

ICES WGPBI REPORT 2008

ICES OCEANOGRAPHY COMMITTEE

ICES CM 2008/OCC:06

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

1–3 April 2008

Sète, France



ICES

International Council for
the Exploration of the Sea

CIEM

Conseil International pour
l'Exploration de la Mer

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

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2008. Report of the Working Group on Modelling Physical/Biological Interactions (WGPBI), 1–3 April 2008, Sète, France. ICES CM 2008/OCC:06. 62 pp.
For permission to reproduce material from this publication, please apply to the General Secretary.

The document is a report of an Expert Group under the auspices of the International Council for the Exploration of the Sea and does not necessarily represent the views of the Council.

© 2008 International Council for the Exploration of the Sea

Contents

Contents	i
Executive summary	1
1 Opening of the meeting.....	2
2 Present and discuss new results concerning physical-biological interactions (ToR a)	2
3 Complete the publication of papers from WKAMF (ToR b).....	3
4 Complete the draft of the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History and suggest future coordinated research actions (ToR c).....	4
5 Demonstrate potential effects of climate change on the lower trophic levels of marine ecosystems (ToR d).....	4
6 Develop a statement of requirements for monitoring data to be useful for development and validation of models of physical-biological interactions (ToR e)	5
7 Report on lessons learned from application of holographic imagery to zooplankton-phytoplankton-turbulence interactions (ToR f)	6
8 Document how PBI tools can be useful in estimating fish habitats potentials and survival windows and their variation in the context of climate change (ToR g)	7
9 Review proposed approaches for coupling regional models of NPZD-type biogeochemistry with higher trophic levels (ToR h)	9
10 Report on approaches for combining field and laboratory data together with biological-physical models to examine processes controlling zooplankton populations (ToR i).....	10
11 Discuss and report on how WGPBI fits into the new ICES structure. ToR j).....	16
12 Report of subgroup on Larval Fish.....	17
13 Other Business	18
14 Final Business.....	22
Annex 1: List of Participants.....	23
Annex 2: Terms of Reference for 2008 Meeting	24
Annex 3: Agenda for 2008 Meeting.....	25
Annex 4: WGPBI Terms of Reference for the 2009 meeting	27
Annex 5: Recommendations	30

Annex 6: Theme Session Proposals	31
Annex 7: Resolution for an ICES Internal Publication.....	32
Annex 8: Resolution for a Workshop	34
Annex 9: Action Items 2008/2009.....	36
Annex 10: WGPBI Activities.....	37
Annex 11: WGPBI Larval Fish Group	39
Annex 12: Abstracts from Joint Session with WGZE.....	42
Annex 13: Abstracts	48

Executive summary

Sixteen papers from the Workshop on *Advances Modelling Physical-Biological Interactions in the Early Life of Fish* were published as a Theme Section in Marine Ecology Progress Series, Volume 347 (October 2007).

The *Manual of Recommended Practices for Modelling Physical-Biological Interactions in the Early Life of Fish* has been completed and will be sent to the Publication Committee for consideration as an ICES Cooperative Research Report. The manual summarizes appropriate methods for modelling physical-biological interactions during the early-life of fish, recommends modelling techniques in the context of specific applications, and identifies knowledge gaps.

A new era in modelling physical-biological interactions has begun. Simulations are being reported that integrate from physics to adult fish populations. The simulations are largely exploratory in nature but they represent a substantial increase in what is possible and the beginning of comprehensive ecosystem modelling.

A proof of concept 'Oyster Restoration Optimization' model demonstrates that ecosystem characteristics (hydrodynamics, phytoplankton growth, oyster filtration, oyster population dynamics) and social objectives (water quality, harvest, spawning stock sanctuaries, and economic considerations) can be linked in an optimization framework that supports ecosystem-based management decisions in Chesapeake Bay. The model makes testable predictions and quantifies the tradeoffs associated with different management decisions.

New digital holographic techniques have enabled the creation of holographic movies. These movies allow us to study behaviour, feeding and physical/biological interactions for copepods, nauplii, diatoms and dinoflagellates.

1 Opening of the meeting

The 2008 meeting of the Working Group on Modelling Physical Biological Interactions was held in Sète France from 1 – 3 April 2008. 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 25 scientists (Annex 1). The meeting include a joint day with the Working Group on Zooplankton Ecology.

The working group thanks Delphine Bonnet (Université Montpellier II) for the local arrangements

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

There were eight talks in this session:

- Elizabeth North: Coupling ecosystem and optimization models for oyster restoration
- Rubao Ji: Processes controlling plankton dynamics in the Gulf of Maine
- Frank Janssen: Inter-annual variability of cyanobacteria blooms in the Baltic Sea.
- Margaret Sexton: Nowcasting Sea Nettle populations in Chesapeake Bay.
- Lennart Funkquist: Migration of crab larvae, a combined model and field study.
- Matteo Sinerchia: Virtual Ecology Workbench version 3.3.
- Colleen Petrik: Prey selection of larval haddock and cod on copepods with species-specific behaviour
- Alexander G. Trofimov: The influence of oceanographic conditions on abundance of the Norwegian spring-spawning herring at the early life stages

Abstracts are given in Annex 13.

North presented the Oyster Restoration Optimization model, which aims to identify the most suitable locations for restoring the oyster population in the Chesapeake Bay. The model considers management objectives such as reducing seston, increasing water clarity, stock enhancement, and oyster harvest. The model incorporates the transport, growth and mortality of oyster larvae, as well as the 3-D dynamic biogeochemistry of the waters. The model highlights the conflicts between different management objectives and testifies to the importance of linking disparate models.

Ji discussed numerical experiments with the Finite-Volume Coastal Ocean Model, (FVCOM) aimed at understanding the non-linear interactions among the multiple biological and physical processes that control the distributional pattern of *Pseudocalanus spp.* in the Gulf of Maine – Georges Bank region. The model results suggest that spatial- and temporal- dependent mortality rate play a key role in determining seasonal dynamics; that the Georges Bank population is unlikely to be self-sustaining; and that the temperature-dependent top-down control may play a significant role in regulating population dynamics.

Janssen presented simulations of cyanobacteria blooms in the Baltic Sea for the period 1960–2005. Interannual variability was large, but at the decadal scale it is

characteristic that large late summer blooms are only prominent after the mid-1980s. The simulations suggest the hypothesis that these blooms are made possible by excess phosphorus in the surface layer. This phosphorus is due to a thick mixed layer which in turn is caused by high wind stresses in the spring. This provides a link from a high index of the North Atlantic Oscillation, and to strong cyanobacteria blooms.

Sexton presented an operational model for forecasting the abundance of sea nettles in the Chesapeake Bay. Sea nettles are a concern to the public due to their impact on recreational use of the Bay. The model combines 3-D hydrodynamics and physics with an empirical relationship between temperature, salinity and probability of sea nettle presence. The model sheds light on interannual fluctuations in sea nettle abundance and distribution: Sea nettles tend to appear in the summer when water temperatures rise above 20 degrees Celsius. Meanwhile, they are confined in space to regions where the salinity is near 20 PSU, and these regions shifts between wet and dry years due to fresh water runoff.

Funkquist presented a combined modelling and field study of migration of crab larvae. The study investigates the larvae's control of its dispersal, and the importance of circulation vs. larvae behaviour on larvae transport. The model tracks individual crab larvae in space, including active vertical migrations and using Monte Carlo methods to represent turbulence. The study stresses the need for high-resolution circulation and turbulence statistics, and illustrates the importance of vertical behaviour on horizontal transport: Bottom-swimming larvae are advected and dispersed less than surface-swimming ones.

Sinerchia presented the Virtual Ecology Workbench; a software tool for simulating plankton ecosystems with a strictly individual-based approach. The model tracks the vertical position and phenotypical state of each plankton until its death, and so the model predicts the vertical structure of plankton communities in the mid-ocean. The input to the model is parameters characterizing each species in the community. The software has been designed with an emphasis on user friendliness so that it may be applied also by scientists who are not familiar with the internal workings of individual-based models.

Petrik presented a model of the feeding on copepods by larval haddock and cod on Georges Bank. The model takes into account the escape behaviour of the most important prey species among copepods, as well as the bioenergetics of the fish larvae. Both cod and haddock prefer *Pseudocalanus* over *Calanus finmarchicus*, but haddock prefer smaller prey and are more exposed to food limitations on growth. The intended use of the model is as a component in 3-D coupled physical-biological models of recruitment.

Trofimov presented a statistical model for estimating the abundance of 0-group herring as well as the area occupied by herring. The model bases the estimation on physical environmental conditions such as temperature, flow, and stratification, as well as the abundance and fecundity of mature herring. Among the physical covariates, those related to stratification were found to be of prime importance. In addition, the bulk flow was determining for the area occupied by herring.

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

The publication 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 complete (Marine Ecology Progress

Series (2007) 347:121–306). The “thematic” classification of a total of 15 publications was: 1 introduction, 1 review, 3 small-scale physical processes (turbulence), 2 feeding, 3 behaviour, 3 methodology (backtracking, PDF/optimisation, model setup and connectivity), 4 applications (NS flounder, Benguela ichthyoplankton, GoM cod and Icelandic cod), and 1 future directions. The articles were published as OPEN ACCESS so that the electronic copies can be downloaded for free from the MEPS website: www.int-res.com/abstracts/meps/v347.

4 Complete the draft of the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History and suggest future coordinated research actions (ToR c)

The *WKAMF Manual of Recommended Practices for Modeling Physical-Biological Interactions in the Early Life of Fish* was presented to WGPBI. This large document (> 120 pages) summarizes appropriate methods for modeling physical-biological interactions during the early-life of fish, recommends modeling techniques in the context of specific applications, and identifies knowledge gaps. Working group members congratulated the authors and editors for their substantial accomplishment that will provide a valuable resource to the community. WG members endorsed the document and recommend that it become an ICES Cooperative Research Report. Minor edits and additional references were suggested. Editors requested that WGPBI members send their specific comments to E. North by 1 May, 2008.

Resolution to ICES Publication Committee: WGPBI recommend that the ICES Publication Committee consider publication of the *WKAMF Manual of Recommended Practices for Modeling Physical-Biological Interactions in the Early Life of Fish* as an ICES Cooperative Research Report (Annex 7).

5 Demonstrate potential effects of climate change on the lower trophic levels of marine ecosystems (ToR d)

Morten Skogen reported (via email) on two EU projects that IMR is involved with that address the potential effects of climate change on marine ecosystem. Within ECOOP (European COastal-shelves OPerational observing and forecasting system) an estimate of the future primary production (and associated variables) will be produced from downscaled climate simulations, and new monthly climatologies will be produced. In RECLAIM (REsolvingCLimATIC IMPacts on fish stocks) the focus is broader and includes higher trophic levels. He plans to report on progress at the 2009 meeting.

Within ECOOP, quantitative estimates of future shelf seas primary production and associated variables such as functional groups of algae, nutrients and benthic or bottom layer oxygen will be made by running relevant models with forcing from the climate scenarios. This will allow prediction of e.g. the individual and combined effects of changes in Atlantic inflows, sea ice, temperature, and stratification on primary production. Through a combination of numerical and statistical models, the results from the primary production modelling will be used to produce quantifiable estimates of the changes in zooplankton production. One of the applications will be to determine the effect of climate scenarios on the coupling between zooplankton and phytoplankton, in particular possible changes in the timing (phenology) of the production cycles. Where necessary the population dynamics of specific key zooplankton life stages or life cycles of specific species will be modelled separately by

combining estimates from zooplankton IBMs or stage-based models into coupled bio/physical models.

Two specific examples of potential effects of climate change on lower trophic levels arose from the presentations at the meeting. These are described next.

The modelling results presented by Frank Janssen on the 'Inter-annual variability of cyanobacteria blooms in the Baltic Sea and its relation to climate variability' showed a potential link between the NAO and cyanobacteria blooms in the Baltic. The potential mechanism is that high NAO index leads to high wind stress and low ice cover. This leads to deeper high mixed-layer depth and greater entrainment of deep water into the surface mixed layer in the winter. This results in greater excess phosphorous concentrations (relative to the Redfield ratio) and sets the conditions for strong cyanobacteria blooms in the summer. This is relevant to climate change because it has been proposed that the secular increase in the NAO over the last 40 years is a signature of global warming.

The forecasting system for sea nettle (*Chrysaora Quinqucirrha*) populations in Chesapeake Bay, presented by Maggie Sexton, uses an empirical habitat model to predict the probability of occurrence of medusae as a function of sea-surface temperature and salinity. The basic result is that temperature controls the timing and the salinity controls the spatial distribution. This provides very straight-forward predictions of climate change impacts on jellyfish populations; warmer water will lead to longer jelly fish seasons. In addition, increased run-off will push the sea nettle population towards the mouth of the Bay, whereas decreased run-off will move the populations towards the head of the Bay.

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

The following is the current state of the draft text of the statement of requirements. It needs substantial work and WGPBI will work on the statement intersessionally.

Modelling physical-biological interactions required the best possible simulations of the physical environment. Therefore monitoring must make the observations required for the physical models. In addition the flux of nutrients and materials between the different oceanographic domains must be measured as inputs to the models (e.g. between the deep ocean and the shelf; between the land and the ocean; and between the surface ocean and the benthos). In particular the time varying flux of nutrients from the rivers must be monitored and better estimates of the time varying flux of nutrients and organisms (e.g. calanus species) from the deep ocean to the shelf are required for most shelf regions.

Routine large scale surveys (monitoring) of phytoplankton and zooplankton are useful for assessing the skill of regional models at reproducing seasonal cycles, interannual variability and large scale gradients. The combination of biological and physical data can be analyzed using spatial analysis techniques such as 'self organizing maps' (Allen *et al.*, 2007) to establish whether the model is reproducing the observed relationships between the variables.

Large scale surveys are useful for demonstrating that a set of model solutions are plausible. However they do not discriminate between plausible models nor do they provide the information to develop the next generation of models. For zooplankton, visual systems such as video and holographic systems offer the opportunity to

observe zooplankton in their natural environment. New digital holographic techniques allow high resolution imaging of a three dimensional volume of water without the need for film and can be used to create holographic movies. The development of video and holographic systems continues as does the software for automated species identification and analysis. Using these systems one can identify zooplankton species, measure distances between organisms, estimate the parameters describing zooplankton movement and observe the details of predator prey interactions. These instruments will provide the basis for understanding the interactions between individual organisms in the ocean which will be the basis for the next generation of zooplankton and larval fish models.

These systems have the potential when incorporated into environmental moorings to assess and ground truth the seasonal development of populations and the resultant species interactions for the identification of key processes in situ for the further development of ecosystem and IBM modelling activities. For example there are plans to incorporate a holographic system into an ARGO float. A coordinated effort to support the routine use of these instruments and the systematic archiving of the enormous amount of output could provide the databases required for the development of individual based models.

A potentially useful way to validate coupled ecosystem-zooplankton population models is to use at least weekly samples of copepodite stages at monitoring stations to resolve the temporal distribution in terms of number of generations. This indicates a need for at least weekly sampling at monitoring sites (as compared to say monthly sampling).

This statement of requirements should address minimum requirements for archival and accessibility.

Reference

Allen, J.I., Somerfield, P.J., and Gilbert, F.J. 2007. Quantifying uncertainty in high-resolution coupled hydrodynamic-ecosystem models. *Journal of Marine Systems*, 64: 3–14.

7 Report on lessons learned from application of holographic imagery to zooplankton-phytoplankton-turbulence interactions (ToR f)

As part of the joint session with WGZE, Tom Osborn gave a talk entitled 'Holographic techniques for predator prey interaction and physical/biological coupling.' The talk summarized recent developments in the digital holography and illustrated the potential application with several examples.

Holograms observe the particles in the sample volume by scattering coherent light from the particles. This technique allows observation of many small particles in a relatively large three-dimensional volume. The comparison with microscopy is that while the resolution in the plane of the particle is the same, the resolution in the third dimension is not limited by the optical depth of field of the imaging system. Thus, holographic techniques for studying the plankton community have the advantage of seeing the small particles in a sample volume that is both wide and deep relative to the particle size.

A major breakthrough came with the development of numerical techniques for analyzing the holograms, which obviated the need for an optical bench to reconstruct the image by sending light through the film. The new, high resolution, high frame rate, digital cameras make ideal data capture vessels. Upon collection, the holograms

are digital and not film based. The reconstruction can proceed directly using the numerical developments. These developments have enabled holographic, PIV movies. These movies allow us to study behaviour, feeding and physical/biological interactions for copepods, nauplii, diatoms and dinoflagellates.

