local mixing model is proposed. The method obtains empirically the coefficients of the transilient matrix, which is the discrete descriptor used in the non-local mixing model. The parameterization is based on the microstructure data analysis, in particular the Thorpe displacement profiles, and is decomposed in three main steps: turbulent patch identification, turbulent patch characterization and data integration. The proposed method has been tested comparing the results obtained with field data and those obtained through numerical simulation. The final results indicate that the estimated transilient coefficients, and the mixing parameters derived from them, are in accordance with those expected from the background external forcing, the observed thermal structure and the parameters obtained from the numerical model.

[1] This presentation was not given

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PS4.17

Zooplankton within the North Sea ecosystem model ECOHAM2 – annual cycles and regional differences.

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The "Ecological North Sea Model, Hamburg, Version2" (ECOHAM2) simulates the carbon and nitrogen cycle of the North Sea using 13 bulk state variables, including the zooplankton total biomass and the population dynamics of a single key copepod species (*Pseudocalanus elongatus*) (additionally 9 state variables). In contrast to the earlier version ECOHAM1, the present version includes the carbon cycle. The nutrient and phytoplankton state variables are validated using aggregated box data for different box sizes. The years 1986 and 1995 are presented to show different weather conditions. The simulation of the zooplankton is presented as monthly horizontal maps. The comparison for vertical profiles, especially of bulk zooplankton is necessary. The implementation of the structured zooplankton population is under progress; first results are shown.

PS4.18

A synoptic view of the respective roles of physical and biological processes in determining the distribution and nature of the rate of algal loss in pelagic ecosystems.

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Satellite-based estimates of chlorophyll a and primary production have provided an unprecedented perpective phytoplankton dynamics at the global scale. Only a few studies have used the same satellite data to characterize the loss terms associated with biomass variability. Loss rates are a major gap in our understanding of pelagic ecosystems. The total loss rate (L) is easily obtained from the equation dB/dt=P-L, if the biomass (B) and primary production (P) are known. To date a major obstacle in using satellite data to study algal loss rates is that dt has been too large, i.e. typical cloud free global coverage ca. 30 days. With the advent of the MODIS sensor, almost perfect cloud free global coverage is obtained within an 8-day period, a more relevant time step for studying phytoplankton loss terms. Based on 8-day calculations, 12 monthly global composites of L were derived, as well as monthly composites of the parameter M=L/P. M has been proposed as an indicator of areas where algal production/loss rates are either dominated by physical or biological processes. This study provides the first insight into the global distribution and dynamics of these variables over a single year. The resulting distributions are in accordance with published estimates. For example, the subtropical gyres stand out as areas where the loss terms are relatively high and also dominated by biological processes.

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