Further Discussion of Trade-Offs in the Use and Implementation of IEEFMs

Over the last two decades there has been increasing development of models that include various disciplines such as fish ecology, fisheries economy and sociology. They have been used, *inter alia*, as a tool for *ex ante* impact assessments and management advice for which formal and quantitative results are often required.

Here we have used meta-analysis tools supplemented with conference theme session and working group discussions to address a range of characteristics and questions in relation to the IEEFMs. These questions refer to the way in which different types of ecological models have been used in the past with respect to biological and economics based advice, and how case specific they are and need to be in their use. This also covers to which extent we can use existing models to provide meaningful and solid economic or ecosystem or social indicators (see also Hicks et al. 2016) that can easily be provided to stakeholders or interest groups; whether this depends on what kind of management we are talking about and the information needed for that. In this context it is essential to address what economic advice society needs, and how we can provide an appropriately integrated level of advice. Another important question is whether the models can be used to help improve the acceptance of models, and the advice provided on the basis of the models, by stakeholders; whether stakeholders will be ready to participate in management strategy evaluations and advice on options to explore using the models (i.e. are the models sufficiently advanced that they can provide useful stakeholder engagement tools). This goes further to cover aspects regarding how specific or strategic models can be included efficiently in the advice process.

By use of the meta-analysis tools we have tried to address all these questions as well as implications regarding trade-off between complexity and usefulness of the models (i.e. how complex must a model be). Usually, the models are complex, but some more complex than others. More complex models may provide more realism and allow for exploration of feedbacks between different component parts of the natural-human system. But often that complexity comes at a price in terms of ease of use and understanding as well as more general, repeated application. With respect to this it is also important whether the models can be validated and can generate uncertainty estimates as well as provide accuracy, benchmarks and prognoses. Related to this, the level of data required to construct the model with any degree of confidence or robustness is important – what processes can be addressed, what system aspects are covered by available data, e.g. food web, stock sizes, fleet dynamics, behavior of fishermen and fish, and different types of management systems. With respect to the latter the meta-analysis provides information about how different management objectives are captured in the models, and whether a model can address cross management objectives or is limited to only one or two options.

The IEEFMs enable evaluation of how economic aspects impact the biology and vice versa - how biological knowledge affects the economic processes in a model and how those feed-back to affect biological processes. Here it is important to know exactly what variables are affected and on what levels those affects play out. Integrating a model that incorporates both aspects equally is obviously difficult, but improvements in core models doing this are occurring globally. The IEEFMs enables discussion on common assumptions of biological and economic models, as well as the importance of those assumptions. Also, they enable visualization of why space (and time) is important, e.g. in relation to evaluation of marine protected areas (MPAs) and in economic context of MSP and the increasing competition for uses of marine areas. At the same time, the models illustrate the

difficulty of accounting for spatial heterogeneity when dealing with fish and fisheries which continuously move in time and space. The present evaluation of different type of models has shown that there are tradeoffs in complexity of models between accounting for the dynamics and interaction of agents/species versus being able to simulate individual behavior at a finer level. Also, time and time steps are important in relation to whether it is a static or a dynamically explicit model, and how time is incorporated in the model as time may not play the same role in all models. Models are universally quite complex, though some much more so than others.

To guide design and efficient implementation of IEEFMs it seems necessary to get fishery managers and stakeholders to formulate specific management requests, both with respect to ecological sustainability and economic efficiency so the models are capable of providing the wished type of advice. It is also necessary to consider how and when strategic advice moves into tactical advice, i.e. in what precise advisory context are the IEEFMs supposed to develop and be used? Adequate governance structures under which relevant stakeholders and model developer experts are involved and can work together in implementing the IEEFMs (e.g. a top-down process) are also key to success. It is important to involve model developers and advanced users with cross disciplinary expertise covering biological, economic and sociological disciplines to develop, adapt and apply the models for advice, as well as to assure financing. Accordingly, it is important that governance structures are in place for establishing processes that enable stakeholders to participate in management strategy evaluations (see e.g. Fulton et al. 2011; 2014). However, even if one has the institutional set-up and governance structures in place that is still insufficient, it is also necessary to have (1) a mandate support by enabling legislation (e.g. Australia's Environment Protection and Biodiversity Act, which requires export and federally managed fisheries demonstrate they are ecologically sustainable), and (2) common trust in the structures. It seems necessary to institutiona-

lize stakeholders in management and advice – involving them with respect to models and data used, and definition of needs.

In US there have in some instances been problems with insufficient trust in those structures, at least in some regions. The missing ingredient is typically the lack of trust between stakeholders; in this case integrated models will not evolve and not be used. It takes a long time to build up trust in the management structures and between the user groups in order to cooperate on IEEFM approaches. It needs to be considered how such trust is built up in advance (participatory, regional, national, regional). In some cases there has been mistrust in relation to science, in other cases it has been mistrust between user groups. Furthermore, it seems necessary for formulate specific requests and take initiatives to establishment of such structures. Consequently, leadership, trust and control are necessary. Future research can aim at answering the question about whether a bottom-up approach is adequate or whether a top-down approach is needed. In many instances the latter seems necessary because it will demand broader political decisions, choice of influence of each stakeholder, and extensive economic resources to establish and run such systems, and the structures need to be given formal legal and political decision power which likely will demand change of existing legislation. In this process also potential property rights need to be considered as well economic and sociological incentives in relation to management.

