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## Interim Report of the Working Group on Integrative Physical–Biological and Ecosystem Modelling (WGIPEM)

6–8 June 2016

Brest, France



**ICES**  
**CIEM**

International Council for  
the Exploration of the Sea

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## Executive summary

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The Working Group on Integrative Physical-Biological and Ecosystem Modelling (WGIPEM) met in Brest, France, on 6–8 June 2016. Plenary discussions focused on new achievements in the fields of ecosystem modelling, analyses of lower trophic levels, habitat connectivity, end-to-end modelling, and how to include human and animal behaviour in models. Furthermore, new as well as completed projects and meetings dealing with the ToRs of the group were presented, the involvement of the group in upcoming meetings was addressed and the cooperation with other ICES working groups (mainly WGIAB, WGBIOP, and WGIMM) was discussed. How to link and couple models, how to define scenarios for future projections and how to implement those as well as identifying emerging modelling science fields were part of the plenary discussions. Three breakout groups were formed: the first one focusing on comparing how perturbations in mortality terms will influence the spatial and temporal dynamic of trophic cascades as represented in lower trophic level models of different complexity. This approach will help identify how different model parameterizations, trophic structures (e.g. the links between the ecosystem components) and local specifics will influence zooplankton and phytoplankton components; a second group identified methods and possibilities to perform sensitivity analysis and parameter testing for complex ecosystem models. End-to-end and other complex models are often criticized for lacking confidence estimates in their predictions, the hypersensitivity to certain assumptions or their hyper-stability due to over-parameterization. The aim of the subgroup was to identify ways on how to tackle and enumerate these feature and problems to allow end-users to customize and chose the set of models and outputs that best suits their approaches and set of questions; the third subgroup dealt with physiological based models of foraging and growth and how to most appropriately include thermal limits such as by including aerobic scope as depicted in the Oxygen and Capacity Limited Thermal Tolerance (OCLTT) paradigm.

**Working Group name**

Working Group on Integrative Physical-biological and Ecosystem Modelling (WGIPEM)

**Year of Appointment within the current cycle**

2015

**Reporting year within the current cycle (1, 2 or 3)**

1

**Chair(s)**

Morgane Travers-Trolet, France

Marc Hufnagl, Germany

**Meeting venue**

Brest, France

**Meeting dates**

6–8 June 2016



WGIPEM 2016 participants

## 1 Terms of Reference a) – h)

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- a) Advance and increase the reliability of Multispecies and Ecosystem models to allow for a strategic advice on an ecosystem based approach. This includes improvement of benchmarking, model stress tests, validation, sensitivity testing approaches, and intermodel comparisons. Provide tools and methods like coupled bioeconomic models to enumerate trade-offs between management options.
- b) Identify ways to make the best use of models and model outputs for management purposes. Maintain an interface for the public and scientific community by providing tools, outputs, and algorithms through e.g. the WGIPEM webpage, workshops or conference sessions dealing with stakeholder engagement to finally increase visibility and end-user confidence in coupled physical-biological and ecosystem modelling approaches. Determine the potential use of models to improve sampling strategies and inform survey designers.
- c) Identify gaps in knowledge that need to be closed and spot emerging fields in coupled physical-biological and ecosystem modelling approaches to improve process descriptions and ecosystem responses to anthropogenic and environmental drivers to eventually and on the longer term be able to give model based strategic management advices.
- d) Discuss and provide basis for setting up future scenarios of anthropogenic pressure and climate variability. Based on the different scenarios, provide estimates of ecosystem states, functioning or services. Determine factors influencing species distribution. Discuss overarching interdisciplinary standards to be used in future scenarios.
- e) Improve and develop routines to describe behaviour of species and man and to include evolution and adaptation in coupled physical-biological and ecosystem modelling approaches.
- f) Advance our understanding of bottom up and top down controls within foodwebs. Identify drivers and rules of trophic coupling, the evolution of cascades and match–mismatch processes.
- g) Provide tools to improve our understanding of habitat connectivity to support and advice spatial management plans.
- h) Identify and include key physiological processes and mortality sources in models to understand recruitment dynamics, life cycle dynamics, and population drivers.

## 2 Summary of Work plan

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Year 1	Annual meeting to report on the state-of-the-art of some of the identified topics in ToRb and their related gaps of knowledge – Update of the previous established model code library for subroutines of biophysical and ecosystem models – Specific workshop on some of the identified topics
Year 2	Annual meeting to report on the state-of-the-art of the identified topics in ToRb, identification of gaps of knowledge and actions to take to fill some of them –Joint meeting with other expert groups – Update of the WGIPEM website – Specific workshop on some of the identified topics
Year 3	Final report on the state-of-the-art and gaps of the identified topics in ToRb –Joint meeting with other expert group – Specific workshop on some of the identified topics – update of the WGIPEM website



### 3 List of Outcomes and Achievements of the WG in this delivery period

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#### 3.1 Publications and reports