- Movies were shown of a nauplii attempting, but failing, to capture a food particle.
- The feeding currents of a copepod were shown in real time while the creature sank through the water. The data were then all centered on the copepod and the close circulation pattern of the feeding currents became apparent.
- Spatial distributions of dinoflagellates were shown to be random in the absence and presence of prey, but the distribution of predator to prey spacing is not random. It was shown how the behaviour of different species and strains of dinoflagellates changes with the introduction of prey and with time after the introduction.

Some movies are available at: <http://www.me.jhu.edu/~lefd/shc/shc.htm>

A good reference that will lead to other interesting papers is:

Sheng, J., E. Malkiel, E., Katz, J., Adolf, J., Belas, R., and Place, A. 2007. "Digital Holographic Microscopy Reveals Prey-Induced Changes in Swimming Behavior of Predatory Dinoflagellates". *Proceedings of the National Academy of Sciences (PNAS)* 104. 44 (2007):17512–17517.

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

The group discussed the subject of combining, in a spatially-explicit context, models of the full life cycle of fish with lower trophic models. The subject is the key to understanding the many controls of population dynamics that occur at various stages in the life history. Also mechanistic tools are necessary to increase predictability of changes in fish distribution and productivity under global change scenarios and for fishery management plans. In order to envisage which PBI tools would be appropriate as inputs (either output fields or derived fields) to models of fish, the group reviewed available fish models and listed the processes that needed to be modelled.

PBI tools (e.g. lower trophic level NPZD model outputs) and operational oceanographic products (e.g. maps of frontal activity) are useful as forcing variables on fish physiological and behavioural models. Recruited juveniles and adult fish were considered here. Recent work within ICES has been undertaken to identify meso-scale oceanographic features (WKIMS, 2006) and cross-map these with fish habitats (SGRESP, 2004–2006). The cross-mapping was 'empirical' in the sense that it was a superposition of maps. Here, the discussion reviewed mechanistic models that allow one to relate fish responses to their physical and lower trophic level environments. The fish models discussed were: bioenergetics models of growth and reproduction; displacement models of migration and habitat occupation; and feeding models that formulate the interaction with the lower trophic levels.

Bioenergetic models allow the integration of the current and the past individual fish histories and make predictions about growth and fecundity based on such space-time integration of effects. Examples of combining fish growth and reproduction

responses to lower trophic model outputs through bioenergetic models were the Nemuro-Fish on Pacific herring and saury (Megrey *et al.*, 2007) and anchovy in Biscay using DEB (Dynamic Energy Budget) modelling (Pecquerie, 2007). Fish displacement can be modelled using an advection-diffusion (Eulerian) approach where displacement occurs along a gradient of a 'suitability' variable with added density-dependence (e.g. Bertignac *et al.*, 1998). The 'suitability' variable can be output from a physical or biogeochemical model. Movement decision can also be modelled in an IBM context as the result of a search to maximise individual 'fitness' given the local environmental conditions (e.g. Huse and Giske, 1998). Still, other behavioural processes have been documented as important in determining migration patterns (ICES 2006b). Spatial memory and condition state are behavioural determinants of subpopulation structure. The physiological state is expected to affect migration capabilities, meaning that migration is length or condition-dependent (e.g. Slotte, 2001). Also, migration routes are not just determined by the environment as they are also maintained by cross-generational learning processes which result in a 'tradition' at population level (e.g. Petitgas *et al.*, 2006). Therefore potentially suitable habitats may not be occupied. Combining these processes seems necessary for modelling migration patterns. Feeding models could be either formulated as a functional response as in the DEB or Nemuro-Fish models or explicitly including behaviour and trade-offs and using evolutionary algorithms (e.g. Huse and Giske, 1998). Although sharing some common aspects, full life cycle models of fish populations are to be distinguished from end-to-end models (e.g. Fennel, 2008; Travers *et al.*, 2007). Spatially explicit displacement fish models as well as full life cycle models were considered major challenges (e.g. Lett *et al.*, in press). The need to account for behaviour in these models was stressed. Further review work on these topics (processes involved and model structure) is necessary allowing the group to provide guide lines on what processes to model, how to model them and what outputs are needed from hydrodynamic and NPZD model runs.

During the GLOBEC-Germany observational program a full data set on small copepod prey fields for sprat recruitment were observed and used to estimate sprat recruitment success in the German Bight. Only model simulations including the relevant zooplankton population can resolve the temporal scale for analysis of match-mismatch hypothesis on a climatic time scale (Kuhn *et al.*, 2008).

References:

- Bertignac, M., Lehodey, P., and Hampton, J. 1998. A spatial population dynamics simulation model of tropical tunas using a habitat index based on environmental parameters. *Fisheries Oceanography*, 7(3/4): 326–334.
- Fennel, W. 2008. Towards bridging biogeochemical and fish-production models. *Journal of Marine Systems*, 71: 171–194.
- Huse, G., and Giske, J. 1998. Ecology in Mare Pentium: an individual-based spatio-temporal model for fish with adapted behaviour. *Fisheries Research*, 37: 163–178.
- Kühn, W., Peck, M.A., Hinrichsen, H.-H., Daewel, U., Moll, A., Pohlmann, T., Stegert, C., and Tamm, S., 2008. Spatial and temporal changes in the habitat suitability of the German Bight (southern North Sea) for larval sprat: An IBM approach using size-structured prey fields. *Journal of Marine Systems*. In Press.
- Megrey, B., Rose, K., Klumb, R., Hay, D., Werner, F. Eslinger, D., and Smith, S. 2007. A bioenergetics-based model of Pacific herring (*Clupea harengus pallasii*) coupled to a lower trophic level nutrient-phytoplankton-zooplankton model: description, calibration, and sensitivity analysis. *Ecological Modelling*, 202: 144–164.

- ICES. 2006a. Report of the Workshop on Indices of Meso-Scale Structures (WKIMS). ICES CM 2006/OCC:01.
- ICES. 2004-06b. Report of the Study Group on Regional Scale Ecology of Small pelagic Fish (SGRESP). ICES CM 2004/G:06, 2005/G:06, 2006/LRC:05.
- Lett, C., Rose, K., and Megrey, B. (in press). Biophysical models of small pelagic fish. In: *Climate Change and Small Pelagic Fish*, Eds. D. Checkley, J. Alheit, Y. Oozeki and C. Roy, Cambridge University Press.
- Pecquerie, L. 2007. Bioenergetic modelling of growth, development and reproduction of a small pelagic fish: the Bay of Biscay anchovy. Ph.D. doctoral thesis. Ifremer and Vrije Universiteit Amsterdam.
- Petitgas, P., Reid, D., Planque, B., Nogueira, E., O'Hea, B., and Cotano, U. 2006. The entrainment hypothesis: an explanation for the persistence and innovation in spawning migrations and life cycle spatial patterns. ICES CM 2006/B:07.
- Slotte, A. 2001. Factors Influencing Location and Time of Spawning in Norwegian Spring Spawning Herring: An Evaluation of Different Hypotheses. In: F. Funk, J. Blackburn, D. Hay, A. J. Paul, R. Stephenson, R. Toresen, and D. Witherell (Eds.), *Herring: Expectations for a New Millennium*. University of Alaska Sea Grant, AK-SG-01-04, Fairbanks, pp. 255–278.
- Travers, M., Shin, Y., Jennings, S., and Cury, P. 2007. Towards end-to-end models for investigating the effects of climate and fishing in marine ecosystems. *Progress in Oceanography*, 75(4): 751–770.

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

The coupling of NPZD type models with stage resolved zooplankton models and higher trophic levels are happening in many places. During the meeting there were several talks that discussed applications that involved coupling NPZD type models with stage resolved zooplankton models, larval fish models and adult fish models. The abstracts for the talks by Wolfgang Fennel, Andreas Moll and Matteo Sinerchia are given in Annex 12 and the one for the talk by Cisco Werner is given in Annex 13.

The applications make different approximations in order to create simulations which are computationally tractable. In the NEMURO.FISH application (Werner), which includes a global 1° simulation of physics and NPZ, the fish life cycle is closed using a stock-recruitment relationship. Fennel's Baltic Sea model includes a detailed fish life cycle model but it is presently implemented as a single box model. Both models use decadal scale simulations to look at the variability in response to environmental change and they are not concerned with year to year recruitment fluctuations. In contrast Moll's North Sea model has stage resolved copepods and explicit larval fish IBMs embedded in a 3d model. The focus is on year to year variability in larval survival and does not close the fish life cycle. Sinerchia's squid recruitment model implements an entire NZP model plus larval and adult squid in a Lagrangian framework (Virtual Ecology Workbench, Woods 2005) and does close the squid life cycle. The simulations investigate both the year to year and decadal scale variability in plankton, zooplankton, and squid recruitment. The computational demands limit the simulations to a one dimensional water column.

Mike St. John talked at the EU project MEECE (Marine Ecosystem Evolution in a Changing Environment). Central to the MEECE project is WP 2 the goal of which is to create a library of plug and play type models which can be coupled to existing coupled hydrodynamic and intermediate and complex NPZD type models and

thereby provide the integrated modelling tools necessary to assess how ecosystems are impacted by global change via drivers such as ocean circulation, ocean climate, ocean acidification, pollution, over fishing and invasive species. At present most models in marine ecosystems are developed to address specific trophic levels, species or processes and consist of either a single code or are driven 'offline' using the stored results of hydrodynamic models. The overall goal of MEECE is to create an integrated model structure following a modular approach and employing couplers to communicate between the different components. Couplers are a software system for integrating different software components into a single integrated system. The different model components can have different grids and time steps, the coupler is supposed to deal with the required interpolations. Couplers are common in climate models and in numerical weather prediction; they are a novel concept in ecosystem modelling. In order to accomplish these objectives MEECE WP2 will

- identify system specific and generic key feedbacks and forcing for focused modeling activities.
- assemble a library of biogeochemical, ecosystem, higher trophic level, alien invasive species and ecotoxicology models necessary to assess the impacts of MEECE drivers on ecosystem dynamics.
- develop a modular modeling structure to enable the flexible coupling of biogeochemical, ecosystem, higher trophic level, alien invasive species and ecotoxicology sub models modules to existing ocean atmosphere models.
- develop trophic couplers to enable the implementation of feedback loops into end to end modeling frameworks.

MEECE, which is coordinated by Icarus Allen of PML, is scheduled to commence in the last half of 2008 and to run for 4 years. WP 2 contains many members of WGPBI and is coordinated by Mike St. John of the University of Hamburg with regular updates of activities to be presented to the WG. The various models included in MEECE are listed in the Abstract in Annex 13.

No general recommendations on coupling to higher trophic levels can be formulated yet. Nevertheless, it is clear that coupling to higher trophic levels can be done successfully. The key is careful consideration of the question being asked when choosing which components of the system need to be modelled in detail and which can be heavily approximated.

Reference

Woods, J.D. 2005. The Lagrangian Ensemble metamodel for simulating plankton ecosystems. *Progress in Oceanography* 67: 84–159.

10 Report on approaches for combining field and laboratory data together with biological-physical models to examine processes controlling zooplankton populations (ToR i)

The joint meeting was held at the Hotel Port Marine, Sète, 2 April 2008 and was attended by 29 members of the Working Group on Zooplankton Ecology (WGZE) and 25 members of the Working Group on Modelling Physical-Biological Interactions (WGPBI). The aim of the meeting was to bring modellers and field scientists together to explore how data and models could be combined to elucidate mechanisms explaining observed variations in zooplankton and ecosystem dynamics. Thus the joint meeting builds on the separate strengths of the WGZE and WGPBI, to further

our understanding of zooplankton and ecosystem dynamics by combining data and models from these two WGs.

The meeting was divided into three sessions: Session 1 with presentations by WGPBI members intended to demonstrate the range of modelling techniques available to the community and a new observational technique; Session 2 where WGZE members presented available data sets and examples of statistical modelling approaches; and Session 3 with joint discussions on possible future interactions between the two groups. The abstracts are given in Annex 12.

Session 1: Modelling (WGPBI)

Lead Uffe H Thygesen, Rapporteur Charles Hannah

Hannah gave an overview of WGPBI's history and philosophy. There was a lively discussion that ranged across issues such as model validation and the need for the involvement of observation lists and experimentalists in the modelling process.

Osborn's talk demonstrated how new digital holographic techniques can be used to study behaviour, feeding and physical/biological interactions for copepods, nauplii, diatoms and dinoflagellates (see Section 7 above for more details).

Sinerchia discussed the Lagrangian Ensemble methodology and the VEW (Virtual Ecology Workbench) software for simulating the entire ecosystem using individual based models. Simulations at an Azores site, under stationary annual forcing, showed that after an initial transient period, the ecosystem converges to an attractor, in which the inter-annual variation of species biomass or demography is lower than the demographic noise (<15%). The biomasses were comparable with observations at a nearby site. Overall the simulations were intrinsically stable, ergodic and provided a good signal: noise ratio.

Neuheimer discussed the application of an age-within-stage population dynamics model to investigate the cause of the dramatic decline in *C. finmarchicus* naupliar abundance in May followed by an increase in June, every year on Georges Bank. She showed that the use of field-estimated mean mortality rates results in modelled abundance that are in error by over an order of magnitude and that time-varying and spatially explicit mortality rates were required to reproduce observed naupliar densities. These temporal variations in mortality appeared to be correlated with *C. finmarchicus* female abundance, which suggest that cannibalism as a major regulatory factor of naupliar abundance.

Fennel's contribution aimed at bridging biogeochemical models and fish-production models, by coupling a NPZD-model with a fish model. The Baltic Sea was chosen as an example system, where the main fish dynamics is covered by two prey species (sprat and herring) and one predator (cod). The dynamics of the fish model is driven by size dependent predator-prey interactions. The linkage of the model components is established through feeding of prey fish on zooplankton and recycling of fish biomass to nutrients and detritus. He used the NPZD plus Fish model (NPZDF) to discuss how the choice for parameterization of the fish in an NPZD model affects the simulations. The model truncation affects not only the zooplankton mortality but also the dynamics of nutrients and detritus.

Moll presented the coupling of a 3d regional NPZD model with a stage resolved model of *Pseudocalanus elongates* that competes with the bulk zooplankton. The *P. elongates* then provides food for an individual based model of larval sprat. The presentation focused on the validation of the zooplankton component of the

simulations. In particular, Moll raised the question of how to validate a stage resolved zooplankton model. He was able to show that the model is able to calculate reliable stage development and abundances of *P. elongatus* as well as the range of bulk zooplankton biomass, and thus the ratio of population biomass to total biomass. In the German Bight, the population is below 20% in spring. The ratio increases up to 30% during summer. The number of generations was estimated from peaks in egg abundance to about 4–7 generations of *P. elongatus* in the southern North Sea.

Moll had several questions for the audience, in particular

- 1) Is the comparison at Helgoland Reede affected by island effects, not covered in the simulation?
- 2) What other long-term station data are available on the northwest European continental shelf?
- 3) Do we have robust estimations of generation numbers as an integrative measure? The number of generations produced during the year integrates many biological processes and has the potential to bypass the classic zooplankton sampling problem of being under resolved in space.
- 4) What are your suggestions for better ways of comparison (e.g. generation time and number of generations)?

Session 2: Data (WGZE)

Lead: Astthor Gislason, Rapporteur: Arno Pollumae

Astthor Gislason opened the session with a short presentation of WGZE, introducing the history of the group, the attendance statistics and most important products over the years.

Mark C. Benfield gave an overview of zooplankton sample collection methods, past and present. In order to answer the questions: what are the numbers and kinds of zooplankters in the sea at any given time and place and how it varies with time and space; a variety of sampling gears and methods have been developed during the last century. The history, basic design and working principles of plankton nets (single, non-opening/closing, opening/closing, multinetts, specialized nets and traps, plankton recorders), pumps, optical systems (particle counters and imaging systems) and high-frequency acoustics, were presented with many pictures and animations. Strengths and weaknesses of every sampling gear type were pointed out as well as the kind of data that derive from the different approach. Mark ended his presentation by drawing the attention of the group to a recent review by Wiebe and Benfield 2003 (From the Hensen net toward four-dimensional biological oceanography, *Progress in Oceanography* 56) as further reading on the topic.

