ICES Oceanography Committee
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Report of the Working Group on Modelling of Physical/Biological Interactions (WGPBI)

10–11 March 2004
Barcelona, Catalonia, Spain

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark
Telephone + 45 33 15 42 25 · Telefax +45 33 93 42 15
www.ices.dk · info@ices.dk

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1 Welcome and opening of the meeting

The first meeting of the ICES Working Group on Modelling Physical-Biological Interactions was held at the Centre Mediterrani d'Investigacions Marines i Ambientals in Barcelona, Spain, from 10–11 March 2004. Our host was Francesc Peters of the Institut de Ciències del Mar. Francesc was also the host and co-Chair of the very successful Workshop on Future Directions in Modelling Physical-Biological Interactions (WKFDPBI) held at the same location on the previous two days.

The group has grown substantially in the six months since the conversion from a Study Group to a Working Group. There are now 34 members. Some of the growth is likely due to the high profile of the Workshop. The WG meeting was attended by 27 people (Annex 1).

The most important issue facing the group was developing a plan for future activities. The basis for the plan is the strategy document developed over the three meetings of SGPBI and summarized by Hannah (2003; ICES CM 2003/P:04). Review of the presentations and discussions that took place during the Workshop provided additional ideas.

2 Terms of Reference

The Study Group on Modelling Physical/Biological Interactions [SGPBI] will be re-established as the **Working Group on Modelling of Physical/Biological Interactions** [WGPBI] (Chair: C. Hannah, Canada) and will meet in Barcelona, Spain, from 10–11 March 2004 to:

a) present and discuss new results related to developments and validation in the modelling of physical/biological interactions;

b) review experimental simulations on nutrient load reduction;

c) incorporate the findings of the Workshop on Future Directions in Modelling Physical-Biological Interactions;

d) identify emergent physical-biological interaction issues relevant to other Expert Groups;

e) review, finalise and start to implement the strategic plan prepared intersessionally that will provide the framework for the future activities;

f) cooperate with SGBEM to explore Baltic ecosystem models;

g) review the 2003 Regional Ecosystem Study Group for the North Sea and Planning Group on the North Sea Project reports and consider opportunities to contribute to regional integrated assessments.

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

3 Conclusions

1) New observational techniques such as the holographic submersible system that records movies of plankton *in situ* and the emerging thin layer techniques will have an enormous impact on studies of plankton.

2) There is an increasing interest in modelling processes over time scales longer than a few months. This has several consequences for modelling, including

    a) The need to model the physical and biological coupling between the deep ocean and the shelf (especially in open shelf environments);
    b) The need to couple water column models with benthic models because of the storage capacity of the benthos;
    c) The need to model the ecosystem in greater detail as the time scale of interest increases.

3) In modelling PBI, where even the form of the equations is in doubt, analysis of sensitivity to changes in parameter values is not sufficient. Sensitivity to the form of the equations should be considered.

4) Model validation continues to be an important issue. The reason is clear: in order to improve any model, the model's weaknesses must be known and ranked in order of importance, and improvement must be measurable when changes are made. Approaches such as the Ecological Turing Test (Woods, 2002) and the Pragmatic Approach to Model Validation (Dee, 1995) provide frameworks for model validation.

5) Acquiring datasets that can provide stringent tests of PBI models for a particular application requires close interaction between the modellers and the observationalists because the answer the question 'What observations do you need to test the model?' is neither simple nor obvious.

6) Advancements in modelling PBI would be enhanced by a community approach. Development of easily accessible open-source code and standardization of model input/output would speed progress.

7) WGPBI will establish a Numerical Experimentation Subgroup to investigate best practice in modelling physical-biological interactions (PBI) in plankton ecosystem models used for fisheries recruitment, HABs and pollution studies.

8) Members of WGPBI and WGRP (Working Group on Recruitment Processes) share the common goal of enhancing, guiding, and promoting use of coupled physical-biological models for prediction of fisheries recruitment. WGPBI will cooperate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment.

4 Present and discuss new results (ToR a)

The presentation and discussion of new results was much shorter than usual because of the need to focus on developing a work plan for the group. This was more than offset by the 2 days of presentations and discussion that took place during the Workshop. Most of the presentations built on talks and posters presented at WKFDPBI.

Elizabeth North talked about her plans for modeling oyster larvae dispersal in Chesapeake Bay. Her model uses IBMs coupled with 3-D circulation models and state-of-the-art turbulence parameterizations. The results from an idealized estuary triggered discussion of turbulence models and how biological modelling probably places greater demands on the physical models than simulating circulation.

Stephanie Magri discussed a 1-D model for the vertical distribution of fish eggs. The physical model includes an advanced turbulence closure scheme. She noted that the proposed application is very close to that discussed by Guillermo Boyra during WKFDPBI and that the two groups were planning collaboration on future work.

Hans Burchard introduced the General Ocean Turbulence Model (GOTM) which is an open source code that contains all the common two equation turbulence closure models. It is available from www.gotm.net. Then he talked about progress in embedding general biogeochemical models (NPZD type models) into GOTM.

John Woods talked about the Virtual Ecology Workbench (VEW3) and how it could contribute to the aims WGPBI. VEW3, which does ecosystem simulations using individual based models, provides a platform for computing ecological consequences of changing the way we model physical-biological interactions in comprehensive ecosystem models. The presentations on GOTM and VEW3 were the basis for further discussions later in the meeting that led to the creation of the Numerical Experimentation Subgroup.

John Woods talked about the statistical concept of ergodicity, the idea that the inter-instance statistics of an ensemble are identical to inter-annual statistics in one instance. He noted that 1) the ergodic hypothesis is embedded in most models and 2) that many biological processes produce non-ergodic statistics in ecosystem properties, including birth and death rates and the time to extinction of populations. Using VEW3 he showed the existence of non-ergodic properties in the dynamics of a zooplankton species with intra-population variability in biological state (e.g., body-weight). Copepods that over-winter with higher body-weight reproduce earlier. As the result their offspring attain a higher body-weight in the following winter, so the advantage is passed through the lineage. This effect (he called it

copepod aristocracy) produces a difference of a few percent between ensemble and time statistics in the zooplankton population. While seemingly small it swamps recruitment statistics (one in a million for cod). So assuming ergodicity in recruitment models can lead to serious error. This point provides one answer to the challenge raised by Pierre Pepin during his presentation at WKFDPBI, when he called for an examination of the statistical assumptions made in the models of larval fish growth and development.

Einar Svendsen presented *MONCOZE* (Monitoring the Norwegian Coastal Zone Environment) a pilot system for monitoring and prediction of the Norwegian marine coastal environment with particular focus on dominant physical and coupled physical-biochemical processes within the Norwegian Coastal Current. The website (moncoze.met.no) provides an interface for accessing data such as surface temperature and chlorophyll and model products such as nowcasts and forecasts of currents, oxygen levels, nutrients, chlorophyll, flagellates and diatom concentrations.

Tom Osborn presented results from a holographic submersible system that record movies of plankton *in situ.* The system has been developed at The Johns Hopkins University Department of Mechanical Engineering by Professor Joe Katz, Dr Ed Malkiel, and Jen Sheng (Malkiel *et al*. 2003). Each hologram provides a 3-D snapshot of the particle field within a 732 ml volume. It can resolve spherical particles as small 5 micron and linear characteristics (such as setae) with diameters as small as 1 micron. The movies of untethered individual copepods swimming, feeding and fighting held the audience spellbound. The system is also able to reconstruct the 3D flow field in the sample volume. The ability to watch an individual, with sufficient resolution to see the motions of the feeding appendages of a copepod, combined with reconstructed flow field will have an enormous impact on studies of plankton of all types. Further details can be found at http://www.me.jhu.edu/~lefd/shc/shc.htm and in:

Reference

Malkiel, E., Sheng, J., Katz, J., and Strickler, J. R. 2003. The three-dimensional flow field generated by a feeding calanoid copepod measured using digital holography. J. Exp. Biol., 206: 3657–3666.