Involvement of stakeholders and establishing suitable advisory and management structures to enhance implementation of IEEFMs may be particularly challenging in the EU which consists of a variety of member countries bound together with several supra-national institutions (Marchal et al. 2016). There are some very important characteristics of and differences between the Australian, US, New Zealand, Canadian, Icelandic and European management systems which according to the

previous described pre-requisites very much determines the extent of the IEEFM implementation into the management and advisory processes, as well as which parties/stakeholders are involved herein. With respect to the fisheries management and advice processes then the Australian, New Zealand, US, Canadian and Icelandic systems are characterized as being systems under sovereign governments governed by 1 minister. The scientific management advice in the EU and Iceland for conservation and utilization of the resources is mainly conducted by scientists using IEEFMs for providing advice while advice and according use of IEEFMs is provided by scientists and stakeholders in cooperation in Australia, US, Canada and New Zealand using IEEFMs in an interactive and integrative way for providing common agreed advice and management. The informal consultations in decision making in EU and Iceland, while there are mandatory and formalized consultations with stakeholders both in scientific advice and decision making in Australia, US and New Zealand (Marchal et al. 2016).

Decisions about fisheries is in Iceland taken by Ministry of Fisheries and Agriculture based on advice from the national research institute, in New Zealand by the Minister for Primary Industries, and in Australia and the US the management is shared between the Federal Government and State Governments based on regional management and advisory bodies directly involving stakeholders such as regional resource assessment groups and management advisory committees, i.e. here there are several types of advice and research providers involved (Marchal et al. 2016). Similar to the management process, the scientific advisory process is mainly central and supra-national based in the EU as provided by primarily ICES (North-East Atlantic) or GCFM (Mediterranean) or the Scientific and Technical Committee for Fisheries (EU STECF) according to fish stocks and not decentralized into management regions or eco-regions. For Australia, US, New Zealand and Iceland there are cost recovery of stakeholder participation in the advisory (and management) process,

while in EU there are no or only very limited EU wide cost recovery for stakeholder participation in scientific advice.

Even though the EU does not formally involve stakeholders in the advisory process, progress has been made through the Advisory Councils (ACs), previously known as Regional Advisory Councils, consisting of stakeholders. However, scientists are not direct members here, but can be invited. The very limited involvement of scientists in those councils accordingly also limits the implementation and use of IEEFMs in the advice provision by those regional advice councils. In a review on implementation of ecosystem models Hyder et al. (2015) conclude that it is necessary to establish a stronger link to social and economic systems to increase the range of policy-related questions that the models can address, and it is also important to improve communication between policy and modelling communities so there is a shared understanding of the strengths and limitations in the use of ecosystem models.

For every proposal of a new EU fisheries regulation the European Commission is required to provide an assessment of ecological, economic and social impacts of the regulation. Over the last decade several impact assessments have been undertaken applying the available bio-economic models. Especially in EU research projects the models for this have been further developed and implemented to be able to provide the necessary tools for the assessments For example, the EU-FP7-VECTORS project implemented the FISHRENT/SIMFISH model in the North Sea and the Atlantis model in the North Sea and Baltic Sea (e.g. Simons et al. 2014a; 2014b; Bartelings et al. 2015; Palacz et al. 2016). In the FP 7 project SOCIOEC also several of the here included bio-economic models were applied to assess impacts of a wide range of management measures, especially the instruments in the new basic regulation of the CFP (Regulation EU No 1380/2013).

144 The landing obligation as an important new EU management approach has been assessed by
145 FISHRENT in the North Sea saithe fishery (Simons et al. 2015a) and the North Sea mixed demersal
146 fisheries (Andersen et al. 2014). Another instrument was spatial explicit fisheries management
147 including area closures according to e.g. NATURA 2000 areas and windmill farm implementations
148 with an application of e.g. the DISPLACE model (Bastardie et al. 2014; 2015a; 2015b). Here, also
149 more broad cross sector technical interactions and marine spatial planning was considered. Other
150 fishing closures was evaluated in the same project in the North Sea with the SIMFISH model
151 (Bartelings et al. 2015) or FISHRENT (Simons et al. 2015b) models. Under the EU-FP7-MYFISH
152 project the MSY approach has been evaluated by several methods including FCUBE in the North
153 Sea (Ulrich et al. 2016) and DISPLACE in the Baltic Sea (Bastardie et al. 2016). EU STECF has
154 applied bio-economic models to assess possible impacts of multi annual management plans, e.g.
155 SIMFISH or FCUBE for North Sea mixed demersal fisheries (EU STECF 2015b,c). For the Bay of
156 Biscay the IAM and FLBEIA have been used (EU STECF 2015a). The latter was also used for the
157 case of the Atlantic Iberian waters, Bay of Biscay and Celtic Sea (EU STECF 2015a). On basis of
158 the assessments, the results have been included in the impact assessment for the discussion of the
159 proposed new multi-annual management plan within the European Parliament and European
160 Council.
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162 *Conclusion*
163 More research and workshops are needed to identify and explore the processes that lead to an
164 integrated modeling approach and enhanced use and implementation of IEEFMs in fisheries
165 management advice including worldwide comparative case studies. Such research also needs to
166 involve stakeholders. We should explore further evaluation methods for comparing IEEFMs and
167 identify better ways of communicating the advice that can be generated from these models.

Even though stakeholder involvement is important for effective use of IEEFMs then it is not a necessary pre-condition for implementation. Stakeholder involvement can be useful both for getting better uptake and implementation but also to improve modeling, e.g. stakeholders can help modelers identify the questions of interest and perhaps some understanding of the fishery system. It has been explained why stakeholder involvement in Europe is more difficult than in other parts of the world. However, several modeling efforts in Europe have been at least somewhat successful in respect of they have been used in the policy process. If the models do not get into the more formal advice process the models are not likely to have much impact.