- Akimova, A., Hufnagl, M., Kreus, M., Peck, M.A. (2016). Modeling the effects of temperature on the survival and growth of North Sea cod (*Gadus morhua*) through the first year of life. *Fisheries Oceanography*, 25(3): 193–209.
- Broms, C., Strand, E., Utne, K.R., Hjøllø, S.S., Sundby, S., Melle, W.: Vitenskaplig bakgrunns-materiale for forvaltningsplan for raudåte. (Scientific background for a management plan for *Calanus finmarchicus*). Inst. of marine research, 2016
- Dalpadado, P., Arrigo, K.R., Hjøllø, S.S., Rey, F., Ingvaldsen, R.B., Sperfeld, E., van Dijken, G.L., Stige, L.C., Olsen, A., Ottersen, G. (2015): Productivity in the Barents Sea - Response to Recent Climate Variability. *PloS one* 9 (5), e95273
- Girardin, R., Vermard, Y., Thébaud, O., Tidd, A., Marchal, P. – 2015. Predicting fisher response to competition for space and resources in a mixed demersal fishery. *Ocean & Coastal Management* 106: 124-135
- Huret, M., Bourriau, P., Gatti, P., Dumas, F., Petitgas, P. (in press). Size, permeability and buoyancy of anchovy (*Engraulis Encrasicolus*) and sardine (*Sardina Pilchardus*) eggs in relation to their physical environment in the Bay of Biscay. *Fisheries Oceanography*.
- Illing, B., Moyano, M., Berg, J., Hufnagl, M., Peck, M.A. (2016). Behavioural and physiological responses to prey match-mismatch in larval herring. *Estuarine, Coastal and Shelf Science*, doi:10.1016/j.ecss.2016.01.003.
- Illing, B., Moyano, M., Hufnagl, M., Peck, M.A. (2016) Projected habitat loss for Atlantic herring in the Baltic Sea. *Marine Environmental Research* 113: 164-173.
- Lehuta, S., Girardin, R., Mahévas, S., Travers-Trolet, M., Vermard, Y. (in press). Reconciling complex models and fisheries advice: Practical examples and leads. *Aquatic Living Resources*.
- Peck, M.A., Arvanitidis, C., Butenschön, M., Canu, D.M., Chatzinikolaou, E., Cucco, A., *et al.* (2016) Projecting changes in the distribution and productivity of living marine resources: A critical review of the suite of modelling approaches used in the large European project VECTORS. *Estuarine Coastal and Shelf Science*. doi:10.1016/j.ecss.2016.05.019.
- Maar, M., Markager, S.S., Madsen, K.S., Windolf, J., Lyngsgaard, M.M., Andersen, H.E., Møller, E.F. (2016). The importance of local versus external nutrient loads for Chl a and primary production in the Western Baltic Sea. *Ecological Modelling* 320:258-272.
- Møller, E.F., Bohr, M., Møhl, M., Kjellerup, S., Swalethorp, R., Maar, M., & Niesen, T.G. (in press). *Calanus finmarchicus* egg production at its northern border. *J Plankton Research*
- Politikos, D., Huret, M., Petitgas, P. (2015). A coupled movement and bioenergetics model to explore the spawning migration of anchovy in the Bay of Biscay. *Ecological Modelling*, 313, 212-222. <http://doi.org/10.1016/j.ecolmodel.2015.06.036>
- Queiros, A.M., Huebert, K., Keyl, F., Stolte, W., Maar, M., Kay, S., *et al.* (in press). Solutions for ecosystem-level protection of ocean systems under climate change. *Global Change Biology*
- Rindorf, A., Jensen, H., Wright, P.J., Maar, M. (2016). The effect of physical and biological factors on growth and condition of lesser sandeel in the North Sea. *Journal of Experimental Marine Biology and Ecology* 479: 9-19.
- Skaret, G., Dalpadado, P., Hjøllø, S.S., Skogen, M.D., Strand, E. (2015): *Calanus finmarchicus* abundance, production and population dynamics in the Barents Sea in a future climate. *Progress in Oceanography* 125, 26-39.

Steenbergen, J., Kooten, T., van Wolfshaar, K.E., van de Trapman, B.K., van der Reijden, K.J., 2015. Management options for brown shrimp (*Crangon crangon*) fisheries in the North Sea. IMARES (Report / IMARES C181/15).

### 3.2 Conferences

#### **Zooplankton Production Symposium 2016 Workshop**

Geir Huse, Rubao Ji co-organized a workshop on “Zooplankton as the on the “To” in end-to-end models” at the Zooplankton Production Symposium (ZPS), Bergen, Norway (May 2016). The focus of the workshop was on presenting new ideas for improving the functionality of end-to-end models, emphasizing zooplankton implementation and how that affects the overall functioning and results of end-to-end ecosystem models. There were five oral presentations and one poster presentation, with an invited talk from Øyvind Fiksen. More than 30 people participated in the workshop. The main threads of the discussion were on collaboration between modellers and observationalists, examining model complexity, and usage of end-to-end models.

#### **Envisioned AMEMR 2017 session (1)**

Given the community interests in the ZPS workshop and its topic, the WGIPEM members are also planning to submit a session proposal to AMEMR 2017 (Advances in Marine Ecosystem Modelling Research 3–6 July 2017, abstract deadline on 31 July 2016) with the title: “Modeling zooplankton: from population to ecosystem level.” Chairs will be Morten Skogen, Geir Huse, Rubao Ji, and Marie Maar. The submitted abstract is outlined below:

The “Grand challenge” in marine ecosystem modelling is to achieve realistic end-to-end three-dimensional models where the entire ecosystem is simulated from the physics all the way up through the foodweb. Zooplankton play a crucial role in the ecosystems as the link between the lower and the higher trophics, and one of the key challenges for end-to-end ecosystem models are representing the proper zooplankton diversity with regards to size, function, and parameterization of key processes like growth, reproduction, predation, and prey of zooplankton. In this session, we will focus on presenting new ideas for improving the modelling of zooplankton with different functional complexity, varying from populations to communities that are influenced by bottom-up (predator) and/or top-down (prey) forcing.

#### **Envisioned AMEMR 2017 session (2)**

Many ecosystem models have been designed to provide strategic advice and to answer questions related to future and past management option. Linking with stakeholders and decision-makers and to learn from examples where ecosystem models have been successfully applied beyond pure academic issues is the focus of WGIPEM ToR b. The WGIPEM members are thus planning to submit a session proposal to AMEMR 2017 (Advances in Marine Ecosystem Modelling Research 3–6 July 2017, abstract deadline on 31 July 2016) with the title: “Ecosystem modelling to inform management: Practical examples.” Chairs will be Marie Savina-Rolland, Morgane Travers-Trolet, and Sigrid Lehuta. A preliminary abstract is outlined below:

Ecosystem-based management (EBM) is the dominant paradigm for marine resource management. Marine ecosystem models have long been advocated as tools to support EBM. However, there are still relatively few case studies illustrating uptake of these models by stakeholders and decision-makers. Examples include the use of NPZD

(nutrient-phytoplankton-zooplankton-detritus) model to test the impacts of watershed management on marine eutrophication, or the use of foodweb models to provide natural mortality rates for fish stock assessments.

This session invites contributions presenting model products and how they have been or are ready to be used to inform Ecosystem based management (including any kind of mechanistic models: multi or mono specific population dynamic, NPZD, end-to-end...). Contributors are encouraged to address how the managing process was entered, if a benchmarking process was required (potentially involving stakeholders or managers), and report on the fit between managers needs and what models provide.

### 3.3 Tools

#### **Atlantistools**

Performing model sensitivity studies, improving automated model parameterization, providing confidence estimates and comparing different ecosystem models is one of the focus areas of the working group and developing new and freely available tools that can be shared with the community is a challenging task. Alexander Keth developed and released an R package tailored to the ATLANTIS end2end model that allows to do these kinds of analyses and which is free. “Atlantistools” offers a variety of output routines, automated runs for different parameter settings, and an automated parameter optimization tool is envisioned.

