M E F E P O

Work Package 5 Report

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Development and selection of operational management strategies to achieve policy objectives

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Table of Contents

Executive summary

Since the reform of the EU Common Fisheries Policy in 2002, effort has been devoted to addressing the governance, scientific, social and economic issues required to introduce an ecosystem approach to fisheries management (EAFM) in Europe. Building upon previous studies, the core concept of the Making the European Fisheries Ecosystem Plan Operational (MEFEPO) project is to deliver operational frameworks (FEPs) for three regional seas: North Sea (NS), North Western Waters (NWW) and South Western Waters (SWW) RAC regions. These regions were selected as they represent a range of challenges in terms of: knowledge; data availability; the number of national interests; spatial extent; and a broad range of physical and biological characteristics.

The aim of this work package (WP5) was to develop operational objectives to achieve the ecological objectives identified in an earlier work package (WP2). A framework was developed that allowed us to combine scientific information based on modelling or expert judgement with stakeholder preferences to examine management scenarios to achieve the ecological objectives based on the current state of understanding of the ecosystem components and social and economic impacts of the proposed management measures.

The framework incorporates the three pillars of sustainability reflecting ecological, social and economic objectives that should be achieved simultaneously. The ecological pillar is made up of four Marine Strategy Framework Directive (MSFD) descriptors which are considered to be affected by fisheries (biodiversity, commercial fish and shellfish, food-web and seafloor integrity). Two descriptors were chosen for the economic pillar (efficiency and stability) and three for the social pillar (community viability, job attractiveness and food security). Each descriptor has at least one indicator.

Decision-making in fisheries management is complex and involves uncertainty, multiple objectives and multiple stakeholders and the application of decision support tools may structure discussions, improve communication among stakeholders and lead to additional insight on possible solutions to the issues. Recent policy documents (e.g. the revised Common Fisheries Policy) emphasize the importance of increased stakeholder participation in the management process; the involvement of fishers is expected to increases the likelihood that management measures will be supported by the fishing industry and thus increase the likelihood of management success. We used informal interviews, a stakeholder workshop and preference questionnaires to gather input and feedback from stakeholder on the framework that had been developed to incorporate ecological, economic and social objectives. We also applied multi-criteria decision analysis (MCDA) in combination with the simple multi-attribute ranking technique (SMART) to use stakeholders’ opinions in a structured and transparent process, and examine how the human component can be incorporated into EAFM.

Stakeholder preferences

At the stakeholder workshop in Dublin, November 2010, we collected data on stakeholders' preferences by asking them to assign weights (between 0-100) and importance (6 being very important; 1 being not important) to the pillars and the descriptors within the developed framework.

- *Weights assigned to pillars*: responses of policy representatives (management authorities) were closest to the overall average for all stakeholders. However, policy representatives assigned less weight to the social pillar compared to the average response, and compared to industry and NGO respondents. It is worth noting that all stakeholder groups assign the lowest weight to the social pillar. Respondents from the industry stakeholder group assigned more weight to economic than ecological interests; NGO respondents assigned the highest weight to the ecological pillar.
- *Weights to descriptors*: Overall, the commercial fish descriptor was given the highest weighting, followed by foodweb, biodiversity and efficiency. The lowest weight was assigned to job attractiveness.
- *Differences between stakeholder groups*: across all stakeholder groups, similar (high) weight was given to commercial fish. Industry assigned relatively high weights to descriptors such as efficiency, commercial fish and stability compared to the other stakeholder groups; low weights were assigned to sea floor integrity, foodweb, biodiversity and job attractiveness. NGO representatives assigned the highest weights to food web and biodiversity, and lower weights to efficiency, stability, community viability and job attractiveness. Both industry and NGOs showed preference for the economic descriptors over the social descriptors (except for food security); policy representatives assigned the highest weights to three of the four ecological descriptors.

Evaluation of management scenarios

Five management scenarios were developed that differed in emphasis in terms of the objectives they are trying to achieve:

- Business as usual (BAU): based on the current management situation, none of the three pillars in the management scenario is given particular emphasis.
- Achieve Good Environmental Status (GES): achieve the minimum ecological requirements for Good Environmental Status (GES).
- Maximum long-term harvest (MSY): emphasis on ability to harvest food from the sea, strong link with the social pillar in terms of contribution to global food supply but to achieve a sustainable harvest of seafood there must be healthy commercial stocks.
- Maximum long-term employment (MEMP): emphasis on the social pillar and resilience of fishing communities.
- Maximum long-term profit (MPRO): focus on economic pillar and economic efficiency.

Simulation models were used to help evaluate management scenarios by examining impacts of proposed management regulations. However, modelling approaches are limited by the quality of the data incorporated, and modelling methods may be precluded due to the absence of appropriate (quantitative or geographic) data.

- ***North Sea (NS)***: a model was developed to calculate the impact of fishing on the North Sea fish community essentially by combining two existing models: one simulating the fish community and the other simulating the removal of fish by different fisheries. Four different management scenarios were examined (BAU, COM, GES, MSY) through the application of different Harvest Control Rules (HCRs). Overall, the MSY scenario performed well (and in many cases best) across the descriptors (ecological, social and economic); BAU was found to be the worst scenario.
- ***North West Waters (NWW)***: the modelling resources for the NWW were not as developed as those for the NS. This model considered the demersal fish community and main demersal fisheries in the on-shelf Celtic Sea, and utilised a multi-metier, multi-species model that simulated the multi-species 'technical interactions' of fishing operations but did not include biological interactions either between species, or between species and their environment. Five management scenarios (BAU, GES, MSY, MEMP, MPRO) were examined. A consistent trend apparent in the results is that all of the management scenarios, apart from the MEMP scenario, lead to improvement in all indicators apart from the employment indicator. Conversely the MEMP scenario only leads to an improvement in the employment indicator.
- ***South West Waters (SWW)***: data limitations prevented the use of the modelling approaches adopted in the NS and NWW, principally due to the absence of data on fisheries and ecosystems. Therefore, expert judgment (MEFEPO project team and literature) was used to predict likely effects of five management scenarios (BAU, MSY, GES, MEMP and MPRO) based on three trawl fisheries: French trawl fishery targeting nephrops; Spanish mixed trawl Fishery; and Portuguese mixed trawl Fishery. MEMP performed badly for all but the social descriptors. GES performed the best for the ecological descriptors and MSY and MPRO both provided benefits across all pillars.

Limitations in data access were apparent and crude assumptions had to be made for the social and economic indicators which had implications for the outcomes and interpretation of the modelling process. Sensitivity analysis on the NS model demonstrated that the outcome of the preferred scenario was dependent on the assumptions behind the calculation of the indicators. It is essential that we are transparent about the assumptions, particularly where there is high uncertainty. Whenever such assumptions are necessary, sensitivity analysis should be presented to stakeholders to help them to understand the limitations of the modelling exercise.

Decision support tools and stakeholder preferences

MCDA was used to combine stakeholder preferences with the scientific (modelling or qualitative) information to determine the preferred management scenarios for the Fisheries Ecosystem Plans (FEPs). Stakeholder preferences were based on weightings assigned to descriptors by the different stakeholders groups (policy, industry, NGO/other).

- In the NS, 4 management scenarios were considered (BAU, COM, GES, MSY): MCDA showed that stakeholders perceived that the BAU scenario performed the worst, and MSY performed the best.
- In the NWW, 5 management scenarios were considered (BAU, GES, MSY, MEMP, MPRO): MEMP preformed the worst and GES performed the best.
- In the SWW, 5 management scenarios were considered (BAU, MSY, GES, MEMP and MPRO; again MEMP performed the worst and MPRO performed the best.

For all three regions the difference in weighting between stakeholder groups did not affect the outcome of the exercise, i.e. the selection of the preferred management scenario. This is likely due to the fact that the management scenarios chosen for this exercise were abstractions of some rather crude and very divergent policy aims resulting in such large differences in indicator values that the relatively subtle differences in weighting provided by the stakeholders did not make any difference. The main message from this exercise is that the decision-support tool that was applied as a means to involve stakeholders in the process appeared appropriate.

General stakeholder feedback

In general, the MEFEPO project was considered to be very useful and timely in the light of the developments of the MSFD and the CFP. There was support for the framework used to integrate ecological, economic and social aspects in an ecosystem approach to fisheries management. However, specific issues were raised, such as the selection of descriptors and indicators, and the development of management scenarios to test policy/management options.

Stakeholders could see the usefulness of the management scenarios as a tool to check whether it is possible to balance the different ecological, economic and social objectives against each other in the management process. However, they highlighted tensions between the need for simplicity in terms of model outputs, and the need for complexity in order to deliver useful results. It was suggested effort should be invested in improving the models rather than expanding them. It was also highlighted that regional diversity (smaller scale than the regional seas) needed to be recognized.

Stakeholders were concerned whether the suggested economic and social descriptors and indicators were the most relevant or appropriate, particular with respect to "job attractiveness". Economy was perceived as THE driving force to improve sustainability but the economic pillar was considered to be the least sophisticated component in our models. This limitation was acknowledged by the MEFEPO team who highlighted difficulty in identifying appropriate descriptors for the economic and social pillars due to limitations in terms of data availability or information to parameterise the models. A further criticism was that the framework did not include any interactions and feedbacks between pillars or descriptors.

Whilst the work presented to the stakeholders was considered to be a good start in incorporating socioeconomic viability of the fishing industry with the objectives of the MSFD, stakeholders felt that there is still a long way to go. Social and ecological aspects of the process were considered to be too theoretical and require further development to make the exercise more credible.

Summary

This WP has demonstrated that decision-support tools could be used to deliver a preferred management scenario to achieve policy objectives in a formal and transparent process that takes the stakeholders opinion into account and combines this with scientific evidence, provided that the management scenarios utilised are meaningful and that there is sufficient appropriate and reliable information to parameterise the underlying modelling approaches. There are still major issues with the scientific information supposed to underpin this framework. Differences in the available of scientific evidence between regions required different simulation models approaches in the NS and NWW, with different degrees of sophistication and thus data requirements. Data limitations in SWW prevented modelling approaches from being implemented, and scientific information was based on expert judgement. Considerable health warnings were given in both the NS and NWW approaches as a result of the assumptions and confidence in the model output in general; the sensitivity analysis conducted for the NS showed that at least some of these assumptions had considerable consequences on the model output and thus the outcome of the process. This underlines the importance of finding the right balance between quantitative and qualitative information depending on the information available when presenting this information to stakeholders The applied decision-support tool appeared appropriate to combine the scientific information with stakeholder preferences in order to determine the best management options to achieve policy objectives.

1 Introduction

Since the reform of the EU Common Fisheries Policy in 2002, effort has been devoted to addressing the governance, scientific, social and economic issues required to introduce an ecosystem approach to fisheries management (EAFM) in Europe. Fisheries management needs to support the three pillars of sustainability (ecological, social and economic) and Fisheries Ecosystem Plans (FEPs) have been developed as a tool to assist managers considering the ecological, social and economic implications of their decision. Building upon previous studies (e.g. the FP5-funded European Fisheries Ecosystem Plan project), the core concept of the Making the European Fisheries Ecosystem Plan Operational (MEFEPO) project is to deliver operational frameworks (FEPs) for three regional seas.

The project focus is on how best to make current institutional frameworks responsive to an EAFM at regional and pan-European levels in accordance with the principles of good governance. This involves developing new linkages and means of allowing dialogue between the disparate groups of marine stakeholders and developing a decision-making process which integrates a wide breadth of interests. It also requires integration of the considerable body of ecological, fisheries, social and economic research which has been developed in recent years to support an ecosystem approach and investigate how existing institutional frameworks need to evolve to incorporate this information and develop both dialogue between the disparate groups of marine stakeholders and develop a decision-making process which integrates a wide breadth of interests.

The regional seas selected for the project are the North Sea (NS), North Western Waters (NWW) and South Western Waters (SWW) RAC regions. These regions were selected as they represent a range of challenges in terms of knowledge, data availability, number of national interests, spatial extent, and a broad range of physical and biological characteristics. OSPAR has invested considerable effort mapping and defining regions on the basis of their ecological functions and interconnectedness. This has proved to be a difficult task but has now resulted in the delineation of OSPAR/ICES eco-regions. These map to the marine sub-regions identified in the proposed Marine Strategy Directive (CEC, 2006). We will not use the term 'eco-region' in this document to avoid confusion with these other policy initiatives (ICES, 2004; EC, 2006) which have mapped marine eco-regions differently to the RACs regions. However, the approach developed here will be applicable to whatever region / subregion structure is adopted in the future to unify European marine management policy.

The aim of this work package (WP5) was to develop operational objectives to achieve the ecological objectives identified for the 3 regional seas in WP2 (NS, Le Quesne et al. 2009; NWW, Nolan et al. 2010; SWW, Borges et al. 2009). The ecological objectives were drawn from the Marine Strategy Framework Directive (MSFD), the thematic strategy for the protection and conservation of the marine environment, which aims to achieve good environmental status (GES) across all European waters by 2020. The initial set of eleven qualitative descriptors of GES listed in the MSFD was examined and four descriptors were selected that were deemed to need explicit consideration by fisheries managers: biodiversity, commercial species, food webs and sea-floor processes (Le Quesne et al. 2009).

A framework was developed that allowed us to combine scientific information based on modelling or expert judgement with stakeholder preferences to examine management scenarios to achieve the ecological objectives based on the current state of understanding of the ecosystem components and social and economic impacts of the proposed management measures. Whilst fisheries management needs to support the ‘three pillars of sustainability’ (ecological, social and economic), achieving these objectives simultaneously remains a key challenge, and trade-offs between the pillars may have to be considered. It has been argued that the economic and social pillars should be considered subsidiary to the ecological pillar since the loss of an ecological resource base prevents social and economic benefits from being realised. It is clear that an understanding of the links between ecological, social and economic systems is necessary to ensure that management decisions are appropriately informed.

This report describes the development and implementation of a transparent and formal process that should lead to identification of the “best” operational management strategies for an EAFM, based on sound scientific information and stakeholder involvement (e.g. regional industry groups, citizen groups, managers and other interest groups). Ultimately, the outcomes from this WP will be incorporated into the regional FEPs to ensure that the operational objectives are acceptable to a wide range of stakeholders and considered ecological, social and economic requirements.

2 Framework

A framework was developed to allow the combination of scientific information based on modelling or expert judgement with stakeholder preferences to examine preferred management scenarios that should be incorporated into the regional FEPs, taking account the three pillars of sustainability. It was intended to be used to develop a list of the “best” operational strategies for implementing an EAFM.

The framework is based on the following assertions:

- It incorporates the three pillars of sustainability reflecting ecological, social and economic objectives that should be achieved simultaneously. The ecological pillar is made up of four Marine Strategy Framework Directive (MSFD) descriptors which are considered to be affected by fisheries (biodiversity, commercial fish and shellfish, food-web and seafloor integrity). Two descriptors were chosen for the economic pillar (efficiency and stability) and three for the social pillar (community viability, job attractiveness and food security). Each descriptor has at least one indicator.

- Stakeholder involvement is crucial if the outcome of the process is to be acceptable to a wide group of stakeholders and the relative importance of the three pillars of sustainability will determine the outcome of the process. The weighting of the pillars and their associated descriptors/indicators is a subjective process and thus cannot be achieved by science alone.

- The process needs to have a solid scientific basis, and the most appropriate state-of-the-art knowledge and models need to be utilised. These sources of information should provide the outcome of the management strategies or scenarios for each of the indicators, and should be quantitative where possible. This information is considered objective and should highlight the trade-offs where different scenarios are more (or less) beneficial to certain indicators.

- Finally, the objective information describing how different management scenarios affect the different indicators and descriptors in each of the three pillars must be combined with stakeholder preferences for specific descriptors to identify the preferred management scenario(s). This will be achieved by applying Multi-criteria decision analysis (Goodwin and Wright, 2004).

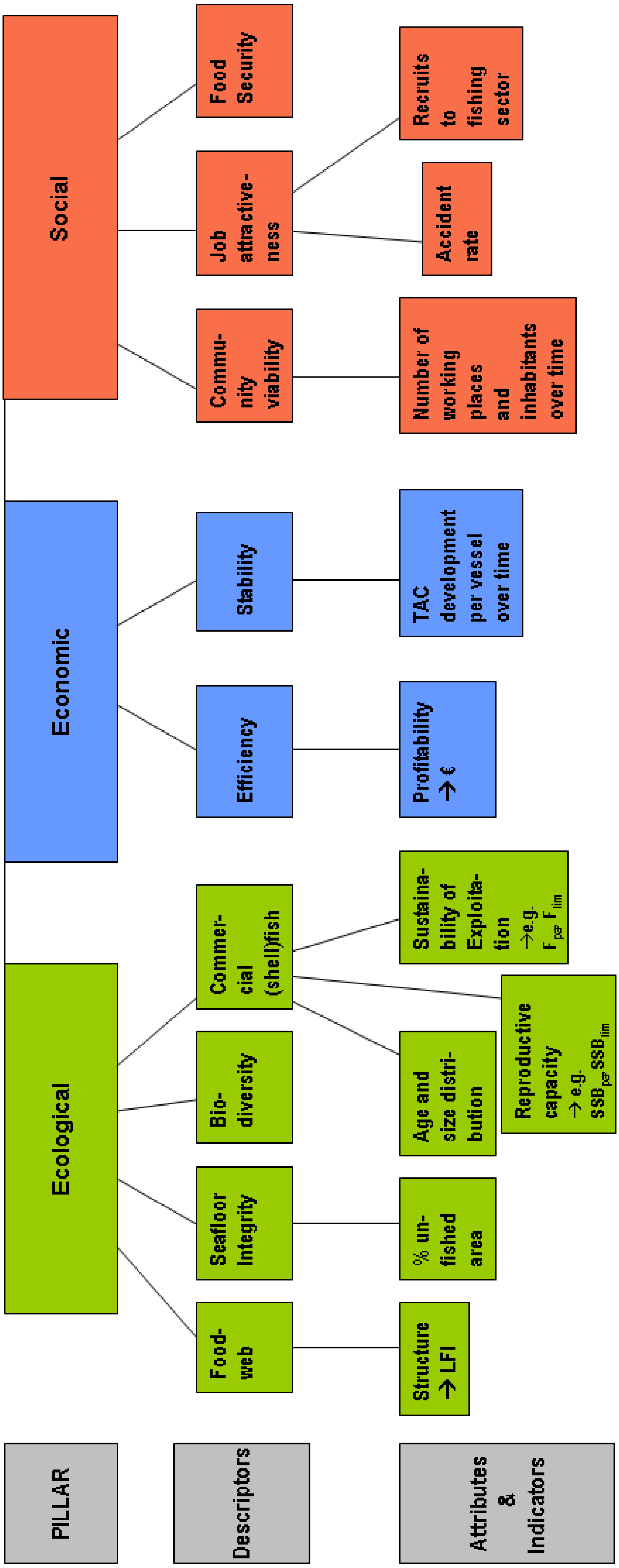

Fig. 2.1. Hierarchy approach involving descriptors and attributes/indicators based on the three pillars of sustainability

2.1 Indicators

At least one indicator was developed for each of the descriptors; the rationale for the choice of descriptors is described below (Table 2.1).

