MareFrame

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Deliverable 6.2

A decision support toolbox for EAFM

01/06/2015

(rev 25/11/2015)

Preamble

This is a revised delivery in which the issues addressed in the interim project review have been considered.

The nature of this deliverable is a journal manuscript, and the title of the deliverable is misleading, and does not match the original deadline. The deadline was M12 which is long before the decision support toolbox would be finished. The only journal manuscript it would have been possible to write on this issue by M12 would have been one outlining plans and underlying concept; there would have been no details on actual design and functionality, and no sample runs. This would have been an unsatisfactory publication and difficult to get accepted, but to wait until the very end of the project to publish on the decision support toolbox would obviously not be in line with the intention of the DOW. A compromise is to produce the paper after the toolbox (D6.3) has been completed, but before we have all the sample runs for the specific cases (these would constitute separate, case-specific publications). D6.3 has revised deadline M25, so the revised deadline for D6.2 should be M30 (time for writing, submitting, and getting response). This is in line with the recommendation in the review report "Such deliverables should not be accepted at this stage but be re-scheduled at a later stage of the project".

Executive Summary

Deliverable 6.2 is a journal manuscript with a working title „A decision support toolbox for EAFM". It is an output from Subtask 6.2: Develop decision support tools (DST). The manuscript describes the rationale and context of the DSF interface which is computerized in MareFrame (D6.3). At the same time, we define the process which is designed to achieve structured decision making support in fisheries management pursuing improved appreciation for the ecosystem components. The decision support workshops in MareFrame will provide the basis for selecting a preferred choice, which will subsequently be improved through sustained co-creation, and which will comprise the starting point for the development of management proposals for each case study.

For each case study, the *DSF interface* integrates information from the ecosystem models (Ecopath with Ecosim, Gadget, and/or Atlantis) with Multi-Criteria Analysis (MCA) and Bayesian Influence Diagram (BID) decision tools into a common framework. We discuss the merits of these two approaches in the decision support. What they have pivotally in common is synthesis of facts (outputs from ecosystem models) with values perceived by the stakeholders under alternative management scenarios. The management scenarios are defined in other parts of the MareFrame project through a cooperative process to represent candidate approaches addressing the identified case study problems. The identified stakeholder objectives and concerns form the starting point for creating the management scenarios. In the *DSF interface* the user evaluates the relative merits of the alternative management scenarios in terms of a set of key indicators. The user does so through defining utility functions and by adjusting the relative importance (i.e. weights) between the different attributes. The *DSF interface* also visualizes the likely impacts for the set of alternative management scenarios and, thus, enables the user to explore the consequences of the choices.

The *DSF interface* is primarily intended as a tool to be used in facilitated decision support workshops (see Milestone 16), but may also be used online by individuals. Individual choices may be recorded, enabling a transparent basis for comparison and collective decision-making.

At the time of writing, a prototype of the *DSF interface* is working and accessible via the internet, but many of the planned functionalities are yet to be implemented. The *DSF interface* is expected to be completed and in full operation by the end of 2015. D6.2 will be finalized and submitted to journal soon after the DSF interface, which D6.2 is describing, has been completed.

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CONTENTS

Abstract 6

1. Introduction 7

2. Decision support process 8
   Identifying the indicators 11
   Acquiring "the facts" 13
   Socioeconomic forecasts make a specific challenge 16
   Elicitation of knowledge 17
   Decision alternatives 18
   Values 20
   Analysis 21
   Communication 21

3. MareFrame Decision support toolbox 22
   Visualization 24
   Bayesian Influence Diagrams (BID) 25
   Multi-criteria analysis 28

4. Conclusions 30

5. References 33

6. Appendix. Food for thought 35

Abstract

Multiannual management plans are a central instrument in a transition towards an ecosystem approach to fisheries in Europe. The development of plans is complex due the difficulties and uncertainties involved in model representation and forecasting key aspects of ecosystems and because many commercial and non-commercial stakes are potentially affected by a given management approach. This work describes decision support tools in support of for developing management plan proposals through collaboration between stakeholders and researchers. This approach entails collaborative problem identification and development of alternative management approaches. The estimated impacts and relative advantages and drawback of alternative scenarios are made accessible through a computerized interface that links scenario information with decision support methods. This enables a structured and transparent collective evaluation and of alternative approaches, which in turn form the starting point for developing a proposal for a management plan.

The goal of any decision support process related EAF aims to achieve the best fulfilment of societal objectives. DSF interface provides a toolbox for structuring decision support process. The main benefits are linked to setting the objectives and developing measurable indicators to evaluate the extent which the alternative management choices fulfil the objectives. In addition, DSF interface is forcing the engaged participants to explicitly consider what they are interested about in the fishery, environment and society. The identified knowledge gaps will highlight the needs to improve the ecosystem models which are applied to forecast the consequences from choosing among the alternative management scenarios. The decision support framework (DSF) is by itself a planning instrument guiding the resource for scoping and clarifying the planning context in the ecosystem approach to fisheries (EAF) type problems, and for compiling and making relevant information available. Conclusions can be drawn after DSF interface has been tested with stakeholders in the test of prototype I at the end of 2015.

1. Introduction

European countries have committed themselves to pursue a transition from fisheries management to an ecosystem approach to fisheries (Jennings and Rice, 2011). The overarching objective is to achieve healthy and productive seas through an integrated approach. Within the European Union, this commitment is reflected in high-level policies and co-existing policies such as the Marine Strategy Framework Directive (MSFD 2008), the reformed Common Fisheries Policy (CEC, 2013) and the Integrated Maritime Policy (CEC 2008). The commitment involves significant change from the existing fisheries management system in at least three respects. First, it involves a broadening of the policy scope from a sector-based approach to a cross-sectorial approach. Second, it expands focus from commercial fish stocks to include ecosystem considerations. Third, it is aligned with ideas of shifting from centralized and top-down decision making to an approach that is more responsive to regional concerns and differences (Symes, 2012) and that accommodates participation of stakeholders in processes of knowledge production, planning, and implementation (CEC 2001).

The 2002 reform of the Common Fisheries Policy represented a milestone with regard to stakeholder involvement as it instituted Regional Advisory Councils. The Advisory Councils (ACs) are broad-based stakeholder arenas, with representatives from a range of commercial and environmental interest groups, although fisheries interests in practice tend to be better represented or even dominate over other interests (Khalilian et. al 2010). The ACs are generally regarded a successful as an instrument to enhance stakeholder involvement, and that they have gained increasing influence over time (Long 2009). However, their role in the management process formally remains consultative, and they have not been granted a formal role within decision making and implementation processes.

Although ambitious in terms of its final goals, the ecosystem orientation in Europe is evolutionary in character as it seeks to move towards long term goals through incremental steps with a departure from the existing management arrangements. The legal framework for planning and decision making is not expected to change within the next decade, i.e. the time frame of the newly reformed CFP (ref. workshop). This means that the scope for moving towards an ecosystem approach through devolution of decision making to a regional level will be limited within the next decade (van Leuwen et. al 2014).

Seen from a fisheries management perspective, this implies incremental change from centralized single stock management to mixed fisheries management and then moving on towards a management approach that addresses fisheries and ecosystem concerns in an integrated way, while increasingly accommodating stakeholders into knowledge and views into the planning processes. The revised CFP (CEC 2013: 3) identifies multiannual plans as key instruments in this transition:

"Multiannual plans should, where possible, cover multiple stocks where those stocks are jointly exploited. The multiannual plans should establish the framework for the sustainable exploitation of stocks and marine ecosystems concerned, defining clear time-frames and safeguard mechanisms for unforeseen developments. Multiannual plans should also be governed by clearly defined management objectives in order to contribute to the sustainable exploitation of the stocks and to the protection of the marine ecosystems concerned".

Importantly, the CFP states that even that the plans must be formally adopted centrally through co-decision of the European Council and the European Parliament, they can be proposed by other actors. The CFP states that plans should be adopted in consultation with Advisory Councils, operators in the fishing industry, scientists and other stakeholders (CEC 2013: 3).

In a CFP context, there are examples of single stock management plans that have been developed in cooperation between stakeholders and researchers and which subsequently have been formalized and adopted by centralized European authorities (Hegland and Wilson 2009, Coers et al. 2012). Other proposals of that kind have been submitted, but a decision on whether they can be adopted has not yet been made, mainly because difficulties with resolving details of the decision-making process.

2. Decision support process

There is a need for a recognition that fisheries management is a matter of balance, not conflict: "Take no fish this year and you do not have a fishery. Take too many this year and you will soon not have a fishery. Take an intermediate amount and you have the basis for lasting prosperity, balancing the taking with the leaving." The attempts of governments to address the problems of 20th Century offshore fisheries, however, proceeded through top-down, command-and-control approaches, creating conflict where there should have been support. The MareFrame Decision Support Framework (DSF) is a pragmatic planning process that aims at facilitating a transition towards Ecosystem Approach to Fisheries Management (EAFM). For each case study, the DSF focuses on developing a management proposal that addresses fisheries and ecosystem concerns through a co-creation process. This involves collaboration between stakeholders and project researchers about problem definition, and the evaluation of a preferred management approach. The whole process promotes decision support to make an informed choice between the alternative management scenarios. Pivotally, computerized tools will aid in making a logical choice between the alternatives, based on the explicitly stated objectives, the expected consequences of the alternatives, and the stakeholder preferences.