#### **ZoopLib: a community repository for zooplankton models**

*Nicholas R. Record and Rubao Ji*

The Zooplankton Model Library (ZoopLib V1.0) was initiated as an open repository of code, commentary, and references to primary literature for zooplankton models. The objectives of version 1.0 were: (1) to provide a single portal or jumping off point for accessing the wide range of zooplankton models currently in use; (2) to provide a collaborative forum for discussion and improvement of models; (3) to facilitate exchange of models and standardization of modelling practices. The repository was created by Nick Record ([nrecord@bigelow.org](mailto:nrecord@bigelow.org)) and Rubao Ji ([rji@whoi.edu](mailto:rji@whoi.edu)), and is hosted by and has been archived at Google:

<https://code.google.com/archive/p/zooplib/wikis/Introduction.wiki>

Plans for version 2.0 include the following components: (1) Migrate existing content to GitHub; (2) Include executable example modules, rendered using Jupyter notebook; (3) Outreach to build out repository; (4) Meta-analysis of zooplankton models; (5) Explore links with other modelling communities' repositories. The primary bottleneck is personnel resources. Funds for a postdoc or graduate student to devote effort to the next version would greatly facilitate its implementation.

## 4 Progress report on ToRs and workplan

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### 4.1 Progress on Atlantis modelling activities and presentation of OceanCertain (ToR a)

#### Presentation of Atlantistools by Alexander Keth (UHAM)

A new R toolbox (see also previous section) has been presented that allows for an easy comparison of different Atlantis model outputs, a comparison of Atlantis outputs with observations, includes different spatial and temporal plotting routines which either have been newly created or modified and streamlined from existing routines. Furthermore, the toolbox allows for automated parameter perturbations and memory efficient output storage. There is a potential to extend the toolbox to other models like SMS or EwE and is therefore also of relevance for other groups like e.g. WGSAM's ToR on comparison of multi-model outputs.

#### Presentation of the Eastern English Channel Atlantis model by Marie Savina Rolland (Ifremer)

An update on the Eastern English Channel model was presented by Marie Savina Rolland. The model is beyond the state of balancing and has been coupled to a random utility model representing a fleet dynamically reacting to varying fishing conditions. Different management scenarios including closed areas and mixed fisheries have been addressed and are summarized in the manuscripts and the dissertation by Raphael Girardin (see Section 1).

#### Presentation of the Strait of Sicily Atlantis model by Matteo Sinerchia (IAMC CNR)

The SoS ecosystem is represented by 58 functional groups, 26 of which are vertebrates. The most important commercial species (anchovies, sardine, red mullet, hake, red prawn, and pink prawn) are represented at species level. The process of alternative management scenarios (business as usual,  $F_{MSY}$  for hake and pink prawn, spatial closure and gear selectivity) was done with the active involvement of stakeholders and results of these simulations were shown.

#### Summary of Ocean Certain Work by Jonathan Beecham, Sonja van Leeuwen, Robert Thorpe, and Luz Garcia-Garcia, Cefas Lowestoft laboratory

The aim of the Ocean Certain project is to create more certainty about our oceans under climate change. This is a project which draws together inputs from physical and quantitative modelling into a framework that is built upon less quantitative methodologies including data mining of existing literature, input from stakeholders and an overarching fuzzy cognitive net which operates on a -1 to +1 scale of definitely has a negative effect, through degrees of uncertainty to definitely has a positive effect. It can be characterized as 'post normal science' because it relies on an ensemble of less rigorous techniques to deal with areas of knowledge, which are highly uncertain. Cefas is responsible for the physical and ecological modelling in Work Package 2. There are three study areas: Barents Sea, Eastern Mediterranean, and a Southern Chilean Fjord.

The Lower trophic level component uses the Cefas ERSEM model. The Barents Sea component has been validated with a +100-year time-series dataset on temperature and salinity and is found to be in good agreement, so long as a degree of relaxation towards the quantitative data is allowed. However, the model needs improvement with regards to the summer profile of nitrates and phosphates. The Higher trophic

level model will use Ecopath with Ecosim as a point model and a community of around 40 species dominated by a link between herring and cod. The aim is to see what shifts occur when we allow for a scenario of representative common pathway 8.5. The scenarios will include socio-economic changes and effects on aquaculture, fisheries, and tourism.

#### 4.2 Progress on communication and best use of model outputs (ToR b)

**Presentation on the accepted VECTORS model review paper: Projecting Changes in the Distribution and Productivity of Living Marine Resources: A Critical Review of the Suite of Modelling Approaches used in the Large European Project VECTORS by Myron Peck (UHAM).**

A summary was provided of the recent review paper comparing four broad categories of spatially-explicit modelling approaches currently used to understand and project changes in the distribution and productivity of living marine resources including: 1) statistical species distribution models, 2) physiology-based, biophysical models of single life stages or the whole life cycle of species, 3) foodweb models, and 4) end-to-end models. Single pressures are rare and, in future, models must be able to examine multiple factors affecting living marine resources such as interactions between: i) climate-driven changes in temperature regimes and acidification, ii) reductions in water quality due to eutrophication, iii) the introduction of alien invasive species, and/or iv) (over-) exploitation by fisheries. Statistical (correlative) approaches can be used to detect historical patterns, which may not be relevant in future. Advancing predictive capacity of changes in distribution and productivity of living marine resources requires explicit modelling of biological and physical mechanisms. New formulations are needed, which (depending on the question) will need to strive for more realism in ecophysiology and behaviour of individuals, life-history strategies of species, as well as trophodynamic interactions occurring at different spatial scales. Coupling existing models (e.g. physical, biological, economic) is one avenue that has proven successful. However, fundamental advancements are needed to address key issues such as the adaptive capacity of species/groups and ecosystems. The continued development of end-to-end models (e.g. physics to fish to human sectors) will be critical if we hope to assess how multiple pressures may interact to cause changes in living marine resources including the ecological and economic costs and trade-offs of different spatial management strategies. Given the strengths and weaknesses of the various types of models reviewed here, confidence in projections of changes in the distribution and productivity of living marine resources will be increased by assessing model structural uncertainty through biological ensemble modelling.