Eilif Gaard described the inventory of existing or known zooplankton and ambient data series from North Atlantic and Mediterranean Sea. Most of the North Atlantic series presented are included in Plankton Status Report. Eilif said that in the North Atlantic, there is generally good temporal and spatial coverage of hydrography, nutrients, phytoplankton abundance and zooplankton biomass, but less data on rates and processes. The knowledge gaps and data needs were acknowledged in many aspects for such fields as biochemistry, ecosystem functioning and exploited resources.

In the discussion that followed, Gaby Gorsky said that very high-resolution zooplankton data were available from off Villefranche, data collected since 1966 five

times per week. Andreas Moll (WGPBI) noted that he now knew much more about where to find good data for model verification. The question was asked how to include rate measurements in long-term monitoring programs? The answer seems to be that it is complicated to acquire such data and therefore they tend to be missing from the monitoring series.

Roger Harris discussed available data sets from laboratory studies. There are existing large data-sets, where data from multiple experiments are compiled (e.g. within the US GLOBEC programme). However, Laboratory experiments have a specific purpose, and are usually designed to test a specific hypothesis, so the data generated may not necessarily be appropriate for models. Large projects such as US GLOBEC and TASC (Trans-Atlantic Study of *Calanus finmarchicus*) may be sources of zooplankton experimental data, but the data-sets may not be easily accessible, and long term availability is a problem. Roger continued to say that some of the best data were literature compilations. Some examples:

- Bunker and Hirst, 2004. Fecundity of marine plankton copepods: global rates and patterns in relation to chlorophyll a, temperature and body weight. *Marine Ecology progress Series* 279:161–181.
- Hirst and Kiørboe, 2002. Mortality of marine planktonic copepods: global rates and patterns. *Marine Ecology Progress Series* 230: 195–209.
- Hernandez-Leon, Fraga and Ikeda, 2008. A global estimation of mesozooplankton ammonium excretion in the open ocean. *Journal of Plankton Research* (submitted).
- Hernandez-Leon and Ikeda, 2005. A global assessment of mesozooplankton respiration in the ocean. *Journal of Plankton Research* 27:153–158.
- Buitenhuis *et al.* 2006. Biogeochemical fluxes through mesozooplankton. *Global Biochemical Cycles*. 20.

Roger ended his presentation by describing an initiative to work with a few publishers of scientific journals to implement a Data Submission System (DSS) where authors are required to submit raw data directly to a long-term data-base in order as part of the publication process.

A discussion followed where it was noted that there is already a system, where links in articles are leading to databases not hosted by the publisher but somewhere else.

Cecilie Broms showed a few examples how multivariate techniques could be used to extract information from field data. Ecologists often need to analyze the response of several species (response variables) in an ecosystem on several environmental factors (explanatory variables) simultaneously, so they end up with multivariate methods. One multivariate method is ordination – arrangement or ordering of species and/or sample units along gradients. Ordination is a family of methods and there is a choice of sub-methods. An example was presented how ordination methods were used to relate the geographic distribution of *C. finmarchicus*, *C. glacialis* and *C. hyperboreus* in the Norwegian Sea and adjacent areas to environmental variables.

Jeff Runge concluded Session 2 by talking about what biological questions the models should address. He identified three families of biological questions about pelagic marine ecosystems: 1) questions about biogeochemical fluxes and carbon sequestration; 2) questions about community ecology including multispecies trophic interactions and top down effects; 3) and questions about bottom up controls on primary productivity and higher trophic level population dynamics, noting that the last question, addressed by coupled physical-biological models, appeared to be

particularly appropriate to top priorities of the new ICES Science Plan, including impact of climate change on the distribution, physiology and behaviour of marine biota. Jeff concluded his talk by saying that modeling integrates knowledge across scientific disciplines. He said that there is need for collaboration among disciplines, and that simulations provide predictions that can be tested against data. The computer could be a medium for communicating to non-experts and experts the complex synthesis of system knowledge.

Session 3: Future collaboration between WGZE and WGPBI

Lead: Charles Hannah, Rapporteur: Cabell Davis

To lead off this discussion, Peter Wiebe presented a BASIN slide showing conceptualization of sampling system. He discussed the rationale for BASIN, including the need to sample the deep basins; the shelves are sampled fairly well. There is a need for a comparative approach in sampling the shelf and basin ecosystems, as they are connected.

Erica Head said that comparative ecosystem and model analysis is being done in the U.S. via the CAMEO program. Elizabeth North said Moll's example of physical models and ecosystem dynamics indicated that physics most important.

Andreas Moll said that of the seven 3d circulation models he examined, only 2 models had a cost comparison done; i.e. only 10% of models had been validated. Charles Hannah showed slide describing what validation is, saying it is a process. Moll explained why it is a process: when you change a state variable, you need to change validation for whole new model. You need to validate the model for all state variables. Charles Hannah said that is why modellers are so attached to their own models.

Steve Hay said that we also have an emotional connection with the data! He has seen the process of model validation, and there is a need for more data, new processes, etc.

Charles Hannah showed that the modelling policy includes experimentalists/-empiricists.

Anna Neuheimer asked in comparing model and data, what is the truth? In answer to that, Cabell Davis suggested that Hannah show the 'What is truth' slide Dan Lynch presented at the GLOBEC Pan Regional meeting in Boulder Colorado, USA, 27–30 November 2006. The slide shows a triangle, with the truth at the top vertex and model and data at the two bottom vertices (Figure 5). There is error in both the data and the model. We are comparing models-data misfit, in hopes of being closer to the truth.

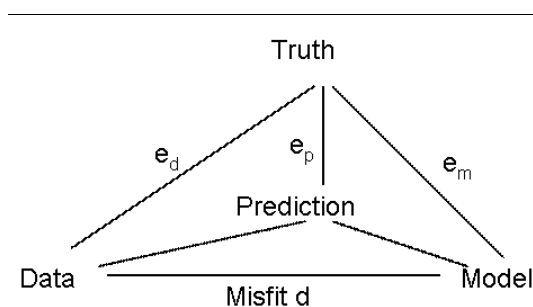


Figure 5. Relationships between models, data, and reality (modified from D. Lynch's presentation at the GLOBEC Pan Regional Meeting, 27–30 November 2006 in Boulder, Colorado, USA).

Catherine Johnson said that one of the products of a model is the identification of weak areas of data. The models are needed to point out where we need to sample and what is most sensitive to measure. This modelling can provide important information for the observation list. Steve Hay said that there is never enough data and that it is probably not possible to conduct enough experiments. We need to know what the functional relationships are.

Jeff Runge asked a philosophical question: what level of detail is needed? What level do you need to validate the model, can you come up with simple metrics, red, green, yellow. Charles Hannah stressed need for iterative interactions between modellers and observation lists. How detailed does the model need to be? There is no method for determining this level.

Elizabeth North considered a thought experiment: design an experiment using modelling approach, and observation system simulation experiment. Use the model of BASIN to design experiments. Andreas Moll said that approach is valid for well validated models but for unvalidated models you need data first to validate the model, so use literature. Priscilla Licandro agreed with Elizabeth North saying that we need validation in this way.

Erica Head said we can use conceptual models. She asked what are the hypotheses of basin? Michael St. John answered that one hypothesis focuses on the biogeochemical processes associated with spring bloom.

Elizabeth North asked what recommendations can we provide ICES? Following up on this Todd O'Brien asked what data modellers need. Charles Hannah answered we don't know. It depends on the model.

Uffe Thygesen suggested using crude model with 1st guess at parameters to design sampling. We need to be specific about which questions the model needs to answer and how to test the model.

Catherine Johnson said that optimal design of monitoring programs has been abandoned because the underlying question is changing over time. For example sampling for larval fish randomly may not provide data for zooplankton, so there is need to change sampling plan.

Peter Wiebe said we need to use models to help design field program, but for the N Atlantic basin, we don't have enough data to do this. The spatial coherence is 500–1000 km from CPR data. Coupling to shelf seas depends on shelf-ocean exchange. He referred to Benjamin Planque's thesis work. Catherine Johnson said that Scotian shelf coherence scales are 100km along shore, but resolution is limited.

Steve Hay said the state of community structure needs to be studied. Key species are the usual focus, but what about community structure? Are there modellers studying the species interactions and succession of species? Michael St John said that plankton functional group models of including succession are being developed. Charles Hannah said that prior studies have found that models with greater than 60 species lead to greater stability.

Mark Benfield asked that Todd O'Brien tell the modelling group how to access his online database. Todd O'Brien then gave a presentation on the copepod database availability, the same information he had presented earlier in the WGZE meeting, but it was very useful for the modellers to see and was well-received. The data can be accessed via the WGZE and Copepod websites (see WGZE report for further details).

WGPBI members were very impressed by the new NOAA Coastal & Oceanic Plankton Ecology, Production & Observation Database. COPEPOD is an online, global coverage plankton database (O'Brien, 2005) that can be found at <http://www.st.nmfs.noaa.gov/plankton/index.html>. The goal is to provide an integrated data set of quality-controlled, globally distributed plankton abundance, biomass and composition data, along with co-sampled environmental data. The maps of biomass are fascinating. In addition to data distribution maps the site offers a variety of content summaries and searching options.

Astthor Gislason asked what joint regional projects are possible. Peter Wiebe said we need trans-regional studies combining data and models.

Elizabeth North said that one of the outcomes of the larval fish workshop earlier in the week was the recognition of the need to quantify mortality in larval fish. She suggested having a joint session on mortality of fish, zooplankton, and phytoplankton. Peter Wiebe said that we have great NWA GLOBEC data set on mortality of larval fish.

Luis Valdes, as Chair of ICES Oceanography Committee, congratulated the WGPBI and WGZE for their excellent work as working groups and in the joint meeting.

At the end of the session, the group thanked Delphine Bonnett for her hard work and excellent job in hosting the joint meeting.

Reference

O'Brien, T.D. 2005. COPEPOD: A Global Plankton Database. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-73, 136 p. Available online at <http://www.st.nmfs.noaa.gov/plankton/index.html>

11 Discuss and report on how WGPBI fits into the new ICES structure. ToR j)

The group discussed a PowerPoint presentation on the new ICES structure provided by Luis Valdéz (Chair of OCC).

WGPBI fits very nicely under Strategic Goal 3:

ICES should lead the development of methods and tools needed in support of operational ecosystem observation services, in order to improve the understanding of climate change and impacts to our oceans and marine ecosystems.

The members of WGPBI contribute in several areas of the proposed Research Themes, including:

- 1) Climate Change Processes
- 2) Operational ecosystem modelling
- 3) Climate Change Predictions
- 4) Cumulative Impacts in coastal zone
- 5) Spatial Planning
- 6) Indicators
- 7) Life History
- 8) Coastal Habitat

It is not clear what the consequences of the proposed 'Program Structure' will be for WGPBI. Additional meetings for members or chairs are not likely to be well received.

WGPBI supported the creation of the new WG on Operational Oceanography. This may prove to have been a mistake if the 3D ocean modellers who have formed one of the core elements of WGPBI stop coming to WGPBI because of meeting overload.

Recommendation: We recommend that ToRs of Expert Groups be coded with reference to major goals of the ICES Science Plan and that such coding be used to help with the integration of Expert Groups results towards achieving these goals

12 Report of subgroup on Larval Fish

WKAMF Collaborators Meeting. The WKAMF Collaborators Meeting was held on 31 March 2008 in Sète, France, and was attended by 27 people. It was chaired by Elizabeth North, Alejandro Gallego, and Pierre Petitgas. The meeting provided a forum for the continued interactions of researchers that attended the "Workshop on advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions" (WKAMF) that was held in Nantes, France, in 2006. See <http://northweb.hpl.umces.edu/wkamf/home.htm> for information and products from the WKAMF workshop. The objectives of the meeting were to share current research findings, coordinate on-going research programs, and develop plans for future efforts to fill the knowledge gaps that were identified at the WKAMF workshop. The agenda for the workshop is in Annex 11.

All objectives of the workshop were met. After seven contributed talks in the morning, workshop participants described their research areas with the aim of identifying colleagues who were interested in similar subject matter and potential research collaborators. Information about the developing BASIN program, a potential source of funding for international research teams, was presented. The following discussions focused on current understanding and impediments associated with the six major research needs identified at the WKAMF workshop:

- 1) validation and sensitivity methods,
- 2) model complexity,
- 3) physics (turbulence, mixing and circulation prediction),
- 4) energetics,
- 5) mortality, and
- 6) behaviour and cues.

After discussing each of these topics, workshop participants decided that mortality was a knowledge gap that pervaded many disciplines and a targeted 'WKAMF' approach would be warranted, involving a theme section at the ICES Annual Science Conference in 2009 and a workshop just before the 2010 WGPBI meeting with results disseminated in the peer review literature.

More details on the discussions can be found in Annex 11.

Coupled Biophysical IBM Book. WGPBI member Sarah Hinckley and co-authors Bern Megrey and Al Hermann propose to produce a book tentatively titled "Methods for spatially-explicit individual-based modelling of marine organisms: coupling of biology with hydrodynamics." Although the book was inspired by the WKAMF Manual of Recommended Practices, it will be significantly different from the Manual of Best Practices, but may overlap somewhat in subject matter. The organization of

the book would follow a step by step process of model development that follows the scientific method and include case studies for illustration. The book is intended for students/scientists with problems that appears to be suited for a IBM/hydrodynamic model treatment, but who haven't developed or used such models, and for students learning methods of modelling in marine science. Chapters would include, but not be limited to, the history of coupled biophysical models, potential applications, problem definition (hypotheses and modelling objectives), conceptualization, implementation, calibration/validation, analysis of output, case studies, and future directions.

WGPBI would be the 'home organization' of the book, provide advice and guidance, and would put the book on its list of tasks. WKAMF members/WGPBI collaborators would be encouraged to serve as contributors and peer reviewers. An Advisory Board, consisting of Elizabeth North, Alejandro Gallego, Pierre Petitgas (and others if interested) would provide general guidance for the project and ensure international breadth. After discussions with a Blackwell editor last fall, Hinckley *et al.* were encouraged to submit a proposal (which they would like to do by fall).

WGPBI members applaud Hinckley *et al.* for their willingness to undertake a substantial project that will provide a valuable resource for the modelling community. Members were not aware of other efforts on coupled IBM models, but recommend that authors review W. Fennel and T. Neumann's book "Introduction to the Modelling of Marine Ecosystems" to minimize overlap. It is not clear if the book will be suitable for a semester-long class, but could be ideal for an intensive summer school setting. Members suggest that a model tutorial component be added, and that the book be synthetic (more than just a collection of papers) if additional authors will write chapters.

WGPBI encouraged Sarah Hinckley, Bern Megrey and Al Hermann to move forward with planning and writing the book "Methods for spatially-explicit individual-based modelling of marine organisms: coupling of biology with hydrodynamics" and report on its status and progress at the 2009 WGPBI meeting. North, Gallego and Petitgas will participate on the advisory board and support this effort.

13 Other Business

ICES/PICES Conference for Early Career Scientists.

Elizabeth North

The ICES/PICES Early Career Scientists Conference, entitled "New Frontiers in Marine Science", was held at the Conference Center at the Maritime Institute Baltimore, Maryland, U.S.A., from 26–29 June 2007 (www.pices.int/newfrontiers.aspx). Over 100 early career scientists (mostly postdocs and PhD students) and ~15 senior scientists attend the conference. Twenty nations were represented. This first joint activity of ICES and PICES was organized by a Scientific Steering Committee (SSC) that included early career scientists Jens Floeter, Sukyung Kang, Julie Keister, Franz Mueter, Elizabeth North (local host), and Angel Lopez-Urrutia. Adi Kellermann (ICES) and Skip McKinnell (PICES) provided excellent guidance to the SSC. Elizabeth North was appointed to the SSC by the ICES Oceanography Committee. Conference theme sessions included:

- Biodiversity and productivity of marine organisms from pole to pole
- Processes at ocean margins
- The last frontier: processes in the deep sea

- The role of behaviour in marine biological processes
- The effect of climate on basin-scale processes and ecosystems
- Humans and the marine environment

A more detailed summary of the conference written by Franz Mueter can be found at http://www.pices.int/publications/pices_press/volume15/v15_n2/pp_11_13_ECSC-Mueter_f.pdf. In addition to raising the profile of ICES and PICES with the next generation of young scientists, establishing lasting contacts and networks for conference participants, and encouraging early career scientists to think and act on an international level, papers based on talks at the conference have been submitted to a theme section in ICES Journal of Marine Science. North and Mueter are serving as guest editors. Currently 10 papers are in revision, with resubmission by end of April and target completion date for the theme session on 1 September 2008. The wide range in the subject matter of papers, from biogeochemical modelling of East China Sea to fish behaviour discerned through acoustics, reflects the diverse and innovative approaches of conference attendees.

