ICES WGPBI Report 2007

ICES Oceanography Committee
ICES CM 2007/OCC:03

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

25–28 March 2007

Bergen/Bodø

ICES
International Council for the Exploration of the Sea
CIEM
Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

- Within the EuroGOOS area there are now 600 environmental (physical) time-series being reported in real time and 100 operational and pre-operational models reporting output in real time. The concept of real time data for real time use is being realized.
- Operational estimates (annual) of the eutrophication status of the North Sea, Skagerrak, and Kattegat are being produced by an ensemble of ecosystem models. This is being extended to a joint status assessment with the Baltic.
- To assess the importance of prey for larval fish, look at mortality rates not at growth rates. Larval fish seem to grow at close to maximal rates even when prey availability is low.
- Several groups are now coupling stage structured zooplankton models (representing a single species) to NPZ models. The developments are still in the early stages but the results are encouraging. This is an important step towards providing prey fields for models of fish early life history models.

The development of a graphical user interface for the GOTM-BIO model allows experts and non-experts to evaluate the sensitivity of ecosystem model predictions to the choice of both the ecosystem model and the vertical mixing scheme in a realistic 1D setting. GOTM-BIO is the General Ocean Turbulence Model with biological modules.

The workshop on Advances in Modelling Fish Early Life History was very successful and the publication of the papers in Marine Ecology Progress Series is proceeding smoothly with an expected publication date of late 2007.

A Manual of Best Practice for modelling physical biological interactions in relation to fish early life history has been drafted and mechanisms for publication and for updating the document in the future are being considered.

Distribution- and trait-based models provide a maximal account of food-web and adaptive diversity while using a minimal number of model parameters. As a consequence, they can be constrained by data to a much larger degree compared to standard approaches. In addition, with their ability to represent a high number of tropic levels they integrate two traditionally separated aspects of ecosystem modelling, one starting from marine biogeochemistry, the other from fish population dynamics. This integrative nature and the representation of adaptive processes may make them valuable tools especially for estimating climate change impacts on marine ecosystems. WGPBI will continue to encourage developments in this area.

1 Opening of the meeting

The 2007 meeting of the Working Group on Modelling Physical Biological Interactions was hosted by the Institute of Marine Research in Bergen, Norway, from 25–28 March 2007. The meeting was held onboard the coastal steamer Polarlys enroute from Bergen to Bodø.

The Terms of Reference for the meeting are given in Annex 3. The agenda (Annex 2) was adopted and then modified during the meeting to accommodate the needs of the discussions. The meeting was attended by 23 scientists (Annex 1).

The Co-Chairs (Hannah and Thygesen) thanked Morten Skogen for the local arrangements.

2 Present and discuss new results concerning physical-biological interactions (ToR a)

There were six talks in this session.

- Morten Skogen: BANSAI: Baltic and North Sea marine environmental modelling assessment initiative;
- Andreas Moll: Seasonal dynamics of *Pseudocalanus elongatus* in the North Sea using the ecosystem model ECOHAM3 with competing bulk zooplankton;
- Jorn Bruggeman: A Graphical User Interface to the General Ocean Turbulence Model (GOTM-GUI);
- Elizabeth North: The influence of larval behavior on spatial patterns in larval settlement and population connectivity;
- Marina Chifflet: New Results of the IFREMER Hydrodynamic Model of the Bay of Biscay (for Lagrangian Transport Simulations);
- Frank Janssen: Implementation of an ecosystem model at BSH - current status and future plans.

Abstracts are given in Annex 10.

Skogen reported on a model based eutrophication assessment for the North Sea, Skagerrak and Kattegat. The assessment is based on three models from national labs in Norway, Sweden and Denmark. Model quality was assessed using observations at three stations. A eutrophication assessment requires reference values to define the status. The choice of location-specific reference values for eutrophication status has been one of the serious difficulties within the project. The common assessment methodology is being extended into the Baltic in the near future.

Moll reported on the efforts in German GLOBEC to couple a structured zooplankton population model with five stage groups adapted to *Pseudocalanus elongatus* into the marine ecosystem model ECOHAM3. Numerical experiments were done with 0D and 1D models to test the zooplankton model. The simulated generation durations were compared with observations at Helgoland Reede and showed reasonable agreement with the number of generations. A full 3D simulation of the North Sea showed that the *Pseudocalanus elongates* biomass is generally less than 30% of the total zooplankton biomass.

This work is part of a larger trend. Several groups are now coupling stage structured zooplankton models to NPZ models (e.g. WGPBI 2006). The developments are still in the early stages but the results are encouraging. This is an important step towards providing prey fields for models of fish early life history models.

Bruggeman presented a graphical user interface for the General Ocean Turbulence Model (or GOTM) which is a 1D model for turbulence and physical and biogeochemical tracers in the water column. The GUI offers a user-friendly interface while hiding the specifics of the

FORTRAN implementation. The interface supports configuration of a scenario through a straightforward, wizard-like interface, and allows import and visualization of initialization and forcing data files. The user can then simulate the scenario, and visualize all output variables in easily customized figures. A public version of the program will be released together with the upcoming 4.0 release of GOTM, and will be freely available at the GOTM home page (www.gotm.net).

This interface is a big advance; it will allow non-experts to evaluate the sensitivity of ecosystem model predictions to the choice of both the ecosystem model and the vertical mixing scheme in a realistic 1D setting.

North talked about how differences in larval behaviour of two oyster species (*Crassostrea virginica* and *C. ariakensis*) influence spatial patterns in settlement and connectivity in Chesapeake Bay. Results indicated that differences in behaviour had significant consequences for larval transport in the Chesapeake Bay by influencing dispersal distances, settlement success, and the degree of connectivity between subpopulations in different tributaries. Most particles (>96%) did not return to the same bar on which they were released, and species-specific spatial patterns in 'producer' and 'sink' characteristics of oyster bars were apparent.

Chifflet discussed work to validate and calibrate Lagrangian trajectories in a model of the Bayof Biscay (Model for Applications at Regional Scale or MARS3D, developed by Ifremer). The validation was based on a 16-years simulation that reproduces the main characteristics of the seasonal evolution of the SST (e.g. order of magnitude, north-south gradient, cold coastal band along the French coast, temperature front near Ouessant Island, upwelling periods). Simulated Lagragian drifters reproduce the seasonal tendency of the sub-surface Lagrangian circulation, retention or southward tendency during the spring, south-eastward tendency near the slope and north-westward tendency near the coast in summer, and a strong and recurrent north-westward current along the coast in autumn. However, an exceptional event during the spring 2000 (north-westward current) was not reproduced by the model.

Janssen discussed the various components of the modelling system at the Federal Maritime and Hydrographic Agency (BSH). Sea level forecasts, storm surge warnings, oil drift and spreading as well as search and rescue are the most important applications. Increasing concerns about environmental conditions in the North Sea and the Baltic Sea have led to the decision to add an ecosystem component to the model system. The main problem in setting up an ecosystem model for the coupled North Sea/Baltic Sea region is the strong salinity gradient with salinities ranging from near zero in the most eastern and northern parts of the Baltic Sea to open ocean conditions (S>35.2 psu) in the northern North Sea. This large range in salinity has a strong influence on the ecosystems in North and Baltic Sea, which are quite different and it is the main reason that there is no ecosystem model available which covers both regions. Several different ecosystem models are being implemented and evaluated. The final solution may be a combination of two or more ecosystem model in order to have a system which is able to give reasonable results in the whole region.

3 Complete the publication of papers from WKAMF (ToR b)

Alejandro Gallego reported on progress towards the publication of the papers from the Workshop on Advances in Modelling Fish Early Life History. To date 12 papers have been accepted for publication and three more are in the revision and reassessment stage. Final publication in Marine Ecology Progress Series is expected in late 2007.

4 Complete the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History (ToR c)

Elizabeth North presented the current state of the WKAMF Manual of Recommended Practices (MRP). A first draft has been completed. This is a substantial effort involving over 20 co-authors. The WG was impressed with progress to date and appreciation was expressed for the efforts of the co-authors and the editors (North, Gallego, Petitgas).

A new ToR to complete and publish the manual was adopted. The WG emphasized that the manual was never intended to cover all aspects of the field; rather it was intended to be a first step. As such the editors should not unduly delay publication in the hope of finding authors to contribute to sections which would improve the overall coverage. The MRP should be viewed as a living document; improvements will be made as willing contributors are found and as advances are made in the field.

The following action items and tasks were adopted.

Action Items for MRP: WGPBI Members congratulated and thanked contributors of the *Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History* (MRP) for their substantial efforts to communicate their knowledge and share their insights. The publication will be a valuable reference and will help advance the field. WGPBI members have two main recommendations for the editors and authors of WGPBI:

1. Publish the MRP in a manner that makes it as accessible and widely distributed as possible. The manual should be published in an outlet that will make it searchable in standard literature databases. In addition, members suggested that, after initial publication, it could become a living document (as in Wikepedia articles) that will allow practitioners to add sections and enhance the document. If/when additions and enhancements are substantial, WGPBI members may consider releasing updated versions in the future.

- Task: North will check on procedure and requirements for an ICES Cooperative Research Report or a publication by the Integration-Application-Network of University of Maryland Center for Environmental Science and make recommendations to MRP authors. If MRP authors decide to release the report as an ICES Cooperative Research Report, then WGPBI members give their approval and will forward their recommendation to the ICES Publication committee.

2. Enhance the MRP by reducing redundancy and finish incomplete sections. WGPBI members expressed concern about repetition of similar concepts in multiple sections and the imbalance between sections. WGPBI members recommend that the editors work to eliminate redundancy and streamline the manual, then send the edits to authors for their review and approval.

- Tasks: A description of hydrodynamic model grids and the influence of grid resolution on model predictions is needed. Paul McCloghrie and Martin Huret will help North with the hydrodynamic model section. Moll will send references for inclusion in this section. There is still need for help with initial conditions for egg production.
- Tasks: The MRP needs to be edited to reduce redundancy. North, Gallego, and Petitgas will make editorial suggestions and forward them MRP authors for their review and approval.

