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

14–15 April 2011

Pasaia, Spain

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

The WGPBI met in Pasaia, Spain, on 14–15 April 2011. Working group members discussed recent advances in:

- biological-physical modelling of copepods and larval fish;
- comparing models to observations using individual-based and NPZD models;
- three dimensional habitat volume modelling;
- bio-physical interactions that result in thin layer formation;
- development of end-to-end models;
- use of biophysical models for studying connectivity between spawning areas and nursery habitats of key marine species;
- phytoplankton thin layers can be formed by combination of phytoplankton behaviour and shear.

WGPBI members Alejandro Gallego (UK) and Elizabeth North (USA) together with Ed Houde (USA) are co-editors of a theme section in *Journal of Marine Systems* based on WGPBI's "Workshop on understanding and quantifying mortality in pelagic, early life stages of marine organisms: experiments, observations and models (WKMOR)". There are 18 submitted papers that are expected to be published in winter .

Working group members discussed the proposed creation of a working group on end-to-end modelling as well as reintegration with WGOOFE. Reintegration with WGOOFE was strongly supported by members, with the hope of revitalizing physical oceanographic themes within the group. The proposed creation of a separate working group on end-to-end modelling was met with mixed reviews: some saw no harm, others felt that the overlap between the groups would cause attendance/membership issues in the ICES modelling community.

Additional highlights include: 1) a manuscript based on the review of the physiological characteristics of marine fish larvae has been submitted, 2) the theme section on *Journal of Marine Systems* based on WGPBI's workshop WKMOR is on course to be published this year.

Myron Peck (Germany) and Rubao Ji (USA) were nominated as Chairs to replace Uffe Thygesen and Elizabeth North who are stepping down.

1 Opening of the meeting

The 2011 meeting of the Working Group on Modelling of Physical-Biological Interactions was held in Pasaia, Spain, on 14–15 April 2011. The meeting was attended by 17 scientists from 7 countries (Annex 1). The agenda (Annex 2) was adopted. The terms of reference for the meeting are given in Annex 3.

The working group thanks Marina Chifflet (AZTI, Spain) for the splendid local arrangements.

2 New results (ToR a)

Six presentations were made that described results of observations and modelling efforts. These presentations covered a variety of topics related to modelling physical-biological interactions:

- Observations and modelling of vertical distribution of anchovy and sardine early life stages in the Bay of Biscay confirm that the egg density is the most sensitive factor affecting vertical distribution, when compared to mixing by wind or tide (Huret).
- Impacts of circulation patterns on the early stages of small pelagic fish in North and Northwest Iberia is being explored through a coupled bio-physical model (García-García).
- Careful comparison of NPZD model and CPR observations reveals challenges in both observational and model data, as well as their comparison (Huebert).
- A biological-physical modelling of Calanus biogeography in the Arctic ocean is being developed and shows shifts in ranges based on climate variations (Ji).
- An IBM model has been applied to identify factors that cause interannual differences in larval haddock survival (Petrik).
- A3D habitat volume model has been developed to calculated suitable habitat from 3D hydrodynamic model results for a suite of fish and shellfish species (North).

Abstracts from talks can be found in the Annex 9.

3 Report on publications coming out of WKMOR (ToR b)

As an outcome of WKMOR, 18 contributors volunteered manuscripts (not counting co-chairs). There were some common authorships among those but on the other hand some authors offered more than one manuscript. Of those, three potential authors withdrew their offer relatively early-on. An agreement was put in place with the *Journal of Marine Systems* around June 2010 for a Special Issue, with the workshop co-chairs as guest editors, Ed Houde, Elizabeth North and Alejandro Gallego (the latter, Managing Guest Editor). In reality, 10 mss finally submitted after considerable delays. Only a couple met the original end of September deadline and mss were submitted all the way to 30 December. These constituted a combination of "research" mss and reviews. There were a number of reasons for the slow progress. The current status of WKMOR mss is: 4 mss under revision by the authors; 1 ms waiting decision by one editor; and 5 mss still under review. The workshop co-chairs are waiting for a more finalised shape of the Special Issue before progressing on an introductory ms.

The Elsevier deadline has been extended to 1 June but in the view of the managing guest editor, given the slow progress in the reviewing process, meeting this deadline will be quite challenging.

4 Report on a review of the physiological attributes of early life stages of marine fish (ToR c)

Myron Peck provided an update on the 2010 ToR, a review of the physiological characteristics of marine fish larvae. The review is ongoing and is structured using parameters of a balanced bioenergetics budget that includes the major pathways of energy gained from foraging (e.g., swimming speed, visual perception, prey capture success, assimilation efficiency), and energy lost (respiration rate). These bioenergetics attributes are being linked to morphological characteristics of the species (fish mass-at-length, mouth gap, body depth, eye diameter). These bioenergetics parameters are currently utilized within physiological-based biophysical individual-based models of foraging and growth of larval fish. At the time of the 2011 WGPBI meeting, a number of data sets had been compiled including: i) development rate of endogenous reserves (yolk) versus temperature for embryos (fertilized eggs and yolk sac larvae) of 64 marine fish species, ii) the effects of temperature, body size and swimming activity level on respiration rates of marine fish larvae in 13 families (43 data series from 28 studies), iii) gut evacuation rates and maximum gut contents of 16 and 12 marine fish species, respectively, iv) assimilation efficiency as impacted by larval body sizes (ontogeny). The first point (i) includes essential information for physiological based Lagrangian particle tracking (e.g., drift studies of early life stages) providing, among other things, estimates of spatiotemporal variability in connectivity to essential nursery habitats. A presentation on generic modelling that utilizes this data set is planned for the 2011 ICES ASC which should provide a catalyst to move forward with publishing the material. One manuscript is currently in preparation on point ii above (respiration losses). The other datasets will likely also be published separately or could be combined – forming the basis for a long review article or book.