5 Review experimental simulations on nutrient load reduction (ToR b)

During the last two years, three different studies have been performed to investigate the responsiveness of ecological models to changes in anthropogenic loads.

The first study was done in the North Sea using NORWECOM. Four different scenarios were simulated, and the results showed clear effects in the areas influenced by the main rivers. Results from this study was presented at the ASC (ICES 2003/W:01) and are published by Skogen *et al* (2004).

Models to explore responses of the Baltic Sea ecosystem to changes in nutrient loading are also available and applicable. Several experiments have been carried out. The focus here has also been on the reconstruction of pre-industrial conditions. Main message from load reduction scenarios is that different time constants of response of N and P and the long residence time change at least temporarily the N to P ratio and in turn cyanobacteria get an advantage. The results from this study were presented at the ASC (ICES 2002/P:12), and have been published in Neumann & Schernewski (2001); Neumann *et al*. (2002); Schernewski & Neumann (2004).

In the third study, three different models have been applied to the North Sea, Baltic Sea and their transition area. In line with the reductions of anthropogenic nutrients proposed by, e.g., HELCOM and OSPARCOM, scenarios with 30 % reductions in the total dissolved inorganic nutrient input have been carried out. The effects of the nutrient reductions are found to differ between the model areas, but also between the models. The largest sensitivities are found on the west coast of Denmark, the Kattegat, Gulf of Riga and the Bay of Bothnia. The results are published by Stipa *et al* (2004).

The work of Stipa *et al* (2004) and Skogen *et al.* (2004) was the subject of posters presented at the WKFDPBI.

A review of the three studies will be presented at the next WGPBI meeting (2005).

References

Neumann, T., Fennel, W., and Kremp, C. 2002. Experimental Simulations with an Ecosystem Model of the Baltic Sea: A Nutrient Load Reduction Experiment, Global Biogeochemical Cycles 16, No 3, 7–1 – 7–19.

Neumann, T., G. Schernewski (2001). Cost-effective versus proportional nutrient load reductions to the Baltic Sea: Spatial impact analysis with a 3D-ecosystem model, Water Pollution VI, editor: C.A. Brebbia, WITPRESS Southampton, Boston.

Schernewski, G., and Neumann, T. 2004. The trophic state of theBaltic Sea a century ago? A model simulation study. J.of Mar.Systems in press.

Skogen, M.D., Søiland, H., and Svendsen, E. 2004. Effects of changing nutrient loads to the North Sea. J.of Mar.Systems, 46(1–4): 23–38.

Stipa, T., Skogen, M.D., Hansen, I.S., Eriksen, A., Hense, I., Kiiltomaki, A., Søiland, H., and Westerlund, A. 2003. Short term effects of nutrient reductions in the North Sea and the Baltic Sea as seen by an ensemble of numerical

models. MERI, Report series of the Finnish Inst.of Mar.Res., 49: 43–70. A version of the report is available from http://www.imr.no/~morten/nocomments/.

6 Incorporate the findings of WKFDPBI (ToR c)

The Workshop on Future Directions in Modelling Physical-Biological Interactions (WKFDPBI) was very successful. The program and abstract can be viewed at the Workshop webpage www.icm.csic.es/bio/projects/wkpbi/wkpbi.htm. The attendance was close to 85 and the discussions were lively. The feedback has been very positive. We thank Francesc Peters for his vision and determination to make the workshop happen.

The goal here was to extract the big ideas and the emerging issues from the talks, posters and discussions at the Workshop. A summary of the workshop will be reported elsewhere.

The group was divided into 3 breakout groups each with a mandate to identify the big ideas and emerging issues. The reporting notes from each group are given in Annex 7.

One group used the workshop discussion as a basis for their own big idea.

- In physical space we can use adaptive grids that automatically provide higher spatial resolution at sensitive locations. Francesc Peters and John Woods suggested the concept of an Adaptive Biological Complexity (ABC) grid in the same line. The idea would be to have a low resolution ecosystem model that would increase in complexity as needed at sensitive points or times. It was deemed that technical modelling difficulties should be easily overcome and the work ahead would lay in determining the triggers that would automatically focus in and out in ecosystem complexity. For instance, modelling chlorophyll as a proxy for all phytoplankton may be good enough for large areas and certain times of the year but during blooms and/or near the coast it may be necessary to split the box into at least diatoms and small autotrophic flagellates. After river run-off events and/or the formation of thin layers, the complexity would need to be increased to incorporate several species.

This idea is a wonderful challenge for theoretical model builders.
One group selected two ideas as key:

1) Model validation is not quantitative enough.
2) With respect to zooplankton and larval fish modelling, the work at the individual level is proceeding but scaling up to the population level has not happened.

The first point reflects a common concern at both the workshop and the meeting: how to test and validate the models. What observations do we require to validate a model for a particular application? What are the relevant test metrics? How do we integrate the modelling and the observations? The concern with model validation and metrics has been an issue for this group since the first meeting and is part of the planning document.

One group made several broad points:

- Modellers should make their results publicly available in standard formats (e.g., net-CDF) and non-modellers should be encouraged to analyse these data for their own research questions. This should include results from long-term simulations to foster work with these data sets similar to that with observed long-time series from stations. For the North Sea, Moll and Radach (2003, Progress in Oceanography, 57:175–217) recommend that 3d biogeochemical simulation data be made available.
- There is a balance between complex model systems (full forcing, coupled calculations) and process-oriented models (idealised forcing, sub-models, zero- or one-dimensional modelling). The complex model systems should learn from the process-oriented models.
- The issue of how much complexity must be modelled to answer key questions is an open one. WGPBI should consider addressing this issue for a few key questions as it is a fundamental issue for all PBI modelling.
- Ecosystem models should develop towards community models. For example GOTM could become a library for biogeochemical models.
- The more model results are used and analysed the more central the question of model validation is. For this, benchmark data sets are needed.

The discussions in the breakout group and in plenary were vigorous. The results of these discussions are reflected in the next two sections (related to ToRs d and e).

7 Identify emergent physical-biological interaction issues (ToR d)

The following issues in PBI were identified.

New observational techniques such as the holographic submersible system that records movies of plankton *in situ* (presented in Section 4) and the thin layer techniques presented by Percy Donaghay at WKFDPBI will have an enormous impact on studies of plankton.

There is an increasing interest in modelling processes over time scales longer than a few months. As the time scales of interest increase so do the space scales. In open shelf environments this implies a need to model the interaction between the shelf and the deep ocean. As a result, the coupling of shelf models with basin-scale models is becoming an important issue. Some of the issues are:

a) technical issues related to the actual coupling including allowing for the shelf processes to feedback to the basin-scale model;
b) a need for improved modelling of the physical and biological processes at the shelf break.

The increasing demand for simulations exceeding a few months in length has several other consequences:

a) the need to couple water column models with benthic models because of the storage capacity of the benthos;
b) the need to model more and more of the ecosystem as the time scale of interest increases.

During the discussion Tom Osborn made the following point: Biological processes are very sensitive to the details of the physical models (e.g., bottom boundary layer heights, surface wind stress, mixed layer depths). It is likely that accurate biological simulation requires more accurate simulation of the physical processes that a typical physical application (e.g., estimating circulation). Thus the need for biological modelling will drive improvements in the physical models.

Model validation continues to be an important issue. In order to improve any model, the model's weaknesses must be known and ranked in order of importance, and improvement must be measurable when changes are made. Model testing has been an underdeveloped aspect of modelling PBI and needs to be improved. In modelling PBI, where even the form of the equations is in doubt, analysis of sensitivity to changes in parameter values is not sufficient. Sensitivity to the form of the equations should be considered.