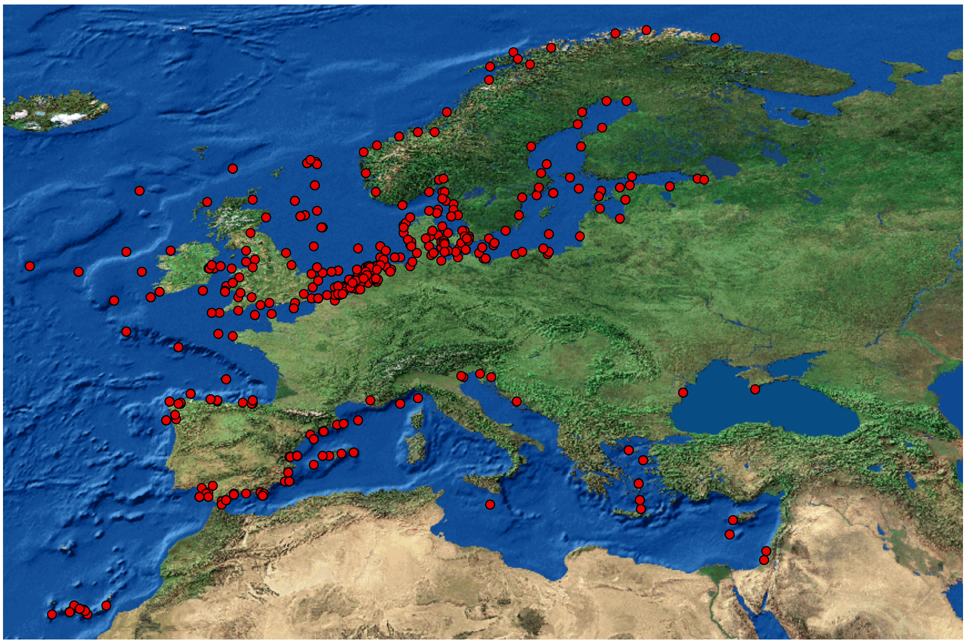
5 Review existing operational data flow from sustainable observational and modelling systems such as GOOS (Tor d)

Hans Dahlin reported on progress in EuroGOOS in two areas:

1) The concept of real time data for real time use;
2) An inventory of operational models.

A recent inventory of observations available in real time reveals 338 stations reporting 631 time-series (222 Sea level; 125 Waves; 130 Temperature; 40 Salinity, 29 Currents; 85 Wind). The spatial distribution is shown on the map below. Of these time-series 461 are freely available and that number is increasing. EuroGOOS plans to get all of the time-series into the meteorological real time data systems so that they are routinely archived and can be accessed in real time by interested parties.

Map showing the locations of the 338 stations reporting ocean data in real time.



EDIOS, the European Directory of the Ocean-observing System, is a searchable database of metadata (www.edios.org). One uses EDIOS to find out where the data is that one really wants.

EuroGOOS has also commissioned a review of all of the operational and preoperational models with output being report in real time. A preliminary version of the report described 92 models (Annex 11). Like the data, the models are primarily physical models but there are some ecosystem models.

Martin Huret discussed work at IFREMER to develop algorithms for chlorophyll-a and suspended particulate matter (SPM) estimation in coastal areas (Case 2 waters) of the Bay of Biscay. In the framework of MARCOAST (GMES service) and now ECOOP (European COastal shelf Operational and forecasting system), these algorithms are now applied to a wider area covering the IBI-ROOS (Iberian-Bay of Biscay-Ireland Sea Regional Ocean Observing System) region. Images are provided in near real-time from www.ifremer.fr/nausicaa/marcoast/private/browser.htm.

6 Report on promising alternative approaches for ecosystem modelling (ToR e)

There were four talks in this session.

- Charles Hannah: Complexity theory and marine ecosystem models: a view from 30 000 feet;
- Jorn Bruggeman: From species to traits: biodiversity-inspired ecosystem models;
- Kai Wirtz: Size-based and optimality approaches to simulate adaptation in ecosystems;
- Ken H. Andersen: Size as a functional trait.

Hannah discussed the concept of self-organized criticality and the importance of feedback loops. A review of foodweb theory emphasizes that the structure of the foodweb (who is connected to who) is equally important as the process details in determining the stability and persistence of foodwebs. He argued that modellers should be willing to sacrifice process detail in order to include more feedback loops. However he did not provide insight into how to model the structural complexity of marine foodwebs without adding an enormous numbers of state variables and free parameters. The next three speakers provided some ideas.

Bruggemen reviewed the concepts of trait based models. Ecosystem models are traditionally built by linking population models of species. These models suffer from the problem that they are limited to a subset of the existing species. Ecosystems may be more easily characterized by a small set of “traits” or quantifiable characteristics such as autotrophy, heterotrophy, predation, and defence. Given a set of relevant traits, the ecosystem is modelled as a probability distribution in trait space. This distribution is characterized by its moments (total biomass, mean, covariances), which evolve dynamically in time. Several applications in spatial context were shown: a phytoplankton community characterized by light harvesting and nutrient harvesting traits showed formation of a subsurface chlorophyll maximum and nutrient-governed succession, and a community of phytoplankton and bacteria exhibits changes in community composition in time and depth that are known from classic aquatic literature. Such qualitative agreements with observations suggest that in time, trait-based ecosystem models may prove capable of elegant, simple parameterizations of key ecosystem behaviours.

Bruggeman, J., and Kooijman, S. A. L. M. (in press). "A biodiversity-inspired approach to aquatic ecosystem modelling." Limnology and Oceanography.

Wirtz motivated his talk with data from Helgoland Roads in the German Bight that showed that the biomass of diatoms and microzooplankton pre-bloom exhibited no dynamics but the size composition of diatoms shows some dynamics. He argued that the complexity inherent in marine food-webs is still a major challenge to coupled biological and physical models. Even though the last decades have seen an increasing complexity of models, there are still unresolved problems related to testability and to basic features of the natural system. Prominent examples are adaptive processes on the organism and community scale or feed-backs due to the linkage between lower and higher trophic levels. Resulting limits of concurrent modelling are here illustrated using observations of the phytoplankton biomass and size composition taken at

Two different modelling studies were presented to illustrate the potential of new model types to deal with the complexity apparent in these and other data. First, adaptation in algal edibility was simulated by a simple predator-prey model which included a time-variable edibility (φ). The evolution equation makes sure that trait changes optimize the relative growth rate as formulated by the Adaptive Dynamics methodology. The equation therefore contains the variance of φ as well as the total derivative of the growth rate with respect to the edibility(φ). The derivative also has to account for the non-linear correlation between φ and the nutrient affinity of algae. This trade-off together with the value for the variance is found to be critical in order to reconstruct observed predator-prey cycles in chemostat experiments (Fussmann *et al.* 2001). In particular, a substantial prolongation and dampening of cycles with higher adaptability of prey as evident in the data can be well reproduced.

A similar stabilization of predator and prey biomass before a spring bloom was analyzed in a second study to illustrate elements of a new distribution- and trait-based model. The model is build upon the concept of generic plankton groups, each characterized by a set of key properties like biomass of adults and larvae and, more importantly, effective traits like mean size or autotrophy to heterotrophy ratio (similar to Bruggeman above). A semi-mechanistic formulation of trade-offs enables to implicitly describe an infinite number of trophic interactions giving rise to a self-organization of the food-web and to a continuous distribution of traits over the entire plankton spectrum from bacterioplankton to fish-larvae. First model tests indicate that adaptations in the size composition of algae may be responsible for the biomass stabilization effect.

Andersen showed how the size of an individual and the asymptotic size of a species group could be used as the basis of a model of the whole fish part of the ecosystem. The model was based on description of processes taking place on the individual level only. The processes are: 1) scaling of intake, 2) the encounter of prey through a search volume, which is an increasing function of size, and 3) a selection of prey size through a formalization of the rule: big fish eat small fish. From this the slope and the total abundance of the size spectrum of the whole community can be derived. This type of size based model may provide a way to add higher trophic levels to NPZ type models.

There was lively discussion of the content of the presentations and the idea that trait and size based models might offer a viable alternative to traditional NPZ models. The key to the trait based models is that one models trade-offs such as light harvesting versus nutrient harvesting and predation versus defense mechanisms. In a traditional NPZ model the species specific processes of light harvesting and nutrient harvesting are modelled and then one expects the trade offs to be reflected in the biomasses of the different species. In trait modelling, the trade offs are modelled directly.

Distribution- and trait-based models provide a maximal account of food-web and adaptive diversity while using a minimal number of model parameters. As a consequence, they can be constrained by data to a much larger degree compared to standard approaches. In addition, with their ability to represent a high number of tropic levels they integrate two traditionally separated aspects of ecosystem modelling, one starting from marine biogeochemistry, the other from fish population dynamics. This integrative nature and the representation of adaptive processes make them valuable tools especially for estimating climate change impacts on marine ecosystems.

The robustness of predictions about ecosystem change should be increased when these new models are mature enough to be used in conjunction with NPZ type ecosystem models; the fundamentally different structure will make the predictions more independent than comparing two NPZ type models.

7 Assess the state of the art in the study of small scale feeding processes (ToR f)

This session targeted the modelling of feeding processes, in particular fish larvae feeding on zooplankton. These processes have implications for the growth and survival of fish larvae, and thus for recruitment, and provide a link from the physics of the ocean to the population dynamics of fish stocks. There is an on-going effort in the scientific community not only to expand on our knowledge of these processes, but also to condense them to a form which allows them to be included in large-scale models.

There were two talks in this session:

- Øyvind Fiksen: Behaviour mediates predation and growth rates in larval cod;
- Alejandro Gallego: A few thoughts about modelling small scale processes relevant to (zooplankton and) fish larvae.

The abstracts are in Annex 10.

Fiksen discussed the trade-offs that larvae are facing. Environmental conditions such as food availability affect both larval growth and survival. A change in environment will modify the trade-off, so the larva will respond with behavioural changes. He discussed a situation, for North Sea cod, where increasing food availability leads to decreased feeding activity and thus reduced exposure to predation and increasing survival. For the same reason, increased food availability did not lead to significantly improved growth. This somewhat unexpected result leads to the conclusion that to assess the quality of the environment, one should look at the number of survivors and not on the condition of the survivors.

Gallego discussed the complexity of small scale process (transport, growth and mortality) models, which are derived from individual-level process studies primarily in the laboratory. Listing more than 50 functional relationships in these models, he argued that these models are impractical from the point of view of large-scale models. This holds also because the biological processes operate on spatial and temporal scales much finer than those in large-scale models. In this situation the key question is to assess the level of complexity required for large-scale modelling. It remains a formidable task to single out those small-scale dynamics which have large-scale implications.

8 Complete the review of maximum phytoplankton growth rates and primary production as function of temperature (ToR g)

This review has proven more difficult than anticipated and is still incomplete. St. John and Hannah plan to write a short paper during 2007, perhaps for publication in the 'Horizons' section of the Journal of Plankton Research. The ToR was not continued for next year. The activity remains on the list of Action Items for next year.

9 Collaborate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment (ToR h)

The work on the publication of the papers from WKAMF (Advances in Modelling Fish Early Life History) and the writing of the *Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History* represent substantial effort on this ToR. New ToRs were generated and should be completed during 2007/2008.

10 New Expert Groups (ToR i and j)

WGPBI supports the work of PGPYME to create a new Expert Group related to phytoplankton and microbial ecology.

