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Contents

Executive summary **1**

1 Introduction **2**

1.1 Organisation of the workshops and of this report 2

2 Integrated modelling in marine ecosystems; existing approaches, ongoing projects and needs for the future **3**

2.1 Keynote speakers 3

2.2 Ongoing related projects 7

2.3 Managers' needs for the future 10

3 WKIEM: Ongoing projects, technical issues and future research lines. **12**

3.1 Building integrated models (I); the building blocks 12

3.1.1 Hydrodynamics and lower trophic levels: 12

3.1.2 Intermediate trophic levels 13

3.1.3 Upper trophic levels 13

3.2 Building integrated models (II): coupling the pieces 13

3.2.1 Some examples 13

3.2.2 Challenges and pitfalls 14

4 Summary of the Workshop Meeting of WKMED: Models for the Ecosystem Approach to Fisheries in the Mediterranean Sea **15**

4.1 Introduction 15

4.2 The utility of the models 16

4.3 Where to create synergies 21

4.4 WKMED Propositions 22

5 Discussion and conclusions **23**

6 Acknowledgements **24**

Annex 1: Bibliography **25**

Annex 2: List of participants **27**

Annex 3: Programme **29**

Annex 4: Preliminary review of models in the Mediterranean region **33**

Annex 5: WKIEM 2010 terms of reference **37**

Annex 6: Recommendations **38**

Annex 7: Proposal for a follow-up Expert Group **39**

Executive summary

MARIFISH-ICES Joint Workshop on Integrated Ecosystem Modelling; building our capacity to understand and manage marine ecosystems in a changing world (WKIEM), chaired by M. Bernal, Spain, I. Allen, UK, S. Neuenfeldt, DK, E. Curchitser, USA and J. Ruiz, Spain met in Barcelona, Spain from 18–19 November 2011.

This report contains a summary of the contents of two combined Workshops related to integrated modelling of marine ecosystems in a global context (WKIEM) and within the Mediterranean Sea (WKMED), and their use for scientific purposes, management objectives or as a risk-assessment tool. The main objective of the report is to provide references and links to various ongoing integrated or end-to-end modelling approaches and to summarize the discussions within the WK. A large variety of projects and some overview of the managers' expectations and critical evaluation of the usefulness of these models were presented in the WK. Model development, uncertainty, skill assessment tools, and the incorporation of human pressures, necessities and behaviour in the models were among the main issues discussed. Overall, integrated models together with scenario building and testing are devised as powerful tools to synthesize existing knowledge, advance in ecosystem functioning understanding and provide an integrated view of the ecosystem responses to different scenarios. Scenarios themselves should be built with a specific objective (simulate reality, compare management options, etc.), and are key parts of the end-to-end model building exercise. However, there is also a general consensus that end-to-end models are often data-poor in relation to model complexity, uncertainty is in the best cases underestimated, and prediction capabilities (*sensu strictu*) are poor. Therefore, they are not yet prepared to be integrated in most ecosystem assessment routine processes. In the best cases, they do, however, provide an integrated view of current understanding of the ecosystem, therefore providing a promising tool for risk assessment and decision-making. The contents of these WKs are expected to be further elaborated in an open discussion paper and in a future expert group.

1 Introduction

Between the 15 to 19 November, two coordinated workshops took place in Barcelona, with the common objective of discussing the state-of-the-art and the future of integrated ecosystem modelling as a tool to investigate marine ecosystems. The two workshops shared an interest on integrated models as a tool to improve the understanding of marine ecosystems and ultimately improve our capacity to manage them. In order to do that, worldwide experts on ecosystem models and EU project coordinators met together with managers and representatives of funding agencies to coordinate ongoing projects and devise future requirements. The two workshops were:

- WKIEM: MARIFISH-ICES Joint Workshop on Integrated ecosystem modelling; building our capacity to understand and manage marine ecosystems in a changing world CLIMAFISH programme
- WKMED: MARIFISH Workshop on Models for the Ecosystem Approach to Fisheries in the Mediterranean Sea

The thematic of both workshops was similar, although the aims and the regions covered were slightly different. WKMED focused on identifying research needs in relation to integrated modelling of marine ecosystems in the Mediterranean region, with the final aim to propose future research to fill those gaps and further advance in integrated modelling in the area. WKIEM focused on discussing pitfalls, technical solutions and potential uses of different ongoing approaches to integrated modelling worldwide. The workshops were originally proposed from two programmes within the ERA-NET MARIFISH; WKIEM was proposed by the programme on Climate and Fisheries, whereas WKMED was proposed by the regional programme of the Mediterranean Sea. Early in the organization process WKIEM was also proposed to ICES and was approved as a joint ICES-MARIFISH workshop. Both workshops were finally organized together to take profit of their synergies. Also, because of the thematic of both workshops, early information on the organization of the workshops was sent to the Eur-Oceans consortium, which decided to endorse the objectives of the combined meeting.

1.1 Organisation of the workshops and of this report

The meeting was organized in different blocks, separated into plenary meetings (Monday 15, Tuesday 16, and Friday 19 November) with attendance from participants in both workshops, and parallel sessions (Wednesday 17 and Thursday 18 November) in which the two workshops were conducted independently. The plenary meetings included a large number of experts that provided an overview of the scientific current state-of-the-art in relation to ecosystem modelling, and an overview of manager and funding agencies expectations. The parallel sessions provided the opportunity to discuss ecological and methodological questions and approaches in ongoing projects, as well as the opportunity to identify gaps and potential partners to develop future projects in the required areas.

WKIEM was also organized in various blocks; a first group of blocks dealt with the various trophic levels used in integrated models (hydrodynamics and lower trophic levels, medium trophic levels and upper trophic levels and socio-economics), whereas a second group of blocks dealt with various issues on how to couple the different modules of an integrated model.

In this report, a wrap up of the notes taken on the main topics discussed within the common sessions of the combined workshop, together with the specific topics discussed in WKIEM are presented. WKMED report (prepared by the MED participants) is also included for completeness. The main objective of this report is to provide some information on the related ongoing projects (main references and web page links) and a brief resume of the discussions and conclusions that took place during the WK. The contents of the discussions that took place in those workshops are expected to be further elaborated in a follow-up Open Questions paper that will be prepared by the participants on those workshops.

The complete agenda of the workshops is included in Annex 2.

2 Integrated modelling in marine ecosystems; existing approaches, ongoing projects and needs for the future

A total of 6 keynote speakers and 6 ongoing projects were presented in the first day and a half plenary sessions, and three more projects were also presented within the WKIEM sessions (see Table 2.2.1 and Section 3 below for WKIEM discussion). These presentations cover a variety of methods and objectives.

2.1 Keynote speakers

Keynote speakers cover a range of approaches from physiological effects of climate change to differential equations models and dynamic budgets of various spatial, species and temporal resolutions to to-ways coupled hydrodynamic – lower trophic levels – higher trophic levels models.

William Cheung: "Modelling climate change effects on life history, distribution and potential catches of exploited marine species"

This presentation dealt with how various expected changes in the ocean induced by climate will affect marine species. Expected effects in the ocean due to climate change include change in ocean heat content, salinity, nutrient concentration, sea level, sea ice, acidification, changes in marine habitats and marine productivity. Those changes will in turn have effects at all levels of marine ecosystems: organism to populations, ecosystems, fisheries and global issues, and effects include shifts and changes in distribution, species composition, body size, etc. Those changes will in turn ecosystem services (both to other members of the ecosystem and to humans) and resource management. An integrated ecosystem model that includes physical conditions, plankton and other organisms distribution, preferences (i.e. temperature, etc.) and bioenergetics in relation to body size is used to analyse effects such as: shifts in a given species, biodiversity (Cheung *et al.*, 2009), local extinction, movement towards the pole, and maximum potential catch rate (Cheung *et al.*, 2010). Results from applying these models in climate change scenarios include the prediction of changes in phytoplankton community structure (size), which can in turn affect the transfer of energy, changes in body size and decrease in catches in lower latitudes, and in general a loss in landed value, which means endowment needed to compensate for economic loss

Questions:

- Philippe Moguedet: forecasting potential, differences between forecast and prediction. Response: simulation and scenarios; understand how the ecosystem will behave.

- Enrique Curchitser: Error bars, range of tolerance, where does the signal of change comes from? (There is not much change in temperature in the models, although there is a wide tolerance range): Response: accumulated response will have an effect on the long term, even if things are within the tolerance range.
- Daniel Howell: how are the errors propagated? How to put error bars on predictions? Response: patterns can be useful (comes back to scenario analysis). They also try to find the main uncertainties in the analysis, and learn from that.
- Kenneth Rose: in reply to forecasting; they can be used to scenarios analysis and long term analysis.

Daniela Banaru: Object-oriented Simulator of Marine ecOSystems Exploitation (OSMOSE; Developed by Y. J. Shin and M. Travers)

This presentation show some of the characteristics of OSMOSE and its use in a specific case study in the Gulf of Lions (Mediterranean Sea), together with some other examples worldwide (see for example Travers *et al*., 2006). OSMOSE is a multispecies individual-based model focused on fish species, with detailed information on species life cycle, and coupled with biogeochemical models. OSMOSE takes into account things such as variability of time and space of fish diets, cannibalism and interactions between species. The foodweb is based on a size based predation relation, with thresholds for predator/prey size ratio, and with diets related to these thresholds and to spatio-temporal co-occurrence of the species. Foodwebs are therefore variable in structure and trophic relations. Model requirements include: spatial distribution by species (Yemane *et al*., 2008), age/size class and implicit migration patterns, natural mortality (in some cases estimated by genetic algorithms) predation efficient, reproduction capacity and fishing mortality. Starvation is generated when no food is available at the required sizes. OSMOSE is used to analyse the combined effects of climate and humans, by using the model under various scenarios (scenario fishing, scenario climate and scenario fishing + climate). Coupling with lower trophic levels is done in a two way (i.e. with feedbacks; fish impose mortality on lower trophic levels; Travers *et al*., 2009). OSMOSE outputs include various indicators: size-based, species-based and trophodynamics. A list of pros and cons of the model was presented, together with some examples of its use worldwide. Main hypothesis is that the model does not include any diet preference but predation is based on species size. Main objectives include to be of use for species-based management and to analyse the combined effect of humans and climate on fish stocks.