Action: Complete ICES Journal of Marine Science theme section based on the ICES/PICES Early Career Scientists Conference (Baltimore, June 2007) and report to WGPBI in 2009. (North)

BASIN: Basin-scale Analysis, Synthesis, and Integration (A status report)

Cisco Werner and Mike St. John

BASIN is a proposed joint EU / North American research programme initiative with the primary focus on the integration and synthesis of existing and future data sets for coupling with modelling studies at the basin-scale in order to elucidate the mechanisms underlying observed changes in physical and biological changes in the North Atlantic Ocean and to predict consequences of climate and environmental change. The ultimate goal is the development of an understanding of the links between climate and the marine ecosystems of the North Atlantic Basin and the services these ecosystems provide including exploited marine resources, and to use this understanding to develop ecosystem based management strategies that will anticipate the effects of climate change on the living resources of the region. Thus the overarching aim of the BASIN initiative is to understand and predict the impact of climate change on key species of plankton and fish, and associated ecosystem and biogeochemical dynamics in the North Atlantic in order to improve ocean management and conservation. Reports of past BASIN meetings can be found at the <http://web.pml.ac.uk/globec/structure/multinational/basin/basin.html> website. The Science Plan is being written. A draft will be posted for public comment, with targeted completion for the autumn of 2008.

Skill Assessment of Physical-Biological Models

Cisco Werner and Charles Hannah

Simulation models coupling physics to biological processes in the ocean are central to a large number of current research programs. Ocean physical models have approached a high level of simulation sophistication, as the state space and the physical relationships within it are canonical; and modern computational technology for fluid mechanics has been advanced in scholarly communities for two generations or more. The complexity of biological processes in the ocean presents an enormous explosion of state variables and their interaction. As a result, there is a recognizable

mode of operation wherein 'complete' physics is coupled to reduced-complexity biology; and successful simulations are typically chosen to fit field problems and available data. The upshot of this situation is enormous diversity in what is possible in 'replicating observations', and even more importantly, in assimilating them into simulations and creating forecast systems. The biological problems therein are of immediate societal concern, and there is a sense that skilful simulations can be constructed. Yet what is meant by 'simulation' in this context is typically very different depending on the target problem. Examples include the Joint Global Ocean Flux Study (JGOFS), Ecology and Oceanography of Harmful Algal Blooms (ECOHAB), and Global Ecosystem Dynamics (GLOBEC), all of which have had numerous regional manifestations in terms of target organisms, interactions, and data. We reviewed the status of an activity that focused on skill assessment in marine systems across species and ecosystems, geographical places, and data types. A special issue in the *Journal of Marine Systems* is near completion (18 manuscripts have undergone peer review and have been recommended for acceptance). Publication of the Special Issue, guest-edited by D. Lynch, D. McGillicuddy and C. Werner, is expected for the summer of 2008.

EUROCEANS Vital Rates Database

Mike St. John

Goals

The aim of this EUROCEANS funded project is to construct a **single point access database** for end-to-end ecosystem model parameterisation by:

- 1) compiling recent data on key species vital rates (growth, feeding, hatching, energy expenditure, energy requirements) measured in controlled laboratory experiments (lower trophic levels, fish larvae) and in situ (top predator bioenergetics), and
- 2) transforming data into carbon/nitrogen flux units (or energy requirements in J/kg for top predators) for model assimilation.

Development is primarily funded through EUROCEANS Data Transformation Call as well as with the support of Alfred Wegner Institute, EUROCEANS WorkPackages for Model Interfacing (WP 3.1) and Ecosystems End-to-end (WP 4). The database provides key information for the parameterisation of biogeochemical and ecosystem models by WGPBI members as well as the modelling and experimental community not only for model parameterisation but also for identification of gaps in process and physiological understanding. **DATA PARTNERS** contribute data to the data base effort and in exchange will gain full access to other partner's data while the effort is ongoing, until May 2008 when the all data will be made public.

Access

The vital rates database will be shared with partners only until **MAY 2008** after which access will become public. As of January 2008, the database contained over 18 500 open access data points on:

Bacteria	3 500 (90% production)
Coccolithophorids	1 000 (production)
Diatoms	750 (production and respiration)
Nanozooplankton	2000
Microzooplankton	450 (growth and respiration)
Mesozooplankton	9 500 (EPR, growth and mortality)
Fish Juveniles	170 (growth and respiration)
Fish Adults	1 000 (respiration and clearance)

The list of partners and other information is given in the Abstract in Annex 13.

Temperature and phytoplankton growth

St. John and Hannah

The relationship between temperature and phytoplankton growth is an outstanding issue in the modelling of phytoplankton bloom dynamics and the incorporation of carbon and hence for WGPBI. Early work by Eppley (1972) provided a major synthesis of the area when he compiled laboratory data on growth rates as a function of temperature. The Eppley curve provides the maximum possible growth rate as a function of temperature. The Eppley (1972) growth rates are expressed in terms of 'cell doublings' whereas the majority of models that use the Eppley curve use it in relation to the amount of carbon (or nitrogen) fixed. This involves an implicit assumption that cell size and carbon (or nitrogen) content is independent of temperature. In contradiction there is the general rule that cell size decreases as temperature increases (e.g. Montagnes and Franklin 2001) and there is the experimental result of Goldman and Ryther (1976) that the generation of particulate organic carbon was maximized for temperatures less than the temperature that maximized cell doubling (the optimal temperature). In addition Li (1980) observed that phytoplankton in the ocean tend to occur in temperatures less than the optimum for cell doubling.

In this study the literature has been reviewed for laboratory experiments examining the relationship between doubling rate, cell volume, cell carbon content and temperature. Preliminary analysis supports the general rule that cell size decreases with temperature (note that the general rule derived across species need not apply to a single species). There is also a suggestion that the rate of carbon fixation is roughly independent of temperature. In particular, the decrease in cell size with temperature is balanced by the larger number of cells at lower temperatures with carbon to volume being independent of temperature. Analysis, interpretation and a manuscript are in progress.

References

- Eppley, R.W. 1972. Temperature and Phytoplankton Growth in the Sea. *Fishery Bulletin*, 70: 1063–1085.
- Goldman, J.C., and Ryther, J.H. 1976. Temperature-Influenced Species Competition in Mass Cultures of Marine Phytoplankton. *Biotechnology and Bioengineering*, 18: 1125–1144.
- Li, W.K.W. 1980. Temperature adaptation in phytoplankton: cellular and photosynthetic characteristics, pp. 259–279. In P.G. Falkowski [ed.], *Primary productivity in the sea*. Plenum.

Montagnes, D.J.S., and Franklin, D.J. 2001. Effect of Temperature on Diatom Volume, Growth Rate, and Carbon and Nitrogen Content: Reconsidering Some Paradigms. *Limnology and Oceanography*, 46: 2008–2018.

14 Final Business

The group discussed the request from the Working Group on Harmful Algal Blooms (WGHABD) to hold a joint meeting in 2009. This would consist of co-location with one joint day. This idea was accepted.

It was noticed that the number of 3d comprehensive modelers in attendance was much lower than normal. This could be a problem if the trend continues. It was suggested that in the near future one or more meetings should be held at labs with large modeling groups to increase the number of 3d modelers.

Charles Hannah (Co-Chair) noted that the group needs to nominate a new Co-Chair next year.

The meeting was adjourned at 1 pm Thursday 3 April 2008.

Annex 1: List of Participants

Name	Address	email
Marina Chifflet	AZTI Spain	mchifflet@pas.azti.es
Wolfgang Fennel	Leibniz-Institut für Ostseeforschung Warnemuende, Germany	wolfgang.fennel@io- warnemuende.de
Lennart Funkquist	SMHI, Sweden	Lennart.Funkquist@smhi.se
Alejandro Gallego	FRS Marine Lab, Aberdeen, UK	A.Gallego@MARLAB.AC.UK
Charles Hannah (Co-Chair)	BIO/DFO, Halifax, Canada	HannahC@mar.dfo-mpo.gc.ca
Martin Huret	Ifremer, France	martin.huret@ifremer.fr
Frank Janssen	BSH, Hamburg, Germany	frank.janssen@bsh.de
Rubao Ji	WHOI, USA	rji@whoi.edu
Geneviève Lacroix	MUMM, Belgium	g.lacroix@mumm.ac.be
Andres Moll	University of Hamburg	moll@ifm.uni-hamburg.de
Elizabeth North	UMCES Horn Point Lab, Maryland, USA	enorth@hpl.umces.edu
Anna Neuheimer	Dalhousie University, Halifax, Canada	Anna.Neuheimer@phys.ocean.dal.ca
Tom Osborn	Johns Hopkins University, USA	osborn@jhu.edu
Pierre Petitgas	Ifremer-Nantes, France	Pierre.Petitgas@ifremer.fr
Anna Pfeiffer- Herbert	GSO/URI, USA	annaph@gso.uri.edu
Marie Savina	IFREMER-Brest France	marie@niyelopell.com
Maggie Sexton	UMCES Horn Point Lab, Maryland, USA	msexton@hpl.umces.edu
Matteo Sinerchia	Imperial College, London, UK	matteo.sinerchia02@imperial.ac.uk
Katie Smith	UMCES Horn Point Lab, Maryland, USA	
Michael St John	University of Hamburg, Germany	michael.st.john@uni-hamburg.de
Uffe Thygesen (Co-Chair)	DIFRES, Denmark	uht@difres.dk
Alexander Trofimov	PINRO, Murmansk, Russia	trofimov@pinro.ru
Cisco Werner	University of North Carolina, USA	cisco@unc.edu
Colleen Petrik	WHOI, USA	cpetrik@whoi.edu
Pierre Fréon	IRD, France	
Christophe Lett	IRD, Sete, France	Christophe.Lett@ird.fr

Annex 2: Terms of Reference for 2008 Meeting

2007/2/OCC06 The **Working Group on Modelling Physical Biological Interactions [WGPBI]** (Co-Chair: C. Hannah, Canada and U. Thygesen, Denmark) will meet in Sète, 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 and suggest future coordinated research actions;
- 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) report on 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) report on approaches for combining field and laboratory data together with biological-physical models to examine processes controlling zooplankton populations;
- j) discuss and report on how WGPBI fits into the new ICES structure.

Annex 3: Agenda for 2008 Meeting

Monday March 31: WKAMF Follow-up workshop. See Annex 11

Tuesday April 1

- | | |
|-------------|--|
| 09:00–09:15 | Welcome, etc. |
| 09:15–10:15 | Presentation of new results: 3 x 20 minutes
<i>North: Coupling ecosystem and optimization models for oyster restoration</i>
<i>Ji: Processes controlling plankton dynamics in the Gulf of Maine</i>
<i>Janssen: Inter-annual variability of cyanobacteria blooms in the Baltic Sea.</i> |
| 10:15–10:30 | Discussion |
| 10:30–11:00 | Coffee |
| 11:00–12:00 | Presentation of new results: 3 x 20 minutes
<i>Sexton: Nowcasting Sea Nettle populations in Chesapeake Bay.</i>
<i>Funkquist: Migration of crab larvae, a combined model and field study.</i>
<i>Sinerchia/Woods: Virtual Ecology Workbench version 3.3.</i> |
| 12:00–13:30 | Lunch |
| 13:30–13:50 | Model coupling (St. John, Bolding, action item 13) |
| 13:50–14:10 | Skill Assessment for Coupled Biological/Physical Models of Marine Systems (Werner and Hannah, action item 15) |
| 14:10–14:30 | Dynamic coupling of fish with hydroclimate and lower trophic levels: What to do about it? Discussion. (action item 12) |
| 14:30–15:00 | Coffee |
| 15:00–15:20 | Maximum phytoplankton growth rates as a function of temperature. (Review by Mike St. John, Charles Hannah; action item 4) |
| 15:20–15:40 | Requirements for monitoring data for PBI models. (Dahlin and Hannah action item 10) |
| 15:40–16:15 | WKAMF: The theme section in MEPS + the Manual of Best Practices + IBM book project. North, Gallego, Petitgas + Hinckley in absentia (action items 7,8) |
| 16:15–16:20 | Report on the ICES/PICES Early Career Scientists Conference, 2007. North. |
| 16:20–17:00 | Discussion. |

Wednesday April 2: Joint meeting with WGZE

WGPBI session

- | | |
|-------|---|
| 09:00 | Hannah: Overview of WGPBI |
| 09:10 | Osborn: Holographic imagery of turbulence and plankton (action item 11) |
| 09:30 | Woods: The LERM-ES model |
| 09:50 | Neuheimer: Modelling juvenile <i>Calanus finmarchicus</i> on Georges Bank: Where have all the nauplii gone? |
| 10:10 | Fennel: Food web modelling – from nutrients to fish |
| 10:30 | Zooplankton modelling in GLOBEC-Germany, with a view towards higher trophic levels (Moll, action item 13) |
| 10:50 | Discussion |

11:00 End of session

WGZE Session

Discussion

Thursday April 3

09:00–10:00	Complete unfinished business from Monday
10:00–10:30	Review of action items for 2007. Draft proposals for ICES ASC theme sessions in 2009.
10:30–11:00	<i>Coffee</i>
11:00–13:00	Discussion The new ICES science structure Add items to the WGPBI Activity list Ideas for invited speaker next year Resolutions for 2009 workshop(s). Draft WGPBI Resolution for 2009 – Terms of Reference – Location and local host for 2009 meeting (Dates can be set later). – Joint meeting with WGHABD in 2009. Announce WGPBI sponsored Theme Sessions for 2008 Outline writing assignments for Working Group Report Action Items for 2008 – who is actually doing things? Close the meeting
13:00	<i>Lunch</i>

Annex 4: WGPBI Terms of Reference for the 2009 meeting

The Working Group on Modelling Physical Biological Interactions [WGPBI] (Co-Chairs: Charles Hannah, Canada, and Uffe Thygesen, Denmark) will meet in El Rompido (Huelva) Spain from 31 March to 2 April 2009 to:

- a) Discuss and evaluate new results concerning physical-biological interactions;
- b) Complete the publication of the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History;
- c) Prepare for the ASC theme session on “Death in the Sea,” the Workshop on Mortality (WKMOR) and evaluate advances on modelling fish early life stages;
- d) Prepare for the ASC Theme Session on “Combining models of the full life cycle of fish with lower trophic models: integration and prediction” and continue to evaluate proposed approaches for coupling regional models of NPZD-type biogeochemistry with higher trophic levels;
- e) Demonstrate potential effects of climate change on the lower trophic levels of marine ecosystems;
- f) Develop a statement of requirements for monitoring data to be useful for development and validation of models of physical-biological interactions and review the state of micro-instrumentation available for use in monitoring;
- g) Meet with the Working Group on Modelling Harmful Algal Bloom Dynamics (WGHABD) and develop projects of mutual interest (please fix this).