WGPBI supports the work of PGOOP to create a new expert group on operational oceanography products. A discussion of potential chairs for the new group was held during the meeting. Names were provided to Einar Svendsen.

11 Other Business

Theme Sessions from 2006

Han reported on the successful Theme Session on Operational Oceanography at the 2006 ASC. The session has 18 oral presentations and four posters. Contributions covered a wide range of aspects in the context of operational oceanography and applications to ecosystem sciences and fisheries management, including project initiatives, observational monitoring, data exchange and management, model developments, data assimilation, service and products, HAB modelling and prediction, fish recruitment, and emergency response. Presentations cover a wide range of geographic areas from global- and basin-scale (Atlantic, Arctic) applications to regional seas such as in the Baltic Sea, Mediterranean Sea, North Sea, Irminger Sea off the US west coast and in Japanese waters.

The presentations and discussions in this session indicate that most of the present operational oceanography systems are focused on physical oceanographic aspects. Much more efforts need to be made in advancing biological and fisheries aspects. In addition to many other challenges, a critical issue from the ICES community perspective remains the communications between operational oceanography community and their user groups in ecosystem and fisheries management. Although the session was very well attended, audience was primarily oceanographers. It's the time for the oceanography community and fisheries scientists to sit together to discuss opportunities and needs more closely than ever before. An important task ahead is to understand what operational oceanography can produce and what users require and can really use. One initiative in this direction from this meeting is that Jake Rice from Canada, David Mountain from USA and others are working to set up a planning group for operational oceanography products that can well serve ICES community.

Theme Sessions for 2007

WGPBI is sponsoring two sessions at the 2007 ASC. They are:

- "Integrating observations and models to improve predictions of ecosystem response to physical variability" with conveners Elizabeth North, Penny Holliday and Sarah Hughes. This is joint with WGOH
- "Linking oceanographic physical features with biological production and fish habitat potentials" with conveners Pierre Petitgas, Corinna Schrum, and Charles Hannah.

Theme Sessions for 2008

There are two proposals for Theme Sessions for 2008 ASC.

Han, Skogen and Moll have written a proposal for a theme session titled 'Coupled Physical and Biological Models: Development and Validation' (Annex 6). This is a natural follow on to the theme session on Operational Oceanography in 2007

Andersen and Bruggeman have written a proposal for a theme session titled 'Alternative approaches for ecosystem modelling' (Annex 6). This is a replacement for the previous proposal 'Biodiversity inspired models for plankton ecosystem dynamics' by Bruggeman and Hannah.

Workshops

Pierre Petitgas put forward a proposal for a workshop on the use of physical models and ecosystem models for the prediction of fish habitat and how these models could be used to assess changes in habitat as a result of global climate change. The decision was made to include a ToR for next years meeting and then to assess whether to propose a workshop for 2009.

Kai Wirtz and others are planning a workshop in 2009 on 'Distribution based models for foodweb structure for models from bacteria to whales.' They are interested attracting a wide range of participants from biogeochemical modellers to marine mammal population modellers. They will investigate whether holding the Workshop as an ICES Workshop holds any advantages

Numerical Experimentation SubGroup

A few people expressed regret at the demise of the Numerical Experimentation SubGroup. However none have volunteered to take it on. Reviving such a group would be one way to get more numerical methods into the meeting and increase the interest of the physical oceanographers.

Next meeting

The next meeting will include a 1 day session joint with the WKZE. It will be held on 1–3 April 2008.

Annex 1: List of participants

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Annex 2: Agenda

Monday, 26 March, Morning

0900–0910: Welcome, etc.

0910–1010: Presentation of new results: 3 x 20 minutes (Skogen, Moll, Bruggeman)

1010–1025: Papers from the WKAMF Theme section (Gallego). 15 min.

1025–1100: Coffee

1100–1200: Presentation of new results: 3 x 20 minutes (North, Huret, Janssen)

Monday, 26 March, noon

(Extended lunch break 1200–1500 due while the ship is in port in Ålesund)

Monday, 26 March, afternoon

1515–1800: Alternative approaches for ecosystem modelling. (Bruggeman, Hannah Wirtz, Andersen)

1900: Dinner

Tuesday, 27 March, morning

(No programme)

Tuesday, 27 March, afternoon

1215–1300: Review existing operational data flow from sustainable observational and modelling systems such as GOOS and report on activities relevant for the work of WGPBI. (Dahlin and Werner).

1300–1400: Lunch

1400–1530: Presentation of the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History. Discussion. (ToR c)

1530–1600: Coffee

1600–1730: Small scale feeding processes. 1.5 hour.

Organised by Thygesen; contributions by Fiksen, Gallego. (ToR f)

1730–1800: Plenum discussions

Wednesday, 28 March, morning

0900–1015: Review of action items for 2006.

Draft proposals for ICES ASC theme sessions in 2008.

Resolutions for 2008 workshops.

Draft WGPBI Resolution for 2008

- Terms of Reference
- Location and local host for 2008 meeting (Dates can be set later).

1015–1030: Coffee

1030–1200: Add items to the WGPBI Activity list

Ideas for invited speaker next year

Announce WGPBI sponsored Theme Sessions for 2007

Outline writing assignments for Working Group Report

Action Items for 2007 – who is actually doing things?

Close the meeting

Annex 3: WGPBI Terms of Reference for this meeting

2006/2/OCC03 The **Working Group on Modelling Physical Biological Interactions** [WGPBI] (Co-Chairs: C. Hannah, Canada and U. Thygesen*, Denmark) will meet in Bergen, Norway from 25–28 March 2007 to:

a) present and discuss new results concerning physical-biological interactions;

b) complete the publication of papers from WKAMF;

c) complete the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History;

d) review existing operational data flow from sustainable observational and modelling systems such as GOOS and report on activities relevant for the work of WGPBI;

e) report on promising alternative approaches for ecosystem modelling;

f) assess the state of the art in the study of small scale feeding processes (with particular reference to zooplankton and fish larvae) and make recommendations for model parameterisation;

g) complete the review of maximum phytoplankton growth rates and primary production as function of temperature;

h) collaborate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment;

i) take part in the intersessional work led by PGPYME in developing the mission and draft resolutions for a new Expert Group related to phytoplankton and microbial ecology;

j) take part in the intersessional work led by PGOOP in developing the mission and draft resolutions for a new Expert Group related to operational oceanographic products and services.

WGPBI will report by 13 April 2007 for the attention of the Oceanography Committee.

Annex 4: WGPBI terms of reference for the next meeting

The **Working Group on Modelling Physical Biological Interactions** [WGPBI] (Co-Chair: C. Hannah, Canada and U. Thygesen, Denmark) will meet in Montpellier, France from 1–3 April 2008 to:

a) Present and discuss new results concerning physical-biological interactions;

b) Complete the publication of papers from WKAMF;

c) Complete the draft of the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History;

d) Demonstrate potential effects of climate change on the lower trophic levels of marine ecosystems;

e) Develop a statement of requirements for monitoring data to be useful for development and validation of models of physical-biological interactions;

f) Review of lessons learned from application of holographic imagery to zooplankton-phytoplankton-turbulence interactions;

g) Document how PBI tools can be useful in estimating fish habitats potentials and survival windows and their variation in the context of climate change;

h) Review proposed approaches for coupling regional models of NPZD-type biogeochemistry with higher trophic levels;

i) Review approaches to combine field and laboratory data together with biological-physical models to examine processes controlling zooplankton populations;

j) Discuss how WGPBI fits into the new ICES structure.

WGPBI will report by 28 April 2008 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: Action Plan no. 1.5 (modelling biological-physical interactions in the sea), Action Plan no 1.1 (provide feedback about research needs), Action Plan no 1.2 (increase knowledge with respect to functioning of the ecosystem). Term of Reference a) Providing a forum for the presentation and discussion of new results is an important component of the Group's mandate. Term of Reference b) The review process of the manuscripts from the workshop on 'Advancements in Modelling Physical-Biological Interactions in Fish Early-Life History: Recommended Practices and Future Directions' (WKAMF) is nearing completion. Publication in Marine Ecology Progress Series is expected in late 2007. Workshop co-chairs are serving as guest editors and will contribute an overview article. Term of Reference c) The participants at WKAMF have completed the first draft of the "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History". Mechanisms for publication, potentially as an ICES Cooperative Research Report, are being considered. Term of Reference d) Global circulation models predict significant warming throughout the globe under higher levels of greenhouse gas. Precipitation and wind fields are also predicted to

	change and these atmospheric changes will impact the ocean with effects on hydrographic properties, currents and ultimately marine ecosystems. Politicians, fisheries managers and increasingly the public are demanding answers from scientists on the most likely outcome from predicted climate change. Term of Reference e) The amount and availability of environmental monitoring data is increasing in the ICES area. As potential users of the data, the modellers need to make a statement about the requirements for the data to be useful for model development and application over the next 5–10 years. For example what are the modellers requirements for a minimum suite of observables, and for archival and assessibility? Term of Reference f) Holograpic imagery is an emerging technology in marine science. A review of the lessons learned from the application of the technology to zooplankton-phytoplankton-turbulence interactions and the implications for robust parameterizing predator prey interactions will be an important contribution to the proposed joint work between WGPBI and WGZE (ToR i). Term of Reference g) The development of quantitative relationships between the physical environment and fish habitat is a field of growing interest and has been the subject of several ICES ASC theme sessions over the last few years. The goal here is to review the application of the modelling tools developed by the physical-biological interaction that are useful for describing fish habitat and propose operational products of potential interest for fisheries ecology users. Term of Reference h) Coupling numerical models for atmosphere, ocean, land and ice is a central issue in the climate research community but the coupling issue is in its infancy in the modelling of marine ecosystems. Couplers, i.e. the software interface between the different models, allows the realization of coupled simulations on different types of platforms at a minimal cost, the testing of different coupling algorithms (e.g. time strategy or interpolation methods), and an objective intercomparison of coupled models by changing some or all component models. A review of approaches employed in climate modelling as well as their potential utility in the modelling of trophic interactions between NPZD-biogeochemistry and higher trophic levels of (coastal) marine ecosystem model types will be presented. Term of Reference i) Zooplankton provides the link between primary production and the fisheries. Modelling zooplankton is important to both those who need zooplankton as prey for fish models and those who need zooplankton as a predator (a closure term) in primary production models. WGPBI and WGZE will have an overlapping meeting in 2008. This ToR represents our goals for joint work. Term of Reference j) The Oceanography Committee has requested that WGPBI discuss how it fits into the new ICES structure.
RESOURCE REQUIREMENTS:	None
PARTICIPANTS:	The WG is normally attended by some 20–30 members and guests. 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:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	ACFM, ACE
LINKAGES TO OTHER COMMITTEES OR GROUPS:	ICES-IOC Working Group on Harmful Algal Bloom Dynamics, WGRP, BSRP, WGLESP, WGZE, LRC
LINKAGES TO OTHER ORGANIZATIONS:	The work of this group is closely aligned with similar work in GEOHAB (IOC/SCOR), GLOBEC (IOC/SCOR), IMBER and PICES.