The phrase 'model validation' can mean different things to different people. M. Skogen expressed the 'Pragmatic Approach to Model Validation' following Dee (1995):

"Validation of a computational model is the process of formulating and substantiating explicit claims about the applicability and accuracy of computational results, with reference to the intended purposes of the model as well as to the natural systems it represents."

In this approach, validation is a process that encompasses a wide range of activities. Claims about model accuracy which are based on comparing model results with measurements are inherently limited in scope, since they strictly apply only to the specific type of situation that the measurements pertain to. The statement *a model has been validated* does not imply that the model is correct, nor that it deserves some kind of stamp of approval. Rather, it signifies that the model has been subject to a variety of validation activities; that the results of these activities are available in the form of explicitly stated claims about the quality of model results ; that the substantiations of these claims have been thorough; and that the evidence upon substantiations are based can withstand scrutiny.

Dee (1995) makes the important point that:

"Those who are ultimately most concerned with the quality of the results of a computational modelling study are the end-users of those results. The users, rather than the modellers themselves, will eventually dictate what it takes for them to be convinced that a computational modelling is in fact worthwhile."

During the Workshop, in response to a question, John Woods summarized his method for verification of simulations of the plankton ecosystem. He gives it the name "Ecological Turing Test" (ETT). It is documented in Ch 18 of his book "Ocean Forecasting" (Springer, 2002). The ETT compares the same feature of the ecosystem in the simulation and in field observations. It asks the question: Could they both be samples of the same system? If so the simulation survives the test. That is the case when the difference between simulation and observation is less than the uncertainties in each. There are very few observations that are suitable for such testing, largely because of uncertainty due to inadequate sampling errors in the field observations. ETT has been used to compare the annual cycle of ocean colour at the Azores simulated by a Virtual Ecosystem and observed by SeaWIFS (Liu and Woods 2004a, b).

The essential feature of a complex system like the plankton ecosystem is that every emergent property is affected by errors (or uncertainty) in just one feature of the model or of the scenario used to integrate it. Errors in every feature of the model-plus-scenario contribute something to the differences between observation and simulation of an emergent property. So it is impossible to determine what the source errors are by ETT verification of emergent properties.

However, the sensitivity of emergent properties to uncertainties in each feature of the model-scenario can be established by laborious numerical experiments. That should always be done.

His conclusion was that there is no test that can say that a particular parameterisation of a physics-biology interaction in the model is correct. At best, we can hope to say that switching from one parameterization to another reduces the difference between emergent properties in ETT verification.

The 'Pragmatic Approach' and the ETT are two views of the same process. They emphasize different aspects but the goal is the same. For WGPBI several important points emerge from the discussions:

1) Model validation is a process not a yes/no decision.
2) Quantitative metrics are important.
3) In terms of the data available for model assessment, the available observational data sets are only able to reject badly flawed models. Focussed experiments that result in high quality data sets are required. However achieving such data sets for a particular application will require close interaction between the modellers and the observationalists because the answer the question 'What observations do you need to test the model?' is neither simple nor obvious.

References

Dee, D.P. 1995. A pragmatic approach to model validation. *In* Quantitative Skill Assessment for Coastal Ocean Models. Edited by Lynch, D.R. and Davies, A.M. American Geophysical Union. pages 1–14.

Liu, C.-C., and Woods, J. D. 2004a. "Prediction of ocean colour: Monte Carlo simulation applied to a virtual ecosystem based on the Lagrangian Ensemble method." International Journal of Remote Sensing, 25(5): 921–936.

Liu, C.-C. and Woods, J. D. 2004b. "Deriving four parameters from patchy observations of ocean color for testing a plankton ecosystem model." Deep-Sea Research II (in press).

8 Review, finalise, and start to implement the Strategic Plan (ToR e)

SGPBI had prepared a draft strategy document on Future Directions in Modelling Physical-Biological Interactions. C. Hannah presented this at the ASC 2003 during the theme session on physical-biological interactions. The presentation was well received. Based on feedback he revised the strategy document, now called a planning document and distributed it to the group. The final section of the document included potential activities for the group over the next 5 year. The goal of this meeting was to develop concrete plans for the next few years.

Based on discussions, two breakout groups were created to develop concrete action plans. One group considered the PBI aspects of modelling fish recruitment and the other discussed VEW3 and GOTM, the two ecosystem modelling workbenches presented earlier (see Section 4).

8.1 Fish Recruitment Modelling group

The Fish Recruitment Modelling group returned with a project called 'Towards the development of best practices for the modelling of early life history of fish.' The three major items were: 1) a review paper on larval fish modelling; 2) a theme session on larval fish modelling at the 2005 ASC; and 3) a workshop on larval fish modelling in 2006. It is expected that members will stay in close communication with members of the Working Group on Recruitment Processes. Alejandro Gallego and Thomas Miller are members of both WGRP and WGPBI and will facilitate this interaction. See Annex 3 for more details.

8.2 Numerical Experimentation group

The second breakout group took as a starting point the idea of best practice in modelling physical-biological interactions (PBI) in plankton ecosystem models used for fisheries recruitment, HABs and pollution studies. They concluded that at the end of 5 years it should be possible for a simulation of the BATS site (Bermuda Atlantic Time Series) to pass an Ecological Turing Test (see Section 7 above). The experience gained in achieving this difficult goal would contribute towards providing authoritative guidance to ecosystem modellers on best practice for modelling the PBI aspect of their models.

The proposed steps were:

- Establish a Numerical Experimentation Sub-group (NESG) within the ICES WGPBI
- Initial meeting to identify high priority topics for numerical experiments

- Design meeting for the chosen experiment(s).
- Experiments to be set up and run by those groups with workbenches.
- Analysis meeting to consider the results.

There was active discussion of the ideas in plenary and there was broad agreement with the goals. The only concern was related to the fact that one on the strengths of WGPBI is the active participation of the wide range of scientists in the general discussions. Would the creation of a subgroup weaken participation of all the working group members? The chairman agreed to monitor this potential problem.

The WG decided to proceed with the creation of the Numerical Experimentation Sub-group. This group will hold an initial meeting during the year and report at the next WGPBI meeting. Hans Burchard and John Woods will convene the initial meeting. More details can be found in Annex 4.

8.3 Other items

Many other items emerged from the discussions:

- F. Peters, T. Stipa and E. North will develop a WGPBI webpage that would host discussions relevant to WGPBI and provide a location to archive useful documents. They will work on this during 2004.
- As part of NTAP, F. Peters is developing a database on effects of turbulence on planktonic organisms. This database will be made available on the WGPBI website.
- There was mention that the International Polar year is in 2007/08. WGPBI should mark the event, and perhaps meet in northern location.
- C. Werner and C. Hannah agreed to consider an ICES/GLOBEC/PICES Symposium on Modelling Physical/Biological Interactions in 2008. They should write the ICES Resolution by May 15, 2004 if they are serious.
- The Numerical Experimentation Subgroup will consider offering a course on ecosystem modelling for research students. This may occur in cooperation with EuroOceans. M. St. John will lead this effort.

Several important information items that came up during the meeting:

- The GLOBEC program will be doing comparisons between upwelling systems in the form of a 1 month course on ecosystem modelling for students. This will start in 2006 and proceed for 2 or 3 years. The program will be led by Dale Haidvogel (Rutgers) and others.
- In 2004, there will be a workshop on parameterization of ecosystem models, if it is funded by the EU (contact Mike St. John).
- Warnemunde Turbulence Days will occur in September 2005. The call should occur in late 2004. Watch www.io-warnemuende.de/phy/wtd for details.

The idea of an ICES/GLOBEC/PICES Symposium on Modelling Physical/Biological Interactions has been suggested several times. In May 2004, Werner and Hannah decided not to put forward resolution.