Questions:

- Stelios Somarakis: How do you choose your species in the Gulf of Lions (R: from ecopath). Which of the biological parameters (growth, reproduction, mortality) are dynamic and which are not. R: Most of them are fixed.
- Stefan Neuenfeldt: The model is mimicking a Hollow II predation functional response, which has some implicit assumptions; should that be made explicit?
- Patricia Reglero: What is the range, spatial scaling of predators? (Do they migrate outside the study area?)

Stephanie Mahevas: Quantitative diagnostics of the impact of management measures on fisheries using ISIS-Fish

This presentation shows the use of ISIS-Fish to evaluate and diagnose various management measures on fisheries, with some examples of its application to Bay of Biscay anchovy fishery and to other fisheries. ISIS - Fish stands for Integration of Spatial Information for Simulation of Fisheries dynamics (Mahévas and Pelletier, 2004), and its main scope is to address issues such as: assessing the impact of management measures, understanding functioning of fisheries and providing support for decision-making in fisheries management. ISIS-Fish is multispecies and include socio-economics, and outputs are designed to be easy to analyse available using statistical tools available within R. The model includes a differential equations population module (similar to population assessment models), a fleet dynamics module and a management strategy module. It can be coupled with hydrodynamic models, and has been used to test hypothesis on various issues related to fisheries. The Bay of Biscay example (Pelletier *et al*., 2009) was used to evaluate various management strategies, including marine protected areas and temporal fishing bans.

Questions:

- Dimitris Politikos: How is migration parameterized in the model? R: By migration coefficients
- Cedric Bacher: is the model being accepted by managers? R: It has been used in the anchovy assessment WK, for the assessment of MPA's (RAC). It includes information from fisherman in the model building process.
- Philippe Mogüedet: For the specific case of Bay of Biscay, model time-scale may not be able to handle the fleet dynamics properly.
- Olivier Thebaud: Has the relative influence of uncertainty in various parameters been assessed? R: Sensitivity was done on catch and biomass, if you do it in a different variable, maybe different response.

Simone Libralato: Ecopath with Ecosim & Examples of End-to-End implementations

Ecopath, Ecosim and Ecospace are a suite of models developed in the late 90's and currently applied in a variety of ecosystems worldwide (Christensen and Walters, 2004; Pauly *et al*., 2000; Polovina, 1984). These models are based on a functional group – based foodweb, with functional groups being form by single species, a group of similar species, specific life stages, etc. The model ensures mass-balance for all components, and relations between functional groups are based on vulnerability parameters, which are formulated as type-II functional forms. The differences between Ecopath, Ecosim and Ecospace are that Ecopath is a static mass-balanced snapshop, while Ecosim is time explicit and Ecospace is spatio-temporally explicit (Walters *et al*., 1997). Coupling to lower trophic levels and hydrodynamic models is currently being developed, and it has already being used to analyse potential changes using climate scenarios (Libralato and Solidoro, 2009). Next steps include simulating changes in the ecosystem due to combined effects of climate and human.

Questions:

- Cedric Bacher: Are processes affecting reproduction – recruitment (aggregation) included in this approach? R: you can disaggregate life cycles to improve resolution of those processes. Ecospace should be used to do space disaggregation
- Daniel Howell: Recruitment; over-smoothing the recruitment; also when you go to fine scale, how can you have data on each grid to validate the model?

- Daniela Banaru: Limitation on number of compartments? R: No. Q: effect of grouping species? R: Rules (ecological similarities)

Kenneth Rose: From Climate to Physics to Fisheries: A Demonstration of an End-to-End Model for the California Current System.

One of the main reasons for developing end-to-end models is that they provide a framework where it is possible to have climate to fish linkages that include bottom–up, middle-out and top–down controls (Plagányi, 2007; Fulton and Allen, 2009; Fulton, 2010). The reasons for why they are being developed now include the existence of spatial detailed data, behavioural measurements, improvements in computing, modelling advances (physics and biology) (Rose *et al.*, 2010). The ingredients and pressure is there to do it. In this presentation an example of a dynamic spatial and temporal explicit coupled climate – hydrodynamics – lower, medium and upper trophic levels (including fleet) model is presented. In the model everything is solved simultaneously, which allows including feedbacks between compartments. Feeding, growth, reproduction, mortality and movement (Railsback *et al.*, 1999; Humston *et al.*, 2004) are dynamically represented by Individual Based Models of a certain number of fish species. Super individuals are used to allow representing the large abundance of fish. Density dependence is implicitly included in a simplistic way due to feedbacks in lower trophic levels (reduction of food fields) and the potential for cannibalisms. These models are computationally very expensive, but examples of a working model in the California Current are provided. Expected outputs include simulations of population dynamics under a 50 years climate scenario, as well as fleet outcomes.

Questions:

- Manuel Ruiz-Villareal: In the example, biomass of small pelagics concentrated offshore, why? R: Upwelling in the area seems to transport everything offshore. Implementation still in progress; egg vertical position should changes with stage, vertical migration with larvae
- Patricia Reglero: 1) Mortality, should it be size specific? R: for juvenile and young adults stage should be size dependent. 2) How is migration implemented? R: Rule based
- Stelios Somarakis: 1) Selection of prey, 2) up to which length are larvae passive. R2: mix advection and behaviour is crucial for given lengths. R1: prey selection is done by Type II functional forms. k's calibrated to get growth right. It is only size-based because k's can change
- Daniela Banaru: Comparison of outputs with surveys. R: will be done, but not yet. Sardine has stock assessment, so that will also be checked.
- Icarus Allen: We have to start assessing the forecasting potential
- Philippe Cury: What is the strategy to reduce uncertainty to make these models more useful? R: synthesis of information; can allow to channel a large amount of info.
- Jordi Salat: Deterministic approach? Is all fixed? How can you tune your model to adapt to observations? R: Tuning is very difficult to do. Other validation information should be used, a plan is needed.

Olivier Thebaud (and Beth Fulton) Integrated modelling of marine social-ecological systems with Atlantis

Integrated modelling is a tool that allows tackling ecosystem and economics systems in a common framework. It allows assessing the impacts of fishing (species, community, and ecosystem) and environmental pressures at different scales including ecosystem-wide effects. These models aim to understand, predict, identify indicators and evaluate management strategies. They work as "flight simulators" where scenarios can be tested before decisions are actually taken ("try before you do it"). Integrated models encompass a suite of models with differences in structure, and different questions are expected to need different approaches. Atlantis incorporates various exchange processes between the water column and the seabed, seabed types and various processes of ocean – atmosphere interchange (Fulton *et al.*, 2003; Fulton *et al.*, 2005). Hydrodynamic information is aggregated in boxes, and a number of ecological processes can be incorporated. The model can work with functional groups and/or key species, which optionally include invertebrates (aggregated in various biomass pools). Interconnectivity among compartments is based on a maximum potential proportion of the prey population that a predator can access at any one time. Movement and reproduction is also included, although larvae are not yet included in the model (plan is to include them); recruits are input directly as young of the year. Fishing is highly explicitly detailed in the model (F, dynamic causal models, changes in gear, effort allocation, economic and social drivers, management constraints, bycatch, by-product, etc.; Guyader and Thebaud, 2001). Stock assessment is implicit in the model, as well as uncertainty analysis. The model allows synthesizing a large amount of information in a coherent framework, however, the data needs are high, and a complete calibration experiment is impossible. Also, it is very complex to communicate.

Questions/comments:

- Daniela Banaru: how you allow for diseases

2.2 Ongoing related projects

A list of the projects presented in this WK is shown in Table 2.2.1. A summary of the projects presented in the plenary session and within WKIEM is written below.

Icarus Allen: MEECE: Marine Ecosystem Evolution in a Changing Environment (http://www.meece.eu)

MEECE responds to the challenge of giving support to various policy challenges; from the EU Common Fisheries Policy to the new Marine Strategy Framework, and in general to ultimately build tools to help in the long term EU marine strategy. The project relies heavily on coupled physical – biogeochemical – higher trophic level models, as they allow including interactions and do forecast under different scenarios. A large effort on model assessment, evaluation of different approaches and quantification of various sources of uncertainty is being carried out within MEECE. Also, the project includes the development of various specific and generic couplers, as well as a data portal for a broader community. EXAMPLES

Stefan Neuenfeldt: FACTS: Forage fish interactions (http://www.facts-project.eu/)

FACTS main objective is to understand the role of forage fish particularly with regards to ecosystem stability and biodiversity. The project contributes to support the integration of the ecosystem approach in the EU Common Fisheries Policy, by addressing questions such as: what are the main drivers of changes in commercially and ecologically important forage fish populations within European waters? What are the ecological and economical consequences of changes in forage fish? What are the consequences of changes in predator populations on forage fish? The project focus on case studies on the North Sea, Baltic Sea, Barents Sea, Bay of Biscay and a generic case study to allow for comparison, integration and synthesis of information from all case studies. Different case studies have different model structure, all of them trying to integrate different parts of the ecosystem to incorporate bottom up, sideways and top down control effects. FACTS is planning to have a dedicated ICES theme session next year, and a dedicated symposium in 2012.