Annex 5: Recommendations

RECOMMENDATION	ACTION
1. WGPBI continues to support creation of a WG on operational oceanography	Oceanography Committee
2. WGPBI should meet jointly with WGZE in 2008.	WGPBI and WGZE
3. Complete and publish the Manual of Best Practice before the next meeting, possibly as an ICES Cooperative Research Report.	WGPBI, E. North, A. Gallego, P. Petitgas.
4. Theme Session for 2008 ASC 'Coupled Physical and Biological Models: Development and Validation', with convenors Han, Skogen, Moll. Annex 6	ICES and Oceanography Committee
5. Theme Session for 2008 ASC 'Alternative approaches for ecosystem modelling' with convenors Andersen and Bruggeman. This replaces a previous proposal by Bruggeman and Hannah.	ICES and Oceanography Committee

Annex 6: Theme Session Proposals

Two theme sessions proposed for 2008 ICES ASC

Theme Session – Coupled Physical and Biological Models: Development and Validation

Conveners: Guoqi Han (Canada), Morten Skogen (Norway) and Andreas Moll (Germany)

Coupled physical and biological models on global, basin and regional scales have emerged as an essential tool in monitoring, studying and predicting ecosystem status, variability and changes. These coupled models include hydrodynamic models and biogeochemical models in combination with in situ and remotely sensed data to hindcast, nowcast and forecast ocean state variables (currents, temperature, salinity, biogeochemical, and plankton variables). They can be used to generate key indices that are of significance to fisheries management and ecosystem sciences.

The validation of these models is a key step for the model development and towards applications. Physical processes at various time and space scales can affect biological processes in very different ways. How do we validate them from physical, biological, and/or ecosystem perspectives? How do we collect field data for validation purposes? How do we define effective metrics? How do we deal with different temporal and spatial scales?

In this session we solicit papers related to development and applications of coupled physical and biological models, with a particular emphasis on their validation of state-of-the-art coupled models in deep ocean basins, shelf seas and coastal domains.

Theme Session - Alternative approaches for ecosystem modelling

Convenors: Ken Haste Andersen (Denmark), Jorn Bruggeman (Netherlands)

Unifying biological principles, such as thermodynamic considerations and body size scaling, can offer the potential to derive ecosystem models through unifying a wide ranges of marine species. One motivation for these new approaches is that traditional ecosystem models are based on extensions of single species models and require detailed quantitative knowledge of all relevant species. The process seems endless as ecologists and physiologists uncover relevant species and processes at rates that far exceed those at which high-quality quantitative knowledge on species becomes available. This theme session will provide a forum for discussion of the strengths and weaknesses of alternative approaches to ecosystem modelling *of communities ranging from plankton to whales* with a focus on the capability to generate reliable quantitative predictions of biological variables *and ecosystem response to exploitation*.

Note: This is a replacement for the previous proposal ‘Biodiversity inspired models for plankton ecosystem dynamics’ by Bruggeman and Hannah.

Annex 7: Action Items 2006/2007

Item 1: Review existing operational data flow from sustainable observations and models and report on activities relevant for the work of WGPBI. Dahlin and Werner. Dahlin reported on progress in EuroGOOS

Item 2: WKAMF: Complete MEPS issue. This is nearing completion. Generated a new ToR North, Gallego, Petitgas

Item 3: WKAMF: Draft of manual of best practices for next meeting. A draft has been completed. Generated a new ToR. North Gallego Petitgas

Item 5: Develop a GOOS WG & WGPBI strategy. This was a recommendation of the WG. Follow up by Dahlin, Svendsen. PGOOP was created to develop a new WG.

Item 6: Invite several speakers for a ½ day discussion on biodiversity inspired ecosystem models for the 2007 meeting. This happened at 2007 meeting Hannah, Bruggeman.

Item 7: Assess the state of the art in the study of small scale feeding processes (with particular ref to zooplankton & Fish larvae) and make recommendations for model parameterisation. Thygesen organized talks by Fisken and Gallego.

Item 8: An important issue that arose in the general discussion was that it would be good to have some plankton specialists joining the group "to keep the modellers on the right track". Of particular interest to WGPBI are improved parameterizations of processes related to primary production. Names that came up were P.Gentien, L.Naustvoll, and J.Adolff. Einar Svendsen will contact Lars Naustvoll.

Item 9: Approach Grimm to present IBM state of the art modelling to the group. This fell through due to lack of funds to support travel by Grimm. G.Huse

Item 10: Report on Conferences of interest to PBI e.i., Euroceans Symposium on Ecosystem model Parameterisation, ICES/PICES young scientist conference, BASIN inititative.

Item 11: Develop an ASC Theme Session for 2008 to address the state of the art and issues regarding model validation. Han will do this. Done

Item 12: Revive the Numerical Experimentation SubGroup. Several people have expressed interest in reviving this group in order to get more numerics into the meeting. However none have volunteered to take it on.

Item 13: Set up the PBI model inventory page so that people can submit suggestions for models/urls to add. This was done, but no suggestions have been submitted. North

Item 14: At 2007 meeting consider the following ToR for 2008, 'Review the state of the art with respect to the use of hydrodynamic models to predict optimal habitats' This was replaced by Workshop proposed by Petitgas for 2009.

Item 15: At 2007 meeting consider the following two ToRs for 2008: 1) Continue to investigate (pre)operational applications of PBI models with special focus on the availability of its products; 2) Review, by using recent inventories, the access to operationally produced data that may be used for the development and validation of PBI models. Hans Dahlin and EurOceans have this well covered for the physical models and they are keeping track of PBI models. Add this to list of action items for 2007/08

Item 16: The work of WKIMS should be carried on. WKIMS proposed the following ToR: Review progress in the estimation of meso-scale indices of oceanographic features and evaluate the reliability of the indices for their use in explaining fish distribution patterns. This requires a volunteer to pursue the work and report on it. Petitgas added a new ToR.

Annex 8: Action Items 2007/2008

Item 1: Need to ensure that people with zooplankton models couple with NPZ models show up. This should include Geir Huse, Andreas Moll, Thomas Neumann and possibly Wolfgang Fennel and Francois Carlotti. Hannah and others.

Item 2. Joint meeting with WGZE. Contact Chair. Dates set.

Item 3: Bruggeman should make sure Oschlies and Vezina are on list of potential Theme Session speakers. Hannah

Item 4: Complete the review of maximum phytoplankton growth rates and primary production as function of temperature and write a short paper during 2007, perhaps for publication in the 'Horizons' section of the Journal of Plankton Research. St. John and Hannah.

Item 5: At 2008 meeting consider the following two ToRs for 2009: 1) Continue to investigate (pre)operational applications of PBI models with special focus on the availability of its products; 2) Review, by using recent inventories, the access to operationally produced data that may be used for the development and validation of PBI models. Hans Dahlin and EurOceans have this well covered for the physical models and they are keeping track of PBI models.

Item 6: The work of WKIMS should be carried on. Consider Petitgas proposal for a workshop in 2009 on fish habitat. Petitgas.

Item 7: WKAMF: Complete MEPS issue. This is nearing completion. Generated a new ToR North, Gallego, Petitgas

Item 8: WKAMF: Draft of manual of best practices for next meeting. A draft has been completed. Generated a new ToR. North Gallego Petitgas

Item 9: Demonstrate potential effects of climate change on the lower trophic levels of marine ecosystems. The core is an IMR project (Skogen, Svendsen) to down scale climate change scenarios using their ecosystem model. It could be expanded to include work using trait based models if applied to climate change problems.

Item 10: Develop a statement of requirements for monitoring data to be useful for development and validation of models of physical-biological interactions. (which quantities, archived, accessible). What do we need in design of system? Proposed by Dahlin. Hannah will have to try and coordinate a discussion during the year.

Item 11: Review of lessons learned from application of holographic imagery zooplankton-phytoplankton-turbulence interactions. Osborn.

Item 12: Document how PBI tools can be useful in estimating fish habitats potentials and survival windows and their variation in the context of climate change. On that basis propose operational products of potential interest for fisheries ecology users. Petitgas to coordinate.

Item 13: Review proposed approaches for coupling higher trophic levels with NPZD models (St. John E2E, plus, Moll)

Item 14: Discuss how WGPBI fits into the new ICES structure. Hannah and Thygesen need to find out what the new structure is.

Item 15: Review conclusion of international workshop on 'Skill Assessment for Coupled Physical-Biological Models of the Coastal Ocean' Hannah talk to Werner.

Item 16: Can we find an inspiring lecturer on methods for dealing with complexity? Mercedes Pascal. Perhaps delay to 2009. Hannah talk to Werner.

Item 17: Start search for new co-chair to replace Hannah after 2009 meeting.

Annex 9: WGPBI Activities 2004–2008

YEAR	EVENT
2004	Workshop on 'Future Directions for Modelling Physical Biological Interactions.', chairs Peters and Hannah (Barcelona, March 2004).
	WGPBI meeting (Barcelona, March 2004).
	Theme Session at ICES ASC on Physical-Biological Interactions: Experiments, Models and Observations (September 2004, Vigo Spain).
	WG web page is located at www.icm.csic.es/bio/projects/wgpbi/wgpbi.htm and maintained by Cesc Peters.
2005	Theme Session at ICES ASC on 'Connecting Physical-Biological Interactions to Recruitment Variability, Ecosystem Dynamics, and the Management of Exploited Stocks' with convenors North, St. John, and Gallego. Joint with WGRP.
	First meeting the Numerical Experimentation Subgroup (Hamburg, 6 April 2005).
	First meeting of the Larval Fish Group (Hamburg, 6 April 2005).
	WGPBI meeting (Hamburg, April 2005).
	Draft review of nutrient load reduction experiments. See Section 5 of 2005 Report.
	Report on the interannual variability comparison is now published as Skogen, M.D. and Moll, A., 2005. Importance of ocean circulation in ecological modelling: An example from the North Sea. Journal of Marine Systems, 57(3-4): 289–300.
	Draft manuscript of modelling techniques for larval fish. T. Miller. What is current status?
2006	Workshop on 'Advancements in modelling physical-biological interactions in the early-life history of fish: recommended practices and future directions larval fish modelling.' 3–5 April 2006 in Nantes France. Co-chairs: A. Gallego, E. North, P. Petitgas.
	WGPBI meeting 6–7 April 2006 in Nantes, France.
	Database on effects of turbulence on planktonic organisms. F. Peters. What is current status?
	Peters, F., and C.G. Hannah (editors). 2006. Special Issue on Future Directions in Modelling Physical-Biological Interactions. J. Marine Systems. In press.
	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'. Joint with WGHABD. Co-convenor T. Stipa
	Theme session at ICES ASC on 'Operational Oceanography' (joint with PICES). Co-convenor: G. Han.
	Workshop on 'Indices of Meso-scale Structures in ICES waters', 22-24 Feb,2006 in Nantes France. Joint with ICES SGRESP (Study Group on Regional Scale Ecology of Small Pelagics). Co-chair: C. Schrum
	Synthesis of progress on zooplankton modelling in German GLOBEC. T. Neumann and A. Moll
	Invite Geir Huse to give talk at WGPBI 2006 on zooplankton IBMs. M. Skogen.
	Radach, G. and Moll, A., 2006. Review of three-dimensional ecological modelling related to the North Sea shelf system - Part 2: Model validation and data needs. Oceanography and Marine Biology; an Annual Review, Vol. 44:in press.
	WGPBI "Inventory of Operational and Preoperational Models" at http://northweb.hpl.umces.edu/WGPBI/WGPBI_links.htm.
	WKAMF Participants Web Page at http://northweb.hpl.umces.edu/wkamf/home.htm