The DSF involves several iterative steps: a) Formulation of case specific management problems and identifying the stakeholders, b) Cooperative formulation of a limited number of scenarios representing competing management approaches, c) Quantitative evaluation of likely impacts of each approach/scenario, d) Guided User Interface (GUI) based decision support for presenting and evaluating scenarios while eliciting relative priorities, and e) Selection and adaptation of favoured approach as basis for management plan proposal (Fig. 1). Complexity of decision space needs to be reduced by useful approach. Importantly, the process should be started by exploring what we (stakeholders, interest groups, society) want, i.e. the key values and objectives. Only after figuring that out, alternative ways reaching the objectives should be discovered (Gregory et al. 2012).

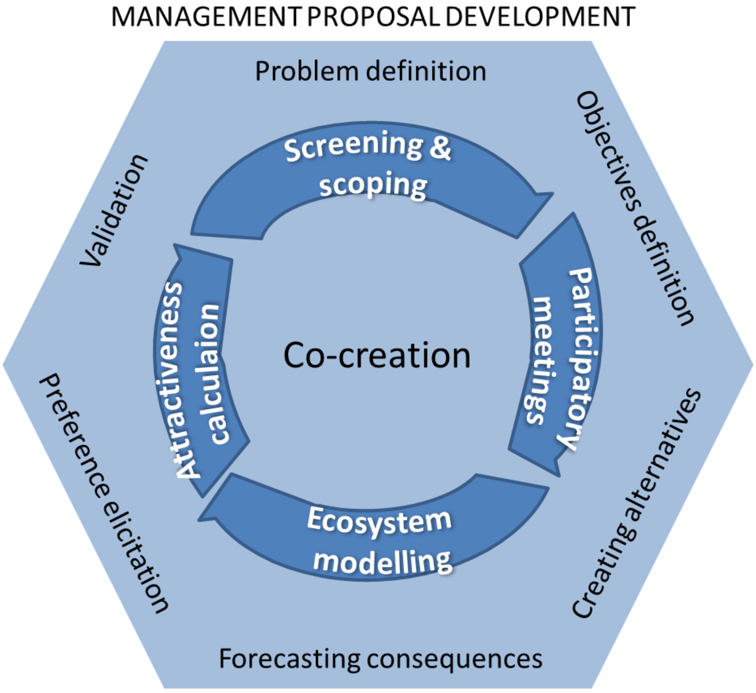

Figure 1. Workflow in co-creation aiming at informed decisions supporting development of management proposals. Co-creation highlights the unceasing communication and cooperation. The inner circle (in blue) describes the four stages of a looping process. The process is iterative with sustained feedback, and the boundaries of the stages are not clear-cut. The order of execution may vary among the loops within a case, and among cases. The grey hexagon represents the specified tasks in the decision-making context that is leading towards the prioritization stage. MareFrame DSFGUI (toolbox) assists in reaching a structured approach to complete the tasks on the hexagon. The available tools are Multi-Criteria Analysis (MCA) and Bayesian Influence Diagrams (BID). They link the management objectives/concerns with the ecosystem models, used to forecast the consequences of management choices on the interest variables (things that matter), take stakeholder preferences and values as inputs, and finally calculate the attractiveness of the decision alternatives. Screening & scoping refers to identifying the concerned groups, setting the rules of engagement, and framing the problem. Participatory meetings highlight the sustained dialogue with all the stakeholders through co-creation during the whole process in developing management proposals. The stakeholder objectives and concerns are discussed and agreed, as well as performance criteria to measure effectiveness of the management alternatives in reaching the objectives (or in avoiding the concerns). Ecosystem models refers to the models used in the project: EwE, Gadget, Atlantis, Pope's model, and others. Attractiveness calculation stage merges outputs from the ecosystem models utilizing all the available data, weights and value functions obtained from the stakeholders, and the objectives and decision alternatives in a mathematically rigorous manner.

In the beginning of the decision support process, it is necessary to recognize the management problem which can be defined as unhappiness for the present situation due to perceived suboptimal performance of the management scheme or conflicts among the stakeholders. Defining and involving stakeholders is critical, because at this stage it is decided whose concerns are considered and whose are not. Stakeholders can be anyone who is influenced by or can influence the decision and decision process. In stakeholder analysis often distinction is made between the most relevant stakeholders and less relevant stakeholders, which can depend on to what extent these stakeholders can influence or are influenced by the decision. Stakeholders can be managers, politicians, NGOs (representatives), but also scientist can be stakeholders. For a comprehensive overview of stakeholder involvement in environmental policies see Reed (2012). Dugan et al. (2013) developed a stakeholder analysis for fisheries management models, so that modellers can improve the design of interfaces and thus improve the communication with stakeholders.

FAO (2015) provides a web based toolbox[4] for EAF. The toolbox contains pragmatic guidelines for e.g. initiation of decision support process and planning stakeholder support, and identifying the assets and their priorities. One of the key issues is to create adequate situational awareness including jurisdictional (laws and directives) and institutional context of the process, by considering the local, regional, and international dimensions. A number of relevant questions should be made: are all impacted groups involved in decision making process and whose mandate are the participators using? After that, stakeholder interests and concerns can be elaborated. There may be unresolved current issues and new emerging ones. Dynamics of participatory modelling are not within the scope of this paper.

A decision support process that increases stakeholder participation would align better with EAFM than a process which does not enable stakeholder participation (Espinoza-Tenorio et al. 2011). Different ways of stakeholder involvement are possible, depending on the aim of the DSS, the issue at hand (is stakeholder involvement wanted or not), financial resources and time available (Röckmann et al. 2012, Fulton et al. 2015). Participatory modelling can have different purposes compared to decision support, such as enabling learning, building (common) understanding the system, increasing stakeholder interactions, evaluating management strategies and inclusion of local knowledge (Bots & Daalen 2008, Röckmann et al. 2012).

Stakeholder knowledge is increasingly identified as an important component in successful fisheries management (Garcia and Charles 2007, Smith et al. 1999, Haapasaari et al. 2007, Röckmann et al. 2012). Fishery science is notorious in assessment and management failures which have led in collapse in both fish stocks and fisheries communities. They have called upon self-criticism and improved science and management approaches (Stephenson & Lane 1998). Fisheries experiences certainly provide lessons to be sighted in the environmental management in general. In fisheries, participatory modelling, consensus seeking, and building trust among the stakeholders have been found to be corner stones of better implementation and improved outcome of management (Haapasaari et al. 2012).

National (Iceland, UK, Sweden, Italy, Romania etc.) and regional governments (e.g. EU, US Federal government, etc.) are the only institutions that can balance the interest of resource users (fishers) and the common public. This is the very essence of fisheries management institutions. At its best, these institutions would be populated by people with a long-term perspective i.e. professional managers, and not only politicians with an election background. And also in an ideal case, science, the industry, other stakeholders (NGOs like WWF or Greenpeace) and the management institution would cooperate in a transparent process to achieve societal consensus on what, how and how much to fish. Therefore stakeholder participation has to be more formalized into the management process, the RCA within the EU CFP are a first step in this direction.

[4] http://www.fao.org/fishery/eaf-net/en

Next we describe conceptualization of the decision, elicitation of the facts, and stakeholder preferences and values.

Identifying the indicators

After stakeholders have reached shared understanding and common agreement about the management objectives in the preceding stages in the participatory process, it will become necessary to define descriptors which can be used to measure the degree to which the objectives will be met under the alternative management scenarios. Indicators combine both tactical and strategic management aspects into a single strategy that supports the rational decision making.

Formulating the indicators requires simultaneous consideration of the objectives and the variables that the applied models are capable to estimate. These indicators operationalize objectives and should have at least preferred direction of change (positive or negative) or a target level defined. They can also indicate constraints on value ranges, indicate how to avoid the indentified risks, and appreciate the risk attitudes of the stakeholders.

A management proposal for a case study should be evaluated in relation to a set of objectives and criteria (Table 1). Some criteria are derived from the main polices that apply to the case study (the CFP and the MSFD). For instance, the CFP requires that the spawning stock biomass (SSB) of any commercial fish stock should be at or above the level consistent with a Maximum Sustainable Yield (MSY) no later than the year 2020.

Table 1. An example for operationalization of objectives of a management plan proposal.

Objectives for the management plan proposal	Candidate operational objectives and indicators
Recovery of the cod stock	• Cod SSB ≥ 22.000 t (Bpa[5]) by the end of the planning period
Recovery of the whiting stock	• Whiting SSB ≥ = 22 000 t (Bpa) by the end of planning period
Ensure strong economic performance of demersal fisheries	• An optimum combination of Multispecies Maximum Economic Yields of key demersal species is suggested

[5] Bpa is the precautionary spawning stock biomass level defined by ICES. The risk of impaired recruitment is estimated to be low when the SSB is above Bpa.