Table 2.1 Descriptors and rationale for their selection.

Pillar	Descriptor	Rationale
Ecological	Food-web	It is important to maintain a healthy foodweb structure, specifically the ratio of small and large fish, as this increases the stability of the system (LFI, Large Fish Index).
	Sea floor integrity	It is important to preserve a certain percentage of un-fished area to strengthen the resilience of the marine ecosystem.
	Biodiversity	It is important that quality and occurrence of habitats, and distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.
	Commercial (shell)fish	It is important that exploitation levels do not harm the sustainable use of commercial species and the spawning stock size (SSB) of commercial species is high enough to secure recruitment.
Economic	Efficiency / Profitability	It is important to optimize the economic outcome of fishing (average profit over a number of years).
	Economic stability	It is important that catch opportunities (TACs) do not vary too much over time.
Social	Community viability	It is important that communities dependent on fishing activities are resilient in population and employment and that they have capacity to absorb and overcome change.
	Job attractiveness	It is important to ensure safe working conditions and reduce the number of industrial accidents, to attract new, young employees, recruiting to the industry.
	Food supply	Population growth increases the demand for proteins from the sea; it is thus of vital importance that the harvest of these proteins is sustainable and optimised.

2.2 Management scenarios

The project developed 5 management scenarios that differed in emphasis in terms of the objectives they are trying to achieve:

Business as usual (BAU)

This scenario is based on the current management situation, and is the management scenario against which the other will be compared. None of the three pillars in the management scenario is given particular emphasis. Applying the same management measures (e.g. Harvest Control Rules, precautionary values, similar selectivity etc.).

Achieve Good Environmental Status (GES)

The goal of this management scenario is to achieve the minimum ecological requirements for Good Environmental Status (GES). The aim here is to meet these minimum conservation requirements for biodiversity, foodwebs, commercial fish species and seafloor integrity by meeting existing targets or at least avoiding further ecological degradation.

Maximum long-term harvest (MSY)

In this scenario emphasis is put on the ability to harvest food from the sea. There is a strong link with the social pillar in terms of contribution to global food supply. In order to achieve a sustainable harvest of seafood, it is a prerequisite that commercial marine species are in a healthy status, and seafood needs to be affordable. Eventually, a multi-species maximum sustainable yield (MSY) could be the target value.

Maximum long-term employment (MEMP)

Emphasis is put on the social pillar, where the resilience of communities depending on fishing activities is important. Often, there will be a minimum threshold for the number of working places and people in a community, below which most social and welfare services are closed down. This may lead to a depopulated community.

Maximum long-term profit (MPRO)

The focus on this scenario is on the economic pillar and economic efficiency, which involves maximising economic yield (MEY), i.e. the difference between revenues and costs. This implies that the most efficient vessels are employed, followed by more inefficient vessels, until the catch opportunities (TAC and/or other limitations) are exhausted.

2.3 Decision-support tools

Decision-making in fisheries management is complex and involves uncertainty, multiple objectives and multiple stakeholders. Objectives may be conflicting, and there can be disagreement between stakeholders who are involved in the decision-making process. Decision support tools can lead to a greater understanding of different stakeholder positions and thus increase awareness of the issues involved and the root of any conflict. The application of decision support tools may structure discussions, improve communication among stakeholders and lead to additional insight on possible solutions to the issues. This may increase stakeholder buy-in to the decision as the decision process is more transparent and thus the decision more easily defended, and provides a documented basis for possible modifications of the decision in the future (Jarre et al. 2010). The main reason for employing tools for decision support is that the decision process remains structured, transparent and documented, and that there is scope for better decisions in this way.

Multi-criteria decision analysis (MCDA) is a set of formal approaches which seek to take explicit account of multiple criteria in helping decision-makers explore decisions (Goodwin and Wright, 2004). They also allow to document, in a structured manner, the way a decision was reached and in this way make the decision process transparent. In MCDA, a decision problem typically is broken down into a set of smaller problems that are easier to address, and a formal mechanism is then applied for integrating the results of the partial problems to develop a course of action to address the overarching issue.

Methods of preference modelling are useful when the problem structuring phases have generated a set of alternatives solutions, and a set of criteria against which these alternatives can be evaluated and compared. The model representing decision makers' preferences and value judgments contains two primary components, (i) preferences in terms of each individual criterion, and (ii) an aggregation model. Value function approaches encourage explicit statements of acceptable trade-offs between criteria. These methods notably comprise value measurement and utility theory. (Leung 2006)considers preference modelling approaches particularly well suited to characterize the complex decision–making process facing fishery management authorities.

Weighted averaging techniques, such as the simple multi-attribute ranking technique (SMART) is an example of a deterministic preference modelling method (Goodwin & Wright 2004). For SMART, a set of criteria (what is important) relevant to a decision is established. For each criterion, alternatives are scored on a scale from 0 to 100, where the worst alternative scores 0 and the best 100. Weights are assigned to each criterion which combine the perceived importance of each criterion and the spread between "worst" and "best" for that criterion. The overall score is then calculated as the weighted sum of the scores on each criterion. (Belton & Stewart 2002) recommend the use of such methods particularly within workshop settings, for facilitating the construction of preferences by working groups of a limited size, or groups which only represent a subset of stakeholder interests.

In the MEFEPO project we applied MCDA in combination with the SMART technique to use stakeholders' opinions in a structured and transparent process, as part of a workshop to determine preferred fisheries management scenarios. Here the different descriptors were used as the criteria, the management scenarios as alternatives that result in a score against each descriptor (represented by an indicator).

3 Stakeholder involvement

3.1 The human component as part of an ecosystem approach

The term "ecosystem approach" (EA) was initially developed through the Convention on Biological Diversity (CBD). It was first mentioned during a meeting of the CBD's intergovernmental scientific advisory body (the Subsidiary Body on Scientific, Technical and Technological Advice; SBSTTA) in 1995, and built upon similar approaches such as the "systemic approach" which was applied to the management of natural resources by the Man and Biosphere programme (UNESCO 1970). An ecosystem approach, as defined by the CBD "*recognizes that humans, with their cultural diversity, are an integral component of many ecosystems*" (CBD 2000).

Ecosystem-based management (EBM) is an environmental management approach that encompasses the human component, taking account of the full array of interactions within an ecosystem, rather than considering single issues, species, or ecosystem services in isolation (Christensen et al. 1996, McLeod et al. 2005). There has been a change in emphasis in marine management; it is not about managing fish or ecosystems, but rather managing human activities (e.g. fishing) that impact upon fish and ecosystems. As a broad concept, EBM focuses on protection (and where possible restoration) of ecosystem structure and function, and maintenance of associated ecosystem benefits for resource users for current and future generations (Jennings 2004; Leslie and McLeod 2007). EBM recognises that people are an integral part of the ecosystem and must therefore be part of the management process (Charles 2001).

Recent policy documents (e.g. the revised Common Fisheries Policy, January 2003) emphasize the importance of increased stakeholder participation in the management process (EC, 2009; EC[1]) the involvement of fishers is expected to increases the likelihood that management measures will be supported by the fishing industry and thus increase the likelihood of management success. A large body of research is attempting to get a clearer picture of how an ecosystem approach to fisheries management (EAFM) can be made operational, and how the human component can be incorporated (Sissenwine & Mace 2001, Garcia & Cochrane 2005, Fee et al. 2009, Wilson 2009).

MEFEPO has collaborated extensively with stakeholders in other work packages and has utilised interviews, questionnaires and presentations at stakeholder meetings (e.g. at the Regional Advisory Committee meetings). MEFEPO also held a stakeholder workshop in WP2 (Task 6) which focused on determining the ecological (environmental) objectives for an EAFM. The focus of WP5 was the development and selection of operational management strategies for an EAFM. As part of this process, input and feedback from stakeholder was sought on the framework (Fig. 2.1) designed to incorporate ecological, economic and social objectives. A number of different mechanisms were used to gather feedback and these are

[1] European Commission website: http://ec.europa.eu/fisheries/cfp_en.htm

described in detail below. The feedback received will also be used to inform the remaining MEFEPO WPs including for planning of the next MEFEPO workshop (WP6, Operational challenges to an EAFM) and in the development of FEPs for the three regions (WP7).

3.2 Stakeholder involvement in WP5

3.2.1 Informal interviews on the suggested framework

The framework to operationalise the ecosystem approach to fisheries management (Fig. 2.1) was developed in the first WP5 MEFEPO project meeting in February 2010. The scientific basis for the ecological pillar was predominantly derived from work related to defining Good Environmental Status (GES), as defined in the Marine Strategy Framework Directive (MSFD). The economic and social pillars were developed MEFEPO project members to be comparable to the ecological pillar.

Feedback on the framework was sought from stakeholders who were familiar with fisheries management and policy to ensure that the framework was useful and realistic (February to June 2010). A short document (2 sides of A4, referred to as a "2-pager") was developed that presented an overview of the framework; one page showing the 3-pillar framework structure, the other one outlined the proposed management scenarios that would be tested with scenario model runs (Annex 1). Seven of the MEFEPO project institutes sought feedback from selected stakeholders (2-3 per institute).

We posed the following specific questions:

(a) 3-pillar framework

- Have we selected the most crucial descriptors/ indicators?
- Which of them do you consider redundant?
- Are there other factors missing that you consider crucial?

(b) Proposed management scenarios

Please give us your feedback on the usefulness of these scenarios.

- Do they make sense to you?
- Do they cover policy relevant issues?
- Which of them would you modify and how?
- Do you have any additional scenarios that you think are relevant and important?

Comments received were discussed at a second MEFEPO project meeting (June 2010); comments were addressed either through modifications of the framework or by providing feedback to comments that were not considered to be relevant to the WP. Annex 2 details the complete list of comments received and MEFEPO responses.

3.2.2 Dublin stakeholder workshop

The next round of stakeholder involvement was a stakeholder workshop in Dublin (November 2010). The workshop was designed to be informal, and consisted of a series of talks, open discussions, breakout groups and consensus building. A key consideration was the impact of the changing policy landscape (e.g. Reform of the CFP and the MSFD) on the future of fisheries management. The aim of the workshop was to capture the diverse range of views of regional industry groups (e.g. the Regional Advisory Councils, RACs), citizen groups, managers and other stakeholders on the current state of the ecosystem and the perceived social and economic impact of the proposed management measures driven by MSFD considerations. An overview of feedback gathered during the workshop can be found in Annex 3.

More specifically, we asked stakeholders for feedback on the following MEFEPO developments and ideas:

- The 3-pillar structure, with descriptors and indicators, derived from the MSFD approach to define GES (Fig. 2.1)
- The choice/ selection of descriptions
- The choice/ selection of indicators
- The choice/ selection of management scenarios
- The modelling approaches presented for each of the regions.

Questionnaires were designed to determine how stakeholders value or weight the different pillars as well as descriptors of the MEFEPO framework (Annex 4); the results of this analysis were used to identify preferred management scenarios (Section 3.2.3).

3.2.3 Preference questionnaire

The MEFEPO project wanted to learn about the preferences of different stakeholder groups with an interest in fisheries with respect to 1) the three overarching pillars of sustainability (ecological, economic, and social), and 2) the specific descriptors and indicators used in the framework (Fig. 2.1). A range of tools can be used to systematically collect and handling information about stakeholders' preferences and we wanted to use a simple technique to allow the data to be treated quantitatively. Quantitative methods include ranking from the most important to least important, assigning weights, and assigning importance; and differences in collecting data on preferences are known to influence the outcome of the preference exercise.

At a MEFEPO project meeting in Tromsø, Norway, the MEFEPO team responsible for the organisation of the Dublin workshop tested the three methods of collecting information on preferences. The analysis of this "self-test" allowed us to examine how different ways of data collection can affect the resulting preference scores and determine the most appropriate method.

We tested assigning preference scores on (a) the three pillars, and (b) the nine descriptors. With respect to pillar preferences, we tested only one method: assigning a value to each pillar, with the total of all three summing up to 1. For descriptor preferences, we tried three ways of assigning preference values:

1. assigning importance on a scale from 1-6;
2. ranking from 1-9; and
3. assigning a value between 1-100, with the aggregate summing up to 100.

We also tested the weighting of the descriptor preference scores with the pillar preference scores (Method iv, Annex 4). However, due to differences in number of descriptors per pillar (four descriptors for the ecological, two for the economic, and three for the social pillar), the combined preference score was biased as when the ecological descriptor weights were aggregated they summed up to a number higher than the weight that was assigned to the ecological pillar. Therefore, it was not possible to combine the pillar preference scores with the indicator preference scores.

The results from the weighting of the pillars corresponded with our weightings, rankings and importance values of their respective descriptors. Therefore, respondents' weighting of the pillars and of the descriptors within the pillars was consistent. Furthermore there is good agreement between the preference orders resulting from each of the three methods utilised. The only exception was for the descriptor community viability, which is preferred as number 6 out of the 9 descriptors according to the importance-method, whereas it is preferred as number 9 out of 9 according to the weighting-method. For all other descriptors the difference in ranking was not more than one (e.g. preferred as number 3 out of 9 instead of as number 2 out of 9). Participants were also asked to indicate their educational background (whether they had a social science, ecological or interdisciplinary education). Detailed results of this preparatory test are included in Annex 6.

From this preparatory exercise, we concluded that the results were not method-dependent regarding the three tested alternative methods for assigning preferences.

Therefore, in Dublin, we asked all stakeholders to fill in three questionnaires (Annex 4):

1. assigning their preferences as a weight to the nine descriptors;
2. assigning their preferences as an importance score to the nine descriptors; and
3. assigning their preferences as a weight to the three pillars.

A brief introduction to the exercise was given prior to the distribution of the questionnaires, explaining the purpose of the survey and the methods being used. It was also emphasised that participants should respond to the questionnaire according to their personal opinions and not the opinion of the employer, company or organisation that they were representing.

3.3 Main issues raised by stakeholders

The following sections summarise key feedback received from stakeholders gathered through the informal interviews on the initial “2-pager” and the Dublin stakeholder workshop; more detailed summaries can be found in Annexes 2 and 3 respectively.

3.3.1 Project focus

In general, the MEFEPO project was considered to be very useful and timely in the light of the developments of the MSFD and the CFP. The combined presence of fishing industry, national ministries and NGOs was highlighted as positive and novel in these two regulatory settings.

3.3.2 General approach

It was emphasized that MEFEPO needs to be more transparent about its approach in terms of the detail of information required, for example when and where is our approach based on qualitative and when is it based on quantitative data? It was suggested that qualitative and quantitative modelling approaches could be combined. In particular in the SWW region, where quantitative data is distinctly lacking, we should not restrict ourselves to quantitative models but utilise other sources of information (e.g. qualitative data and expert judgement).

The information that MEFEPO provided before the workshop was not considered to be sufficient. It was suggested to provide more extensive and comprehensive information next time about what the MEFEPO project is doing and why; we should be clear about how we intend to use stakeholder input.

Stakeholders highlighted the tension between the need for simplicity and the need for complexity in order to deliver useful results. It was suggested effort should be invested in improving the models rather than expanding them, by improving data input, parameter assumptions, and verifying model structures as opposed to increasing and further complicating the models by adding factors or indicators.

3.3.3 Pillar framework

Generally, stakeholder supported the presented framework to integrate ecological, economic and social aspects in an ecosystem approach to fisheries management (Fig. 2.1). However, specific issues were raised, such as the selection of descriptors and indicators, and the development of management scenarios to test policy/management options.

It was commented that the three pillars might not be sufficient and that a governance pillar was required. This was discussed over the course of the Dublin workshop and the outcome was that governance could not be added as a fourth pillar but should be seen as an overarching requirement, i.e. that the pillar structure would collapse without governance. Governance was highlighted as the most relevant issue in fisheries management.

In response to this, the MEFEPO team highlighted that governance is considered as part of the project; WP4 specifically addressed governance structures and institutional arrangements. These were considered when choosing the management scenarios. In addition, WP6 will address the operational challenges to implementing an EAFM which included governance issues. Finally, the information from all WPs will be incorporated into the regional FEPs that will be produced in WP7.