YEAR	EVENT
2007	WGPBI Meeting. Bergen, Norway, 25–28 March 2007.
	Peer reviewed publication from larval fish workshop. Gallego, North, Petitgas
	Draft of manual of best practices for larval fish modelling. Gallego, North, Petitgas
	Workshop on ‘Parameterizing Trophic Interactions in Ecosystem Models’ from 20–24 March 2007, Cadiz Spain. Organized as part of EurOceans. St. John
	Theme Session at ASC on ‘Integrating observations and models to improve predictions of ecosystem response to physical variability.’ Convened by Elizabeth North, Penny Holliday and Sarah Hughes. Joint with WGOH
	Theme Session at ASC on ‘Linking oceanographic physical features with biological production and fish habitat potentials’ Conveners: Pierre Petitgas, Corinna Schrum, and Charles Hannah
	Good ideas for next generation of zooplankton modules in PBI models. Non-mass state variables and stage resolved, etc. All
2008	Update WGPBI Inventory of Operational and Preoperational Models
	ICES ASC Theme Sessions
	Review of temperature dependence of maximum growth rates for phytoplankton. M. St. John and C. Hannah

Annex 10: Abstracts

New results (ToR a)

Seasonal population dynamics of *Pseudocalanus elongatus* in the North Sea using the ecosystem model ECOHAM3 with a population and competing bulk zooplankton

Andreas Moll, Christoph Stegert, Wilfried Kühn, Markus Kreus and Johannes Pätsch,

(with acknowledgements to François Carlotti, Wulf Greve and Michael Krause)

This work outlines an approach to couple a structured zooplankton population model with state variables for five stage groups adapted to *Pseudocalanus elongatus* into the complex marine ecosystem model ECOHAM3. For the carbon and nitrogen cycle, 14 state variables represent the functional units phytoplankton, bacteria, detritus, dissolved organic matter, and bulk zooplankton, which stands for all zooplankton other than the structured population. Mesocosm studies under temperature and food conditions comparable to the North Sea conditions were used for parameterisation of the stage-dependent copepod life cycle processes. Annual cycles under realistic meteorological and hydrographical conditions were studied applying a three-dimensional version of the coupled ecosystem-zooplankton model. In part 1 the results at two contrasting regimes were analysed: at a southern and northern North Sea position. The main ecosystem state variables were validated against observed monthly means. The vertical profiles of selected state variables were compared with respect to differences between bulk and structured zooplankton biomass. The simulated generation durations were compared with observations at Helgoland Reede. Simulated generation times were mostly affected by food availability and to a lesser degree by temperature. Regional differences in *Pseudocalanus elongatus* generation times and abundances were studied. Simulation runs to investigate competition in the northern North Sea showed a time lag of about 1 month between bulk and structured zooplankton biomass maxima in spring and lower biomass levels for both zooplankton types during summer. In the southern North Sea the structured and bulk population exhibited an earlier biomass development compared to the northern region; further on during the whole production period bulk and structured zooplankton showed several biomass peaks. The three-dimensional model application evaluates regional differences and annual cycles of zooplankton biomass and abundance in the North Sea and quantifies the ratio of the population biomass in terms of the total zooplankton biomass mainly below 30 percent.

"GOTM-GUI": a Graphical User Interface to the General Ocean Turbulence Model

Jorn Bruggeman, Vrije Universiteit Amsterdam

The General Ocean Turbulence Model (GOTM) is a 1D model for turbulence and physical and biogeochemical tracers in water columns. It offers a number of state-of-the-art turbulence parameterizations and has been embedded in several 3D circulation models. The original model is coded in FORTRAN, published under the GNU General Public License, and freely available at http://www.gotm.net. Here we demonstrate a preliminary version of a Graphical User Interface (GUI) that offers a user-friendly interface to all GOTM settings while hiding the specifics of the FORTRAN implementation from view. The interface supports configuration of a scenario through a straightforward, wizard-like interface, and allows import and visualization of initialization and forcing data files. The user can then simulate the scenario, and visualize all output variables in easily customized figures. Finally, the user can choose to generate a report that describes the scenario settings and includes figures for a user-selected set of output variables. A public version of the program will be released together with

the upcoming 4.0 release of GOTM, and will then be freely available at the GOTM home page.

The influence of larval behavior on spatial patterns in settlement and population connectivity

E. W. North[1], Z. Schlag[1], R. R. Hood[1], M. Li[1], L. Zhong[1], T. Gross[2], V. S. Kennedy[1]

[1]University of Maryland Center for Environmental Science, Horn Point Laboratory

[2]NOAA/NOS and Chesapeake Research Consortium

A numerical approach was applied to determine if differences in larval behavior of two oyster species (*Crassostrea virginica* and *C. ariakensis*) could influence spatial patterns in settlement and connectivity in Chesapeake Bay, a partially-mixed estuary. A coupled particle-tracking and hydrodynamic model was forced with observed winds and freshwater flow and included settlement habitat for oyster larvae. Model scenarios were conducted with hydrodynamic predictions from five years (1995–1999) to simulate a range of physical conditions. Vertical swimming velocities were parameterized with results from laboratory experiments and the literature. Behavior was the only biological process represented in the model in order to isolate the effect of circulation, settlement habitat and species-specific behavior on the spatial trajectories of particles. Results indicated that differences in behavior had significant consequences for larval transport in the Chesapeake Bay by influencing dispersal distances, settlement success, and the degree of connectivity between subpopulations in different tributaries. Most particles (>96%) did not return to the same bar on which they were released, and species-specific spatial patterns in 'producer' and 'sink' characteristics of oyster bars were apparent. Model results have implications for fisheries management and oyster restoration activities.

Validation of the simulated Lagrangian transport over the continental shelf of the Bay of Biscay.

Marina Chifflet, Pascal Lazure, Pierre Petitgas, Martin Huret

IFREMER, France. To increase the ability of fish larvae IBM coupled to Lagrangian drifters to accuracy predict fish recruitment, uncertainty in the transport of biological particles needs to be assessed. Our major objective in this study is to validate and calibrate Lagrangian trajectories in a 3D circulation model. The coastal 3D hydrodynamical Model for Applications at Regional Scale (MARS3D, developed by Ifremer) is applied in the whole Bay of Biscay. It computes the variations in tides, momentum, heat and salt fluxes with a horizontal resolution of about 4 km and 30-sigma levels on the vertical. A 16-years simulation from 1990 to 2006 has been performed. To validate the annual cycle of temperature, the simulated SST have been compared to satellites images. The model reproduces the main characteristics of the seasonal evolution of the SST (e.g. order of magnitude, north-south gradient, cold coastal band along the French coast, temperature front near Ouessant Island, upwelling periods….). The improvement of the model to validate the simulated hydrological results is still in progress (e.g. strong mixing in the Channel). We have now a modelling tool, applied to the whole Bay of Biscay, to assess Lagrangian transport.

Available trajectories from drifters, released in the Bay of Biscay during the Modycot cruises (SHOM and IFREMER, from 1997 to 2002) and the Pelgas and Juvaga cruises (IFREMER, 2004–2005) have been compiled in order to compare them to simulated trajectories. Passive particles have been released in the model for year each periods from 1997 to 2002, at same dates, same geographical positions but along a transect over the shelf, and same depth (60 m for these years). The model reproduces the seasonal tendency of the sub-surface Lagrangian circulation: retention or southward tendency during the spring (1998, 1999, 2001), south-eastward tendency near the slope and north-westward tendency near the coast in summer

(1997, 1999), and a strong and recurrent north-westward current along the coast in autumn (1998, 1999, 2001, 2002). However, an exceptional event during the spring 2000 (north-westward current) is not reproduced by the model. We are presently studying this special event to improve the model (wind direction conditions and density gradient impact especially).

Future works are: (*i*) development of a method to quantify the validation, (*ii*) comparison of simple 2D advection with 0-30 m mean current to 3D trajectories over the 0-30 m upper layer and (*iii*) 3D fish larvae trajectories with advection, diffusion and vertical behaviour.

Implementation of an ecosystem model at BSH – current status and future plans

Frank Janssen and Stephan Dick

Federal Maritime and Hydrographic Agency, Germany

The model system at the Federal Maritime and Hydrographic Agency (BSH) consists of several models of different kind, ranging from wave and circulation models to Eulerian and Lagrangian dispersion models. Sea level forecasts, storm surge warnings, oil drift and spreading as well as search and rescue are the most important applications of the model system. During the last years there was a strong increase in request concerning environmental conditions in the North Sea and the Baltic Sea and it was therefore decided to add an ecosystem component to the model system.

The main problem in setting up an ecosystem model for the coupled North Sea/Baltic Sea region is the strong salinity gradient with salinities ranging from near zero in the most eastern and northern parts of the Baltic Sea to open ocean conditions (S>35.2 psu) in the northern North Sea. This large range in salinity has a strong influence on the ecosystems in North and Baltic Sea, which are quite different and it is the main reason that there is no ecosystem model available which covers both regions so far.

The 1st step in the development of an ecosystem model was the implementation of a suspended particulate matter model in co-operation with the GKSS research centre. The next step is to make a proper choice from existing, well established ecosystem models. The technical implementation of the model will be done in the framework of the water-column model GOTM-BIO (http://www.gotm.net, Burchard *et al.*, 2006).

In co-operation with the IfM Hamburg the ecosystem model ECOHAM2 was coupled to the Eulerian dispersion model BSHdmod.E. ECOHAM2 has been used in many North Sea applications at IfM and was designed and calibrated for this region. The next steps will include the coupling of the ecosystem model ERGOM in co-operation with the Baltic Sea Research Institute, Warnemünde and a comprehensive test of both ecosystem models in the North Sea/Baltic Sea region. The final solution is probably a “combination” of both ecosystem models in order to have a system which is able to give reasonable results in the whole region. However, “combination” might mean quite different things, from exchange of model parameterisations or compartments to ensemble simulations.