5 Report on progress on the book on Individual-based modelling (ToR g)

Elizabeth North, on behalf of Sarah Hinckley, reported that the book project has been discontinued. The book was proposed as "Individual-based modelling of aquatic organisms: Coupling biology and physics" by S. Hinckley, A.J. Hermann, B.A. Megrey, and K.A. Rose. Due to the untimely loss of their exemplary collaborator and good friend, Bern Megrey, the authors have decided to stop work on the project. WGPBI members expressed their understanding and condolences for their great loss, and for the loss to our community at large.

6 Discuss advances in models and observations at mesoscales (ToR e)

Lennart Funkquist presented ideas related to modelling and observations of processes that occur at mesoscales. Recent developments in instrumentation and deployment technology have made it possible to detect very thin layers of organisms in the sea. While their horizontal extent has a scale of kilometres, their vertical extent can be 1 m or even less. Earlier attempts to explain features like this by solely physical arguments have failed and even the inclusion of simple migration patterns failed. However, new lab experiments have shown that the gyrotactic behaviour caused by the asymmetry in shape or weight in combination with a vertical current shear can

explain the accumulation of phytoplankton in thin layers. This recently published research on thin layers was conducted by William M. Durham, *et al*. (2009, Disruption of Vertical Motility by Shear Triggers Formation of Thin Phytoplankton Layers, Science 323, 1067).

7 Focus session on end-to-end modelling (ToR i)

Marina Chifflet, Jonathan Beecham, Myron Peck, and Miguel Bernal discussed ongoing work, future plans and helpful tools for end-to-end modelling efforts.

Marina Chifflet and co-authors are implementing an end-to-end model of the Bay of Biscay (see abstract in Annex 9 for more details). Currently, the implementation of the ROMS-PISCES model in the Bay of Biscay is on-going, with a long-term hindcast simulation 1980–2009, in order to couple it to the higher trophic levels (HTL) model APECOSM (Apex Predators ECOSystem Model, Maury *et al*., 2010). The end-to-end model ROMS-PISCES-APECOSM is developed in the Bay of Biscay in the context of two European projects (MEECE and Reproduce) in order to analyze the impact on ecosystems of changes in temperature, circulation, mixing, acidification, and light.

APECOSM is a climate driven and physiologically-structured model of ecosystem dynamics based on axioms: energy and mass are conserved; size structures opportunistic trophic interactions; size, food and temperature control metabolism (DEB theory); physiology & behaviour drive trophic interactions. The rhomboïd approach articulates three generic communities (OOPCs) and focus species to capture biodiversity. In a first step, the APECOSM model will be used offline, with results of ROMS-PISCES as input, and focusing on the generic communities.

Jonathan Beecham provided information about coupling of the ERSEM and Ecosim models. As part of the Meece project two way coupling has been achieved between the ERSEM lower trophic level model and the Ecosim component of EwE. Both models are complex - with 6 phytoplankton and 4 zooplankton groups in ERSEM, plus bacteria and several benthic groups. The Ecosim North Sea Model has 60+ functional groups including whales, seabirds, most commercially exploited fish and several benthic groups, which are not entirely consistent with ERSEM groups. The linking was performed at the herbivorous mesozooplankton level, with phytoplankton consumed and various detritus groups modified. Critical to the linked model was the partition between benthic and pelagic components, with some nutrients, specifically silicon, higher in the benthic components as a result of the coupling. Consequently the demersal species: plaice, sole, cod, nethrops tended to have slightly higher populations in the coupled model than in the EwE model alone. The results from the more pelagic species were more mixed, typically between 0.5 and 1.0 times EwE baseline. Norway Pout was only around 0.2 of the EwE level. Overall considering the natural variation between surveys, the coupled models performed reasonably in terms of absolute magnitude of populations. However to get to this point, seasonality had to be imposed on the Ecosim model, rather than it being an emergent dynamic. There are concerns as to the ability of the model to represent shifts in season timing, reserves and compensatory growth amongst others. It is suggested that at the current time the coupled model should be seen primarily as an exploratory / scientific tool, rather than as a predictive tool.

Myron Peck provided some information on a new EU program (VECTORS) which is moving forward with a variety of biophysical modelling activities among its 37 partners working in the North, Baltic and, Mediterranean Seas. A VECTORS workshop was announced for 23–27 May in Copenhagen led by Beth Fulton, the developer of.

"Atlantis", an ecosystem box-model intended for use in management strategy evaluation that has been applied to multiple marine systems (from single bays to large marine ecosystems) in Australia, south Africa and the United States. Atlantis represents an End-to-end model that will be parametized and utilized in the three VECTORS regional seas.

The overall structure is based around multiple alternative sub-models that represent each step in the management strategy and adaptive management cycles. At the core of Atlantis is a deterministic, 3-d biophysical sub-model. This model tracks the nutrient flows through the main biological groups found in the target ecosystem. Atlantis treats most lower (invertebrate) trophic levels as biomass pools while the vertebrates are represented using an age- and stock-structured formulation (which tracks the condition of average individuals). The physical environment is also represented explicitly - via a set of polygons matched to the major geographical and bioregional features of the simulated ecosystem allowing the model to be spatially-explicit in regions of particular interest, capturing the critical dynamics while still achieving computational efficiency. Exchange between the polygons is via advection or directed movements.

Atlantis also features a detailed exploitation model including impacts of pollution, coastal development and broad-scale environmental change, but is focused on the detailed dynamics of fishing fleets. It allows for multiple fleets, each with its own characteristics (regarding gear selectivity, habitat association, targeting, effort allocation and management. A wide range of alternative assumptions and model implementations are possible given the modular construction and pre-parameterization of the model. The complexity can be determined by the user at the desired level.

