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

25–26 March 2010

Aberdeen, United Kingdom

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CIEM Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

The WGPBI met in Aberdeen, Scotland, on 25–26 March 2010. Working group members discussed recent advances in:

- models of transport and dispersal, growth and mortality of early life stages of fish, for studying connectivity and recruitment,
- coupled models of circulation, biogeochemistry and planktonic population dynamics,
- models of atmospheric patterns for driving regional physical-biogeochemical processes,
- end-to-end models and coupling of models describing different aspects of ecosystem dynamics.

The Workshop on understanding and quantifying mortality in pelagic, early life stages of marine organisms: experiments, observations and models (WKMOR) was held immediately before the WGPBI meeting and chaired by WGPBI members Alejandro Gallego (UK) and Elizabeth North (USA) together with Ed Houde (USA). The workshop targeted mechanisms that control mortality of eggs, larvae and juveniles. It was attended by 35 scientists. Workshop interactions and planned products will serve to advance our understanding and prediction of recruitment variability.

The book proposal "Individual-based modelling of aquatic organisms: coupling biology and physics" by WGPBI member S. Hinckley together with A. Hermann, B. Megrey and K.A. Rose, has been accepted by a publisher. The book will present the state of the art regarding techniques for development of these models which are of increasing importance in marine research.

Additional highlights include: 1) pre-operational biogeochemical models of the North and Baltic Seas are robust, stable and suitable for operational application; 2) an extensive review of physiological characteristics of marine fish larvae is underway and will provide important information to advance modelling of fish early life; 3) correlations have been found between flow fields and climate indices like the NAO in multiple systems; 4) direct coupling of 3D hydrodynamic and biogeochemical models (GOTM/BFM) and Ecosim/Ecospace models is underway; and 5) the combined efforts of WGPBI members may improve understanding of herring recruitment variability.

1 Opening of the meeting

The 2010 meeting of the Working Group on Modelling of Physical/Biological Interactions was held in Aberdeen, Scotland, UK, on 25–26 March. The meeting was attended by 14 scientists from 9 countries (Annex 1). The agenda (Annex 2) was adopted. The terms of reference for the meeting are given in Annex 3. The meeting followed the Workshop on understanding and quantifying mortality in pelagic, early life stages of marine organisms: experiments, observations and models (WKMOR).

The working group thanks Alejandro Gallego (Scotland, UK) for splendid local arrangements.

2 New results (ToR a)

F. Janssen presented recent development with respect to operational biogeochemical modelling in Germany. The well established operational physical model system of the Federal Maritime and Hydrographic Agency has been extended by a biogeochemical model component. Two different biogeochemical models, one "North Sea model" (ECOHAM4, developed at the University of Hamburg), and a "Baltic Sea model" (ERGOM, developed at the Leibniz Institute for Baltic Sea Research) have been implemented and tested for a one year period in a pre-operational environment. It could be shown that both models are robust, stable and suitable for operational application.

M. Hufnagl presented results from a physiologically based, 3-d biophysical individual-based model of Atlantic herring larvae. The study aimed to identify bottom-up factors that could be responsible for recent recruitment failures. The results suggest that the autumn zooplankton bloom in the North Sea is important for the condition of larvae prior to overwintering and, consequently, larval overwinter survival. WGPBI questioned if there are observations of diet shifts in herring larvae during high and low recruitment years. Work by Alejandro Gallego and colleagues at Marine Scotland - Science has also shown that the overwinter larval survival time series in the northwestern North Sea herring subpopulation is determined by feeding conditions during that period and work is underway to extend this analysis to a wider area. The combined efforts of WGPBI members may shed light on herring recruitment variability.

P. Petitgas presented results from the RECLAIM project on downscaling of basin-scale atmospheric patterns to drive regional physical/biogeochemical models. Correlations between indices such as the North Atlantic Oscillation and flow fields were identified. For example, in the Bay of Biscay a negative Eastern Atlantic pattern index was found to co-occur with NNE winds and south-going currents, which favours upwelling events. A discussion followed the presentation. It was suggested that the flow be de-seasonalized prior to the EOF analysis. It is difficult to transform reliably a global climate change scenario and be able to detect whether the NAO index is increased or decreased. Delayed correlation could also be investigated as winter or spring conditions set the scene for summer stratification and primary production.

Myron Peck provided an overview of the potential role of biophysical-models to aid management and projections of stock recovery using specific case studies including European anchovy (in the Bay of Biscay), Atlantic cod (in the Baltic, North and Barents/Norwegian Seas), Atlantic herring (in the Barents/Norwegian Seas) and sprat (in the Baltic and North Seas). The presentation was based upon work within Hinrichsen *et al*. (In Press). For each of these species/stocks, knowledge gained from bio-physical

models on processes impacting fish early life stage survival and recruitment was reviewed. Strengths of current modelling approaches were emphasized including the ability to estimate both spatial and temporal differences in the recruitment potential of larval cohorts. The results demonstrate the applicability of coupled bio-physical models for predicting circulation patterns, temperature and prey fields within marine ecosystems and consequently, variability in early life stage drift, survival, settlement probability of juveniles as well as the connectivity within stocks. These are all factors that are not adequately addressed in standard projections of stock recovery as they fail to account for the uncertainty associated with productivity or carrying capacity changes of the ecosystem. The influence of environmental variability on potential recruitment success can be discerned from model hind-casts. One of the main weaknesses of current modelling approaches is that future environmental variability remains unpredictable. Key products that operational models could provide managers who are charged with establishing viable stock recovery plans and adaptive management strategies were discussed. A key challenge in applying these model-derived tools to management includes a 10 to 100-fold mismatch in spatial scales. This mismatch is the impetus for a theme session proposal for the 2011 or 2012 ICES ASC proposed by member of WGPBI (Myron Peck and Pierre Petitgas).

