ICES WGIPEM REPORT 2012

SCICOM STEERING GROUP ON SUSTAINABLE USE OF ECOSYSTEMS

ICES CM 2012/SSGSUE:01

REF. SCICOM

Report of the Working Group on Interactive Physical-biological and Ecosystem Modelling (WGIPEM)

13-16 March 2012

ICES Headquarters, Copenhagen

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

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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. 2012. Report of the Working Group on Interactive Physical-biological and Ecosystem Modelling (WGIPEM), 13–16 March 2012, ICES Headquarters, Copenhagen. ICES CM 2012/SSGSUE:01. 37 pp. https://doi.org/10.17895/ices.pub.9082

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Executive summary

The Working Group on Integrative, Physical-biological, and Ecosystem Modelling (WGIPEM) held its first meeting in Copenhagen, Denmark at ICES Headquarters from 13–16 March, 2012. The meeting was attended by 50 scientists from 15 countries. Working group members discussed recent advances in biological-physical modelling at various levels of complexity including hydrodynamic models, lower trophic level (NPZD) models, individual-based models (IBMs) for specific groups / species, topological and spatially explicit foodweb models, and end-to-end models.

Although plenary sessions offered members a view of the interests and expertise of participants (many of which were new to ICES), specific workshops allowed WGIPEM members to have focused discussions. A first workshop included model comparison / validation, and uncertainty. For example, a subgroup stemming from the former WGPBI reported on their ongoing efforts to compare hydrodynamic and Lagrangian particle tracking estimates in the North Sea. A second workshop chaired by Kenny Rose (LSU, USA) discussed current methods utilized to represent behaviourally mediated animal movements within models. A third workshop chaired by Beth Fulton and Olivier Thebaud (CSIRO, Australia) discussed how the human element (e.g. fleet dynamics, valuation of ecosystem goods and services) is currently depicted within "end-to-end" representations of ecosystems within and outside ICES waters. Finally, a fourth workshop chaired by Enrique Curchitser (Rutgers University, USA) discussed techniques utilized to downscale global climate model projections to biological systems (e.g. regional ecosystems). The co-chairs of WGOOFE co-chaired a workshop that discussed their working group and ongoing activities at ICES related to operational oceanographic products.

As a result of workshop and other group discussions, WGIPEM has proposed a number of activities to occur during the next year. Stemming from the first workshop, members plan to:

1) propose a training course on methods of quantifying sensitivity and propagation of uncertainty within models of different levels of complexity including end-to-end models. In recognition of a lack of general theory on how to represent animal movement within complex, ecosystem models, a '*movement subgroup*' also proposes to

2) develop a template for reporting existing methods for modelling animal movement and summarize current activities in spatial models, and based upon those templates

3) write a manuscript documents existing methods and proposes a general framework for simulating behavioural movement.

The coupling of lower and upper trophic levels (the zooplankton interface) is critical to the successful development of spatially explicit foodweb and end-to-end models. Thus, WGIPEM members created a '*zooplankton subgroup*' that intends to

4) create a model library for exchanging generic code zooplankton on IBMs,

5) compare effects of different modelled zooplankton fields on upper trophic level dynamics, and

6) review estimates of predatory control of zooplankton in different systems to include more robust parameterizations of zooplankton mortality and trophic coupling.

Other WGIPEM activities relating to the successful implementation and utilization of end-to-end models lead to the development of a fourth subgroup ('human dimension subgroup') that will attempt to:

7) expand membership to include participation of experts in social and economic modelling, and

8) write a manuscript on current state-of-the-art in integrating the human dimension into ecosystem models.

These specific end-to-end model efforts will occur alongside the WGIPEM's regular ('Atlantis subgroup') activities that will:

9) develop new ATLANTIS models for the North Sea, Baltic Sea, eastern Channel and areas within the western Mediterranean and to compare those results with established models (e.g. Australia, Georges Bank, California).

A roadmap for the new group was developed that included both practical (specific recommendations for effective meeting formats) and strategic (group membership and links to the wider modelling community) aspects. To maintain this group's worldwide expertise, additional funding mechanisms will be necessary. Members with advisory experience considered that the effective integration of information gained from WGIPEM modelling tools within individual or multispecies assessments would be critical for future, ecosystem-based advice. Integration will depend upon building successful, concrete examples of how modellers involved in WGIPEM and assessment biologists can work together to improve advice. Although a few single-species working groups (HAWG) and the multispecies group were mentioned, collaboration with integrated assessment working groups will likely provide the most fertile ground for dovetailing biophysical, foodweb, end-to-end, and statistical modelling to generate decision tools for ecosystem-based management and the science needed to advance our understand of key processes and drivers affecting marine systems.

1 Opening of the meeting

The first meeting of the Working Group on Integrative, Physical-biological and Ecosystem Modelling was held in Copenhagen, Denmark, from 13–16 March, 2012. The meeting was attended by 44 scientists from 15 countries (Annex 1). The agenda (Annex 2) was adopted. The terms of reference for the meeting are given in Annex 3.

The working group members thank Claire Welling (ICES HQ) for her help with all of the local arrangements.

2 Convene an annual meeting with specific workshops to promote the development and review of coupled physical-biological and ecosystem modelling (ToR c)

The meeting had initial and final plenary sessions but, similar to future meetings, focused workshops were convened on current topics of high relevance to the advancement of coupled physical-biological and ecosystem modelling. Through these workshops, the co-chairs wished to attract participants having a broad range of expertise (e.g. from hydrodynamics, physiology, trophodynamics, to economics). The 3.5-day meeting had 6 different workshops:

1) Model advancements within large-scale marine research projects
2) Operational oceanography products within integrated models (WGOOFE session)
3) Model Corroboration / Validation
4) Behaviourally driven movement of animals
5) Incorporating human effects within integrated ecosystem models
6) Downscaling climate signals to biological systems

The co-chairs specifically invited Icarus Allen (PML) for theme 1, Beth Fulton and Olivier Thebaud (CSIRO) for theme 3, Kenny Rose (LSU) for theme 4, and Enrique Curchitser (Rutgers Univ.) for theme 5. Workshop / theme leaders were asked to emphasize products (review manuscript, websites, comparative analyses, etc.) that could result from their workshop discussions. WGOOFE held its spring meeting in association with WGIPEM and that group's co-chairs (Bee Berx and Rosa Barciela Fernandez) were responsible for Theme 2.

This first WGIPEM meeting represented a mixture of members of the former WGPBI, members of WGOOFE as well as representatives from WGOH, WGSAM, HAWG, and integrated assessment working groups of the Baltic and North Seas (WGIAB and WGINOSE). For many participants, this was their first ICES working group meeting.

3 Report on the state-of-the-art within the ICES community and worldwide in coupled physical-biological and ecosystem modelling and simulation results (e.g. population connectivity, life cycle dynamics, foodweb interactions and/or ecosystem responses to human activities; ToRs a & b)

A series of first talks helped set the stage for the WGIPEM by providing participants a perspective of different ICES working groups including WGOOFE, WGSAM, and WGOCE. Other talks discussed achievements made within WGPBI. Many of the WGIPEM working group members were members of WGPBI. These first presentations provided needed background information so that, during the course of the meeting, bridges could be proposed with other working groups within and outside ICES. In this regard, a brief summary of ongoing, large-scale marine programs that include biophysical and integrative ecosystem modelling was deemed necessary.

The following section provides a summary of the four workshops by including a representative selection of the 35+talks that were made during the WGIPEM. The next section (Section 4), summarizes discussions stemming from those presentations including recommendations for future work of WGIPEM made by its members.

3.1 Introductory ICES WG Presentations

A number of ICES WGs were represented at the WGIPEM so that an overview could be provided to frame WGIPEM's activities within the larger ICES framework.

The working group on multispecies modelling (WGSAM) was represented by Stephan Neuenfeldt who provided a brief review of the activities of that group. Common membership between WGIPEM and WGSAM should facilitate information exchange and collaboration.

The Working Group on Oceanic Hydrography (WGOH) was represented by Anna Akimova who discussed the main objectives of this group – maintaining, analysing, improving, and expanding the repeated oceanographic stations and sections in the extra-tropical North Atlantic. These dataset cover the whole basin and up to a 100 year time period. The group is in a good position to examine the basin-wide processes, their long-term variability and response of the regional systems to the propagating large-scale signals (such as intensity of the Subpolar Gyre and strength of Atlantic Meridional Overturning Circulation) and the impact of the regional perturbations onto the dynamics of the North Atlantic. The main product of the group available for the ICES Community is yearly updated ICES Report on Ocean Climate (IROC). Potential links between WGOH and WGIPEM would be:

1) The process-oriented model approach, pushed forward by WGIPEM, can be extremely helpful in identification of observational gaps (temporal and spatial resolution of observations, as well as parameters being sampled). Especially it is true for long-term monitoring programs, whose success extremely relies on the well-planned design.
2) The understanding of the variability of the regional ecosystem often cannot be only explained by the regional hydro- and thermodynamics. The propagating larger-scale (basin and sub-basin) signals have to be taken into account. Such signals propagate in form of salinity and temperature anomalies, water transport/exchange variability and are accompanied by

the propagating changes in the ecosystem (e.g. shifts of the species distribution, species migrations, ecosystem shifts). Therefore it is important to consider the functioning ecosystem in the context of its changing physical structure, especially concerning human-induced change and natural variability in climate-driven factors.

3.1.1 Workshop 1: Model advancements within large-scale marine research projects

The Workshop 1 chair (Icarus Allen) could not attend the WGIPEM because of illness. He sent a presentation that described the MEECE program including the website developed by that program. The MEECE program has advanced a number of biophysical and ecosystem modelling tools including a generic model coupler.

Myron Peck provided a brief review of ongoing modelling efforts within VECTORS, an EU FP7 project funded from March 2011 through January 2015. The project is using an integrated, multidisciplinary approach to understanding pressures and vectors of changes in European regional seas. A total of 38 partners from 16 countries are working on pressures and vectors of change in the North Sea, Baltic Sea and Mediterranean Sea. Issues tackled within VECTORS include fisheries, aquaculture, renewable energy exploration, maritime traffic, tourism in light of ongoing changes in climate (distribution and productivity of ecologically and commercially valuable species) and the spread of invasive / non-indigenous species. A number of modelling presentations at WGIPEM were made based upon VECTORS modelling activities. A few examples include the development of Atlantis models in the North Sea, Eastern Channel, and strait of Sicily, utilization of a coupled NPZD-dynamic energy budget model (ERSEM- DEB) for flatfish in the North Sea and efforts to adapt a size-based upper trophic level model (OSMOSE) for use in the North Sea (Figure 1).