Alternative approaches to ecosystem modelling (ToR e)

Complexity theory and marine ecosystem models: a view from 30,000 feet

Charles Hannah, Bedford Institute of Oceanography, Canada

The question ‘How much complexity is enough?’ is one of the oldest in modelling. While there is no definitive answer, the quest provides useful insights. Two key insights from complexity theory are that complex systems exist as a balance between the positive (instability) and negative (stability) feedbacks, and that the interactions, or feedbacks, between system components are at least as important as the details of any individual component. Therefore an ecosystem model needs to represent the important structural features of the ecosystem, even at the expense of process detail. Provisional support for this idea is found in a variety studies. A likely consequence is that improvements to model accuracy will occur as a result of incremental improvements across the system rather than dramatic improvements to any single component of the system. For the purposes of integrating ecosystems from end-to-end, earth system models of intermediate complexity (e.g. Claussen 2002l) provide a better basis for model development than the rhomboid (deYoung *et al.* 2004).

From species to traits: biodiversity inspired ecosystem models

Jorn Bruggeman, Vrije Universiteit, Amsterdam

Ecosystem models are traditionally built by linking population models of (groups of) species. These models suffer from several problems: they are forever limited to a subset of ecosystem species, their parameter values are often uncertain or unknown, and a complete initial state is impossible to obtain. I propose that ecosystems may be easier characterized by a small set of "traits" – quantifiable characteristics of species – rather than by many explicit species. Key traits may be identified by close observation of the ecosystem, or by formal approaches such as principal component analysis. Given a set of relevant traits, the ecosystem is modelled as a probability distribution in trait space. This distribution is characterized by its moments (total biomass, mean, covariances), which are evolve dynamically in time with expressions based on theory from quantitative genetics and theoretical biology. Several applications in spatial context are shown: a phytoplankton community characterized by light harvesting and nutrient harvesting traits shows formation of a subsurface chlorophyll maximum and nutrient-governed succession, and a community of phytoplankton and bacteria exhibits changes in community composition in time and depth that are known from classic aquatic literature. Such qualitative agreements with observations suggest that in time, trait-based ecosystem models may prove capable of elegant, simple parameterizations of key ecosystem behaviors.

Bruggeman, J. and Kooijman, S. A. L. M. (in press). "A biodiversity-inspired approach to aquatic ecosystem modelling." Limnology and Oceanography.

Size-based and optimality approaches to simulate adaptive dynamics in marine ecosystem

Kai Wirtz (wirtz@gkss.de) GKSS, Geesthacht, Germany

The complexity inherent to marine food-webs still defines a major challenge to coupled biological and physical models. Even though the last decades have seen an increasing complexity of models accompanied with problems related to testability, basic features of the natural system are still unresolved. Prominent examples are adaptive processes on the organism and community scale or feed-backs due to the linkage between lower and higher trophic levels. Resulting limits of concurrent modelling are here illustrated using observations of the phytoplankton biomass and size composition taken at Helgoland Roads in the German Bight.

In order to develop new model types better suited to cope with the complexity apparent in these and other data, two different modelling studies are presented. These logically build on the presentations given by Hannah and Bruggeman and will be completed by the approach proposed by Anderson.

First, adaptation in algal edibility is simulated by a simple predator-prey model which includes a time-variable edibility (φ). Its evolution equation makes sure that trait changes optimize the relative growth rate as formulated by the Adaptive Dynamics methodology. The equation therefore contains the variance of φ as well as the total derivative of the growth rate with respect to the edibility. In our case, the derivative also has to account for the non-linear correlation between φ and the nutrient affinity of algae. This trade-off together with the value for the variance is found to be critical in order to reconstruct observed predator-prey cycles in chemostat experiments (Fussmann *et al.*, 2001). In particular, a substantial prolongation and dampening of cycles with higher adaptability of prey as evident in the data can be well reproduced.

A similar stabilization of predator and prey biomass before a spring bloom is analyzed in a second study. To this means, elements of a new distribution- and trait-based model are presented. The model is build upon the concept of generic plankton groups, each characterized by a set of key properties like biomass of adults and larvae and, more importantly, effective traits like mean size or autotrophy to heterotrophy ratio (cmp. Bruggeman, this report). A semi-mechanistic formulation of trade-offs enables to implicitly describe an infinite number of trophic interactions giving rise to a self-organization of the food-web and to a continuous distribution of traits over the entire plankton spectrum from bacterioplankton to fish-larvae. First model tests indicate that adaptations in the size composition of algae may be responsible for the biomass stabilization effect.

Size as a functional trait

Ken H. Andersen, Danish Institute for Fisheries Research

This presentation showed how the size of an individual and the asymptotic size of a species group could be used as the basis of a model of the whole fish part of the ecosystem. The model is based on description of processes taking place on the individual level only. The processes are: 1) scaling of intake, 2) the encounter of prey through a search volume, which is an increasing function of size, and 3) a selection of prey size through a formalization of the rule: big fish eat small fish. From this the slope and the total abundance of the size spectrum of the whole community can be derived. By writing a simple von Bertalanffy like growth model also the spectra of a species group characterized by its asymptotic size can be derived.

Review existing operational data flow from sustainable observational and modelling systems such as goos (ToR d)

Support of IFREMER to WP3 (Better use of remote-sensing data and *in situ* measurements) of ECOOP.

Martin Huret, IFREMER, France.

Specific algorithms have been developed at IFREMER for chlorophyll-a and SPM estimation in coastal areas (Case 2 waters) of the Bay of Biscay. In the framework of MARCOAST (GMES service) and now ECOOP (European COastal shelf Operational and forecasting system), these algorithms are now applied to a wider area covering the IBI-ROOS (Iberian-Bay of Biscay-Ireland Sea Regional Ocean Observing System) region. Images are provided in near real-time on a website (http://www.ifremer.fr/nausicaa/marcoast/private/browser.htm), from which data can be downloaded as netcdf files, together with some SST products (daily images, climatology and anomalies). Other specific websites cover the Mediterranean Sea, the Bay of Biscay and the Channel, with for each area some specific associated dataset (*in-situ* data, wind data, irradiance, runoffs).

Small scale feeding processes:

Behaviour Mediates Predation and Growth Rates in Larval Cod

Øyvind Fiksen, University of Bergen

In a recent review of growth rates of larval cod estimated in the field, Folkvord (2005) pointed out that larvae tend to grow at temperature-limited rates. An implication of this is that prey availability has little impact on estimated growth rates. However, Beaugrand *et al.* (2003)showed that there was a clear correlation between recruitment of cod and an index of prey availability in the North Sea. A theoretical analysis suggests that larval fish typically are facing trade-offs between feeding and predation rates. If larval fish have flexible behaviours in response to environmental conditions and strong size-dependence in their mortality rates, then larval fish foraging activity will increase as prey density decrease, and the growth rate will be relatively insensitive to prey density. Instead, since foraging activity is related to predation rates, the survival probability of larvae will increase with prey density. This potentially reconciles both the lack of growth variability in the field, and the correlation between prey indices and recruitment of fish.

Beaugrand, G., Brander, K. M., Lindley, J. A., Souissi, S., and Reid, P. C. 2003. Plankton effect on cod recruitment in the North Sea. Nature, 426**:** 661–664.

Folkvord, A. 2005. Comparison of size-at-age of larval Atlantic cod (*Gadus morhua*) from different populations based on size- and temperature-dependent growth models. Canadian Journal of Fisheries and Aquatic Science, 62**:** 1037–1052.

A few thoughts about modelling small scale processes relevant to (zooplankton and) fish larvae

Alejandro Gallego, FRS Marine Lab, Aberdeen

The typical maximum resolution of physical models used to model bio-physical processes is in the order of 100s of meters to km (horizontal), meters (vertical) and minutes to hours (temporal), while small scale biological processes relevant to individuals operate at much finer ("sub-grid") scales. Consequently, the tendency has been increasing towards more detailed, mechanistic, modelling of small scale processes. However, the importance of scale depends on the objectives of the model and, where small scale processes themselves are not critical, my view is that the can (and should) avoid explicit modelling of sub-scale processes. This way, growth can be modelled as a function of temperature (and food?) and mortality as a function of size. There are disadvantages in this approach (e.g. too smooth forcing data fields, often population or ecosystem specific relationships, and considerable data requirements). However, the detailed modelling of small scale processes in an integrated modelling framework to model, for example, fish recruitment, can be a daunting process. A cursory trawl through the literature of the relationships and parameters required to model feeding/growth and predation/mortality indicated that some 20+ environmental variables (plus those required in a NPZ model, if used) and some 50+ functional relationships would be required. Therefore, in my opinion:

- detailed biophysical modelling of all small-scale processes relevant to zooplankton/fish larvae is a very serious (too serious?) undertaking at present and therefore it is critical to assess the level of complexity required for any given application;
- Targeted modelling exercises are critical "building blocks" of more comprehensive models;
- Programming tools can be used to:
    - provide parameter estimates;
    - generate hypotheses of potential mechanisms to help to focus observational (field and laboratory) studies;

- Sensitivity analysis will help but it is only as good as the analysis itself;
- All models must be complemented with carefully designed observational work:
  - for the relevant species;
  - for the relevant sizes/ontogenetic stages;
  - recording individual variability;
- Emerging technologies (and old ones!) must be used to acquire observational data at the relevant scales. This is just now becoming feasible!

Annex 11: Summary List of Models

The EuroGOOGS office is compiling and inventory of numerical models that are operational or preoperational in all European waters. This is being done as of the project is called SEPRISE: Sustained, Efficient Production of Required Information and Services within Europe. It will be completed in June 2007. For more information contact the EuroGOOS Office at eurogoos@smhi.se. So far they have received information from 92 “operational and pre-operational” models. The preliminary summary is given below.

Table A11.1. Numerical Modelling and forecasting, summary based on information from the SEPRISE database.