Questions:

- Francesc Sala: effect of fishing on the ecosystem; is there a cascade effect (top down effect) on lower trophic levels by overfishing? (i.e. reduced predation). R: in some cases is clear a bottom up control; zooplankton controls biomass of forage fish.
- Philippe Cury: Models or data driving decisions

Javier Ruiz SESAME: Southern European Seas: Assessing and Modelling Ecosystem changes (http://www.sesame-ip.eu/)

The general objective of SESAME is to provide assessment of the current status, past fluctuations and future responses of Southern European Seas, especially in relation to the services they provide (for society and for the rest of the ecosystem). SESAME coordinated various actions along the Mediterranean and dealt with issues such as how the future circulation on the strait of Gibraltar will be or understanding the dynamics of jellyfish blooms. A part of the project also focuses on how to deal with uncertainty in complex coupled models that include both lower and higher trophic levels. Approaches such as Ecopath-Ecosim or coupled hydrodynamics – lower trophic levels – medium trophic levels Individual Based models are applied to different case studies along the Mediterranean and Black seas. Bayesian models are also used, and provide a way to incorporate uncertainty within the model.

Questions:

- Isabel Palomera: proliferation of jellyfish related to overexploitation, is that included in the model? R: The reason may not be due to overexploitation, Examples in Mar de Plata; sometimes that conclusion has been reached without enough supporting data.

Miguel Bernal: REPROdUCE: understanding REcruiment PROcessess Using Coupled models of the pelagic Ecosystem (http://www.pelagic-ecosystems.net/REPROdUCE)

REPROdUCE aims to develop life cycle models for two specific case studies: 1) sardines and anchovy in the Bay of Biscay; and 2) anchovy in the Aegean Sea. Hydrodynamic models are coupled with lower and upper trophic levels models, and main recruitment drivers are identified through the process. The models will be used to understand the main mechanisms and drivers of the recruitment process and help predict the abundance of new individuals entering the stock. Indices for recruitment strengths will be produced to assist short, medium and long term management plans. Developing indicators of recruitment will be particularly crucial to the management of short-lived species such as sardines or anchovies.

Enrique Curchitser: Mechanisms for low-frequency variability of forage fish: A comparative analysis of North Pacific sardine and anchovy systems (within US project CAMEO: Comparative Analysis of Marine Ecosystems: http://cameo.noaa.gov/pres_ecurchitser.html)

Kenneth Rose previously presented most of the methods used in this project in the first day of the meeting (see Section 2.1 above). This presentation was therefore devoted to detail some of the basic problems inherent to approaches that rely on climate models. In general climate projections integrated in most coupled models come from complex Earth system models that include main forcing affecting Earth climate. Within the ocean part of those models there are high model biases in coastal areas and in boundaries, which are often the most productive areas and those which can be the focus of some fisheries projects. Upscaling the biology and downscaling the climate signal until a common ground is found is not a trivial problem for integrated models, as neither is the fact that most models are not capable of reproducing decadal trends, but else long term signals. Regional effects as well as regime shifts are also not well represented in climate models. In general, links between the ecosystem and climate scientific communities need to continue to expand, and a better understanding of the requirements and outcomes of the different models is still required. Finally, in relation to future scenarios, an open question was posed: Can human activity be reduced to emissions or fishing scenarios?

Questions:

- Javier Ruiz: IPCC is not including the small pattern, that is a paradox, how can you downscale then feedback? Do you capture the small-scale effect? R: the trick is online feedbacks; big differences between hindcast and forecast.

Icarus Allen (signed by M. Barange) QUEST-Fish: The marine environment and the ecological consequences of a business-as-usual scenario (http://www.quest-fish.org.uk/)

This projects aims to translate results for long term predictions of Global Circulation Models to global trends in ecosystem productivity, fish catches and socio-economic effects. Changes in fish biomass due to changes in ecosystem productivity are predicted, and various scenarios of sources of protein for various human uses are tested. In general terms, different trends in fish productivity are predicted for different world regions, emphasizing the importance of managing human responses to these effects in order to minimize regional impacts. The correct incorporation of human responses to any future scenario (climate and human effects) is therefore required to obtain realistic predictions for the future of marine ecosystems.

Questions

- Enrique Curchitser: "In a warming world primary productivity will go down" However there are other evidences suggesting that upwelling may also increase. Both are contrary and differ from Quest-Fish conclusions. R: there may be some regional differences.

Table 2.2.1. List of related projects.

	PROJECT NAME	SHORT SUMMARY
GLOBAL	**IMBER:** Integrated Marine Biogeochemistry and Ecosystem Research	Understand the links between biogeochemical cycles and Climate.
	QUEST-Fish: Quantifying and understanding the Earth System	Understanding how climate change would affect the potential production for global fisheries resources in future
	CAMEO: Comparative analysis of Marine Ecosystems	Various actions: - end 2 end workshop - decadal pelagic fish fluctuations using end to end models
EUROPEAN	**MEECE:** Marine Ecosystem Evolution in a Changing Environment	Coupled ecosystem models (end-to-end models), applied to understand population drivers and the effect of multiple climatic and anthropogenic in marine populations
	FACTS: Forage fish Interactions	Analysis of the pelagic ecosystem focusing on forage fish, aiming to analyse trophic relationship among forage fish and between them and the rest of the pelagic foodweb.
	REPROdUCE: Understanding Recruitment Processes using coupled models of the pelagic ecosystem.	Coupled ecosystem models (end-to-end models) applied to identify main recruitment drivers (and their interactions) for sardine and anchovy
	MEDEX: Inter-basin exchange in the changing Mediterranean Sea: Impact on the ecosystems in the vicinity of the Straits connecting the Mediterranean Sea with the Adjacent Basins	Analysis and prediction of changes in local Mediterranean ecosystems due to changes in the Mediterranean inflow/outflow processes.
	SESAME: Southern European Seas: Assessing and Modelling Ecosystem changes (Mediterranean and Black Sea)	Mathematical models are being used to predict ecosystem responses to changes in climate and anthropogenic forcing. SESAME will also study the effect of the ecosystem variability on key goods and services, including fisheries
	ECOKNOWS: Effective use of ecosystem and biological knowledge in fisheries	The overall aim of the ECOKNOWS project is to extend the use of the Bayesian methodology in fisheries sciences in order to improve the integration of biological process and multiple sources of data in fisheries stock assessments models.
	SYMBIOSES: End-to-End risk assessment for the oil industry	Aims to build a tool that will improve current risk assessment, with the capacity to give tactical/operational input to advice on oil development ("go/no go")
	BEMA: Biological ensemble modelling approach.	Baltic Ecosystem Ensembled models

2.3 Managers' needs for the future

Three presentations address directly the managers' points of view in relation to how to fund research projects that use integrated modelling for a variety of objectives, and also what are the managers' expectations from this kind of models.

First, **Maurice Heral** spoke about MariFish (http://www.marifish.org), a European Research Network (ERA – NET) dedicated to fisheries. MariFish promotes co-programming and multilateral approaches among European funding agencies that often share common scientific challenges as well as regional data and knowledge. MariFish objectives include Socio-economic research, communication improvement, knowledge management and the development of common programming between funding agencies. MariFish outcomes are expected to be of use for managers, scientist and stakeholders. Within MariFish, WP07 is dedicated to synthesis of existing research and knowledge and identification of gaps and research needs. Also, WP08 provides funding via a competitive call in which research agencies provide funding via a "virtual pot" and multinational teams apply for it in a competitive basis. MariFish is currently finishing, but there is another ERA-NET (SEASERA) that also launches competitive calls. The future of various ERA-NETs is currently under discussion, and some kind of similar structure is expected to continue in the near future.

Questions/comments:

- Icarus Allen: It is important to strength the connections between ERA -NETS and with DCR and other commission actions (such as Vessel Monitoring Systems and MyOceans actions)
- Cedric Bacher: Ecosystem Approach to fisheries, Marine Strategy Framework Directive; better understand the marine ecosystems and improve our capacity to manage them.

Philippe Moguedet presented possibilities and requirements for modelling projects in EU FP7, within the DG-Mare and DG-RTD Directions of the EU. There are three main research lines within the FP7 for which integrated models are crucial; (i) Knowledge-base for an Ecosystem Approach to Fisheries Management (EAFM), (ii) Investigating the socio and economic dimension of EU fisheries and aquaculture activities, and (iii) New governance for the implementation of the Common Fisheries Policy (CFP) and its inclusion in the EU Integrated Maritime Policy (IMP). In relation to this lines, various competitive calls have been launched in 2010 and 2011 and a number of projects that include integrated modelling as a main tool to investigate marine ecosystem functioning and the interactions with human extraction have been funded (see Table 2.2.1 for some examples). The variety of modelling approaches within those projects is very large; thirteen completely different approaches were identified from the Commission. The feeling in the Commission is that there is no global strategy in relation to modelling approaches to analyse combined human and environmental effects on marine ecosystems. Poor communication between projects and research groups, together with poor communication and knowledge transfer of project outcomes to stakeholders and managers was also sensed. Also, the EC sensed that the quality control of these models is in general poor and that there is a large degree of overlapping between scientific proposal, and conclude that there is a risk that those models will not deliver what the EC expects, while the funding expenses are high. Taking into account these worries, P. Moguedet presented the main priorities within the DG-RTD; (i) the development of operational models, (ii) the requirement that outcomes of these projects provide support to implement EU policies (Common Fisheries Policy – CFP; Marine Strategy Framework Directive – MSFD) and decision-making, (iii) the development of quantitative indicators of ecosystem status, and (iv) the improvement of communication between scientist and with all stakeholders.

Questions/comments:

- Various questions were raised on the necessity to have better communication between EC and research groups on expectations, requirements and needs from end-to-end models. See the Discussion section for a summary of this discussion and the general discussion.