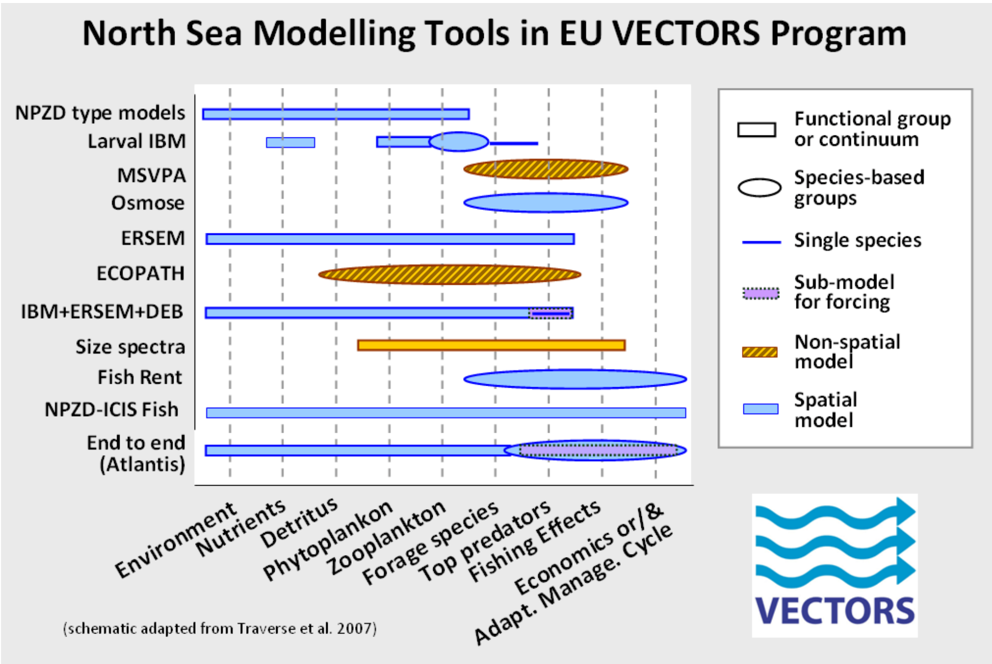

Figure 1. Examples of different models being developed in the EU program VECTORS. VECTORS provided funding for two workshop chairs (Beth Fulton and Olivier Thebaud) to attend the WGIPEM.

Miguel Bernal provided a short review of 'REPROdUCE', a 3-year project (2009–2012) led by the Spanish Oceanographic Institute (IEO) and including research teams from the Hellenic Center for Marine Research (HCMR), the French Institute for Marine Research (Ifremer), AZTI-Tecnalia Marine Research Division, and the Portuguese Institute for Fisheries and Marine Research (IPIMAR). The project focus in two case studies, anchovy and sardine in the Bay of Biscay and anchovy in the northern Aegean Sea, and aims to analyse the combined effect of climate, human pressure and population dynamics in the recruitment potential of these two species. The modelling framework consists on a set of hydrodynamic ocean models coupled with nutrient and lower trophic levels models and individual based models of sardines and anchovies. Main results so far include the finalization of a full life cycle model of anchovies in the Aegean Sea, and the development of early life stages (ELS) models of sardine, ELS and adult IBM models of anchovy in the Bay of Biscay and a generic dynamic egg production model for sardines and anchovies. Recruitment drivers that will be analysed in the last stage of the project include the effect of hydrodynamic energy (transport/retention) in recruitment success, the effect of food availability in sardine and anchovy growth, and the effect of individual condition, spatial distribution and biomass on population recruitment potential. Main model limitations found in the project include implementation of realistic movement and migration (feeding/reproductive) routines for IBMs and lack of dynamic, spatially explicit, mortality rates.

The modelling studies for the US GLOBEC Northwest Atlantic were reviewed by Rubao Ji. As a case study, the modelling study on the biogeographical boundaries of the cold water species *Pseudocalanus* spp. and the warm-water species *Centropages typicus* the northwestern and northeastern Atlantic was presented. A population model coupled to a three-dimensional ecosystem model including species-specific processes and parameters was used in the study. The analysis focused on the relative contribution of feeding strategies, predation control and advection influences. Model experiments were conducted to test whether the model with the same parameter set for *C. typicus* in the Gulf of Maine would reproduce the observed patterns when applied to the North Sea. Differences in the results reflected site-specific adaptations to the ecosystem and suggested possible missing control mechanisms that need to be included in the model.

3.1.2 Workshop 2: Operational oceanography products within integrated models (WGOOFE session)

A presentation made by Frank Janssen discussed operation oceanographic modelling in European waters. Several operational model systems have been developed and applied in the North Sea/Baltic Sea region over the last three decades. During this period the models were expanded in several directions. Today comprehensive model systems covering the North Sea and the Baltic Sea are providing forecasts for the physical environment every day. During recent years ecological components were added to the model systems extending the forecast to bio-chemical state variables such as nutrients and dissolved oxygen (Figure 2). The next development steps include the implementation of data assimilation schemes for the ecosystem component of the model.

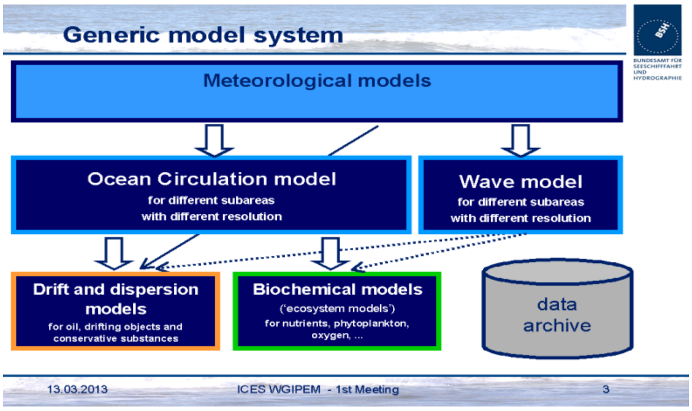

Figure 2. Generic overview of a typical operational model system.

The presentation gives an introduction to the model systems and it's major applications and include an outlook to ongoing and planned developments.

3.1.3 Workshop 3: Model Corroboration / Validation

There were a series of presentations that discussed various aspects of model complexity and agreements between observed and modelled factors. This was a wide ranging discussion that included both physical model outputs (hydrodynamic in relation to population connectivity estimates as well as presentations on short- (decadal) and long-term (multidecadal) runs of lower trophic level (NPZD) models. In contrast to other models presented at the WGIPEM, the first presentation offered a more simple model of foodweb topology. Some of these presentations in Worksop 3 are briefly discussed below.

Numerical models of marine ecosystem models are notoriously difficult to construct because of their complexity as well as the many unknowns features of fundamental processes of ecosystems. In the face of such difficulties, Benjamin Planque and Ulf Lindstrøm provided a presentation on the development and utility of a dynamic stochastic foodweb model constructed for the Barents Sea. Their simple approach was based on a very limited set of constraints (mass-balance, physiology and life-history traits) and stochasticity and was capable of mimicking a wide range of features observed in the Barents Sea. The dynamic stochastic foodweb model can serve as a reference against which other models can be tested and as an experimental device to test possible effects of environmental change on the Barents Sea ecosystem. The purpose of dynamic stochastic foodweb model (DSF) is to provide a realistic representation of foodweb dynamics based on a minimal set of constraints and stochastic trophic interactions. The model constraints include mass-balance (i.e. the conservation of mass within the system), physiology (i.e. satiation: the maximum amount of food intake of a predator per year per unit biomass) and inertia (i.e. the maximum relative variation in biomass of a tropho-species per year). The first prototype of the model for the Barents Sea includes six tropho-species and the trophic interactions between them. Despite its extreme simplicity, the model can reproduce realistic time-series of fluctuations in biomass of individual trophospecies as well as trophic relationships or diet composition. At the ecosystem level, the model also produces realistic fluctuations in trophic controls (top–down and bottom up oscillations), or apparent regime shifts. The DSF model shows that many of the properties that are observed in real ecosystems could simply result from a very minimal set of constraints. This model can serve as a reference model against which other more complex ecosystem models can be tested, or can be used as a tool to evaluate the performance of quantitative resilience indicators. The DSF model is under development to include additional features such as age-structured populations and multiple geographical units.

Marc Hufnagl presented the results of an intercomparison of hydrodynamic model drift and population connectivity estimates started during WGPBI. Part of that work will form a presentation at the upcoming ICES ASC in Bergen (a session co-chaired by WGIPEM members Marc Hufnagl and Genevieve Lacroix). In a second presentation, Klaus Huebert presented a statistical sampling technique recommended for comparison of spatially explicit model estimates and observations. In this example, various physical (temperature) and biological (bulk carbon estimates of phytoplankton, zooplankton groups) from an NPZD model (ECHAM – Johannes Paetsch, University of Hamburg) were compared to continuous plankton recorder estimates over the same 20 year period at the same locations.

In another presentation, efforts to corroborate / validate long-term hindcasts of a lower trophic level model were presented by Ute Daewel and colleagues. ECOSMO is a fully coupled 3d lower trophic level ecosystem model (Schrum *et al.*, 2006) that has been applied to the North and Baltic Sea. Here, an expanded version ECOSMO II was presented that makes this model more applicable to a wider range of ecosystems. A number of additional processes were incorporated, emphasizing especially sediment processes and a third phytoplankton group to account for cyanobacteria. The model has been used to create a reconstruction of the hydrodynamic and biogeochemical environment of North Sea and Baltic Sea for a 60 years period (1948–2008) in order to present a new, consistent, and improved multidecadal reconstruction of the ecosystem dynamics in North and Baltic Seas. This hindcast simulation has been validated against nutrient data from the ICES and HELCOM databases. The validation revealed that the model was able to properly capture patterns in the nutrient dynamics in both seas (Figure 3) and reveals that both the seasonal and long-term variations are properly described. Weak model performance was only observed near the continental coast (region F, G and H) where summer production seems to be too early phosphate limited, while the observations indicate phosphate limitation occurring later.

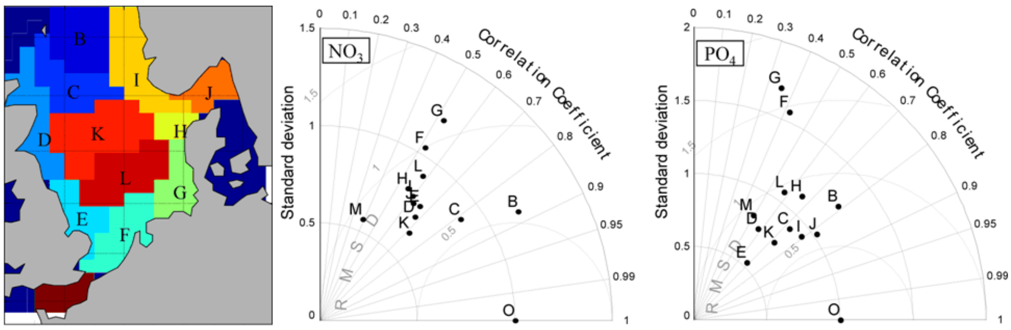

Figure 3. Taylor diagrams for model validation of North Sea surface nutrients in different ICES boxes (Left). Middle: Nitrate, Right: Phosphate. Reference data are from the ICES database.