8 Use of biophysical models for studying connectivity (ToR d)

Genevieve Lacroix and Marc Hufnagl reported on the use of biophysical models for studying connectivity between spawning areas and nursery habitats of key marine species. The discussions that followed their presentations pointed out the interest in comparing drift routes between models. Statistical tests to compare the connectivity matrices could be used. A protocol for running tests of the biophysical models needs to be set up.

Disentangling the effect of biology / hydrodynamics / environment variability on the connectivity of sole larvae in the North Sea

Lacroix G., Volckaert F.

The interannual variability of sole (*Solea solea*) larvae dispersal in the North Sea is very high. The transport of sole larvae from the spawning grounds to the nurseries results from the hydrodynamic processes but the final dispersal pattern and the retention/connection pattern between spawning grounds and nurseries can be affected by biological processes (behaviour as for example the vertical migration) and by environmental conditions (as for example the temperature). It is interesting to assess the relative contribution of biology/environment/hydrodynamics to the recruitment and connectivity variability.

In this study we use a particle-tracking transport model coupled to a 3D hydrodynamic model to investigate the impact of (i) biology (throughout vertical migration), (ii) environment (throughout temperature) and (iii) hydrodynamics (throughout wind) on the recruitment and the connectivity between 6 spawning grounds and their associated nurseries for sole larvae in the Southern North Sea. The sole larvae

transport model developed in the frame of the SOLEMOD project couples the 3D hydrodynamic model COHERENS with an Individual Based Model (IBM) of the sole larvae. In the IBM, sole larvae perform diel and tidal vertical migration according to their stage of development. The spawning date, the duration of stages and the mortality depend on temperature. The model has been implemented in the area between 48.5°N-4°W and 57°N-10°E. A set of reference simulations has been performed for 11 years (1995–2005).

A sensitivity analysis study consisting in three set of runs has been performed over the whole period (1995–2005). In Run 1, the vertical migration has been switched off. In Run2, the temperature and the spawning date of the year 2001 ('average' year in term of temperature) have been imposed for the 11 years. In Run3, the meteorological forcing (wind) of the year 1997 ('average' in term of NAO and water masses transport) has been imposed for the 11 years. The results obtained with the 'perturbed' set of simulations have been compared to the reference simulations in order to assess the impact of respectively biology (Run1), environment (Run2) and hydrodynamics (Run3). Results are analysed in term of final recruitment success and retention/connection pattern over the years 1995 to 2005.

This study shows significant interannual variability of (i) recruitment success in all nurseries, (ii) origin of larvae arriving in the nurseries and (iii) retention/connection pattern between the 6 spawning grounds and nurseries. The average (1995–2005) recruitment predicted by the model is higher (resp. lower) with vertical migration in the FR, BE & NL (resp. GE & UK) nurseries than without. It is also affected by temperature (throughout spawning period), especially in the FR & GE nurseries. The model predicts, on average for the whole period, that the meteorological forcing has only reduced impact on recruitment success excepted for BE and NO nurseries. But, whatever the perturbed simulations, the increase/decrease of average recruitment success over the whole period is lower than the interannual variability (no significant in term of statistics). The retention/connectivity pattern is significantly impacted in the three set of perturbed simulations.

Examine and quantify connectivity between spawning areas and nursery habitats of two North Sea key species brown shrimp and plaice

Marc Hufnagl, Adriaan Rijnsdorp, Richard Nash, Axel Temming, Thomas Pohlmann, Maarten Boersma, Myron Peck

Connectivity between essential habitats can often be a critical bottleneck influencing the recruitment dynamics of marine organisms having pelagic early life stages. We examined connectivity issues in two North Sea key species, brown shrimp *Crangon crangon* and plaice *Pleuronectes platessa*. The early life stages of both species have specific habitat requirements during settlement to shallow coastal waters and tidal flats. Spawning mainly occurs offshore during winter and nurseries have to be reached after a planktonic drift phase.

The connectivity study on brown shrimp was performed to gain a better understanding of the life cycle and how different hydrographic situations influence the recruitment and population dynamics. This was carried out with specific focus on winter and summer recruitment. Timing of simulated recruitment agreed well with observations on larval and juvenile abundance. In general winter recruitment is distributed over a larger area and juvenile shrimps observed at the German coast originate from Dutch and Belgium hatching areas. Summer recruitment on the opposite mainly remains close to the hatching site. Impact of different hydrographic situations on recruitment and North Sea landings were discussed.

We further explored the hypothesis that the distribution of plaice eggs in the North Sea is a reflection of the location of suitable nursery grounds and whether connectivity of known (or suitable) spawning areas changed over time. Spawning locations that were successful over the simulated period were in broad agreement with main centres of egg production. Suitability of south-eastern spawning grounds increased over the 30 year period. Reasons like changes in drift or development were discussed.

9 Theme sessions at ICES ASC 2010

Working group members discussed Theme Sessions that were hosted by PBI at the 2010 ICES Annual Science Conference:

Myron Peck provided a summary of Theme Session L: Spatially-explicit models for plankton and fish: processes, model integration and forecasts. The session was separated into four sub-sessions: 1) zooplankton models, 2) larval fish individual-based models, 3) full life cycle models, and 4) end-to-end models. Within these sub-sessions, there were 5, 4, 4 and 6, oral presentations, respectively. One talk was withdrawn and this time slot was devoted to briefly presenting the 15 posters that were on display from session L.

An important highlight from the zooplankton session included the need to resolve detailed aspects of specific life history characteristics to advance our ability to depict observed patterns of spatial habitat residence and changes in long-term time series data. Within the larval fish IBM section, talks highlighted the potential species-specific differences that exist in important aspects of foraging (prey selectivity, behaviour) and growth (metabolic and feeding rates) that interact with physical processes to impact survival, drift routes (patterns of advection) of larval cohorts. A common issue to arise from full life-cycle talks was the importance of adult movement schemes in terms of model spatial predictions. Finally, discussion of End-to-end topics focused on the tradeoffs that exist between model complexity and the level of biological realism. The ability to represent the appropriate amount of biological realism may be critical to gaining insight on the mechanism behind historical and ongoing changes in marine ecosystems /key players. However, corroborating the outputs of complex models and the increased computer time associated with simulations are two potential drawbacks.