There was no consensus by the stakeholders participating in the Dublin workshop on which of the pillars is the most important. It was stressed that the economic and social dimensions are necessary to reach robustness. Additionally, it was highlighted that regional diversity needs to be recognized and focussing only on models that maximise the economic outcome can be counterproductive in this respect. Several stakeholders supported the idea to look more into economic measures. Economy was perceived as THE driving force to improve sustainability. However, the economic pillar was considered to be the least sophisticated component in our models.

Another criticism was that our framework does not include any interactions and feedbacks between pillars or descriptors and stakeholders indicated that this created problems, in particular when trying to assign preferences. Stakeholders were aware of interactions, e.g. as a fisher a job is only attractive if there is some kind of security that the fish stock you want to fish is in good shape. This suggests the ecological pillar should get precedence as it seems that ecosystem health is seen as the basis for economic and social health. In response, the MEFEPO highlighted that such feedbacks are implicit in the relative weighting of the pillars/descriptors and that this is supposed to be addressed by incorporating the stakeholder preference scores in the scenario analyses.

3.3.4 Specific comments that were highlighted repeatedly

Stakeholders were concerned whether the suggested economic and social descriptors and indicators were the most relevant or appropriate. The MEFEPO team acknowledged that this was probably a valid point but highlighted that in order to apply this approach we had to choose descriptors for the economic and social pillars and that these were chosen based on pragmatic considerations involving data availability or information to parameterise the models.

There was considerable discussion on the descriptor seafloor integrity and how the indicator was calculated based the assumption that seafloor integrity is inversely related to the area trawled and how the different fleets were weighted to achieve this measure. However, it was considered that there is an absence of information to be able to improve this measure (i.e. some measure of seafloor impact per unit of effort).

Another descriptor that was discussed vehemently was *job attractiveness* under the social pillar. It was criticised that MEFEPO has looked at this descriptor in a manner that was too restricted. Many alternative suggestions for possible indicators were given. Indeed this was also considered by the MEFEPO project members as the descriptor where probably the most crude assumptions were required in order to calculate this from the model output.

3.3.5 Management scenarios

In general, the choice of management scenarios was perceived as relevant. Opinions differed with respect to the question whether a particular scenario should be removed, modified or an additional one added. The stakeholders could see the usefulness of the management scenarios as a tool to check whether it is possible to balance the different ecological, economic and social objectives against each other in the management process that comes.

3.3.6 Workshop feedback

At the end of the workshop, participants commented that they would like to give feedback on the workshop. A feedback questionnaire (Annex 6) was therefore designed and distributed to participants by email shortly after the workshop. Nine out of 21 participants returned completed questionnaires; responses are summarised in Table 3.1 and discussed below.

Pre-workshop organisation and facilities

Overall, there was positive feedback from the majority of participants on the workshop location and facilities (Q1), and the majority thought that the information distributed in advance of the workshop was appropriate and sufficient to set the background for the workshop (Q2). However, there was a suggestion that more information could have been distributed in advance of the workshop to provide participants with information on how the project had progressed to this stage, including key decisions and how they had been reached.

Workshop delivery and stakeholder involvement

Participants generally responded positively to the material presented during the workshop, in terms of organisation (Q3), the level at which material was presented (Q4) and presenters' responses to stakeholder questions (Q5). However, there was a more mixed response to the balance of the time allocated to presentations in relation to stakeholder discussions and input (Q6 to Q8) where it was believed that there was too much emphasis on the former. These responses were supported by more general comments received (Q11) which called for more time for group discussions.

One participant thought that a greater diversity of stakeholders should have been invited to attend the workshop, and 2 participants suggested that simultaneous translation services be used to allow greater involvement of, and input from, fishermen and other stakeholders who speak little English.

Table 3.1 Summary of participants' responses to the feedback questionnaire distributed following the Dublin workshop, November 2010 (n = 9).

Question	Participants' responses (%)		
	Strongly agree or Agree	Neutral	Disagree or Strongly Disagree
1. The workshop location and facilities were appropriate and satisfactory	77.8	-	22.2
2. The information distributed in advance of the workshop was appropriate and sufficient to set the background for the workshop	66.7	22.2	11.1
3. The workshop material was presented in a clear and organised manner	88.9	11.1	-
4. The workshop material was presented at an appropriate level	88.9	-	11.1
5. The presenters responded to questions in an informative and satisfactory manner	88.9	-	11.1
6. The time allocated to presentations was appropriate	55.6	44.4	-
7. The time allocated to stakeholder input/activities was appropriate	55.6	27.8	16.7
8. The time allocated to stakeholder questions and discussion was appropriate	50.0	27.8	22.2
9. I have a good understanding of how our input will be utilised by the MEFEPO project	66.7	22.2	11.1
10. The workshop provided a useful opportunity for stakeholders to network with one another	77.8	22.2	-

Feedback on the work being undertaken by MEFEPO

Q12 sought participants' feedback on the work being undertaken by the MEFEPO project; comments were received from 4 participants and are summarised below:

- This was a good start to the work that needs to be undertaken to bridge socioeconomic viability of the fishing industry with the objectives of the Marine Strategy Directive Framework. There is still a long way to go because any measure that does not take into account all the important values will be a waste of time and there is a serious risk that it will not be implemented fairly.
- The descriptors that had been used for the economic/social aspects were too theoretical and not realistic, and that they need further development to make the whole exercise credible.

- It has been a useful process to develop better understanding of the correct routes to be pursued [for European fisheries management], with input from both science and stakeholders. The work that comes from the MEFEPO project is an important tool.
- The MEFEPO project should look into how the various member states are already taking to implement the MSFD and how they are trying to define Good Environmental Status to ensure that the MEFEPO outputs are both practical and useful.

3.4 Stakeholder preferences

3.4.1 Participants and their characteristics

The most important stakeholder groups for fisheries and regulations are: (1) authorities, here encompassing both policy makers and managers; (2) industry, encompassing both fishers, fishing companies and the processing industry; and (3) NGOs representing interests affected by fishing activity, e.g. bird watchers, environmental organisations with an interest in the marine ecosystems, etc. The population in general may also have interests in the fisheries, but for this to have any effect on the fishing activity they have to form pressure groups and thus be a part of the NGOs. Other sectors, such as tourism and energy (oil, gas and renewables), to an increasing degree, have stake in the (spatial) planning of fishing activity. However, to date we have not included other sectors as a stakeholder group in our survey.

We do not have knowledge about the population (number of persons) in each of the identified stakeholder groups, and thus it is not possible to collect information on the population and its characteristics in order to get a representative sample for the survey.

Therefore, we used an alternative approach and used MEFEPO project partners' knowledge on the three stakeholder groups in their country; each partner sent an invitation to a selection of national stakeholders considered to be of vital importance to the fishing activity in their country resulting in a convenience sample rather than a truly representative sample. A summary of the range of stakeholders who took part in the workshop and in the preference survey are given in Table 3.2.

The respondents are split relatively evenly between the stakeholder groups; authorities (6), industry (8), and NGO/other (5). Of the 5 from NGO/other, 3 represented NGOs, one was a scientist and one did not provide details on their profession. Six participants had natural sciences background and 4 had social sciences backgrounds. The remaining participants (9) either did not inform regarding education or were educated within law or interdisciplinary sciences.

Table 3.2 Characteristics of the stakeholder selection (19): NS, natural sciences; SS, social sciences including economists; other, interdisciplinary or no response.

Stakeholder / Country	**Authorities**			**Industry**			**NGO/other**		
Profession	**NS**	**SS**	**other**	**NS**	**SS**	**other**	**NS**	**SS**	**other**
Spain (2)					1	1			
Portugal incl. the Azores (1)					1				
France (1)									1
Netherlands (3)	2		1						
Ireland (4)			1			2		1	
UK (4)	1					1	2		
Denmark (2)					1		1		
Norway (2)			1			1			
Total	**3**		**3**		**3**	**5**	**3**	**1**	**1**

3.4.2 Survey results

We collected data on stakeholders' preferences by asking them to assign weights (between 0-100) to: (1) the pillars; and (2) the descriptors. Stakeholders were asked to assign the weights such that the sum of the weights equalled 100. In addition we asked them to assign "importance" to each of the descriptors. This was done by asking the stakeholders to assign an importance between 6 (very important) and 1 (not important) to the indicators. The reason for including importance, in addition to weights, was to test whether "unrestricted" answers give the same results in terms of the order of the preferences as was demonstrated in the Tromsø-test (Section 3.2.3). By unrestricted we mean that the stakeholders did not need to make trade-offs between the indicators, as the importance assigned should not add up to 100 (or any other number).

Assigning weights to the pillars

The results to the pillar weighting are summarised in Fig. 3.1 based on the average value of the weights for all respondents, and then for the three stakeholder groups independently. The responses of representatives of the policy (authorities) stakeholder group were closest to the overall average for all stakeholders. However, this group assigns less weight to the social pillar compared to the overall responses, and also industry and NGO respondents.

It is worth noting that all stakeholder groups assign the lowest weight to the social pillar. This may be because the content of this pillar was less clear or that the descriptors belonging to the pillar did not represent those social aspects the stakeholders deemed important. Furthermore, whereas the ecological and the economic pillar have obvious proponent stakeholder groups (NGOs and industry respectively), for the social pillar there was no stakeholder groups that would specifically favour this. Respondents from the industry stakeholder group assigned more weight to economic tan ecological interests. NGOs assigned the highest weight to the ecological pillar and regarded the economic and the social pillar as equally important.

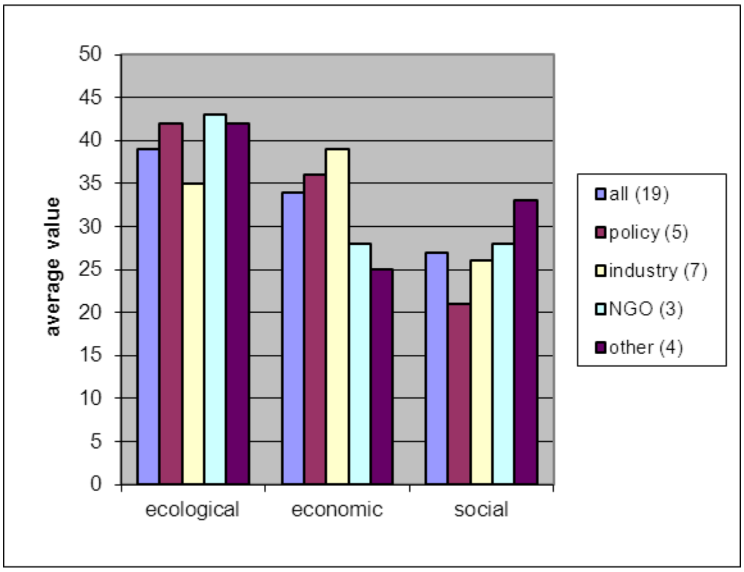

Fig. 3.1 The different participants (policy, industry and NGO) average value for the three pillars, ecological, economic and social (N=19).

Assigning weights to the descriptors

Following the weighting of the pillars, participants were asked to assign weights to the 9 descriptors (Annex 1) to examine individual treatment of each of the descriptors, not as representatives for the three pillars. (This was highlighted to stakeholders before the questionnaire was distributed).

Overall, the commercial fish descriptor was given the highest weighting, (Fig. 3.2), followed by foodweb, biodiversity and efficiency which all had approximately the same weighting. Food security was very closely followed by stability and community viability. The second lowest weight was assigned to sea floor integrity, and the lowest weight was assigned to job attractiveness. It should be noted that the low weighting assigned to the social pillar descriptors may have been influenced by the selection of NGOs.

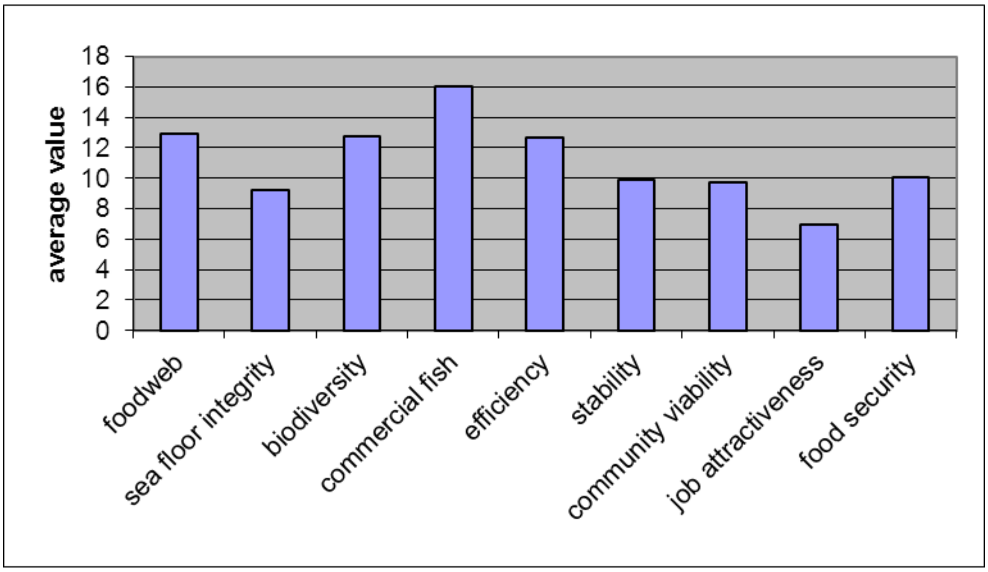

Fig. 3.2 Average value of the descriptors (n=19).

Weighting of the descriptors according to different stakeholder groups

The majority of respondents provided information on their profession (policy, fishing industry, NGO or other) and educational background (social sciences, natural sciences or other). This allows us to examine possible differences in weights assigned to the descriptors between the professional stakeholder groups (Fig. 3.3).

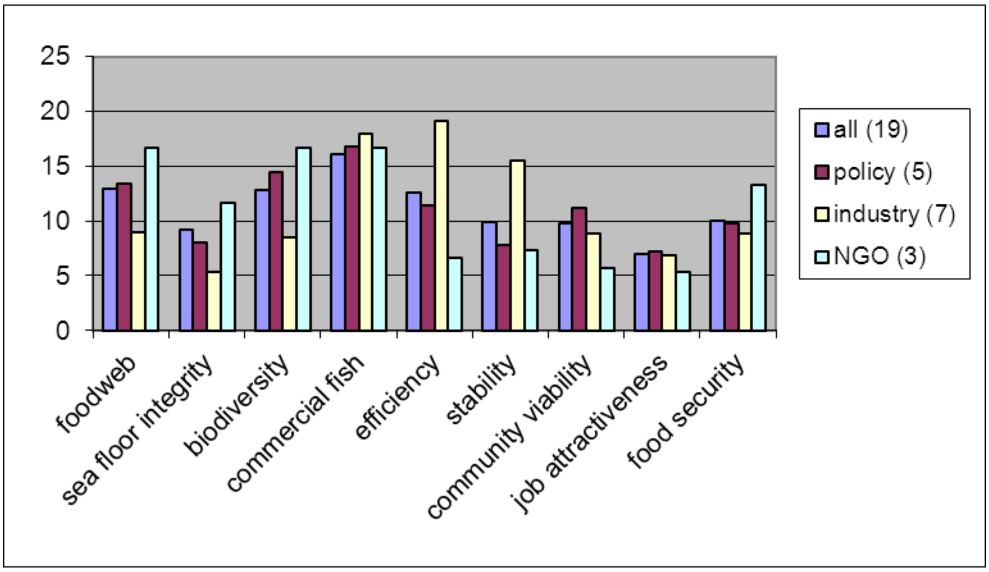

Fig. 3.3 Average value assigned to the descriptors by each of the stakeholder groups.

The most obvious difference is that the industry group assign relatively high weights to descriptors such as efficiency and stability compared to the other groups whereas they assign low weights especially to sea floor integrity, foodweb, and biodiversity. These weightings contrast to the NGO representatives, who assigned the highest weights to food web and biodiversity, and lower weights to efficiency, stability, community viability and job attractiveness. Across all groups, similar (high) weight was given to commercial fish. Both industry and NGOs showed preference for the economic descriptors over the social descriptors (except for food security).

The policy stakeholders assign the highest weights to three of the four ecological descriptors. Efficiency and community viability are weighted above sea floor integrity. As with the industry and NGOs, job attractiveness was assigned the lowest weight.

Assigning Importance to the descriptors

Finally, stakeholders were asked to assign importance, ranging from 1 (low importance) to 6 (very important) to each of the descriptors, and with no limitation on how to assign importance to each of the descriptors (Fig. 3.4).