3.1.4 Workshop 4: Behaviourally driven movement of animals

The first talk in this workshop was given by the invited speaker (Kenny Rose along with 9 co-authors) and was titled 'Modelling movement of fish over spatial and temporal scales: if fish were dumber and people were smarter'. The talk highlighted how realistically simulating the movement of fish in spatially explicit models remains a major challenge, and the importance of correctly simulating movement if one attempts to forecast climate change effects on fish. The presentation reported on collective experiences gained by the co-authors using a variety of movement modelling approaches focused on tracking individuals in population and multispecies models. The models ranged from using time-steps of minutes to days, and from meter resolution cells within a 2-D grid to km resolution cells within a 3-D hydrodynamic grid. Approaches we have attempted include restricted-area search, neural networks, event-based, kinesis, run and tumble, and versions of random walk. Genetic algorithms have been utilized to provide parameter estimation of these approaches.

All of the methods can be configured to produce realistic looking spatial patterns of individuals. In some cases, simply including geographic location information as an input to movement algorithm was sufficient. However, pattern matching can easily result in movement models that have very limited utility for simulating movement under new (novel) conditions. Other aspects of the methods that pose a challenge to the general use of movement models in population-level models include: (1) fixed parameters preventing adaptive and phenotypic variation in behaviour, (2) edge effects, (3) stranding and oscillatory movements, (4) weakly convergent parameter values, (5) renegade individuals, (6) bifurcated movement patterns, (7) short-cut solutions that use geography, and (8) compromise behaviours from multiple cues. The talk illustrated some of these issues with examples from specific models and presented some encouraging initial results of testing movement schemes in novel environments,

The performance of four commonly used movement approaches: restricted-area search, kinesis, event-based, and run and tumble were compared. Each approach was trained in one type of growth and mortality environmental grid using a genetic algorithm and then tested in novel environments (i.e. the other three environments). The next steps include varying the spatial resolution of the grid and testing when growth and mortality dynamically change on the environmental grid. The objective is to determine if these approaches can produce realistic movement in new situations, and under a range of spatial resolutions. The talk ended with advice on how to simulate movement in spatially explicit models.

In a second talk, Geir Huse and colleagues discussed modelling foraging migrations of planktivorous fish in northern European / Subarctic waters. Examples were provided of three different methods including 1) Data driven for herring, mackerel and blue whiting migration in the Norwegian Sea, 2) Fitness based for capelin migration in the Barents Sea, and 3) rule based for cod-capelin interactions in the Barents Sea. These behaviour schemes were either fully or one-way coupled to a larger model framework of the Norwegian and Barents Sea ecosystems (NORWECOM.E2E).

A presentation by Jean-Noel Druon discussed habitat mapping of feeding and spawning areas of large pelagic fish in Mediterranean waters utilizing satellite-derived information. Feeding and spawning habitats are generally separated for bluefin tuna as they correspond to distinct biological requirements and it avoids that the top predator's prey feeds on the top predator's larvae. The JRC bluefin tuna habitat model (Druon *et al.,* 2011) uses satellite data of Sea Surface Temperature (SST) and surface chlorophyll content (chl-a) in turbid-free waters from MODIS-Aqua sensor (NASA) to compute daily habitats since July 2002. The feeding habitat was mainly traced by horizontal changes of surface chlorophyll content (chl-a fronts) created by the convergence of different water masses, while the spawning habitat was mostly inferred from the heating of surface waters and a low range of chl-a content (optimizing larvae survival). Both habitats were defined by the presence of relevant oceanographic features and are therefore potential and functionally linked habitats, as opposite to effective habitats which are always difficult to produce for marine animals, especially highly migratory ones such as tunas.

The daily maps of potential habitat of a common top-predator are likely to provide key information on highly productive areas exploited by the pelagic foodweb. This ecological niche of the pelagic ocean is highly variable in space and time, including from year-to-year, as being derived from the productive oceanic features at mesoscale. The potential distribution of top predators or their preys estimated from the habitat maps may thus be used to either force an E2E model or calibrate/validate it with the appropriate time and spatial scales. The growth and recruitment parameters of top predators may also depend on spatio-temporal fluctuations of the feeding and spawning favourable habitats respectively. This information on habitat may also be used to standardize catch per unit of effort in case mortality by fisheries is a component of the E2E model. Other potential uses in fisheries management are described in Druon (2010). Additional applications of this approach include the identification of finback whale feeding habitats in the Western Mediterranean Sea, yellowfin and skipjack tunas in the tropical Atlantic and western Indian Oceans, and European hake in the Mediterranean Sea.

Another presentation by Genevieve Lacroix *et al*. summarized the impacts of vertical migration and settling delay on the dispersal dynamics of early life stages of sole (*Solea solea*) in the North Sea. Connectivity throughout the life cycle of flatfish remains an open question, especially during the early life stages. The case of sole is of particular interest because it is one of the most valuable commercial species in the North Sea. The transport of sole larvae from the spawning grounds to the nurseries is driven by hydrodynamic processes, but the final dispersal pattern and larval survival/abundance might be influenced by both behavioural and environmental factors. A particle-tracking transport model for sole was coupled to a 3D hydrodynamic model of the North Sea (Lacroix *et al*., under revision) to investigate the impact of behaviour on the recruitment dynamics to the nurseries over a 12-year period (1995-2006). Measured meteorological forcing, SST and river run-off were utilized in order to study the interannual variability of dispersal and transport success to the nurseries due to hydrodynamical and environmental year-to-year variability. The sensitivity of larval abundance at nurseries to behaviour is assessed by estimating the impact of (i) diel and tidal vertical migration and (ii) an extended drift period before settlement (max. 30 days) if the larvae are not close to a suitable sediment type. Results show that larval retention in nurseries increases (resp. decreases) when vertical migration is included for FR, BE and NL (resp. No and Tha) nurseries. Larval recruitment increases when a settling delay is considered.

Karen van de Wolfshaar provided a presentation detailing efforts to parameterize 'Osmose', a spatially explicit foodweb model, for the North Sea upper trophic levels. The model can be forced by lower trophic level model outputs or dynamically coupled to lower trophic levels. Life-history processes modelled include resource dependent growth, predation mortality, starvation, fishing mortality and reproduction. Space can be accounted for by including data from species presence-absence maps, resource distribution maps, and human impact maps (such as MPA's). The output of Osmose is on the species level (e.g. diet, biomass, length, and age structure) and foodweb level (e.g. catches, foodweb structure and size spectrum). Marine Framework Directive indicators may be a direct or indirect output from the model. The North Sea parameterization is ongoing with zooplankton input as a short-term challenge. The long-term wish list is growing.

A presentation made by Dimitris Politikos discussed an individual-based model representing the life cycle and movements of European anchovy (*Engraulis encrasicolus*) developed within the MEECE and REPRODUCE projects. The model depicts the spatio-temporal abundance, growth as well as the transport and the migration patterns of this species in the northern Aegean ecosystem. The fish model is online linked to a hydrodynamic-biochemical model, while it is structured in a modular approach using a bioenergetics growth, a population-reproduction, and fish movement modules. One of the major challenges in the implementation of end-to-end models is to simulate dynamically the fish movement patterns based on the environmental and ecological fields. The main factors that determine fish movements in this model were the currents fields, food availability, bathymetry, fish swimming speed, and the fish life stage. Specifically, the swimming speeds of late larval, juvenile, and adult anchovies were assumed to depend on physiological status. The anchovies moved towards higher food resources while remaining within certain, known bathymetric ranges. The fish actual swimming velocity is adjusted taking account of the current velocity in order to achieve the desired direction. Also, a stochastic term is added to take into account external factors in the movement process (e.g. avoid predation). The fish migration module is applied as a part of the full life cycle anchovy model.

3.1.5 Workshop 5: Incorporating human effects within integrated ecosystem models

The first presentation, by Beth Fulton, described how ecosystem models have come of age scientifically, with applications in 100s of locations around the world but that the use of ecosystem models in management is quite limited. The latter are used in just a few locations (e.g. US and Australia) as a means of informing strategic management decisions. There are many different forms of end-to-end model from qualitative to ones including only a few ecological groups through to whole of system versions that include fairly equal resolution of physical, biogeochemical, foodweb and human sectors. In E2E modelling the anthropogenic activities have received the smallest attention in the literature (and often in the models). Fisheries have received the most attention and can be represented in many ways – from simple catch, effort or fishing mortality forcing, through to simple catch-per-unit-effort models that can capture gross changes in effort and finally quite detailed models of human behaviour including economic, social and psychological drivers.

Fisheries are only one of the sectors active in marine and coastal-zones and these other sectors are beginning to be included in models developed in support of integrated coastal-zone management. For example, in an agent-based model of the Ningaloo Reef — Exmouth Gulf region (of Western Australia) all the major sectors active in the region were dynamically included (conservation, tourism, commercial and recreational fishing, mining, oil and gas, urban development, infrastructure, road networks, shipping, agriculture). The results of the model simulations highlighted the complex relationships between development and environmental status in the region. There is a strong tension between the need for on-land development to arrest problems of an aging population, but such developments need to be carefully monitored and managed to avoid irreversible degradation of marine resources (particularly in association with the cumulative effects of climate change and ocean acidification). Such a system-level perspective of exploited marine ecosystems provides insight into cross-scale dynamics and potential conflicts between sectors operating within the same region. This kind of information is a necessary part of adaptive management. In addition, the collaborative definition and exploration of system models (or simplified forms of them) can also assist discussions between interested parties from the competing industries and system users. Agent-based models have proven quite an effective platform for dealing with the large number of scales and processes that can drive the alternative states of socioecological systems. The approach has sufficient flexibility to include biophysical, social and economic drivers and interactions.

A number of presentation discussed ongoing development of end-to-end models in European waters with the goal of creating decision support tools. Within the fisheries context, the importance of an ecosystem approach to management is largely promoted to sustain marine ecosystems' health and the fisheries that they support. One priority identified is the improvement of knowledge of ecosystem functioning and dynamics (foodwebs, trophic flow, physical-biological coupling models, etc.). This objective requires the development and implementation of realistic and predictive models that are able (1) to account for multiple interactions at different scales, (2) to assess ecosystem responses to environmental drivers and anthropogenic pressures, and (3) to test impact/s of possible management scenarios.