9 Cooperate with SGBEM to explore Baltic ecosystem models (ToR f)

Wolfgang Fennel, Chair of the new ICES Study Group on Baltic Ecosystem Modelling Issues in Support of the BSRP (SGBEM) presented the structure of the Baltic Sea Research Program and the 4 new ICES Study Groups. Then he reported on the first meeting of SGBEM (12–14 January 2004). The SGBEM considers the WGPBI as its parent group, which implies the membership of several scientists in both groups. The SGBEM report will be distributed to the WGPBI in May.

10 Consider opportunities to contribute to regional integrated assessments (ToR g)

Einar Svendsen, as Chair of the Oceanography Committee, explained that the regional assessments were an important part of the future of ICES and the committee was looking for ideas about new products that could be delivered as part of the assessments.

After much discussion it was decided that WGPBI would not respond as a group. The group encourages members to contribute to the review of the REGENS and NORSEPP reports and contribute ideas on other products that could be delivered. Pointers to the relevant documents were provided in the agenda (Annex 2).

Andreas Moll contributed directly to REGNS for their meeting 5–7 April, 2004.

11 Concluding business

The final two items of business were the location of the next meeting and the resolution for the next meeting.

- Mike St. John agreed to host the 2005 meeting in Hamburg in March.
- The resolution for the 2005 meeting is in the next section.

Before closing the meeting the Chair thanked Francesc Peters for hosting the workshop and the meeting. Both were very successful.

12 Actions, recommendations and draft resolutions

Action Item 1: F. Peters and C. Hannah will act as guest editors for a special issue of the J. of Marine Systems based on the WKFDPBI.

Action Item 2: F. Peters, C. Hannah and W. Fennel with co-convene the theme session at the 2004 ASC on Physical-Biological Interactions.

Action Item 3: F. Peters, T. Stipa and E. North will develop a WGPBI website that will host discussions relevant to physical-biological interactions, and provide a location to archive useful documents and links to other websites. They will work on this during 2004.

Action Item 4: T. Osborn will co-convene, with Hendrik van Aken of WGOH, a theme session in 2005 on 'Recent advances in our understanding of marine turbulence.'

Action Item 5: C. Hannah will revise the draft plan to emphasize the need for modellers to interact with observationalists to design observations that will permit rigorous evaluation of the models and allow the community to select and reject models based on quantitative criteria. Done (Annex 5).

Action Item 6: Resolution for larval fish theme session in 2005. North and Gallego. Done (Resolution 2 below).

Action Item 7: Resolution for larval fish workshop in 2006. Gallego and North. Done (Resolution 3 below).

Action Item 8: Resolution for an ICES/GLOBEC/PICES Symposium on Modelling Physical/Biological Interactions in 2008. Werner and Hannah. Decision was made not to proceed.

Action Item 9: Create a Numerical Experimentation Subgroup and convene the initial meeting before the 2005 WGPBI meeting. H. Burchard and J. Woods.

Action Item 10: Respond to WGHABD on a joint Theme Session at the ICES ASC in 2006 with a proposed title 'Harmful Algae Bloom Dynamics; Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge.' The full proposal from WGHABD is as follows.
A joint Theme Session (between the WGHABD and the WGPBI with invited contributions from GEOHAB) at the ICES ASC in 2006 was suggested on: "Harmful Algae Bloom Dynamics; Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge" as in spite of large gaps of basic process knowledge around HAB dynamics, several 3D modeling initiatives are ongoing with respect to studying and predicting HABs. Therefore it is due time to couple the expertise of modelers and biologists to reveal the most urgent needs for better process knowledge to improve the predictability of models. The session aims at participation from 3D modelers and biologist interested in explaining why HABs occur, how they are initiated, how and why they develop in space and time, and why they decay.

Resolution 1:

The Working Group on Modelling Physical/Biological Interactions [WGPBI] (Chair: C. Hannah, Canada) to will meet at Hamburg (Host: Mike St. John) in March/April 2005 to:

a) Present and discuss new results related to developments and validation in modelling PBI.
b) Create a WGPBI website for information exchange.
c) Discuss draft review, prepared intersessionally, on nutrient load reduction.
d) Prepare a review of the state of the art in larval fish modelling.
e) Receive report from the Numerical Experiment subgroup.
f) cooperate with SGBEM to explore ecosystem models.
g) cooperate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment.

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

Supporting Information

Priority:	The WG should be given high priority since it is concerned with the evaluation and development of the modelling tools used to increase the understanding of the interaction between the living resources in the sea and its ambient physical and abiotic environment. This understanding is essential to the successful development of predictive capability of the state and evolution of the ecosystem for issues such as harmful algal booms, eutrophication, marine protected areas, fish recruitment, and global change. This contributes directly to fulfilling the vision of ICES, "to improve the scientific capacity to give advice on the human impact on, and impacted by, marine ecosystems."
Scientific Justification and relation to action plan	The work of WGPBI contributes to the following ICES Activities: • Activity 1.5 (modelling biological-physical interactions in the sea), • Activity 1.1 (provide feedback about research needs), • Activity 1.2 (increase knowledge with respect to functioning of the ecosystem). Contributions towards other Activities are noted in the justification below. a) Providing a forum for the presentation and discussion of new results is an important component of the group's mandate. b) A WGPBI website will be created intersessionally. This site will host discussions relevant to WGPBI and provide a location to archive useful documents. c) The issue of how an ecosystem will respond to nutrient load reductions is of wide interest. During the last two years, members of WGPBI have been involved in three different studies to investigate the responsiveness of ecological models to changes in anthropogenic loads. A review of the three studies will be presented at the 2005 WGPBI meeting. Activity 1.12, 2.8, 2.9. d) A review of the state of the art in larval fish modelling will be prepared intersessionally and submitted to a peer reviewed journal. The review will encompass the interaction between physical processes and 1) egg production, including maternal effects, etc., 2) larval stages, incorporating specific processes such as feeding, growth, mortality, behaviour, etc. and 3) early juvenile stages, addressing issues such as settlement, etc. The review will identify knowledge gaps, highlight the state-of-the art in the field and present alternative strategies. The review will serve as a basis for discussion at the WGPBI meeting. e) A Numerical Experimentation Subgroup will be established to investigate best practice in modelling physical-biological interactions (PBI) in plankton ecosystem models used for

	fisheries recruitment, HABs and pollution studies. At the end of 5 years it should be possible to provide authoritative guidance to ecosystem modellers regarding best practice for modelling the PBI aspect of their models. This group will hold an initial meeting during the year and report at the next WGPBI meeting. Hans Burchard and John Woods will convene the initial meeting. f) The Baltic Sea Regional Project is supported by the World Bank and aims at improvement of infrastructure for science driven monitoring. The new ICES Study Group on Baltic Ecosystem Modelling Issues in Support of the BSRP (SGBEM) considers the WGPBI as its parent group, which implies the membership of several scientists in both groups. Activity 1.12 g) Members of WGPBI and WGRP (Working Group on Recruitment Processes) share the common goal of enhancing, guiding, and promoting use of coupled physical-biological models for prediction of fisheries recruitment. Close coordination between working groups is required to ensure optimal use of resources and prevent duplication of efforts. WGPBI members will invite WGRP involvement in 2004–2006 WGPBI activities including coordination of literature review (ToR d) and joint sponsorship of the proposed Theme Session (2005) and Workshop (2006). We will also work to develop a joint task between WGPBI and WGRP in 2007–2009. For example, WG members may focus efforts on building a community approach for using coupled physical-biological models in recruitment prediction.
Resource Requirements:	No specific resource requirements beyond the need for members to prepare for and participate in the meeting.
Participants:	The working group benefits from the participation of those outside of the modelling community. Observational and experimental scientists with an interest in physical-biological interactions are encouraged to attend.
Secretariat Facilities:	None
Financial:	None
Linkages To Advisory Committees:	ACFM, ACE
Linkages To other Committees or Groups:	ICES-IOC Working Group on Harmful Algal Bloom Dynamics WGZE, WGRP, BSRP SG on modelling
Linkages to other Organisations	GEOHAB (IOC/SCOR), GLOBEC (IOC/SCOR), PICES
Secretariat Cost Share	ICES:100%

Resolution 2: A Theme Session 2005

ICES ASC Theme Session 2005 (WGPBI)

Title: Connecting biological-physical interactions to fish recruitment variability

Conveners: Elizabeth North (USA), Alejandro Gallego (UK)

Description:
Physical-biological interactions are an integral part of understanding fish early-life history and the processes that affect interannual variability in recruitment. All fish early-life stages, from eggs to settling juveniles, are influenced by physical-biological interactions at small scales (e.g., feeding success, predator avoidance) to large scales (e.g., transport to nursery areas, ecosystem productivity). Recent advances in field, laboratory, and modelling research have resulted in numerical descriptions and model parameterizations of fish early-life. Improved understanding and predictive ability provided by these advances will enhance our understanding of fish recruitment variability and will be critical for the success of ecosystem-based fisheries management.