J. Beecham presented a spatial model of benthic communities currently under development at Cefas, Lowestoft. The model allows a high spatial resolution of 30 000 cells and can incorporate physiological relationships in terms of environmental variables. The model is applied to a study of the relationship between beam trawling and mortality in the benthos. The aim of the model is to support spatial management.

E. North presented results from a modelling study on the influence of anoxia on larval connectivity in the Chesapeake Bay. Net lateral circulation from channel to shoals near bottom can exist in estuaries due to tidally-induced differential density gradients. Avoidance of anoxia by oyster larvae may prevent larvae from accessing this lateral transport pathway. The interaction between larval behaviour and anoxia may influence population connectivity by altering larval transport pathways.

U.H. Thygesen discussed backtracking of particles and presented results from a current effort to strengthen the theoretical basis of algorithms for this purpose. The research demonstrates that different algorithms, which each appear justifiable, can lead to contradicting results. This highlights the importance of a careful examination of the assumptions behind algorithms. While a statistical approach based on likelihood estimation is the theoretically most solid, computational considerations favour approximate Bayesian methods. The theoretical development has also produced formulas for shear dispersal of near-passive particles which are relevant to other situations; for example they allow simple and direct estimation of the dilution of egg concentrations due to mixing.

3 WKMOR: Review and follow-up (ToR b)

The Workshop on understanding and quantifying mortality in pelagic, early life stages of marine organisms: experiments, observations and models (WKMOR) was held in Aberdeen on 22–24 March 2010. It was co-chaired by Alejandro Gallego (UK), Elizabeth North (USA) and Ed Houde (USA) and was attended by 35 participants, who gave 20 oral presentations (a combination of contributed and invited talks) and displayed 6 posters. The goals of the workshop were to:

- Review current and emerging laboratory, mesocosm, field and modelling methodology aimed at understanding the underlying mechanisms that control mortality during fish and shellfish early-life stages;
- Summarize the state of our understanding of the mechanisms that control mortality of eggs, larvae and juveniles, identify information gaps, and list future research directions as proceedings from the workshop;
- Develop recommended techniques to quantify mortality in the field and model its impact on subsequent recruitment.

The first two days had a combined format of presentations and discussion sessions, structured into a number of sections:

1) Introduction

2) Laboratory studies: aquaculture, mesocosms, and small-scale interactions

3) Detecting and partitioning mortality in the field from planktonic stages to juveniles

4) Quantifying mortality: assumptions and sensitivity analyses

5) Numerical models: procedures for incorporating mortality and validation techniques

6) Revisiting the paradigms: linking mortality to recruitment.

The final day consisted of discussions in breakout groups and in plenary. The main physical outcomes of the workshop will be an ICES Workshop Report, a special issue in Journal of Marine Systems, and a "Conclusions" paper, probably as part of that submission. This paper will present a "conceptual model" of how the pelagic, early life stages of marine organisms die in the sea, a discussion of how mortality can be estimated in the field, minimising bias (and maximising precision), a description on how experimental work can contribute to our understanding of the relevant processes, and a list of identified knowledge gaps and future directions of research.

WGPBI congratulated the organizers of WKMOR for a successful event.

4 Physiological attributes of early life stages of fish

M. Peck provided an update on the 2009 ToR C, a review of the physiological characteristics of marine fish larvae that are key to understanding species-specific responses to climate-driven changes. The review is ongoing and is structured using parameters of a balanced bioenergetics budget that includes the major pathways of energy gained from foraging (e.g., swimming speed, visual perception, prey capture success, assimilation efficiency), and energy lost (respiration rate). These bioenergetics attributes are also linked to morphological characteristics of the species (fish mass-at-length, mouth gap, body depth, eye diameter). These bioenergetics parameters are currently utilized within biophysical individual-based models of foraging and growth of larval fish. At the time of the 2010 WGPBI meeting, a number of data sets had been compiled including: 1) the effects of temperature on the eggs of 64 marine fish species, 2) the effects of temperature on yolk sac absorption rates of 22 marine fish species, 3) the effects of temperature and body size on respiration rates of marine fish larvae in 13 families (43 data series from 28 studies) and 4) gut evacuation rates and maximum gut contents of 16 and 12 marine fish species, respectively. The first two points (1 and 2) are essential elements in physiological based drift modelling studies (e.g., particle tracking of early life stages) providing, among other things, estimates of spatiotemporal variability in connectivity to essential nursery habitats. It is

envisioned that dataset compilation and manuscript preparation will be completed in the next 6 months. WGPBI members commend M. Peck on his substantial effort and look forward to its completion.