Within the eastern Channel region, Martin Huret, Morgane Travers and other colleagues presented their two-phase approach to creating an end-to-end model. The first phase implements a sequential modelling approach using existing spatially explicit ecosystem-based and fisheries dynamics models developed in the Biscay to southern North Sea shelf (Western Waters) marine zones. These models are often developed as support tools to respond to specific objectives. Each will have its own requirements, capabilities and limitations. We propose to utilize these models comparatively and define areas wherein outputs can be used complementarily. During the second-phase, processes will be defined in order to achieve a concerted (coupled) model of this maritime zone. Several models dedicated to the understanding of the different components of these ecosystems have already been coupled. In this presentation we propose 1) to provide a detailed description of each model focusing particularly on their spatial features (Hydrodynamic MARS, OSMOSE and ISIS-Fish), 2) to present the coupling experiments in the western waters and 3) to explicit our integrated modelling approach. More details are provided on the WGIPEM SharePoint site.

In another talk in this workshop, Triantafyllou and colleagues presented an end to end (E2E) marine ecosystem model coupling a physical, biogeochemical and fish model in the northern Aegean Sea. Previous data assimilation studies estimated the state of the physical and/or biochemical models and work by Triantafyllou and others now focused on the fish model by taking into account key attributes of the population (length of individuals, biomass, and catches). In the most general form, data assimilation into all three submodels is required but, to simply matters, the physical model was assumed to be perfect. Thus, the estimation of the states of the biochemical and fish models using biochemical and fish observations was the focus. Simultaneous assimilation of data into both models is required to constrain both submodels and to assure consistency between their respective analyses. This issue was tackled using a joint low-rank Kalman filter in which the state vector of the ecological model is appended straight into the fish state vector, to form one single state vector for the coupled system. The fish and ecological observations were also appended together into one single observation vector. Each model carries out the time update for the ecological and the fish part. However, the entire augmented covariance matrix is propagated as one. Outcomes of several assimilation experiments examining the impact of assimilating ecological and/or fish data on the estimates of the ecology and the fish were presented and discussed.

Hjøllo and colleagues discussed an individual-based model for *Calanus finmarchicus* based on super-individuals and evolving traits for behaviour, stages etc. that has been two-way coupled to the NORWegian ECOlogical Model system (NORWECOM). After a discussion of typical coupled modelling issues as how to define useful starting fields for ocean state and all trophic levels, how to deal with an increasing number of super-individuals, and validation of model results towards sparse datasets, one year of modelled *C. finmarchicus* spatial distribution, production and biomass were presented. The model results are found to represent observations reasonably well, and experiments with the model system indicates that it provides a valuable tool for studies of ecosystem responses to causative forces such as prey density or overwintering population size (Hjøllo *et al.,* 2012). Our present work includes model module development (krill, other *Calanus* species), long time runs 1995–2005, climate effects studies (using forcing from IPCC AR4) and integration of human effects through involvement in *Calanus* fishery assessment (Figure 4).

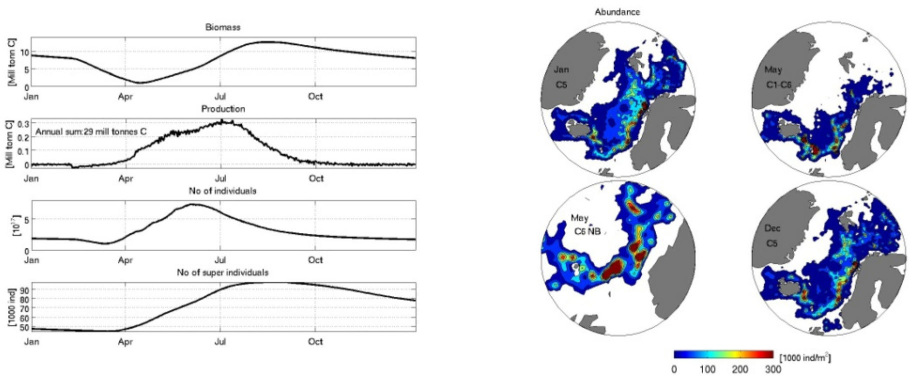

Figure 4. From the model simulation for 1997: left: daily values for biomass, production, no of individuals and super-individuals. Right: High *C. finmarchicus* abundance is found along the Norwegian shelf break in the early summer, while the overwintering population is found along the slope and in the deeper Norwegian Sea basins.

Ji and colleagues presented a modelling study on biogeographic boundary of Arctic Calanus species, including 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, results 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. A simulation of 2°C warming in the Arctic Ocean would greatly increase the area of the central Arctic in which the Arctic endemics could reach diapause but had little effect on the regions of successful diapause for the expatriate species.

3.1.6 Workshop 6: Downscaling climate signals to biological systems

Enrique Curchitser presented results from his work with colleagues on downscaling a climate model in the California Current and linking it to a fish and fleet model for sardine and anchovy. The model is based on the NCAR Community Earth System Model (CESM), the Regional Ocean Modelling System (ROMS), the NEMURO NPZD lower trophic level model and the an individual based model for sardine anchovy and a fishing fleet as schematically described in Figure 5. During his talk, Curchitser made the case that downscaling coupled climate models requires a different approach than regional hindcast simulations. He showed results from a fully dynamically coupled multi-scale climate model and made the case that when downscaling from a coupled model it is important to retain full feedbacks between the downscaled region and the global model (two-way coupling). He then proceeded to show results of ongoing work that couples the multi-scale physical model to the fish and fleet model in the California Current.

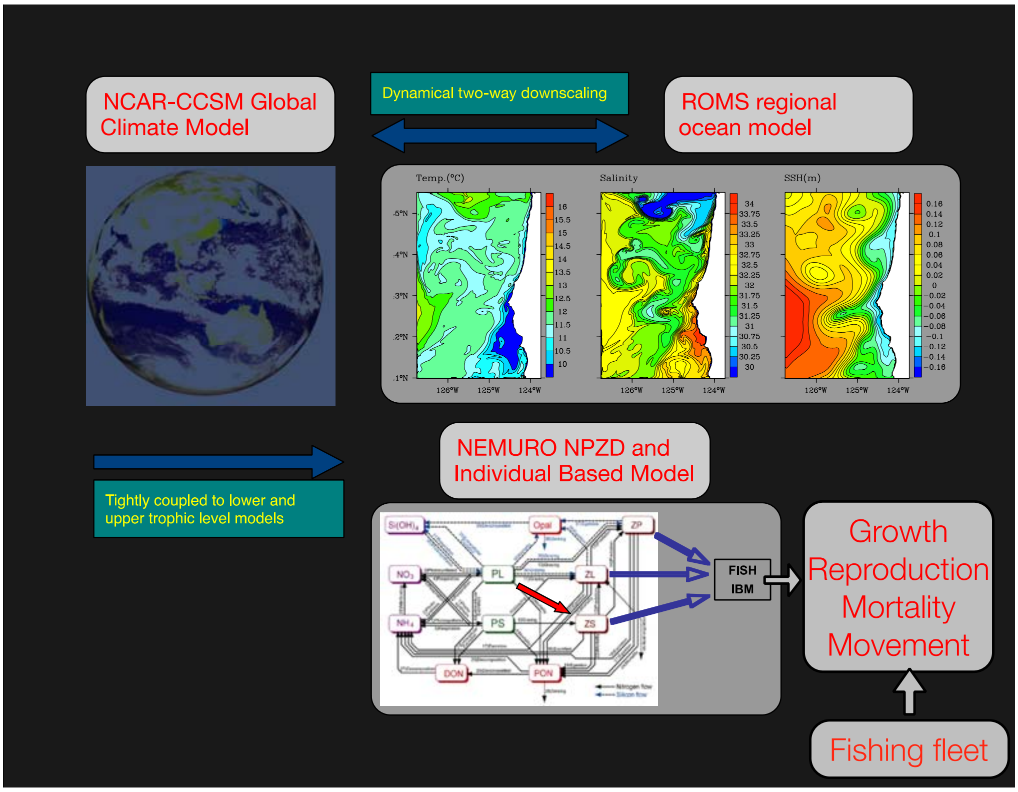

Figure 5. Example of downscaled climate to fish to fisher's model for the California current system.

Susa Niiranean and Helen Andersson discussed the ECOSUPPORT-project, that was the first project to examine potential ecosystem-wide effects of future climate change (-2100) using data from regionalized global General Circulation Models (GCMs). Changes in the Baltic Sea foodweb were studied with an Ecopath with Ecosim foodweb model for the Baltic proper (BaltProWeb), driven by fishery, and environmental forcing from an ensemble of three biogeochemical models. The BaltProWeb model was run for two cod fishing, three nutrient load and two regional climate change (downscaled from the global IPCC scenarios A1B and A2) scenarios, in all combinations. Across the scenarios, the Baltic cod (*Gadus morhua*) stock was negatively affected by the combination of decreasing water salinity and deep-water oxygen concentration. When fishery was not adjusted to accommodate for the deteriorated reproduction conditions, a cod stock collapse was projected. Cod prey sprat (*Sprattus sprattus*) was in most scenarios favored by the increasing temperatures and decreasing predation pressure. The intermediate trophic level groups, such as zooplankton and clupeids, were largely affected by the interactions of multiple drivers, highlighting the importance of holistic ecosystem approaches when the possible climate change effects on marine ecosystems are evaluated. This study demonstrates how information from global climate models can be used to project foodweb futures at regional scale. In addition, we address the potential usefulness of ensembles of higher trophic level models by comparing results between BaltProWeb and a multispecies model BALMAR.

3.2 References supporting Section 3

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Hjøllo, S. S., Huse, G., Skogen, M. D., Melle, W. 2012. Modelling secondary production in the Norwegian Sea with a fully coupled physical/primary production/individual-based *Calanus finmarchicus* model system. Marine Biological Research 8: 508–526.

Lacroix, G., Maes, G. E., Bolle, L. J., and Volckaert, F. A. M. under revision. Short-term dispersal dynamics on the early life stages of sole *Solea solea*.

Schrum, C., Alekseeva, I., St. John, M. 2006. Development of a coupled physical-biological ecosystem model ECOSMO: Part I: Model description and validation for the North Sea. Journal of Marine Systems 61:79–99.

4 Identify gaps in knowledge in these modelling activities and recommend activities to advance coupled modelling approaches and that will make model outputs useful to the management of marine systems (ToR c)

Break-out discussion groups met on 15 March from 14:30 to 16:00 to discuss gaps in knowledge and to recommend WGIPEM actions. Summaries are provided in this section.