The modelling community was saddened by the death of one of this session's co-conveners. Bern Megrey passed away shortly after returning to the USA from this conference.

Geneviève Lacroix provided a detailed summary of Theme session N: Oceanography and ecology of HABs: physical/biological interactions, climate change, and other current issues. The conveners were Donald M. Anderson (USA), Geneviève Lacroix (Belgium), and Patrick Gentien (France). The Theme session had 12 oral presentations (4 presentations of 20' and 8 presentations of 15') on Tuesday 21 September pm and 7 posters presented during the poster session. The session was followed by about 50 people.

The session begun with a dedication in memory of our friend and colleague Patrick Gentien, co-convenor of the session who sadly passed away prior to the meeting.

The session covered a wide range of model formulations and HAB species. Some of the models were empirical, including approaches such as utilizing sustained wind from specific directions to generate a "wind index" that had a predictive value for Dinophysis and Karenia blooms in southwest Ireland. Other models focused on

small-scale behaviour and physics such as the scales of turbulence that affect HABs, and a population health model of the distribution of Alexandrium cells infected by the parasite Amoebophrya. This study demonstrated that it is realistic to have spatial separation of infected cells from healthy cells with the appropriate behaviour. Larger regional-scale models were also presented including a complex ecosystem model that simulated Cyanobacterial blooms in the Baltic given different nutritional initial conditions.

Another large-scale model was a coupled physical-biological model of Alexandrium bloom dynamics in the Gulf of Maine. That model captured the regional dynamics of this species with some skill and is now being used in short-term (days) to seasonal (months) forecasts. In this instance the abundance of resting cysts is a strong determinant of the magnitude of the resulting bloom, though results in 2010 demonstrated how large cyst germination can still fail to provide a significant bloom if growth conditions are not favourable in the water column.

The session included regional reports on the monitoring of toxic phytoplankton from three Icelandic fjords, bio-geochemistry of cyanobacterial blooms in the Baltic Sea, population dynamics in the Ria de Pontevedra in Northwest Spain and transport of Dinophysis blooms along the south coast of Ireland. Looking to the future, a new project entitled "ASIMUTH" was introduced; this will integrate Earth Observation data, models and in situ data to provide regular HAB bulletins in 6 locations along the western European Atlantic coast. A series of poster presentations complemented the oral session. Topics such as climate change and the impact of storms on HABs, the rate of domoic acid production in cultures with different forms of nitrate and the detection of domoic acid by using Solid Phase Adsorption. Regional presentations included the summer phytoplankton in the Baltic and monitoring programme in the southern Caspian Sea. A model of the life cycle of dinoflagellates demonstrated the role of life cycle transitions in regulating bloom dynamics. Overall the breadth of model types presented for different HABs and different management needs were impressive. It is encouraging that this aspect of the HAB field is progressing at a productive pace.

Follow up. At the end of session, a short interview about the HABs was realized by a journalist from radio Nantes for a local broadcast.

10 Theme sessions at ICES ASC 2011

WGPBI members are co-convening the following theme sessions at ICES ASC 2011:

Theme Session L: Biophysical modelling tools and their potential use in marine spatial management: a strategic dialogue. Conveners: Myron A. Peck (Germany), Rubao Ji (USA), Pierre Petitgas(France), and Vanessa Stelzenmüller (Germany).

11 Long term planning of WGPBI

WGPBI members discussed the strategic vision for WGPBI activities for the next 3–5 years in the context of the activities of other working groups and proposed working groups.

Elizabeth North reviewed the WGPBI vision of the future that was based on discussions at the 2010 WGPBI meeting. The following themes emerged as those that are important to pursue:

- Physical oceanography. We would like to attract and maintain a solid core of physical oceanographers as members of WGPBI, from those with expertise and interest in small scale process to global climate change.
- Moving from fish larvae to adults and individuals to ecosystems. We would like to stay updated on new developments in modelling fish communities that coupled physics and lower-trophic level interactions with upper trophic levels and food webs, including NEMURO-SAN and End-to-end models like Steele *et al*.
- Ensure representation of diverse modelling approaches. It is important that we maintain a broad view of model types, keep abreast of new techniques in modelling and maintain a diversity of modelling interests on the group. Representative model types include NPZD, eutrophication, size-spectrum, end-to-end, and habitat models, as well as links between model types such as particle-tracking models linked to upper trophic level food web models, NEMURO-SAN, etc.
- Continue to survey and promote methods to test and validate models. An important part of our role is to identify methods to that demonstrate the robustness of models for use as management tools.

Miguel Bernal presented a proposal for a new group (WGE2E) which has been put forward for consideration by the ICES scientific steering committee.

Martin Huret updated the group on activities of the Working Group on Operational Oceanographic Products for Fisheries and the Environment (WGOOFE). In 2007, the Planning Group on Operational Oceanography Products (PGOOP) organised a Workshop to suggest ways of developing and/or improving the dialog between producers of OO products and the potential users. WKOOP recommended the instigation of WGOOFE as an interface between users and providers, to correct the lack of use (knowledge) of the available products, and the inadequation between what is available and what users require. WGOOFE met 5 times (2008, twice in 2009 and twice in 2010) with ~15 pers., mostly representing providers or intermediate users. Main activities and products of the WG have been:

- disseminate a questionnaire to better identify the user needs.
- outreach and publicity to inform the users and providers of the results of the questionnaire, mainly identifying a gap between both communities. A leaflet was distributed, an article published in ICES Newsletter and a manuscript published: Does operational oceanography address the needs of fisheries and applied environmental scientists ? 2011. Berx *et al*., Oceanography, 24(1).
- create and operate a website (www.wgoofe.org) to help users navigate through the diversity of OOP.