5 Linking models of physics, biogeochemistry, and higher trophic levels

Meece is a large FP7 program which examines the effect of changing drivers (pollution, acidification etc.) on a variety of marine systems, focusing on characteristics such as biodiversity and productivity, among others. One Work package of this is the development of linked models which incorporate physical and biological processes at a range of trophic levels. One example of this is how the GOTM oceanographic model with the BFM model (plankton, detritus etc.) is being linked with Ecosim and Ecospace models. Because the models may represent the same things in very different ways, each model has been extended to supply metadata describing taxonomy, units, dimensions and system information. This is supplied in the popular xml format. The couplerlib library reads the xml and forges the links between models, performing an important quality control role, either on-line or off-line. The coupled models were used input changes in zooplankton dynamics into a North Sea model system, and predict the resulting changes in dynamics of fish populations.

6 The IBM book by S. Hinckley *et al.*

S. Hinckley reported by correspondence on progress on the book with the tentative title "Individual-based modelling of aquatic organisms: coupling biology and physics" by S. Hinckley, A. Hermann, B. Megrey and K.A. Rose. The book proposal was submitted to Wiley-Blackwell (editor – Justin Jeffreys) in January, 2010 and has been accepted. The aim is to have the first draft submitted to the publisher by December, 2012. The outline has changed minimally in content from what WGPBI saw last year, but the organization has changed somewhat. WGPBI congratulates the authors with the acceptance of the proposal. The Group believes that the book will be most valuable to researchers in the field and encouraged the authors in their efforts to prepare the draft of the book.

7 Theme sessions at the ICES ASC 2010

WGPBI members are co-convening the following theme sessions at ICES ASC 2010:

A: Operational oceanography for fisheries and environmental applications. Conveners: Helge Sagen (Norway), Barbara Berx (UK), and Dave Brickman (Canada)

C: Natural mortality variation in populations and communities. Conveners: Dave Reddin (Canada), Ken Haste Andersen (Denmark), and Niels Hintzen (Netherlands)

L: Spatially-explicit models for plankton and fish: processes, model integration and forecasts. Conveners: Pierre Petitgas (France), Thomas Neumann (Germany), Bernard Megrey (USA), Myron A. Peck (Germany).

N: Oceanography and ecology of HABs: physical/biological interactions, climate change, and other current issues. Conveners: Donald M. Anderson (USA), Geneviève Lacroix (Belgium), and Patrick Gentien (France).

8 Long term planning of WGPBI

The 2011 meeting will be hosted by M. Chifflet, AZTI, Pasaia, Basque Country. WGPBI members discussed the strategic vision for WGPBI activities for the next 3–5 years. The following themes emerged as those that are important to pursue:

Physical oceanography

We would like to attract and maintain a solid core of physical oceanographers as members of WGPBI, from those with expertise and interest in small scale process to global climate change.

Moving from fish larvae to adults and individuals to ecosystems

We would like to stay updated on new developments in modelling fish communities that coupled physics and lower-trophic level interactions with upper trophic levels and food webs, including NEMURO-SAN and End-to-end models like Steele *et al*.

Ensure representation of diverse modelling approaches.

It is important that we maintain a broad view of model types, keep abreast of new techniques in modelling and maintain a diversity of modelling interests on the group. Representative model types include NPZD, eutrophication, size-spectrum, end-to-end, and habitat models, as well as links between model types such as particle-tracking models linked to upper trophic level food web models, NEMURO-SAN, etc.

Continue to survey and promote methods to test and validate models. An important part of our role is to identify methods to that demonstrate the robustness of models for use as management tools.

9 Preparation of 2011 meeting

The 2011 meeting will be hosted by M. Chifflet, AZTI, Pasaia, Basque Country, and will take place on 14–15 April 2011. The intention of WGPBI was to invite the Working Group on Harmful Algal Bloom Dynamics to a joint meeting, but by request of this Group the joint meeting is delayed to 2012.

10 Other business

WGPME

A. Gallego attended a brief session on 4 March, during the first Working Group on Phytoplankton and Microbial Ecology (WGPME) meeting, which took place in Aberdeen. The goal of the session was for a number of ICES WGs to describe their work to WGPME and explore linkages. The goals and activities of WGPBI were presented to WGPME, together with an offer to meet jointly at some point in the future, as WGPBI has done with WGZE and WGHAB, if it was considered useful. WGPME were quite receptive to this suggestion, although no specific plans were discussed.

WGOOFE

B. Berx from the ICES Working Group on Operational Oceanographic products for Fisheries and Environment (WGOOFE) gave a brief presentation of the WG's aims and work over the past year. The WG provides an interface between providers of oceanographic data products and the ICES user community. In the past year, WGOOFE have launched their web portal (http://www.wgoofe.org) and conducted a survey of the ICES user community on their oceanographic data needs. Results of this

questionnaire were briefly presented: the WG plans to publish these over the course of 2010. WGOOFE is also a co-sponsor (IGWG, WGPBI, WGDIM, and WGOH) for Theme Session A at the ASC this year in Nantes.

GEOHAB

M. Ruiz reported by correspondence from the GEOHAB (Global Ecology and Oceanography of Harmful Algae Blooms) modelling workshop which was held in Galway (Ireland) last June (http://www.geohab-models.org). The GEOHAB community wants to stimulate modelling activities related to HABs, and they foresee it is crucial for further advances in increasing the knowledge on HAB ecology and also for increasing the capability of predicting them. There is a diversity of HAB species and new observing technologies are providing new insight in HAB ecology. In addition, hydrodynamic state-of-the-art models were shown to realistically describe oceanographic processes influencing HABs. Different modelling approaches for simulating HABs were presented, including empirical models as well as Eulerian and Lagrangian ecological models. Some presentations are accessible on the web site and there is a special issue of Journal of Marine System (Guest Editor: Dennis McGillicuddy) to appear in 2010.