Field, laboratory and numerical contributions that focus on physical-biological interactions in fish early-life with links to population variability are welcome.

We are inviting co-sponsorship from WGRP.

Resolution 3: A Workshop for 2006

A workshop entitled "Advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions" (Co-chairs: A. Gallego, UK, and E. North, USA) will be held in conjunction with the WGPBI meeting in 2006 to:

a) summarize current state of the art in modelling physical-biological interactions in fish early-life history

b) review important technical/methodological issues (including model sensitivity and validation), prioritize important processes to be included in the models, and identify knowledge gaps

c) develop a manual of recommended practices and list of future research directions as proceedings from the workshop

The workshop will report by 15 May 2006 for the attention of the Oceanography Committee.

Supporting Information

Priority:	This workshop will provide guidance at critical juncture in the developing field of modelling physical-biological interactions in the early-life history of fish.
Scientific Justification and relation to action plan	The field of modelling physical-biological interactions in fish early-life history is rapidly developing. A wide range of techniques and approaches has proliferated in the recent past. It is clear that physical-biological interactions are an integral part of understanding fish early-life history and the processes that may affect interannual variability in recruitment. We feel that it is time to review modelling strategies and underlying processes, with the goal of developing a synthesis of recommended practices and identifying knowledge gaps to guide future developments in the field. We will focus on technical/methodological issues, important physical and biological processes, and on future research needs. In addition to providing valuable guidance for the field of physical-biological interactions, this workshop will foster information exchange and advance application of cutting-edge modeling approaches to issues that are critical for the ICES mission such as fish recruitment variability, marine protected areas, and ecosystem-based management.
Resource Requirements:	The Workshop contributes to ICES Goal 1, in particular Activities 1.2.1, 1.3, and 1.5.
Participants:	This Workshop should attract 25-40 participants and will include some scientists from outside the regular ICES scientific community. We plan to identify participants during the 2005 ASC Theme Session proposed by WGPBI entitled "Connecting biological-physical interactions to fish recruitment variability". We also will invite participation from ICES groups with an interest in physical-biological interactions and fish recruitment processes (e.g., WGCCC, WGRP, WGZE, WGFE, SGCRAB) and from groups such as GLOBEC and PICES.
Secretariat Facilities:	None
Financial:	None

Linkages To Advisory Committees:	Relevant to the work of the ACFM, ACE
Linkages To other Committees or Groups:	WGCCC, WGRP, WGZE, WGFE, SGCRAB
Linkages to other Organisations	GLOBEC (IOC/SCOR), PICES, IMBR, GOOS
Secretariat Cost Share	

13 Annexes

Annex 1 List of participants

Name	Address	Telephone no.	Fax no.	E-mail
Hans Burchard	Institut für Ostseeforschung Seestrasse 15 D-18119 Warnemünde Germany	-	-	Hans.burchard@io-warnemuende.de
Asbjørn Christensen	Danish Institute for Fishery Research Charlottenlund Slot DK-2920 Charlottenlund Denmark			asc@dfu.min.dk
Unai Cotano	AZTI Herrera kaia, Portualde z/g 20110 Pasaia (Gipuzkoa) Spain			ucotano@pas.azti.es
Hans Dahlin	SMHI SE-601 76 Norrköping Sweden	+46 11 495 8305	+46 11 495 8350	Hans.Dahlin@smhi.se
Stephan Dick	Bundesamt f. Seeschiffahrt und Hydrographie Bernhard-Nocht-Str. 78 D-20359 Hamburg Germany			dick@bsh.d400.de
Solva Eliasen	Faroese Fisheries Laboratory Nóatún P.O. Box 3051 FO-110 Tórshavn Faroe Islands Denmark			Solvae@frs.fo
Wolfgang Fennel	Institut für Ostseeforschung Seestrasse 15 D-18119 Warnemünde Germany	+49 381 5197110	+49 381 5197 114	wolfgang.fennel@io-warnemuende.de
Luis Ferrer	AZTI Herrera kaia, Portualde z/g 20110 Pasaia (Gipuzkoa) Spain			iferrer@pas.azti.es
Alejandro Gallego	Fisheries Research Services Marine Laboratory P.O. Box 101 375 Victoria Road Aberdeen AB11 9DB United Kingdom			gallegoa@marlab.ac.uk
Guoqi Han	Dept. of Fisheries & Oceans Northwest Atlantic Fisheries Centre P.O. Box 5667 St John's, Nfld A1C 5X1 Canada			HanG@dfo-mpo.gc.ca

Name	Address	Telephone no.	Fax no.	E-mail
Charles Hannah	Dept. of Fisheries & Oceans Bedford Institute of Oceanography P.O. Box 1006 Dartmouth, NS B2Y 4A2 Canada	902-426-5961		hannahc@dfo-mpo.gc.ca
Joakim Hjelm	Institute of Marine Research Box 4 SE-453 21 Lysekil Sweden			joakim.hjelm@fiskeriverket.se
Stephanie Magri Hoeltzener	IFREMER Centre de Brest BP 70 F-29280 Plouzané France			Magri.Hoeltzener@ifremer.fr
Mike St John	Institut für Hydrobiologie und Fischereiwissenschaft Olbersweg 24 D-22767 Hamburg Germany			michael.st.john@uni-hamburg.de
Andreas Moll	Institut fuer Meereskunde Universitaet Hamburg Troplowitzstr. 7 22529 Hamburg Germany	49(0)4042838-2526	49(0)405605724	moll@ifm.uni-hamburg.de
Thomas Neumann	Institut für Ostseeforschung Seestrasse 15 D-18119 Warnemünde Germany			Thomas.neumann@io-warnemuende.de
Elizabeth North	University of Maryland Center for Environmental Science Horn Point Laboratory P.O. Box 775 Cambridge, MD 21613 USA			enorth@hpl.umces.edu
Tom Osborn	Dept. of Earth and Planetary Sciences The Johns Hopkins University Baltimore, MD 21218 USA			osborn@jhu.edu
Francesco Peters	Institut de Ciencies del Mar CMIMA (CSIC) Pg. Maritim de la Barceloneta, 37-49 E-08003 Barcelona, Catalunya Spain	34-93-230-9500	34-93-230-9555	cesc@icm.csic.es
Urmas Raudsepp	Marine Systems Institute Tallinn Technical University Akadeemia tee 21 12618 Tallinn Estonia			raudsepp@phys.sea.ee
Alfred Sandstrom	Slipvägen 19 P.O. Box 584 740 71 Öregrund Sweden			alfred.sandstrom@fiskeriverket.se

Name	Address	Telephone no.	Fax no.	E-mail
Morten Skogen	Institute of Marine Research P.O. Box 1870 Nordnes N-5817 Bergen Norway			morten@imr.no
Tapani Stipa	Finnish Institute of Marine Research P.O. Box 33 FI-00931 Helsinki Finland			Tapani.Stipa@fimr.fi
Einar Svendsen	Institute of Marine Research P.O. Box 1870 Nordnes N-5817 Bergen Norway	+47 55 238500	+47 55 238531	einar.svendsen@imr.no
Alain Vezina	Dr Alain Vezina Dept. of Fisheries & Oceans Bedford Institute of Oceanography P.O. Box 1006 Dartmouth, NS B2Y 4A2 Canada			vezinaa@dfo-mpo.gc.ca
Cisco Werner	Marine Science Program University of North Carolina 12-7 Venables Hall CB3300 Chapel Hill, NC 27599-3300 USA			cisco@marine.unc.edu
John Woods	T.H. Huxley School of Environment Earth Science and Engineering Imperial College London SW7 2BP United Kingdom	44(0)2075947414	44(0)2075947444	j.woods@ic.ac.uk

Annex 2 Draft agenda

ICES Working Group on Modelling Physical/Biological Interactions (WGPBI)
Barcelona, 10–11 March 2004.