In 2011 the group has meet with WGINOSE and will try to meet with other Regional assessment groups in the future, to help disseminate the OOP in the community.

The view of the group concerning its future within ICES was also presented, in particular in the context of coexistence with WGPBI and emerging WGE2E. The consensus is that the group is not the place to welcome these groups, or is not meant to join with these two groups (even if products are of obvious interest for all the modelling studies). WGOOFE should rather keep focusing on being a facilitator for users to access the products, as well as on letting the providers know what are the real needs.

The scientific studies and methodological issues would then be the tasks of WGPBI and WG2E2. The possibility for joint meetings should however be considered.

12 Nomination of WGPBI Co-Chairs

Myron Peck (Germany) and Rubao Ji (USA) were nominated as Co-Chairs to replace Uffe Thygesen and Elizabeth North who are stepping down.

13 Preparation of 2012 meeting

Although members discussed the location of the 2012 meeting, including the kind offer of John Steele to host the meeting in Woods Hole, a place and time was not chosen.

Annex 1: List of participants

NAME	AFFILIATION	COUNTRY	EMAIL
Jonathan Beecham	CEFAS	UK	jonathan.beecham@cefas.co.uk
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Annex 2: Agenda

April 14, 2011

1000-1015: Welcome, logistics

1015-1115: Presentation of new results (ToR-a)

- Martin Huret. Observations and modelling of vertical distribution of anchovy and sardine early life stages in the Bay of Biscay
- Luz García-García. Impacts of circulation patterns on the early stages of small pelagic fish in North and Northwest Iberia
- Klaus Huebert. NPZD-CPR statistical comparisons

1115-1130: Coffee break

1130-1230: Presentation of new results, continued.

- Rubao Ji. Biological-physical modelling of Calanus biogeography
- Colleen Petrik. Interannual differences in larval haddock survival: hypothesis testing with a coupled biophysical model of Georges Bank
- Elizabeth North. 3D habitat volume model: preliminary results and application

1230-1400: Lunch

1400-1430: Presentation/discussion regarding Terms of Reference and Action Items

- Alejandro Gallego: Report on publications coming out of WKMOR, including progress of the special issue in Journal of Marine Systems, and other follow-up activities including writing paper on workshop conclusions (ToR-b, AA-1) – 5 min
- Myron Peck: Report on a review of the physiological attributes of early life stages of marine fish species relevant for projecting climate-impacts using coupled hydrodynamic bio-physical models (ToR-c, AA-2) – <5 min
- Elizabeth North (for Hinckley): Assess progress on the book "Individual-based modelling of aquatic organisms: Coupling biology and physics" by S. Hinckley, A.J. Hermann, B.A. Megrey, and K.A. Rose. (ToR-g, AA-6) – <5 min
- Elizabeth North and Lennart Funkquist: Discuss advances in models and observations of physical and biological processes at vertical scales of meters and horizontal scales of kilometres (ToR-e) – 15 min

1430-1600 Discuss likely directions for next few years. Set stage for next day

- Uffe Thygesen/Elizabeth North: WGPBI: review 2010 vision of the future – 10 min
- Miguel Bernal: present proposal for a new group WGE2E – 10 min
- Martin Huret: update on activities of the Working Group on Operational Oceanographic Products for Fisheries and the Environment (WGOOFE) – 10 min
- Pierre Petitgas: Review arguments for and against combining PBI, OOFE, E2E – 10 min
- All: open discussion on WGPBI, WGOOFE, proposed WGE2E: combine, create, remain separate?

1600 Adjourn

April 15, 2011

1000-1115: Focus session on end-to-end modelling (ToR-i, AA-8)

- Marina Chifflet, E. Machu, O. Maury, X. Irigoien: Towards an End-to End model in the Bay of Biscay – 20 min
- Jonathan Beecham: Report on extensions of linking physical and biological models in 3 dimensions to project marine food web dynamics and an update on the MEECE model library. (ToR-f, AA-5) – 20 min
- Martin Huret: The adaptation needed in lower trophic level models for coupling to higher trophic level models – 15 min
- Miguel Bernal: present and discuss the results of workshop about end-to-end models (WKIEM) – 20 min

1115-1130: Coffee break

1130-1230: Focus session on end-to-end modelling, continued. (ToR-i, AA-8)

- Myron Peck: biophysical modelling activities within VECTORS of change, including ATLANTIS – 15 min
- Final discussion of WGPBI, WGOOFE, proposed WGE2E: combine, create, meet together, remain separate?

1230-1400: Lunch

1400-1500 Report on use of biophysical models for studying connectivity between spawning areas and nursery habitats of key marine species (ToR-d, AA-3)

- Genevieve Lacroix and Filip Volckaert. Disentangling the effect of hydrodynamics/biological variability on the connectivity of sole larvae in the North Sea – 30 min
- Marc Hufnagl, Axel Temming, Maarten Boersma, Thomas Pohlmann, Myron Peck. Modelling southern North Sea habitat connectivity and recruitment of brown shrimp Crangon crangon (maybe also plaice and temporal changes in suitable spawning areas) – 30 min

1500-1530: Workshops, theme sessions, and joint meetings.