Annex 1: List of participants

NAME	AFFILIATION	COUNTRY	EMAIL
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Annex 2: Agenda

March 25

0900–0915:	Welcome, etc.
0915–1230:	Presentation of new results, with discussion.
	(Hufnagel, Janssen, North, Petitgas, Beecham, Peck, Thygesen)
1230–1330:	Lunch
1330–1530:	Presentations and discussion re. Terms of Reference
1530–1545:	Coffee
1545–1615:	Tabulate WGPBI competencies. Inquiry from SSGEF (Petitgas)
1615–1630:	Reporting at the ASC.
1630–1700:	Discuss likely directions for next few years.

March 26

0900–1230:	Presentations and discussion re. Terms of Reference
1230–1330:	Lunch
1330–1430:	Management of the WG
	Introduce new co-chair: E. North
	Draft resolutions for 2010
	Planning of ToRs and Action Items for 2010
	Initialize WG Report
	Venue and theme of next year's meeting
1430:	Close the meeting

Annex 3: WGPBI terms of reference for the 2010 meeting

The **Working Group on Modelling Physical Biological Interactions** (WGPBI), chaired by Uffe Thygesen, Denmark, and Elizabeth North, USA, will meet in Aberdeen, Scotland, UK, on 25–26 March 2010 to:

a) Discuss and evaluate new results concerning physical/biological interactions;

b) Review and assess the results of WKMOR and plan publications and other follow on activities;

c) Publish a review of the physiological attributes of early life stages of marine fish species relevant for projecting climate-impacts using coupled hydrodynamic bio-physical models;

d) Report on recent advances in models and observations of physical and biological processes at scales below the Rossby radius;

e) Report on developments in linking physical models, biogeochemistry models, and higher trophic level models, and disseminate information on common meta-data standards needed for linking these models;

f) Assess progress on the book "Individual-based modelling of organisms within aquatic ecosystems: coupling biology with hydrodynamics";

g) Prepare for ASC Theme sessions on 'Combining models of the full life cycle of fish with lower trophic models: integration and prediction' and 'Physics and biology in modelling HABs: validation and application to forecasting and climate change;

h) Prepare for Workshop on Mapping Potential Fish Habitat using Physical/ Biological Models convened by Petitgas and Peck.

i) Prepare for joint meeting with WGHABD in 2011.

WGPBI will report by 30 April 2010 (via SSGEF) for the attention of SCICOM.

Annex 4: Actions items 2009/2010

1) Produce a report reviewing prey fields likely experienced by zooplanktivorous life stages of marine fish species with recommendations on how best to derive model-based prey fields (including small- and mesoscale spatial attributes). Peck, Ji and others

2) Compile list of programs engaged in end-to-end (E2E) type modelling, starting with Petitgas's list. Beecham, Peck and others.

3) Report on Galway GEOHAB meeting (June 2009). Ruiz.

4) Organize a joint meeting with WGHABD in 2011. There will be a two day overlap. Possible themes: Day 1 small-scale interactions; Day 2: climate change. Osborn, North, Thygesen.

5) Organize a workshop on Mapping Potential Fish Habitat using Physical/Biological Models. This should be joint with WGOOFE. Petitgas, Peck, and possibly Ji.

6) Review and assess the results of WKMOR and plan publications and other follow on activities. Gallego, North

7) Publish a review of the physiological attributes of early life stages of marine fish species relevant for projecting climate-impacts using coupled hydrodynamic biophysical models. Peck

8) Report on recent advances in models and observations of physical and biological processes at scales below the Rossby radius. Organize an event in 2011, probably as part of joint meeting with WGHABD. Obsorn and North

9) Report on developments in linking physical models, biogeochemistry models, and higher trophic level models, and disseminate information on common metadata standards needed for linking these models. Beecham

10) Prepare for ASC Theme session on 'Combining models of the full life cycle of fish with lower trophic models: integration and prediction.' Petitgas, Peck

11) Assess progress on the book "Individual-based modelling of organisms within aquatic ecosystems: coupling biology with hydrodynamics" and find co-authors for the chapters. Hinckley.

12) Prepare for ASC theme session on 'Physics and biology in modelling HABs: validation and application to forecasting and climate change. Lacroix

13) Coordinate MEECE meeting in spring 2011 with WGPBI meeting probably joint with WGHAB. Make the meetings back to back. Beecham

14) Prepare for the ASC Theme session on 'Operational Oceanography for Fisheries and Environmental Applications' with convenors: H. Sagen, C. Hannah.

Annex 5: WGPBI terms of reference for the 2011 meeting

The **Working Group on Modelling of Physical-Biological Interactions** (WGPBI), chaired by Elizabeth North, USA, and Uffe Thygesen, Denmark, will meet at AZTI, Pasaia, Basque Country, Spain, 14–15 April 2011 to:

a) Discuss and evaluate new results regarding modelling of physical-biological interactions;

b) Report on publications coming out of WKMOR, including progress of the special issue in Journal of Marine Systems, and other follow-up activities;

c) Report on a review of the physiological attributes of early life stages of marine fish species relevant for projecting climate-impacts using coupled hydrodynamic bio-physical models;

d) Report on use of biophysical models for studying connectivity between spawning areas and nursery habitats of key marine species

e) Discuss advances in models and observations of physical and biological processes at vertical scales of meters and horizontal scales of kilometres;

f) Report on extensions of linking physical and biological models in 3 dimensions to project marine food web dynamics

g) Assess progress on the book "Individual-based modelling of aquatic organisms: Coupling biology and physics" by S. Hinckley, A.J. Hermann, B.A. Megrey, and K.A. Rose;

h) Prepare for theme sessions at the 2011 ICES ASC;

i) Review existing and novel techniques for building end-to-end models, and discuss results from the WKIEM workshop on Integrated Ecosystem Modelling (Spain, 16–18 November 2010);

j) Prepare a joint meeting with WGHABD in 2012.