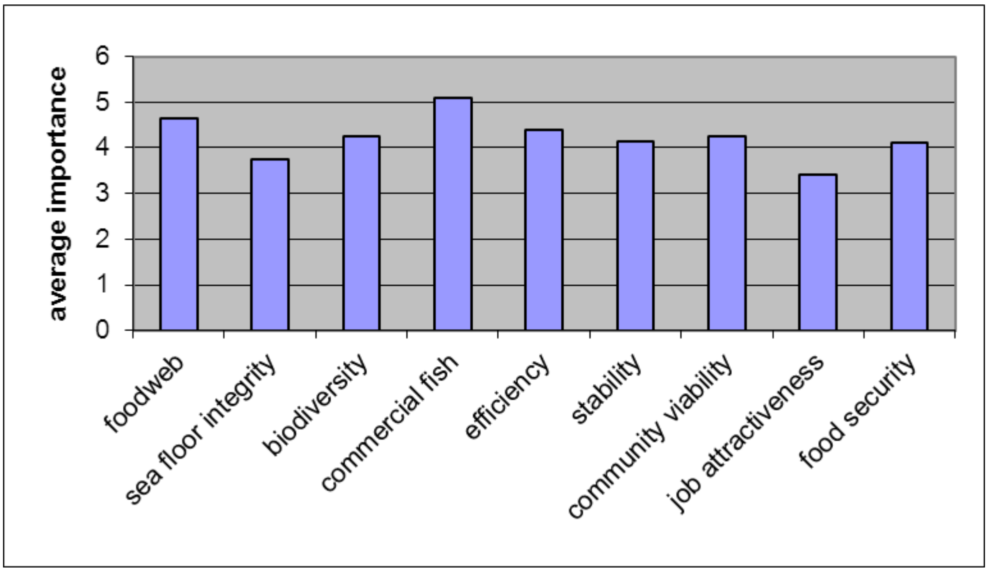

Fig. 3.4 Average importance of the descriptors (N=19)

The pattern in the results from the "importance-method" (Fig. 3.4) do not depart markedly from the results obtained using the using the weighting method (Fig. 3.2). This result supports the result from the Tromsø-test; that the respondents were relatively consistent in their preference between the descriptors, independent upon which method is used to collect the preferences. For both methods commercial fish is the most preferred descriptor, followed by foodweb, biodiversity and efficiency. The only obvious difference was that community viability was now preferred to both stability and food security.

Weighting of the descriptors by academic background

Finally, the results of the weighting of the descriptors were examined based on educational background (Fig. 3.5). Seven respondents said they had studied natural sciences, 3 had studied social sciences including economics, and 8 either had an interdisciplinary degree, a background in law or engineering, or did not provide information on educational background.

The very high weights assigned to the economic descriptors by those with a social science background must be seen in the light of the fact that 2 out of 3 in this group had economics backgrounds. These respondents attach little weight to ecological descriptors such as sea floor integrity and food web, and also to job attractiveness (Fig. 3.5).

Stakeholders with natural science backgrounds are more in line with the overall average (all respondents) and assigned highest weights to ecological descriptors such as foodweb, commercial fish and biodiversity, but also to efficiency and food security. In the majority of cases, the social descriptors had the low weights.

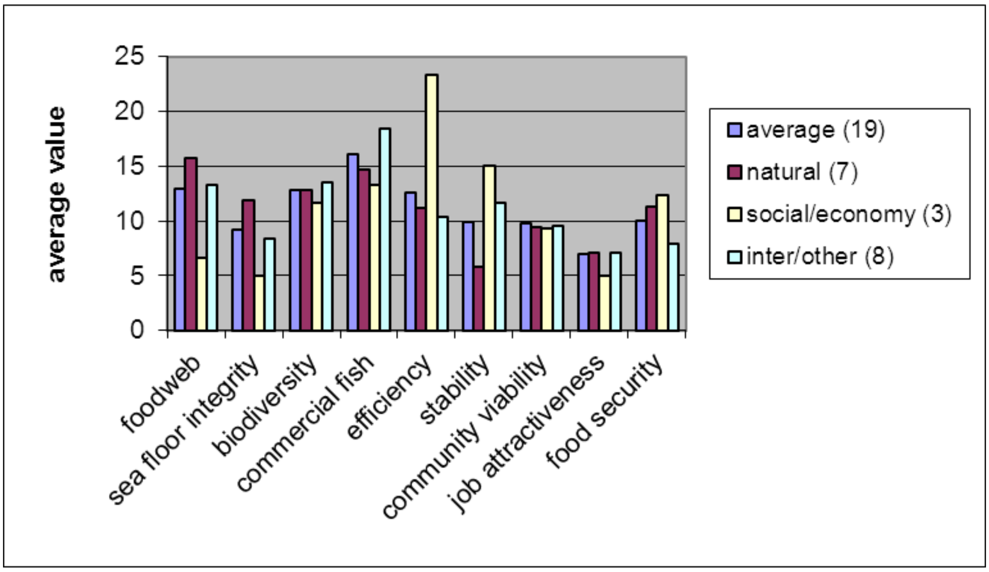

Fig. 3.5 Valuation of the descriptors according to educational background with the number of stakeholders between brackets.

4 Evaluation of management scenarios

Simulation models are useful tools to help evaluate management scenarios by examining impacts of proposed management regulations prior to implementation. Research is on-going to develop models to assist in management decisions as part of EAFM; examples from the two of the main fora in European fisheries management include the *FAO ecosystem computer simulation models* and the *EU status quo impact assessment model:*

> *FAO ecosystem computer simulation model*
> An ecosystem computer simulation model developed at the FAO in collaboration with NOAA intends to test whether multiple management objectives are achievable (Ward et al. 2010b). In this model, net benefits are maximized subject to the fish stock conservation goal while also considering impacts on jobs, income, and sales. The model has been applied to several fisheries in the USA and a hake fishery in Namibia (Ward et al. 2010a). Stakeholders are actively involved, e.g. in the formulation of management goals and providing references for the data used to conduct the policy analysis. This adds to the transparency of the management process.
>
> *EU status quo impact assessment*
> At the European Commission, a scenario modelling study is on-going, attempting to incorporate the EAFM (Brajard 2010). The model assesses the impact of continuing "Status Quo" fisheries management. A number of indicators were selected covering not only ecological, economic and social effects but also fields such as administrative burden, coherence, simplification, aquaculture and external effects.

However, for this exercise we applied a model developed as part of previous EU funded projects (EFEP, MAFCONS) as this was available and familiar to the project partners.

There are many caveats with holistic modelling methods, and extensive sensitivity analyses required to ensure robustness of results, but the approaches above demonstrate the potential for flexible multi-disciplinary models based on an EAFM. Fundamentally, modelling approaches are limited by the quality of the data incorporated, and modelling methods may be precluded due to the absence of appropriate (quantitative or geographic) data.

4.1 North Sea

4.1.1 Simulation model

In order to evaluate the different management scenarios for the North Sea (NS), a model was developed to calculate the impact of fishing on the North Sea fish community. This model was essentially a combination of two existing models: one simulating the fish community (SIBmo) and the other simulating the removal of fish by different fisheries (DIMCOM).

The first model (SIBmo) is a dynamic size spectrum model that consists of 12 interacting fish species and a background resource community. The model is developed from the equations of Andersen and Pedersen (2009) but with an explicit representation of multiple species-specific traits. Each species is characterized by a set of parameters detailing size at maturation, asymptotic size, maximum consumption rate etc. (Table 4.1). For the present analysis all species are assumed to interact and a matrix is included detailing the interaction with other species based on the premise that species interact when they occur in the same spatial habitat.

Table 4.1 Species-specific parameters used in the model. Maturation weight=w^*, Asymptotic weight=W, Food intake rate=h, volumetric search rate γ (g^{-q} yr^{-1}), preferred predator prey mass ratio= β, width of prey size preference= σ.

Species	w*	W	h	γ	β	σ
Sprat	15.7	32.2	10.3	1.41E-11	10000	1
Sandeel	3.6	34.5	14.5	1.33E-11	10000	1.5
Norway pout	46.9	86.1	11.5	1.77E-11	1000	1
Herring	111.1	203.7	11.5	1.05E-11	10000	1.5
Dab	21.7	211.2	7.7	8.87E-12	100	1.5
Grey Gurnard	60.7	612.1	13.6	1.76E-11	10	1.5
Whiting	150.2	684.4	12.3	2.39E-11	10	1
Sole	103.3	886	7.7	8.87E-12	100	1.5
Plaice	203.2	3023.1	8.7	1.00E-11	100	1.5
Haddock	334.7	3118	13.9	1.07E-11	1000	2
Cod	3337.4	19428.6	30.9	5.34E-11	100	1
Saithe	1459.7	45627.2	12.5	1.93E-11	1000	1

The second model (DIMCOM) is a spatially explicit model that determines the direct impact of different fisheries in terms of mortality and removal of fish (Piet et al. 2010). For this model the effort in 2008 of a number of fishing métiers from the Scientific, Technical and Economic Committee for Fisheries (STECF, EU) database was used. The métiers are grouped by their gear characteristics and size of the vessel (Table 4.2), and are described using different characteristics (width of the gear, speed, catch rate, mesh size) that determine selectivity and thus the relative catchabilities of the different species and size-classes. The effort is spatially explicit based on ICES-rectangles. The total effort of 2008 was used as starting effort. Because SIBmo is not spatially resolved, the fish needs to be distributed over the ICES rectangles in order to be linked to DIMCOM. We distributed the initial community of SIBmo (numbers per weight class/length class) over the ICES rectangles using the spatial distribution of the fish in the International Bottom Trawl Survey (IBTS) or Dutch Beam Trawl Survey (DBTS) survey in 2008 (% of a length class in a rectangle) (Fraser et al. 2009, Piet et al. 2010). This data was then combined with the fishing effort with known catchability and selectivity, to calculate the catch consisting of discards and landings. The catch at length was then used to calculate the Fishing mortality (F) at length. This F is used in the next time step of SIBmo. This F however could only be calculated for the demersal species caught in the surveys; for the pelagic species F values from the ICES stock assessments were used.

Table 4.2 Métiers grouped by gear characteristics and size of the vessel based on the Scientific, Technical and Economic Committee for Fisheries (STECF, EU) database (2008).

Métiers	Gear	Size-group	Size (m)
Beam1	Beam	Medium	24-40
Beam2	Beam	Small	12-24
Beam3	Beam	Large	>40
Otter1	Otter	Small	12-24
Otter2	Otter	Large	>24
Static1	Gillnet	Small	
Static3	Trammel	Small	

4.1.2 Approach

Using the combined model, we applied four different management scenarios and calculated as many of the different indicators as possible; the four scenarios were applied through different Harvest Control Rules (HCRs) summarised in Table 4.3. However, it should be noted that these HCRs are just examples of possible HCRs that could be applied in order to achieve the objectives behind the scenarios. They are only intended to show how different management strategies move the system in different directions and are not supposed to be THE best HCRs to achieve the objectives of the respective scenarios.

Table 4.3. Harvest control rules for the four management scenarios: BAU, Business as Usual; COM, details; GES, Good Ecological Status; and MSY, Maximum Sustainable Yield.

Scenario	HCR
BAU	Effort of a specific fishery is only reduced (10%) if SSB of all target species are below Bpa. Effort of a specific fishery is increased (10%) if SSB of one target species is above Bpa.
COM	Effort of a specific fishery is reduced (10%) if SSB of one target species is below Bpa. Effort of a specific fishery is increased (10%) if SSB of all target species is above Bpa.
GES	If the LFI is below 0.3 then the effort of all the beam- and ottertrawls and the F of Norway pout is decreased with 10%. If above LFI then it is increased again.
MSY	Similar to the BAU except that here it is controlled by Fbar, compared to F_{MSY}.

Several indicators are direct outputs from the model; for other indicators we needed to make (often very crude) assumptions and devise proxies based on different weightings that were applied to the model output:

- Food-web: The large Fish Indicator (LFI) is calculated as the proportion of all demersal fish larger than 40 cm.
- Sea floor integrity: As the proposed indicator of percentage of unfished area could not be calculated we developed a proxy by applying a multiplier to the effort of each métier. This multiplier is the seafloor impact index which was calculated as follows:
    - Beam trawl: 25 m wide, 2.6 cm deep, index = 25*2.6=65
    - Otter trawl: 40 m wide, 1 cm deep, index =40*1=40
- Commercial (shell)fish: Two indicators were calculated: Spawning Stock Biomass (SSB) and Fishing mortality (F)
- Efficiency / Profitability: the Profit indicator was calculated as follows:
    - Revenue based on market price (euro/kg) of demersal species/size category and assumed market price of other species (the effect of a change in size on market price was not included)
    - Cost was determined by effort where cost of one unit of effort is calculated per fishery assuming break-even situation at the start of the time-series
    - Profit = Revenue – Cost
- Economic stability: this indicator was an index based on the fluctuation (how often is there a change from increase to decrease or *vice versa*) and deviation (how much is the change) in terms of the yield (see Table 4.4).
- Community viability: the number of jobs was used as a proxy for community viability. This was calculated by applying a multiplier based on the number of crew per unit of fishing in each métier. The following multipliers were used: Beamtrawl, 5.3; Ottertrawl, 3.5; Static, 4.0; Pelagic, 16.0; Sandeel, 4.0; and Norway pout, 3.5.
- Job attractiveness: this indicator utilised a proxy calculated by applying a multiplier based on the operational functionality of the gear to the effort per métier. The following multipliers were used: Beam, 0.3; Otter, 0.4; Pelagic, 0.5; Industrial, 0.9; and Static, 1.6 (ICES, 2006).
- Food supply: the indicator used for this was the total Yield.

To evaluate the management scenarios we ran the model for 30 years using 2008 as the starting year and applying the HCRs associated with each of the scenarios. For each indicator a time-series was created and mean values for the entire (30 year) time-series and the last 10 years were calculated.

4.1.3 Results

The results of the model runs for each of the management scenarios are shown below for each of the indicators (Fig.4.1) and for each of the species (Fig. 4.2).

Table 4.4 The index values per scenario for the economic stability indicator. The index is based on the fluctuation (how often is there a change from increase to decrease or vice versa) and deviation (change by how much) of the yield over the 30-year period depicted in Fig. 4.2.

Senario	Deviation	Fluctuation	Index
BAU	8	6	13
COM	9	4	14
MSY	11	9	20
GES	8	6	14

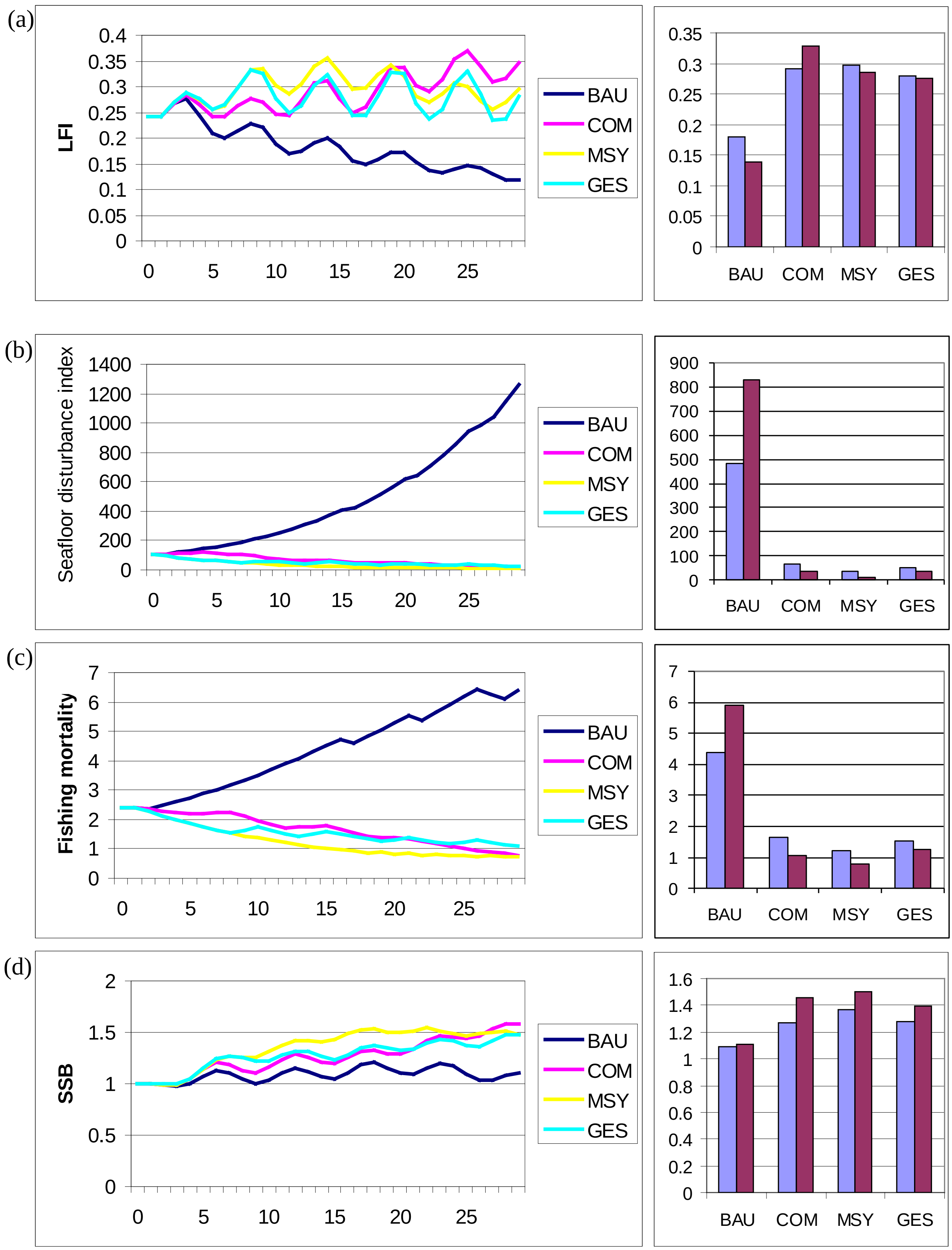

Fig. 4.1 Timeseries for each management scenario and mean value over the whole time-series (blue) and last 10 years (purple) only for each of the indictors: (a) foodweb (LFI); (b) seafloor integrity (seafloor disturbance index); (c) commercial fish (F); (d) commercial fish (SSB); *continued over*.