- Genevieve Lacroix: Report on theme sessions at the 2010 ICES ASC: N: Oceanography and ecology of HABs: physical/biological interactions, climate change, and other current issues. Conveners: Donald M. Anderson (USA), Geneviève Lacroix (Belgium), and Patrick Gentien (France) – 5-10 min
- Myron Peck: L: Spatially-explicit models for plankton and fish: processes, model integration and forecasts. Conveners: Pierre Petitgas (France), Thomas Neumann (Germany), Bernard Megrey (USA), Myron A. Peck (Germany) – 5 min
- C: Natural mortality variation in populations and communities. Conveners: Dave Reddin (Canada), Ken Haste Andersen (Denmark), and Niels Hintzen (Netherlands) – 2 min
- Review upcoming workshops and 2011 theme sessions at ASC, discussion of workshops and theme sessions for 2012
- Elizabeth North: Prepare a joint meeting with Working Group on Harmful Algal Bloom Dynamics (WGHABD) in 2012 (ToR-j) – <5 min

1530-1630: Management of the WG

- Chairs
- Draft resolutions for 2012
- Planning of activities; Terms of reference, actions items
- WG Report (WGPBI will report by 30 April 2011)

1630: Close of meeting

Annex 3: WGPBI terms of reference for the 2011 meeting

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

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

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

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

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

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

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

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

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

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

j) Prepare a joint meeting with WGHABD in 2012.

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

Annex 4: Actions items 2010/2011

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

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

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

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

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

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

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

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

Annex 5: WGPBI draft terms of reference for the 2012 meeting

The **Working Group on Modelling of Physical-Biological Interactions** (WGPBI), chaired by Myron Peck, Germany, and Rubao Ji, USA, will meet in VENUE, DATES (to be announced) to:

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

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

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

d) Report on methods to derive robust model-derived prey fields for zooplanktivores (Huret, Peck, Ji);

e) Report on approaches to model fish movement at juvenile and adult stages as constrained by internal and external factors (Petitgas, Huret);

f) Report on comparing drift routes between connectivity models (Hufnagl, Lacroix);

g) Prepare for theme sessions at the 2012 ICES ASC.

WGPBI will report by 30 April 2012 (via SSGEF) for the attention of SCICOM.

Supporting Information

Priority:	The current activities of this Group support the ecosystem approach to fisheries science by addressing lower trophic levels, early life stages of fish, and relationships between physical drivers and biological responses. The Group combines the knowledge of physical processes, biological processes and modelling expertise that is required to strengthen our understanding of ecosystem functioning. Consequently, the activities of the Group should be given high priority.
Scientific justification:	ToR c: A large number of research projects in the ICES community concern projections of climate impacts. A critical issue in these studies is the recruitment, and thus the modelling of growth and mortality, of early life stages of marine fish. The literature on this subject is vast and providing a synthesizing overview will help advance the field. ToR e,f: Spatial considerations are of growing concern and a key application of biophysical models is to study the transport of early life stages of fish from spawning areas to nursery habitats. It is considered important to advance the state of the art of these models, in particular concerning biological rates, behaviour, and validation. None of the ToRs answer requests from other groups, they are all self-generated and contribute to building scientific capacity. The ToRs relate to the coded ICES Science Plan in the following way ToR a,b,g: have no specific relationship to the Science Plan ToR c: contributes to topic 112 on Climate change ToR d: contributes to topics 144 on Life history and 112 on Climate change ToR e,f: contribute to topics 147 on Life history and 112 on Climate Change
Resource requirements:	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.

Participants:	The Group is normally attended by some 15–25 members and guests.
Secretariat facilities:	None.
Financial:	No financial implications.
Linkages to advisory committees:	There are no obvious direct linkages with the advisory committees.
Linkages to other committees or groups:	The working group is actively pursuing links to other groups within ICES, and strengthening these links through joint meetings. Previously the WG has met with the Working Group on Zooplankton Ecology and the Working Group on Harmful Algae Bloom Dynamics. The WG is also linking to the Working Group on Phytoplankton and Microbial Ecology as well as the Working Group on Operational Oceanographic products for Fisheries and Environment.
Linkages to other organizations:	None.

Annex 6: Actions items for 2010/2011

1) Propose a joint meeting with WGOOFE (E2E) include contact with MYOCEAN (North, Huret, Peck)

2) Try to enlist a physical oceanographer to be co-chair for PBI (Peck)

3) Develop methods to derive robust model-derived prey fields for zooplanktivores (Huret, Peck, Ji)

4) Propose theme session on methods to assess connectivity (Hufnagl, Lacroix)

5) Propose theme session on end to end modelling (Bernal, Beecham)

6) Complete WKMOR publications (Gallego, North)

7) Compare drift routes (Hufnagl, Lacroix)

8) Review approaches to model fish movement at juvenile and adult stages as constrained by internal and external factors (Petitgas, Huret)

9) Finish the database on physiological attributes of marine fish needed for couple-biophysical models (Peck)

Annex 7: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. Theme session at the 2012 ASC: Bridging the distance – Understanding habitat (and life stage) connectivity.	SCICOM, SSGEF

Annex 8: Theme session proposal for ICES ASC 2012

Bridging the distance – Understanding habitat (and life stage) connectivity

Conveners:

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Potential 4th convener: TBD

Abstract

Connectivity between essential habitats can often be a critical bottleneck influencing the productivity and dynamics of marine organisms that have pelagic life stages. Understanding the temporal and spatial mechanisms on how these links have evolved, where these links exist and how these links can be verified is therefore of crucial importance for a sustainable management and for understanding population and ecosystem dynamics and functioning.

Habitat links can be influenced by several naturally evolving or man- made processes acting on stage and drift duration, drift direction, survival, development, food availability or habitat characteristic. Furthermore, as changes in connectivity between existing or newly evolving habitats can have substantial impacts on occupation, abundance or species richness, it is important to gain a holistic knowledge on all facets involved. In short, studies revealing the temporal and spatial dynamics of habitat connectivity, including where these habitat links exist, how they have evolved, and how they can be verified, are of crucial importance for understanding how populations persist, how ecosystems function, and how to build sustainable management plans.