WGPBI will report by 30 April 2009 to 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:	<p>The work of WGPBI contributes to the following ICES Activities:</p> <p>Action Plan no. 1.5 (modelling biological-physical interactions in the sea),</p> <p>Action Plan no 1.1 (provide feedback about research needs),</p> <p>Action Plan no 1.2 (increase knowledge with respect to functioning of the ecosystem).</p> <p>a) Providing a forum for the presentation and discussion of new results is an important component of the Group's mandate.</p> <p>b) The participants at WKAMF have completed the "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History". A resolution for publication as an ICES Cooperative Research Report has been prepared.</p> <p>c) The larval fish subgroup identified mortality as the top priority topic. To address this issue we propose a Theme Session for the 2009 ICES ASC and a workshop for 2010. The group also supports Sarah Hinckley (WGPBI member) and co-authors Bern Megrey and Al Hermann in their proposal to write a book tentatively titled "Methods for spatially-explicit individual-based modeling of marine organisms: coupling of biology with hydrodynamics." The book was inspired by the WKAMF Manual of Recommended Practices. WGPBI will continue to evaluate advances on modelling fish early life stages with a focus on the topics recognised as priority topics by the group in 2008.</p> <p>d)The next big development of physical-biological models is an increase in the number of feedback loops (or equivalently the number of interacting components in the systems) that are routinely implemented in regional models. For example groups are now exploring full life cycle models of fish coupled to regional NPZD models: a Theme Session for the 2009 ASC is proposed. A second example is the EU project MEECE whose goal is to implement a systematic software system for integrating different model components into a single coupled system. In numerical weather prediction this is called a coupler. The use of formal couplers is in its infancy in marine ecosystem modelling but couplers will become important as the need for integrating more and more ecosystem components increases and the required knowledge exceeds the scope of any single group. WGPBI needs to be aware of these developments.</p> <p>e) 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.</p> <p>f) 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 assessability? The draft statement needs to be revised intersessionally. In addition, instrumentation is constantly evolving and getting smaller. The WG needs to understand what is possible in terms of mounting instruments on gliders and floats.</p> <p>g) WGPBI and WGHABD have planned an overlapping meeting for 2009. The goal is to explore topics of mutual interest between members of the WGs and facilitate collaborations between members of the two groups.</p>
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:	ACOM
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 WGHABD in 2009.	WGPBI and WGHABD
3. WGPBI recommends that the ICES Publication Committee consider publication of the WKAMF Manual of Recommended Practices for Modeling Physical-Biological Interactions in the Early Life of Fish as an ICES Cooperative Research Report (Resolution in Annex 7)	Oceanography Committee Publication Committee
4. Theme Session for 2009 ASC “ Death in the sea – Mortality in the zooplankton and early-life stages of marine fish (estimates, processes and outcomes) ”: Convenors: A. Gallego, E. North, E. Houde. Annex 6	Oceanography Committee
5. Theme Session for 2010 ASC “ Combining models of the full life cycle of fish with lower trophic models: integration and prediction ” Convenors: P. Petitgas, plus. Annex 6	Oceanography Committee
6. Workshop for 2010: WKMOR “ Understanding, quantifying and predicting mortality in fish early-life stages: experiments, observations and models ” Resolution in Annex 8	Oceanography Committee
7. The ToRs of Expert Groups should be coded with reference to major goals of the new ICES Science Plan and that such coding be used to help with the integration of Expert Groups results towards achieving these goals.	Oceanography Committee and CONC

Annex 6: Theme Session Proposals

Theme sessions proposed for 2009 ICES ASC

Death in the sea – Mortality in the zooplankton and early-life stages of marine fish (estimates, processes and outcomes)

Convenors: A. Gallego, E. D. Houde, E. W. North

With the development of new laboratory and field observational techniques, and the advance of modelling methodology, it is time to review approaches for estimating, simulating, and improving our understanding of the processes that control mortality in the zooplankton and early-life stages of marine fish. Mortality is difficult to quantify in the field (e.g. teasing apart “true” mortality from advection/diffusion effects). In addition, little is known about the relative importance of individual processes (e.g. disease, parasitism, starvation, predation, and density-dependence) and how they contribute to overall survival at the end of the larval/early juvenile period. This theme session will survey methods for 1) estimating mortality in the field, 2) understanding underlying processes, and 3) constructing process-based forecasting tools that quantitatively link adult biomass/egg production with post-juvenile stages. We invite contributions based on laboratory and mesocosm experiments, field studies, modelling research, and synthetic approaches that elucidate, estimate, and forecast mortality of zooplankton and pre-recruit stages in marine fish.

Theme Session for 2010 ICES ASC

Combining models of the full life cycle of fish with lower trophic models: integration and prediction

Convenors: P. Petitgas, plus

Rationale: The subject is the key to understanding the many controls of population dynamics that occur at various stages in the life history. Mechanistic tools are necessary to increase predictability of changes in fish distribution and productivity under global change scenarios and for fishery management or restoration plans. Some models and applications have already been developed and a first review is timely on this topic of growing scientific interest.

Presentations are welcomed on: bioenergetics models, displacement models and feeding models of the juvenile and adult fish at individual and population levels, as well as on their demonstrative use in applied cases.

Dr. Petitgas will search for a co-convenor from the GLOBEC community (possibly M Barange) or the PICES community (possibly B. Megrey or C Werner).

Annex 7: Resolution for an ICES Internal Publication

The report on the **Manual of Recommended Practices for Modelling Physical-Biological Interactions during Fish Early Life**, edited by E. W. North (USA), A. Gallego (UK), and P. Petitgas (France), as reviewed and approved by the Chair of the Oceanography Committee, will be published in the *ICES Cooperative Research Report* series. The estimated number of pages is 122.

The Working Group on Modelling Physical-Biological Interactions (WGPBI) agrees to submit the final draft of the proposed publication by 1 July 2008.

Supporting Information

Priority:	Modelling physical–biological interactions in the early life of fish is becoming an important technique for enhancing our understanding and prediction of marine ecosystem dynamics, fisheries recruitment variability, and population connectivity. Coupled bio-physical models have been applied to gain new insight on how planktonic dispersal, growth and survival are mediated by changing physical and biological conditions. They have contributed to enhanced understanding of fish population variability and stock structure and have been used to design marine protected areas. A synthesis of current methodologies, recommended techniques, example applications, and a summary of knowledge gaps is needed to advance the field and efficiently train early career scientists.
Scientific justification:	The objectives of the Manual of Recommended Practices (MRP) are to summarize appropriate methods for modelling physical-biological interactions during the early life of fish, recommend modelling techniques in the context of specific applications, and identify knowledge gaps. The MRP presents a synthesis of recommended practices for coupled biological-physical models that incorporate predictions from three-dimensional circulation models to determine the transit of fish eggs, larvae, and juveniles from spawning to nursery areas. This manual is intended to provide a reference for early career modellers who are interested in applying these numerical models to fish early life. For current practitioners of numerical modelling in fish early life, the manual provides updates on latest techniques and areas in need of further research. Although the focus of the manual is on finfish, many of the summarized modelling techniques and recommended practices apply to modelling planktonic organisms including zooplankton and other meroplankton (e.g. molluscs and crustaceans).
Resource requirements:	Publication of this material as a CRR will cost ca. 10 000 DKK. The material in the report is fairly straightforward, and therefore no specific additional costs are necessary. There may be some additional costs for hardcopy production because of a number of colour figures.
Participants:	Approximately one month's work is required by the editors to finalise this draft.
Secretariat facilities:	About one month of the services of Secretariat Professional and General Staff will be required.
Financial:	Publication of this material as a CRR will cost ca. 10 000 DKK. There may be some additional costs for hardcopy production because of a number of colour figures.
Linkages to advisory committees:	No direct linkages.
Linkages to other committees or	Working Group on Recruitment Processes.

groups:	
Linkages to other organizations:	EUROCEANS and GLOBEC endorsed the activities and objectives of WKAMF.

Annex 8: Resolution for a Workshop

A Workshop entitled **Understanding and quantifying mortality in fish early-life stages: experiments, observations and models** [WKMOR] will be established with Co-Chairs: A. Gallego*, UK, E. North*, USA, and E. Houde*, USA, will be held on 22–24 March 2010 in Aberdeen, Scotland [dates and venue to be confirmed], to:

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

The workshop will report by 15 May 2010 for the attention of the Oceanography Committee.

Supporting Information

Priority:	This workshop will bring together state-of-the-art knowledge about a process which is critical for the understanding of recruitment in marine fish.
Scientific Justification and relation to Action Plan:	<p>The Workshop contributes to the new ICES Strategic Goal #3 that ICES should lead the development of methods and tools needed in support of operational ecosystem observation services, in order to improve the understanding of climate change and impacts to our oceans and marine ecosystems.</p> <p>The topic of fish early-life mortality has been the subject of considerable research. Nevertheless, it is still considered one of the main topics where substantial progress remains to be made (see WKAMF Report). With the development of new laboratory and field observational techniques, and the advance of modelling methodology, it is time to review approaches for estimating, simulating, and improving our understanding of the processes that control mortality. The workshop goal is to develop recommended practices for quantifying mortality in the field (e.g. accounting for advection/diffusion effects) and for constructing process-based forecasting tools that quantitatively link spawning stock biomass/egg production and post-juvenile stages. The proposed workshop will focus on technical and methodological issues, important physical-biological processes (inc. density-dependence), and on future research needs. This workshop will foster information exchange between international organizations such as ICES and PICES. The workshop, and the international collaboration that result from it, will advance the application of cutting-edge modelling approaches to issues that are critical for fisheries management such as understanding fish recruitment variability.</p>
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 25–50 participants and will include some scientists from outside the regular ICES scientific community. We plan to identify participants during the 2009 ASC Theme Session proposed by WGPBI entitled "Death in the sea – Mortality in the zooplankton and early-life stages of marine fish (estimates, processes and outcomes)". We also will invite participation from ICES groups with an interest in physical-biological interactions and fish recruitment processes (e.g. WGRP, WGZE, WGFE) 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 advisory structure
Linkages To other Committees or Groups:	WGRP, WGZE, WGFE

Annex 9: Action Items 2008/2009

- Item 1. Joint meeting with WGHABD. Plan joint day. Hannah, Lacroix, and others, plus WGHABD. Dates set.
- Item 2: 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 3: At 2009 meeting consider the following two ToRs for 2010: 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 4: The work of WKIMS should be carried on. Consider Petitgas proposal for a workshop in 2010 on fish habitat. Petitgas.
- Item 5: WKAMF: Complete publication of Manual of Best Practices. North Gallego Petitgas
- Item 6: 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 7: 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. Have a rough draft. Needs work intersessionally. Hannah will have to try and coordinate a discussion during the year.
- Item 8: 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 9: Review proposed approaches for coupling higher trophic levels with NPZD models (St. John E2E, plus, Moll)
- Item 10: Start search for new Co-Chair to replace Hannah after 2009 meeting.
- Item 11: Encourage Hinkley, Megrey, and Hermann on their book with the working title "Methods for spatially-explicit individual-based modeling of marine organisms: coupling of biology with hydrodynamics."
- Item 12: Prepare for WKMOR in 2010. Gallego, North, Petitgas.

Annex 10: WGPBI Activities

YEAR	EVENT
2004	<p>Workshop on 'Future Directions for Modelling Physical Biological Interactions.', Chairs Peters and Hannah (Barcelona, March 2004).</p> <p>WGPBI meeting (Barcelona, March 2004).</p> <p>Theme Session at ICES ASC on Physical-Biological Interactions: Experiments, Models and Observations (September 2004, Vigo Spain).</p> <p>WG web page is located at www.icm.csic.es/bio/projects/wgpbi/wgpbi.htm and maintained by Cesc Peters.</p>
2005	<p>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.</p> <p>First meeting the Numerical Experimentation Subgroup (Hamburg, 6 April 2005).</p> <p>First meeting of the Larval Fish Group (Hamburg, 6 April 2005).</p> <p>WGPBI meeting (Hamburg, April 2005).</p> <p>Draft review of nutrient load reduction experiments. See Section 5 of 2005 Report.</p> <p>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. <i>Journal of Marine Systems</i>, 57(3-4):289-300.</p>
2006	<p>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.</p> <p>WGPBI meeting 6-7 April 2006 in Nantes France.</p> <p>Database on effects of turbulence on planktonic organisms. F. Peters. What is current status?</p> <p>Peters, F., and C.G. Hannah (editors). 2006. Special Issue on Future Directions in Modelling Physical-Biological Interactions. <i>J. Marine Systems. Journal of Marine Systems</i>. Volume 61, Issues 3-4, Pages 115-274 (July 2006).</p> <p>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</p> <p>Theme session at ICES ASC on 'Operational Oceanography' (joint with PICES). Co-Convenor: G. Han.</p> <p>Workshop on 'Indices of Meso-scale Structures in ICES waters', 22-24 February 2006 in Nantes France. Joint with ICES SGRES (Study Group on Regional Scale Ecology of Small Pelagics). Co-Chair: C. Schrum</p> <p>Synthesis of progress on zooplankton modelling in German GLOBEC. T. Neumann and A. Moll</p> <p>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. <i>Oceanography and Marine Biology; an Annual Review</i>, Vol. 44:in press.</p> <p>WGPBI "Inventory of Operational and Preoperational Models" at http://northweb.hpl.umces.edu/WGPBI/WGPBI_links.htm.</p> <p>WKAMF Participants Web Page at http://northweb.hpl.umces.edu/wkamf/home.htm</p>

YEAR	EVENT
2007	<p>WGPBI Meeting. Bergen Norway 25–28 March 2007.</p> <p>Gallego, North, Petitgas (editors) Special section of Marine Ecology Progress Series devoted to papers from the Advancements in modelling physical-biological interactions in the early-life history of fish: recommended practices and future directions larval fish modelling.</p> <p>Hannah, C.G. 2007. Future directions in modelling physical-biological interactions. Marine Ecology Progress Series. 347: 301–306. Summarizing main themes from 5 years of deliberations of SGBPI and WGPBI.</p> <p>First draft of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History. Gallego, North, Petitgas (editors).</p> <p>Workshop on 'Parameterizing Trophic Interactions in Ecosystem Models.' 20–24 March 2007, Cadiz Spain. Organized as part of EurOceans. Mike St. John</p> <p>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</p> <p>Theme Session at ASC on 'Linking oceanographic physical features with biological production and fish habitat potentials' Conveners: Pierre Petitgas, Corinna Schrum, and Charles Hannah</p>
2008	<p>Meeting of Larval Fish subgroup to consider activities flowing from WKAMF. Sete, France, 30 March 2008.</p> <p>WGPBI meeting, 31 March to 3 April 2008, Sete, France. One day joint session with WGZE</p> <p>Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History is complete. A resolution will be written for publication in ICES Cooperative Research Reports. North, Gallego, Petitgas.</p> <p>Theme Session at ASC on 'Coupled Physical and Biological Models: Development and Validation.' Co-Convened by Han and Moll. Joint with XXX</p> <p>Theme Session at ASC on 'Size is almost everything! Size and trait based processes and models in ecosystems and management'. Co-Convened by Ken Haste Andersen. Joint with XXX</p> <p>Review of temperature dependence of maximum growth rates for phytoplankton. St. John and Hannah. A manuscript is in preparation.</p> <p>Good ideas for next generation of zooplankton modules in PBI models. Non-mass state variables and stage resolved, etc. All. No progress</p>
2009	<p>WGPBI meeting 31 March – 2 April 2009, Huelva, Spain. Joint with WGHABD.</p> <p>Theme Session for 2009 Death in the sea – Mortality in the zooplankton and early-life stages of marine fish (estimates, processes and outcomes): Convenors: A. Gallego, E. North, P. Petitgas</p> <p>Publication of Manual of Best Practise.</p>
2010	<p>WGPBI meeting 25–26 March 2010, Aberdeen.</p> <p>Workshop on 'Understanding, quantifying and predicting mortality in fish early-life stages: experiments, observations and models' (WKMOR) 22–24 March, 2010. Aberdeen. Gallego, North, Petitgas.</p> <p>Theme Session for 2010 'Combining models of the full life cycle of fish with lower trophic models: integration and prediction'. Convenors: P. Petitgas, plus Hinkley, Megrey, and Hermann. Methods for spatially-explicit individual-based modeling of marine organisms: coupling of biology with hydrodynamics. Draft of book.</p> <p>Update WGPBI Inventory of Operational and Preoperational Models. Need to discuss for ToRs in 2009.</p>

Annex 11: WGPBI Larval Fish Group

WKAMF Collaborators Meeting

31 March 2007

Hotel Port Marine in Sète, France

Description

The WKAMF Collaborators Meeting will provide a forum for the continued interactions of the teams of researchers that were formed during the WKAMF workshop. The “Workshop on advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions” (WKAMF) was held in Nantes, France, on 3–5 April 2006 and was Co-Chaired by Alejandro Gallego (UK), Elizabeth North (USA) and Pierre Petitgas (France) (<http://northweb.hpl.umces.edu/wkamf/whome.htm>).

At the WKAMF Collaborators Meeting, participants will discuss recent research findings, current issues, and new model validation/parameterization techniques. Objectives are to share information about the advancing field, coordinate efforts, and develop ideas for future collaborative work and proposals for research programs. This meeting will be held just before the joint meeting of the ICES Working Group on Modelling Physical-Biological Interactions and the ICES Working Group on Zooplankton Ecology. The coordination of the WKAMF Collaborators meeting with the ICES working group meetings will facilitate the involvement of members of these groups.