Finally within this section, **Philippe Cury** presented a view into the future of integrated ecosystem models and its use to improve marine ecosystem management. P. Cury presentation stresses the role of scenarios as a tool to improve scientific knowledge and management of marine ecosystems. Scenarios are not forecasting on what will happen in future, but else generate the appropriate questions and helps providing answers and guidance for action (to widen perspectives and illuminate key issues). Two kinds of scenarios are proposed; a) projections-like Scenarios and b) pathway scenarios. Examples of projections-like scenario include scenarios based on global warming expectations, overexploitation etc. (Moss *et al*., 2010; Allison *et al*., 2009; Mullon *et al*., 2005). Pathway scenarios provide exploratory scenarios, where various alternatives to achieve a given ecosystem status can be tested. Scenarios provide a new way of generating new scientific knowledge, different from the traditional hypotheses testing framework. However, to use these tools, it is important to follow some rules on how to evaluate and document the models and the scenarios used (Schmolke *et al*., 2010). Also, communication of complex scenarios and models will become a challenge, and new communication tools (e.g. ECOSCOPE) and skills will be required. P. Cury also argued that in order to improve the efficiency of these approaches, some top–down control on model development should exist, in order to standardize the tools and the assessment procedures.

Questions/comments:

- Stefan Neuenfeldt: Communication, we as scientist may not be qualified and do not have the time.

3 WKIEM: Ongoing projects, technical issues and future research lines.

A total of 20 presentations divided in 5 blocks were presented within the WKIEM sessions on Wednesday and Thursday (see Annex 2 for a complete list). Each block was followed by about an hour discussion and at the end of the WK there were two hours for general discussion and wrap up. Main take-home messages from each session are briefly outlined below.

3.1 Building integrated models (I); the building blocks

3.1.1 Hydrodynamics and lower trophic levels:

Take home messages:

Hydrodynamics have advanced mesoscale phenomena are captured by the models; however, problems in forcing may translate into poor biological simulations. It is often hard to distinguish whether poor physics or poor biology is to blame.

Continuous (and in some aspects increasing) need for data and empirical analysis, to both parameterize processing in models and provide empirical relationships with which to test models.

Large existing efforts in improving validation and providing model skill assessment tools (e.g. Lynch *et al*., 2009 and associated papers): As a minimum expectation a model should do better than random prediction

3.1.2 Intermediate trophic levels

Take home messages:

Simulation of dynamic properties is required to explore population responses: reproduction, growth, feeding requirements

Biological properties crucial for spatial analysis in relation to hydrography: (not so) passive movements, active movement, migration

Some criticism: Density dependence in intermediate trophic levels not implemented (or only partially)

3.1.3 Upper trophic levels

Take home messages:

Do we know how much mortality do the upper trophic levels predators impose on intermediate trophic levels preys? How does it compare with fishing mortality in exploited intermediate trophic levels (e.g. pelagic fish) populations?

An extra effort to develop models of apical predators (cetaceans, but also others) is needed

Fleet dynamic models; there are both simple and very detailed models. In recent years, there is an overall improvement on modelling human behaviour, although society is more complex. Socioeconomics include both modelling how much we extract and what society gets and how it reacts.

3.2 Building integrated models (II): coupling the pieces

3.2.1 Some examples

In addition to the examples presented in the plenary sessions (see Section 2 above), some other examples were presented in this session. In particular, two type of approaches that differ from the previously presented ones were discussed; statistical approaches and simplified end-to-end models (which to some extent can be included in the class of Minimum Realistic Models –MRM- made in Plaganyi, 2007)

Various statistical approaches were presented, including a Bayesian analysis of ecosystem dynamics and a foodweb model based on multivariate auto-regression models. These approaches require a data-rich environment, but in turn provide some predictive power if the assumed functional forms can be extrapolated to the prediction domain. Statistical approaches in general incorporate some uncertainty on the processes within the model, also providing some hints on the confidence limits of the predictions. Examples include the work carried out within ECOKNOWS (http://www.ecoknows.eu/), as well as the POLCOMS-ERSEM-Bioenergetics model (http://www.pol.ac.uk/home/research/polcoms/eco.php).

A simplified end-to-end model used for risk analysis in the context of oil industries was also presented. This approach has clear objectives; to improve risk analysis and to act as a decision-making tool. The model focuses on hindcast and scenario analysis, rather than operational forecast, but provides a tool to assess various options and perform risk-analysis. In order to achieve objectives, stakeholders need to be integrated in the project at all stages, from model development, to scenario building to risk analysis.

Other examples presented include ensemble analysis, where different models are combined to include some model uncertainty, with the extra advantage of providing integrated assessment. This approach can potentially include uncertainty in future prediction, although when same data and similar principles are used in the various models, then uncertainty estimates may not be realistic.

3.2.2 Challenges and pitfalls

Over the last 5 years we have made massive strides forward and now have several coupled physical - ecosystem models, capable making climate forced scenarios of ecosystem states. The advantages of this approach are: synthesis of existing knowledge and data, possibility to formulate and test existing hypothesis, true interdisciplinary work, support in risk analysis and decision-making. Thus allowing integrated assessment

However there are still many issues to address before these models become fully mature. Problems include coupling climate, physics and biology: downscaling, climate uncertainties, scope of the different modules, acclimation and adaptation.

4 Summary of the Workshop Meeting of WKMED: Models for the Ecosystem Approach to Fisheries in the Mediterranean Sea

4.1 Introduction

The Marine Board-ESF Position Paper (SEAMBOR) published in 2010 describes the science requirements for a proper implementation of the Ecosystem Approach (EA) in the context of the Integrated Maritime Policy. This report identifies six most critical science goals or priorities, among which the improvement of knowledge of how ecosystems functioning (foodwebs, physical-biological coupling, etc.) support goods and services is underlined (see Box 1). Such effort includes the development and implementation of models capable to account for multiple interactions, assess ecosystem response to environmental drivers and anthropogenic pressures, and analyse management scenarios. The applicability of some models to management has been analysed in depth in the FAO report on models for an Ecosystem Approach to Fisheries (EAF), which reviewed and compared the available methods for assessing the interactions between species and fisheries and their implications for marine fisheries management. It identified advantages, disadvantages and limitations of 20 approaches, together with a set of commonly asked questions pertaining to EAF and the potential of the various modelling approaches to address these questions. This evaluation process showed that strengthening these approaches is crucial and that considerable scope exists for significant future developments with respect to their use as tools in EAF – e.g. effects of model structure and complexity on model outputs, treatment of uncertainty, representation of socio-economic factors and human behavioural drivers, multiple sector dynamics and management, representation of biodiversity.

Box 1. Critical science priorities to underpin the Ecosystem Approach to Management of Biotic Ocean Resources (Marine Board-ESF Position Paper 14, SEAMBOR).

1. Develop tools for integrated policy evaluation to improve the ability of decision-making to take account of the important interactions between humans and marine ecosystems;
2. Improve the knowledge of how ecological support systems (foodwebs, physical-biological coupling, etc.) are linked to the provision of goods and services which benefit, and are utilized by humans;
3. Assess the consequences of ecosystem changes for economies/societies, and investigate and develop mitigation and/or adaptation options;
4. Evaluate the advantages and limitations of alternative ecosystem conservation policies, including the use of economic incentives;
5. Ensure science support for strategic (regional) environmental assessments, including socio-economic factors;
6. Take measures to improve data management and inter-operability of data sources and analytical methods.

Some of these modelling approaches have been applied to specific areas of the Mediterranean (MED) sea (see for instance http://www.eur-oceans.eu/WP3.1/shopping_tool/all_models.php) but several challenges remain due to specificities of the MED sea (e.g. complex circulation of marine waters, climate variability, heterogeneity of and connectivity between sub regions, lack of regional governance of the MED sea), the need to build a stronger multidisciplinary modelling force capable to develop and apply a series of complementary models and the need to bridge scientific knowledge and fishery management within the EAF framework. The main objectives of the MED workshop were therefore to:

- Demonstrate functionalities of existing model platforms
- Examine applicability of models in areas considering the available data and quality
- Review existing projects in the MED on integrated coastal-zone management (ICZM) and EAF (if any) to identify the possible linkage
- Prepare some future training on modelling in connection with EUROCEANS
- Prepare a MARIFISH recommendation for the EC to support development of EAF tools in the MED region, taking into account MED specificities.
- Build a partnership addressing EAF models

The MED workshop was organized in conjunction with the IEM (Integrated Ecosystem Modelling) workshop, which allowed showing some modelling platforms during a plenary joint session: OSMOSE, Ecopath with Ecosim, ISIS-FISH, ATLANTIS (see Meeting Agenda in the Annex). The discussion within the working group also considered some questions raised during the plenary session on the use and applicability of models to address management issues. This synthesis summarizes the discussions and propositions and was presented in the plenary final session of both IEM and MED workshops.

4.2 The utility of the models

The European Commission (EC) recently stated that 'the criteria for the achievement of good environmental status are the starting point for the development of coherent approaches in the preparatory stages of marine strategies' and made a decision on the criteria which must be used to assess the extent to which good environmental status is being achieved . These criteria are defined according to a series of descriptors (see Box 2).

Box 2. Descriptors listed in the Marine Strategy Framework Directive (MSFD).

Descriptor 1: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions.

Descriptor 2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.

Descriptor 3: Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

Descriptor 4: All elements of the marine foodwebs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

Descriptor 5: Human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.

Descriptor 6: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

Descriptor 7: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

Descriptor 8: Concentrations of contaminants are at levels not giving rise to pollution effects.

Descriptor 9: Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.