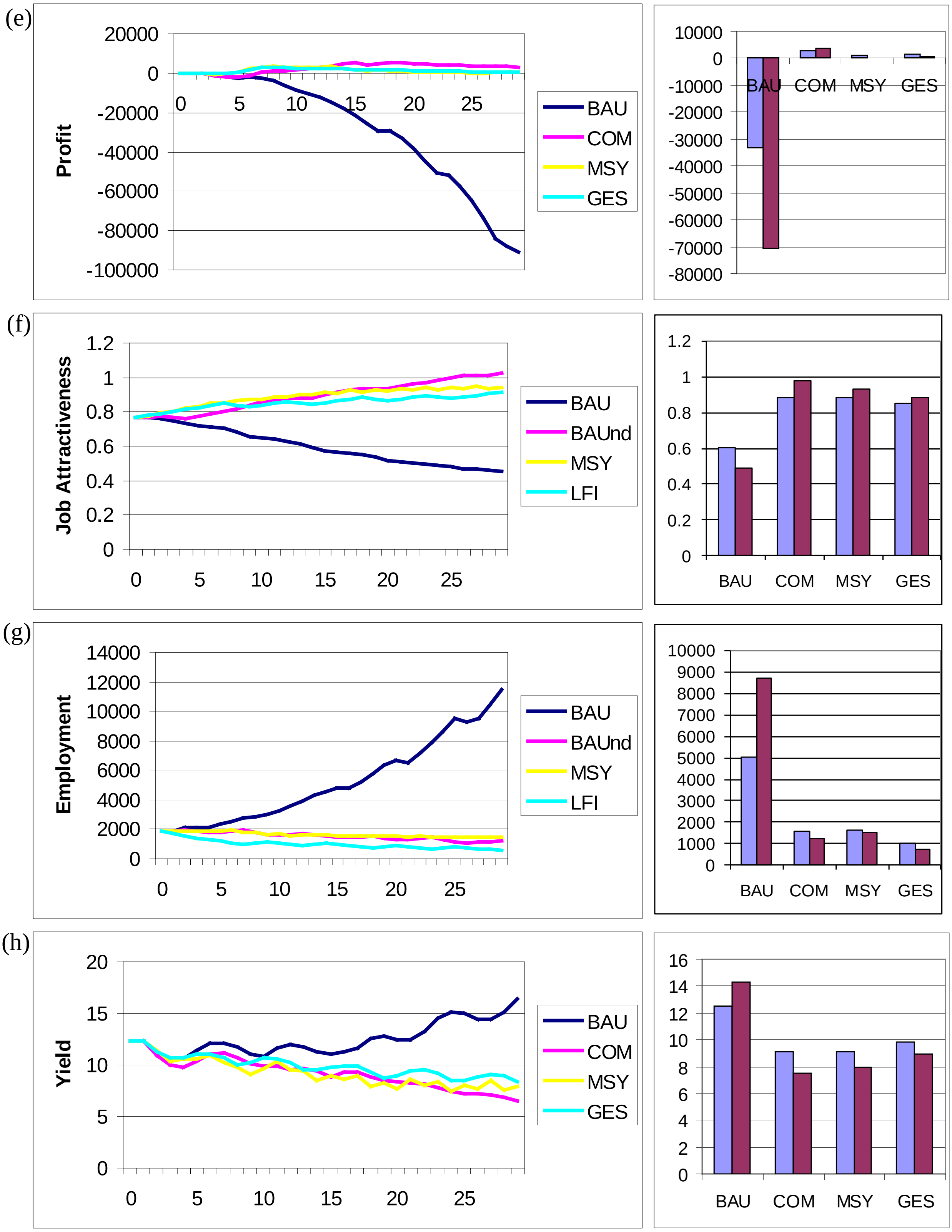

Fig. 4.1 *continued.* Timeseries for each management scenario and mean value over the whole time-series (blue) and last 10 years (purple) only for each of the indictors: (e) economic efficiency (profit); (f) job attractiveness; (g) community viability (employment); and (h) food security (yield).

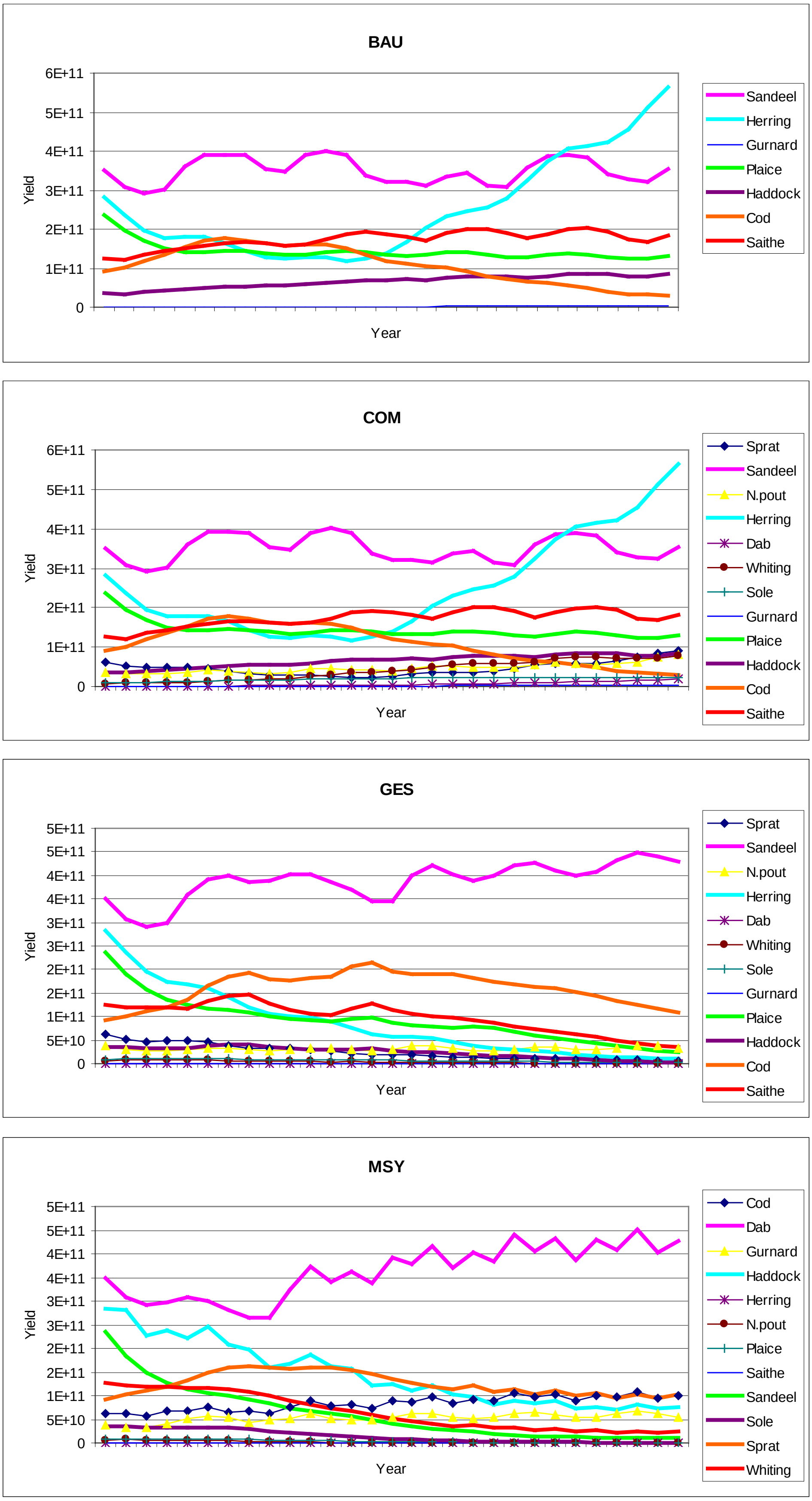

Fig. 4.2 Time-series for each management scenarios by species; the index values per scenario in Table 4.4 for the economic stability indicator are based on these.

From the model outputs (Fig. 4.1) we calculated the scores per scenario for each descriptor (Table 4.5). These scores (as well as the previous figures) demonstrated that the MSY scenario performs well (and in many cases best) across the descriptors. For the ecological descriptors it is either the best or the second best scenario, it performs best for both economic descriptors and reasonably well on the social descriptors. BAU is the worst scenario, only performing best for the food security descriptor due to what is probably an artefact of the model i.e. stocks do not crash even at extremely high exploitation rates.

Table 4.5 Scores of different scenarios per descriptor based on mean indicator values of the last 10 years. Per descriptor the worst scenario gets a score of 0, the best 100, the other two relative to the minimum and maximum values.

Descriptor	BAU	COM	GES	MSY
Foodweb	0	72	78	100
Seafloor integrity	0	97	100	97
Commercial SSB	13	9	0	100
Commercial F	0	91	100	94
Economic efficiency	0	96	96	100
Economic stability	7	2	0	100
Community viability	0	100	90	93
Job attractiveness	0	81	91	100
Food security	100	80	0	65

4.1.4 Sensitivity analysis

In order for the model to be able to provide output on all of the indicators/descriptors crude assumptions needed to be made and in several cases the indicators that were calculated were at best proxies of the attributes that were supposed to be measured. For example, job attractiveness was assumed to be dependent on the operational functionality of the gear purely because this information was available quantitatively. Similarly for seafloor integrity, a proxy was developed of impact on the seabed based on a multiplier of effort per metier. Below we will explore the sensitivity of the model output to such assumptions.

The initial assumption was that job attractiveness was determined by the operational functionality of the gear for which quantitative information was available from an exercise carried out by the ICES Working Group on Fishing Technology and Fish Behaviour (ICES 2006). Operational functionality was determined by five characteristics: safety, durability, gear costs, ease of use and applicability, each of which were scored separately and from which an overall score was distilled.

The base row in Table 4.6 shows the overall score for operational functionality that was then used as a multiplier to calculate the job attractiveness indicator from the model output. The safety row shows the scores from the same study but based on safety only, and while the beam row is completely fictional, and thus used for indicative process only, it reflects a strong preference for beam trawling and the opposite for industrial fishing. Fig. 4.3 demonstrates that the application of different multiplier values may affect the outcome of the model in terms of the preferred management scenario for the job attractiveness descriptor, for example. When the beam multiplier values are applied the preferred scenario shifts from COM to GES.

Table 4.6 Possible scores for the multiplier that determines job attractiveness per fishing métier.

Multiplier	Beam	Otter	Static	Pelagic	Industrial
Base	0.3	0.4	1.6	0.5	0.9
Safety	0.7	0.7	2	0.7	1.7
Beam	3	0.7	2	0.7	0.2

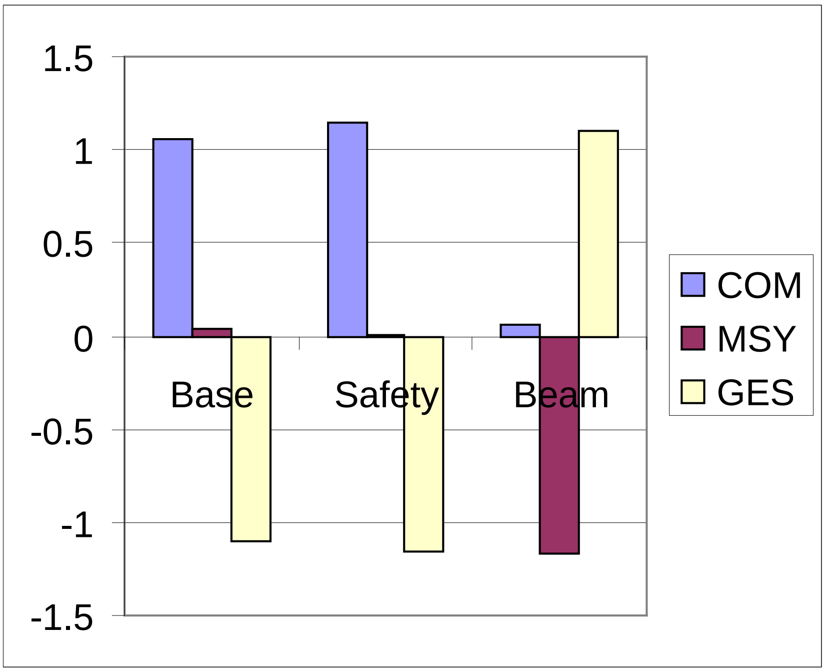

Fig. 4.3 Normalized model results for the descriptor job attractiveness of three scenarios depending on different multiplier scores.

The sensitivity of the model output for the seafloor integrity descriptor may be dependent on the multiplier for seafloor impact and this was explored by varying this multiplier (Table 4.7). The base row shows the multiplier scores that were applied in the initial modelling, these were based on both the width and the depth of the impact of the gear. The width row gives the values if this was based on width only and the Indus row gives multiplier values if industrial fishing also disturbs the bottom. Fig. 4.4 shows that when industrial fishing is also assumed to disturb the bottom, the preferred scenario for seafloor integrity shifts from MSY to GES.

Table 4.7 Possible scores for the multiplier that determines the seafloor impact per fishing métier.

Multiplier	Beam	Otter	Static	Pelagic	Industrial
Base	65	40	0	0	0
Width	25	50	0	0	0
Indus	25	50	0	0	50

Fig. 4.4 Normalized model results for the descriptor seafloor integrity of three scenarios depending on different multiplier scores.

For the community viability descriptor the assumption was that this was determined by the number of jobs created through each of the management scenarios. The indicator for job availability was a relative measure calculated by applying a multiplier to the effort per métier. The multiplier values that were initially applied are given in the Base of Table 4.8. Lowpel is based on the assumption that most of the jobs are not filled by fishermen from local communities (hence the decrease from 16 to 5); handling assumes that both the trawl fisheries (otter and beam) require more fishermen. Fig. 4.5 shows that when the multiplier values of the Handling row are used the preferred scenario changes from GES to MSY.

Table 4.8 Possible scores for the multiplier that determines the job availability per fishing métier.

Multiplier	Beam	Otter	Static	Pelagic	Industrial
Base	5	3	4	16	4
Lowpel	5	3	4	5	4
Handling	10	10	4	16	1

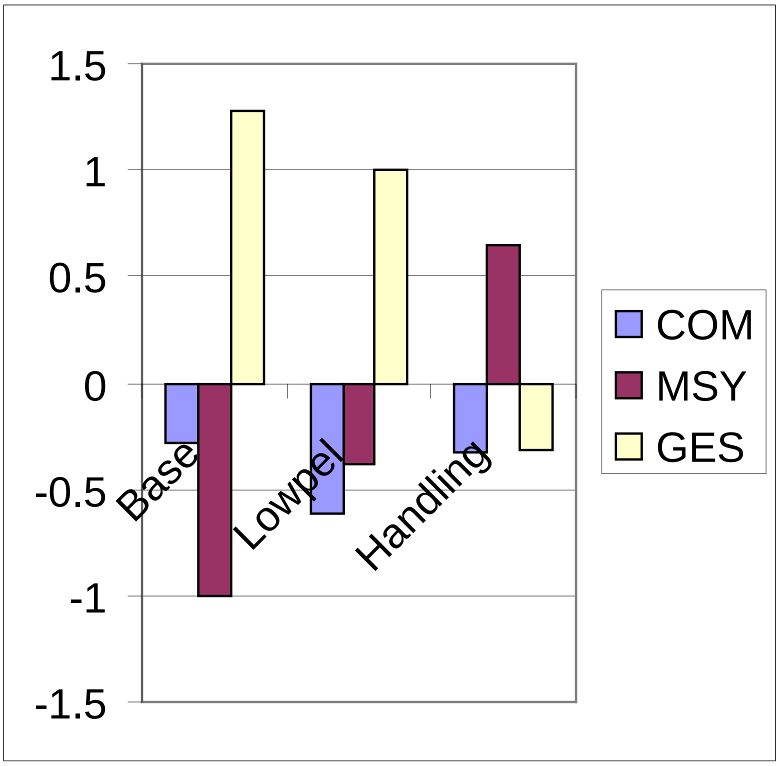

Fig. 4.5 Normalized model results for the descriptor Community viability of three scenarios depending on the different multiplier scores.

Not surprisingly, this sensitivity analysis shows that the outcome of the preferred scenario is dependent on the assumptions behind the calculation of the indicators. It is therefore important to be transparent about these assumptions, certainly when there is great uncertainty. Whenever such assumptions are necessary, it is essential that, as a minimum, this type of sensitivity analysis is presented to stakeholders to help them to understand the limitations of the model.

4.2 North Western Waters

4.2.1 Introduction

The simulation modelling under taken for the North Western Waters (NWW) case study considered the demersal fish community and main demersal fisheries in the on-shelf Celtic Sea (ICES sub-divisions VII f,g,h, Figure 4.6). In order to evaluate the different management scenarios for the NWW a multi-species model was developed to calculate the impact of different management scenarios on the case study fisheries and fish community with respect to the selected descriptors and indicators. The modelling resources for the NWW were not as developed as those for the NS; therefore a related, but different modelling approach was applied to the NWW compared to the NS case study described in Section 4.1 of this report.

The model developed, and applied, in the NWW is a multi-metier, multi-species model that simulates the multi-species ‘technical interactions’ of fishing operations, but does not include biological interactions either between species, or between species and their environment. The analysis covered all demersal fish in ICES VII f,g,h that occurred in both the survey and commercial fishing records with a maximum length (L_{max}) greater than 25cm.