**Presentation on complex model development and use by Sigrid Lehuta (Ifremer).**

The move toward an ecosystem-based fisheries management (EBFM) requires new operational tools in order to support management decisions. Among them, ecosystem and fisheries-based models are critical to quantitatively predict the consequences of future scenarios by integrating available knowledge of the ecosystem across different scales. Despite increasing development of these complex system models in the last decades, their operational use is still currently limited in Europe. Many guidelines are already available to help the development of complex system models for advice yet they are often ignored. We identified three main impediments to the use of complex system models for decision support: (1) their very complexity, which is a source of uncertainty, (2) their lack of credibility, (3) and the challenge of communicating/transferring complex results to decision-makers not accustomed to deal with

multivariate uncertain results. In this paper, we illustrate these somehow theoretical "best practices" with tangible successful examples, which can help the transfer of complex system models from academic science to operational advice. We first focus on handling uncertainty by optimizing model complexity with regards to management objectives and technical issues. We then list up methods, such as transparent documentation and performance evaluation, to increase confidence in complex system models. Finally, we review how and where complex system models could fit within existing institutional and legal settings of the current European fisheries decision framework. We highlight where changes are required to allow for the operational use of complex system models. All methods and approaches proposed are illustrated with successful examples from fisheries science or other disciplines. This paper demonstrates that all relevant ingredients are readily available to make complex system models operational for advice.

**Presentation: Towards an E2E model for the Norwegian Sea: Uncertainties in zooplankton biomass estimates by Morten D. Skogen and Solfrid S. Hjøllø (IMR)**

There is an ongoing work at IMR to develop an E2E model for the Norwegian Sea. The model, NORWECOM.E2E, is bottom-up, and a number of Individual Based Models (IBM) for key species are two-way coupled to a three-dimensional lower trophic (NPZD) model.

The model has been used to investigate the long-term (1995–2007) variability of the biomass of *Calanus finmarchicus* in the Norwegian Sea, and the model has been compared with estimates from observations. The interannual variability of modelled *Calanus* biomass in May was large (up to a factor of three), and there was a negative trend toward the end of the time-series. As the predation pressure from fish was constant in the experiment, this negative trend was explained by bottom-up processes. The mean modelled annual production was found to be 22.6 million tonnes (Mt) carbon (= 150 Mt wet weight), with a maximum in 1997 (34.5 Mt carbon) and a minimum in 2004 (13 Mt carbon). Taking into account patchiness in the zooplankton fields, an observational spatio-temporal window is suggested and related to uncertainty in the biomass estimates. The actual sampling patterns for the field observations were used to perform a virtual re-sampling in the model. The sampling patterns themselves proved to be of great significance, strongly influencing the biomass estimates which due to this variability varied by a factor of three for the individual years.

**Summary of the breakout group on model sensitivity and benchmarking**

During a breakout group of the 2016 WGIPEM meeting, we discussed ways and possibilities on how to address uncertainty in complex Ecosystem models. The general idea was to focus the discussion on the questions how to calibrate the models, which values to use to identify if a model is a "good" model, how to aggregate (on which spatio-temporal or species, trophic level) outputs to compare them to observations, and how to make perturbations or sensitivity analysis for models with large numbers of parameters.

Several studies do exist that address model validation, calibration and benchmarking (e.g. about the benchmarking process of the Atlantis California Current model) and the group decided that all members need to collect the insights and suggestions provided there first. Based on the actual knowledge of the group the schemes have so far not been picked up so one question would be if the goals and steps provided in the literature are too ambitious and if not, how they can be used for the models used by the members of the group. The group already agreed that only emerging properties should be used for benchmarking and not direct of modified input variables. This is

often not an easy task as some features might be directly linked to input data but are, at the same time, modified by other independent model features. Possible data to compare the model against are single and multispecies assessment data, surveys observations, biomass estimates, biomass/abundance at age, catch data, and spatial density patterns.

Should all metrics be weighed equally, and does the model need to fit all of those observations even if the actual user is only interested in one aspect like e.g. size-at-age of one species?

How many trophic layers above or below the species of interest are needed to get right results, which other patterns do need to match, what could be done if no observation data are available?

These kinds of questions were discussed. Again the participants decided to go deeper into the literature e.g. on pattern oriented modelling or indicators describing the foodweb (e.g. on a more global and general scale).

To kick off the dialog with field biologists it was also decided to identify parameters that would be needed to improve or benchmark the model from a modellers perspective but also what patterns would need to be represented by the models so that stakeholders classify it as a “trustworthy” and “usable” model.

A part of the discussion also focused on how to technically address sensitivity and whether general guidelines can be defined to do so. One suggested option was group screening, meaning a focused variation of a group parameters e.g. like all mortality rates in an ecosystem model or all parameters describing one species. In general, the sensitivity analysis will guide programmers and end-users to identify the most sensitive/weak parameters, classes and species. However, the question arose what the target value should be in the benchmarking/sensitivity study that describes the goodness of the model. This is especially problematic if observations are scarce, erroneous or not collected at the right scale. As example, it was mentioned that due to the fixed natural mortality of 0.2 in single species assessment models  $F$  is over (or under) estimated to compensate for the fixed rate and thus  $F$  is not always applicable for a comparison.

Field biologists and modellers both benefit from close cooperation. For example, aggregating or resampling of observational and modelled data might be necessary for comparing scarce observations with fine scale model results. The choice of time and space scales for aggregation can be difficult to define, and should be done compared with field biologists. Another possible observation-model interface is in survey design, where identifying model areas that show the highest or lowest variation, or areas that captures the main features of the region, could be another way to bridge the field biologists and ecosystem modellers.

Ecosystem models will only find use in advice and management if uncertainties are clearly defined and communicated so that end-users can decide on whether the results will be used for strategic or specific advice, short-, mid- or long-term predictions. The benchmarking might help in this case to classify the maturity of a model, e.g. if you get the trends right: strategic, if the model covers the interannual variation: advice. Stakeholders and end-users can provide valuable insights into which pattern and features the ecosystem model should represent to increase applicability and trustworthiness. In this context quite often the request is to get the pattern (spatially and temporally) right or to get the ranking of various options right and not the absolute level e.g. “we know that this location is a good fishing spot” or “this was a par-

ticularly good year why is this not shown in the model results". A real and fruitful co-creation with the stakeholders can also only take place if the data presentation is appealing and understandable and detailed documentations are available. Furthermore including other pressures and drivers in the models besides e.g. fishing will also provide the opportunity to take other management options and might inspire round table discussions.

It was decided to propose a session at the AMEMR conference 2017 (<http://www.amemr.com/>) on the use of mechanistic ecosystem model outputs in advice on behalf of the group (see Section 1)

#### **4.3 Progress on identifying emerging fields and gap of knowledge (ToR c)**

Updates, new modelling and visualization techniques were provided in all talks but specific new emerging fields have not been addressed particularly. Some discussion arose about the importance of patchiness for both plankton and fish dynamics but this is currently not resolved within end-to-end models and has thus been identified by the group as an important gap that the community should address in the modelling frameworks currently in use.