	• An optimum balance between shrimp and whitefish is suggested
Healthy commercial fish stocks	• All commercial stocks ≥ Blim[6] by end of planning period • All commercial stocks ≤ Flim by end of planning period • At least 75% commercial stocks ≥ SBB MSY or: • 95% commercial stocks ≥ SSB MMSY (if defined) by end of planning period
Maintain foodweb integrity	• The Large Fish Indicator (relative weight of large fish in catches) > 0,4 by end of planning period • Mean trophic level ≥ value in starting year by end of planning period

Desirable properties for indicators (based on ICES 2005, and Rice and Rochet, 2005) includethe following properties:

- Concrete: directly observable and measurable rather than abstract or only estimated indirectly
- Theoretical based: reflect features of ecosystems and human impact relevant to objectives and be based on well-defined and validated theoretical links
- Consistently understood: public understanding and technical meaning should be consistent
- Cost: cost-effective given limited monitoring resources
- Measurable: measurable using existing instruments, monitoring programmes and analytical tools, available on spatial and temporal scales needed for management, have minimum or known bias and the signal should be distinguishable from noise
- Context: supported by existing or time-series of data to aid interpretation of
- trends and to allow a realistic setting of objectives
- Sensitive: sensitive to changes in the state, pressure or response it is intended to measure
- Responsive: provide rapid and reliable feedback on the consequences of management actions
- Specific: respond to the properties intended to be measured rather than to other
- factors and/or it should be possible to disentangle the other effects from the observed response

[6] B_{lim} is the critical spawning stock biomass reference point defined by ICES. The stock is estimated to be at risk of suffering from impaired recruitment when the SSB is below B_{lim}.

Acquiring "the facts"

As Nobel Laureate Steven Chu has put it, everyone has right for opinions of his own, but not for the facts of his own.

Environmental decision support should use the best available scientific knowledge to help decision makers to evaluate consequences of management choices. In MareFrame, a number of ecosystem models are applied to evaluate how the alternative management choices will fulfil to objectives which relate to the biological fishery system and the causal linkages. Societal preferences have to be described and elicited by participatory engagement.

Theory behind ecosystem-based management (EBM) and ecosystem-based fisheries management (EBFM) is now well developed. However, the implementation of EBFM exemplified by fisheries management in Europe is still largely based on single-species assessments and ignores the wider ecosystem context and impact. The reason for the lack or slow implementation of EBM and specifically EBFM is a lack of a coherent strategy. Such a strategy is offered by recently developed integrated ecosystem assessments (IEAs), a formal synthesis tool to quantitatively analyse information on relevant natural and socio-economic factors, in relation to specified management objectives. Here, we focus on implementing the IEA approach for Baltic Sea fish stocks (Möllmann et al. 2014).

With regard to DSS for fisheries management, (Plaganyi et al. 2014)distinguish three levels of complexity in models, namely end-to-end models, Models of Intermediate Complexity for Ecosystem Assessment (MICE) and single stock or single species models. End-to end models and MICE are often used for conceptual or strategic purposes, while single species stock models are often used for tactical purposes. However, MICE do have the potential to be used for tactical decision-making, as these type of models are more focused than end-to-end models (Plaganyi et al. 2014)

A valid question is then, which model types and model uses fit the EAFM. Espinoza-Tenorio et al. (2011) analysed to what extend models with different complexity fit EAFM based on the five main EAFM goals. The five main EAFM goals the authors identified are: society participation; the understanding of ecosystem dynamics; take into account the spatio-temporal variability of ecosystems; conservation and use should be balanced; and integrated management. These five goals are closely related to the three main characteristics described in the previous section (stakeholder involvement, multiple drivers and pressures, ecosystem as geographical notion).

Distrust of the numbers generated by fisheries scientists, and perceptions built around the variability of local fish availability (which hides trends from anyone who does not have access to statistical analyses), is a paradox in the fisheries knowledge creation. If combined with ignoring socie-economic aspects in the fisheries assessments, they make a paramount problem influencing implementation of management advice. Only by increasing transparency of the assessment conclusions and scientists admitting that any fair critique will initiate an evaluation of robustness of the management conclusions, the polarization may decrease. The co-creation approach persues this kind of change in cooperation between the stakeholders and the scientific community.

The perused change requires consideration about how scientific knowledge can be represented and quantified so that it matches to the largest possible extent the stated stakeholder objectives and concerns. Additionally and simultaneously, the alternative management choices, and the variables which the ecosystem deals with in forecasting, are used to provide understanding about the consequences of management decisions. All these elements need to match with each other. The concepts and forecasts about the interest variables need to be visualized to support communication with fishers, managers, authorities, policy makers, and the eNGOs and public. We propose an approach, outlined in environmental decision support literature (Gregory et al. 2012), which is well-structured procedure for transparent environmental knowledge integration based on a clear-cut separation of scientific forecasting and societal valuation. We highlight the aspects of societal valuation separately for MAUT and BID in the successive sections because they consider value functions and utilities in a different way in supporting decisions under risk. Also, uncertainty is treated in differently between MAUT and BID.

Outputs from ecosystem model simulations will be input for decision analysis (Fig. 2). The focal objective of the decision analyses is to compare the modelled consequences of scenarios: which one performs best on a range of criteria, given the utilities and priorities of the stakeholder / decision maker using the decision support tool.

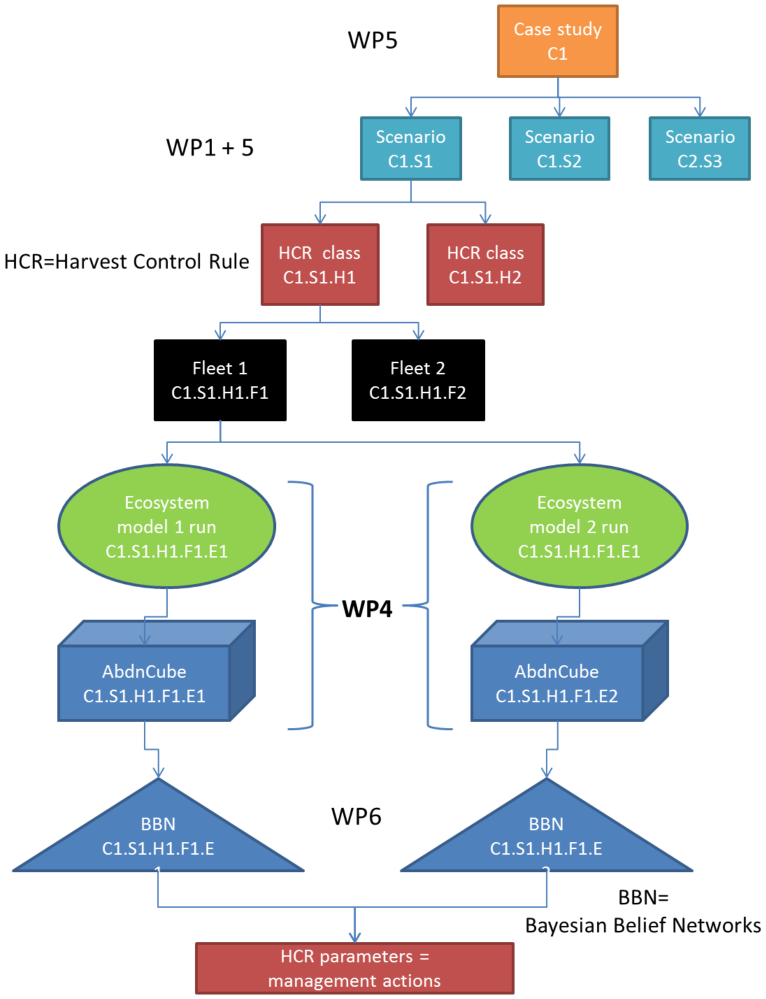

Figure 2. Linking the input and output parameters of the EwE ecosystem model with alternative harvest control rules (HCR) and within a decision support tool (BBN).

The number of foodweb and end-to-end models is growing in number and coverage of the global oceans. While they are an informative means of exploring system dynamics they are not an appropriate risk assessment tool for many applications (such as tactical stock assessments). Nevertheless, experience with such models and other multi-species methods is providing insights into what kinds of ecological idiosyncrasies can undermine the performance of models with static parameters. Environmental drivers, habitat dependencies, critical predator or prey linkages can shape population trajectories by creating bottlenecks at key points in a stock's life history. In addition, shifting environmental regimes and ecosystem status highlight the importance of considering non-stationary parameters – not just for recruitment, but also size and natural mortality rates. Not all of these additional concerns will always be relevant, but it is a simple reminder that good model practice is to periodically revise what are key processes, links and feedbacks that need to be considered for the case in point, to check the assumptions.

Fisheries assessment now normally include uncertainty as an integral part of the modelling approach, but how consistently is uncertainty applied in the many parameters of complex models, or in the structure of the model itself? While there is an intuitive expectation that reducing uncertainty is desirable, how can priorities be set and the value of reducing relevant individual uncertainties be judged? Are uncertainties on ecological and socio-economic parameters treated the same or differently?

It will be difficult to change the structure of the decision model at the workshop. The difficulty comes from the fact that ecosystem model outputs are needed to describe the consequences of management scenarios. As there will be no live link between the DSFGUI and the ecosystem models, it will not be possible to develop these consequences during test of prototype I. Stakeholders should also be informed that there will be an opportunity to adapt it based on user feedback, i.e. when developing prototype II. For instance, "fisheries-induced "evolution can substantially modify the fundamental population-productivity relationships that form the primary population-dynamical basis for fisheries stock assessment projections (Kuparinen et al. 2014). Inclusion or exclusion of these effects will cause model uncertainty in the forecasts.