The assessment of the direct impact of fishing on fish populations is similar to the DIMCOM section of the NS model as far as the method applied for the estimation of mortality. In the NWW case study assessment of the implications of estimated fishing mortalities are taken forward by applying yield-per-recruit (YPR) models established for each species. The effect of fishing on population dynamics and fishery yields was assessed by running the YPR models to stability, and the resulting YPR and spawning-stock-biomass-per-recruit (SSB) were then calculated. The species-specific outputs were used to calculate the higher order indicators applied in the scenario analysis.

Fishing mortalities for each species were initially calculated for a base year (2008) and linked to effort applied by the beam trawl, otter trawl and set net fleets (see below). The potential impact of fishing on the demersal fish community, and resulting fishery yields, was examined by running the model under the current F patterns and across a range of different metier-specific effort patterns. These simulations assumed that the effort specified at the start of a simulation is maintained at a constant level.

Due to the resolution of the underlying data the final model is not spatially resolved. As the model does not include any density dependent terms, nor biological interactions, it is not expected to provide accurate long term forecasts. Therefore the outcomes of the management scenarios should be seen as indicative of the types of changes that could occur in response to different effort regimes, rather than as specific accurate predictions.

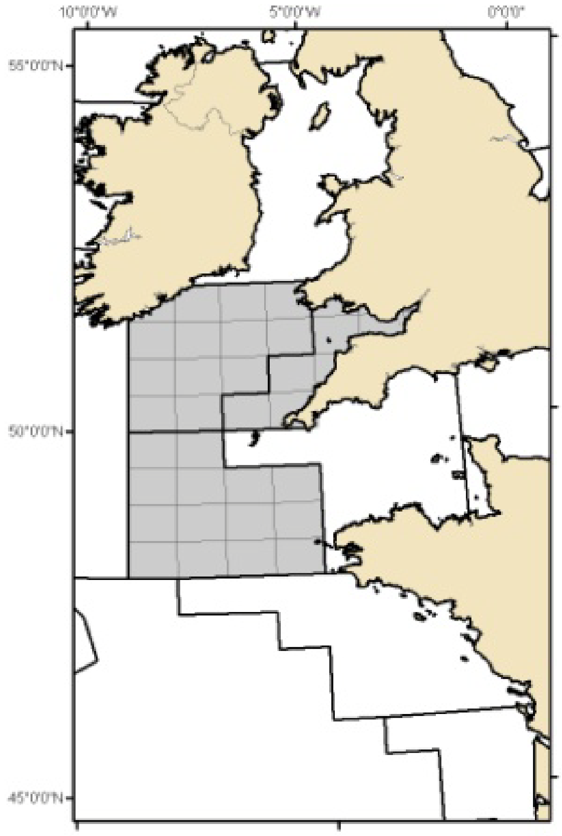

Fig. 4.6 ICES sub-divisions VII f,g,h, covered by the NWW simulations.

To allow the model to be specified and run, estimates of abundance at age, and landing and discard mortality by metier by species at age were required for the base year. The main steps in the analysis and scenario evaluation were broadly as follows:

- Abundance: calculate abundance at size per ICES statistical rectangle on the basis of the Cefas quarter 4 Western Ground Fish Survey (Q4WGFS) and the French EVHOE survey. Abundance at size converted to abundance at age by cohort splitting with species-specific von Bertalanffy growth curves.
- Mortality: calculate total international mortality (landings + discards) per species at age on the basis of English and Welsh discard observer database records scaled to total international effort and subsequently scaled to reported ICES landings data.
- Estimate F at age: Fs calculated from the estimated abundance and mortality on the basis of rearranging the standard catch equations.
- Establish species-specific ‘per-recruit’ models: species-specific models set up on the basis of life-history relationships that allow necessary parameters to be calculated on the basis of taxonomic affinity and L_{max}.

- Develop relative recruitment multipliers: on the basis of survey estimates of juvenile abundance calculate relative recruitment multipliers to allow whole community YPR, and associated values, to be calculated from multiple YPR models.
- Run comparative scenarios: run scenarios under a range of different metier-specific fishing efforts to examine effects of different effort control management regimes on the descriptors of environmental, social and economic performance of the fishery.

A more detailed description of the method and data sources used is presented in Appendix 1.

4.2.2 Scenarios

The five management scenarios specified in Section 2.2 were examined with the NWW multispecies simulation model. To allow the outcomes of the management simulations to be evaluated with respect to the multiple environmental, social and economic objectives specified in this analysis (Fig. 2.1), indicators were assigned to, and calculated for, each of the descriptors apart from ‘job attractiveness’ for which no pertinent metrics could be derived from the model. In some cases the indicators provided measures that directly relate to the objective of the descriptor, however in other cases the model did not provide directly relevant outputs and proxy indicators were applied. Details of the indicators and their calculation are presented in Table 4.9.

The formulation of the model did not allow each of the management objectives to be evaluated exactly according to the objectives specified for the scenarios in Section 2.2; the approach adopted for each management scenario is detailed in Table 4.10.

Management regulation operated in the model through effort regulation, either by controlling total effort or by métier-specific effort. The effort regime that best fit each management objective was assessed by running the model across all co-varying combinations of effort by the different métiers, ranging from 0.2x current effort to 2x current effort incrementing in multiplier steps of 0.1, to create a master table of results. Once compiled, the master table of results was examined to find the effort patterns leading to conditions that best fit the objectives of the management scenarios. As the model did not allow recruitment failure, nor did it simulate reductions in fishing effort due to fleets operating at a financial loss, arbitrary constraints had to be placed on some objective functions to stop the analysis settling on wildly unrealistic optimizations. Similarly, in relation to the GES management scenario the relationship between the calculated environmental indicators and the requirements for achieving Good Environmental Status as defined by the Marine Strategy Framework Directive are unknown so arbitrary targets for the environmental indicators were selected.

Table 4.9 Description of indicators calculated for the management scenarios.

	Descriptor	Indicator	Calculation description
Ecological	Food web	Large fish indicator (LFI)	Weight of fish larger than 40cm as a proportion of the total weight of the fish community.
	Seafloor integrity	Relative trawl intensity	Fishing effort by mobile gears (otter + beam trawls) in scenario as a proportion of the trawl effort in the base year. Assumes otter and beam trawls have similar impact.
	Biodiversity	Number of species above conservation SSB threshold	Number of species where the SSBPR in the scenario is greater than 10% of the SSBPR predicted under a no fishing scenario.
	Commercial species	Number of species above commercial SSB threshold	Number of species where the SSBPR in the scenario is greater than 30% of the SSBPR predicted under a no fishing scenario.
Economic	Efficiency	Total value of landings	Sum total of weight landings per species multiplied by value of species per unit weight. Only considers total value of landings, does not taken account of operating costs (profit).
	Stability	Value weighted SSBPR compared to $SSBPR_{F=0}$	Landings value weighted average SSBPR in scenario compared to SSBPR predicted under a no fishing scenario. Assumes more stable landings can be taken from species at a higher SSBPR, and value weighted to give emphasis to commercially important species.
Social	Community viability	Employment	Employment generated in man days employment at sea, does not account for shore based processing and maintenance employment. Employment multipliers per day fishing: Beam trawlers- 4; Set nets -4; Otter trawls 5/8 for small/large vessels where ratio of effort by small:larger otter trawlers is 1:15.
	Food security	Total yield	Total yield landed from all species combined.

Table 4.10 Description of objective functions utilised to find management strategy that best achieved each management scenario objective.

Management Scenario	Acronym	Objective Function
Business as usual	BAU	Maintain current effort levels
Achieve Good Environmental Status	GES	Maximise total value of landings whilst improving biodiversity commercial species indicators by 2 species, and improving LFI and relative trawl intensity indicators.
Maximum long-term harvest	MSY	Maximise total yield indicator.
Maximum long-term employment	MEMP	Maximise employment indicator without decreasing yield compared to the BAU scenario.
Maximum long-term profit	MPRO	Maximise total value of landing indicator.

4.2.3 Results

The results of the management scenario optimizations are presented in Figure 4.7. The outcomes of each indicator under the different management scenarios were ranked by indicator value, the rankings are presented in Table 4.11. A consistent trend apparent in the results is that all of the management scenarios, apart from the MEMP scenario, lead to improvement in all indicators apart from the employment indicator. Conversely the MEMP scenario only leads to an improvement in the employment indicator. There is a consistent trend for the model to propose an increase in effort by the set net fleet, this is most likely driven by the set nets generally targeting older age classes in the model.

Whilst the model outputs provide indicative outputs of analyses that can be conducted in support of operational implementation of ecosystem based fisheries management the specific predictions must be viewed with caution. Limitations in data access, particularly in relation to the French fleet which is an important component of the Celtic Sea demersal fishery, compromised model parameterization. The underlying biological model is not validated and therefore no specific level of confidence can be ascribed to the outputs of the biological model. In the case of calculating some of the social and economic indicators crude assumptions had to be made with regards to value and employment multipliers. Given that the model lacks internal biological interactions it may support short term forecasts, but is unlikely to accurately provide accurate longer-term forecasts of the type generated in this analysis, albeit that the trends predicted may be informative. As noted above, for several of the indicators calculated, they can only be viewed as proxies for the properties that they are meant to report on. No specific sensitivity tests have been conducted to attempt to ascertain the sensitivity of the model to this uncertainty.

Table 4.11 Ranking of indicator values for each indicator under the different management scenarios.

	LFI	Seafloor	Conservation	Commercial Species	Stability	Value	Employment	Yield
BAU	4	4	4	4	4	5	2	5
GES	1	1	1	1	1	2	4	2
MSY	2	2	2	2	3	4	5	1
MEMP	5	5	5	4	5	3	1	4
MPRO	3	3	3	3	2	1	3	3

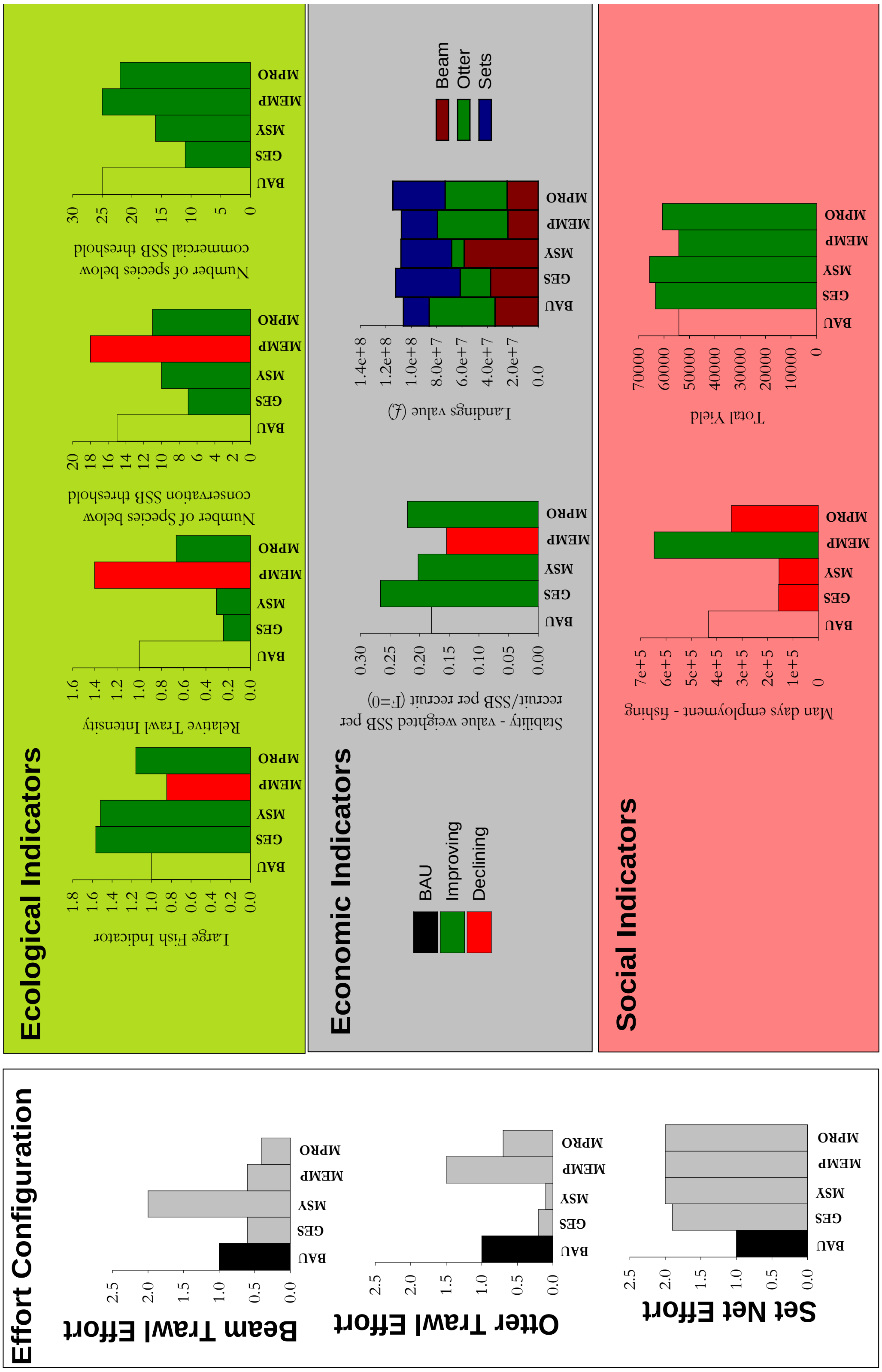

Figure 4.7 Indicator performance under the effort configurations that maximise the objective functions of the different management scenarios. Effort charts show effort in the management scenarios relative to the BAU scenario. Note: outputs from an unvalidated model

4.3 South Western Waters

Data limitations for the South Western Waters (SWW) prevented the use of the modelling approaches adopted in the North Sea and the NWW (Celtic Sea) to assess potential management scenarios and effects on the different GES descriptors.

Specific issues for the different case studies included:

- *Mixed demersal hook and lines case study (Azores)*: there was insufficient data to identify suitable indicators for two of the GES descriptors (biodiversity and food web).
- *Pelagic purse seine (Spain and Portugal):* acoustic scientific surveys are undertaken annually to provide information to assess the state of the exploited stocks but give little information on other components of the ecosystem. Therefore it is difficult to assess the effect of management measures on the GES descriptors and indicators. Despite this, effects of pelagic fisheries on seafloor integrity are considered to be negligible since this gear is not designed to interact with the seafloor. A recent ICES Pelagic RAC meeting discussed the impact of mackerel fisheries on GES and the general consensus was that this fishery does not significantly impact the achievement of GES; it is considered that mackerel fisheries are similar in nature to the pelagic fisheries in this case study.

The effects of the trawl fisheries on the GES descriptors and the potential outcomes of the management scenarios are easier to assess; both the management measures and their effects on the ecosystem and GES descriptors (biodiversity, the food web, the seafloor integrity and the commercial stocks) have been more extensively studied although data was not sufficient to allow modelling to be used. Therefore, expert judgment (MEFEPO project team and literature) was used to predict likely effects of different management measures.

The French trawl fishery targeting Nephrops (Bay of Biscay)

This is one of the most important fisheries in the SWW area and nephrops are targeted on a sand-muddy area called “La Grande Vasière”. Approximately 250 boats are involved in this fishery, which targets multi-species; hake (*Merluccius merluccius*) is also an important target. Each vessel employs between 3 and 5 men on board, average vessel length and age are c.a. 15 m and 19 years old respectively. In total, the *Nephrops* fishery accounts for approximately 1100 jobs, this includes 350 fishermen, 320 FTE directly related to the fishery and 500 jobs on the economy related to it (Descamps, 2004). As a result this fishery is important in terms of economics, social factors and ecology.

Management of the *Nephrops* fisheries is essentially based on conservation measures including a quota of licenses (since 2004), maximum vessel size, logbooks and TACs, in addition to minimum landing size (MLS; 9 cm, compared to MLS of 7 cm in the rest of Europe), minimum net mesh size (70 mm stretched mesh) and selective gears for hake (since 2005) and juvenile *Nephrops* (since 2008). Despite these measures, discards remain a major problem for this fishery with sometimes large quantities of undersized target species (hake and *Nephrops*) or non-target species (blue whiting, horse mackerel) discarded after the catch is sorted. Recently new management measures have been proposed (in ICES divisions a, b, c, d and e): increased cod-end mesh size (from 70 mm to 80 mm); 100 mm square mesh panel on bottom of the trawl conical part; and sorting grid with 13 mm between bars. For associated species (hake) (ICES divisions a, b, d and e, hake box included) this required an 100 mm square mesh panel on the upper part and at the entry of the trawl.

Spanish mixed trawl Fishery (SWW region)

Data from 1989-1993 (STECF, 2005) showed that landings of hake, which had been the main target species in the 1970s, had decreased by 6% in terms of total weight, while catches of blue whiting and horse mackerel had increased by 47% and 18% respectively. The Spanish mixed trawl fleet includes both bottom otter trawlers (OTB) and bottom pair trawlers (PTB), each vessel employing between 3 and 10 crew members. The OTB fleet, utilises two different gears, baca and jurelera. The baca is the traditional trawl gear used to target demersal species; It has a codend mesh size of 65 mm and a vertical opening of 1.2 to 1.5 m. Jurelera gear also uses a codend mesh size of 65 mm but has a larger vertical opening of 5 to 5.5 m.[2] The trawling fleet is regulated through TACs, technical measures (minimum landing size, minimum mesh size) and effort limitations (including closed areas) and in 2006 a recovery plan was implemented for Iberian hake stock and Nephrops.