WGPBI will report by 30 April 2011 (via SSGEF) for the attention of SCICOM.

Supporting information

Priority:	The current activities of this Group support the ecosystem approach to fisheries science by addressing lower trophic levels, early life stages of fish, and relationships between physical drivers and biological responses. The Group combines the knowledge of physical processes, biological processes and modelling expertise that is required to strengthen our understanding of ecosystem functioning. Consequently, the activities of the Group should be given high priority.
Scientific justification and relation to action plan:	ToR c: A large number of research projects in the ICES community concern projections of climate impacts. A critical issue in these studies is the recruitment, and thus the modelling of growth and mortality, of early life stages of marine fish. The literature on this subject is vast and providing a synthesizing overview will help advance the field. ToR d: Spatial considerations are of growing concern and a key application of biophysical models is to study the transport of early life stages of fish from spawning areas to nursery habitats. It is considered important to advance the state of the art of these models, in particular concerning biological rates, behaviour, and validation. ToR e: Processes at vertical scales of meters and horizontal scales of kilometers remain poorly described theoretically and difficult to study empirically, yet

	these scales are relevant to many biological processes. It is considered important to strengthen our knowledge of physical and biological processes at these scales. ToR f,i: A key concern in the construction of end-to-end models is how to connect established models of different parts of the ecosystem, such as connecting ocean physics with higher trophic levels.
Resource requirements:	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants:	The Group is normally attended by some 15–25 members and guests.
Secretariat facilities:	None.
Financial:	No financial implications.
Linkages to advisory committees:	There are no obvious direct linkages with the advisory committees.
Linkages to other committees or groups:	The working group is actively pursuing links to other groups within ICES, and strengthening these links through joint meetings. Previously the WG has met with the Working Group on Zooplankton Ecology and the Working Group on Harmful Algae Bloom Dynamics. The WG is also linking to the Working Group on Phytoplankton and Microbial Ecology as well as the Working Group on Operational Oceanographic products for Fisheries and Environment.
Linkages to other organizations:	None.

Annex 6: Actions items for 2010/2011

1) Finish the WKMOR report. Prepare special issue in Journal of Marine Systems containing results presented at WKMOR, and lead writing paper on conclusion (Gallego, North).

2) Review physiological attributes of early life stages of marine fish species relevant for projecting climate-impacts using coupled hydrodynamic biophysical models (Peck).

3) Examine and quantify connectivity between spawning areas and nursery habitats of key marine species including sensitivity analysis (Hufnagl, Lacroix).

4) Prepare joint meeting with WGHABD in 2012 (North, Lacroix).

5) Develop proof-of-concept for linking physical and biological models in 3 dimensions to project marine food web dynamics (Beecham).

6) Draft book "Individual-based modelling of organisms within aquatic ecosystems: coupling biology with hydrodynamics" and find co-authors for the chapters. (Hinckley).

7) Co-convene theme sessions at the ICES ASC 2010 and submit proposals for theme sessions for ICES ASC 2011.

8) Organize a focus session at the 2011 WGPBI meeting on end-to-end modelling (Huret, Peck).

Annex 7: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. Theme session at the 2011 ASC: Physical-Biological Modelling: Assimilation, Validation, and Application	SCICOM, SSGEF
2.Theme session at the 2011 ASC: Biophysical Modelling Tools and Spatial Management of Marine Resources: A Strategic Dialogue	SCICOM, SSGEF

Annex 8: Theme session proposals for ICES ASC 2011

Physical-Biological Modelling: Assimilation, Validation, and Application

Conveners: Guoqi Han (Canada), Frank Janssen (Germany)

One of the important ways for addressing ecosystem science and management issues is through physical and biological modelling. The modelling system can consist of hydrodynamic and biogeochemical models, and may be constrained by observations at different levels. In the Past decade, the model ocean state variables (currents, temperature, salinity, biogeochemical, and plankton variables) have been increasingly used to describe ecosystem status and interpret its changes.

From model development to ecosystem application, data assimilation is a key technique and model validation is an essential step. How do we establish effective and efficient assimilation schemes? How do we collect field data for data assimilation and model validation purposes? How do we validate them from physical, biological, and/or ecosystem perspectives? How do we define effective metrics that are effective to represent accuracy and precision and that are easy to understand for end users? How do we apply these models to help solve ecosystem science and management issues?

Physical processes and individual behaviour can both affect biological processes in very different ways, depending on temporal and spatial scales. The interactions of these physical and biological processes lead to unique states at any time and subsequent changes at population, trophic, and ecosystem levels. In this session we welcome papers in all aspects of physical-biological modelling that incorporate and integrate physical and biological processes and individual behaviour, with an emphasis on assimilation, validation and application of both physical-biological and individual-based models that aim to address ecosystem sciences, aquaculture and fisheries management issues.