Socioeconomic forecasts make a specific challenge

The integration of multiple perspectives and stakeholder participation in development of models have become important (Courtney 2001, McIntosh et al. 2011). For use in EAFM, this integration of social aspects is a necessity, as is clear from the EAFM definition and principles. NOAA and some of the regional fisheries science centers do hold meetings and workshops with stakeholders in which they discuss issues related to policy and model uncertainty. In two reports of NOAA, stakeholder involvement in ecosystem modelling is recognized as being of importance and needs improvement with regard to reducing uncertainty and improving model use in the policy process (Lovewell M. A., I. C. Kaplan, Y. deReynier, M. B. Sheer, R. Howell, L. & Wooninck 2012, Link et al. 2010). Identifying production functions (population dynamics) and entry/exit dynamics in resource economics are important for regulation purposes (Hildén et al. 1994). Entry dynamics might imply new fleets which are not participating the current co-creation.

There are emerging reasons to expect issues in forecasting the socioeconomic effects. The ecological system can be modelled as described in the previous section but models which capture the behaviour of the fisheries system are likely to be far more complicated than ecological models. Complexities of human behaviour make attempts to forecast response of industry and fishing vessel skippers futile. Fishermen can shift between fisheries, emigrate to fish new regions of the ocean or even leave the sea to work ashore. Whenever a resource recovers, there are many fishermen and potential fishermen waiting to enter the newly-prosperous fishery.

As for managing loss of fishermen's income, there have seen instances where boat buyback programs have proven to be problematic, with some fishermen getting rid of their older inefficient boats and taking the proceeds to invest in bigger & faster boats to get out to the fish ahead of the others. So there's a game in that regard. Paying fishermen to stay home has been discussed frequently, but when that sort of thing hits the newspapers, many in the general public balk at the public expense. Often the fishermen's lobby groups themselves are mistrusting of government management of the fisheries in general, so they tend to vote for politicians promising to limit the power of the management agencies".

When a minority is pressed hard, it should generally be listened to and not simply be subjected to the dictates of the majority. A lot of citizens would probably change their votes if their primary source of income was under threat. That makes politicians generally responsive to the fishermen's lobby.

Many fishery resources are badly depleted and it will take much more than a year or two of reduced catches to rebuild them. Even if people in the industry are persuaded by the numbers (and there is a huge credibility gap between the fishing industry and fisheries scientists), individuals face massive problems in surviving through long periods of very low fishing effort -- especially when sustaining the high catches of the future means keeping effort down and so cutting capacity below past levels.

Present pain is not welcomed if the future gain will go to other people. There are also serious questions about whether the industry could re-expand after prolonged periods of near-zero fishing. Fisheries have to draw labour (fishermen) from communities with rather unusual characteristics. If fishermen's children find work ashore, fishermen's families get used to having their breadwinners home every evening, boat yards close, waterfront land is developed for hotels, consumers develop a taste for other foods, can a new fishery emerge when resources are finally rebuilt?"

Where resources are currently at levels that can sustain harvests of optimum yield, the interests of the seafood industry and the individuals within it are long-term. Fisheries capital is non-malleable -- fishing boats have little value outside the fishery for which they were built.

Continuity of profession of generations: if a fishery is near long-term stability, everyone within it will be looking decades ahead. Politicians' interests are much shorter-term, not often stretching even as far as the next election. We should be asking why people in the fishing industry press their politicians for short-term responses instead of demanding effective long-term management.

These effects can be evaluated in MCA by defining weights for long-term and short-term objectives.

Elicitation of knowledge

Experts and stakeholders may possess relevant information for decision making. This expert knowledge may improve the reliability of the assessments and forecasts about the consequences of alternative decisions, but also provide completely new information (Yamada et al. 2003) if no published results or primary data are available. In the Bayesian modelling approach, the information obtained from literature, databases and experts is formulated as prior probability distributions that describe the quality of knowledge about the system which can be, e.g., fish stock dynamics, an ecosystem, or fishery dynamics in an ecosystem. Once the alternative model structures and prior distributions for parameters have been specified, the Bayesian approach is to update these beliefs in light of observed assessment data.

O'Hagan et al. (2006) introduce structures of an elicitation process, and Mäntyniemi (2008) provide a five-step revision of them. The first step is the background and preparation work. In this phase the model is designed and the variables that will be elicited are identified. In the second phase the experts are identified and recruited. Suitable experts are willing to be interviewed and lack stake in the findings of the research. The third step is to motivate and train the experts. They are informed of the reasons of the research and of what will be done with the results. This was done in the interview with a presentation of the topic and the method, and by describing the use of the results. The fourth step is the structuring and decomposition, where the final structure of the model is designed and the evidence that the experts will use are reviewed. In this thesis, the experts were only met once, and the fourth step was integrated into step 1, since the model was designed mainly without the help of experts. The final phase in Mäntyniemi's (2008) revision is the elicitation itself. This consists of making the questions, fitting the distribution and checking the results with the expert. In this thesis a feedback mechanism was designed for the experts to be able to check the consistency of their results

Unfortunately, reliability of expert elicitation has been challenged (Yamada et al. 2003, Maddock and Samways 2000).Human estimators may be prone to overconfidence, i.e. giving probabilities that are excessively close to zero (will never happen) or one (will always happen) (Burgman 2005, Morgan and Henrion 1990). The bias is that when experts consider the event improbable, they tend to provide too low estimates (Van der Laag et al. 2002). This may be the situation with unusual cases such as extreme environmental condition or stock collapse. Experts also have tendency to anchor their judgments to initial estimates, especially if they can defer their opinions to people they believe have higher authority (Burgman 2005). In order to diminish these biases, researchers should follow structured guidelines (Kuhnert et al. 2010).

The objective of good expert elicitation is to eradicate connotations and irrationalities, and to structure the process in a way that expert can evaluate their knowledge and experience in a rational manner (O'Hagan et al. 2006).

MareFrame GUI will have capability to perform expert elicitation. In this application, the expert may choose from 3 alternative parametric distributions: normal, log-normal, and beta. They cover basically all types and ranges of probability distributions which may appear necessary in describing beliefs about the EAF-type management issues.

Decision alternatives

The decision choice can only be as good as the best alternative that is considered(Gregory et al. 2012). Good alternatives do not come out of the blue, but they need to be developed in participatory process, which we call co-creation in the context of MareFrame. A specific simple tool rcommended by (Gregory et al. 2012) are strategy tables which are efficienyt in comparing the key features of the alternatives. High quality alternatives also find win-wins and unnecessary trade-offs may be avoided.

The seven MareFrame case studies have different objectives and different sets of alternative management scenarios. Any combination of options is called scenario in this paper. In the literature, they are often referred to as harvest control rules (Fig. 2.). HCRs are an attempt to move away from ad hoc advice to a more rigorous management structure in which objectives such as targets for exploitation and limits to sustainability are formally considered. FAO defines HCRs (also termed decision rules) as pre-agreed specifications for the management actions that will be taken to respond to estimated or perceived states of nature (FAO, 1996).

"HCRs have traditionally been categorized into constant catch, constant fishing proportion, and fixed escapement (e.g. Getz and Haight, 1989; Restrepo and Powers, 1999; Figure 1). However, HCRs need not involve linear functions relating catch to population size. Curves, lines with breakpoints, etc., are also possibilities (Hilborn and Walters, 1992). Strategies based on a target fishing mortality (such as F0.1 or Fmax) are a special case among constant proportion strategies and have been used extensively in some jurisdictions (e.g. Rivard and Maguire, 1993). The properties of these basic strategies and some variants thereof have been investigated (e.g. Quinn et al., 1990), and should be considered when proposing HCRs for evaluation "

"The parameters of a HCR can be adjusted so that the rule aims to achieve implicit or explicit management objectives, such as to maximize yield (e.g. the International Whaling Commission's New Management Procedure; Butterworth and Best, 1994). Threshold management strategies (Quinn et al., 1990) are used extensively as part of the management process for the groundfish fisheries off the west coast of North America. Those HCRs depend on reference points expressed in terms of fractions of unfished spawning biomass and proxies for the fishing mortality at which MSY is achieved."

"Although most conventional HCRs are applied to the results from stock assessments, this need not be the case, and empirical HCRs based on directly measurable quantities have been proposed (Hilborn et al., 2002). The rules used to determine management actions for anchovy (*Engraulis encrasicolus*) and sardine (*Sardinops sagax*) off South Africa (De Oliveira and Butterworth, 2004) and rock lobsters (*Jasus edwardsii*) off New Zealand (Breen et al., 2003) are empirical HCRs; they do not depend directly on the results of stock assessments. However, unlike for conventional approaches to management, it is not possible to determine the values for the parameters of these types of HCR from policy considerations; rather, it is necessary to use the MSE framework for this purpose."

"Empirical HCRs have to be applied in data-poor situations, where no estimates of population size are available. In these cases, the HCR would be a function of indicators of the state of the resource such as commercial catch per unit effort (CPUE), mean fish size, or egg production. However, the performance of such HCRs may be poor if the link between the indicators on which the HCR is based and the state of the resource is weak, with the result that management actions could be triggered either too early or too late (Punt et al., 2001a)."

"Effectively, HCRs almost always form the basis for fisheries management advice, but in many cases (e.g. in the NE Atlantic), the HCR has neither been specified explicitly nor been adopted formally. In Europe, the implicit HCR is to select an annual TAC on the basis of a two-year catch forecast based on the population size one year prior to the fishing season (see (b) above). Previously this rule was associated with a Blim reference point and two trigger points: Bpa and Fpa (ICES, 2006b; Figure 2), and in some cases, the HCR has been supplemented with constraints on year-to-year variation in the resulting TAC to stabilize the catch (Kell et al., 2005a)."