#### **4.4 Progress on setting up future scenarios (ToR d)**

Myron Peck updated the group on ongoing, parallel activities within the EU project CERES, the ICES-PICES Strategic Initiative on Climate Change Impacts on Marine Ecosystems (SICCME), and the Fish-MIP to define future scenarios to be used in climate project modelling of commercially important fisheries. In all three cases, physical models (GCMs and downscaled regional hydrographic models) will utilize RCPs 2.8, 4.5, and 8.5. For each of these three scenarios, various Shared Socio-economic Pathways (SSPs) will be defined. Fish-MIP held a workshop in Potsdam, Germany, three weeks after the WGIPEM meeting. An ICES-PICES workshop on future scenarios is planned for Saturday 24 September 2016, in conjunction with the ICES Annual Science Conference (ASC) in Riga. A list of invited researchers includes members of the three groups. Using common future scenarios is an exciting development in the international community making climate projections because it will allow the outputs of different regional and global models to be more easily compared. Within European waters, various regional tools are available from single-species distribution models (Dynamic Bioclimate Envelope Model) to more complex end-to-end models (e.g. Atlantis).

#### **4.5 Progress on integrating human behaviour (fleet dynamics) into models (ToR e)**

**Presentation:** From a sector based desire of a MP to a model of shrimp along the coast<sup>1</sup> by Karen van de Wolfshaar (IMARES)

The fisheries of brown shrimp (*Crangon crangon*) in the southeastern North Sea are of regional economic importance. Especially the Dutch and German fleet, representing together 2/3 of the total fleet targeting the shrimps in the coastal regions, take over 80% of the catch (ICES WKCCM Report). The shrimp fishery has developed in the

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<sup>1</sup> Steenbergen, J. ; Kooten, T. van; Wolfshaar, K.E. van de; Trapman, B.K.; Reijden, K.J. van der - 2015. Management options for brown shrimp (*Crangon crangon*) fisheries in the North Sea. IMARES (Report / IMARES C181/15)



past decades to a mature fishery and there are concerns about its sustainability in future, yet the stock is not managed. The Dutch fleet itself has requested for management advice for the brown shrimp, while catches are still high and in advance of possible decreases in catches, to ensure the future of the population as well as its fishery (ICES WKCCM Report). To that end, a mechanistic model was developed to test harvest control rules. The population dynamics of brown shrimp in the North Sea shore area and its fisheries are modelled using a Dynamic Energy Budget approach for individual level processes of shrimp. A second model shell then keeps track of all individuals, their growth, mortality and reproduction, and includes a dynamical resource, while the fishing fleet is modelled agent-based. This approach allows for assumptions at individual shrimp level while population level dynamics and fleet catches are an emergent property of following all individuals and vessels in time. We find that model results comply with individual growth, density and catch data, and that the model provides mechanistic understanding, based on growth overcompensation and resource competition, of the effects of the evaluated harvest control rules.

#### 4.6 Progress on the understanding of top-down control (ToR f)

**Presentation and summary:** How do ‘top-down’ forced trophic cascades emerge in marine pelagic foodwebs; a modelling assessment by Marie Maar (AU)

A collaborative study on “How do changes in top–down forcing emerge in the plankton community assessed by various three-dimensional ecosystem models?” led by Marie Maar (Aarhus University AU) have been presented in plenary and discussed in details in subgroup.

The aim of the present study is to provide new knowledge of TD trophic cascades on the plankton community by applying similar zooplankton mortality scenarios to a wide range of three-dimensional NPZD-models, which are currently applied to support management or scientific studies in different marine ecosystems. The objectives are to reveal differences in model responses to changes TD forcing and if there are any overall patterns of trophic cascades within and between ecosystems generated by the models.

We collected data from eight ecosystem models covering six different ecosystems in the Atlantic Ocean. The models are provided by different institutes and the general features of the applied models are described below (Tables 1 and 2). The models have all been documented in previous studies and are currently applied to support management decisions and research questions. The models were set up for a Baseline and two TD scenarios representing changes in the background mortality (model closure term) of the highest trophic levels by +/- 20%, which is within the natural variability of zooplankton mortality (Maar *et al.*, 2014). The model period in Baseline and scenarios depended on the available set-ups, but generally covered a period of four to six years within a time span of 2001–2008 (Table 1). The spin-up time varied from two to ten years depending on the model. The plankton biomasses were calculated as annual means for the upper 50 m of the water column except for the Benguela Upwelling System using 0–300 m. The cascade strength for each trophic level was estimated as the relative change ( $\Delta C$ ) in biomass between the Baseline (B) and the scenarios (S) normalized by the change in forcing ( $F = 0.20$ ):

$$\Delta C = \frac{(S - B)}{B \times F}$$

where a value  $< 1$  means that the impact is attenuated and a value  $> 1$  means that the impact is amplified by the system. The trophic cascade (TC) ratio was used to esti-

mate the cascade strength of the phytoplankton group relative to the change of the highest zooplankton trophic level (HZ):

$$TC - ratio = \frac{\Delta C_{phy}}{\Delta C_{HZ}}$$

In the applied models, the number of PFTs including bacteria, phytoplankton, and zooplankton varied from two to eight and the number of zoo-PFTs from one to three (Table 2). The planktonic foodweb structure in the different models could be reduced into four types of major grazer pathways depending on the number of PFTs and prey preferences scheduled in conceptual diagrams (Figure 1). For simplicity, we only consider phyto- and zoo-PFTs and ignore cannibalisms and grazing on bacteria and detritus. Nutrient uptake by phyto-PFTs is also simplified to competition for one resource (e.g. nitrogen or phosphorous) in the diagrams. This extra information can be found in Table 2 and in the model descriptions (in the paper). Prey preferences are set priori by the models and there are no differences in the nutritional quality of prey.

