ICES WKAMF Report 2006

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Report of the Workshop on Advancements in Modelling Physical-Biological Interactions in Fish Early-Life History: Recommended Practices and Future Directions (WKAMF)

3–5 April

Nantes, France

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

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Contents

Executive summary

The goal of the "Workshop on advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions" (WKAMF) was to evaluate the present state and next steps in the developing field of modelling physical-biological interactions in the early-life of fish. The workshop focused on recent advances in coupled biological-physical models that incorporate predictions from three-dimensional circulation models to determine the transit of fish eggs and larvae from spawning to nursery areas. These coupled bio-physical models have been applied to gain new insight on how planktonic dispersal, growth and survival are mediated by physical and biological conditions and have contributed to enhanced understanding of fish population variability and stock structure.

WKAMF was attended by 54 participants from 14 different countries. The workshop included 23 oral presentations, 16 posters, general discussions, and writing sessions. Invited and contributed presentations, a poster session, and structured discussions occurred on 3–4 April, 2006 to survey recent advances in the field, develop a list of recommended practices, and identify research needs. The final day of the workshop (5 April) was attended by 28 participants and focused on writing sessions devoted to developing teams for international collaborative proposals and a manual of recommended practices.

The workshop was designed to survey major components of bio-physical models of fish early life, address numerical techniques and validation issues, define recommended modelling practices, and identify future research needs. The workshop focused on aspects of modelling fish early-life history including: initial conditions (egg production, spawning location/time), small-scale processes (turbulence, feeding success), mesoscale transport processes (physics and larval behaviour), and biological processes (development, growth, mortality, juvenile recruitment, metamorphosis, settlement). A range of bio-physical modelling approaches were addressed, including Lagrangian, Eulerian, and Individually Based Models. Workshop results will provide guidance and direction for integration of coupled bio-physical models with observing systems, operational models, monitoring programs, and ultimately to improve fisheries management recommendations. In addition to enhancing the field of physical-biological interactions, this workshop fostered information exchange and supported collaboration between international workshop participants.

Workshop participants agreed on six major themes that were important research needs in modelling physical-biological interactions and would result in advances in the field:

- validation and sensitivity methods,
- model complexity,
- mortality,
- behaviour and cues,
- energetics, and
- physics.

A description of research needs and recommendations from theme sessions and the consensus discussion can be found in Sections 3 and 4.

The workshop had the following **Terms of Reference** (Annex 3):

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

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

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

ToRs a) and b) were addressed in the workshop theme session presentations, posters and discussions. ToR c) was answered by organising cross-disciplinary groups which will produce the "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History" which is expected to be finalised in 2007.

There will be four modes of results dissemination from the workshop (Section 5): 1) submission of manuscripts to *Marine Ecology Progress Series*, 2) production of the "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History", 3) development of international collaborative proposals, and 4) maintenance of the workshop website (http://northweb.hpl.umces.edu/wkamf/home.htm).

WKAMF was held under the auspices of the International Council for the Exploration of the Sea (ICES) Working Group on Physical-Biological Interactions and the ICES Working Group on Recruitment Processes. It was hosted by the French Research Institute for Exploitation of the Sea (IFREMER) Centre in Nantes, France with support from IFREMER, the US National Marine Fisheries Service, the US National Science Foundation, the UK Fisheries Research Services, and the University of Maryland Centre for Environmental Science. It was endorsed by GLOBEC and Eur-Oceans.

1 Opening of the meeting

Co-Chairs Alejandro Gallego, Elizabeth North, and Pierre Petitgas opened the meeting. Co-Chair Petitgas, the local host, welcomed participants to IFREMER and explained logistics of the meeting. Co-Chair Gallego described the history and objectives of the workshop and explained the ICES Terms of Reference for the workshop. He described the Theme Sessions and outlined the conference-style format for the first two days of the meeting. Co-Chair North explained the objectives of group discussions, the format for the writing sessions on 5 April, and discussed the means of results dissemination for the workshop. Acknowledgements were made to the organizations that sponsored and endorsed WKAMF.

2 Adoption of the agenda

The agenda of the workshop was supported by workshop participants. Over the course of the meeting, the specific strategies and discussion topics for Wednesday writing session breakout groups evolved from group discussions. Participants recognized that "best" practices are goal specific; i.e., methodologies will depend upon the goal of the modelling endeavour. It was deemed that cross-disciplinary groups that focused particle tracking, connectivity, recruitment prediction, and adaptive sampling were the optimum methods for organizing writing sessions for the manual of recommended practices and proposal teams.