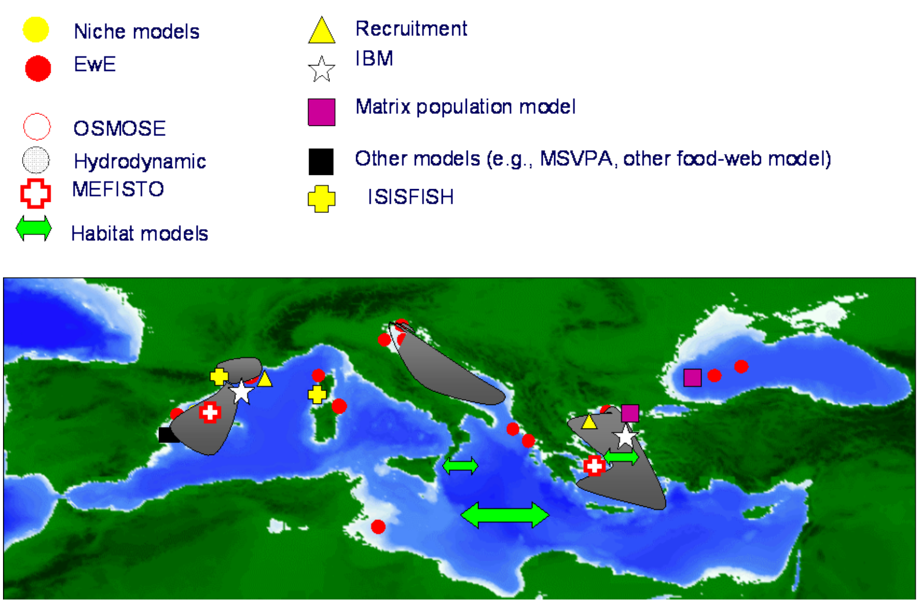
Descriptor 10: Properties and quantities of marine litter do not cause harm to the

coastal and marine environment.
Descriptor 11: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Several of these descriptors refer to ecosystem components, functions or structure which can be altered by environmental changes and pressures related to human activities. As an example, the EC listed a series of criteria and indicators for biological diversity (Descriptor 1) focusing on species distribution, population size, condition, and demographic characteristics, habitat extent and condition, ecosystem structure (see Box 2). Due to multiple interactions, scales of changes and ecosystem complexity, field observations need to be completed by different types of models. The WKIEM/WKMED workshops showed a wide variety of models capable to give complementary insights to assess ecosystem changes and management scenarios – e.g. ecotrophic, size based ecophysiological, biogeochemical, habitat, bioeconomic, management, stock assessment models.

For the MED region, we discussed the issues and the applicability of models according to their objectives and scales : assessment of ecosystem productivity, prediction of recruitment and habitat for target species, effect of environmental changes and anthropogenic pressures on population dynamics, sensitivity of trophic interactions to pressures and changes, interactions between management and population dynamics, long term changes of species niches (see Annex 4 for a review and Figure 1 for a map of existing models). A good example of model application to assess the responses of ecosystem trophic fluxes and holistic properties to changes and pressures is given by Tsagarakis *et al*. (2010). We reviewed existing knowledge, environmental and fishery issues in some of the most documented MED regions: Catalan Sea, Gulf of Lions, strait of Sicily, Adriatic Sea, Aegean Sea, as well as projects over the whole MED.

Figure 1. Map of existing models in the MED and BS regions (K. Tsagarakis, com. pers.) – see Annex 4 for a model detailed list of models.



Discussions highlighted several major strategic issues:

- Models can be distinguished according to their technical specifications (assumptions, mathematical formulations, number and types of interactions, spatial representation); scales and objectives (see Plagányi, 2007). No single model can address all the number of issues afore-mentioned, but there is a considerable interest in i) applying and combining several complementary approaches, ii) assessing and comparing ecosystems functioning and responses using the same modelling frame and ecological concepts.
- Even though ecosystem are complex and a lot of uncertainties and unknowns remain, there is some convergence towards key ecological concepts and key processes which play a role in ecosystem dynamics – e.g. trophic interactions, bioenergetics and macroecology, niche preference and species distribution, biogeochemistry, hydrodynamics and thermodynamics. This also stands for the interactions between socio-economy and ecosystem dynamics. Models rely upon these most recent advances in ecology and economy, and play a major role in identifying new scientific challenges related to knowledge gaps.
- WKMED clearly showed a variety of spatial and temporal scales and resolution. For instance, habitat models are applied over the whole MED region with a high spatial resolution. Nested biogeochemical models account for global/local interactions and allow investigating mesoscale and submesoscale structures in subregions. Some ecosystem models depict the global foodweb structure and flows, while habitat models prescribe the potential presence/absence of single species as a function of environmental factors and/or oceanic features at the scale of the whole MED. Because maps of potential habitat are mainly derived from independent E2E model data (satellite environmental data and sightings), these products can be used in the frame of E2E model calibration and validation. The combination of models and the coupling between physical, biological and socioeconomic models will increase the scope of existing models in the near future.
- Models can be operated in different ways to provide information useful for decision-makers. Examples were given concerning the use of remote sensing to predict habitat and help fishery managers to identify the location of target species on real time. Bioeconomic models help in testing long term effect of management scenarios and accounting of stakeholders' behaviour (e.g. fishers). Indicators of ecosystem health and impact of pressures are built upon reconstruction of ecosystem foodwebs. New trends appear regarding scenario building, identification of pathways towards a desired state, integration of decision-making process, etc.
- Models require a lot of quantitative and qualitative information. Data are used in several ways: forcing functions, boundary conditions, parameterization of mathematical equations, test of model outputs (calibration, validation), and building of scenarios dealing with possible futures or management options. Uncertainty or missing information can be managed up to a certain extent using literature reviews, automatic calibration procedure, and uncertainty analysis. The lack of information can however be detrimental to the validation of model in all dimensions – physics, biology, socio-economy. Besides, some data exist but may be difficult to use (due to

poor quality, lack of standardization procedure or heterogeneity) or retrieve (e.g. property rights). The availability of data were extensively discussed by reviewing existing data on several MED regions (see WKMED agenda).

The demonstration of models joined to a review of available data, management and ecological issues in some of MED regions emphasized some major issues:

- Data collection and availability: a lot of environmental, biological and fishery data have been collected within several national and European projects. In most cases, these data are analysed and displayed through the publication of scientific papers. There is a considerable interest for archiving and sharing this information for a series of further uses: calibration of models, comparison of systems (meta-analysis), assessment of long term changes, possible standardization of model construction. This issue is not MED specific (see SEAMBOR report – item 6 in Box 1), but the concern is especially true in the MED due to the number of international bodies and countries. The availability of and accessibility to data (e.g. MEDITS) therefore makes necessary to reinforce the strategies at the scale of the MED. It includes basic data regarding the economic and social dimensions of uses in coastal areas which are still lacking in many places (SEAMBOR, op. cit. p 36). Moreover, there is a need to standardize and validate methods of data acquisition (e.g. acoustic surveys) and disseminate widely the use and utility of operational tools (e.g. remote sensing).
- Applicability of complementary models: it has been noticed that no food-web models have been generally applied at scales that allows to work within national boundaries. As an example, although several types of models are readily available in the Adriatic region, none includes the Croatian part of it. This example illustrates the need for transnational modelling approaches in addition to the sharing of national and regional databases mentioned above.
- MED modelling applications are not homogeneously applied in the basin, being clear the absence of applications in the Southern part of the MED (except for an forthcoming application in the Gulf of Gabes). Therefore, for an EAF at MED scale there is a clear need for improving the models applications in MED Southern countries, to favour transnational collaborations (see above) and to invite scientist from these MED Southern countries in next activities (meetings, workshops, schools, programmes).
- As for other ecoregions, the assessment of responses of ecosystem structure and services to changes are a high priority for coastal sciences. The review of projects in the WKMED clearly showed that more effort must be put on integration tools able to address the effects of climate change, to describe ecosystem functioning and structure in relation to multiple pressures including fishery, to account the ecological and socio-economic effects of aquaculture, and to assess long term changes on ecosystem functions, habitat and species distribution. The review showed the need for integrated tools that allows for simultaneously accounting for the multiple stressors (and services) the MED is subjected to for a comprehensive assessment and management.
- Effort has also to be maintained on ecological studies. While small pelagic fish in the MED area have received a great attention during the past dec-

ades (e.g. SARDONE, REPRODUCE projects) for a series of reasons (small pelagic fish play a major role as a trophic link within coastal ecosystems, they are short living species very sensitive to short-term environmental changes, and they are an economic resource), more knowledge is needed on key processes – e.g. feeding preference, migration, reproduction, population dynamics, abundance and importance of top predators. The MED must be seen as a mosaics of habitats with various temporal and spatial connected scales. Ecological studies should also consider the connectivity between MED regions with relevant spatial and temporal scales. Connectivity plays a key role in biological invasions which are recognized as an important factor of biodiversity change in the MED (SEAMBOR, op. cit. p. 27). It also affects interactions between species through predator–prey relationships.

- Management Strategy Evaluations have been developing during the past decade as a means to test different management options taking into account uncertainties about ecosystem processes, resource status, fleet operations and regulations (SEAMBOR, op. cit., p. 65). Very few examples are documented in the MED area, and there is a need to further apply models in support to such strategies. In particular new fishery policy and long term changes in heavily exploited fish populations have been moving fishers activity towards other marine activities (e.g. switch from fishery to aquaculture or tourism activities). These recent or new trends must be analysed in terms of management of ecosystem services.
- With respect to model improvements, methodological developments have been highlighted. Making models operational impose to capture errors and bias by accounting for sources of errors of different types - e. g. uncertainty of parameters, random or non controlled variability of forcing functions, alternative mathematical formulations, simulating alternative assumptions. Models must be associated to data acquisition strategies through the analysis of the most important parameters and forcing functions. Models become more and more generic, and there is a need to create database of the most used parameters. There is also a need for evaluate models through analysis of quality of input data and skill assessment.
- Improve linkage with other Coordination bodies – e.g. FAO. Under the FAO umbrella, the General Fisheries Commission for the Mediterranean (GFCM, http://www.gfcm.org/gfcm/en) is instrumental in coordinating efforts by governments to effectively manage fisheries at regional level following the Code of Conduct for Responsible Fisheries. Its objectives are to promote the development, conservation, rational management and best utilization of living marine resources, as well as the sustainable development of aquaculture in the Mediterranean, Black Sea and connecting waters. GFCM encourages, recommends, coordinates and, as appropriate, undertakes research and development activities, including cooperative projects in the areas of fisheries and the protection of living marine resources. The following regional projects have been formulated and operated:
    - ADRIAMED, www.faoadriamed.org, Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea,
    - COPEMED II, www.faocopemed.org, Coordination to Support Fisheries Management in the Western and Central Mediterranean,

- MEDSUDMED, www.faomedsudmed.org, Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily,
- EASTMED, http://www.faoeastmed.org, Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean
- MEDFISIS, Mediterranean Fishery Statistics and Information System, http://www.faomedfisis.org/index.html,
- ArtFiMed, www.faoartfimed.org, Développement durable de la pêche artisanale méditerranée au Maroc et en Tunisie,

Such projects enhance transnational efforts to collect data and information regarding fishery activities and fish stocks. They are complementary to scientific projects on ecosystem approaches.