Agenda

9:00 am	Opening: goals, rationale, agenda
9:20 – 9:40	J. Pierson. <i>Validating a novel hypothesis about zooplankton foraging behavior through model-data comparison.</i>
9:40 – 10:00	P. Verley. <i>Ichthyop: a Lagrangian tool for modelling ichthyoplankton dynamics.</i>
10:00 – 10:20	M. Huret, P. Petitgas, M. Woillez. <i>Description of the dispersal kernel with geostatistics.</i>
10:20 – 10:40	E. North, Z. Schlag, M. Li, L. Zhong, C. Hannah. <i>Parameterizing biophysical particle-tracking models: recommendations and implications for planktonic organism dispersal.</i>
10:40 – 11:00	Break
11:00 – 11:20	T. Kristiansen, F. Vikebø, F. E. Werner, R. G. Lough, S. Sundby, E. G. Durbin. <i>Factors determining growth and survival in early life stages of North Atlantic Cod: a comparative study between the NW Atlantic and Norwegian Sea ecosystems.</i>
11:20 – 11:40	A. Gallego. <i>The role of early life history in the maintenance of cod sub-population structure.</i>

11:40 – 12:00	J. Woods and M. Sinerchia. <i>A prognostic model of fisheries recruitment.</i>
12:00 – 13:30	Lunch
13:30 – 15:00	Coordinating research programs: discussion and strategic plans
15:00 – 15:20	Break
15:20 – 15:30	Developing research proposals: introduction
15:30 – 15:40	C. Werner. <i>Update on BASIN, a potential source of funding for international collaborative proposals.</i>
15:40 – 17:00	Developing research proposals: Discussion and strategic plans
17:00 – 17:30	Wrap up
17:30	Adjourn

WGPBI “Larval Fish Group” 2009–2011 Workplan

A Research Theme – MORTALITY in the early life stages of marine fish

Early-life stages are characterised by high mortality levels which are one of the main drivers of recruitment variability. Mortality is challenging to quantify in the field and its underlying processes are still not sufficiently understood. It is a critical parameter in models of pre-recruit fish, yet is it difficult to parameterize and often used as a closure term. Due to knowledge gaps which limit our understanding and prediction of fish early life, the WGPBI ‘Larval Fish Group’ will focus efforts on mortality for the next three years.

Proposed Methodology

We proposed to follow the same approach we used to review the current status and future directions in modelling physical-biological interactions in the early life of fish: ICES ASC Theme Session (2009), workshop adjacent to WGPBI annual meeting (2010) and – ideally – publication of workshop outcomes in the peer-reviewed literature and/or ICES CRR (edited in 2010–2011).

ASC Theme Session Description

Death in the sea – Mortality in the zooplankton and early-life stages of marine fish: estimates, processes and outcomes [title subject to change]

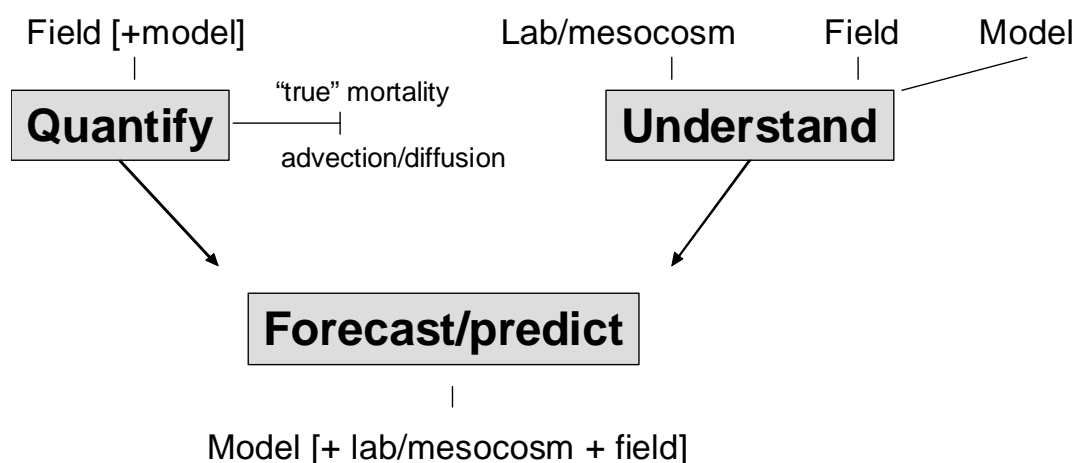
Relatively small changes in mortality levels may result in large variability in adult abundance. Mortality is difficult to quantify in the field (e.g. teasing apart “true” mortality from advection/diffusion effects). Moreover, little is known about the relative importance and mechanisms of individual processes (e.g. disease, parasitism, starvation, predation, and density-dependence) and how they contribute to overall survival at the end of the larval/early juvenile period. We invite contributions from laboratory and mesocosm experimental research, field studies, and modelling work to advance our ability to quantify mortality in the field, understand the underlying processes and their influence on zooplankton abundance and marine fish recruitment, and enable the development of predictive tools that make process-based quantitative linkages between adult stock biomass/egg production and post-juvenile stages. This includes relevant innovative approaches from studies of marine fish (including juvenile stages) and lower trophic levels (zooplankton).

2010 Workshop

“Understanding, quantifying and predicting mortality in fish early-life stages: experiments, observations and models” WKUM [title subject to change]

We propose to host a 3-day workshop in March/April, 2010, in Aberdeen, Scotland. The workshop will include talks from invited speakers, a poster session, and plenary and break-out discussions. In addition to a workshop report, a theme section in a peer-reviewed journal and/or an ICES CRR is expected products of this effort.

Here is the conceptual model that we will use to guide our activities:



Other activities

In addition to the above activities, the ‘Larval Fish Group’ of WGPBI will continue to address (e.g. through intersessional work to be presented at the annual WG meetings or invited presentations at WG meetings) the remaining topics identified as important in WKAMF:

- Validation and sensitivity
- Model complexity
- Physics
- Energetics
- Behaviour

Annex 12: Abstracts from Joint Session with WGZE

Holographic imagery of turbulence and plankton

Tom Osborn (Johns Hopkins University, Baltimore Maryland, USA)

Holograms observe the particles in the sample volume by scattering coherent light from the particles. This technique allows observation of many small particles in a relatively large three-dimensional volume. The comparison with microscopy is that while the resolution in the plane of the particle is the same, the resolution in the third dimension is not limited by the optical depth of field of the imaging system. Thus, holographic techniques for studying the plankton community have the advantage of seeing the small particles in a sample volume that is both wide and deep relative to the particle size.

A major breakthrough came with the development of numerical techniques for analyzing the holograms, which obviated the need for an optical bench to reconstruct the image by sending light through the film. The new, high resolution, high frame rate, digital cameras make ideal data capture vessels. Upon collection, the holograms are digital and not film based. The reconstruction can proceed directly using the numerical developments. These developments have enabled holographic, PIV movies. These movies allow us to study behaviour, feeding and physical/biological interactions for copepods, nauplii, diatoms and dinoflagellates.

- Movies were shown of a nauplii attempting, but failing, to capture a food particle.
- The feeding currents of a copepod were shown in real time while the creature sank through the water. The data were then all centered on the copepod and the close circulation pattern of the feeding currents became apparent.
- Spatial distributions of dinoflagellates were shown to be random in the absence and presence of prey, but the distribution of predator to prey spacing is not random. It was shown how the behaviour of different species and strains of dinoflagellates changes with the introduction of prey and with time after the introduction.

Some movies are available at: <http://www.me.jhu.edu/~lefd/shc/shc.htm>

A good reference that will lead to other interesting papers is:

Sheng, J., E. Malkiel, J. Katz, J. Adolf, R. Belas, and A. Place. "Digital Holographic Microscopy Reveals Prey-Induced Changes in Swimming Behavior of Predatory Dinoflagellates". *Proceedings of the National Academy of Sciences (PNAS)* 104. 44 (2007):17512–17517.

LERM – The first LE plankton ecosystem model with four trophic levels

Matteo Sinerchia and John Woods (Imperial College, London, UK)

LERM (Lagrangian Ensemble Recruitment Model) is an individual-based model designed to be integrated under the Lagrangian Ensemble metamodel which creates virtual ecosystems. It was created on the Virtual Ecology Workbench. LERM includes a classical food chain composed of phytoplankton (diatom), herbivorous zooplankton (calanoid copepod), carnivorous zooplankton (Loligo) and top predators, which are all modelled explicitly. The model uses phenotypic equations for all biological functions, including the physiology and behaviour of individual plankters. These equations were derived from the scientific literature.

Simulations were run at an Azores site under stationary annual forcing. After an initial transient period, the ecosystem converges to an attractor, in which the inter-annual variation of species biomass or demography is lower than the demographic noise (<15%). The emergent biomasses were comparable with observations at a close site. LERM is intrinsically stable, ergodic and provides a good signal:noise ratio.

The Virtual Ecology Workbench (VEW) is a software tool that makes it easy for biological oceanographers to create one-dimensional mathematical simulations of the plankton ecosystem in a mid-ocean mesocosm. It uses the Lagrangian Ensemble metamodel (Woods 2005), which computes emergent demography and biofeedback from individual-based models comprising phenotypic equations for the biological functions of each species in the modelled plankton community. The VEW is designed to be used by scientists who have no skills in computer programming; the VEW automatically writes Java code from phenotypic equations written in familiar form. Nor does the user need to be skilled in ecosystem modelling; the VEW automatically manages such tasks as chemical budgeting.

Modelling juvenile *Calanus finmarchicus* on Georges Bank: Where have all the nauplii gone?

A. B. Neuheimer, W. C. Gentleman, and C. Galloway (Dalhousie University, Halifax, NS)

Calanus finmarchicus dominates the copepod biomass and is a key link between primary production and higher trophic levels throughout the North Atlantic. On Georges Bank, the early life stages are a major prey source for larval cod and haddock, and peak fish spawning coincides with peak naupliar abundance in March/April. Data for *C. finmarchicus* repeatedly demonstrate a dramatic decline in naupliar abundance in May and an increase in June in every sub-region of the Bank. Understanding the cause of this trend is critical, as shifts in timing of the seasonal cycle of *C. finmarchicus* may lead to mismatch in co-occurrence with larval fish.

We use an age-within-stage population dynamics model to investigate the factors controlling the observed temporal variation in *C. finmarchicus* nauplii. The model incorporates temperature- and food-dependent development rates, field-estimated egg production rates (EPR), and female abundance based on observations of the U.S. Global Ocean Ecosystem Dynamics (GLOBEC) program. Use of field-estimated mean mortality rates results in modelled abundance that is erroneous by over an order of magnitude. This data/model discrepancy cannot be explained by food limitation or variation in egg production. Instead, time-varying and spatially explicit mortality rates are required to reproduce observed naupliar densities. These temporal variations in mortality appear correlated with *C. finmarchicus* female abundance, implying cannibalism as a major regulatory factor of naupliar abundance. Our results indicate the need for higher temporal and spatial resolution in mortality estimates. Moreover, this biological control of *C. finmarchicus* populations must be considered as an indirect avenue for the effects of climate change.

Food web modelling – from nutrients to fish

Wolfgang Fennel (Leibniz Institute for Baltic Sea Research, (IOW) Rostock, Germany)

Modeling of marine ecosystems was broadly divided into two branches – biogeochemical and fish production models. The biogeochemical models see the fish only implicitly as mortality rates, while fish production models see the lower food web basically through prescribed food, e.g. copepod biomass.

The contribution aims at bridging biogeochemical models and fish-production models, by coupling a NPZD-model with a fish model. The Baltic Sea is chosen as an example system, where the main fish dynamics is covered by two prey species (sprat and herring) and one predator (cod). The dynamics of the fish model is driven by size dependent predator-prey interactions.

The linkage of the model components is established through feeding of prey fish on zooplankton and recycling of fish biomass to nutrients and detritus. The model, which is in the current stage basically a box model, conserves strictly mass.

Experimental runs with fishing mortality and nutrient loads provide scenarios of fish catches in response to nutrient inputs. The relatively complex NPZDF-model makes it possible to analyse the choices for parameterizations of unresolved processes in truncated NPZD models in the light of a full food web representation. The model truncation affects not only the zooplankton mortality but also the dynamics of nutrients and detritus.

The model refers to the example of the Baltic Sea, but the approach can well be adjusted to other systems.

Zooplankton modelling in the German Bight during GLOBEC-Germany with a view to study sprat larvae growth – do we simulate copepod abundance correctly?

Andreas Moll, Christoph Stegert, Markus Kreuz and Wilfried Kühn (University of Hamburg, Hamburg, Germany)

The talk introduced the investigation of lower and higher trophic levels of the North Sea ecosystem, which are both influenced by their physical and biological environment. Copepods were focused due to their key role within the ecosystem acting simultaneously as predator and prey item within the food web. An improved ECOHAM version (ECOlogical Model, HAMBURG) has been developed to simulate the North Sea ecosystem and to study the temporal development and spatial variability of zooplankton biomass and abundance. The zooplankton was enhanced by a stage-structured population representing *Pseudocalanus elongatus* competing to the rest zooplankton biomass. Simulated three-dimensional fields were analysed to investigate the regional distribution of primary and secondary production in relation to the locally different stratification and circulation characteristics and their influence on population dynamics and total zooplankton biomass. Using reported weight-length relationships we gained a size-resolved spectrum of food items, which served as input for a coupled transport and individual-based growth model (IBM) for fish larvae. The IBM predicts growth and survival of larval sprat (*Sprattus sprattus*) depending on local prey availability and hydrodynamical conditions in the German Bight. The ecosystem model determined high variability of the different zooplankton prey size classes due to the physiological succession of copepod stages resulting in alternating match/mismatch patterns of prey for the sprat larvae, which could not be resolved using zooplankton biomass only. Due to this application of simulated zooplankton abundance data we questioned the reliability of three-dimensional zooplankton biomass and abundance data. Thus, in the second part of the talk an extensive comparison to German Bight observations were presented. The total zooplankton biomass was compared to monthly mean values derived from abundance counts obtained from CPR surveys for 1°x1° boxes. The zooplankton biomass resembled the observed annual cycle for most boxes. Measurements of copepod abundances were available from the GLOBEC Germany surveys in 2004. Counting was done during seven cruises between February and October at numerous

stations in the German Bight. Copepodite abundances were gained by Bongonets, while for the nauplii data from Multinet hauls were used. Comparing the annual cycle of model stage groups with those from field abundances one can see, that the model computed the high variability of the data, though the model tended to generate higher abundances. By comparing the development in space and time, the simulation showed less spatial variance but more peaks within the annual cycle. Finally, the simulated abundance data for *P. elongatus* were compared with observations at Helgoland Reede, and the simulation showed similar structure of fast increase followed by a slower decrease for “several generations”. Such undulating development of simulated abundances could not be measured during the GLOBEC-Germany cruises. This validation of influential state variables gives confidence that the model is able to calculate reliable stage development and abundances of *P. elongatus* as well as the range of bulk zooplankton biomass, and thus the ratio of population biomass to total biomass. In the German Bight, the population is below 20% in spring. The ratio increases up to 30% during summer. The number of generations was estimated from peaks in egg abundance to about 4–7 generations of *P. elongatus* in the southern North Sea. For the discussion with the ICES group WGZE the following questions were intensively illustrated. 1) How can we compare observed field abundances with simulation results? 2) Is the comparison to Helgoland affected by island effects, not covered in the simulation? 3) What other long-term station data are available on the northwest European continental shelf (NECS)? 4) Do we have robust estimations of generation numbers as an integrative measure? And 5) What are your suggestions for better ways of comparison (e.g. generation time and number of generations)? The WGZE Chair summarized the discussions by proposing intense bi-lateral cooperation with WGZE members providing zooplankton observations in the NECS area.

Mesozooplankton sample collection methods

Mark C. Benfield (Louisiana State University, Baton Rouge, Louisiana USA), Jörn Schmidt (Leibniz-Institute of Marine Sciences, Duesternbrooker Weg 20, 24105 Kiel, Germany) and Peter H. Wiebe (Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA)

At the end of the 19th century, Victor Hensen, a pioneering zooplanktologist posed two fundamental questions: What are the numbers and kinds of things in the sea at any given time and place? And how does this material vary from season to season and year to year. In 2007 these are basically the same questions that we are still attempting to answer. Hensen was armed only with simple plankton nets while our toolbox has evolved to include single and multi-net systems, plankton pumps, imaging systems and high-frequency scientific echosounders.