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Belgium	MUMM	Optos_Wave	2nd generation wave model based on HYPAS	Greater North Sea, Southern Bight, Belgian Coastal Zone	Wave spectra E(f,Θ) and indirect variables (1D spectrum E(f), wave direction Θ (f), total wave energy, significant wave height H_S, low frequency energy E_{10} …)	Op	
Belgium	MUMM	Optos_bcz	3D model for tide and wind driven circulation in the Belgian Exclusive Economic Zone. Implementation of the COHERENS model	From 2.08333°E to 51.92°N	3D current field and sea surface elevation	Op	
Belgium	MUMM	Optos_float	Model to forecast the drift of various floating objects under the influence of wind and surface currents	North Sea From 4°W to 57°N	Position	Op	
Belgium	MUMM	Optos_nos	3D model for tide, wind and density driven circulation in the North Sea. Implementation of the COHERENS model	From 4°W to 57°N	3D current field, sea surface elevation, temperature and salinity	Op	
Bulgaria	IO-BAS	WAM cycle 4	Third-generation phase-averaging wave model	Black Sea	Significant Wave Height Wave Direction Mean Wave Period	Pre-op	
Cyprus	UCY	CYCOFOS-SWAN	The SWAN wave model is used for a high resolution coastal wave model domain around Cyprus.	Mediterranean, 31º 50E - 35º 25E, 34º 00N – 36º 25N	Significant wave height and direction.	Op	

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Cyprus	UCY	CYCOFOS-WAM-Levan	The WAM wave model used in CYCOFOS-WAM-Levan to provide wave forecasts for the Levantine Basin.	Mediterranean, 28º 00E – 36 º 25E, 30º 45N - 37 º 00N	Significant wave height and direction.	Op	A1
Cyprus	UCY	CYCOFOS-WAM-Med	The WAM wave model used in CYCOFOS-WAM-Med to provide wave forecasts for the entire Mediterranean. The CYCOFOS–WAM-Levan wave model for the Levantine Basin is nested with the coarse resolution CYCOFOS-WAM-Med model.	Mediterranean, 05º 50W - 36º 25E, 30º 50N - 44º 37.5N	Significant wave height and direction.	Op	A1
Cyprus	UCY	CYCOFOS-CYCOM high	The 3D flow model used in the CYCOFOS-CYCOM high is based on POM model. The CYCOM-high is nested hierarchically with the ALERMO model. CYCOM-high uses the VIFOP for initialization of the model.	NE Levantine Basin, Eastern Mediterranean 31 30'E - 36 13'E and 33 30'N – 36 55'N	1) 3D fields for currents, temperature, and salinity. 2) sea level.	Op	A1
Cyprus	UCY	CYCOFOS-CYCOM low	The 3D flow model used in the CYCOFOS-CYCOM low is based on POM model. The CYCOM-low is nested with the MFS-OPA.	NE Levantine Basin, Eastern Mediterranean 31 30'E - 36 00'E and 33 30'N – 36 45'N	1) 3D fields for currents, temperature, and salinity. 2) sea level	Op	A1
Cyprus	UCY	CYCOFOS-MEDSLIK	The MEDSLIK- Mediterranean oil spill is a 3D oil spill model designed to predict the transport, fate and weathering of an oil spill in the Mediterranean	Levantine Basin, Adriatic, Malta Sea area, NE Levantine, Mediterranean	Oil slick: at sea surface, evaporated, dispersed in the water column, stack on coast. Oil slick viscosity, oil density, oil slick volume.	Op	
Denmark	DHI	MIKE 3 SW	3rd generation spectral wave model. Finite volume flexible mesh.	Global / North Atlantic / North Sea / Baltic Sea	Wave & Swell parameters.	Op	

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Denmark	DHI	MIKE 3 PA, SA	3D Particle & Spill Model, Dynamical Nesting, finite difference	North Sea / Baltic Sea	Different chemicals and sediment, oil spill	Pre-op	
Denmark	DHI	MIKE 3 HD + Ecolab	3D operational baroclinе circulation and eutrophication model	North Sea / Baltic Sea	Temperature, Salinity, Water level, Currents, Chlorophyll-a, Nutrients, Oxygen	Op/Pre-op	
Denmark	DMI	cmod	3D hydrodynamical model (hydrostatic) using two-way nested grid	North Sea / Baltic Sea	Sea surface elevation. Zonal and meridional current velocity components, Salinity, Sea temperature. Sea ice thickness	Op	A1
Denmark	DMI	3D Oil Drift and fate Forecast model (BSH-Dmod).	The model calculates oil transport, drift and fate at sea surface and subsurface.	The North Sea – Baltic Sea	• Oil drift animation • Amount of particles • Middle-position of the oil slick • Wind speed and direction at the middle position • Released oil mass • Total mass of oil • Total oil volume • Total oil area • Oil radius • % Water content • % Oil evaporated • % Oil emulsified (oil-in-water suspension) • % Oil stranded on the seabed or coastlines • % Oil at sea surface • % Oil in subsurface/dispersed • Oil viscosity • Mean oil layer thickness	Op	B

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Denmark	DMI	MPI-OM-1 or HOPE	Primitive equation ocean general circulation model	Global coverage.	Temperature, salinity, currents (u,v,w), sea level , and sea ice (and snow) drift, concentration and thickness.	Pre-op	D
Denmark	DMI	HYCOM	3D isopycnic	North Atlantic Ocean and Arctic Ocean	Sea surface height (elevation) Velocities Salinity Temperature Sea ice	Op	A1
Denmark	DMI	Mike21	2D hydrodynamical model running on a number of successively two-way nested regular UTM meshes.	North Sea – Baltic Sea.	Sea surface elevation Zonal and meridional transport	Op	A1
Denmark	DMI	MOG2D	Finite element shallow water 2D tides storm surge	North Sea / Baltic Sea	Sea surface height (elevation) Depth integrated velocity	Pre-op	C
Denmark	DMI	Noamod	2D hydrodynamical model	North Sea / Baltic Sea	Sea surface elevation. Zonal and meridional current velocity components.	Op	C
Denmark	DMI	SMILLA	Dynamic finite element sea ice mode	Cape Farewell (Greenland)	Sea ice concentration, thickness, and velocity	Pre-op	C
Denmark	DMI	DMI WAM-cycle4	The 3rd generation wave model, to provide forecast on wave height, direction, period and swell	North Atlantic, Mediterranean Sea, North Sea-Baltic Sea	Significant wave height, mean wave height, mean wave direction, peak period, mean period, swell height, swell direction, swell period, wave spectrum	Op	A1
Denmark	RDANH	WAVEWATCH-III	WaveWatch-III (WW3) performs a numerical solution of the stochastic equation for spectral action density balance for wave number–direction spectra.	1) North-east North Atlantic, 9x9 nmi 2) North Sea, Baltic Sea, 3x3 nmi 3) Danish Belts and the Sound, 1x1 nmi	Significant wave height (Hs) Mean wave period (T01 and T02) Mean wave direction Peak period Wind sea period Wind sea direction Wind sea wave length Wind sea characteristic slope	Op	A1

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Denmark	RDANH	GETM	Spherical coordinate system (lon-lat) with general vertical coordinates. 3D primitive equations for u, v, T, and S. Hydrostatic approximation for pressure. Free surface. Eddy viscosity assumption. Second-order turbulence closure model from GOTM. Parallel computation with sub domains distributed to multiple compute nodes using message passing.	North Sea, Danish Straits, Baltic Sea	Water level (2D field) Salinity (3D field) Temperature (3D field) Currents (u,v,w) (3D field)	Pre-op	A1
Denmark	RDANH	Seatrack Web	Seatrack Web is an operational oil drift forecasting system for spill response purposes	The Baltic Sea area and the eastern part of the North Sea	Oil spill / object drift trajectory, state of oil	Op	B
Finland	FIMR	BalEco	Ocean circulation model Ocean ecosystem model	Baltic Sea	- T,s,U,V,(W),eta - DIN, DIP, DSi, 4*phytoplankton	Op	
Finland	FIMR	HELMI	The HELMI model is a multi-category sea-ice model that resolves evolution of a level, rafted and ridged ice motion, thickness and concentration.	Baltic Sea	Total sea ice concentration, undeformed ice thickness, deformed ice mean thickness and concentration, ridge thickness, ice velocity and ice compression	Op	
Finland	FIMR	WAM	Wave model	Baltic Sea	Significant wave height, mean wave direction, mean wave period, peak wave period, peak wave direction, friction velocity, stokes drift, wave stress, drag coefficient	Op	
Finland	FIMR	PATS	Drift model for operational purposes	Northern Baltic Sea		Op	
Finland	SYKE	OpHespo	Hydrodynamic model for drift prediction coupled with the Finnish HIRLAM model	Gulf of Finland	Currents, sea level	Op	B

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
France	IFREMER	MARS	Chain of nested models based on the Ifremer Mars2D and Mars3D numerical models:	The Channel, the Bay of Biscay, the North-western Mediterranean	Temperature, salinity, velocities, Turbulent kinematic energy	Op	
France	Mercator	Mercator	Mercator model configurations are based on the general ocean circulation OPA-Nemo model	Global, North Atlantic, Azores, Mediterranean, Global coverage	• 3D Temperature (°C) • 3D Salinity (psu) • 3D Zonal velocity (m/s) • 3D Meridian velocity (m/s) • 3D Vertical diffusivity coefficient (m2/s) • 2D Sea surface height (m) • 2D Temperature ocean mixed layer thickness (m) • 2D Density ocean mixed layer thickness (m) • 2D Ocean barotropic stream function (m3/s) • 2D Wind stress northward Ty component (N/m2) • 2D Wind stress eastward Tx component (N/m2) • 2D Total net heat flux (W/m2) • 2D Water flux (mm/jour) • 2D Barotropic height (m) • 2D Surface downward solar heat flux (W/m2)	Op	
France	Météo-France	Telemac2D	Based on the resolution of shallow water equations by a finite elements method	Gironde estuary	Vertically-integrated current, sea elevation, surge height.	Op	
France	Météo-France	MOTHY	Drift model	Global	Drift of oil spill, containers, floating objects, person in water.	Op	

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
France	Météo-France	Oceanic storm surge prediction model	Based on the resolution of shallow water equations by a finite differences method	1)First domain: North Sea, Channel, near Atlantic Ocean –gulf of Biscay- (south of 59°N, east of 8°30' W, north of 43°N); 2) Second domain: Western Mediterranean basin	Vertically-integrated current, sea elevation, surge height.	Op	
France	Météo-France	VAG	2G-Wave model	1) Global 2) European Seas 3) French Coast	Wave spectra and derived parameters	Op	
Germany	BSH	BSHdmod.L	Lagrangian drift and dispersion model for oil, floating objects and conservative substances, oil weathering processes included, backwards tracking	North Sea and Baltic Sea	Drift paths, distribution of water soluble substances and oil, oil properties	Op	C
Germany	BSH	BSHdmod.E	Eulerian dispersion model using shock capturing scheme for simulation of conservative substances and suspended matter	North Sea and Baltic Sea	Concentration and distribution of water soluble substances and SPM	Op	C
Germany	BSH	noamod	2D hydrodynamical model	North-East Atlantic + North Sea	water levels, currents	Op	C
Germany	BSH	BSHsmod	barotropic two-dimensional prognostic HN model finite differences flooding and falling dry of tidal flats	North Sea	water levels, surge data	Op	B
Germany	BSH	BSHcmod	baroclinic three-dimensional prognostic HN model	North Sea and Baltic Sea	water levels, currents, salinity, temperature, eddy coefficients, ice thickness and compactness	Op	B