**Table 1. overview of the applied models.**

MODEL NAME	MODEL DOMAIN	PERIOD	SPIN-UP (YEARS)	INSTITUTE AND CONTACT PERSON
MIRO&CO	S. North Sea	2003–2006	10	Royal Belgian Institute of Natural Sciences, Belgium Genevieve Lacroix: glacroix@naturalsciences.be
NORWECOM.E2E	Barents Sea Nordic Seas	2001–2005 2001–2005	?	Institute of Marine Research, Norway Morten D. Skogen: morten@imr.no
HBM-ERGOM	North Sea Baltic Sea	2003–2007 2003–2007	2 2	Aarhus University, Denmark Marie Maar: mam@bios.au.dk
MOM-ERGOM	Baltic Sea Benguela System	2002–2008 2003–2008	4 4	Leibniz Institute for Baltic Sea Research, Germany Hagen Radtke: hagen.radtke@io-warnemuende.de Anja Eggert: anja.eggert@io-warnemuende.de
DELFT3D-GEM	North Sea	2003–2008	?	Deltares, the Netherlands Tineke Troost: Tineke.Troost@deltares.nl
ECOSMO	North Sea Baltic Sea	2001–2005 2001–2005	?	Nansen Environmental and Remote Sensing Center, Norway Ute Daewell: ute.daewell@nersc.no
POLCOMS-ERSEM	North Sea	?	?	Plymouth Marine Laboratory, UK Sevrine Sailley: sesa@pml.ac.uk
GoM model	Gulf of Maine region	2005	4	Woods Hole Oceanographic Institution, USA Rubao Ji: rji@whoi.edu

**Table 2. Overview of the PFTs and mesozooplankton background mortalities applied in the different models. The background mortalities are characterized as: first order =  $c \cdot z$ , second order =  $c \cdot z^2$ , and hyperbolic =  $c \cdot z \cdot z / (z + k)$ , where  $z$  is the (meso)zooplankton biomass,  $c$  is the closure term constant and  $k$  is the mortality half-saturation constant. Other explicit mortality terms may include cannibalism and hypoxia.**

MODEL NAME	MODEL DOMAIN	NUMBER OF PFTs	NUMBER OF ZOO-PFTs	BACKGROUND MORTALITY (CLOSURE TERM)	OTHER EXPLICIT MORTALITY OF HIGHEST TROPHIC LEVEL
MIRO&CO	S. North Sea	6	2	Second order	No
NORWECOM.E2E	Barents Sea	4	2	Hyperbolic	No
	Nordic Seas	4	2	Hyperbolic	No
HBM-ERGOM	North Sea	5	2	Hyperbolic	Cannibalism, hypoxia
	Baltic Sea	5	2	Hyperbolic	Cannibalism, hypoxia
MOM-ERGOM	Baltic Sea	4	1	Second order	Cannibalism, hypoxia
	Benguela System	6	3	Second order	Cannibalism, hypoxia
DELFT3D-GEM	North Sea	5	1	First order	No
ECOSMO	North Sea	5	2	First order	No
	Baltic Sea	5	2	First order	No
POLCOMS-ERSEM	North Sea	8	3	Hyperbolic	Cannibalism, hypoxia
	Baltic Sea	8	3	Hyperbolic	Cannibalism, hypoxia
	Mediterranean	8	3	Hyperbolic	Cannibalism, hypoxia
Gulf of Maine	Gulf of Maine	5	2	Hyperbolic	No

Preliminary results show that all models gave responses in the same direction for each scenario (Figure 2), but there is a high variability of the level of responses between models (Figure 2). Plankton responses are more sensitive to the first-order mortality term than for the other two (Figure 3) and 'High' zoo-mortality generally gave higher responses than 'low' mortality (Figure 2). It is planned to finish all model runs (ERSEM, NORWECOM, DELFT3D, GoM) during summer 2016, in order to make analysis of trophic cascades in relation to mortality terms and foodweb types and submit the related paper before the next meeting.

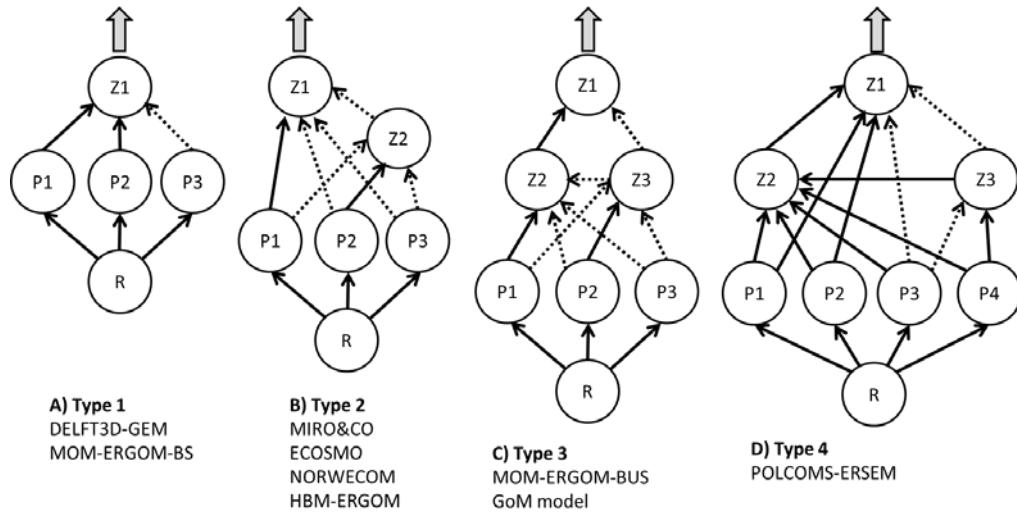


Figure 1. Conceptual diagrams of the four (A-D) dominant grazing pathways in the planktonic foodweb in the applied models. Circles with either  $Z_i$  or  $P_i$  are the  $i^{\text{th}}$  numbers of the zoo- (Z) and phyto- (P) plankton functional types (PFTs), black arrows show the direction of energy transfer and the grey arrow shows background mortality of the highest trophic level, which is modified in the scenarios. A solid line indicates high prey preferences, whereas the dashed lines indicate a range from low to high prey preference depending on the model. The phyto-PFTs are competing for a common nutrient resource (R) e.g. nitrogen. Other nutrients (e.g. silica for diatoms) and grazing interactions (cannibalism, grazing on bacteria, and detritus) are ignored in the diagrams, but can be found in the model descriptions.