3 Theme Section Summaries

3.1 Session I: Initial conditions: Egg production, spawning location/time

The amount of detail in initial conditions depends upon the objectives of model (e.g. predicting recruitment vs. identifying population connectivity). Sensitivity analyses can be used to estimate which characteristics of spawning (patchy vs. uniform, higher/lower frequency, spawning location/time, depth, etc.) are important for the model application. Patterned Oriented Modelling is a useful approach for deriving processes from observed patterns (Grimm and Railsback, 2005). A call was made for better information on the underlying processes that drive spatial and temporal patterns in spawning, including adult characteristics (e.g. maternal effects). It was noted that egg production modelling was not treated in detail in the workshop. Observations (spawning location, timing, etc.) are critical for validation of egg production models.

3.2 Session II: Small-scale processes (turbulence, feeding success)

In situ measurements of kinetic energy do not fit turbulence theory in coastal environments. On the shelf, dissipation appears to anisotropic, resulting in measured dissipation being higher than what isotropic theory would predict. We need a better understanding of basic turbulent processes. In addition, many turbulence measurements measure the average intensity (dissipation) over depths $\geq$1 m. We need to develop measurements of turbulence that are appropriate for the scales of predator-prey interactions and document and parameterize encounter, capture, and feeding processes at scales from 1 mm to 1 m.

Early larvae were observed to have little capability to detect and escape predation, or select prey. In addition, it was observed that the detection volume of cod larvae was wedge-shaped instead of spherical. The influence of turbulence on feeding success was sensitive to the detection volume shape. In addition, larval reactive distance was found to be the most sensitive parameter in models that include feeding processes. Enhanced species-specific

information on feeding processes would help assess the implications of these finding for theory and models.

Sub-grid scale processes are important for predicting dispersal of particles in numerical models; the quality of predictions depends on the hydrodynamic model. The use of robust, validated hydrodynamic model with sufficient grid resolution to resolve processes of interest was recommended.

3.3 Session III: Mesoscale transport processes I: Physics

The relative costs of Eulerian vs Lagrangian approach for a system, species, and objective of a modelling program should be assessed before model development. For Lagrangian particle tracking, a standard set of test cases should be established and published, both in the literature and on a dedicated web site. The tests should be easy to implement, cover the practical issues, and become standard procedure. “Biased binned random walk”, a compromise between Eulerian and Lagrangian models, could be used with sinking or floating particles.

Larval behaviour can influence transport. It was recommended that vertical migration and temperature should always be considered in model formulation. Before developing a coupled physical-biological IBM for recruitment prediction, the critical period for year class strength determination should be assessed. This will help identify which early-life stages are necessary to include in the model to capture the relevant processes. High resolution forcing (e.g., winds) may be necessary for recruitment prediction.

The horizontal resolution of hydrodynamic models can influence Eulerian predictions and particle diffusion. Model grid sizes smaller than the internal Rossby radius was recommended as a rule of thumb to capture horizontal mixing processes appropriate for the system. Another recommendation was that hydrodynamic models should be validated at spatial scales that are important to biology. Publishing quantitative validation statistics and results of benchmark tests of circulation models will help biologists recognize the skill of the hydrodynamic models. Biophysical modelling should involve oceanographers and biologists to ensure that the models are consistent with the demands of both disciplines.

3.4 Session IV: Mesoscale transport processes II: Larval behaviour

Perspectives derived from behavioural ecology can enhance our understanding of fish early life and help identify processes that emerge from the interplay of physiological mechanisms and fitness. Realistic patterns emerge from models that incorporate tradeoffs between growth (food heaven) and survival (predation hell). We need to understand mechanisms of internal (physiology) and external drivers (environmental signals, prey, predators). The light environment, as affected by primary production, suspended sediment, and associated sources of fresh water, is likely an important driver.

There is a clear need for field/laboratory studies of behaviour, especially related to horizontal orientation. We should challenge established parameter values (e.g. swimming speeds) in experimental and more realistic settings and relate both (at least for some spp.). The potential difference in swimming ability between temperate vs tropical larvae was discussed. From a technical standpoint, theory development/elucidation is needed to determine if numerical methods satisfy theoretical requirements when sub-grid scale turbulence and directed swimming are used in combination in particle tracking models.