This session we focus on studies dealing with connectivity in a broad sense. This might include laboratory, field, and/or as well as modelling studies that try to 1) find, verify or analyze existing or developing links, 2) that try to predict future changes in connectivity, 3) that help advance our understanding of mechanism involved in connectivity, or 4) that provide data that help to validate models of connectivity. Understanding how anthropogenic factors influence connectivity is also of

high interest, such as construction of potential stepping stones (e.g. offshore windmill, artificial reefs, reclamation), changing food availability (eutrophication), increasing (fishing) or decreasing mortality (e.g. installation of Marine Protected Areas).

Within this session we accept oral and poster presentations and posters from scientists dealing with connectivity aspects (all life stages) in either hydrodynamic modelling (e.g. drift studies), biological (e.g. fingerprinting, otolith reading), assessment (e.g. acoustic, satellite or classic surveys) or management (e.g. MPA, offshore windmills) studies on resident or invasive species (e.g. transport by ballast water or hull fouling).

Annex 9: Abstracts for presentations at the WGPBI meeting

Towards an End-to-End model in the Bay of Biscay

Marina Chifflet (AZTI, Spain), Eric Machu (IRD, France), Olivier Maury (IRD, France), Xabier Irigoien (AZTI, Spain)

The regional hydrodynamic-ecosystem coupled model ROMS+N2P2Z2D2 has been implemented in the Bay of Biscay (North Atlantic). A 13-years simulation has been performed, from 1997 to 2009, using 6-hours NCEP reanalysis as atmospheric forcings and considering the daily flow observations of the 20 most important rivers in the regions. In order to calibrate the model and validate the results, we have collected in situ data (AZTI cruises and SISMER server), satellite images (AVHRR, Seawifs, MODIS) and the BoBY climatologies (Ifremer).

In terms of hydrology, the 13-years monthly mean simulated SST and SSS have been compared to monthly climatologies respectively from AVHRR and BoBYclim, using Taylor diagram and metrics as Pbias and RMSE. The model reproduces the seasonal cycle of SST and SSS in the Bay of Biscay, and local processes: cold band water along the Atlantic French coast in winter; warming and north-south gradient in spring; Galician upwelling, Ouessant front and cold slope band in summer; and rivers plumes. The Taylor diagram between simulated monthly mean SST and AVHRR monthly climatology shows a correlation between 0.8 (July/August) and 0.9, and a normalized standard deviation between 0.75 and 1.25. The comparison of simulated SSS to BoBYclim shows simulated rivers plumes to much coastal, and then an overestimation of the salinity by the model.

Comparing the model results with CTD profiles, the simulated temperature appears warmer at the surface (MRD<0) and colder in depth (MRD>0) in spring, and colder at the surface and warmer in depth in autumn, showing a too strong mixing in the model. Thereby, more comparison of hydrology results to CTD profiles will be done, using Taylor diagram, to check the stratification. Moreover, SST validation with satellite images along time to check the interannual variability, and sub-regional RMSE will also be performed.

The comparison of the simulated surface chla to MODIS images, from 2003 to 2009, indicates a well captured interannual variability by the model but a too early simulated spring bloom (about 1 month). As an example, the strong spring blooms in 2005 and 2009 were reproduced by the model. Nevertheless, chla developments in rivers plumes on the shelf are much more extended on MODIS and SeaWiFs images than in the model. However, coastal waters are charged in particulate matter from rivers input and this could induce a perturbation in satellite images.

Currently, the implementation of the ROMS-PISCES model in the Bay of Biscay is ongoing, with a long-term hindcast simulation 1980–2009, in order to couple it to the higher trophic levels (HTL) model APECOSM (Apex Predators ECOSystem Model, Maury *et al*., 2010). The end-to-end model ROMS-PISCES-APECOSM is developed in the Bay of Biscay in the context of two European projects (MEECE and Reproduce) in order to analyze the impact on ecosystems of changes in temperature, circulation, mixing, acidification, and light.

APECOSM is a climate driven and physiologically-structured model of ecosystem dynamics based on axioms: energy and mass are conserved; size structures opportunistic trophic interactions; size, food and temperature control metabolism (DEB theory); physiology & behaviour drive trophic interactions. The rhomboïd approach

articulates three generic communities (OOPCs) and focus species to capture biodiversity. In a first step, the APECOSM model will be used offline, with results of ROMS-PISCES as input, and focusing on the generic communities.

References

ROMS: Shchepetkin, A. F. and McWilliams J.C., 2005. "The Regional Ocean Modeling System: A split-explicit, free-surface, topography following coordinates ocean model". Ocean Modelling, 9, 347-404.

PISCES: Aumont, O. and Bopp L., 2006. « Globalizing results from ocean in situ iron fertilization studies ». Global Biogeochem. Cycles, 20, GB2017, doi:10.1029/2005GB002591.

APECOSM: Maury O., 2010. « An overview of APECOSM, a spatialized mass balancd « Apex Predators ECOsystem Model » to study physiologically structured tuna population dynamics in their ecosystem ». Progress in Oceanography 84, 113-117.

Impacts of circulation patterns on the early stages of small pelagic fish in N and NW Iberia

Luz María García García

The Group of Physical Oceanography and Modelling at the Instituto Español de Oceanografía (IEO) runs a ROMS configuration for the area of N and NW Iberia. The comparison of the hydrodynamic results against observations obtained from different sources (cruises, remote sensing, etc) demonstrates that the model is able to reproduce the main dynamic features in the area.

Once the hydrodynamic basis has been validated, two biological related experiments has been performed, being the preliminary results presented at the WGPBI:

- Experiment 1 consisted of analysing the transport of eggs during November 2006 by the currents when two different egg densities are considered. The results show that lower densities lead to higher offshore dispersion in the Cantabrian during the studied period, thus highlighting the importance of properly accounting for this parameter.
- Experiment 2 is related to the coupling of a Lower Trophic Level model (Fennel, 2006) to the hydrodynamic model. Preliminary results aimed at evaluating the correct model performance are shown for the month of October 2006. Indeed, it can be seen that a weak upwelling event leads to the uplift of nitrate and the growth of phytoplankton in the Portuguese coast.