"An additional complication is that, at the decision-maker level, the outcome of a HCR can be critically evaluated and the TAC subject to requests for change when politically sensitive issues are at stake. Moreover, where effort-based tactical approaches are used (e.g. the North Sea cod (*Gadus morhua*) recovery plan, where effort regulations based on reductions in days at sea per vessel and gear category are used to try to reduce fishing mortality on cod; CEC, 2004a), these have not yet formed a component of the HCR. The result is that, in Europe, although it appears that HCRs are used, the reality is that the actual HCRs (i.e. the algorithms) are much more complicated and less well specified and predictable than would be necessary for the technical calculations used by scientists to make population and catch projections."

Values

The purpose of the decision support workshop, where stakeholders engage the participatory process, is to evaluate and get structured feedback on which scenario represents the preferred management approach. The feedback will be discussion based as well as analysis of the information that will be collected through the decision analysis (i.e. relative weighting of priorities of different attributes, etc.). It should be made clear in advance that the workshop is a step in a continuous planning activity, and that there are certain constraints that a management proposal must meet in order to be viable. A proposal for a CFP case study will most likely not be successful if it disregards CFP objectives entirely. In a multispecies context, however, it may not be possible to achieve all (single species) MSYs. In this context, stakeholders and case study researchers may offer their advice on a pragmatic approach that meets stakeholders concerns and interest to the extent possible.

Values, i.e. weights, describe stakeholder preferences. These values can be elicited from individual stakeholders. Alternatively, stakeholders can re-group to groups which have internally about similar preferences. In these sub-groups, consensus seeking discussions will be necessary to formulate a common agreement about the weights. This process is repeated for all levels of a value tree in MCA approach.

However, utility is the key element to describe preferences in BID. The risk analysis relies on the Bayesian decision analysis framework where utility (loss) function plays an important role. How to define utility in these problems is not clear. For example, how to value the different values in the society in terms of utility, and how to specify these in the utility function? Prospect theory (Kahneman & Tversky 1979) provides general guideline to approach benefits and losses. Utility will decrease more rapidly as a function of loss, compared to a similar gain in benefit. In other words, giving a stakeholder what he expects will only be seen as just, earning no political reward, whereas taking away what he wants will be seen as an evil to be punished at the ballot box.

Voss & Tahvonen (2011) provide a specification of stakeholder utility function. In their article, the term [1/(1-h)] formulates the fact that there is a broad aversion against large fluctuations in catches or income between years in the fishing industry. The higher the h, the more a constant income stream over time is preferred. Such a desire for relative constancy is reflected in several management plans for European fish stocks (e.g. Baltic cod; EU Commission, 2007), which have been agreed upon by a broad range of stakeholders, including fishers. For example, the formulation stipulates that TACs shall not change by more than a certain percentage between two subsequent years (15% for Baltic cod). For h = 0, the objective function, Equation (3), was the net present value of resource rents (or net revenues). In their study, results were calculated by applying a slightly non-linear objective function, h = 0.1.

Analysis

(Reichert et al. 2015) argue that a combination of probability theory and scenario planning with multi-attribute utility theory (MAUT) fulfils the key requirements of the decision support approach. MareFrame DSF interface contains both the MAUT and probabilistic (Bayesian Influence Diagram, BID) approaches, and they can be combined to carry a specific stages in the process. The interface puts more emphasis on the decision analysis, and there is no live link to ecosystem models.

We discuss the need for testing "non-standard" value aggregation techniques, the usefulness of flexibility of value functions regarding attribute data availability, the elicitation of value functions for sub-objectives from experts, and the consideration of uncertainty in value and utility elicitation.

- BBN & MCA
- when could/should they be applied
    - The concept of wicked problems relate to the concepts of normal and post-normal science. Earlier, science was based on certain, accepted norms and paradigm, referred to as normal science. In the 90s, this concept of normal science used in policy and management was challenged. The concept of post-normal gained ground, where science is seen in the light of uncertainties and diverging perspectives (Funtowicz & Ravetz, 1994)
- pros/cons/requirements/limitations of these two approaches
- but if stakeholder views of the causal structures differ, how can they all be fairly accommodated in the same model?

Communication

MareFrame DSFGUI visualization technology is being developed by MAPIX currently. A lot of emphasis will be given to visualization of uncertainty (probabilities), as communication it is a challenging task. The likely approach will include "standardised" levels of uncertainty and the probabilities (Table 1 in the minutes of Helsinki workshop). Outputs are related to defined indicator thresholds (such as Blim / Fmsy) when possible. Potential lierature include as well:

- Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties 2010
- https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf
- Communicating scientific uncertainty Fischhoff & Davis 2013
- http://www.pnas.org/content/111/Supplement_4/13664.full.pdf
- Improving Communication of Uncertainty in the Reports of the Intergovernmental Panel on Climate Change Budescu et al. 2009
- http://pss.sagepub.com/content/20/3/299.short
- Recall Pilli-Sihvola & Ollikainen 2014

3. MareFrame Decision support toolbox

A www-based decision support tool with Guided User interface (GUI) aims to remove some of the common slow downs in starting use of computer based solution. These slow downs include installation and running problems of the application. The anticipated key target groups for the MareFrame Decision Support Toolbox include policy makers, managers, and all stakeholders are involved in fisheries management issues potentially benefiting from structured approach in the decision making. They likely have deep insight about the fisheries managament context of the case study but the complexity of the situation may be overwhelming to be solved using common sense only. For instance, the Vismon (Booshehrian 2012) target group are fisheries managers who are highly knowledgeable about the fisheries domain but not experts in simulation software and statistical data analysis.

Decision Support Systems (DSS) were developed out of the need for technological means to help resolve complex problems (McIntosh et al., 2011). The definitions of decision support tools (DST), decision support systems (DSS) and models are not clear cut. We note two main distinctions between a DSS and a computer model. Firstly, a model in itself does not have to support decision-making, but a DSS has it as a clear aim. Secondly, a DSS can be expanded with Decision Support Tools (DST) and become a framework for decision support. Fletcher & Bianchi (2008) and (Mustajoki & Marttunen 2013)) present an extensive list of different DSTs that can be used within the EAFM context.

The concept of DSS originates from management and more specifically in the context of large companies to support decision where one of the phases of the decision-making was either semi-structured or unstructured (McIntosh et al., 2011; Power, 2007). The Carnegie Institute of Technology and Massachusetts Institute of Technology developed the concept of DSS, thus technology plays a central role in DSS and most definitions of DSS contain the words 'computer-based' or 'computer-aided' (Malczewski 1999, Shim et al. 2002, McIntosh et al. 2011, Janssen et al. 2014). The most widespread definition used for DSS is from Gorry and Morton (1971), who define a DSS as "a computer-aided systems that help to deal with decision-making where at least one phase (intelligence, design or choice) was semi- or unstructured".

A notable obstacle highlighted in a previous group work (ICES, 2007a) is that a problem encountered when presenting results from scenarios was that members of the STECF (Scientific, Technical and Economic Committee for Fisheries, a body established by the European Commission; CEC, 1993), who traditionally relied upon reaching consensus about a best model, were unable to agree on the effect of the alternative plans given by different models based upon alternative structures and assumptions. To do so requires weighting the plausibility of the hypotheses, either statistically or based upon expert judgement (ICES, 2007a). Such structural uncertainty in knowledge about fishery systems is important and needs to be incorporated into advice in future. MareFrame DSFGUI allows users to define a model individually using the same initial set of variables but different structure. The final set of variables may differ from the initial set regarding the random and utility variables in the BBN. However, decision alternatives, i.e. management scenarios which are evaluated in the decision support process, have to be identical in each model.

MareFrame Toolbox allows considering structural uncertainty by supporting development of several models (either value trees or influence diagrams) which can be analysed separately. What counts as important is whether the ranking of the decision alternatives will differ among the models. If ranking of the decisions does not depend on the structure of the model, the decision is robust for the structural uncertainty. If ranking changes along the model structure, this is an issue which needs to be considered with the stakeholders.

Environmental covariates that might be driving these changes were in the focus in (Mäntyniemi, et al 2013) and (Haapasaari, et al 2013). They developed a structured interview that was used to elicit the knowledge of stakeholders and experts and encode them into probability statements about external factors that affect the dynamics of a fish stock. However, it turned out that eliciting the structure of the entire assessment model from a set of stakeholder representatives would be a daunting task, and a mixed approach where a ready-made model framework is used as a basis could be more feasible (Mäntyniemi, et al 2013). In this approach the basic components of population dynamics was specified by a small group of researchers, and the model was then presented to a group of stakeholders whose next task was to fill in their beliefs about the external factors driving the dynamics.

Diversities in the stakeholders' model structure indicate differences in the logic of reasoning among them and in the assumed causal structures in the fisheries system, and indicate structural uncertainty as well.

The challenge in allowing using several models is that there will be no live link between the ecosystem models and the DSFGUI. Therefore, it will not be possible to effortlessly develop forecasts for the interest variables under alternative model structures. Using co-creation, this can be done iterative meetings where stakeholders-facilitators-researchers discuss and agree about the model structures that will require reruns of the ecosystem model to produce the estimates describing the consequences of the choices related to the model structure. However, because the ecosystem models applied the MareFrame are genuinely deterministic, the uncertainty estimates needs to be developed by expert judgment if BBN approach is used. This will cause a considerable increase in the effort required to apply BBNs, needs in arranging more meetings, and time lags in the decision support process. The challenge is less articulated when MCA approach is applied as there will be no need to develop the distributions for the estimates but the expected values, derived by the ecosystem models, can be readily applied in the value trees.