4.1 Human Dimension Subgroup (4 participants)

1) Discussions of this group focused on developing a roadmap on how to include the "human dimensions in ecosystem models".
2) A brief presentation of a current earth system modelling project in the USA, which includes a strong economic and social network modelling component, was provided by Enrique.
3) There was agreement that WGIPEM needs to increase its expertise in the economic and social sciences, and a list of people who could be contacted and invited will be made. The expertise needed includes ecological-economic modellers, social scientists with an interest in modelling human behaviour, environmental valuation specialists, and agent-based modellers.
4) New contacts should be made in such a way that these different areas of expertise can be represented, but the subgroup remains of a manageable size (around 10 people max).
5) To interest colleagues in joining the group, a focused project should be developed such as to carry out a review of the state-of-the-art in including human dimensions in marine ecosystem models, with the aim to prepare a commentary paper. Although the specific focus of the review would need to be discussed and finalized with the new participants, key aspects that could structure the review include the following:
   - Focus on human behaviour at multiple scales, and how this can (or can't) be modelled as part of ecosystem models;
   - Focus on marine ecosystem modelling but use experience gained in other domains in where there is an attempt to couple ecosystem- dynamics and human behaviour (e.g. ecological-economic modelling of coastal systems such as the Dutch coast, Mediterranean lagoons, Chesapeake Bay; agent-based modelling of natural resource systems; coupled economic-climate models; …);
   - Identification of major gaps and key research areas.
6) The "human dimension" group also considered the possible opportunities to meet alongside forthcoming international workshops / meetings, such as the Bioecon and EAERE conferences.
7) WGIPEM should also engage with other ICES WGs or STECF around questions of overlapping interests (e.g. on the question of data needs and data availability regarding models of fisheries, or the selection of modelling approaches).

8) Participants in the discussions also expressed an interest in being involved in other, cross-cutting activities undertaken by the WGIPEM, including: i) model coupling. ii) discussion on where and when end-to-end modelling is useful, and iii) comparison of movement modelling across human / biological system components

9) The subgroup was composed of Soile Kulmala, Rolf Groeneveld, Enrique Curchitser, and Olivier Thebaud.

4.2 Fish Movement Subgroup (16 participants):

1) A long-term plan was discussed, of which the first step would be a paper on developing a theoretical foundation for modelling movement in spatially explicit models, including end-to-end models.

2) The long-term plan is to: (a) first document the existing movement algorithms used, than bring in literature on behaviour, cognition, sensory abilities, and learning, and then propose a foundation for modelling movement; (b) select some of the existing movement algorithms, plus some new ones from paper 1, and plug them into an existing Atlantis application. In paper 2, we would then perform a simulation experiment with one factor as alternative movement algorithms and the other factor being the scenarios. The scenarios could be baseline, closed areas, reduce fishing, and climate change. This would be paper 2 from the movement group.

The basic idea of the long-term plan is see what has been done, what additional information can be used to formulate a sound theoretical basis, what should be aware of, and then with Atlantis, what are the implications of different movement algorithms within an end-to-end model.

3) At paper 2, the human group (Atlantis) and the movement group reassemble and perhaps work together on the Atlantis comparison of movement alternatives.

Including fishing fleets also involves modelling movement, and at some point, the human group and movement groups should come together before paper 2, and see the commonalities and differences between animal movement and fisher movement modelling.

4) Two other topics were proposed that may be best addressed with small subgroups. One topic is how to represent super-individuals in end-to-end models (closed life cycle, competition, predation, movement). The second other topic was how to test movement in end-to-end models using field data. The data on organism movements is advancing quickly, and how should we use the data to test movement models. The idea is how to compare hydroacoustics and tagging data (e.g. CFEAS) vs. model predictions.

5) We include all organisms in this committee's activities. These include zooplankton, fish larvae and vertical migration, juvenile and adult fish, mammals, and even people as fishers. All of these involve movement, and share common needs and approaches.

6) We focus on short-term (day-to-day) and longer-term movements (e.g. spawning migrations offshore). True migration involves a homing component.

7) In paper 1, we will first discuss the reasons why movement is important and why a conceptual basis is needed. There are many reasons. One is the

need to look at area closures, another is that as stocks rebuild, can they repopulate historically good spawning areas. In the North Sea, zooplankton and fish accumulate at frontal zones, and herring aggregate at wind warm structures.

8) There are examples where the plasticity in movement has been critical aspect. For example, sprat stopped vertical migration when prey changed, and herring reversed day/night vertical migration dependent on predator type. Fish can change activity to keep energy intake constant over a wide range of prey biomasses. Forced movement (statistical models fit to data) has difficulty in predicting these types of changes in behaviour.

9) We need to understand some of the mechanisms at a coarse level to include movement that can respond to changing and new conditions.

10) Thick tails on variability of movement responses can protect the population under extreme events.

11) Some ideas to cover in paper 1:

a) Great variability among individuals.

b) Movement depends also on the internal state of the individual.

c) Cognition, learning, sensory abilities, and physiology.

d) Evolutionary memory vs. short-term memory.

e) How to deal with potentially important sub-grid scale variability. This can be the scale that the organism is operating within, but is not near the temporal and spatial resolutions of the models.

f) Costs of alternative movement reactions and its effects on fitness. Does the journey matter? If just circling within the nursery area, why bother to model the fine-scale movement within the nursery area? Turning can cost 6x the energy as going straight.

g) Role of optimization and game theory in movement.

h) Schooling is a major aspect of survival and how to deal with schooling in larger models. There is also the issue of mixed-species schools.

i) We can benchmark the responses with forcing organisms in bad places, a random walk, and best possible fitness (complete omniscience and a perfectly behaving organism).

j) Gradients vs. restricted area.

k) How to include competition and predation risks.

l) Sub-daily and diurnal patterns within model time-steps.

m) Translating behaviour from individuals to super-individuals.

n) How do we include the level of detail in movement that is needed for our questions, but not any more detail than is needed? Movement is scale-dependent.

o) The alternative to mechanistic movement modelling is to forced spatial distributions and then the results are conditional on the forced movement patterns. This can work well for some questions, but become a problem for forecasts under new conditions when movement patterns can change.

12) The 16 attendees were: Kenny Rose, Stefan Neuenfeldt, Loes Bolle, Anna Akimova, Dimitris Politikos, George Triantafyllou, Diego Macias, Bee Berx, Rosa Barciela, Klaus Huebert, Jean-Noel Droun, Morgane Travers,

Lorna Teal, Morten Skogen, Mark Dickey-Collas, and Myron Peck. Geir Huse, Beth Fulton and Olivier Thebaud could not attend but mentioned wanting to be involved in activities.

4.2.1 End-to-end (Atlantis) Subgroup (6 participants)

There are currently four Atlantis models being developed by WGIPEM members in collaboration with Beth Fulton (CSIRO). The domains for these Atlantis models cover: a) The Strait of Sicily (key contact is Bernardino Patti (CNR, Italy)), b) The Eastern Channel (key contact person is Raphael Girardin (Ifremer), c) The North Sea including the eastern Channel at lower spatial resolution (The key contacts are Marc Hufnagl (vTI-UHam), Alexander Kempf (vTI) and Will Le Quesne (Cefas), and d) The Baltic Sea (contact here is DTU-Aqua). These models are in various stages of development with most having identified and initially parameterized foodweb components. When completed, these models will be able to simulate adaptive management cycles for each region that take into account the costs and trade-offs (and interactions) among various economic sectors in light of ongoing anthropogenic changes in those ecosystems (e.g. North Sea = Fisheries, Renewable Energy / Windfarms in light of Climate Change). An example of the spatial resolution of the North Sea model is provided in Figure 6.

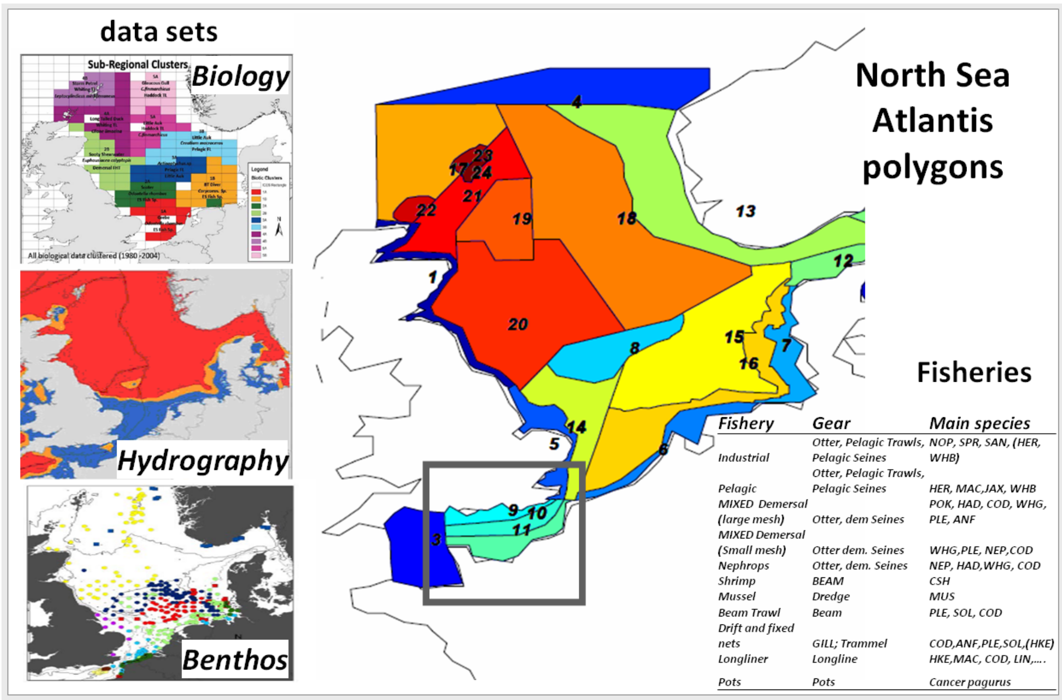

Figure. 6. Example of the spatial resolution of polygons and datasets (e.g. pelagic and demersal and benthic foodwebs, hydrography, fishing fleets, etc.) utilized for the North Sea Atlantis model being generated by researchers in Germany and the UK.

Three of the WGIPEM members (Marc Hufnagl, Bernardino Patti, and Raphael Girardin) are planning extended visits to CSIRO during 2012 to work with Beth Fulton to finalize model parameterizations and produce initial runs. Work is also ongoing at IMR Bergen to create an Atlantis model for the Barents / Norwegian Sea area. This subgroup frequently meets to discuss model developments.

4.2.2 Modelling Zooplankton Dynamics Subgroup (10 participants)

Consensus was reached that two primary research areas need to be addressed to advance biophysical integrative foodweb models. These areas will be the focus of both review activities as well as new research (model simulations) performed in this subgroup.