Comparing empirical (CPR) and modeled (ECOHAM) zooplankton data

Klaus Huebert, Johannes Pätsch, Rabea Diekmann, Myron Peck

Over twenty years of data from one empirical (continuous plankton recorder) and one modelled (ECOHAM) dataset for zooplankton biomass in the North Sea were compared using a statistically robust non-parametric method. Each empirical observation was paired with the single modelled data point nearest in space and time. Spatial regions with good temporal sampling coverage were identified, and the ranks of data in each region were averaged by month. For each region, inter-annual, intra-annual, and total rank correlation of mean zooplankton rank was calculated. Overall, the modelled data represented the empirical data well in terms of seasonal patterns

(intra-annual variability). However, inter-annual variability in the two datasets was not significantly correlated.

Vertical distribution of early life stages of anchovy and sardine in the Bay of Biscay. Observation and modelling.

Martin Huret, Paul Bourriau and Pierre Petitgas.

New data on vertical distribution of anchovy and sardine eggs and larvae are available for the Bay of Biscay, for several months of several years, with repeated day-night stations, so for a wide range of hydrology profiles. A 1D vertical Lagrangian model was set-up to predict vertical distribution of early life stages of both species at sampled stations. The model is forced by realistic wind, tide and hydrology profiles from CTD casts. Preliminary results on comparison of model results with observations are proposed.

For most stations, maximum egg concentrations are found at surface (first 10 meters), which the model is able to simulate, by adjusting the egg density in an observed range of variation for the Bay of Biscay area. This study confirms the egg density to be the most sensitive factor affecting vertical distribution, when compared to mixing by wind or tide. For larvae, a dial vertical migration is evidenced for both species, more obvious for anchovy as early as 6mm SL on. The model is able to simulate it under light dependence, but more information is still needed to better constrained maximum depth concentration during the day, in particular food availability.

Biological-physical modelling of *Calanus* biogeography

Rubao Ji[1], Carin Ashjian[1], Robert Campbell[2], Changsheng Chen[3], Guoping Gao[3], Cabell Davis[1], Geoffery Cowles[3], Robert Beardsley[1]

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Calanus spp. copepods play a key role in the Arctic pelagic ecosystem. Among four congeneric species of Calanus found in the Arctic Ocean and its marginal seas, two are expatriates in the Arctic (C. finmarchicus and C. marshallae) and two are endemic (C. glacialis and C. hyperboreus). The biogeography of these species likely is controlled by the interactions of their life history traits and physical environment. Using a 3-D spatially-explicit individual-based model, we show that C. finmarchicus is unable to penetrate into the Arctic Ocean under present conditions of temperature, food availability, and length of the growing season, mainly due to insufficient time to reach its diapausing stage and slow transport of the copepods into the Arctic Ocean during the growing season or even during the following winter, at the depths the copepods are believed to diapause. For the two endemic species, the model suggests that their capability of 1) diapausing at earlier copepodite stages and 2) utilizing ice-algae as a food source (thus prolonging the growth season length) contribute to the population sustainability in the Arctic Ocean.

Sensitivity of fish and shellfish habitat to climate change

Elizabeth North, Adam Schlenger, Zachary Schlag, Katharine Smith

This study estimates the change in potential habitat for a suite of marine species and life stages due to intra- and interannual variability in salinity, temperature and dissolved oxygen. We developed a numerical that calculates to volume of suitable habitat using the output of coupled 3D circulation and biogeochemical models as well as the physiological tolerances of organisms. The model calculates the daily, and after integration, the annual volume of potential habitat and allows for comparison between species, seasons, and years. Preliminary results for a low and a high freshwater flow year in Chesapeake Bay suggest that Atlantic sturgeon and striped bass are most sensitive to interannual variability and hypoxia, whereas bay anchovy, blue crab and blue fish are less sensitive. Future simulations that incorporate nutrient load reductions and climate change will enable prediction of habitat range expansion, contraction, and potential extirpation for each species, and identify which species would be most affected by climate change and nutrient management. The habitat volume model is compatible with any ROMS model output, can be used to provide habitat forcing functions for EWE models, and may provide information that could reduce variability in stock-recruitment relationships. It will be released as open source code with a User's Guide.

Interannual differences in larval haddock survival: hypothesis testing with a coupled biophysical model of Georges Bank

Colleen M. Petrik, Cabell S. Davis, Rubao Ji

There is a relationship between recruitment and processes during the larval stage for haddock population on Georges Bank during the GLOBEC Northwest Atlantic/Georges Bank study period of 1995–1999. The 1998 haddock year-class was the largest of the study period, while 1995 was a year of low recruitment. Additionally, both recruitment per hatched egg and larval abundance at 15 days post hatch were higher in 1998 than 1995. We coupled a hydrodynamics model, a lower trophic level model, a copepod population model, and a larval haddock individual-based model to simulate the processes on Georges Bank during the larval period of haddock. The model was used to compare 1995 and 1998 with respect to survival over the larval period and the three hypothesized sources of larval mortality: advection, predation, and starvation. Specifically, we tested the role of hatch location and abundance, the physical environment, prey density, vertical swimming behaviour, and predation in accounting for the observed differences between 1995 and 1998. Hatch location, advection, prey availability, and vertical behaviour were rejected as causes of the interannual variability. Changes to the predation rate produced the only model results that agreed with observations. These findings suggest that predation on larval haddock was greater in 1995 than 1998, and was the dominant source of mortality during the larval period. The model results stress the importance of predation and necessitate more top-down investigations, including tests of whether predation mortality during the larval phase explains recruitment variability for a broader time period.