The comparison between uncertainty-accounting and deterministic policy indicates that a stochastic uncertainty-accounting policy may perform better over a range of scenarios (Baresel & Destouni 2007).

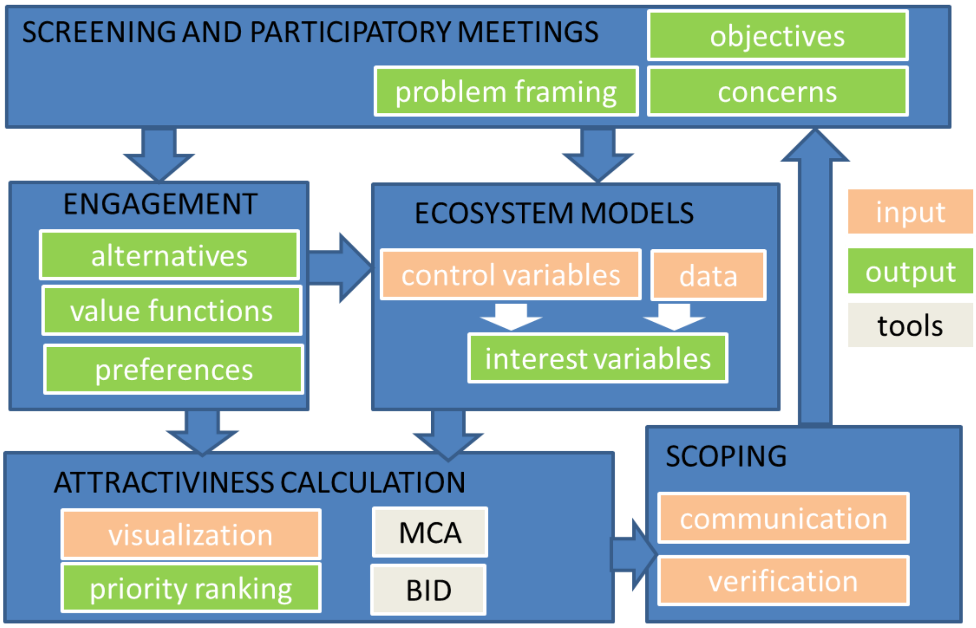

Figure 3. A schematic of the decision support process. The blue boxes are proxies of stages in figure 1. Green colour indicates outputs to the other stages of the process. Orange colour indicates inputs from the other stages of the process. The identified stakeholder objectives and concerns are translated into interest variables which future state are forecasted using the many ecosystem models. The control variables specify the alternatives, i.e. management scenarios which are created jointly by stakeholders, project researchers, and the process facilitators. Grey colour indicates tools which synthesize understanding about the decision problem, forecasts about the consequences, and stakeholder preferences. These preferences are elicited from stakeholders in the participatory meetings. DFSGUI also visualizes the forecasts for the interest variables.

The preferred method for the decision analysis will be Bayesian Belief Net (BBN), but note that this requires that probability distributions can be generated for the interest variables of each scenario. The alternative, and a risk-averse option, is to use multi-criteria analysis (MCA) because applying BBN will require noticeably greater effort by WP4 in carrying out a larger array of simulations, and by WP6 in eliciting expert judgments about uncertainties and applying the decision support method.

Visualization

The tool will include traffic lights approach, AMOEBAs (Collie et al. 2003), visualization of probability to be above certain reference levels, and the possibility to evaluate how variability on selected processes (i.e., recruitment for all CS, but also specific processes more relevant to each CS like growth for Baltic cod, time and extension of migration for Icelandic species, etc.) propagate to other model components.

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Bayesian Influence Diagrams (BID)

Bayesian networks are quantitative modelling tools whose applications in several scientific domains are becoming more popular. It is argued that the capability of representing rather complex, not necessarily causal but uncertain relationships makes Bayesian networks an attractive modelling tool for fisheries management. Furthermore, as data are scare and knowledge is still rather uncertain, the possibility to combine data with expert knowledge and the easy way of updating the model after acquiring more evidence further enhance their feasibility. However, eliciting the probabilities from the experts might be challenging and the model validation can be tricky. Regarding expert elicitation, (Reichert et al. 2015) addresses that in some cases, due to too large ambiguity, scientists may even hesitate to formulate their predictions as imprecise probabilities. Here, it may be useful to combine alternative future scenarios with conditional probabilistic predictions and search for decision alternatives that are robust regarding the scenarios. Bayesian Influence Diagrams have capacity to carry out this kind an approach.

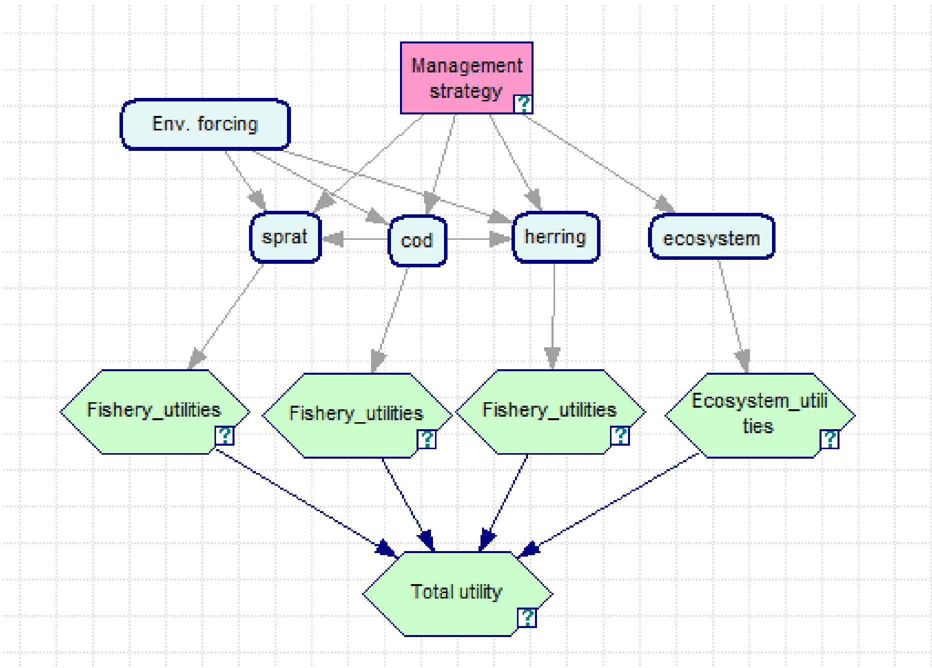
The Bayesian approach is based on subjective knowledge. Thus, a real-world problem structured into a Bayesian model is based on the researcher's interpretation of the existing knowledge related to the problem. The knowledge can originate from new experimental data, the literature, pre-existing models, or statistics. It can also be elicited from scientific or other competent experts. In most cases, ''expert knowledge'' refers to knowledge elicited from a scientific expert, in relation to a model structure or probability distribution, or both. In the subjective terms, the probability is expressed as a degree of belief which means a private assessment of how likely an event is, based on the available evidence (Ramsey 1926 combined probabilities with consequences in decision theory; Spiegelhalter et al. 1993; Gelman et al. 1995; Nau 2001). While formulating subjective probabilities is one of the practical challenges of the Bayesian approach, they make a consistent combination of different types of information possible.

Consideration of uncertainty in preferences is carried out differently in MCA and BID. In MCA, this can be done by sensitivity analysis (Scholten et al. 2014). However, preference uncertainty is not accounted for in "standard" expected utility theory (Reichert et al. 2015).

With the utilization of several data sources, Bayesian updating, dynamic modelling, and hidden nodes for latent variables, Bayesian networks are rather well-suited tools for fisheries management and decision-making."

Using Bayes theorem "too little" data does not pose a serious issue. Expert judgment can substitute data in Bayesian approach when no measured observations are available, or data sets can be complemented with expert judgment to estimate posterior probabilities. Even though expert judgment is subjective and has not been verified empirically, it can be the best available information for many types of analysis because experts may use both published and unpublished information sources and their own reasoning in developing estimates.

Oliveira: "it has taken a long time to improve understanding of the issues that affect the success of environmental management, such as dealing with risk and uncertainty (Hilborn, 1996; Harwood and Stokes, 2003; Jennings, 2004), and such insight should not be wasted. The assumption that solutions are simple, when their consequences are overlooked or untested, has led to many false dawns in environmental management. For example, in cases where the conservation of one species requires management of fisheries by closed areas or gear restrictions, the displacement of effort or the use of new gears may simply mean that the problem is transferred to another species. This was found for North Sea cod, where closed areas imposed as a conservation measure for cod recovery meant that trawling effort was displaced to areas that previously had been relatively undisturbed (CEC, 2007)." We need holistic approach to recognize risks and account for unexpected events and responses. Therefore, there has been a trend towards the use of computer simulation to identify management strategies that can satisfy multiple objectives and that are robust to uncertainty (caused by limits in scientific knowledge and predictions). Probabilistic models have as advantage that they deal with uncertainty and are based on causal relationships that can be represented by causal diagrams that are somewhat easier to understand than the mathematical modelling used for deterministic models (sometimes referred to as 'black box'). Resource use also should aim at risk-averse decisions which is not possible with deterministic approach.