## Model results

Delta change =  $(S-B)/B/0.20$   
 $>1$  amplification,  $<1$  attenuation

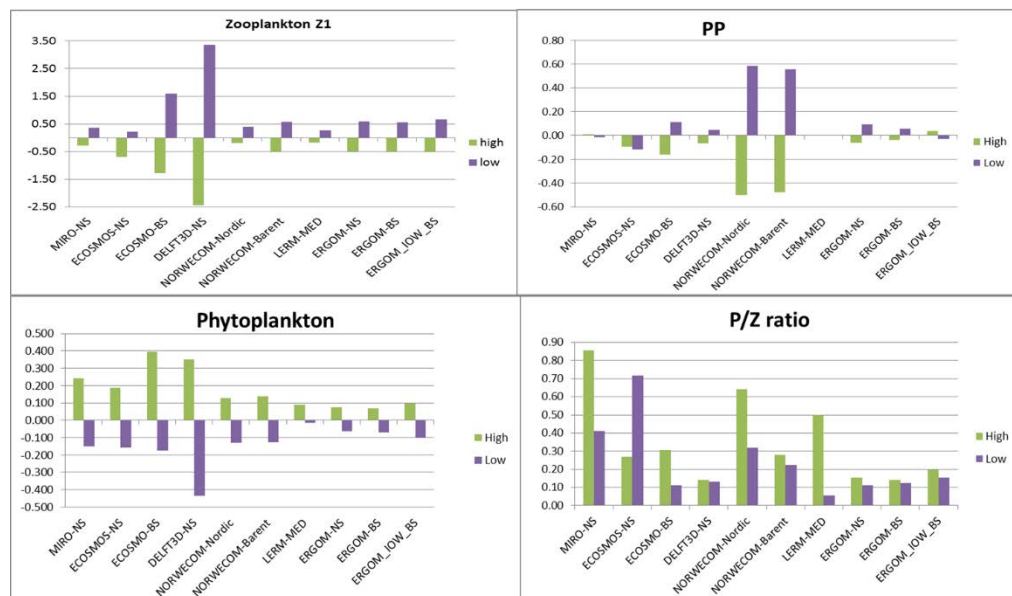


Figure 2. The model results of the delta-changes of zooplankton (z1), primary production (PP), phytoplankton biomass (P), and the TC-ratio (P/Z, absolute numbers).

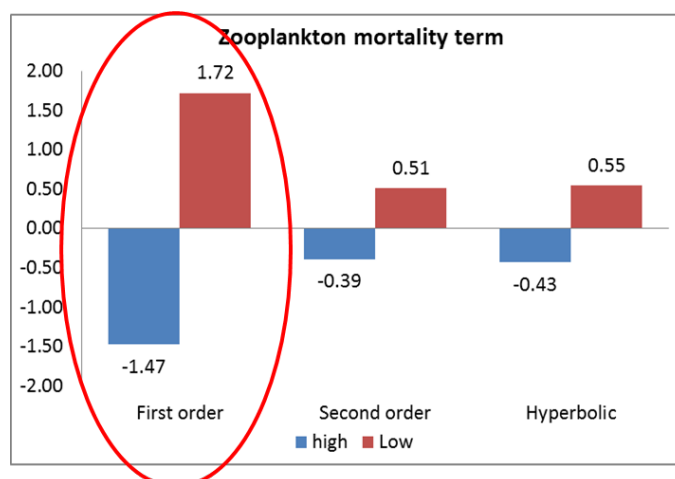


Figure 3. Delta changes in zooplankton biomass for different closure terms (first- and second order and hyperbolic mortality functions) for the scenarios low and high mortality.

**Presentation on Top-down control on 'Z' by Rubao Ji (WHOI)**

Marine zooplankton are influenced by both bottom-up (through changes in physical environment and/or food resource) and top-down (through changes in predation) forcing. Evaluating the sensitivity of zooplankton to the bottom-up and top-down forcing is an essential step towards the prediction of future marine planktonic ecosystem changes. Most of previous studies are based on statistical analyses that correlate zooplankton with both preys of zooplankton (e.g. phytoplankton) and predators of zooplankton (fish or invertebrate predators). Very few studies have conducted quantitative assessment based on dynamic models. In this presentation, a case study in the Gulf of Maine will be presented, with a coupled hydrodynamics and foodweb model to identify model sensitivity to changes in predation pressure on zooplankton. The results suggest that trophic cascading effect is detectable: annual mean phytoplankton biomass increases when zooplankton biomass decreases as a result of zooplankton mortality loss. The magnitudes of the changes decrease as the trophic level moving down from zooplankton to phytoplankton and nutrients. There is also strong seasonal and spatial variability of top-down influence on both zooplankton and phytoplankton.

#### 4.7 Progress on connectivity of habitats for fish larvae (ToR g)

**Presentation: How is connectivity of flatfish impacted by reproductive strategy? By Geneviève Lacroix (RBINS)**

A particle-tracking transport model (Larvae&Co) coupled to a three-dimensional hydrodynamic model has been used to assess the larval dispersal and connectivity pattern between spawning grounds and nurseries of four flatfish species (*Solea solea*, *Pleuronectes platessa*, *Scophthalmus maximus* and *Platichthys flesus*) in the North Sea. The impact of different life traits and behaviour on connectivity has been estimated. Preliminary results showed that there are two groups: (1) sole and turbot (spring-summer spawners) and (2) plaice and flounder (winter spawners) which have a short and long pelagic larval duration (PLD) respectively. The two groups also differed by their dispersal pattern. Plaice and flounder seemed to have higher larval dispersal than sole and turbot. For the latter group, the model predicted no connectivity between the Southern North Sea (ICES 4c) and the Central North Sea (ICES 4b) contrarily to plaice and flounder (Figure 4).

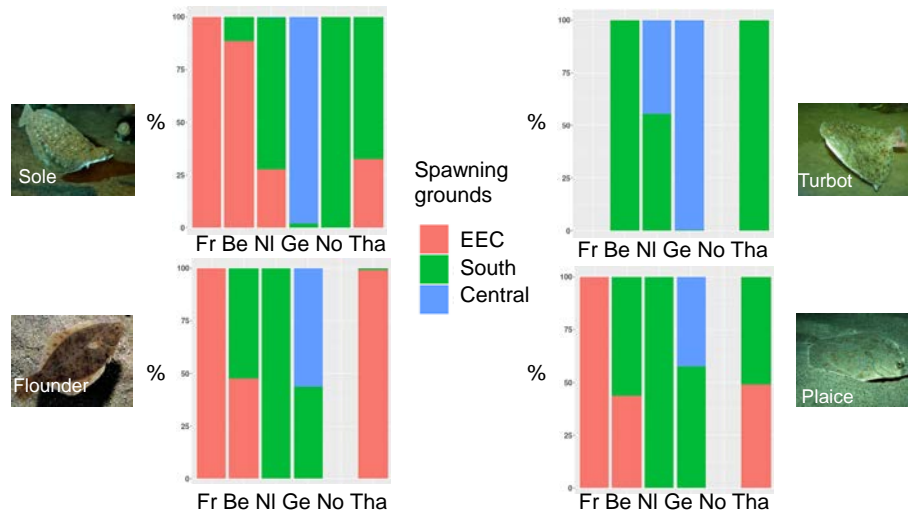


Figure 4. Percentage of larvae coming from the different spawning grounds (EEC: Eastern English Channel, (ICES 7d), South: Southern North Sea (ICES 4c) and Central: Central North Sea (ICES 4b)) arriving in the nurseries as defined in Lacroix *et al.*, 2013 (Fr: France, Be: Belgium, NI: The Netherlands, Ge: Germany, No: Norfolk and Tha: Thames).