Plankton are inherently patchily distributed in space and time. Consequently, sampling their distributional patterns poses certain challenges. The ingenuity of zooplankton ecologists has produced a diverse array of sampling devices. This presentation summarizes the following general groups: (1) Nets: single, non-opening/closing; single, opening/closing; multiple opening/closing; LHPR/CPR; specialized nets and traps; pumps; (2) optical systems; particle counters; 2D imaging systems; 3D imaging systems; and (3) high-frequency acoustics. The principle of operation of each type of system was summarized. Each system has strengths and weaknesses which are summarized with respect to whether they: provide a physical sample, their vertical and horizontal resolution, the level of taxonomic resolution they provide, potential for avoidance by target organisms, degree of damage to fragile taxa, ability to detect rare taxa, and sample processing time.

Available field data sets from the North Atlantic and the Mediterranean

Eilif Gaard (Faroese Fisheries Laboratory, Faroe Islands) and Erica Head (Bedford Institute of Oceanography, Canada)

Time series on field data set on zooplankton and ancillary data from the North Atlantic and the Mediterranean Sea were described. In addition to the Continuous Plankton Recorder data, collected since 1946, a large number of national monitoring programs are collecting zooplankton and ancillary data (usually hydrography and chlorophyll and/or phytoplankton) on continental shelves. Most of these time series have been operated since the early or mid 1990s, although a few data sets go back to 1950s and 1960s and 1970s. Most data are from shelf areas, although some monitoring programs run in oceanic areas, e.g. a section across the Labrador Sea and a broad-scale monitoring program in the Norwegian Sea. In most cases samples are collected seasonally or once a year, but for some monitoring programs the samples are collected more frequently, e.g. in the Helgoland and Stonehaven monitoring programs in the North Sea, in the Atlantic Zone Monitoring Program at coastal stations on the Scotian and Newfoundland shelves and in the Gulf of St Lawrence and also in the Mediterranean Sea. Detail information on zooplankton monitoring programs in the North Atlantic is available on www.wgze.net and on Mediterranean Sea monitoring on www.ciesm.org/marine/programs/zooplankton.htm. While zooplankton abundance and composition is relatively well monitored, especially for shelf areas, monitoring data on processes are scarce.

Available Data Sets: Laboratory Studies

Roger Harris (Plymouth Marine Laboratory, UK) and Xabier Irigoien (AZTI, Spain)

Laboratory experiments have a specific purpose, and are usually designed to test a specific hypothesis, so the data generated may not necessarily be appropriate for models. With this reservation in mind available data sets were reviewed briefly. Large projects such as US GLOBEC and TASC (Trans-Atlantic Study of *Calanus finmarchicus*) may be sources of zooplankton experimental data, but the data-sets may not be easily accessible, and long term availability is a problem. Some of the best sources of data are from individual literature compilations such as those by Hirst and Kiørboe (2002) on zooplankton mortality and Hernandez-Leon and Ikeda (2005) on respiration. Finally new approaches were considered, for example the idea of a single source of data for parameterizing species of key interest for ecosystem end-to-end modelling being developed as part of EUR-OCEANS, and an initiative to work with a few publishers of scientific journals to implement a Data Submission System (DSS) where authors are required to submit raw data directly to a long-term data-base in order as part of the publication process. In conclusion it was questioned whether current modelling approaches are reasonable for systems where species interact? Perhaps simple mesocosm experiments should be proposed with two or three species to see if models considering only external forcing are able to produce accurate predictions. See as an example Beninca *et al.* 2008 (Nature 451:822–825).

Statistical analysis – some examples

Cecilie Broms and Webjørn Melle (Institute of Marine Research, Bergen, Norway)

At the ICES WGZE-WGPBI joint session 2008, the presentation “Statistical analysis – some examples” was given. The objective of the presentation was to give an introduction to some statistical methods used by ecologists, and the main focus was on ordination and other regression methods. Background-theory of the different methods was complemented by showing examples from field studies. Ecologists

often want to analyse the response of several species (response variables) in an ecosystem on several environmental (explanatory) variables by using multivariate analysis. One multivariate method is ordination, which is a family of gradient analyses. Principal component analysis (PCA, indirect ordination) was used to describe the geographic distribution of *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus* in the Norwegian Sea and adjacent areas. The PCA scores, plotted in maps of the investigated area, showed that *C. finmarchicus* had highest concentrations in the Norwegian Sea Gyre. Redundancy analysis (RDA, direct ordination) was used to gain quantitative knowledge on how *Calanus* species and stages respond to the physical environment of the Norwegian Sea and adjacent areas. The results were presented in a triplot. *C. glacialis* and *C. hyperboreus* were negatively correlated to temperature and found in Arctic water. Old copepodite stages of *C. finmarchicus* were related to high-salinity Atlantic water. The young *C. finmarchicus* stages, on the other hand, were negatively related to older stages, and associated with Norwegian Coastal water. The reason for this is not clear, but it might be that Coastal water offers good recruitment conditions for *C. finmarchicus*, or that advection of young stages into Coastal water is high. Generalized additive model (GAM) was used to examine demographic responses of *Calanus* on environmental variables, and to examine *Calanus* life cycle. GAM extends generalized linear models and use smoothing operators to fit smooth non-linear relationships. Young copepodite stages had highest concentrations in the phytoplankton bloom, and the demographic response of *C. finmarchicus* coincided with one generation per year.

Needs from models: approaches to the biological questions

Jeffrey A. Runge (School of Marine Sciences, University of Maine and Gulf of Maine Research Institute, 350 Commercial Street, Portland, Maine, 04101 USA) and Catherine L. Johnson (Bedford Institute of Oceanography, Department of Fisheries and Oceans, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4H2, Canada)

We identified three families of biological questions about pelagic marine ecosystems: questions about biogeochemical fluxes and carbon sequestration, questions about community ecology including multispecies trophic interactions and top down effects, and questions about bottom up controls on primary productivity and higher trophic level population dynamics. The latter, addressed by coupled physical-biological models, appear to be particularly appropriate to top priorities of the new ICES Science Plan, including impact of climate change on the distribution, physiology and behaviour of marine biota, operational ecosystem modelling combining oceanography, ecosystem and population processes, and climate change predictions. Using the coastal Gulf of Maine as an example, we briefly review advances in coupled NPZ, zooplankton life cycle and larval fish trophodynamic modeling. Applying the rhomboid approach discussed by de Young *et al.* (2004: Science 304:1463–1466), we suggest that a system of linked, coupled physical-biological models could be developed into operational ecosystem modelling, providing decision support tools for questions about bottom up climate impacts on population dynamics, the outlook for environmental conditions affecting recruitment, sources and sinks among spawning areas, and transport of planktonic stages of invasive species.

Annex 13: Abstracts

AN ECOSYSTEM APPROACH FOR OYSTER RESTORATION AND MANAGEMENT

E. W. North, D. M. King, J. Xu, R. R. Hood, R. I. E. Newell, K. T. Paynter, M. L. Kellogg, M. K. Liddel, D. F. Boesch

In addition to supporting a harvest, the eastern oyster (*Crassostrea virginica*) in Chesapeake Bay provides ecosystem services such as removing seston, enhancing water clarity and creating benthic habitat. Our objective was to create a flexible ecosystem-based decision-making tool to support oyster restoration and management. This Oyster Restoration Optimization model (ORO) incorporates predictions from three-dimensional water quality (NPDZ with biogeochemistry, oxygen dynamics and oyster filtration) and larval transport models; calculates size- and salinity-dependent growth, mortality, and fecundity of oysters; and incorporates economic costs of restoration efforts. An optimization approach is used to identify the most suitable locations for oyster population restoration that maximize one or more benefits such as reduction in seston, increase in light penetration, spawning stock enhancement, and harvest, subject to cost constraints and other limitations. The iterative solution technique incorporates and estimates uncertainty such as that caused by environmental variability. Preliminary results indicate that the restoration of oysters in three sub-systems of the Chesapeake Bay would maximize different suites of benefits due to interactions between salinity gradients, salinity-dependent growth and mortality rates of oysters, the residence time of water in the sub-systems, and the relationship between size of oysters and the number of bushels harvested. Although the proof-of-concept ORO successfully links disparate models, provides spatially-explicit recommendations and testable predictions, and quantifies the tradeoffs associated with different management decision, development is needed. The strengths and constraints of the ORO model as applied to ecosystem-based fisheries management were discussed.

PROCESSES CONTROLLING PLANKTON DYNAMICS IN THE GULF OF MAINE

Rubao Ji (WHOI), Cabell S. Davis (WHOI), Changsheng Chen (UMass Dartmouth), David Townsend (University of Maine), Jeffery Runge (University of Maine), Robert Beardsley (WHOI)

The dynamics of copepod populations in coastal and shelf ecosystems are mainly controlled by non-linear interactions of multiple biological and physical processes and forcings that operate on vastly different spatio-temporal scales. Here we present a biological-physical coupled model to quantify these interactions and to understand underlying mechanisms that control the distributional pattern of *Pseudocalanus spp.* in the Gulf of Maine – Georges Bank region. The model consists of a meteorological model (MM5/WRF), an unstructured-grid hydrodynamic model (Finite-Volume Coastal Ocean Model, FVCOM), a nitrogen-phytoplankton-zooplankton-detritus (NPZD) model, and a mean-age stage-based zooplankton population dynamics model. The numerical experiments include baseline model runs and scenario testing with different freshening intensity, food limitation and mortality formulations in order to examine the importance of bottom-up vs. top-down control. The self-sustainability of population on Georges Bank (GB) was also examined by initializing the model with and without the population on the Bank. The model results suggest that 1) freshening-induced change of winter-spring phytoplankton bloom dynamics

alone cannot explain the observed variability of *Pseudocalanus* population dynamics, 2) spatial- and temporal- dependent mortality rate play a key role in determining seasonal dynamics; 3) Population from outside of the Bank (primarily the western Gulf of Maine) is an important source for GB *Pseudocalanus* population and GB population is unlikely to self-sustain; and 4) both temperature and phytoplankton co-vary with *Pseudocalanus* population and the seasonality of the population might be triggered primarily by temperature variation, indicating that the temperature-dependent top-down control may play a significant role in regulating population dynamics.

INTER-ANNUAL VARIABILITY OF CYANOBACTERIA BLOOMS IN THE BALTIC SEA AND ITS RELATION TO CLIMATE VARIABILITY

Frank Janssen, Federal Maritime and Hydrographic Agency, Germany

Thomas Neumann, Baltic Sea Research Institute, Germany

The inter-annual variability of late summer cyanobacteria blooms in the Baltic Sea has been investigated using the 3D ecosystem model ERGOM. A long-term simulation for the period 1960–2005 was carried out with realistic forcing. The simulated variability in cyanobacteria blooms was in good agreement with satellite observations. The area mean cyanobacteria concentration showed strong inter-annual and decadal variability, the most pronounced feature being the step-like increase from near zero concentrations in the middle of the 1980s to very high values in the late 1980s. The analysis of the nutrient conditions in the surface layer revealed a very high correlation between the summer mean (July and August) cyanobacteria bloom intensity and the winter mean (February and March) excess phosphorus (eDIP) concentration. In order to account for the amount of available nutrients and changes in the N:P ratio at the same time we calculated the excess phosphorus (eDIP) according to the formula: $eDIP = DIP - DIN/16$. The very fast change in the nutrient conditions was caused by changes in the mixed layer depth which increased strongly in the late 1980s, reaching down into the nutrient pool below the nutricline at approximately 50m depth. The increase in the mixed layer depth was in turn caused by changes in the surface wind stress also increasing strongly at the same time. These changes in the surface wind stress can be related to changes in the northern hemisphere atmospheric wind field manifested in a change of phase of the North Atlantic Oscillation (NAO). It is hypothesised that the impact of the NAO is transferred to the cyanobacteria blooms by a cause-and-effect chain starting in winter and developing until late summer: high NAO index © high wind stress, low ice cover © high mixed-layer depth, strong upwelling © high surface-layer eDIP concentration © (potentially) strong cyanobacteria bloom and vice versa.

MIGRATION OF CRAB LARVAE, A COMBINED MODELLING AND FIELD STUDY

Lennart Funkquist, Swedish Meteorological and Hydrological Institute

Per-Olav Moksnes, Gothenburg University

The aim of this project to combine field observations of shore crab larvae with modelling tools to be able to answer questions like i) how does the larvae control their dispersal, ii) is there a diurnal migration in phase with the sea-breeze, iii) how important is the pure drift by currents and finally iv) is there a connection between larvae drift and estuarine circulation in fjord regions.

Another issue is the question of how strong is the adaption to tidal areas. To answer this question we have studied larvae drift both in a macro- and micro-tidal environment.

In this experiment we have combined several years of observations of crab larvae abundance in different locations and at different depths with physical data from both observations and numerical atmospheric and ocean models. The larvae drift is coded in a particle-tracking model which is forced by output from the ocean model. This model also permits the larvae to behave differently depending on age, time of the day and location of release.

The success of the particle-tracking model depends very much on the horizontal and vertical resolution of the ocean model. In this experiment, the results from the tide-dominated area at the Danish west-coast are from a 3 nautical miles resolution while the results from the micro-tidal Swedish west-coast are from a finer resolution of 1 nautical mile. The vertical resolution is only 4 to 6 meters in the upper layers which in fact is too low and will affect the way turbulence influences the vertical movements of larvae. The particle-tracking model gets the horizontal transport as a sum of an advective transport from the 3D ocean model and a stochastic part (Monte Carlo technique), while the vertical transport is a sum of vertical velocity plus a turbulent part from a dispersion model which is a particle model represented by a Markov sequence constructed on the basis of the Langevin equation of motion in a similar manner as described in Legg and Raupach (1982). The lagrangian time scale and vertical velocity variance which are the crucial elements of the particle model are calculated from turbulent kinetic energy and its dissipation, which in turn are the output from the ocean model.

The preliminary experiments consist of 6 different 40 days periods during the summer 2001, 2 locations and 100 particles are released in each experiment. For each location and period we let the larvae experience four different behaviour: i) swimming at surface, ii) swimming at bottom, iii) swimming towards surface at ebb and towards bottom at flood and iv) daily migration which means towards bottom during day and towards surface during night and after 25 days the pattern change to the opposite phase.

The preliminary test runs shows what could be expected, i.e. surface-swimming larvae released outside Esbjerg are caught by the Jutland current and transported up to the northern coast of Denmark. Similar results hold for surface-swimming larvae released outside the Swedish west-coast where the Baltic coastal current brings the larvae up against Norway and either follow the Norwegian coastal current or are kept in the anti-clockwise gyre in the Skagerrak. The bottom-swimming larvae on the other hand seem to be able to stay in the vicinity of the point of release.

HINDCASTING AND FORECASTING SEA NETTLE (CHRYSAORA QUINQUECIRRHA) POPULATIONS IN CHESAPEAKE BAY, U.S.A

Margaret A. Sexton, Raleigh R. Hood, Christopher W. Brown, Thomas F. Gross, Mary Beth Decker and Jennifer E. Purcell

Jellyfish are important predators in marine systems that can have a profound impact on plankton dynamics. A growing body of evidence suggests that jellyfish blooms are becoming more frequent worldwide, yet factors that cause day-to-day and year-to-year variations in bloom development are not well understood. We used the scyphomedusa, *Chrysaora quinquecirrha*, as a model to examine how fluctuations in the physical factors that control jellyfish populations influence their abundance and distribution. Over 700 *in situ* observations collected from Chesapeake Bay U.S.A and its tributaries during 1987–2000 were used to develop an empirical habitat model that predicts the probability of occurrence of medusae as a function of sea-surface temperature and salinity. This habitat model can be forced with short-term forecasts and retrospective estimates of temperature and salinity derived from an operational 3-dimensional hydrodynamic model of Chesapeake Bay to generate maps of medusa occurrence. In this paper we describe our operational modeling system and use it to show how interannual fluctuations in temperature and salinity from 1995 through 2003 influence the occurrence of medusae in Chesapeake Bay, and we use this information to project how climate change might impact jellyfish populations and plankton dynamics in the future.

VIRTUAL ECOLOGY WORKBENCH (VEW) – A TOOL FOR BUILDING VIRTUAL ECOSYSTEMS

Matteo Sinerchia, John Woods and Wes Hinsley (Imperial College, London)

The Virtual Ecology Workbench (VEW) is a software tool that makes it easy for biological oceanographers to create one-dimensional mathematical simulations of the plankton ecosystem in a mid-ocean mesocosm. It uses the Lagrangian Ensemble metamodel (Woods 2005), which computes emergent demography and biofeedback from individual-based models comprising phenotypic equations for the biological functions of each species in the modelled plankton community. The VEW is designed to be used by scientists who have no skills in computer programming; the VEW automatically writes Java code from phenotypic equations written in familiar form. Nor does the user need to be skilled in ecosystem modelling: the VEW automatically manages such tasks as chemical budgeting.