Biophysical modelling Tools and Spatial Management of Marine Resources: A Strategic Dialogue

Myron A. Peck (Germany), Pierre Petitgas (France), NN (from the management side)

Mapping the location of key habitats and understanding spatial and temporal changes in those habitats are prerequisites for effective spatial management of marine fish and shellfish resources. Recent advancements in biophysical modelling (from individual-based particle tracking of early life stages of single species to end-to-end ecosystem models) now allow researchers to move beyond mere static representations of key habitats for marine fish and shellfish species (e.g., maps of nursery grounds) and allow dynamic representations that include estimates of the spatial and temporal variability in key habitats. These recent advances in spatial modelling have not yet been utilized by fisheries management due to a number of reasons including the ten- to 100-fold mismatch in spatial scales between model estimates (1 to 10s of kms) and marine management (100s to 1000s kms).

This theme session attempts to bridge the gap between spatial modeling and management by providing examples of model-derived estimates of the dynamics of essential habitats (e.g., seasonal and inter-annual variability in suitability and connectivity) and scenario tests (e.g., projected future changes). Presentations on this research should attempt to identify realistic ways in which model outputs can be util-

ized by management (including sensitivity analyses of results). Furthermore, the session offers a platform for managers to engage researchers on how best to use these tools in light of the reformed common fisheries policy. The ultimate goal of the session is to open a dialogue between managers and researchers to ascertain how to most effectively utilize advancements in modelled physics and biology within ecosystem-based fisheries management.

Annex 9: Abstracts for presentations at the WGPBI meeting

(Pre-) Operational biogeochemical modelling in Germany

Frank Janssen, Larissa Müller, Stephan Dick

Federal Maritime and Hydrographic Agency

Germany

A model system consisting of several numerical models of different type and complexity has been built and applied in an operational environment during the last two decades at the Federal Maritime and Hydrographic Agency. Today, 2D storm surge models and 3D circulation models produce daily forecasts of the physical state, i.e. sea level, currents, temperature, salinity and sea ice of the North Sea and the Baltic Sea. Based on archived data from the 3D circulation model Eulerian and Lagrangian dispersion models are applied on demand, e.g. in case of oil spills or for search-and-rescue purposes.

Recently BSH's model family has been extended by model components for the simulation of the biogeochemical state of North Sea and Baltic Sea. Development and implementation followed a stepwise procedure. The 1st step was the coupling of a wave model (k-model, developed by GKSS) to the circulation model in order to better describe the water column-sediment interaction, e.g. resuspension, erosion of sediment. As the light conditions and therefore the biological production especially in the North Sea strongly depend on the amount of suspended particular matter (SPM) in the water column, a SPM module (GKSS, Gayer *et al*., 2006) was implemented as a 2nd step. For the implementation of the biogeochemical module a general interface based on the GOTM-BIO model (General Ocean Turbulence Model, www.gotm.net) was chosen, which provides the opportunity to easily switch between different biogeochemical components. Unfortunately, there is so far no biogeochemical model available which is able to simulate the different ecosystem dynamics in the North Sea and the Baltic Sea at the same time. It was therefore necessary to implement two biogeochemical models, one for the North Sea (ECOHAM4, University of Hamburg), and one for the Baltic Sea (ERGOM, Leibniz Institute for Baltic Sea Research). Both models have been tested in a pre-operational environment for the period of one year within the ECOOP project. It could be shown that both models are robust, stable and suitable for operational application. Both models were able to reproduce the main biogeochemical features in the North Sea and the Baltic, as shown e.g. by validation against satellite based Chl-a estimates.

There are plans for further development of the biogeochemical model component. These plans include the development of an unified biogeochemical model component for North Sea and the Baltic Sea, probably by extending one of the models to the other region. In order to provide high quality forecasts of e.g. phytoplankton blooms the application of data assimilation methods will be very helpful. First steps in this direction have been done by the implementation of a data assimilation scheme for sea surface temperature in the circulation model. The selected data assimilation method (local SEIK filter, implemented by PDAF filter framework, developed at AWI) has already shown to work also for biogeochemical models.

So far the development of the biogeochemical model component has been done in several projects. The approach has shown to work in a pre-operational environment and is ready to become operational also this is not yet established.

How do basin-scale atmospheric patterns downscale in regional models of the North Sea and the Bay of Biscay?

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Downscaling basin-scale climate scenarios in regional seas requires to force regional models with adequate atmospheric forcing conditions. Presently these are not available (Drinkwater, 2009). The patterns generated in the models were correlated to basin-scale indices, which allowed to understand how basin-scale conditions downscaled in the North Sea and the Bay of Biscay. The analysis presented concerned patterns in the flow fields.