Wednesday morning (0900–1300)
Welcome, Introductions
Discuss agenda
Workshop wrap-up – ToR c and d.

- Rapporteurs reports: 4 sessions at 15 minutes each: 1 hour
- 2-4 Breakout Groups – What were the key ideas from the workshop? 1 hour
- Plenary review and discussion
- Special Issue of JMR
- Workshop Report

ICES Study Group on Baltic Ecosystem Modelling –20 minutes – ToR f
Wolfgang Fennel

Lunch (1300–1500)

Wednesday afternoon (1500–1800)
Presentations of new work – 2 hours . ToR a

- Elizabeth North Modeling oyster larvae dispersal in Chesapeake Bay (15 min)
- Stephanie Magri A 1D model for the vertical distribution of fish eggs (15 min)
- Hans Burchard GOTM with embedded biology (30 min)
- John Woods How the VEW can contribute to the aims of the WGPBI. (15 min)
- John Woods Ergodicity (15 min)
- Einar Svendsen *MONCOZE* - Monitoring the Norwegian Coastal Zone Environment (20 min)

Short break (15 min)

Introduction to the draft five-year plan (Hannah) 1 hour

- Presentation of proposed ideas
- Presentation of new proposals and ideas

Thursday morning (0900-1300)
The five-year plan. 3 hours ToR e

- Discussion
- Breakout Groups to work on elements of plan (order emerges from chaos)
- Review of elements of plan

Discussion of unfinished business – 1 hour

- Discussion of how to address ToR b.
- Thomas Neumann

ToR g was added by ICES. How do we address it?

- Reports related to ToR g
  - http://www.ices.dk/reports/OCC/2003/PGNSP03.pdf
  - http://www.ices.dk/reports/ACE/2003/REGNS03.pdf
  - The ICES Study Group on Information Needs for Coastal Zone management has sent a questionnaire. We should respond.
  - SGINC 2003 Report at http://www.ices.dk/reports/MHC/2003/SGINC03.pdf

Lunch (1300–1500)

Thursday afternoon (1500–1800)
Working Group Report.
Resolutions for 2004 ASC.
Revisions to five-year plan.
Date/location/host for next meeting.
Request for April/May. Do we want to change? What is argument for March?

Annex 3 Towards the development of best practices for the modelling of early life history of fish

Rationale

The field of bio-physical modelling of the early life history of fish is a rapidly developing one and a wide range of techniques or approaches has proliferated in the recent past. It is clear that physical-biological interactions are an integral part of understanding fish early life history and the processes that may affect interannual variability in recruitment. We feel that it is now the time to review modelling strategies and underlying processes, with the aim to develop a synthesis of best practices and identify knowledge gaps to guide future developments in the field.

Strategy

Literature review

We propose to conduct a review of the literature to synthesise the latest understanding and methodologies used in bio-physical modelling of early life history of fish. The review will encompass the interaction between physical processes and

- Egg production, including maternal effects, etc.
- Larval stages, incorporating specific processes such as feeding, growth, mortality, behaviour, etc.
- Early juvenile stages, addressing issues such as settlement, etc.

The review will identify knowledge gaps, highlight the state-of-the art in the field and present alternative strategies. The review will serve as a basis for discussion at the WGPBI meeting.

ASC Theme Session

We propose to convene a Theme Session at the ICES ASC to bring together quantitative field, laboratory and modelling research focused on developing numerical descriptions and parameterisations for modelling the early life history of fish. We will encourage contributions that focus on processes that act on the individual scale and have the potential to scale up to the population/ecosystem level.

Workshop

We proposed to hold a workshop to develop a document of best practices for bio-physical modelling early life history of fish. This should deal with technical/methodological issues, including model validation, as well as identifying the important processes to be included in the models. The participants in the workshop will be identified at the Theme Session.

Timeline

Spring 2005: Review completed and presented to at the WGPBI 2005 meeting. The review will be discussed and a preliminary best practices document will be hatched. We aim to have the review published in a peer-reviewed journal as soon as possible after the WGPBI meeting.

Autumn 2005: ASC Theme session.

Spring 2006: Workshop immediately prior to WGPBI 2006 meeting. A document of best practices will be drafted at the workshop and finalised as soon as possible after the meeting.

Annex 4 Numerical Experimentation Subgroup

A Numerical Experimentation Subgroup will be established to investigate best practice in modelling physical-biological interactions (PBI) in plankton ecosystem models used for fisheries recruitment, HABs and pollution studies. At the end of 5 years it should be possible to provide authoritative guidance to ecosystem modellers regarding best practice for modelling the PBI aspect of their models.

The initial activities of the group will focus on 1D modelling using the two workbenches that were presented at the meeting (VEW3 and GOTM). The aim is to explore the ecological consequences of changing the way particular PBIs are modelled. The workbenches allow the user to quickly set up numerical experiments for this purpose.

The integration of what is learned in the 1D models into the 3D comprehensive models will be integrated into the work program.

The proposed steps are:

- Establish a Numerical experimentation group within the ICES WGPBI
- Initial meeting to identify high priority topics for numerical experiments
- Design meeting for the chosen experiment(s).
- Experiments to be set up and run by those groups with workbenches.
- Analysis meeting to consider the results.

The initial meeting will be convened by Hans Burchard and John Woods.

Terms of reference

- The aim of the NESG is to establish best practice in modelling physics-biology interactions in ecosystem models
- It will do so by commissioning numerical experiments designed to compare alternative methods for modelling the same PBI process, and assessing the results of those experiments.
- The numerical experiments will be performed by research groups with appropriate resources.
- The NESG will assess the results of the numerical experiments
- The NESG will run a training workshop on PBI in ecosystem modelling aimed at research students and postdocs.
- The NESG will report their findings to the WGPBI.

Membership

- The membership of the NESG will include:
  - A representative of each research group that has the resources needed to perform PBI numerical experiments
  - Other members of the ICES WGPBI
- Each year the NESG will choose a Chair for the next year

Plan for the first year

Before the March 2005 meeting of the WGPBI the NESG will:

- Identify groups that have the resources to perform numerical experiments in PBI.
- Invite each of those groups to nominate a representative to serve on NESG
- Identify PBI processes in marine ecological models that can be the subject of numerical experiments
- Select an initial set of experiments for the following year
- Start to plan a training course on PBI in ecosystem models
- Hold a one-day meeting immediately before the 2005 meeting of the WGPBI
- Present a plan of work to the WGPBI

Annex 5 Draft plan for WGPBI

11 May, 2004

The goal of the ICES Working Group on Modelling Physical-Biological Interactions (WGPBI) is to foster the development of tools required to increase the understanding and predictability of the interaction between living resources in the sea and the physical environment. This document presents the principles that will govern the activities of the working group and a draft of the group's activities for the five-year period 2004–2008.