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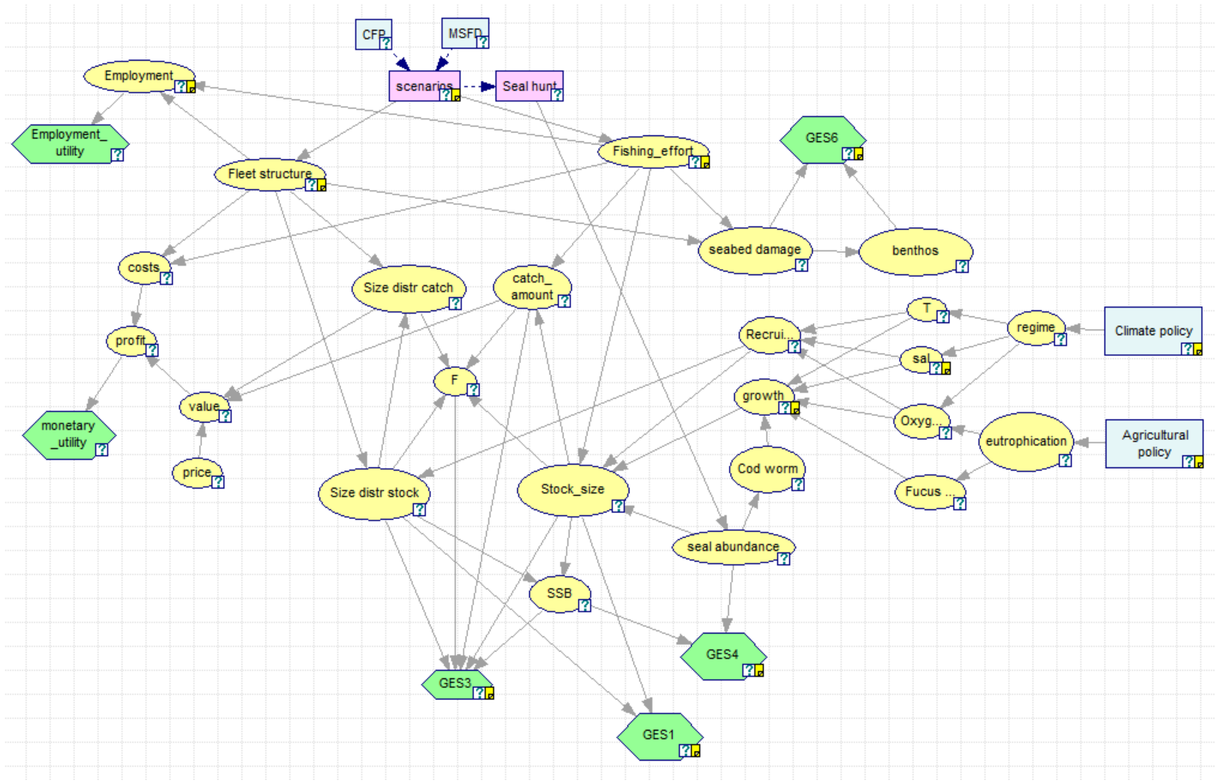

Figure 4. A first draft of the decision support context in the Baltic Sea case study, presented for the stakeholders in the second plenary meeting via a video conference. The top graph describes the preliminary structure of main model where there will be 3 fish species (cod, sprat, herring) having basically a similar stock dynamics assembly. The BID describes the links which the case study leader has identified as important with respect to the management issue. This graph is rather a mind map, not an influence diagram, and will be simplified during the stakeholder discussions. This is also for one fish species only, while there will be 3 species considered in the CS.

The theoretical challenges include risk migration which is implementation of a countermeasure which may negatively affect other parts of the system. Another challenge is long incubation period or errors meaning that factors may lie dormant for a long time before they contribute to an incident. Lastly, limited oversight where any actor in the risk management has only a partial image of the state of the system poses a challenge for risk management.

Bayesian decision theory is profoundly personalistic. It prescribes the decision d that minimizes the expectation of the decision-maker's loss function with respect to that person's opinion. Attempts to extend this paradigm to more than one decision-maker have generally been unsuccessful (Kadane & MacEachern 2014).

The ecosystem models applied in MareFrame are deterministic and, thus, so not provide information about the uncertainty of the estimates. Therefore, their use is not completely sensible with the BID approach. However, there are methods to evaluate uncertainty of deterministic models. They include (Uusitalo et al. 2015):

1. Expert assessment
2. Model sensitivity analysis (Monte Carlo, suited for EwE)

3. Model emulation (statistical approximation of the original simulation model)
4. Temporal or spatial variability in the deterministic models
5. Multiple models (ensemble modelling, approach used extensively by IPCC)
6. Data-based approaches (bootstrapping, applied for GADGET)

Multi-criteria analysis

Multi-Criteria Analysis (MCA) is concerned with structuring and solving decision and planning problems involving multiple criteria (Keeney & Raiffa 1976, Huang et al. 2011). These problems consist of a finite number of alternatives, explicitly known in the beginning of the solution process. In MareFrame, the management scenarios that have been developed in a co-creation process with the stakeholders make the finite set of alternatives. Each of them is evaluated by its performance in multiple criteria. Typically, there does not exist a unique optimal solution for such problems and it is necessary to use decision maker's preferences to differentiate between solutions. The aim of using MCA is finding a set of viable alternatives, rather than pursuing the best alternative for a decision maker. MCA has been applied earlier to support planning of ecosystem based fisheries management[7].

Thus, there are different interpretations to solving the decision problem. It could correspond to choosing the best alternative from a set of available alternatives (where the interpretation of "best" is "the most preferred alternative" of a decision maker). Another interpretation of solving could be to choose a small set of good alternatives, or grouping alternatives into different preference sets.

- robustness
    - small changes in management targets may require large changes in alternative options
    - options probably have different uncertainties

Quantifying the value function of technical attributes is difficult for stakeholders. Therefore, it may be useful to elicit this type of value function from experts. Alternatively, the function can possible be derived based on existing ecological assessment procedures. Technical attributes are typically at the low branches of the MCA hierarchy (i.e. value tree). When relying on expert value functions, it is important to explain and visualize the meaning of these values to allow the stakeholders to formulate their aggregation rules at higher hierarchical levels (Reichert et al. 2015). The stakeholder role is becoming increasingly focal as the trade-offs are being formalized by expressing the preferences in the form of weights at the medium and top levels of the value tree.

The MCA Page contains the following components (Fig. 5):

[7] https://www.liv.ac.uk/mefepo/ (last visited 27.05.2015)

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- The case study name and objective
- A value tree consisting of the following columns:
    - Main objective for the case study
    - Sub-objectives that relate to the main objective
    - Attributes that connect the sub-objectives and each of the management scenarios
    - Management scenarios
- A matrix with rating of each attribute on each management scenario
- A table with weighing of sub-objectives and attributes

Moreover, there is space for a (composite priorities) bar chart showing the user's management scenario preference and a (sensitivity analysis) line chart. These, however, are not visible until the user has entered their weighing.

Clicking on the boxes in the value tree, the user sees a dialog box for that particular box. Clicking on the Main objective box, the user sees a table with the weighing of the sub-objectives.