PREY SELECTION OF LARVAL HADDOCK AND COD ON COPEPODS WITH SPECIES-SPECIFIC BEHAVIOR

Colleen M. Petrik (WHOI) in collaboration with Trond Kristiansen, Cabell S. Davis, and R. Gregory Lough

Mechanistic feeding subroutines are used in coupled physical-biological models of larval fish. This information on prey selection is necessary for determining how much food is available to larvae that experience food-limited growth. The literature was reviewed to collect information on the escape behaviour of the copepods *Calanus finmarchicus*, *Pseudocalanus spp.*, *Oithona similis*, and *Centropages typicus*, the dominant prey of larval haddock (*Melanogrammus aeglefinus*) and cod (*Gadus morhua*) on Georges Bank, for use in a mechanistic foraging model. The foraging model was coupled to a bioenergetics model to simulate larval haddock and cod feeding on equal and natural prey densities. These models are the first to describe haddock

foraging in general and larval fish foraging on prey with different species-specific behaviours. Both larval haddock and cod demonstrated positive selection of *Pseudocalanus* and negative selection of *Calanus*, with differences in escape abilities affecting selection more than encounter rate. The modelled preference of larval cod better matched observations than previous models of larval cod foraging behaviour. The foraging and growth model constructed for haddock reproduced observations of: (1) the relative amounts of the four main copepod prey species in the gut, (2) smaller average prey width eaten than cod, (3) the degree of preference for most species and stages of copepods in relation to cod, and (4) growth that is more food limited than cod. Differences in prey selection and growth between haddock and cod were mainly the result of different mouth sizes and metabolisms. The functions generated to describe prey species-specific escape behaviour can be used in future models of larval fish. The haddock foraging and growth models will be implemented in three-dimensional coupled physical-biological individual-based models of larval haddock on Georges Bank.

THE INFLUENCE OF OCEANOGRAPHIC CONDITIONS ON ABUNDANCE OF THE NORWEGIAN SPRING-SPAWNING HERRING AT THE EARLY LIFE STAGES

Alexander G. Trofimov, Tatiana A. Prokhorova, Victor A. Ivshin

Polar Research Institute of Marine Fisheries and Oceanography, Murmansk, Russia

The aim of the work is to develop an approach to estimating 0-group herring abundance using a set of oceanographic and biological parameters determining the abundance.

The area index (a sum of two areas: an area occupied by scattered fish concentrations and an area occupied by dense concentrations multiplied by 10) and index of absolute abundance (corrected for catching efficiency) for 1983–2004 were used as indices of 0-group herring abundance. The oceanographic parameters to study were a length index of the Barents Sea thermal frontal zones in August, an indirect indicator of water stratification in the spawning areas in February–March, temperature and density differences between the bottom and surface in the spawning areas in February–March, wind-driven and total volume fluxes through the sections crossing the main currents of the Barents Sea, an autumn–winter (October–January) North Atlantic Oscillation index and temperature in the 0–50 m layer in the Kola Section in August; the biological ones – total and spawning stocks of herring as well as its population fecundity.

The regression analysis of the chosen variables was made and the regression equations for the 0-group herring abundance indices were built. The equations show a quite close relationship between the chosen biological and oceanographic parameters, on the one hand, and the 0-group herring abundance indices: the index of absolute abundance ($r=0.85-0.90$) and the area index of abundance ($r=0.81-0.89$), on the other hand. To check the efficiency of the regression equations their probability was compared with the probability of the deviation from the long-term mean. The information ability of the equations is sufficient (adjusted R-squared reaches 64–76%).

It was found that the biomass of herring spawning stock described 40.9% of the variability of the absolute 0-group herring abundance index, and the indicator of water stratification described 24.1%. The autumn–winter North Atlantic Oscillation index, wind-driven fluxes through the sections crossing the Spitsbergen Current

(June-July), Central (June) and Northern (May-July) branches of the North Cape Current and total flux through the section crossing the North Cape Current (June-July) separately describe 5.5 to 9.0% of the variability. The variability of the area index of 0-group herring is determined by the total flux through the section crossing the Northern branch of the North Cape Current (June-July) by 35.6% and by the density difference between the bottom and surface in the spawning areas in February-March by 22.3%. The water temperature in the 0–50 m layer in the Kola section in August, wind-driven fluxes through the sections crossing the Spitsbergen (June-July) and Bear Island (May-July) Currents, the Northern branch of the North Cape Current (May-July) and total fluxes through the sections crossing the Bear Island Current (June-July) and Central branch of the North Cape Current (June-July) separately describe 7.1 to 12.6% of the variability.

The built regression equations are possible to be used for restoration and estimation of the indices of 0-group herring abundance. The work is oriented to be used further within the complex approach to the study of herring abundance forming

NEMURO and NEMURO.FISH (Status and next steps)

Cisco Werner (University of North Carolina)

NEMURO, the North Pacific Ecosystem Model for Understanding Regional Oceanography, simulates the temporal evolution and dynamics of the North Pacific's nutrient-phytoplankton-zooplankton food web. By coupling the lower trophic levels to include fish growth or fish population dynamics NEMURO.FISH has been used to study the bottom-up (climate-forced) response of target fish species. Case studies are contained in a special issue of *Ecological Modelling* (2007), volume 202, edited by M. Kishi, B. Megrey, S. Ito and C. Werner. Included in the special issue are regional and basin scale studies of the North Pacific's biogeochemistry, lower trophic ecosystem variability, its controls, hindcasts of the last 50 years and forecast studies for the coming century. Case studies of the response of fish focused on Pacific herring and saury and attempts to determine basin-scale synchronies within and across species as a response to local conditions are assessed. In some realizations the coupling of the fish to the lower trophic levels included density-dependent effects, i.e. grazing effects of fish on zooplankton are explicitly included. Next steps in the evolution of NEMURO include the addition of new biological state variables at lower trophic levels to better represent the diversity of oceanic species and their differences under changing environmental conditions, and higher trophic levels to allow for inter-specific competition.

EUROCEANS VITAL RATES DATABASE

Mike St. John (University of Hamburg)

Goals

The aim of this EUROCEANS funded project is to construct a **single point access database** for end-to-end ecosystem model parameterisation by:

- 1) compiling recent data on key species vital rates (growth, feeding, hatching, energy expenditure, energy requirements) measured in controlled laboratory experiments (lower trophic levels, fish larvae) and in situ (top predator bioenergetics), and
- 2) transforming data into carbon/nitrogen flux units (or energy requirements in J/kg for top predators) for model assimilation.

Development is primarily funded through EUROCEANS Data Transformation Call as well as with the support of Alfred Wegner Institute, EUROCEANS WorkPackages for Model Interfacing (WP 3.1) and Ecosystems End-to-end (WP 4). The database provides key information for the parameterisation of biogeochemical and ecosystem models by WGPBI members as well as the modelling and experimental community not only for model parameterisation but also for identification of gaps in process and physiological understanding. **DATA PARTNERS** contribute data to the data base effort and in exchange will gain full access to other partner's data while the effort is ongoing, until May 2008 when the all data will be made public.

Data Partners as outlined in the proposal submission by Trophic Level

Bacteria

Richard Rivkin (DGOM Consortium)

Angel Lopez-Urrutia (Instituto Español de Oceanografía, Spain)

Phytoplankton

Corinne Le Quere / Erik Buitenhuis, UEA/BAS, UK

Richard Geider, UESSEX, UK

Ciliates/dinoflagellates Sevrine Saille / Chistine Klaas Julie Rose – WHOI

Microzooplankton and Meso-zooplankton

Eric Buitenhuis (UEA/BAS)

Ylenia Carotenuto (Stazione Zoologica "A. Dohrn", Naples, Italy)

Claudia Halsband-Lenk (PML)

Andrew Hirst (BAS, UK)

Adrianna Ianora (Stazione Zoologica "A. Dohrn", Naples, Italy)

Christine Klaas / R. Rivkin

Corinne Le Quere (UEA/BAS)

Angel Lopez-Urrutia (Instituto Español de Oceanografía, Spain)

Macrozooplankton

Roisin Moriarty / Andrew Hirs

Vesselina Mihneva – IFR, Varna, Bulgaria (EUROGEL)

Lene Friis Møller – Göteborg University (EUROGEL)

Ichthyoplankton

Mike St John – michael.st.john(at)uni-hamburg.de

Myron Peck – myron.peck(at)uni-hamburg.de

Access

The vital rates database will be shared with partners only until **MAY 2008** after which access will become public. During development access will be restricted to contributing individuals only ([list of partners](#)), and [view-only access](#) will given to non-participants.

Status:

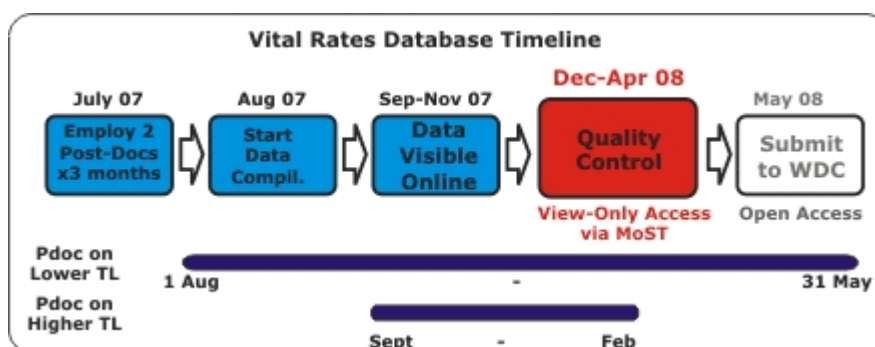
As of **January 2008**, the database contained over **18 500** open access data points on

- Bacteria = 3500 (90% production)
- Coccolithophorids = 1000 (production)
- Diatoms = 750 (production and resp.)
- Nanozooplankton = 2000
- Microzooplankton = 450 (growth and respiration)
- Mesozooplankton = 9500 (EPR, growth and mortality)

- Fish Juveniles = 170 (growth and respiration)
- Fish Adults = 1000 (respiration and clearance)

Accumulation of vital rate data is ongoing until the 3rd Quarter of 2008. For further information contact:

ivo.grigorov@eur-oceans.eu
 +33 298 49 86 73



TaskTeam Members

- Corinne LeQuere (WP 3.2 Leader)
- Icarus Allen (PI)
- Marco Zavatarelli (PI)
- Christian Mollmann (PI)
- Mike St John (PI / WP4 Leader)
- Yunne Shin (PI)
- Xabier Irigoien (PI)
- Christiane Lancelot (PI)

COUPLERS AND MEECE

Mike St. John (University of Hamburg)

In order to further our knowledge and the predictive capacities necessary to resolve how marine ecosystems will respond to global change, i.e. combinations of climate change and anthropogenic drivers, a successful EU project has been developed. MEECE (Marine Ecosystem Evolution in a Changing Environment) employs a combination of data synthesis, numerical simulation and targeted experimentation to the knowledge base and predictive capacities regarding the influence of the drivers ocean circulation, climate, ocean acidification, pollution, overfishing and invasive species on marine ecosystems is central to the successful fulfilment of the goals of the European Marine Strategy (EMS). Central to the MEECE project is WP 2 the goal of which is to create a library of plug and play type models which can be coupled to existing coupled hydrodynamic and intermediate and complex NPZD type models and thereby provide the integrated End to End modelling tools necessary to assess how ecosystems are impacted by global change via drivers such as ocean circulation, ocean climate, ocean acidification, pollution, over fishing and invasive species. At present most models in marine ecosystems are developed to address specific trophic levels, species or processes and consist of either a single code or are driven 'offline'

using the stored results of hydrodynamic models. As such these modelling tools are limited in their ability to address the impacts of multiple drivers and critically incorporate two-way feedbacks between and within trophic levels and the abiotic environment. Hence the overall goal of MEECE is to create an integrated model structure following a modular approach and employing couplers on key nodes in order to understand and develop predictive capacities. In order to accomplish these objectives this work package will

- identify system specific and generic key feedbacks and forcing for focused modeling activities.
- assemble a library of biogeochemical, ecosystem, higher trophic level, alien invasive species and ecotoxicology models necessary to assess the impacts of MEECE drivers on ecosystem dynamics.
- develop a modular modeling structure to enable the flexible coupling of biogeochemical, ecosystem, higher trophic level, alien invasive species and ecotoxicology sub models modules to existing ocean atmosphere models
- develop trophic couplers to enable the implementation of feedback loops into end to end modeling frameworks.

MEECE, which is coordinated by Icarus Allen of PML, is scheduled to commence in the last half of 2008 and to run for 4 years. WP 2 contains many members of WGPBI and is coordinated by Mike St. John of the University of Hamburg with regular updates of activities to be presented to the WG. The various models included in MEECE are presented in the table below.

HTL Model	Complexity	Description	References
SYSTMOD	Multispecies fish and fisheries	Piscivores and small pelagics with climate driver	Hamre and Hatlebakk 1998
ECOPATH with ECOSIM	Mutli compartment from detritus to marine mammals	Food web model with temporal and spatial dynamics.	Christensen et al 2004 Harvey et al. 2003
OSMOSE	multispecies and Individual-based model (IBM)	School based predator-prey model, focus on fish species, fish life cycles	Travers et al 2006 Shin and Cury 2004 Shin et al 2004 Sin and Cury 2001
4M	Multi-species, -fleet, -area model	MSVPA derivate, including fleets/areas covering top-predators, piscivores fish and small pelagics	Vinther, 2001 Köster et al. 2003
SMS	Stochastik multispecies fish and fisheries	Piscivores and small pelagics	Lewy and Vinther, 2004
APESCOM	Whole ecosystem	Spatially explicit size-based model of open-ocean ecosystems. Dynamic energy budget based.	Maury et al 2007a and b <i>In Press</i>
BIMS_HTL	small, medium and large pelagics	Dynamic mass flux model for the prey-predator interactions in the Black Sea	Oguz, 2007 (in press)

Coupled model	Complexity	Description	References
ECOSMO	Intermediate 2N,2P,2Z,D	3D pelagic ecosystem model coupled to a nonlinear baroclinic C-grid z-level model. Optimised for parallel vector computers; IBM modules for online and offline coupling available for egg and larval growth of sprat, brown shrimp, sandeel	Schrum et al 2006a Schrum et al 2006b
POLCOMS-ERSEM	Multi-PFT C,N,P,Si, 4P, 3Z, B, DOC, POC, Carbon chemistry	3D bulk biomass functional type pelagic-benthic ecosystem model coupled to baroclinic B-grid s-coordinate model. Optimised for massively parallel computers	Allen et al 2001 Holt et al 2004 Blackford et al 2004 Allen et al 2007a, b
ROMS-NPZD		3D pelagic ecosystem model coupled 3D ROMS a split-explicit, free-surface oceanic model,.	Penven et al. 2001 Penven et al. 2006 Shchepetkin A., and McWilliams, J.C. 2005
BIMS	Multi-PFT	3D pelagic lower trophic food web model (BIMS_ECO) coupled to POM-based circulation model (BIMS_CIR). Multiple functional groups of plankton coupled with nutrient cycling and redox processes	Oguz et al. 2000, Oguz 2002
POM-BFM	Multi PFT C,N,P,Si, 4P, 3Z, B, DOC, POC,	Pelagic model and benthic model coupled to Princeton Ocean Model (3D barocline, s-coordinate)	Polimene et al 2007. Vichi et al 2007
ROMS-NORWECOM	Intermediate	3D pelagic ecosystem model coupled to a nonlinear baroclinic split-explicit, free-surface oceanic model,.	Skogen M. D., et al 2004
GOTM/GETM	Flexible	3D coupled physical/bio-geochemical modeling system based on modular exchangeable model components. Currently implemented are NPZD, FASHAM, ERGOM and BFM(ERSEM) bio-geochemical models. Runs on single and parallel systems.	Umlauf et al. 2003 Banas and Hickey 2005 Burchard et al 2006
NEMO-PISCES	2P / 2Z Fe,Si,P,N co-limitation	3D global biogeochemical model. Coupled to IPSL climate model.	Aumont and Bopp, 2006 Bopp et al. 2005