1) The first question of interest is: What is the effect of different phyto- and zooplankton fields from NPZD models on higher trophic levels, such as Osmose? (Note, the aim of this work is not to assess which NPZD is 'best'). This can be addressed by using spatially explicit observed and modelled plankton densities within Osmose simulations and comparing outputs to a baseline scenario with a fixed prey density and no spatial differences. Some specific work-steps have been outlined including:

    i) CPR data can be utilized (Klaus Huebert)

    ii) Five sources for modelled zooplankton estimates have been identified including Ercom (Marie Maar), Ecosm (Ute Daewel), Norwecom (Solfrid Hjollo), ECOHAM (Klaus Huebert via Johannes Pätsch), and Ersem (Rosa Barciela-Fernandez), depth-integrated phyto- and zooplankton in biweekly time-steps within a common year (2004) will be simulated,

    iii) differences in simulation outcome within Osmose may be compared at individual- (e.g. diet, growth), population- (biomass, trophic level) and at ecosystem-(size-spectrum) levels, and

    iv) these zooplankton estimates can also be linked to larval fish IBMs (Genevieve Lacroix, Myron Peck) to understand how differences in lower trophic level models impact estimates of larval fish survival, growth and habitat connectivity.

2) The second focus topic will be on top–down control of modelled zooplankton in ecosystem models. Most lower trophic level ecosystem models are restricted to nutrient, phyto- and zooplankton dynamics. The link to higher trophic level production and hence the resulting dynamics for zooplankton production is often either missing or incorporated non-dynamically (e.g. by using constant mortality rates). The zooplankton subgroup (Ute Daewel and colleagues) agreed to tackle this issue by generating a common paper based upon research that utilizes different models of group members. This should include

    i) A review on the topic with respect to available modelling tools, methods and theoretical approaches that deals with this issue.

    ii) A review of available observations and model estimates on predation pressure of fish on zooplankton and Biomass transfer within the different systems.

    iii) Modelling experiments picking up one or more methods that should be implemented in the different model available in the group.

    - For this purpose we might e.g. use the findings from the first paper that could serve as basis for a respective parameterization.
    - The model experiments should be kept relatively simple to allow as much persons and regions as possible to join.

iv) Comparison and discussion of experiments emphasizing the relevance of a dynamical zooplankton predation pressure within different models and regions.

3) The zooplankton subgroup (Marie Maar and colleagues) will explore whether different upper trophic level models are available to compare predation rate impacts and perform sensitivity analyses of the results. At the present time, one model (Osmose) has been identified, but others include Atlantis and potentially will provide foraging rates of fish on plankton. This result will be given back to the NPZD modellers.

4) The following people were involved in discussions: Genevieve Lacroix, Jan van Beek, Solfrid Hjollo, Ute Daewel, Morgane Travers, Rubao Ji, Susa Niiranen, Martin Huret, Marie Maar, Karen van de Wolfshaar. Two additional WGIPEM members were interested in participating in this subgroup's activities (Klaus Huebert and Myron Peck). Two members of WGOOFE were also interested to participate in activities (Corinna Schrum Barciela-Fernadez).

5 Provide an interface to the public and scientific community by building a model code library and maintaining the ICES WGOOFE activities including its website (ToR d)

The terms of reference for WGOOFE were approved after those of WGIPEM, thus the language in the document for WGIPEM needs to be changed to reflect that WGOOFE will be maintained as a separate group and that WGIPEM will not be responsible for its activities or its website.

During the joint WGOOFE – WGIPEM meeting on website development, a clear consensus was reached that the two groups should maintained separate website (although links between the websites would be important). Comments from Corinna Schrum (WGOOFE) suggested that developing a website similar to the MEECE project was challenging in an ICES context. Websites such as MEECE can effectively communicate the accomplishments of projects or project tasks but they become rapidly outdated without a modelling group maintaining and further developing the modelling tools and the website.

Corinna Schrum (WGOOFE) and members of WGIPEM stressed the point that providing state-of-the-art model tools to the community will be challenging in an ICES context because a lot of resources will be required. One example of resource allocation to this task is the German climate research community that has founded the 'Models and Data group' with several modellers on full time and permanent positions with the goal to provide, maintain, and further develop climate community models (including version control, technical updates with changes of computer resources, and the development and maintenance of couplers).

There was a general agreement that, similar to the WGOOFE, the primary service of the WGIPEM could be to provide links to places / organizations where modelling codes are being developed and that make these codes available to the community (with full version control and responsibility for documentation). An alternative strategy could be to start efforts to establish initiatives for building a modelling tool service at national or EU levels, perhaps making use of platforms such as EUROGOOS, or ROOSEs or ICES.

The 'zooplankton subgroup' discussed the interest in an online model library, and found that a place for easy deliverance and exchange of model code (well documented and as generic coded as possible), module couplers, data for model parameterization, etc. could be useful. However, technical issues as host, maintenance, etc. were not agreed upon. The group will identify a WGIPEM member that will produce a rough outline of potential library content and format, as well as to secure communications on the coupling between this potential library with similar efforts underway elsewhere (e.g. the MEECE-project library).

Without knowledge of the amount of effort required to produce a WGIPEM website, no members volunteered to work on this ToR. Furthermore, the consensus in WGIPEM was that ICES should be approached and asked to help with the construction of this website. An important aspect will be the integration of websites of ICES groups – it was thought that this integration of modelling (WGOOFE, WGIPEM, etc.) and other working groups was best handled by ICES.

6 Preparation of 2013 meeting

The time and place of the 2013 meeting are currently under discussion. Three offers were provided by working group participants including 1) Paris, France, 2) Amsterdam, The Netherlands, and 3) Tromsø, Norway. A week-long meeting is envisioned that includes well-planned workshops and plenary. That meeting will have less plenary (few, invited keynote talks) and include follow-up workshops on 2011 action items including updates on recent advancements in end-to-end modelling including i) parameterization of ecosystem components (hydrodynamics, lower and upper trophic levels) and ii) human activities and behaviour. Specific workshops will be convened to discuss how iii) behaviourally driven movements are depicted and iv) zooplankton are modelled in coupled upper and lower trophic level models. New workshop themes will be discussed in the coming months. It is envisioned that the meeting will take place at some point between late February and early April 2013. A doodle calendar will be established in an attempt to find the most suitable dates (and venue).

7 Other business

This meeting was partially sponsored by the EU Framework 7 program 'VECTORS'. VECTORS graciously agreed to pay some of the travel costs of two of the invited workshop chairs (Beth Fulton and Olivier Thebaud). There were ad hoc discussions throughout the meeting on how best to obtain funding to promote the activities of this group. Developments in the modelling tools discussed at the WGIPEM are occurring globally and it will continue to be important to engage scientists and colleagues within and outside ICES countries (e.g. PICES).

Photo of participants of the first WGIPEM meeting on Friday 16 March 2012. Standing (from left to right): Alejandro Gallego, Benjamin Planque, Olivier Thebaud, Bee Berx, Ulf Lindstrom, Dimitris Politikos, Lorna Teal, Marc Hufnagl, Kenny Rose, Morten Skogen, Diego Macías, Klaus Huebert, George Tryantafyllou, Alex Kempf, Stefan Neuenfeldt, Raphael Girardin, Karen van de Wolfshaar, Jean-Noel Druon, Jan van Beek, Martin Huret, Helen Andersson, Loes J. Bolle, Solfrid Sætre Hjøllo, Marie Maar, Susa Niiranen, Samuel Subbey, and Enrique Curchitser. Sitting (from left to right), Myron Peck, Mark Dickey-Collas, Beth Fulton, Morgane Travers, and Anna Akimova. Not pictured: Marina Chifflet, Ute Daewel, Rolf Groeneveld, Geir Huse, Frank Janssen, Rubao Ji, Soile Kulmala, Geneviève Lacroix, Will Le Quesne and Miguel Bernal.

Annex 1: List of participants

NAME	AFFILIATION	COUNTY	E-MAIL
Anna Akimova	vTI Sea fisheries	Germany	anna.akimova@vti.bund.de
Helen Andersson	SMHI	Sweden	helen.andersson@smhi.se
Barbara Berx	Marine Scotland Science	UK	barbara.berx@scotland.gsi.gov.uk
Loes J. Bolle	Wageningen IMARES	Netherlands	loes.bolle@wur.nl
Marina Chifflet	AZTI	Spain	mchifflet@pas.azti.es
Asbjørn Christensen	DTU Aqua	Denmark	asc@aqua.dtu.dk
Enrique N. Curchitser	Rutgers University	USA	enrique@marine.rutgers.edu
Ute Daewel	University of Bergen	Norway	ute.daewel@gfi.uib.no
Mark Dickey-Collas	Wageningen IMARES	Netherlands	mark.dickeycollas@wur.nl
Jean-Noel Druon	JRC	Italy	jean-noel.druon@jrc.ec.europa.eu
Rosa M. Barciela Fernandez	Met Office	UK	rosa.barciela@metoffice.gov.uk
Beth Fulton	CSIRO	Australia	beth.fulton@csiro.au
Alejandro Gallego	Marine Scotland Science	UK	a.gallego@marlab.ac.uk
Raphael Girardin	Ifremer	France	raphael.girardin@ifremer.fr
Rolf A. Groeneveld	Wageningen University	Netherlands	rolf.groeneveld@wur.nl
Guoqi Han	Fisheries and Oceans	Canada	hang@dfo-mpo.gc.ca
Solfrid Sætre Hjøllo	IMR	Norway	solfrid.hjollo@imr.no
Klaus Huebert	University of Hamburg	Germany	klaus.huebert@uni-hamburg.de
Martin Huret	Ifremer	France	martin.huret@ifremer.fr
Geir Huse	IMR	Norway	geir.huse@imr.no
Frank Janssen	BSH	Germany	frank.janssen@bsh.de
Rubao Ji	WHOI	USA	rji@whoi.edu
Alexander Kempf	vTI Sea Fisheries	Germany	alexander.kempf@vti.bund.de
Soile Kulmala	MTT Agrifood Research	Finland	solie.kulmala@ymparisto.fi
Geneviève Lacroix	MUMM	Belgium	g.lacroix@mumm.ac.be
Will Le Quesne	Cefas	UK	will.lequesne@cefas.co.uk
Ulf Lindstrøm	IMR Tromsø	Norway	ulf.lindstroem@imr.no
Marie Maar	NERI	Denmark	mam@dmu.dk
Diego Macías	CSIC	Spain	diego.macias@icman.csic.es
Stefan Neuenfeldt	DTU Aqua	Denmark	stn@aqua.dtu.dk
Susa Niiranen	Stockholm University	Sweden	sniir@mbox.su.se
Mark Payne	DTU Aqua	Denmark	mpa@aqua.dtu.dk
Myron Peck (Chair)	University of Hamburg	Germany	myron.peck@uni-hamburg.de
Benjamin Planque	IMR Tromsø	Norway	benjamin.planque@imr.no
Dimitris Politikos	HCMR	Greece	dimpolit@ath.hcmr.gr
Kenneth Rose	Louisiana State University	USA	karose@lsu.edu
Morten D. Skogen	IMR	Norway	morten.skogen@imr.no
Samuel Subbey	IMR	Norway	samuel.subbey@imr.no
Lorna Teal	Wageningen IMARES	Netherlands	lorna.teal@wur.nl
Olivier Thebaud	CSIRO	Australia	olivier.thebaud@csiro.au
Morgane Travers	Ifremer	France	morgane.travers@ifremer.fr
George Tryantafyllou	HCMR	Greece	gt@ath.hcmr.gr
Jan van Beek	DELTARES	Netherlands	jan.vanbeek@deltares.nl
Karen van de Wolfshaar	Wageningen UR CMP	Netherlands	karen.vandewolfshaar@wur.nl