**Presentation:** Update on the North Sea comparison of drift models by Marc Hufnagl (UHAM).

Various hydrodynamic and Lagrangian Drift models were compared to identify the range of variability that can be expected when applying these models in connectivity analysis. A paper related to this topic has been submitted to the special issue: North Sea Coastal Systems by the Journal of Sea Research.

#### 4.8 Progress on bioenergetics modelling activities (ToR h)

**Presentation:** Regional environment explains variability in biological traits of anchovy populations along a European latitudinal gradient: a Dynamic Energy Budget approach by M. Huret, K. Tsiaras, U. Daewel, M. Skogen, P. Gatti, P. Petitgas, S. Somarakis (Ifremer)

Anchovy distribution in European waters spans from the Mediterranean Sea to the North Sea. Despite a relative lack of data in the northern regions, namely the North, the Norwegian and the Baltic Seas, observations reveal differences in biological life traits among regions, and in particular between the Aegean Sea and the Bay of Biscay. These differences are significant on growth patterns, maximum size and reproduction timing. The objectives were first to test the ability of a bioenergetic model to simulate the observed regional variability of those traits, and second to use the model in understanding the underlying mechanisms behind the regional patterns of growth, as well as reproduction strategies. We used the Dynamic Energy Budget model, forced by seasonal climatology of temperature and zooplankton output from regional coupled physical-biogeochemical models. The model was calibrated with data from the Bay of Biscay population. Only one parameter, the half saturation coefficient, needed to be slightly modified for the model to reproduce the observed growth patterns in other areas. It appeared that there is a gradient from food-limited growth in the Aegean Sea, leading to a smaller maximum size, to a temperature-limited growth in the North Sea. Model results also revealed that the seasonality in regional environment conditions drives the reproduction timing strategy among populations. Indeed, from southern to northern regions, spawning window based on a temperature

threshold is more and more limited, and the successful spawning window is even reduced based on the minimum energy required to pass the first winter as juvenile.

#### **4.9 Changes/ Edits/ Additions to ToR**

No changes have been made to any ToRs

#### **4.10 Cooperation with other WG**

Several ICES working groups have been identified and contacted concerning potential cooperation.

##### **Working Group on Integrating Ecological and Economic Models (WGIMM)**

During the 2015 WGIPEM meeting a web conference was held with members of WGIMM and potential fields of cooperation between and interest of both groups have been identified and the WGIMM ICES ASC 2015 Session M chaired by Rasmus Nielsen, Jörn Schmidt, and Eric Thunberg addressed part of them. Furthermore it is the focus of a review paper, which shall be submitted by ICES WGIMM this year. Future cooperation between WGIPEM and WGIMM shall especially address bio-economic modelling in complex ecosystem models and stakeholder communication.

##### **Working Group on Biological Parameters (WGBIOP)**

A dialogue between the two groups has been initiated by WGBIOP. WGBIOP is a new working group that has been formed to provide support to the development and quality assurance of biological parameters used in Integrated Ecosystem Assessments (IEA) and advice. One subgroup of WGBIOP has been tasked with identifying potential new biological parameters needed for Integrated Ecosystem Assessments and is aiming to form a link between IEA working groups and groups dealing with model development, data collection and sampling design, by providing information on new biological parameters such as computational methods, data requirements and examples of their use.

WGBIOP asked WGIPEM to provide a list of new and useful, model-based biological parameters where “new”, concerning WGBIOP, means either parameters that are currently used but that are relatively new (i.e. may not be used by all IEA groups but may be useful to them) or parameters that WGIPEM thinks would be useful to IEA models but do not currently exist. Furthermore interest has been stated concerning how biological data are incorporated into integration of ocean models with ecosystem models.

During the WGIPEM meeting, it was started to compile such a list and to collect examples and where and how field data have been integrated. The list shall be provided to WGBIOP before their meeting in September.

##### **Working Group on Multispecies Assessment Methods (WGSAM)**

Both groups WGSAM and WGIPEM use, develop, and provide output from multispecies models and thus deal with similar challenges and problems. Several scientists are members of both groups. Updates and news are exchanged between both groups in this way.

**Working Group on Integrating Surveys for the Ecosystem Approach (WGISUR)**

A first contact between WGISUR and WGIPEM has been established with the aim to exchange modelled maps of important physical and ecosystem properties and features (comparable to the request by WGBIOP). Integrated ecosystem monitoring focuses on trying to assess the processes that occur by taking status observations at different times and places. Modelling offers the opportunity to quantify those processes and if done in accordance with the sampling can be used to test specific hypothesis about the way the ecosystem functions. In other words, modelling guides the adaptive development of the monitoring program. Identifying the key uncertainties in the model provides opportunity for modellers to suggest what is most important to monitor given current uncertainties and monitoring actors to see how one could adapt monitoring to reduce the overall uncertainty of the model, or the uncertainty with regards to some specific management objectives. Therefore, WGISUR sees a continuum of the kind:

Data collection ↔ Model ↔ Assessment/Policy Advice

From their (a survey group's) perspective also interest has been stated in being able to provide insight (based on survey design and data quality/continuity issues) into how the data could be used better/or if it is likely to have weaknesses for the proposed purpose.

The list of parameters and maps envisioned to be compiled by WGIPEM for WGBIOP shall also be shared with WGISUR as a first step to start the cooperation.

**4.11 Cooperation with Advisory structures**

Future cooperation is envisioned as soon as efficient ways in output provision are established and the analysis of the benchmarking and sensitivity group has advanced.

**4.12 Science Highlights**

See abstracts on presentations



## **5 Revisions to the work plan and justification**

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No changes needed in the work plan

## **6 Next meetings**

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The 2017 WGIPEM meeting will be held in June in Oristano (Sardinia), Italy – dates still to be confirmed.

## Annex 1. List of participants

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