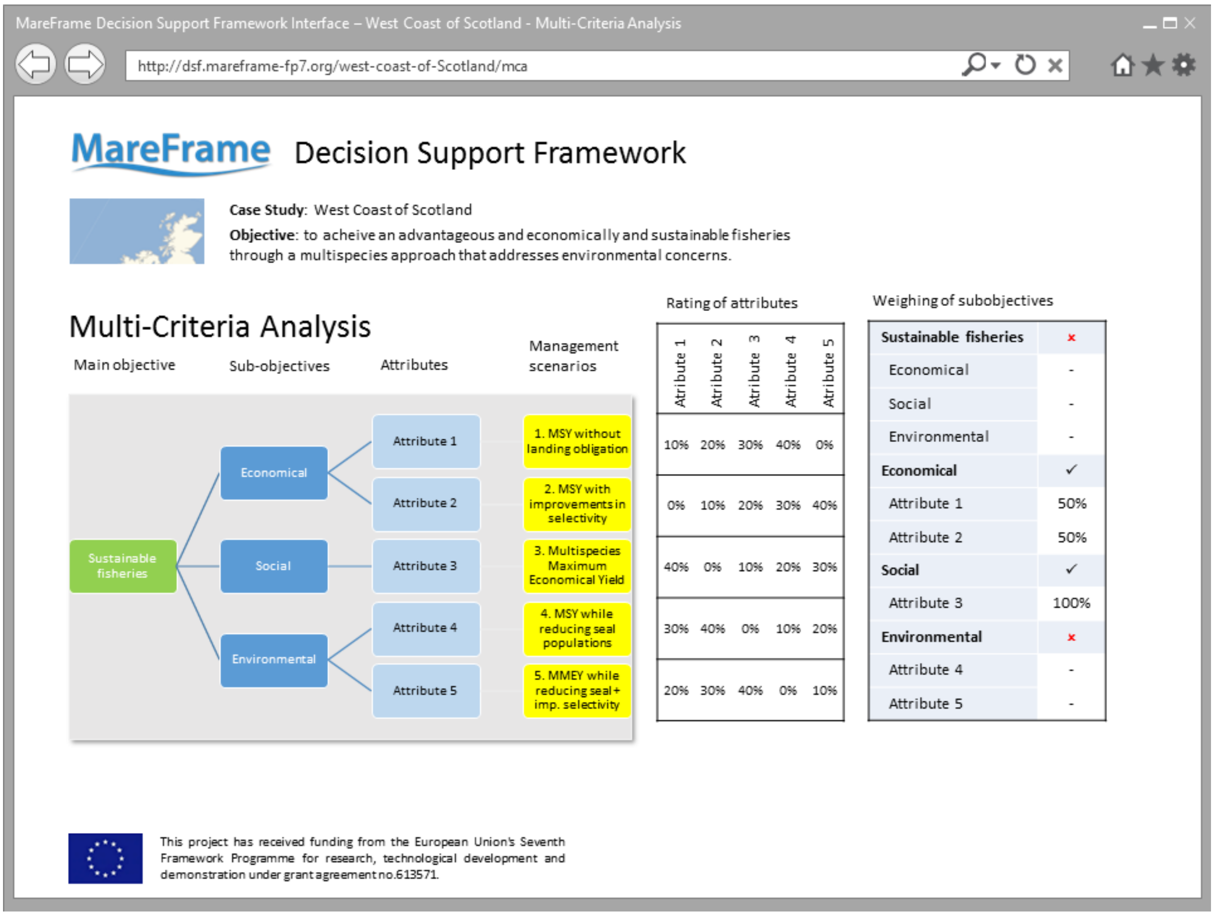

Figure 5. Value tree of Multi-Criteria Analysis Page for the West Coast of Scotland case study.

A menu bar will be used for assigning preferences for different objectives as well as setting other constraints of relevance to the specific region allowing investigation of management measures, and potential consequences of their implementation on economic, ecological and social aspects in the region.

4. Conclusions

Despite the importance of success in modelling the decision issue using either MCA or BID, the key factor in supporting decision making in environmental management is facilitating the dialogue and cooperation between the many stakeholder groups, which have at least partially conflicting interests. This outcome is possible by seeking for openness and transparency in problem framing and knowledge building. The fishermen's lobby can be noisy and active, but might politicians ignoring the fishermen's lobby actually be doing the industry a service in the long run?

Co-creation is dependent on the individuals during the practical face-to-face interaction, but critically on institutions as well. There seem to potential for sub-optimal achievements at both individual and institutional level. Stakeholder exhaustion seems to be a real issue. It has been hard to get them participate the launching events. Stakeholders have also commented that scientists contact them too often and make too many questions. Contacting the stakeholders via ICES could have been more successful than contacting them as a MareFrame partner.

Linked to the previous issue, institutional credibility appears to be very important for the stakeholders. Projects such as MareFrame do not possess that much credibility as established fisheries institutions, ICES being the most prominent one. At least one of the stakeholders mentioned that the assessment and management outputs of MareFrame are not reliable because they are products of a short term project, not ICES products. Mandate for participating the launching event was not adequate or clear to all stakeholders. One of the stakeholders has commented that MareFrame should only deal with decisions influencing biological aspects such as structure, functioning, dynamics and resilience of the ecosystem. According to him, any decisions and analysis influencing trade-offs among the fleets or regions should be transferred to political arena from MareFrame agenda as he felt the involved people do not have mandate to consider socioeconomic issues. His view got support from other stakeholders.

Co-creation is a wonderful concept but it is easy to stumble in pitfalls. When chairman asked stakeholders to suggest some relevant management issues requiring decision support in the Baltic, at least two stakeholders mentioned seal induced problem to fisheries as the number one issue. At this point, our scientists denied this proposal as GADGET nor ECOPATH does not currently include seal population as a component of the model. Instead, scientists proposed a couple of issues they were by themselves interested in analysing with the available model structure, and stakeholders had to adapt to the ideas advised by scientists. Science (model restrictions, researcher interests) may get a dominating position during problem framing, causing reduced motivation for co-creation in the subsequent phases of the project.

There are some potential cures to these issues. For instance, a) using remote meetings limited to 2-3 key players each time to address specific issues. , b) in situ visits to key players (case study leader), c) attend an Advisory Council meeting to present the model, d) evidence that facilitators are open to stakeholders suggestions, and e) ensuring that the CS is linked to stakeholders current agenda (e.g. CFP targets)

Stakeholder fatigue

- how should we increase participation, how to motivate, how to ensure usability of the product after the project's end
- stakeholders spend their valuable time to participate, they expect added value in turn)

Practical issues learnt relate to video conferences. Their pros include saving time and money as no-one has to leave his office to attend a meeting. However, interaction can be difficult via a video link, in particular if some participants are connected via a video link while the others are in a same room. Depending on who is speaking and whether his face is towards the microphone on the table, it can vary from reasonably easy to impossible to hear what people are saying. It may not help to ask them speak louder, as it may help for few seconds only. If participants have not met before, and only some them can be seen on the monitor screen, it may not be not possible to know who is was speaking. For a smaller group meetings VC can be fine, though.

About the case studies: DSF interface has facilited close collaboration with scientists and all the stakeholder groups. Training and educating them to apply the interface has been essential.

Compare pros and cons of MCA and BID: amount of necessary research effort, formulation of utility functions.

How to aggregate multiple utilities? Can MCA be applied in deriving GeNIe MAUTs? They will be additive, though. (Reichert et al. 2015): "More attention should be given to the elicitation of the aggregation scheme, instead of assuming additivity when calculating the degree of fulfilment of an objective based on the degrees of fulfilment of its sub-objectives. Particularly in ecological valuations, the importance of the joint fulfilment of goals regarding complementary aspects of an ecosystem leads to the need for non- additive aggregation (Langhans et al., 2014a)".

We have abandoned the idea to allow the user to explore outcomes outside robust model limits as long as this prompts warnings. That would have been educational and reflect generic constraints with using models. There should have been intelligence developed in GUI to achieve this. This was not realistic?

Although relevant, it might not necessary to worry about the risk that users will set projections outside the boundaries where the model has been evaluated. User can actually learn from that if a system of warnings is developed to detect, map and alert the users if and in which part/component of the model the boundaries are passed. Ultimately, this is a general problem for all ecological models.

The use of data compilation tools perhaps needs to be assisted by scientist. Metadata is important for evaluations and transparency. Updating data sets is problematic in a project environment. Case specific inference requires case specific data. Limits usefulness of VISMON.

EBFM is intended to ensure that the planning, development and management of fisheries will meet social and economic needs without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems ((FAO 2005)Oliveira)). This requires that a wide range of fisheries impacts on ecological, economic and social factors must be considered when setting objectives for fisheries, with consequent requirements for reliable scientific advice and effective management decision-making (Jennings et al., 2002). For example, the EU is implementing long-term plans that consider biological, ecosystem, economic and social objectives through consultation with stakeholders, and MSE will become an increasingly important tool for running "what if" scenarios, so that stakeholders can evaluate the trade-offs among objectives of different management plans. Moreover, the MSE framework has been used in Australia at the level of a whole fishery management plan (accounting for both ecological and economic aspects of the fishery) to assess a broad range of management options for the southern and eastern scalefish and shark fishery (Smith et al., 2007). This application involved initial development of a qualitative MSE, from which a refined set of management options was taken forward into a full quantitative MSE with an operating model that consisted of biophysical, economic and management components (Fulton et al., 2005; Smith et al., 2007).

The principles for decision-making in the European Union (EU) are contained in the Common Fisheries Policy (CFP; CEC, 2006a), and they include setting fishing opportunities annually in order to achieve the sustainable exploitation of living aquatic resources, taking into account economic, environmental and social factors. However, it is recognized that economic and social sustainability depends on biological sustainability, and the European Commission therefore places biological sustainability at the heart of decision-making in fisheries. Objectives are to be met by the progressive implementation of an ecosystem-based approach to fisheries management, incorporating commitments under international agreements, such as those under the WSSD to rebuild fish populations (by 2014 if possible) to levels at which MSY can be taken. The European Commission is therefore currently developing long-term management plans under which both long-term goals and ways to reach them are defined. In this context, MSE is becoming of increasing importance because, although it is frequently assumed that solutions are simple, consequences are often overlooked (Jennings, 2004). MSE allows plans to be evaluated with respect to trade-offs between multiple objectives prior to implementation.

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Renae Tobin at JCU (http://research.jcu.edu.au/stfa/people/staff/dr-renae-tobin-1) wrote her PhD on the relationships between commercial and recreational fisheries in Australia, with some similar issues mentioned with respect to perceptions about tradition and who is responsible for resource depletion etc.

6. Appendix. Food for thought

In Europe there are some case-studies where that sort of conflict and possible solutions were highlighted. http://www.coexistproject.eu/

A conflict between two resources users. Literature about the institutions, property rights and incentives to influence /manage users' behaviour.

Hilborn et al (2005), some important problems between fisheries users and solutions about their conflicts http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1636099/

Ostrom's literature: to understand the institutional framework, at formal and/or informal level, where fishermen and other stakeholders interact.

http://books.google.es/books/about/Governing_the_commons.html?id=4xg6oUobMz4C&redir_esc=y

http://www.krepublishers.com/02-Journals/JHE/JHE-46-0-000-14-Web/JHE-46-2-000-14-Abst-PDF/JHE-46-2-235-14-2448-Proches-C-G/JHE-46-2-235-14-2448-Proches-C-G-Tx[13].pdf

http://www.myfishproject.eu/myfish-regional-studies/myfish-decision-support-tables