Within the EU project RECLAIM (Resolving Climate change impacts on fish stocks: http://www.climateandfish.eu/) longterm hindcasts of coupled physical biogeochemical models were achieved. The Bay of Biscay hindcast, 1971–2009, was done with ECOMARS3D (Lazure and Dumas, 2008) and the North Sea hindcast, 1980–2004, with ECOSMO (Schrum *et al*., 2006). The forcing atmospheric conditions were taken from the re-analysis of ERA40. Patterns in the monthly flow fields were extracted with a multivariate EOF analysis (Preisendorfer, 1988; Kaihatu *et al*., 1998; Petitgas *et al*., 2009). Amplitudes of the patterns were correlated to the monthly NAO (North Atlantic Oscillation) and EA (Eastern Atlantic pattern) indices. NAO and EA are themselves amplitudes of patterns extracted from atmospheric pressure fields. They were downloaded from the web page of the NOAA Climate Prediction Centre (ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/tele_index.nh). In the Bay of Biscay, the NAO does not relate to the flow fields but the spring EA does. A positive EA downscales into a spring coastally flow to the North (SSW wind regime). A negative EA downscales into a coastally flow to the South (NNE wind regime). This situation is argued to favour upwelling events (Borja *et al*., 2008). In the North Sea the EA is not influencial but the winter NAO relates to the winter flow fields. A positive NAO strengthens the flow from NW to SE while a negative NAO weakens it or even reverses it. The approach could be extended to a variety of indices proposed by Huret *et al*. (2009) to characterize meso-scale features such as stratification, fronts, gyres, or river plumes.

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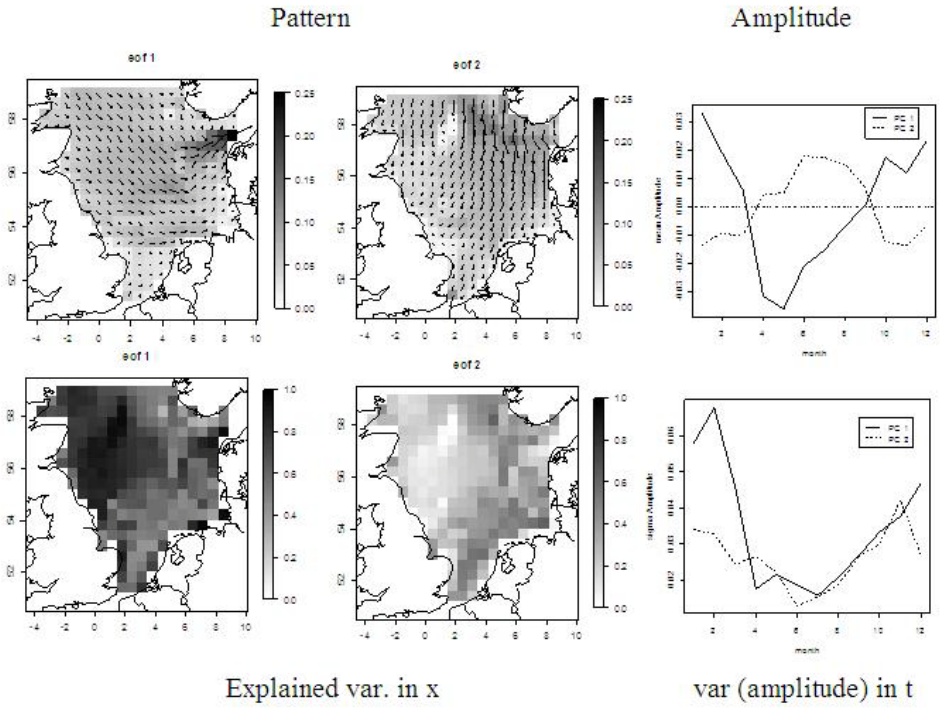

Figure 1. EOF analysis on the flow field in the North Sea: first and second eigen fields, explained variance, monthly amplitudes (top right) and interannual variation in these (bottom right).

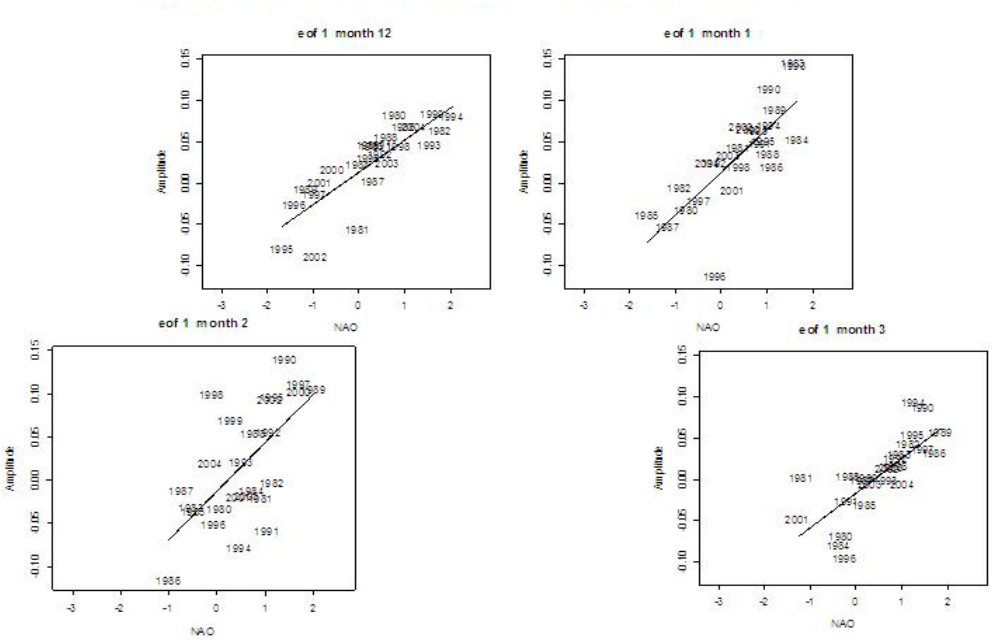

Figure 2. Correlation between NAO and the amplitude of EOF1 for winter months from December to March in the North Sea.