- As in other geographical regions, communication and use of model results become a concern of increasing importance within the implementation of Marine Strategy Framework Directive (MSFD) and EAF. Several topics must be considered:
    - Types of communication channels and ways of communicating must be adapted to the 'target', e.g. stakeholders, decision-makers, other scientists, NGOs, EC, fishers, regulatory authorities. Meetings must be planned to present results in an adapted way on a regularly basis and exchange views as a part of communication plan including public outreach.
    - Utility of models for managers can be demonstrated through the production of predictive habitat maps, indicators of ecosystem state, changes and responses to management options, advice based on stock assessment models.
    - Participatory approach will develop as a component of the modelling design. It will allow identifying needs and expectations, simulating management strategies in relation with decision-makers, making the models more friendly and transparent, providing information, etc. As an example, fishers can provide information not available by other means (e.g. seasonal campaigns) and help in feeding models with data.

4.3 Where to create synergies

Synergies are necessary to address some of previously identified issues. They will increase the capacity of the scientific community to implement, improve and test models as a tool to better assess ecosystem functions and services and help in evaluating management options. More specifically, synergies have been proposed to solve the following key methodological questions:

- Combination of spatial scales. Scales depend on ecosystem functioning, life cycle of fish population, fishers' activity and management objectives. Data and methods must be shared to define the appropriate scales, identify the available information and gaps and avoid the duplication of effort in model development.
- Regarding methods, important efforts must be dedicated to the use of different approaches and to the coupling of models, e.g. inclusion of space in models, coupling between ecosystem and habitat models, use of climate and watershed models to drive ecosystem models of coastal areas, devel-

opment of management (e.g. Marine Protected Areas) and bioeconomic models, implement participatory approaches, build scenarios of possible or suitable futures. Working groups on such topics would help in making collective progress.

- Joint efforts on ecosystem assessment would benefit to all the scientific community and help in building confidence in the models. They would consider meta analysis of ecosystems using model based indicators, comparison of ecosystems functions and responses to changes over a wide range of ecosystems, compare model projections, analyse past history (hindcast and analysis of time-series).
- Following the preliminary work on data availability carried out during WKMED, there is a lot to gain from group working on data needs, availability and accessibility, and discussion on new protocols regarding the use of extension of field campaigns to provide new environmental data.
- The implementation of the MSFD requires collective thinking to adapt models, share data and build relevant indicators considering the descriptors published by the EC (see Box 2) and the MSFD objectives – assess ecosystem state and responses to change, evaluate restoration measures, etc.

4.4 WKMED Propositions

Propositions have been made to improve collaborative work regarding the implementation and improvement of models in the MED, and are summarized below:

- Joint programming. MARIFISH has already funded several collaborative projects which will improve the understanding on key processes (e.g. REPRODUCE). Several participants are involved in a response to the FP7 call "Ocean of tomorrow" which will submitted in January 2011. Another call has been launched by BIODIVERSA and would be an opportunity to deal with ecosystem services related to marine fisheries. Besides, coordination between national initiatives in the MED must be reinforced. A large multidisciplinary Mediterranean Experiment has been initiated by the French CNRS. It will structure the scientific activity in the MED and will complement international initiatives in the same region. As for the North/South cooperation FAO projects on EAF in the MED and other existing projects (e.g. MedPAN South project, lead by WWF on MPA [1]) based on a lot of bilateral cooperation must be reviewed to avoid duplication and identify potential partners.
- Capacity building. Methodological improvements of existing models and development of a new generation of models able to address EAF and MSFD objectives required to strengthen and widen the use of models. Working groups and training sessions could be dedicated to the following specific objectives:
    - Use of Ecopath with Ecosim: define relevant and standard functional groups, build and document a database of parameters, improve the implementation of a quality insurance procedure.

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wwf.panda.org/what_we_do/where_we_work/mediterranean/about/marine/marine_protected_areas/medpan_south_project/

- Habitat modelling: how to use remote sensing to analyse environmental variability (e.g. temperature, chlorophyll a), which statistical methods and tools can be used to predict habitats.
- Sensitivity and uncertainty analysis: statistical and simulation techniques accounting for uncertainty of parameters, random or non controlled variability of forcing functions, alternative mathematical formulations and model assumptions, general model skill assessment.
- Integrated social-ecological models: such models are necessary to tackle complex systems and to assess management scenarios regarding economic, ecological or institutional drivers using system approach and appropriate methods to build scenarios and indicators.

5 Discussion and conclusions

There is an increasing interest in integrated models to understand and predict marine ecosystems and their response to change. This interest emerges from a combination of things, mainly the current capacity to build such models and the subsequent interest in using them in a climate change and ecosystem holistic management framework. The current capacity to build such models arises from large improvements in modelling of most elements of the marine ecosystem; from hydrodynamic and biogeochemical models to models that describe the individual behaviour of intermediate (or even lower; e.g. zooplankton) trophic levels, to those that describe human interaction with the ecosystem (fleets, socio-economics, etc.). Integrated model development has also benefited from a large increase in computing power, which allows performing the required number of computations in a timely manner. On the other hand, there is interest in these models from both the scientific community and funding bodies. Reasons for this interest includes (i) the potential to synthesize a large body of existing knowledge and information, coming from a diversity of science branches, (ii) the necessity to integrate bottom–up, sideways and top–down effects to analyse the combined effect of human and climate in the ecosystem, and (iii) the interest to manage the ecosystem as a whole, taking into account all ecosystem services (to the marine environment and to human beings).

The field of integrated models is emergent and has shown rapid growth in recent times, as indicated by a number of scientific symposia and workshops, several of recent papers in the literature and even its inclusion as potential tools in various management plans (e.g. the EU Marine Strategy Framework Directive).

Notwithstanding the general interest in these approaches, and the clear interest of the people attending this event, within this WK there was a necessity to discuss pitfalls and shortcomings of these models, as well as to try to delimitate what they can and cannot provide in their current status. A clear message from the discussions within the WK is that models need to deliver what they promise; they should be realistic in objectives and transparent in methods. Model assessment needs to be included in the projects and in the outcomes. Guidelines on how to perform various levels of model assessment have started to appear in the main literature (see a monograph introduced by Lynch *et al.*, 2009), and an effort to perform a quality check in the models seems crucial. It is also important to put much effort into how to communicate the methods, results and outcomes of these models to a diverse audience that includes stakeholders, funders, managers, and the scientific community will be required. Links with data and submodel products providers (such as various EU initiatives to make those data available to scientist) are also crucial to develop these models, as well as the integration of different stakeholders in the model building process.

Finally, the WK concludes that a number of follow-up initiatives should be put forward. The discussion from the group will be further elaborated in an "open questions" manuscript on the roadmap we will like the development of these models to follow. Also, we will like to establish a forum where the development of end-to-end models can be reviewed and discussed, and therefore we recommend creating a dedicated ICES WG to address the aforementioned issues. (See Recommendations section)

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Annex 3: Programme

General programme:

Monday 15th November		
14:00 – 15:00:	Introduction Maurice Heral: MARIFISH Miguel Bernal – WKIEM Cedric Bacher - WKMED	Sponsors, objectives, agenda and presentations
15:00 - 15:30:	Coffee break	
15:30 – 16:30:	Willian Cheung: Climate envelope	Examples of end-to-end implementations
16:30 – 17:30:	Simone Libralato: ECOPATH/ECOSIM	
17:30 – 18:30:	Stephanie Mahevas: ISIS-FISH	
Tuesday 16th November		
08:30 – 09:30:	Daniela Banaru: OSMOSE	Examples of end-to-end implementations
09:30 – 10:30:	Kenneth Rose: ROMS/LTL/MTL/Predators	
10:30 – 11:00:	Coffee Break	
11:00 – 12:00:	Olivier Thébaud: ATLANTIS	
12:00 – 12:20:	Icarus Allen: MEECE	Ongoing EU and US projects
12:20 – 12:40:	Stephan Neuenfeldt: FACTS	
12:40 – 13:00	Javier Ruiz: SESAME	
13:00 – 14:30:	Lunch break	
14:30 – 14:50:	Miguel Bernal: REPROdUCE	
14:50 – 15:10:	Enrique Curchitser: CAMEO	
15:10 – 15:30:	Icarus Allen: QUEST-FISH	
15:30 – 16:00	Coffee Break	
16:00 – 16:20:	Philippe Moguedet: EU representative	EU - Project Managers
16:20 – 16:40:	Philippe Cury: EUROCEANS	
16:40 – 18:00	Discussion: products, expectations and information exchange	
Wednesday 17th November		
09:00 – 10:30:	Break up for WKIEM and WKMED	WKIEM and WKMED parallel sessions
10:30 – 11:00:	Coffee Break	
11:00 – 13:00:	Break up for WKIEM and WKMED (cont.)	
13:00 – 14:30:	Lunch Break	
14:30 – 15:30:	Break up for WKIEM and WKMED (cont.)	
15:30 – 16:00:	Coffee Break	
16:00 – 17:00:	Break up for WKIEM and WKMED (cont.)	
17:00	**Barcelona tour and dinner** - TABLAO DE CARMEN	
Thursday 18th November		
09:00 – 10:30:	Break up for WKIEM and WKMED	WKIEM and WKMED parallel sessions
10:30 – 11:00:	Coffee Break	
11:00 – 13:00:	Break up for WKIEM and WKMED (cont.)	
13:00 – 14:30:	Lunch Break	
14:30 – 15:30:	Break up for WKIEM and WKMED (cont.)	
15:30 – 16:00:	Coffee Break	
16:00 – 18:00:	Break up for WKIEM and WKMED (cont.)	
Friday 19th November		
09:00 – 10:00:	Methods and objectives	Wrapping up session
10:00 – 11:00:	Products: what, when and how should be delivered?	
11:00 – 11:30:	Coffee Break	
11:30 – 12:00:	Proposed actions: coordination and dissemination	
12:00 – 12:20:	Farewell and WK finish	

WKIEM programme:

Wednesday 17 November

09:00 – 09:30: Presentation, objectives and agenda

09:30 – 10:30: Wrap up of plenary discussion

- Fill in approaches from the different EU projects (ICES ToR 1 and 2)
- What do Managers expect from us? What do we think we can provide?