The field of physical-biological interactions can cover the spectrum from bacteria to whales. WGPBI restricts itself to planktonic organisms, considered to include larval fish.

The WG also restricts itself to dynamical (or mechanistic) models generally derived from an understanding of the basic processes. In addition, the WG focuses on models that have the potential to be spatially and temporally explicit and thus could be coupled to a circulation model.

We take an axiom that all models are approximations to reality and that a key modelling challenge is to determine the level of detail necessary to capture the essential features relevant to the problem being addressed.

The overall theme of the WG's activities is improving the predictive power of the models. This implies a focus on models intended for practical applications. The discussion of the future developments and required improvements is broken into three categories:

- basic biological knowledge;
- the generality of our models;
- the ability to rigorously test models with ocean observations.

Improvements in basic biological knowledge

The field of modelling physical-biological interactions is dominated by two facts:

- There are 1000s of planktonic species for which there is not sufficient biological information to construct models.
- There are substantial gaps in our knowledge of the best studied species.

These knowledge gaps are one of the great challenges of modelling PBI. They limit the kinds of questions that can be asked and the kinds of models that can be developed for practical applications.

For the purposes of modelling PBI, the basic description of an organism should include:

- The ability of organisms to adapt and exploit to the local environment.
- The range of variability of basic biological parameters values for that species.
- Phase transitions in the life cycle.
- Responses to realistic variability in the environment.
- Formulation of the physiology and behaviour of planktonic species in mathematical terms

This list of elements in the basic description reflects the fact that change and variability are major factors in the future requirements for modelling. Some examples are: 1) for some species the temperature for optimum growth depends on the recent history of the organisms; 2) within a given species, the organisms are not clones and conditions that are less than optimal for one part of the population may be just fine for another; 3) many organisms have different phases to their life history, diapause in some zooplankton species, the cyst stage for some harmful algal bloom species, the developmental stages of larval fish. All of these features can have an enormous impact on an organism's interaction with its environment.

Improvements in model generality

By generality we mean the ability to move the model from place to place without having to revisit the entire model structure and recalibrate the model. If you calibrate an ecosystem model in one bay, you should have some confidence that it will work in the next bay over. In the context of global models for climate change simulation, one needs confidence that the model parameterizations are valid for different regions of the global ocean and under different climate regimes.

There is tension, perhaps creative tension, between the need for generality and the axiom that a key modelling challenge is to determine the level of detail necessary to capture the essential features relevant to the problem being addressed. The community needs to combat the tendency to say that every problem and every piece of the ocean is so unique that it requires it own special model. Overall, we need to recognize differences and pursue generality.

As stated earlier, all models are approximations. One of the fundamental approximations is aggregation; the collection of individuals into species and species into communities, assemblages, and/or functional groups. Methodologies are required for aggregation depending on the problem and these methods need to account for the fact that changes in the biological and physical environment can shift the composition of the assemblage and thereby alter the associated functional responses and parameters. Two areas for research are: 1) understanding how the choice of aggregation affects the model's error, sensitivity and uncertainty; and 2) making the aggregations dynamic, so that they adjust to the environment.

Another approximation is the abiotic environment that the virtual organisms experience. The quest for realistic and detailed simulations of physical-biological interactions, and the quest for simulations of responses to a changing environment leads to the requirement for detailed simulations of the abiotic (physical and chemical) environment. Many models of PBI (such as ecosystem models and larval fish IBMs) have become very sophisticated and sensitive to the details of the physical forcing fields (Franks, 1997; Chen and Annan, 2000) and for many applications the biological component of the physical-biological models have matured to the point where at least some of the error (deviation from observations) can be attributed to errors in the physical forcing (e.g., Sarmiento *et al*. 1993). Further development and validation of models of physical-biological interactions will require the best possible physical forcing and this generally requires high quality physical models. This follows standard practice in the atmospheric sciences, where studies of air quality, pollutant transport and detailed process studies use circulation fields from meteorological analysis that combines observations and models to provide the best estimate the circulation.

For models designed to be useful in practical applications, the pursuit of generality requires rigorous assessment to determine the level of confidence in model predictions, to know when a model can be expected to fail, and to know where improvements are needed. The modelling of physical/biological interactions is still in the early stages of development in this area and current methods of model validation are primitive. In many cases the proper metrics for quantifying model error, sensitivity and uncertainty are not obvious and they are likely problem-dependent.

This document has deliberately avoided commenting on particular details of modelling technology. However we need to make a few comments related to individual based models in order to provide guidance on the likely directions of model development.

The first statement is that biological models must be based on approximations consistent with individual dynamics. This is not a bold statement. Our understanding of the dynamics of the overall system has to be consistent with our understanding of the individual organisms. However, the connections may not be obvious. In the language of dynamical systems theory, there may be 'emergent properties' that are not clearly connected with the dynamics at the level of the individual. But the community needs to demonstrate that the emergent properties are consistent with each individual doing its thing.

The second statement is an observation. The use of Individual Based Models (IBMs) will continue to increase as computer power and the biological information required for IBMs increases.

Improvements in the ability to rigorously test models with ocean observations

In order to improve a model, any model, you need to know where the weaknesses are, you need to be able to rank the weaknesses by their importance and when you make changes you need to be able to measure the improvement. Model testing has been an underdeveloped aspect of modelling PBI and needs to be improved (see comments in Moll 2000; Moll and Radach 2001; Soiland and Skogen 2001; SGPBI 2002 Section 5.4). In modelling PBI, where even the form of the equations is in doubt, analysis of sensitivity to changes in parameter values is not sufficient. Sensitivity to the form of the equations should be considered.

In terms of the data available for model assessment, we believe that available observational data sets are only able to reject badly flawed models. Focussed experiments that result in high quality data sets are required. However achieving such data sets for a particular application will require close interaction between the modellers and the observationalists because the answer the question 'What observations do you need to test the model?' is neither simple nor obvious.

A complement to the focussed data sets will be the large volumes of data that will arise from the many ocean observing systems being developed under GOOS (global ocean observing system) and Coastal GOOS. The volume of data will provide both challenges and opportunities for the community.

The way forward for WGPBI

WGPBI will play an important role in keeping the ICES community informed of new advances in modelling physical-biological interactions and of emerging issues that required improved models. The success of theme sessions related to physical-biological interactions at the ICES ASC in 2002 and 2003 indicates that the field is important to the ICES community. WGPBI will continue to sponsor theme sessions at the ASC to provide a forum for work in this field. In addition, the open forum for the presentation and discussion of new results will continue to be an important feature of WG meetings and WGPBI will maintain ongoing communication with other ICES working groups on the topic of physical-biological interactions.

Many scientific communities are making progress across the range of issues discussed above and members of WGPBI are actively involved. We believe that WGPBI can make a contribution by promoting a community approach to modelling PBI and encouraging progress in the following areas:

- Common notation;
- Shared tools (model code, visualization, etc.);
- Model intercomparison studies;
- Regional comparisons;
- Standard test cases.

A community approach to modelling is not driven by grand visions, but by people choosing to work together in an open fashion. WGPBI may contain a sufficient number of like minded people for a successful community approach.

The reason for promoting a community approach is to enable the rapid transfer of successful ideas and approaches from one species to another and one region to another. One barrier to this rapid transfer is the wide range of notation for PBI and the fact that is often difficult to understand the similarities and differences of two models of the same process. A second barrier is that the computer code for many models is intimately tied to a particular physical model for a particular region. Thus the models tend not be very portable and a large investment is required to move a sophisticated PBI from one physical model to another.

A second theme in the activities of WGPBI is defining best practice; the state of the art in modelling physical-biological interactions for different applications. 'Best Practice' is often application and context dependent and may not use the most sophisticated models. However this should not prevent us from trying to describe best practice where we can. In the future a manual of best practice could be a web based document describing the best practices for modelling physical-biological interactions for a variety of applications. For the moment we confine ourselves to defining best practice in the projects described below.