3.5 Biological processes I: development, growth, and mortality

Research has shown that a hierarchy of factors is required to parameterize biophysical models fish early-life history, with temperature and body size being identified as the main ones, followed by prey concentrations, dispersal/retention, predation, physical structure/features,

turbulence, light, etc. Feeding by fish (adults and larvae) on plankton appears to follow a random encounter process on the local scale (Poisson distributed); and spatial overlap is an important first step in understanding both feeding (and therefore growth) and predation mortality. A variety of growth models have proven to be very sensitive to assimilation efficiency as well as to changes in size spectrum of prey so a better understanding of the causal mechanisms is required. Predictions of predator feeding rates (i.e. mortality on larvae) from laboratory, field and simple models differ significantly (10-fold, respectively) and consequently modelling predator feeding requires better observations and greater effort to validate any model developments.

3.6 Session VI: Biological processes II: Juvenile recruitment, metamorphosis, settlement

A novel model optimization approach was presented as a promising advance in model parameterization. Model validation was again identified as critical, and backtracking was proposed as a useful technique to that effect. It was also emphasized how sensitive models are to model formulation and consequently how important it is to understand the dynamics and controls in the model. An interesting application of bio-physical models to the generation of indices that can be correlated to recruitment and therefore are relatively easily applicable to management was presented but it was emphasized that the 'correct' circulation model critical in these applications, so validation is again very important. Improved understanding of energetics is highly relevant, particularly when addressing processes taking place in the later stages of the early life history of fish. Finally, the role of density dependence in nature needs to be further investigated and incorporated into models, where appropriate.

3.7 Session VII: Future Directions: Integration with observing systems, operational models, monitoring programs, and management recommendations

Spatially-explicit coupled models have been useful for studies of transport of planktonic stages of marine fish. Further use of these models to study mechanisms of recruitment, growth, predation, stock structure, effects of climate change, as well as optimal survey/MPA design, is recommended, both for strategic (decadal time frame) and tactical (year to year) management tools. These models have much potential to improve both single stock and ecosystems management understanding and prediction. Close collaborations with managers and integration with monitoring programs is recommended. Validation of these models is necessary and should occur on multiple scales of modelling (e.g., individual, sub-cohort, population, day, month, year, decade). Managers must trust these models.

The way forward entails addressing many technical issues, including assessment of: models resolution in space and time, native grids vs regridding, online vs. offline running of biology, tracking algorithms, averaging physical model output, importance of bathymetry and atmospheric forcing, sensitivity analysis methods, visualization methods, validation, test cases, appropriate assimilating of data, etc. We need to incorporate the data generated by new monitoring programmes and even influence these programmes so that they generate the measurements that are useful to bio-physical models.

Advances in the field will occur at the intersection of disciplines: physical oceanographers and biologists must work together. The groups that come to grips with both the rhomboid approach to model complexity (de Young *et al.*, 2004) and the lab/model/observation triad will lead the way to the future.

4 Consensus Discussion Summary

Workshop participants agreed on six major themes that were important research needs in modelling physical-biological interactions and would result in advances in the field:

- **Validation and sensitivity methods**
- **Model complexity**
- **Mortality**
- **Behaviour and cues**
- **Energetics**
- **Physics**

The need for, and utility of, validation and sensitivity methods, was addressed in every theme session and figured prominently in group discussions. Consistency of model with observations is important and data quality is paramount. Methods of model-data comparison need to be applied and developed. In addition, the validity of quantitative metrics needs to be addressed.

Appropriate model complexity was another topic of discussion. Models should be as simple as possible but as complex as necessary. Additional of layers of complexity should only happen after assessment of need based on the objectives of the modelling endeavour. The GLOBEC 'rhomboid approach' was suggested as a conceptual framework for addressing model complexity.

To advance models of the early-life of fish, fundamental information is needed on the biological processes of mortality, behaviour, and energetics. These stage-dependent, and often species-specific, processes pose challenges for investigation, but recent advances in field and laboratory techniques will likely revolutionize the field of larval fish modelling.

Hydrodynamic model predictions critically influence biological predictions. Basic improvements in understanding of turbulence and in predicting mixing and circulation patterns will advance the field of larval fish modelling. Ensemble methods and probabilistic approaches offer promising techniques that should be implemented when possible.

Finally, general recommendations were made: 1) lab, field, model practitioners must work together to advance the field and 2) translation of results and models to managers will happen and should be done in collaboration with scientists to ensure quality control.