Portuguese mixed trawl Fishery (SWW region)

This is the second most important fleet in Portuguese waters after the purse-seine fishery, and comprises two components: 1) the trawl fleet catching demersal fish (using 65 mm mesh size) and 2) the trawl fleet directed at crustaceans (70 mm mesh for nephrops; 55 mm mesh for other crustaceans, (e.g. rose shrimp *Parapeneus longirostris*, or red shrimp *Aristeus antenatus*). The fleet targeting demersal fish operates along the length of the Portuguese coast predominantly at depths between 100 and 200 m; the fleet targeting crustaceans tends to focus its activities south and southwest of Portugal in deeper waters, from 100 to 750 m.

Portuguese fleet has decreased in size since the early 1980s due to restructuring to meet EU legislation designed to adjust fishing capacity to available resources. Vessels have been modernized to improve on-board fish conservation methods and mechanise processing, electronic navigation and fish detection systems have also been installed.

Fisheries management is based on TACs and quotas for certain species and fishing areas, technical conservation measures and limitations on fishing effort. Technical measures used in the Iberian Sea waters include: minimum size/weight for fish caught, minimum mesh sizes,

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[2] **IBERMIX project: Identification and segmentation of mixed-species fisheries operating in the Atlantic Iberian peninsula waters (IBERMIX project) FINAL REPORT to European Commission Directorate-General for Fisheries and maritime Affairs (Contract Ref.: FISH/2004/03-33)**

maximum percentage of by-catch and minimum percentages for target species, and restriction of fishing in certain areas, seasons and with certain gears.

For the mixed bottom trawl fisheries in both Portugal and Spain, expert judgement has been used to predict expected effects of the different management scenarios on the different indicators.

The French mixed bottom trawl fishery on north Biscay presents a situation similar to case study c (see above), and the measures being enforced nowadays are similar to those proposed for the Portuguese and Spanish mixed trawl fleet as reported in recent or ongoing research projects:

The expected results of these combined measures, according to research programs on selectivity and sustainable fishing, still under way (PRESPO project for Responsible Fishing, www.cripsul.ipimar.pt/PRESPO and CHALUTEC, http://www.aglia.org/Dossier.asp?id=7), are reduced catches of undersized *Nephrops*, hake, and also an apparent positive effect for blue whiting, horse mackerel, pouting and squat lobsters. Although these studies have been performed in French vessels targeting mainly *Nephrops* and hake, they could be reasonably extrapolated to the other trawl fisheries.

4.3.1 Management scenarios for bottom trawl fisheries

Scenario to achieve GES

The predicted outcome of an increasing the mesh size (and including grids for *Nephrops* in the French trawl fishery), on the descriptors and indicators, would be:

- Biodiversity and food web descriptors would improve since the indicators proposed (respectively CSF and LFI) are connected to the survival of large individuals. The increase of the mesh size allows the escapement of recruits and juveniles, and therefore the mean size of the population and the survival rate of the species would increase.
- Seafloor integrity would be unaffected if the fleet remains in the same grounds, or it could be affected negatively if fishing effort increases or is displaced to overcome an initial decrease in the catches.
- The state of the commercial (shell)fish stocks would improve, since a reduction in the mortality of recruits and small individuals is expected after the increase of mesh size.
- The Efficiency/Economic profit of the fishery would increase in the medium-long term assuming a larger market value of large fish, and that the catch of larger fishes would increase the benefits with similar effort and costs.
- Stability (TAC) would remain the same or improve, assuming that stock abundance and SSB would be at the same level or increase.
- Community viability/employment would remain the same or improve in parallel to the efficiency and stability of the fishing activity.

- Job attractiveness would remain the same or improve[3],
- Food supply from the fishery remains the same or slight increase in the long term based on the assumption that the stock would be in a better condition.

Scenario to achieve long-term harvest (MSY)

Effort control could be used to attain a multi-species maximum sustainable yield (MSY). This could be complemented by an increase in the mesh size, and implementation of closed areas to protect nurseries.

The expected results of these measures on the descriptors and indicators would be:

- Food web descriptor would improve as to achieve single species MSY requires an increase mesh size and decrease fishing mortality which would allow survival of juveniles and rebuild the stocks. However, multispecies MSY cannot be achieved at the same level for all species and it is likely that some species with lower MSY of the same fishery would become depleted unless multispecies MSY was kept lower in accordance with the larger fish or more vulnerable species.
- Likewise, biodiversity (conservation status fish) would increase if multispecies MSY was kept at appropriate level.
- Seafloor integrity would improve if MSY was complemented by closed areas for nurseries.
- The state of the commercial (shell)fish stocks would improve, due to the reduction of fishing mortality, assuming that this returns stocks to good status and that they are not overexploited.
- The Efficiency/Economic profit of the fishery would increase in the medium-long term assuming a larger market value of large fish, and that the catch of larger fishes would increase the benefits with similar effort and costs.
- Stability (catch) would improve, assuming that the stock abundance and SSB would increase and remain sustainable at BMSY.
- Community viability/employment would improve in parallel to the efficiency and stability of the fishing activity.
- Job attractiveness would improve due to increases in profit and stability[1].
- Food supply from the fishery would increase in the long term assuming that the stock would be kept sustainable.

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[3] It should be noted that discussion at the stakeholders workshop highlighted that job attractiveness was dependent on many societal factors which are difficult to manage and understand using the available technical measures in fisheries management.

Scenario maximum long-term employment (MEMP)

- Food web and biodiversity descriptors could decrease by maximizing employment, the fishing communities increase up to a maximum level depending of the resources exploited. This could lead to negative effects on the structure of the ecosystem by decreasing the proportion of large fish and biodiversity through targeted exploitation.
- Seafloor integrity would be affected if the fleet size and effort increases on the same grounds.
- The state of the commercial (shell)fish stocks would decrease if fleet size and thus effort increases in the same fishery and grounds.
- The Efficiency/Economic profit of the fishery would increase in the short term and reach a maximum in the long term but would decrease in the long-term if stock exploitation is unsustainable.
- Stability (catch) can be attained at a lower value of catch, to allow for SSB fluctuations.
- Community viability and employment would be maintained up to a maximum according to the local resources sustainability.
- Job attractiveness would improve with an increase in profits and could be maximized if resources are utilised sustainably but would fluctuate if the stocks are close to overfishing,
- Food supply from the fishery could increase in the long term if the stocks are exploited sustainably.

Scenario maximum long-term profit (MPRO)

- Biodiversity and food web descriptors would improve as it would be necessary to fish close to FMSY which could be achieved through an increase mesh size or decrease in fishing mortality.
- Seafloor integrity would not be affected if the fleet remained in the same fishing grounds, but if fishing at MSY was complemented by closed areas for nurseries then it is expected some improvement.
- The state of the commercial (shell)fish stocks would improve since reducing fishing mortality at F0.1 or FMSY would be necessary to maintain stocks in a good status and maximize profit.
- The Efficiency/Economic profit of the fishery would increase in the medium-long term assuming a larger market value of large fish, and that the catch of larger fishes would increase the benefits with similar effort and costs.
- Stability (catch) would improve based on the assumption that SSB would be maintained or increased.

- Community viability/employment would improve in parallel with the efficiency and stability of the fishing activity.
- Job attractiveness would improve due to increases in profit and stability[1].
- Food supply from the fishery increases in the long term assuming that the stocks of this fishery would be kept sustainable.

4.3.2 Results

Table 4.12 summarises the expected effects of the different management scenarios proposed for the SWW trawl fisheries in comparison to the Business as Usual (BAU) management scenario; these results are discussed below.

Table 4.12 Summary of expected effects of the selected management scenarios (GES, MSY, MEMP and MPRO) proposed for the SWW trawl fisheries compared to the Business As Usual (BAU) scenario. Colours reflect the expected outcomes of the management measured based on the expert judgement: green, good or best scenario for the descriptor considered; yellow, intermediate scenario; and red, worst scenario for the descriptor.

	Descriptor	BAU	GES for B	MSY	MEMP	MPRO
Ecological	Food web	20	100	80	0	70
	Seafloor	40	100	80	0	80
	Biodiversity	40	100	80	0	70
	Commercial	220	80	100	0	70
Economic	Efficiency	20	50	80	0	100
	Stability	40	60	100	0	80
Social	Community	60	0	60	80	100
	Job	20	0	60	80	100
	Food supply	35	0	100	20	70

Management scenario performance in comparison to Business as usual (BAU):

Food web — For this descriptor GES provides the most effective scenario, followed by the MSY scenario assuming that at MSY the mjaoirty of the commercial species will be kept inside safe biological limits.

The worst scenario to achieve a healthy food web structure is MEMP as this purely focussed on not depleting stocks and there are no special measures to maintain biodiversity.

Seafloor integrity — The best scenario is GES, followed by MSY and MPRO as closed areas (e,g, marine protected areas, MPAs) have been considered in all of these scenarios. However, MPA effects will not be achieved without complementary effort reduction measures being implemented to prevent an increase in effort in areas outside of the MPA boundaries (Rijnsdorp et al., 2001; Dinmore et al., 2003).

The worst scenario is MEMP, since no areas are closed to fishing and no measures to limit effort in the area were considered; this will eventually lead to further degrading seafloor integrity relatively to BAU.

Biodiversity — The best scenario for this descriptor is GES, followed by MSY and MPRO, as MPAs have been conisdred in all of these scenarios and it is expected that these will preserve the quality and occurrence of habitats, and the distribution and abundance of species

The worst scenario is MEMP because no specific measures have been considered to maintain biodiversity and non-commercial species; the only aim is to maximize employment.

Commercial species — The best scenario for commercial (shell)fish is MSY, followed closely by GES and MPRO if we consider that the aim of the MSY scenario is a multispecies maximum sustainable yield by selecting most commercial species. MPRO scenario will be achieved for the most valuable species close to the MSY.

The worst scenario is MEMP, which is similar to BAU if we assume that the maximum work places in the fishery have already been reached.

Efficiency — The best scenario is MPRO, because the maximum economic yield (MEY) will be achieved i.e. the difference between revenues and costs. In the MSY scenario, the costs can overpass revenues but the overall effect would be similar to that achieved in MPRO.

Again, the worst scenario is MEMP; the effects of this scenario are not dissimilar to those currently under BAU if we assume that we have already reached the maximum number of work places.

Stability — The best scenario is MSY because species stock yields would be maintained over time.

The worst scenario is MEMP based on the assumption that increasing the

	number of work places will lead to overexploitation and thus stocks may be more variable depending of annual recruitment.
Community viability	The best scenarios are MPRO, MEMP and MSY because economic profit will make fishers community more resilient and viable. For communities dependent on the fishery, GES would probably be the worst scenario, because it implies the largest restrictions making the fishery less productive. However, other sources of income (e.g. from tourism) could overcome these losses resulting in a diminished impact on community viability.
Job attractiveness	As for community viability, the best scenario is MPRO and MEMP if fishery revenues are directly related to wages. MSY may also enhance job attractiveness. However, if a large number of restrictions are implemented, leading to smaller catches and revenues, job attractiveness in this multispecies bottom trawl fishery will be minimum.
Food supply	The best scenarios are MSY and MPRO as both produce the maximum sustainable amount of protein due to maximized long-term catches. The worst scenario would be GES as the fishery would be controlled and limited in this scenario to favour the ecological aspects (e.g. sea floor integrity and biodiversity) and this will minimize the supply of proteins in the long-term.

5 Synthesis and conclusion

5.1 Multi-criteria decision analysis

In this section we utilised the MCDA decision-support tool to combine stakeholder preferences with the scientific (modelling or qualitative) information to determine the preferred management scenarios for the Fisheries Ecosystem Plans (FEPs) that will be developed for the three regions considered in the MEFEPO project (North Sea, NS; South-Western Waters, SWW; North-Western Waters, NWW).

The stakeholder preferences were based on weightings given to the different descriptors by stakeholders belonging to different interest groups (Policy, Industry, NGO, Science) collected in the workshop in Dublin (Section 3). The scientific information consists of SMART scores per region for each of the management scenarios based on modelling (NS, NWW) or expert judgement (SWW) against as many as possible of the different descriptors belonging to the three pillars of sustainability (Section 4).

Application of the MCDA method to derive the preferred management scenarios allowed the distinction between stakeholder groups so that we could also assess if the preferences of the different stakeholder groups would result in the selection of different management scenarios.

In the North Sea four different management scenarios were considered (Section 4.1); MCDA showed that the BAU scenario performed worse from a stakeholders perspective and MSY best (Fig. 5.1a). For the NWW, 5 different management scenarios were considered (Section 4.2); MEMP preformed the worst and GES performed the best (Fig. 5.1b). For SWW 5 management scenarios were considered (Section 4.3); again MEMP performed the worst but MPRO performed the best (Fig. 5.1c).

For all three regions the difference in weighting between stakeholder groups did not affect the outcome of the exercise, i.e. the selection of the preferred management scenario. This is likely due to the fact that the management scenarios chosen for this exercise were abstractions of some rather crude and very divergent policy aims resulting in large differences in indicator values and thus scores between the different scenarios where one scenario often performs better overall making the weighting based on trade-offs between the different descriptors, redundant. Only when there are distinct trade-offs between scenarios where one performs better on a different suite of indicators/descriptors than the other will stakeholder preferences become relevant in the process.

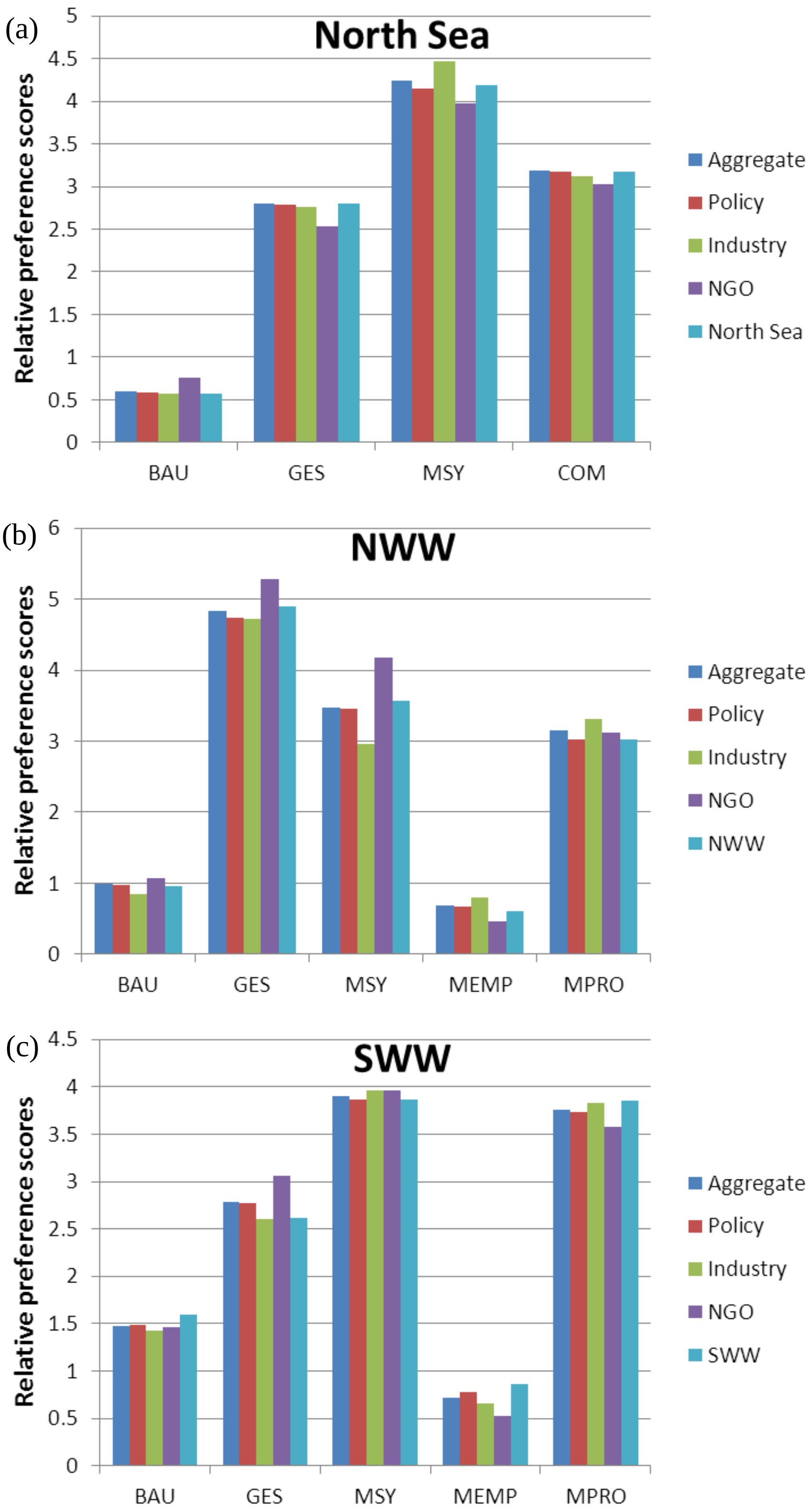

Fig. 5.1 Relative preference scores based on MCDA for the (a) North Sea (NS), 4 management scenarios; (b) North West Waters (NWW), 5 management scenarios; and (c) South West Waters (SWW), 5 management scenarios based on all stakeholders (aggregate), different stakeholder groups and regional stakeholders only (NS, NWW, SWW respectively). (Management scenarios detailed in Sections 4.1 to 4.3),

It is important to highlight that the management scenario names used may be slightly misleading as the actual interpretation of these management scenarios and how they were translated into HCRs determines the outcomes of the modelling exercises and thus the scores against the descriptors. For example in the North Sea this does not necessarily mean that management to achieve MSY would always outperform management aimed at achieving GES, COM or even BAU, just that this particular HCR considered to represent management aimed at achieving MSY outperforms the other specific HCRs. This also may explain (part of) the differences between the regions where for example the GES scenario performed best in the NWW, 2nd best in the North Sea (after MSY), and 3rd best in the SWW (after MSY and MPRO).