10:30 – 11:00: Coffee break

11:00 – 13:00: **The pieces (I): hydrodynamics and LTL modules**

1- Icarus Allen: Validation of LTL models
2- Manuel Ruiz-Villareal *et al*.: Modelling oceanographic conditions influencing early stages of small pelagic fish
3- Jordi Sole: Impacts of circulation patterns on the ecosystem behaviour in the Mediterranean entrance (Alboran Sea)
4- Gonzalez-Quiros, Enrique Nogueira, *et al*.: Fractionated biomass from surveys; spatial and temporal distribution

- Discussion: scales, LTL required detail, validation?

13:00 – 14:30: Lunch time

14:30 – 15:30: **The pieces (II): Intermediate trophic levels**

5- Miguel Bernal *et al*., Simulating dynamic reproductive output in indeterminate spawners; the special case of sardines and anchovies.
6- Martín Huret *et al*.: Coupling the modules of different life stages through the DEB approach
7- Javier Ruiz *et al*.: Understanding and simulating population dynamics in an habitat-evolving life cycle: anchovy in the Gulf of Cádiz
8- Andrés Ospina *et al*.: Dynamics of anchovy early life stages in the NW Mediterranean using a coupled hydrodynamics and biological model.

15:30 – 16:00: Coffee break

16:00 – 17:00: The pieces (II): Intermediate trophic levels Discussion

- o Sideways control; competition, how well the intermediate trophic level has to be described (is a couple of species enough?) to be useful?
- o Gowth, movement (vertical, egg buoyancy) and migration; how is it tackle in the different projects

17:00: End of day; Barcelona tour and official WK dinner

Thursday 18 November

09:00 – 09:30: Wrap up of first day and revision of agenda

09:30 – 10:30: The pieces (III): Upper trophic levels

9- Begoña Santos *et al.,* presented by Stefan Neuenfeldt: Integrating top predators into ecosystem models
10- Kenneth A Rose: Including Fleet models in an end-to-end modelling framework
11- Lars Ravn-Jonsen Ecological-economic modelling from an economist's viewpoint
12- Jordi Lleonart: MEFISTO: a software for bioeconomic modelling in the Mediterranean Sea.

10:30 – 11:00: Coffee break

11:00 – 12:00: The pieces (III): Discussion:

- o Are we imposing the right mortality on LTL?
- o Socioeconomic fleet models; can we predict human behaviour?

12:00 – 13:00: **The coupling (I)**

13- Sakari Kuikka: ECOKNOWS - creating learning components to fish stock assessment
14- Martin Lindegren and Anders Nielsen (SN). Integrated foodweb modelling in the Baltic Sea: a statistical approach
15- Dimitris Politikos: Coupled biogeochemical North Aegean model driving anchovy's full life cycle
16- Kostas Tsiaras: Can we better describe the anchovy dynamics by assimilating chla data into a coupled biophysical-fish model?

13:00 – 14:30: Lunch time

14:30 – 15:30: **The coupling (II)**

17- Enrique Curchitser: Problems in two way coupling
18- Anna Gårdmark, Stefan Neuenfeldt *et al*., Biological Ensemble Modelling of the Eastern Baltic cod future-so far and where to go from here
19- Daniel Howell: SYMBIOSES: End-to-End risk assessment for the oil industry
20- Miguel Bernal. Reporting end2end models; what, how and why.

15:30 – 16:00: Coffee break

16:00 – 17:00: The coupling discussion

- o Closure terms and feedbacks; how to deal with module coupling?
- o Validation: how to evaluate an end-to-end model?
- o Model output; output visualization requirements, list of output metrics.

17:00 – 18:00: WKIEM wrap up:

- Main objectives of end2end approaches and concerns
- Coordination of ongoing projects and initiatives for the future (courses, symposiums, reviews, etc)
- Revisit the manager-scientist question: From observations to models to management advice and policy - what can stakeholders expect? Extending the single- or multispecies prediction-based management perspective to include ecosystem-wide consequences of human induced changes beyond fisheries, accounting for impacts of anticipated climatic fluctuations.

18:00 – 18:30: Closing issues and preparation of report for Friday plenary

WKMED agenda:

Wednesday 17 November - WKMED	
09:00 – 17:00	Cedric Bacher: presentation of objectives and agenda of WKMED
	Simone Libralato: use of EwE in the Mediterranean
	Daniela Banaru: Ecopath, Gulf of Lions
	Francois Le Loc'h: AMPED, Gulf of Lions and other sites
	Jean Noël Druon: Operational habitat models
	Luis Gil de Sola : MED data
	Bernardo Patti : Straits of Sicily
	Marianna Giannoulaki: Habitat models
	Konstantinos Tsagarakis: Aegean Sea models
	Discussion
Thursday 18 November - WKMED	
09:00 – 18:00	Cedric Bacher: MERMEX
	Isabel Palomera: SARDONE project
	Vjekoslav Ticina : Adriatic Sea data and issues
	Jordi Lleonart: Bioeconomic models
	Discussion
	Synthesis

Annex 4: Preliminary review of models in the Mediterranean region

ITALY – GSA16 (SOUTH OF SICILY)				
MODEL TYPE	**INDICATORS AND OUTPUTS**	**OBJECTIVE**	**SCALES**	**TYPE/NAME/SOURCE**
Biogeochemical				
Hydrodynamic				e.g. Sorgente *et al*., 2003; Béranger *et al*., 2004; Gabersèk *et al*., 2007
Single process				
Population				Stock assessment models on demersal species (e.g. hake, pink shrimp, red mullet)
Trophic web				
Habitat	Habitat suitability maps, persistency indices		Specific period for each year;	Giannoulaki *et al*., 2010, submitted
Bioeconomical				
GREECE (N. AEGEAN SEA)				
MODEL TYPE	**INDICATORS AND OUTPUTS**	**OBJECTIVE**	**SCALES**	**TYPE/NAME/SOURCE**
Biogeochemical				ERSEM, Triantafyllou *et al*., 2007
Hydrodynamic				e.g. Lascaratos and Nittis 1998
Single process	Anchovy IBM coupled with NPZD	population dynamics		Politikos *et al*., 2010
Population				Mantzouni *et al*., 2007
Trophic web	Ecological, trophodynamic indicators, TLs, keystone species, MTI, exploitation indices, comparisons with other areas	Foodweb structure, Ecosystem functioning, Fishing impacts	Annual (2003–2006);No space	Ecopath, Tsagarakis *et al*., 2007
Habitat	Habitat suitability maps, persistency indices		Specific period for each year;Greece-Med	Giannoulaki *et al*., 2008; submitted, Tsagarakis *et al*., 2008, Siapatis *et al*., 2008, Schizmenou *et al*., 2008
Bioeconomical				Merino *et al*., 2007; MEFISTO
FRANCE (GULF OF LIONS)				
MODEL TYPE	**INDICATORS AND OUTPUTS**	**OBJECTIVE**	**SCALES**	**TYPE/NAME/SOURCE**
Biogeochemical			NW Medit.	ECO3M - Baklouti *et al*., 2006; Eisenhauer *et al*., 2009
Hydrodynamic			NW Medit., W Mediter.	Symphonie, MARS3D
Coupled hydrodyn. – biogeochim.			NW Medit.	Marsaleix *et al*., 2008; Auger *et al*., 2010