5 Results Dissemination

There will be four modes of results dissemination from the workshop:

- group submission of manuscripts to *Marine Ecology Progress Series,*
- development of a "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History",
- submission of international collaborative proposals, and
- maintenance of the workshop website.

Co-Chairs Gallego, North, and Petitgas will organize workshop submission of manuscripts to *Marine Ecology Progress Series*. Nineteen manuscripts based on oral and poster contributions are planned for submission. Dr. Howard Browman has agreed to facilitate and oversee publication of manuscripts from the workshop in MEPS. Workshop Co-Chairs will serve as guest editors and contribute an overview article. Intended manuscript submission deadline is July 1, 2006.

The second mode of results dissemination involves the development of a "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History". Workshop participants formed four teams to coordinate manual development:

particle tracking (led by David Brickman), connectivity (led by Claire Paris), recruitment prediction (led by Sarah Hinckley), and adaptive sampling (led by Pierre Pepin). Co-Chairs North, Gallego, and Petitgas will coordinate the overall development of the manual. The final draft will be submitted to WGPBI and WGRP members one month prior to the 2007 WGPBI meeting to allow for review and discussion at the meeting. A decision will be made at the 2007 WGPBI meeting regarding the appropriate means of dissemination, potentially as an ICES Cooperative Research Report.

Another strategy for results dissemination was to develop international collaborative proposals. Forming cross-disciplinary multi-national research teams was deemed an important step for addressing the research priorities that were identified during the workshop, a definitive action to advance the field. At least four teams of 3–6 researchers were formed and plan to submit proposals to national funding agencies within the next 12–18 months.

The final mode of results dissemination will be a workshop website. Co-Chair North agreed to maintain the workshop website and transform it into a means for workshop participants to share reports, model test cases, open-source code, and announcements. The website URL is http://northweb.hpl.umces.edu/wkamf/home.htm.

6 Recommendations

WKAMF Co-Chairs North, Gallego, and Petitgas recommend that WGPBI and WGRP support the production of the “Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History”. The final draft of this manual will be submitted to WGPBI and WGRP members one month prior to the 2007 WGPBI meeting to allow for review and discussion at the WGPBI meeting. A decision will be made at the meeting regarding the appropriate means of dissemination, potentially as an ICES Cooperative Research Report.

7 References

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Annex 2: Agenda

Monday, April 3, 2006

8:00 – 17:00 Registration

Introduction: Workshop goals
8:30 – 9:00 Alejandro Gallego, Elizabeth North, Pierre Petitgas
9:00 – 9:25 Thomas Miller, U. of Maryland Center for Environ. Science, USA

Session I: Initial conditions: Egg production, spawning location/time
9:25 – 9:50 Christian Mullon and Christophe Lett, IRD, France
9:50 – 10:15 Timothée Brochier and Christophe Lett, IRD, France
10:15 – 10:20 Presentation of Posters
10:20 – 10:40 Discussion

10:40 Coffee break

Session II: Small-scale processes (turbulence, feeding success)
11:00 – 11:25 Thomas Osborn, The Johns Hopkins University, USA
11:25 – 11:50 Howard Browman and Anne Berit Skiftesvik, IMR, Norway
11:50 – 12:15 Bernard Megrey, S.Hinckley, Carolina Parada, NOAA/AFSC, USA
12:15 – 12:20 Presentation of posters
12:20 – 12:40 Discussion

12:40 Lunch

Session III: Mesoscale transport processes I: Physics
14:00 – 14:25 Bjørn Ådlandsvik, Institute of Marine Research, Norway
14:25 – 14:50 Joachim Bartsch, Consult. and Model. of Marine Ecosys., Germany
14:50 – 15:15 Albert Hermann, NOAA/PMEL, USA
15:15 – 15:20 Presentation of posters
15:20 – 15:40 Discussion

15:40 Coffee break

Session IV: Mesoscale transport processes II: Larval behavior
16:00 – 16:25 Øyvind Fiksen, University of Bergen, Norway
16:25 – 16:50 Frode Vikebø and Øyvind Fiksen, University of Bergen, Norway
16:50 - 17:15 Jeffrey Leis, Australian Museum, Australia
17:15 – 17:20 Presentation of posters
17:20 – 17:40 Discussion