The influence of anoxia on larval connectivity: a model-based hypothesis

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Larvae of the eastern oyster (Crassostrea virginica) in Chesapeake Bay spend 2–3 weeks in the plankton and require hard substrate, preferably oyster shell, for settlement. Results of larval transport model simulations suggest that transport of larvae between oyster reefs is an important component of oyster population dynamics in Chesapeake Bay and that the vertical swimming behaviour of larvae influence spatial patterns in transport between reefs. We hypothesize that anoxia could influence the transport and survival of oyster larvae in Chesapeake Bay, either by causing direct mortality or, if larvae swim to avoid anoxia, by cutting off access to transport pathways that could be created by lateral circulation. We used measurements of anoxic volume coupled with numerical simulations of a larval transport model to assess the feasibility of this hypothesis and to identify where and when anoxia could influence the survival of oyster larvae or the spatial patterns in connectivity between reefs. Model results will be discussed and field methods for testing this hypothesis will be proposed.

Physiological-based biophysical modeling of North Sea larval fish. Is there a bottom up control?

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A physiological-based, 3-d biophysical individual-based model (IBM) was constructed for larval stages of Atlantic herring (*Clupea harengus*) and utilized to test the hypothesis that recent recruitment failures of North Sea herring have been due to changes in climate-driven, bottom-up factors. The larval foraging and growth model incorporated data collected from vast number of laboratory and field studies allowing a species-specific parameterization and extensive validation exercises. The former included schemes for diel vertical migration, parameters required for optimal foraging and growth bioenergetics. The latter included comparison of laboratory and model estimates of growth rate and growth efficiency under controlled environmental conditions (temperatures, prey sizes / concentrations, daylengths). Field growth rates agreed well with modelled growth rates when realistic prey concentrations were used as model inputs. After these corroboration exercises, the model was linked to 3D particle tracking and hydrodynamic models to estimate environments experienced during the overwinter period by larvae originating from different spawning components and released (in the model) at observed times and magnitudes (abundances) each year from 1970 to 2005. Model results suggest that the intensity and spreading of the autumn zooplankton bloom in the North Sea might be an important driver influencing the maximum length of larvae prior to overwintering and, consequently, larval overwinter survival. Furthermore, time series comparison of modelled and observed sizes of larvae after the overwinter period agreed well from 1990 to 2005. In earlier years, the model underpredicted larval length likely due to either 1) increasing rates of mortality and/or 2) decreasing prey quality since 1990. To test which of these scenarios is the more likely a sensitivity analysis was performed applying different growth scenarios based on assumptions about the dry weight condition and allocation of ingested food. First results suggest that the energy yield during winter must have been different prior to 1990 than in comparison to recent years. In the literature there is the suggestion that the North Sea underwent a 'regime shift' around 1988 to 1990 with a shift in the plankton composition which is especially well documented for the species *Calanus finmarchicus* and *C. helgolandicus*. However, bottom-up factors appear to more strongly regulate recruitment potential since 1990 although these changing environmental impacts were initially masked by increasing levels of spawning stock biomass during the early 1990s as a response to North Sea-wide fishing moratorium.

Spatial model of benthic community, with data layer interaction

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A flexible spatial model of benthic communities is being developed by Cefas, Lowestoft. The model uses object-oriented programming techniques to allow user supplied routines for model components to be incorporated in a model with space and population-structure. The library of low-level calculation routines for basic operations allows high resolution models (30 000 cells, 30 groups per functional group for five groups) to run on a modest workstation. It also allows scientists to incorporate physiological relationships for growth, mortality and spawning in terms of environmental variables, such as temperature and chlorophyll, which can be loaded into the model by means of a built in GIS component. The model uses a structuring both in terms of size and calcified structure proportion, An example was presented which used a published relationship between beam trawling and mortality, together with a statistical abstraction of the beam trawling at a scale of 1/64 degree incorporated into a benthic epifauna population component. This model is currently being calibrated to examine implications of spatial management of benthic trawling in scenarios with different physical conditions.

Backtracking and shear dispersal of migrating plankton

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It is by now standard to simulate the motion of near-planktonic organisms through individual-based models which rely on output of circulation models for ocean currents and dispersal. A number of applications call for particle tracking backwards in time, for example to locate the spawning site of an observed fish larva. However, the problem of reversing time in particle tracking models is not well posed, and seemingly reasonable approaches can lead to contradicting and unreasonable results, when particles are not entirely passive. This talk presents results from a currently ongoing effort to strengthen the foundation of particle backtracking algorithms. The results indicate that maximum likelihood estimation of initial position is the theoretically strongest framework for backtracking, but that difficulties with numerics remain to be resolved before the approach is generally applicable. Bayesian estimation of trajectory and initial position may in some situations be theoretically sound and can be implemented; in particular for particles which have non-neutral buoyancy but are passive otherwise. For organisms which display periodic vertical behaviour it is possible to approximate Bayesian backtracking by means of a time scale separation. The heuristic approach of following streamlines backwards in time while adding random walk to model dispersal, should be used with caution for non-passive particles.

A tangential output of the research are formulas for the shear dispersal of organisms that undergo periodic vertical migrations. These formulas are useful for obtaining initial estimates of transport and dispersal and for sensitivity analysis, and apply equally well to forward and backward particle tracking.