NAME	AFFILIATION	COUNTY	E-MAIL
Participating via WebEX			
Manuel Barange	PML	UK	manuel.barange@ices.dk
Miguel Bernal (Chair)	IEO	Spain	miguel.bernal@md.ieo.es
Olivier Maury	IRD	France	olivier.maury@ird.fr
Bernardino Patti	CNR	Italy	bernardo.patti@cnr.it
Yunne-Jai Shin	IRD	France	yjshin@ifremer.fr
Yongsheng Wu	Fisheries and Oceans	Canada	yongsheng.wu@dfo-mpo.gc.ca

Annex 2: Agenda

WGIPEM Tuesday 13 March (Day 1 Plenary)				
ToR	Start	Topic	Lead	Time
	13:00	Logistics	Chairs	10 min
	13:10	Introductions / ToRs	Chairs	15 min
	13:25	WGPBI + End-to-end (WGIPEM)	Myron Peck, Miguel Bernal	10 min
	13:35	WGSAM	Stefan Neuenfeldt, Ulf Lindstrøm	10 min
	13:45	WGOH	Anna Akimova	10 min
WORKSHOP 1 (Operational Oceanography)				
D	14:00	WGOOFE (Operational Oceanography)	Bee Berx, Rosa Barciela	60 min
		WKOOI Summary	Myron Peck / Bee Berx	5-10 min
	C1	Operational Modelling in North & Baltic Seas	Frank Janssen	10 min
	15:30	Health Break		
WORKSHOP 2 (Models in Research Programs / Model Verification)				
ABC	15:50	WORKSHOP 2 – Model products from large-scale Research Projects	**All**	45 min
	C2	VECTORS	Myron Peck	5 min
	C3	REPDRODUCE	Miguel Bernal	5 min
	C4	GLOBEC (& Copepod Modelling)	Rubao Ji	10 min
D		MEECE MODEL LIBRARY DISCUSSION	Myron Peck	
ABC	17:00	sub-session (Verification / Validation)	Chairs / Contributors	
	C5	Stochastic ecosystem models & addressing uncertainty	Benjamin Planque, Ulf Lindstrom	25 min
	C6	Lagrangian Drift Comparison	Marc Hufnagl, Loes Bolle, Jan Van Beek, *et al.*	15 min
	C7	Patchy Comparisons: CPR and NPZD	Klaus Huebert	15 min
	C8	Corroborating long-term hindcasts: Baltic NPZD	Ute Daewel	15 min
	18:15	Final Discussion Day 1	Icarus *et al.*	15 min
	18:30	Close of day 1		

WGIPEM Wednesday 14 March (Day 2 Plenary)				
ToR	Start	Topic	Lead	Content
A-C	09:00	WORKSHOP 3 – movement and behaviour	**Kenny Rose**	45 min
	C9	Life Cycle, DEB modelling of North Sea flatfish	Lorna Teal	20 min
	C10	Impacts of vertical migration and settling delay on short-term dispersal of sole ELS	Genevieve Lacroix	20 min
	C11	Modelling foraging migrations of planktivorous fish	Geir Huse	20 min
	11:30 Health Break			
	11:50	re-convene WK 3		
	C12	Basin-scale modelling of pelagic species habitats	Jean-Noel Druon	20 min
	C13	Osmose development / North Sea	Karen van de Wolfshaar	20 min
		Discussion / Products (prepare for Thursday)	Kenny Rose	
	13:00 **Lunch**			
14:30 Workshop 4				
A-C	14:30	WORKSHOP 4 - Incorporating human effects within integrated ecosystem models	**Beth Fulton, Olivier Thebaud**	50 min
	C14	Ecosystem Services in VECTORS	Rolf Groeneveld	20 min
	C15 and 16	Towards an end-to-end modelling in Bay of Biscay - English Channel area (part I)	S. Mahévas, M. Huret, M. Travers, C. *et al.*	35 mins (parts I&II)
16:00 **Health Break**				
	16:20	**Re-convene WK 4**		
	C17 -19	European Atlantis Updates	Marc Hufnagl, Alex Kempf, Will Le Quesne	35 min
	C20	Status and Plans for NORWECOM.E2E	Morten Skogen	20 min
	C21	Coupled Modelling (zooplankton module).	Solfrid Hjollo	20 min
	C22	Data assimilation (fish catches, chl a) into an E2E model	George Triantafyllou	20 min
	18:00	End of Day 2		

WGIPEM Thursday 15 March (two rooms) – detailed discussions / products				
ToR	Start Time	Topic	Lead	Time
D	09:00	WGOOFE and Website Discussion Links with other ICES WGs	(Biscay Room)	(Bee, Rosa)
A-C	09:00	Follow-up Discussion / presentations / writing (Human effects into E to E)	(North Sea Room)	Beth, Olivier

	13:00	Lunch		
A-C	14:30	Follow-up Discussion / writing / presentations (behaviour)	(Biscay Room)	(Kenny)
	14:30	Follow-up Discussion / EtoE /	(North Sea Room)	(Beth, Olivier)
	18:00	End for Day		
WGIPEM Friday 16 March (Day 4 - plenary until lunch, separate rooms after lunch)				
Workshop 5 (Downscaling Climate Signals to Biological Systems)				
	Time	Topic	Lead	Content
	09:00	Workshop 2 - Downscaling climate signals to biological systems	**Enrique Curchitser**	45 min
	C22	Baltic Sea Projection Modelling in ECOSUPPORT	Helen Andersson	15 min
	C23	Results of Coupled Modelling Activities (ECOSUPPORT)	Susa Niiranen	15 min
	11:30	Strategic Discussion (future goals, links, etc)	Chairs *et al.*	1.5 hrs
	14:00	Close of 2012 WGIPEM		

Annex 3: WGIPEM terms of reference for the 2012 meeting

The **Working Group on Integrative, Physical-biological, and Ecosystem Modelling** (WGIPEM), chaired by Myron Peck*, Germany, and Miguel Bernal*, Spain, will be established and will meet at ICES Headquarters, Copenhagen, Denmark, 12–16 March 2012 to:

a) Report on the state-of-the-art within the ICES community and worldwide in coupled physical-biological and ecosystem modelling and simulation results (e.g. population connectivity, life cycle dynamics, foodweb interactions and/or ecosystem responses to human activities) including:

i) Components of coupled biophysical integrated models (single species to foodwebs;

ii) Coupled, integrative ecosystem (end-to-end) models including all core components;

iii) Calibration, corroboration and confidence in model estimates and management application;

b) Identify gaps in knowledge in these modelling activities and recommend activities to advance coupled modelling approaches and that will make model outputs useful to the management of marine systems including estimates related to:

i) Physics (from small-scale turbulence, mesoscale structures, to basin-scale transport);

ii) Biology (e.g. behaviour, growth physiology, foodweb dynamics such as bentho-pelagic coupling);

iii) Socio-economics within coupled (end-to-end) models;

iv) Interactions between physics, biology and/or economics and different spatial / temporal scales;

v) Downscaling of earth system dynamics to model at relevant scales;

c) Convene an annual meeting with specific workshops to promote the development and review of coupled physical-biological and ecosystem modelling, with the aim to attract participants that have broad range of expertise (e.g. from hydrodynamics, physiology, trophodynamics, to economics):

i) Provide an interface to the public and scientific community by building a model code library and maintaining the ICES Operational Oceanographic Products for Fisheries and the Environment (WGOOFE) activities, including its website;

ii) Liaise with expert groups at ICES (other WGs) and elsewhere (CIESM, and PICES) to develop a roadmap for research collaboration including the application of these biophysical model tools within and beyond the ICES community;

d) Create and/or maintain an interface for the public and scientific community by:

i) Creating an online library of model code for existing biophysical models and their subroutines, and

ii) Maintaining and updating the ICES Operational Oceanographic Products for Fisheries and the Environment website attracting meteorological experts to the group (seen as a merger with WGOOFE). The new Working Group will hold dedicated workshops to achieve these public / community outreach goals;

e) Provide strategic dialogue within the ICES community on biological-physical and integrative models and their application by forming close links and joint activities with other expert groups including.

Supporting information

Priority:	This group's activities will support the ecosystem approach to fisheries science by combining knowledge of physical and biological processes, bioeconomics of multiple marine sectors, and modelling expertise that is required to strengthen our understanding of ecosystem functioning. The Group will foster the development of "end-to-end" modelling tools (e.g. Atlantis) and will provide an interface for physical and biological model code and oceanographic data including those from operational modelling. For these reasons, the activities of the Group should be given high priority.
Scientific justification and relation to action plan:	ToR a and b: Physical, biophysical and coupled integrative modelling are rapidly advancing research tools and providing a synthetic overview is needed, especially to identify gaps in knowledge and to make these tools more applicable to management. ToR c : Hosting an annual meeting is a core activity of the group and, given its broad mandate, both plenary discussions and targeted workshops will be necessary. A 5-day meeting is envisioned that includes 2.5 days of targeted workshops (e.g. WGOOFE activities) to facilitate cross-disciplinary collaboration between modellers, experimentalists / ecologists and economists. ToR d: A web-based interface linking this WG's activities to the public and scientific community are needed. Construction of a library of model code has already started (via MEECE, etc.). Ongoing activities of WGOOFE would be continued in this new WG, eliminating membership overlap and strengthening the group's membership with additional meteorologists / modellers. ToR e: An "application" component is considered critical for success and will ensure that this group's work is not conducted in isolation of other expert groups / organizations. The identification of concrete routes of collaboration and research activities (e.g. leading to peer-reviewed manuscripts) between this and other groups is a high priority for the first meeting. None of the ToRs answer requests from other groups, they are all self-generated and contribute to building scientific capacity. The ToRs relate to all three priority areas of ICES (i) Understanding ecosystem functioning, (ii) Understanding of interactions of human activities with ecosystems, and (iii) Development of options for sustainable use of ecosystems. ToRs a-e contribute to coded topic areas including: Climate Change (112, 114, 115), Biodiversity and Health of Ecosystems (123), Life History (144, 145, 147), Role of Top Predators (173), Impacts of Fishing (211), Renewable Energy issues ( ).
Resource requirements:	This group will be composed of members of the former WGPBI, ongoing WGOOFE, and formerly proposed, end-to-end ICES working groups. In many cases, resources were already committed to the formation and maintenance of the activities of those groups. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants:	It is envisioned that this group will attract a large community of biologists / experimentalists, and modellers – with an annual meeting attended by some 25–40 members and guests. Annual meetings will include workshops on specific topics, increasing interests / attendance.
Secretariat facilities:	We are proposing that the first meeting take place at the secretariat headquarters at some point in March /April, 2012. Two dates have been tentatively reserved.