Larval fish modelling

A strong larval fish group has emerged and proposed a program called 'Towards the development of best practices for the modelling of early life history of fish.' The field of bio-physical modelling of the early life history of fish is a rapidly developing one and a wide range of techniques or approaches has proliferated in the recent past. It is clear that physical-biological interactions are an integral part of understanding fish early life history and the processes that may affect interannual variability in recruitment. It is now the time to review modelling strategies and underlying processes, with the aim to develop a synthesis of best practices and identify knowledge gaps to guide future developments in the field. The program of work includes a review paper, a theme session at the ICES ASC in 2005 and a workshop in 2006.

Numerical experimentation subgroup

A Numerical Experimentation Subgroup will be established to investigate best practice in modelling physical-biological interactions (PBI) in plankton ecosystem models used for fisheries recruitment, HABs and pollution studies. At the end of 5 years it should be possible to provide authoritative guidance to ecosystem modellers regarding best practice for modelling the PBI aspect of their models.

The initial activities of the group will focus on 1D modelling using the two workbenches that were presented at the meeting (VEW3 and GOTM). The aim is to explore the ecological consequences of changing the way particular PBIs are modelled. The workbenches allow the user to quickly set up numerical experiments for this purpose.

The 1D ecosystem model, a water column model, provides a framework where the details of the model of interest can be examined in a controlled setting with modest computation demands (Randall *et al*. 2003). The key concept is a generic framework for incorporating different PBI model formulations into the same abiotic environment where they can be examined and tested. The US JGOFS community is pursuing a related idea with their regional testbeds for model comparisons.

The integration of what is learned in the 1D models into the 3D comprehensive models will be part of the work program.

Other

The issue of how an ecosystem will respond to nutrient load reductions is of wide interest. During the last two years, members of WGPBI have been involved in three different studies to investigate the responsiveness of ecological models to changes in antrophogenic loads in the Baltic and North Sea (Neumann *et al*. 2001, 2002; Schernewski and Neumann, 2004; Skogen *et al* 2004; Stipa *et al*. 2004). A review of the three studies will be presented at the next WGPBI meeting (2005).

A large number of members of WGPBI have research interests in turbulence. The interests range from measuring turbulence in the ocean, to the influence of turbulence on the growth and development of organisms, to modelling the effect of turbulence on the movement of zooplankton and larval fish. However a community of interest has not yet arisen to propose specific work within WGPBI.

An area where WGPBI could contribute is chaos in ecosystem models. It is still an open question whether chaos represents real ecosystem dynamics or is an artifact of modelling techniques. WGPBI could contribute a review, aimed at a broad audience that provides a clear framework for discussing the inherent predictability of the natural ecosystem and virtual ecosystems (as represented by various modelling techniques) at NPZD or higher levels. Is the chaos is real, does it matter, and what are the implications for different applications? No one has taken this project on.

A draft calendar of work activities is presented in Annex 6 of the 2004 WGPBI report. This plan will be reviewed and revised annually as new activities evolve.

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Annex 6 Table of activities

Draft Calendar of Events

Year	Event
2004	Workshop on 'Future Directions for Modelling Physical Biological Interactions'. Special Session at ICES ASC on Physical-Biological Interactions in Marginal and Shelf Seas. First meeting the Numerical Experimentation Subgroup.
2005	Theme Session at ICES ASC on 'Recent advances in our understanding of marine turbulence.' Joint with WGOH. Theme Session at ICES ASC on 'Connecting biological-physical interactions to fish recruitment variability.' Possibly joint with WGRP. Special issue of J. Marine Systems from 2004 workshop. Draft review of nutrient load reduction experiments. Draft manuscript of modelling techniques for larval fish
2006	Workshop on 'Advancements in modelling physical-biological interactions in the early-life history of fish: recommended practices and future directions larval fish modelling.' Database on effects of turbulence on planktonic organisms. Potential to co-sponsor, with WGHABD, a Theme Session at the ICES ASC on 'Harmful Algae Bloom Dynamics; Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge'
2007	–
2008	–

Annex 7 Breakout groups on big ideas from workshop

There were three breakout groups formed to discuss the Workshop and try and extract the big ideas and the emerging issues. Here we simply reproduce the reporting notes from each group. These have been heavily filtered in the body of the report.

Group A

Topics
- Harmful algal booms
- Fisheries recruitment
- Parametrization of turbulence
- Fine-structure
- Model-ecology (field data) interaction
- Model-biology (laboratory data) interaction
- Role of one-dimensional models
- BIG IDEA

Harmful blooms
Need a comprehensive "biologically-coarse" model, into which "biologically-detailed" model can be nested
- Biologically-coarse uses functional groups
- Biologically-detailed uses species
- See BIG IDEA, later

Fisheries recruitment
- Predator-prey description in the models
- Statistics used in empirical models, and in model calibration, tuning, etc.

Parametrizing turbulence
- Need to investigate sensitivity of emergent ecological properties to different methods of parametrizing turbulence
- Scan through the multiplicity of responses by individual plankters to turbulence

Role of 1D models
- Stepping stone to three-dimensional models.
- Useful for WG for sorting out PBI in a simple virtual environment.

BIG IDEA
- An idea that many modellers have played with, brought forward in the meeting by Francesc Peters and John Woods,
- In physical space we can use adaptive grids that automatically provide higher spatial resolution at sensitive locations.
- Can we do the same in the ecosystem?
- Can we automatically enhance the community resolution at sensitive points in the ecosystem by enhancing resolution in multi-dimensional biological parameter space?
- A nice challenge for theoretical model builders.

Group B

- Models are successful at some level: circulation → N, P, > Z.
- Validation is not quantitative enough: data archives and accessibility, experimentalists.
- Work at individual levels is proceeding but not at the population level (applies to fish and zooplankton). The scaling up problem.
- Models of recruitment still lacking.

- Identification of key players in structuring ecosystems.
- Standardize forcings to be able to compare results of ecosystem models.
- Common “currencies” of model/data comparison.
- Data assimilation / GOOS / GODAE – Mercator.
- Numerical schemes have not converged (LES, DNS, FEM, FD)
- Determination of physiological rates is confused (are the experiments reproducible?).
- *In situ* life cycle and relation to physics at the physical scales, e.g., red tides, thin layers, copepods in the deep.
- Identifying remaining/outstanding physics questions, e.g., shelf-ocean coupling.
- There have been significant advances [in modelling] but are we making progress in getting at the big picture.
- System level tasks at the ecosystem level (to reduce disjointedness).
- Alternative ways of thinking/surprises.

The two issues selected to be most important were the second and third one: model validation and the problem of scaling up from individuals to populations.

Group C

This group made several broad points.

Modellers should make their models results publicly available in standard formats (e.g., net-CDF) and non-modellers should be encouraged to analyse these data for their own research questions.

There is a balance between complex model systems (full forcing, coupled calculations) and process-oriented models (idealised forcing, sub-models, zero- or one-dimensional modelling). The complex models systems should learn from the process-oriented models.

Ecosystem models should develop towards community models. For example GOTM could become a library for biogeochemical models.

The more model results are used and analysed the more central the question of model validation is. For this, benchmark data sets are needed.

The model community should deliver simulation results from long-term simulations to the whole community of biological oceanographers to foster the work with these data sets like the work with observed long-time series from stations. A prerequisite is the publication and validation of the model results. It is the responsibility of the modeller to provide these data in the adequate format of data storage common in this community and including a read me and description. For the North Sea, Moll and Radach (2003, Progress in Oceanography, 57:175–217) recommend that 3-D biogeochemical simulation data be made available

Still under big discussion is the question of how complex a model must be to answer key questions. WGPBI should work on that as a fundamental question of PBI modelling. This would be very helpful for the modelling community. (Something for the workplan?). An agreement in our group would be a big success if we can deliver that.