Single process				
Population	Stock, mortality		G. Lions	VIT (hake, red mullets) – CGPM, (Atlantic bluefin tuna)
Trophic web	Ecological, trophodynamic indicators, TLs, keystone species, MTI, etc	Foodweb structure, Ecosystem functioning, Fishing impacts	Annual (2000–2009);No space	Ecopath - Banaru *et al.*, in prep
	Size based, species-based and trophodynamic indicators	Foodweb structure, Ecosystem functioning, Fishing and AMP impacts	spatial, 15 days	OSMOSE (Ifremer-COM) Banaru *et al.*
Habitat	Habitat suitability maps,		Summer – G. Lions (MEDITS), tuna habitat Mediter.	Phd Marie Morfin – Ifremer, Druon *et al.*, 2010
Bioeconomical				
SPAIN (Catalan Sea)				
Model type	**Indicators and outputs**	**Objective**	**Scales**	**Type/name/source**
Biogeochemical	NPZD Model	Primary and secondary production simulation	Weeks to years	Bio-Fennel in ROMS
Hydrodynamic				MARS-3D;Andre *et al.*, 2009
Single process	Anchovy IBM	Recruitment	Spawning period	Ichthyop
Population	Standard population dynamics indicators	Stock Assessment	Usually annual	XSA and VIT. In GFCM/SCSA reports
Trophic web	Ecological, trophodynamic indicators, TLs, keystone species, MTI, exploitation indices, comparisons with other areas	Foodweb structure, Ecosystem functioning, Fishing impacts	Annual (1978–1979, 1994–1997, 2003);	Ecopath, Ecosim (Coll *et al.*, 2006a,b, 2008b,c, 2009; Libralato *et al.*, 2008; Mackinson *et al.*, 2009; Shannon *et al.*, 2009);Niche models (Coll *et al.*, 2008a)
Habitat	Habitat suitability maps, persistency indices			
Bioeconomical	Stock status and economic indicators;Short and medium term trends	Assess alternative management strategies	Annual	MEFISTO
ITALY (AdriaticSea)				
Model type	**Indicators and outputs**	**Objective**	**Scales**	**Type/name/source**
Biogeochemical	retention time; production patterns; water quality management indicators,	water quality analysis;;highlight sensitive parameters/processes;;studying microbial loop; climatic effects	different scales, from lagoons to Gulf of Trieste to the whole basin	TDM (Venice Lagoon; Solidoro *et al.*, 2005; Cossarini *et al.*, 2008);BGC-GoT (Gulf of Trieste; Cossarini and Solidoro, 2008);Adriatic;(Polimene *et al.*, 2006, 2007)

Hydrodynamic	circulation patterns and dense water formation	Study the effect of wind and riverine input	Northen Adriatic Sea;;Adriatic Sea	Querin *et al*., 2006;Cushman-Roisin and Korotenko, 2007
Population	fishing mortality, exploitation rate, biomass at sea	sardine and anchovy	whole basin, from 1973 up to now	Virtual Population analysis (Santojanni *et al*., 2001; 2003; 2006a,b)
Trophic web	habitat comparison; fisheries competition (ecosystem-based MSY); indicators for evaluating MPAs (SOI, mTL, TE etc); indicators for evaluating overfishing; biomass changes according to protection;	Foodweb structure, Ecosystem functioning, Fishing impacts; MPAs effectiveness; climatic effects,	Annual (1998–2000);No space;Annual-Space;(1997–2000);Annual (1975–1976, 1994–1997, 2002) and historical periods;	EwE Lagoon of Venice, (Pranovi *et al*., 2003; Libralato *et al*., 2002); North Adriatic Sea (Zucchetta *et al*., 2003); North Central Adriatic Sea Ecopath, Ecosim (Coll *et al*., 2007, 2008, 2009; Coll *et al*., 2010, Libralato *et al*., 2006, 2008, 2010) and Niche models (Coll *et al*., 2008, Lotze *et al*., 2011);
End2End	state variables from nutrients to fish	Integration of biogeochemical processes and foodweb dynamics	Northern Adriatic Sea	Venice Lagoon (Libralato and Solidoro 2009); Northern Adriatic Sea (Libralato *et al*., under submission)
Habitat	GAM models	Integration of fishing data and remote sensed data	;data from 2003–2005	Falco *et al*., 2007
Bioeconomical	Socio economic (employment rate, income) ; MSY; Social carrying capacity	Impact climate change on clams fishing and aquaculture		Venice Lagoon; (Melaku Canu *et al*., 2010; 2011)
Mediterranean Sea (entire basin)				
Model type	**Indicators and outputs**	**Objective**	**Scales**	**Type/name/source**
Biogeochemical	NPD;NPZD;OPATM-BFM	dynamics of LTL; primary productivity and biogeochemical cycles (P,N,C,Si); climatic changes effects	3D, whole basin, 1/8 degree horizontal resolution	Crise *et al* 1998; 1999; Crispi *et al*., 1999, 2001, 2002; Lazzari *et al*., 2010; Lazzari *et al*., under submission
Hydrodynamic	OPA		3D whole basin; 1/16 degree horizontal resolution	Pinardi *et al*., 1997; Somot *et al*., 2006; Tonani *et al*., 2008;
Population	Blue fin tuna, Swordfish	TAC/quotas definition	whole basin; subdividsion in two areas (west/east)	VPA (age structured models); surplus production model; ICCAT 2009; 2010;Tserpes *et al*., 2008;
SPAIN (Alboran Sea)				
Model type	**Indicators and outputs**	**Objective**	**Scales**	**Type/name/source**
Biogeochemical	NPZD Model	Primary and secondary production simulation	Weeks to years. 2 km resolution.	Bio-Fennel in ROMS

Single process. IBM coupled to Bio-Fennel-ROMS	Anchovy IBM	Recruitment variability and connectivity	Spawning period (days to months)	Ichthyop.

Annex 5: WKIEM 2010 terms of reference

2009/2/SSGSUE14 The **MARIFISH-ICES Joint Workshop on Integrated ecosystem modelling: building our capacity to understand and manage marine ecosystems in a changing world (**WKIEM), chaired by: M. Bernal, Spain, I. Allen, UK, S. Neuenfeldt, Denmark, E. Curchitser USA, and J. Ruiz, Spain will meet in Barcelona, Spain, 16–18 November 2010 to:

a) Review and document marine ecosystem integrative modelling approaches implemented at different ongoing EU and worldwide projects;

b) Analyse potential comparison/validation/integration of results from the different projects;

c) Design a coordinated program to disseminate and discuss results obtained from related projects and scientific networks.

Annex 6: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
Preparation of an open question manuscript about the future of end-to-end models to be submitted to the ICES Journal of Marine Science	WK members and invited contributors
Creation of a WG for the stimulation of the development of end-to-end models	WK chairs to promote the WG

Annex 7: Proposal for a follow-up Expert Group

The **ICES-CIESM-PICES Working Group on the development of marine ecosystems end-to-end models** (WGE2E), chaired by Icarus Allen*, UK, Enrique Curchitser*, US, Stefan Neuenfeldt*, Denmark, and Miguel Bernal*, Spain will be established and will meet during XXX 2011:

Long term ToRs:

To stimulate the development and application of end-to-end models of marine ecosystems in the ICES/PICES communities, as a tool to assess the scientific, technical and socio-economic information relevant to the understanding of climatic and humane impacts on marine ecosystems.

First year ToRs:

ToR 1: To review current state-of-the-art of end-to-end models: with special focus on:

- 1a. Climate scenarios (hindcast and forecast) with end-to-end models.
- 1b. Incorporation of human activities into end-to-end models.
- 1c. Critical gaps in process knowledge.
- 1d. Incorporability of model results into management and decision-making.

ToR 2: Roadmap of WGE2E; define milestones and targets for the Working Group and plan of action, based on the review in ToR 1. The roadmap should explore the following aspects:

- Development advances in model methodology for risk-based prediction using end to end models.
- Quantification of uncertainty and identification of information content that will be used widely by the scientific community, including ICES.
- Informing of policy through improved predictions of near-term climate change and its impacts.
- Engagement of users in order to ensure that maximum utility is gained from marine ecological modelling science.

WKE2E will report by XXXX 2011 (via SSGSUE) to SCICOM.

Supporting information

Priority	By end-to-end we mean models that ultimately aim to incorporate effects of climate, transference of biomass through the trophic web, upper trophic levels and the society on marine ecosystems. This WG is related to the three high priority research topics of the ICES science plan, as it is expected to a) advance in understanding ecosystem functioning, b) incorporate both human and climate effects on the ecosystem, and c) provide tools which can assist in ecosystem management. The WG explicitly recognize the necessity to adopt a holistic approach to manage ecosystems in a changing environment and changing human requirements and pressures, and therefore also address ICES Ecosystem Approach to Fisheries, as well as the EU Marine Strategy Framework Directive. The group will also deliver products useful for the Strategic Scientific Initiative on Climate Change, as well as for the involvement of ICES in the Marine Strategic Framework Directive.
Scientific justification	The WG long term ToR address the importance to have a forum to discuss and review the developments in this field. Involvement in the design and development of common tools and guidelines for various crucial steps of end-to-end model development is expected. This includes (but is not restricted to) tools for model skill assessment, bidirectional couplers (feedbacks) for linking ecosystem modules, guidance on how to incorporate human pressures and necessities in the ecosystem model, etc. ToR (1) is a starting task for this WG, and will build on previous efforts to synthesize state-of-the-art of this models. A focus on incorporation of climate and human driven effects, as well as to evaluate uncertainty and how to incorporate model outcomes into management will provide feedback into the long term ToR. ToR (2) will define a roadmap for the functioning of the WG. This roadmap should define future actions to achieve the long term ToR. We envisage the WG to work by defining specific actions that can involve different communities (scientist and other stakeholders) to address specific questions required to advance in the development and applicability of end-to-end models. The first WG meeting should define the kind of actions required and a roadmap of priorities for those actions and how they will advance in the long term ToR.
Resource requirements	None

Participants	The WG is envisaged to involve a diverse community, which includes both scientist and managers. Different actions proposed will require different people involved. In relation to scientist, the following branches should be involved: Climate Physical oceanographers Biodiversity Biogeochemical cycles Ecologist and fisheries scientist Economist and social scientist. In relation to managers and other stakeholders, various activities of the WG (e.g. model inputs and development, definition of outcomes, scenario building, risk analysis) will require the participation of science and fisheries managers, funding bodies and fisheries industries and fisherman. Communication and knowledge managers are also expected to be required to fulfil some of the WG objectives.
Secretariat facilities	None
Financial	None
Linkages to advisory committees	
Linkages to other committees Groups	WGPBI, WGHABD, WGOOFE, SGMPAN, SSICC, WGFCCIFS, WKNORCLIM, SGEH, WGINOSE, WKBEMIA, WKPELECO
Linkages to other organizations	PICES, CIESM, IPCC, IPBES