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 will actively pursue strong links to other groups within ICES and will propose joint meetings (workshops). A previous group (WGPBI) met with the Working Group on Zooplankton Ecology and the Working Group on Harmful Algae Bloom Dynamics. This proposed WG is recommending membership that includes chairs or co-chairs of other ICES WGs (e.g. Phytoplankton and Microbial Ecology, Multispecies modelling), and a merger with WGOOFE.
Linkages to other organizations:	None. However, it is envisioned that this initial group will include members from Mediterranean (CIESM) and North Pacific (PICES) scientific organizations. We will seek co-sponsorship of this group by other organizations in future. The expertise of working group members would encompass a range of disciplines required to construct and apply biological-physical models in marine systems including: 1) hydrodynamics, 2) numerical methods, 3) ecophysiology, 4) foodweb dynamics, 5) socio-economics, and 6) Earth System dynamics. It is envisioned that this group will be composed of both modellers and experimentalists, fostering interdisciplinary discussions with the end goal of advancing coupled modelling in marine systems. The involvement of leading researchers with active links to ongoing, large-scale European, North American and Asian research programs will help build bridges beyond the ICES community, particularly to recruit new working group members and co-sponsorship by PICES as part of the proposed ICES-PICES strategic initiatives.

Annex 4: WGIPEM terms of reference for the 2013 meeting

The **Working Group on Integrative Physical-biological, and Ecosystem Modelling** (WGIPEM), chaired by Myron Peck, Germany, and Miguel Bernal, Spain, will meet in Paris, France, in spring 2013 (week 9 or 11) to:

a) Prepare discussion documents on the "state-of-the-art" in:

i) Coupling of lower and upper trophic levels including proper representation of zooplankton fields on upper trophic level dynamics and estimates of top–down control of zooplankton in marine foodwebs

ii) The role and influence of animal movement in spatially explicit models of single species and/or marine foodwebs

iii) Skill assessment of estimates stemming from various modelling activities (from hydrodynamics, to ecosystem productivity) including the ability to make either short- and/or long- (climate relevant) projections

b) Continue to develop end-to-end models for selected regions within and outside ICES waters by:

i) European applications of ATLANTIS, Osmose and other models and exploring lessons learned from other regions

ii) Exploring how to integrate the human dimension into ecosystem models.

iii) Exploring the appropriate spatial scale for downscaling global models, especially when considering climate scenarios.

c) Build and maintain a website that provides information on integrative physical-biological and ecosystem models and/or their outputs within and beyond the ICES community

d) Document the research priorities for integrative ecosystem modelling in the ICES area.

WGIPEM will report by 30 March 2013 (via SSGSUE) for the attention of the SGSUE.

Supporting Information

Priority	The current activities of this Group will enable the development of biophysical and ecosystem models that can provide relevant information to aid ICES assessment and management including end-to-end models that explicitely include management evaluation frameworks.
Scientific justification	Term of Reference a) Several topics were chosen by WGIPEM members to be the most relevant activities for the advancement of spatially explicit models and that link most strongly with ongoing activities within the wider biophysical and ecosystem modelling community. This TOR will result in potential working papers aimed at publication. b) this is directed at maintaining the development of ecosystem models in ICES and providing an interface with non-ICES memebers of the group. It will allow cross fertilization of ideas and allow the experience of developers of the European models to build on the experience of others. c) an interface is required to document and provide a resource to ICES scientists working on developing ecosystem models d) this will provide funders of research with a prioritized list of areas that

	require extra resources to bring ecosystem modelling in the ICES area up to world class standard.
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 40–60 members and guests.
Secretariat facilities	WGIPEM may request meeting rooms for February / March 2013 if the planned (Paris) venue is untenable. Facilitation support from the new ICES ecosystem advice officer.
Financial	No financial implications.
Linkages to advisory committees	As yet, there are no obvious direct linkages with the advisory committees. However as the concept of intergrated assessments becomes increasingly operational, it is likely that the WGIPEM will become more and more relavant to the advice.
Linkages to other committees or groups	There is a very close working relationship with the ICES-PICES Strategic Initiative on Climate Change (SICCME) and various ICES expert groups having common membership with WGIPEM including: WGOOFE, WGOCE, WGSAM and WGINOSE. Due to the broad modelling activities of the group, collaboration with a larger number of groups is envisioned.
Linkages to other organizations	PICES currently has similar modelling tools and efforts are underway to foster joint workshops and theme sessions between ICES and PICES.

Annex 5: Recommendations

Recommendation	Adressed to
1. Provide support for development of a WGIPEM website	ICES Secretariat
2. Propose a ToR for WGSAM expert group: Document efforts to examine spatially explicit multispecies model parameterizations	WGSAM
3. Support a 2013 ICES ASC Theme Session "Climate-driven changes in distribution of living marine resources: Process knowledge and projection capacity" Proposed conveners: Myron Peck (Germany, ICES), Anne Hollowed (USA, PICES) andWilliam Cheung (CA). The session will invite presentations documenting (and describing the underlying processes reponsible for) changes in distribution of key species within and outside ICES waters and our ability to model historical and project future climate-driven changes in distribution. (proposal in development with ICES-PICES Strategic Initiative on Climate Change)	SCICOM
4. Support a 2013 ICES ASC theme session on "Modelling human behaviour as part of integrated models of marine ecosystems" with proposed Conveners: Eric Thunberg (USA), Olivier Thebaud (Australia), Rasmus Nielsen (Denmark). This session aims to review the current state-of-the-art and open research questions on the modelling of human behaviour in natural resource use, with particular focus on marine and coastal ecosystems.	SCICOM
5. Develop a training course on methods of quantifying sensitivity and propagation of uncertainty within models of different levels of complexity including end-to-end models (Benjamin Planque from WGIPEM). Envisioned as a broad training course with participation of other WGs.	SCICOM and ICES training group
6. Propose a ToR for all integrated assessment working groups to: provide a list of any relevant hydrographic indicators of community-level changes within their region (working with WGOOFE and WGOH). Listing potentially useful, spatially explicit information that might be gained from the models represented in the WGIPEM 2012 would help facilitate future, collaborative work.	SCICOM and Integrated assessment groups (WGNARS, WGIAB, WGEAWESS, and WGINOSE) while informing WGOOFE and WGOH
6. Request faciltiation and organizational support from ICES, through the newly appointed Ecosystem Advice Professional Officer.	SCICOM and ICES secretariat

Annex 6: Theme Session Proposals

Theme session proposal: 2013 ICES ASC

Climate-driven changes in distribution of living marine resources: Process knowledge and projection capacity

Conveners: Anne Hollowed (USA), Myron Peck (Germany), William Cheung (CA)

Shifts in distribution of living marine resources can have dramatic ecological and economic consequences and challenge fisheries managers faced with providing effective advice and stewardship using an ecosystem-based approach. Over the last two decades, research worldwide has effectively documented historical/ongoing shifts in the geographical / latitudinal distribution of key species of marine plants and animals and, in some cases, whole communities. In most cases, research has correlated these changes to changes in the temperature of marine habitats, although a variety of potential abiotic and biotic factors may interact with warming to establish observed patterns of distribution. Projecting future changes in the distribution will require an understanding of how these various factors interact and the development of process-based knowledge of the causes and consequences of range shifts.

The present theme session invites presentations on changes in the distribution of key living marine resources that move beyond merely documenting historical patterns but also explore the underlying processes and develop tools to help build predictive capacity of future changes. Presentations are particularly welcome that address community- and/or ecosystem-level processes and projections. This session hopes to continue the dialogue between fisheries biologists and biophysical modellers by also inviting presentations that address the current capacity of models to project changes in key ecosystem characteristics such as ocean circulation, temperature, oxygen, lower trophic level productivity, and keystone predators. Finally, this session also offers a venue for more mature examples of research linking patterns/observations to processes/mechanisms and predictions/projections to "real world" management concerns/implications.

Anne Hollowed (USA)	ahollowed@noaa.gov	(SICCME)
Myron Peck (Germany)	myron.peck@uni-hamburg.de	(SICCMEN, WGIPEM)
William Cheung (Canada)	w.cheung@fisheries.ubc.ca	(proposed)

Theme session proposal for ICES ASC

Modelling human behaviour as part of integrated models of marine ecosystems

Proposed Conveners: Eric Thunberg (USA), Olivier Thebaud (Australia), Rasmus Nielsen (Denmark)

Considering ecosystem functioning in managing the use of marine resources gained much importance in recent years. Such an "ecosystem approach" strives to balance societal objectives, by taking into account the biotic, abiotic and human components of ecosystems and their interactions. Consequently, there has been a growing call for the development of integrated assessment tools, including those that can be used to identify possible futures and evaluate alternative management strategies. Along with this, there is increasing recognition that understanding the human response to economic, ecological and regulatory changes is a key factor. Hence, the integrated assessment tools should include explicit representations of human behaviour and its drivers.

This session aims to review the current state-of-the-art and open research questions on the modelling of human behaviour in natural resource use, with particular focus on marine and coastal ecosystems. We are particularly interested in presentations of recent work on representing microeconomic decisions in marine fisheries and other ocean and coastal uses, as part of applied bio- economic models, in both developed and developing countries. We are also interested in conceptual models of human use of natural resources, and how these may assist in developing formal representations of the economic and social drivers of resource use in integrated modelling approaches.

In order to explore these issues we invite contributions which respond to the following questions:

- What are the economic and social drivers of resource use which can be captured in integrated modelling approaches?
-
- What tools are available for representing microeconomic decisions in models of marine fisheries and other ocean and coastal use?
-
- What determines the required spatial and temporal resolution in integrated modelling approaches of natural resource use?

Eric Thunberg (USA)	eric.thunberg @noaa.gov
Olivier Thebaud (Australia)	Olivier.Thebaud@csiro.au
Rasmus Nielsen (Denmark)	rn@aqua.dtu.dk