17:40 Poster Session

Tuesday, April 4, 2006

8:00 – 12:00 Registration

8:20 - 8:35 Introduction and Announcements

Session V: Biological processes I: development, growth, and mortality
8:35 - 9:00 Edward Houde, U. of Maryland Center for Environ. Science, USA
9:00 – 9:25 Geir Huse and Are Salthaug, Institute of Marine Research, Norway
9:25 – 9:50 Myron Peck, Ute Hochbaum, et al., U. of Hamburg, Germany
9:50 – 10:15 Pierre Pepin, Fisheries and Oceans Canada
10:15 – 10:20 Presentation of posters
10:20 – 10:40 Discussion

10:40 Coffee break

Session VI: Biological processes II: Juvenile recruitment, metamorphosis, settlement
11:00 – 11:25 David Brickman, Bedford Institute of Oceanography, Canada
11:25 – 11:50 Hans-Harald Hinrichsen et al., Leibniz Inst.of Marine Sci., Germany
11:50 – 12:15 Asbjorn Christensen et al., DIFRES HFI, Denmark
12:15 – 12:20 Presentation of posters
12:20 – 12:40 Discussion

12:40 Lunch

Session VII: Future Directions: Integration with observing systems, operational models, monitoring programs, and management recommendations
14:00 - 14:25 Sarah Hinckley et al., NOAA/NMFS AFSC, USA
14:25 - 14:50 Gwenhael Allain, Pierre Petitgas, Pascal Lazure, IFREMER, France
14:50 - 15:15 Charles Hannah and Mike St. John, Canada and Germany
15:15 – 15:20 Presentation of posters
15:25 – 15:40 Discussion

15:40 Coffee break

Consensus Development: Recommended Practices and Future Directions
16:00 - 17:30 Discussion

17:30 Open-Session Wrap Up and Acknowledgements

20:00 Workshop dinner

Wednesday, April 5, 2006

Introduction and review of research recommendations
8:30 - 9:00

Identification of Writing Teams
9:00 - 9:30

Writing Session I
9:30 - 12:00

10:40 Coffee break

12:00 Lunch

Writing Session II
13:30 - 16:40

15:00 Coffee break

Workshop wrap-up and Acknowledgements
16:40 - 17:00

17:00 Adjourn

Annex 3: WKAMF terms of reference

2005/2/OCC05 A Workshop on **Advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions** [WKAMF] (Co-Chairs A. Gallego*, UK, E. W. North*, USA, and P. Petitgas*, France) will be held in Nantes, France, from 3–5 April 2006 to:

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

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

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

WKAMF will report by 1 May 2006 for the attention of the Oceanography Committee.

Supporting Information

Priority:	This workshop will provide guidance at critical juncture in the developing field of modelling physical-biological interactions in the early-life history of fish.
Scientific Justification and relation to Action Plan:	The Workshop contributes to ICES Goal 1, in particular Activities 1.2.1, 1.3, and 1.5. The field of modelling physical-biological interactions in fish early-life history is rapidly advancing (Werner *et al.* 2001, ICES 2004). Physical-biological interactions are an integral part of understanding fish early-life history and the processes that affect interannual variability in fish recruitment (Werner *et al.* 1997). It is time to review modelling strategies and underlying processes, with the goal of developing a synthesis of recommended practices and identifying knowledge gaps to guide future developments in the field. The proposed workshop will focus on technical and methodological issues, important physical and biological processes, and on future research needs. In addition to providing valuable guidance for the field of physical-biological interactions, this workshop will foster information exchange between international organizations such as ICES, PICES and AFS. The workshop, and the international collaborative research programs that result from it, will advance application of cutting-edge modelling approaches to issues that are critical for fisheries management such as understanding fish recruitment variability, identifying marine protected areas, and implementing ecosystem-based management.
Resource Requirements:	The research programmes which provide the main input to this group are already underway, and resources already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants:	This Workshop should attract 25–40 participants and will include some scientists from outside the regular ICES scientific community. We plan to identify participants during the 2005 ASC Theme Session proposed by WGPBI entitled “Connecting biological-physical interactions to fish recruitment variability”. We also will invite participation from ICES groups with an interest in physical-biological interactions and fish recruitment processes (e.g., WGCCC, WGRP, WGZE, WGFE, SGCRAB) and from groups such as GLOBEC and PICES.
Secretariat Facilities:	None
Financial:	No financial implications
Linkages To Advisory Committees:	Relevant to the work of the ACFM, ACE
Linkages To other Committees or Groups:	WGCCC, WGRP, WGZE, WGFE, SGCRAB
Linkages to other Organisations:	GLOBEC (IOC/SCOR), PICES, IMBR, GOOS
Secretariat Marginal Cost Share:	ICES 100%