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Greece	HCMR	Ocean Hydrodynamic model	3D sigma-coordinate primitive equation model	Eastern Mediterranean and the Aegean Sea	General circulation (3D currents), temperature of sea water in 3D, salinity of sea water in 3D	Op	A1
Greece	HCMR	Surface pollutant transport model – based on the PARCEL model.		The model is applied to the Eastern Mediterranean and/or Aegean Sea	Longitude, latitude and depth of each particle in the sea Evaporated volume of the initial oil Emulsificated volume Volume remaining in the beach	Op	A1
Greece	HCMR	DAUT	2nd generation wave model	Aegean Sea	Wave parameters	Op	A1
Greece	HCMR	WAM	3rd generation-cycle 4 wave model	Mediterranean and Aegean Sea	Wave parameters	Op	A1
Ireland	MI	SWAN	Solves spectral wave action density equation.	Shelf seas west of Ireland	Significant wave height, energy in 32 spectral bands, mean wave period, spectral peak wave period, wave direction of wind waves and of swell, spectral spread.	Pre-op	A
Ireland	MI	ROMS	Model includes tidal potential forcing and ADCIRC TPX06 at the boundaries, and input from 40 rivers. Bathymetry from the Irish National Seabed Survey	NE Atlantic from Biscay to the Scotian Shelf and from the English Channel to the Mid Atlantic Ridge	T, S, sigma-t, u,v,w, ubar, vbar, zeta	Pre-op	A
Italy	INGV	MEDSLICK	MEDSLIK is a three-dimensional model designed to predict the transport, fate and weathering of an oil spill	Adriatic Sea	Percentage of emulsioned oil, Dispersal oil Evaporated oil Location of the slick Beached oil Percentage of oil at surface Oil viscosity	Pre-op	

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Italy	INGV	MFS_sys1_daily	The oceanographic general circulation model (OGCM) of the Mediterranean Forecasting System (MFS) is based on the free surface version of the OPA8.1 model	Mediterranean Sea	3D: potential temperature, salinity, zonal velocity, meridional velocity. 2D: Sea Surface Height, net downward heatflux, down shortwave radiation, net upward waterflux, meridional wind stress, zonal wind stress	Op	
Italy	INGV	AREG	The ocean model used for this Project is the Princeton Ocean Model, POM	Adricosm Sea	3D: potential temperature, salinity, zonal velocity, meridional velocity. 2D: Sea Surface Height, evaporation rate, latent heat flux, sensible heat flux, shortwave radiation, net surface heatflux, longwave flux backward.	Op	
Italy	OGS	ACOAST 1.1	Code: MITgcm	Gulf of Trieste	Velocity field, sea level, temperature, salinity	Pre-op	B
Norway	IMR	VALDEMAR	Implementation of ROMS and sea- ice model	Global (coarse) and fine scale models for North Sea and Barents Sea	S, T, velocities, water level, sea-ice	Pre-op	D
Norway	IMR	NORWECOM	3D baroclinic circulation model with SPM and ecosystem model	Greater north west European shelf , North Atlantic, Arctic	T, S, Current, Turbulence, N, P, Si, Chla, Diatoms, Flagellates (Chattonella), PP, Detritus, ISPM (including sedimentation and resuspension of Detritus and ISPM), light (in the water column)	Op/pre-op	D
Norway	Met.no	MIPOM Surge ensemble	3D homogeneous circulation model. 21 member ensemble run.	Nordic Seas	Water level, 2D currents (U,V)	Pre-op	C
Norway	Met.no	WAM	Deep/shallow water modes, coupled spectral. Assimilates of ERS-2 altimetry data	Greater North European Shelf/Nordic Seas (45km); North Sea (8km)	Waves	Op	A

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Norway	Met.no	WAM.ECwind	Deep/shallow water modes, coupled spectral. Assimilates of ERS-2 altimetry data.	Greater North European Shelf/Nordic Seas	Waves	Op	B
Norway	Met.no	MIPOM.20KM	3D baroclinic circulation model	Nordic Seas	Water level + 3D currents (U,V), temperature, salinity	Op	A
Norway	Met.no	MIPOM Nordic4	3D baroclinic circulation model. Assimilates satellite SST	Nordic Seas	Water level + 3D currents (U,V), temperature, salinity	Op	A
Norway	Met.no	MIPOM Arctic20	3D baroclinic circulation model coupled with sea ice model. Assimilates satellite SST and ice concentration.	Nordic Seas and Arctic Ocean	Water level + 3D currents (U,V), temperature, salinity, ice concentration, ice thickness, ice velocity	Pre-op	B
Norway	Met.no	MI-POM surge	3D homogeneous storm surge model on 20km grid	Greater northwest European shelf		Op	A
Norway	Met.no	OD3D	3D oil spill fate model	NE Atlantic, Nordic Seas		Op	D
Norway	Met.no	LEEWAY	Drifting objects model	NE Atlantic, Nordic Seas		Op	D
Norway	Nansen	TOPAZ	Model: HYCOM Assimilation method: ENKF Assimilates: SLA, SST, ice c.	Arctic + full Atlantic basins	Currents, Temperature, Salinity, SSH, ice concentration, ice thickness	Op	A1
Poland	IMWM	HIROMB	The model is run at SMHI	Baltic Sea	Water temperature, salinity, sea level, currents, sea ice.	Op	B
Poland	MIG	WAM4	Standard WAM4 wave model	The Baltic Sea	significant wave height, direction and period, peak period, swell characteristics	Pre-op	
Portugal	IH	OTIS	Barotropic model with data assimilation from 328 complete orbits of Topex/Poseidon.	Portuguese waters including Azores and Madeira Archipelagos.	Sea Surface Height.	Op	A1
Portugal	IH	SWAN	Third generation spectral wave model	Portuguese continental margin	Wave spectra, significant wave height, wave period, wave direction, wave induce orbital velocities.	Op	A1

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Portugal	IH	WaveWatch III	Third generation spectral global wave model	North Atlantic	Wave spectra, significant wave height, wave period, wave direction	Op	A1
Romania	NMA	WAM	Wave model	Black Sea	Wave height, period and direction	Op	
Slovenia	NIB	AREG	Three dimensional climatologically model, based on POM	Adriatic (and Ionian) Sea north of latitude 39 deg N	sea temperature, salinity, sea currents (three dimensional), sea surface elevation, bottom stress	Pre-op	
Spain	IEO	ROMS	Free surface, high order advection scheme, generic vertical coordinates, high order turbulence closures, tides, freshwater discharges	Iberian Atlantic, pre-operational in Galicia, and in development in the Cantabrian Sea	3D Currents, Temperature, Salinity, Sea Surface Elevation	Pre-op	
Spain	MeteoGalicia	WaveWatch III	Third generation spectral wave model	Three nested grids: 1st North Atlantic	Significant wave height, peak and mean period, peak and mean direction, wave length, directional spread	Op	B
Spain	MeteoGalicia	MOHID	3D baroclinic model. Finite volume. Arakawa-C, suitable for the modelling of baroclinic processes on coastal area	Galician Coast. North Western Coast of the Iberia Peninsula.	Current field.	Pre-op	B
Spain	PE	WAM	Wave generation and propagation. Finite difference grid. Two way nesting scheme	North Atlantic Ocean and Mediterranean Sea.	Wave spectrum and integrated parameters.	Op	
Spain	PE	WAVEWATCH	Wave generation and propagation. Finite difference grid	Strait of Gibraltar	Wave spectrum and integrated parameters.	Op	
Spain	PE	SWAN	Wave generation and propagation. Finite difference grid	Local applications for Harbours	Wave spectrum and integrated parameters.	Op	
Spain	PE	POLCOMS	Baroclinic 3D model	North Eastern side of the Atlantic Ocean	3D currents, temperature and salinity fields. Surface elevation	Op	
Spain	PE	HAMSOM	3D baroclinic model	East Atlantic and Med Sea.	Sea level	Op	

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
Sweden	SMHI	HIROMB	3D circulation model	North Sea, Skagerrak, Kattegat and Baltic Sea	salinity, temperature, currents, different ice-parameters, water level	Op	
Sweden	SMHI	Hypne	2nd generation spectral wave model	North Sea, Skagerrak, Kattegat and Baltic Sea	significant wave height, M2-period, wave direction	Op	
Sweden	SMHI	BOBA	Ice and sst-model	North Sea, Skagerrak, Kattegat and Baltic Sea	SST and ice	Op	
Sweden	SMHI	SWAN	Third generation spectral wave model	North Sea, Skagerrak, Kattegat and Baltic Sea	Wave spectra, significant wave height, wave period, wave direction, wave induce orbital velocities.	Pre-op	
Turkey	STMS	METU3	3rd generation wave model	Black Sea, The Sea of Marmara, Aegean Sea and Mediterranean Sea.	Waves	Op	
UK	MetOffice	Wave Model	Second generation wave model driven by hourly values of 10m wind from Met Office NWP models	Global, European waters, UK Waters (NW shelf)	Wave energy spectrum and integrated parameters	Op	A
UK	MetOffice	TELURAY / SWAN	Near shore wave transformation model,	Site specific, various locations	Near shore wave conditions, significant wave height, period, direction. Offshore wave conditions taken from the appropriate Met office wave forecast model	Op	B
UK	MetOffice	FOAM-HadOCC	Fully coupled biogeochemical-physical general circulation model.		Chlorophyll, phytoplankton, zooplankton, detritus and nutrient concentration. Partial pressure of CO2	Pre-op	D
UK	MetOffice	FOAM	3D, z-coordinate primitive equation model	(a) Global, (b) North Atlantic and Arctic, (c) North Atlantic, (d) Indian Ocean, (e) Mediterranean	Temperature, salinity, velocities, mixed layer depth, stream function, sea surface height, sea-ice concentrations and velocities.	Op	A

Country	Institute	Model name	Characteristics	Area covered	Variables	Op/Pre-op	Category
UK	MetOffice	Medium Resolution Continental Shelf Model	3D baroclinic hydrodynamic model coupled with lower tropic level ecosystem model	North-West European Continental Shelf	Chl, HAB risks, primary productivity, nutrients (NO3, Si, PO4)	Pre-op	A
UK	MetOffice	POLCOMS and POLCOMS-ERSEM	POLCOMS - Hybrid s levels, B-grid, front preserving advection, baroclinic ERSEM - Complex lower tropic biogeochemical model	NW European Shelf Region Nested Irish Sea	Temperature Salinity Currents TKE SSH Sediment Biological variables (POLCOMS-ERSEM only)	Op/Pre-op	A
Ukraine	MHI	MFI	5 km grid step, 35 non-uniformly spaced levels, Arakawa C-grid, Self made	Black Sea	3D Temperature, salinity, currents and velocity	Pre-op	