The scenario for GES that was initially phrased as, “The goal of this management scenario is to achieve the minimum ecological requirements for Good Environmental Status. To meet these minimum conservation requirements involving biodiversity, foodweb, commercial fish species and seafloor integrity by aiming for existing targets or at least avoiding further ecological degradation” (Section 2.2). However, this scenario was interpreted and approached differently in each of the regions:

- In the North Sea the following HCR was applied: “If the LFI is below 0.3 then the effort of all the beam- and otter trawls and the F of Norway pout is decreased with 10%. If above LFI then it is increased again” (Section 4.1).
- In the NWW effort regimes were selected that “Maximise total value of landings whilst improving biodiversity commercial species indicators by 2 species, and improving LFI and relative trawl intensity indicators” (Section 4.2).
- In the SWW the following management measure was evaluated “increasing the mesh size (and including grids for nephrops in the French trawl fishery)” (Section 4.3).

As such it may not be appropriate to compare the GES scenario from one region with that from another; in some cases it may even be more appropriate to compare GES with another scenario (e.g. the MSY scenario in the SWW is about reduction of effort, which may be more comparable to the GES scenario in another region).

5.2 Summary

This exercise has demonstrated that the decision-support tool applied here can deliver a preferred management scenario in a formal and transparent process that takes the stakeholders opinion into account and combines this with scientific evidence. Common perception is that the stakeholder involvement part should be considered the subjective or “soft” part of the process while the science part is the objective or “hard” part. Our results, however, have shown that in spite of the subjectivity the different views of the stakeholders had little affect on the outcome of the process. In contrast we found that there were big differences between regions in how “hard” the available scientific evidence; in the NS and NWW simulation models were applied varying in the level of sophistication and thus data requirements while in the SWW this was based on expert judgement. Moreover, considerable health warnings were given in both the NS and NWW sections on the assumptions we needed to make in these models and on the confidence in the model output in general. The sensitivity analysis conducted for the NS showed that at least some of these assumptions had considerable consequences on the model output and thus the outcome of the process.

While the framework presented in this report appears to be suitable to deliver the "best" management scenarios to achieve policy objectives there are still major issues with the scientific information supposed to underpin this framework. Points for consideration include:

- Choice of descriptors: descriptors for the ecological pillar were drawn from the MSFD but descriptors for the economic and social pillars were selected by the MEFEPO team. What other descriptors could have been used, and how does the choice of descriptor influence stakeholders' weightings of the three pillars?
- Choice of indicators: the choice of indicators for the descriptors was influenced by the availability of suitable (quantitative) data. Were the indicators that were used appropriate for the descriptors and how does the choice of indicators influence stakeholders' weightings of the descriptors and pillars? What other indicators could have been used?
- Given that data on some of the indicators was lacking (particularly for the SWW region), how can we incorporate data from quantitative simulation models with wider empirical evidence and expert judgement and provide robust advice to assist the decision-making process?
- What is the best scientific information available? In terms of the amount of information that is used in a formal framework, sophisticated quantitative simulation models should be preferred to empirical evidence which in turn should be preferred to expert judgement but for each of these sources of information there are issues to be considered (see below).
- Scientific models are based on various sources of information, with varying degrees of reliability, and assumptions e.g. the processes that determine the output of the models. Whilst there will always be issues with confidence in the model outputs, how can we highlight the key issues to decision makers to ensure that uncertainty in model outputs it considered in the decision-making process (e.g. sensitivity analyses, or by combining output from more than one model)..
- More subtle differences in management scenarios should be examined to see how stakeholder preferences affect the choice of preferred management scenarios.
- Finally, in light of potential changes in terms of influence of wider stakeholder groups and governance structure, highlighted in previous MEFEPO work packages (WP3, Aanesen et al. 2010; WP4, Raakjær et al. 2010) it is important for the scientific community to identify who the information is for, to ensure that the information provided is appropriate and accessible to the wider stakeholder community.

5.3 Future preference survey and work packages

Information on stakeholder preferences is useful as preferences may affect the way regulations are formulated. To date we have collected preferences data from 34 respondents (21 workshop attendees and 13 MEFEPO project team members). We are currently in the process of extending the preference survey to approximately 80 respondents to examine the reliability of the weights assigned to the pillars and the descriptors; 5 additional respondents are being sought in each of the MEFEPO project countries (of which there are 10): 2 from policy, 2 from industry and 1 from NGOs.

We will use these results to calibrate a model, where we derive the optimal regulation for a government to set in managing the fisheries activities. This optimal regulation crucially depends on how the government weights the different interests attached to the fisheries, represented by environmental, social and economic interests. We also plan to extend the model to ask how the optimal regulations will be altered if new stakeholder groups, such as NGOs are given a say in the fisheries management.

Finally, alternative models for fisheries management within the EU have been explored in WP4 (*Exploring the Option of Regionalising the Common Fisheries Policy;* Raakjær et al. 2010). The inclusion of new stakeholder groups and changing the hierarchy within the decision making process may also affect which regulations is optimal. These issues will be examined when we look at the operational challenges to introducing an EAFM in the next WP (WP6).

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Annexes

Annex 1: 2-pager developed for the WP5 stakeholder workshop

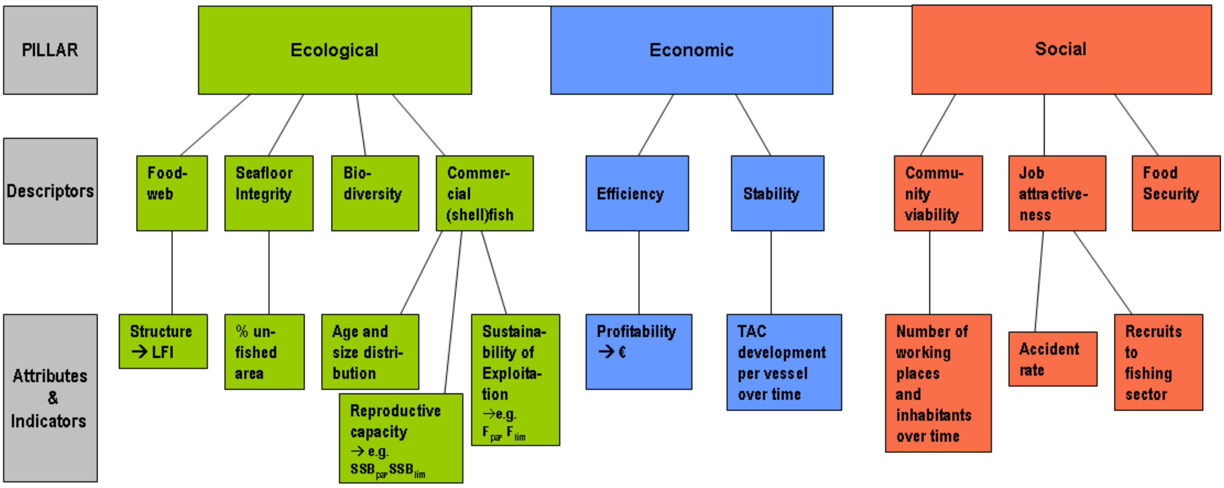
We are seeking your Input and Feedback

The EU project MEFEPO is working towards integrating requirements of the Marine Strategy Framework Directive (MSFD) into operational fisheries ecosystem plans for three major European marine regions (the RAC regions: North Sea, North Western Waters, and South Western Waters). These plans shall provide a vision of the regional ecosystem approach and a description of how it can be achieved. Ecological, economic, and social concerns need to be accounted for equally and concomitantly.

The hierarchical tree below illustrates the MEFEPO approach of monitoring the three pillars of sustainability on the basis of specified descriptors, where each descriptor is linked with a specified indicator. This is based on an approach chosen for the development of the descriptors of Good Environmental Status (GES) for the MSFD.

For the ecological pillar, four of the eleven MSFD GES descriptors were selected, as they are considered the descriptors most impacted by fishing. Similarly, descriptors were selected for the economic and social pillars to assess their development under the different modeled scenarios (cf. next page).

Have we selected the most crucial descriptors/ indicators?
Which of them do you consider redundant?
Are there other factors missing that you consider crucial?



Food-web: →It is important to maintain a healthy foodweb **structure**, specifically the ratio of small and large fish, as this increases the stability of the system (LFI, Large Fish Index). **Sea floor integrity:** →It is important to preserve a certain **percentage of un-fished area** to strengthen the resilience of the marine ecosystem. **Biodiversity:** →It is important that quality and occurrence of habitats and distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions. **Commercial (shell)fish:** →It is important that the **exploitation levels** do not harm a **sustainable** use of commercial species. →It is important that the **spawning stock size** (SSB) of commercial species is high enough to secure **recruitment**. →It is important to have a well developed **age and size structure** of commercial species as this improves stability and resilience of the system.	**Efficiency / Profitability:** → It is important to **optimize** the economic outcome of fishing (average **profit** over a number of years). **Economic stability:** → It is important that **catch opportunities (TACs)** are somewhat predictable over time.	**Community viability:** → It is important that communities dependent on fishing activities are resilient in **population and employment** and that they have capacity to absorb and overcome change. **Job attractiveness:** → It is important to ensure safe working conditions and reduce the number of industrial **accidents**. → It is important to attract **new, young employees**, recruiting to the industry: **Food security:** → Population growth increases the demand for proteins from the sea; it is thus of vital importance that the harvest of these proteins is sustainable and optimised.

Using case studies of specific fisheries operating in each of the three RAC areas, we will explore comparative management scenarios, using a range of management tools, which aim to maximise benefits to each of the three different pillars. The five scenarios described below represent extreme situations. By comparing scenarios with different management goals, we can investigate the trade-offs between social, economic and environmental status, such as the impact on the social and economic pillars of achieving Good Environmental Status in 2020 – the goal of the Marine Strategy Framework Directive.

The scenarios differ in emphasis with respect to the pillars of sustainability, see the brief descriptions below.

Please give us your feedback on the usefulness of these scenarios.
Do they make sense to you? Do they cover policy relevant issues?
Which of them would you modify and how?
Do you have any additional scenarios that you think are relevant and important ?

1. Business as usual (BAU)

This scenario is the current situation against which the other scenarios will be compared. No particular emphasis is given to any of the three pillars.

2. Achieve Good Environmental Status

The goal of this management scenario is to achieve the minimum ecological requirements for Good Environmental Status. To meet these minimum conservation requirements, the following ecological aspects are important and need to be included in the modelling: biodiversity (no loss of species accepted); commercial fish species (all stocks need to be above the precautionary biomass level); Natura 2000 areas and corridors need to be implemented; no further ecological degradation is accepted.

3. Maximum long-term harvest

Emphasis is put on the ability to harvest food from the sea. There is a strong link with the social pillar, contributing to global food supply. In order to achieve a sustainable harvest of seafood, it is a prerequisite that commercial marine species are in a healthy status, and seafood needs to be affordable. Eventually, a multi-species maximum sustainable yield (MSY) could be the target value.

4. Maximum employment

Emphasis is put on the social pillar, where the resilience of communities depending on fishing activities is important. This is closely linked to the economic pillar as stable TACs give a certain security. Often, there will be a threshold for the number of working places and people in a community, beyond which most social and welfare services are closed down. This will start a downward spiral which often ends up in a depopulated community.

5. Maximum profit

Focus lies on the economic pillar. This scenario emphasises economic efficiency, which involves maximising economic yield (MEY), i.e. the difference between revenues and costs. This often implies that the most efficient vessels are first employed and then more inefficient vessels are employed until the catch opportunities (TAC and/or other limitations) are exhausted.

Annex 2: Comments received on the 2-pager (informal interviews)

Contents

Summary of stakeholders' comments on the 2-pager (informal interviews) and responses (R) from the MEFEPO team where approrpriate.

2.1 General comments to the framework and our approach

Governance framework

A governance/institution/policy evaluation framework is missing, decision making systems, political issues etc. Is information from fisheries management accessible, transparent? Do stakeholders know about different views and possible management choices?

R: We are currently unable to include the governance aspects into the modelling. However, governance formed the focus of MEFEPO WP4, so the knowledge is there.

Links between pillars

There was criticism that links between the pillars were neglected. The tree is only linear/ hierarchical and does not include interactions between the pillars. The interconnection complicates things, making the focus on single descriptors perhaps strange and even wrong. Feedback between pillars should be included, and there should be feedbacks in the model.

It was criticised that we are still not really "operationalising" ecosystem based management.

It was suggested that the ecological pillar is the foundation for the rest.

R: The idea behind our framework is to work down from policy objectives to measureable indicators. And to develop models that can address those.

Data availability and quality

Stakeholders have doubts about the data availability for the indicators included: "the starting point is deficient in scientific and technical information".

R: This is a valid point and lack of data is a big problem. However, this is no excuse to wait, because there will always be gaps and uncertainties in knowledge. Since we are aware of the gaps and caveats,we are trying to be open about our abilities and capacities, and we do not promise to model the whole system.

Relevance and suitability of descriptors

It was highlighted that not all descriptors are relevant for each case study/ fishery e.g. for the Portuguese trawl fleet, community viability, number of working places, and accident rate were considered not relevant. In contrast, recruits to the fishery are relevant for the trawl fleet. Biodiversity is considered as relevant for the artisanal fleet.

R: We need to make sure we clearly explain hat different case studies might require different inputs or produce different effects.

Clarity of our approach

Scale (time, business (vessel, fleet)) is often lacking, but is very important.

R: Scales will be defined, case-study and indicator specific.

It was unclear whether the modelling is based on a fisheries or an area based approach.

R: We need to make clearer that our modelling is an area based approach, and therefore it does take account that an area is often exploited by several fisheries. We are aiming for a real ecosystem approach, but this is challenging.

Why are we not using ECOPATH in the Bay of Biscay case study? (SWW fisheries so far excluded due to lack of data and resources).

R: We are not using ECOPATH, because it requires too many parameters that are either unknown or uncertain. It is very much a black box.

2.2 Pillar specific reactions/ comments/ modifications:

(a) Ecological pillar

General

In a permanently changing world, how are we dealing with natural cycles of species, succession, or invasive species? Can we adjust natural goals to the appearance of new species and their sustainable exploitation?

R: These are relevant issues, but go beyond what we are currently able to include in the model. There is too much uncertainty and information is lacking, so we have not included the alien/ invasive species descriptor. The indicators "energy flow" and "structure" are not currently measurable, hence we omit them.
Food-web structure is based on both, commercial and non-commercial species (LFI), in contrast to the age-structure of commercial species.

It was suggested to focus on different life history traits, e.g. to investigate how many species exist where information is available about catch, F, B/SSB, Bpa/Blim and what is their current status.

Descriptor for sea floor integrity

This descriptor needs to be defined better. Stakeholders feared that it implies the establishment of new MPAs or other closed or no-take zones. In the MSFD, sea-floor integrity is listed as descriptor 6, together with the following explanation, "*Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected*." We can identify untrawled areas with VMS (and unfished areas exist, also in the Bay of Biscay). A problem is the choice of time scale for areas untrawled or trawled, as it depends on the modeler's choice. We should keep the indicator (% unfished) because we might get areas untrawled in the future. What is the time scale regarding seafloor integrity that we are looking at in the models? Is it true that the indicator as calculated in the model is on a yearly basis? Is the indicator appropriate?

R: We have we not included anything on sensitive and fragile habitats. As part of the CFP, scientists had been asked to advice on input to address ecosystem issues. This was done by identifying indicators. The % unfished indicator was one of the indicators proposed, and it has been adopted by the Commission in the MSFD. GIS maps on fragile habitats do not exist. However, at the moment we have no data to include the % unfished indicator in the models.

Descriptor for biodiversity:

What are the spatio-temporal scales of the biodiversity descriptor?

R: We need to include the descriptor biodiversity, as it is required by policy (MSFD). Indicators for biodiversity are available, but coming up with the appropriate indicator is difficult. There are many different indicators, but there is little guidance on selecting the most appropriate one. Hence, biodiversity is difficult to include in a model.
In WP2, conservation status was suggested as an additional indicator, but we cannot model it.

Descriptor for commercial fish:

What about non-commercial species?

R: Theoretically, they are included under the biodiversity and foodweb descriptors; practically they are not yet included in the models. We are still working with single species reference points levels and not only with MSY, because this approach was decided on earlier in MEFEPO WP2.

(b) Economic pillar

General

Overcapacity and subsidies are missing.

R: Capacity is a poor indicator, as it does not include the activity of the vessel. These are structural problems. We are not looking at potential capacity (e.g. the optimal level). Overcapacity, as a measurement for inefficiency, could possibly be measured in relationship to the profits (i.e. negative profits means subsidies or overcapacity), but data to incorporate this are not available.

Issues relating to compliance and control are missing.

R: We could look at compliance, e.g. number of illegalities correlated with declines in TAC, negative profits, etc., and combine these with the scenario outputs in the models. Could it be measured in relationship to negative profits → non-compliance?

Are we dealing with harvest rules under stability?

R: The focus should be on developing operational policy options and not on dynamics.

The Community viability descriptor should be also included here, not (only) under the social/ cultural pillar.

Descriptor for stability

Our initial indicator proposal was "TAC development per vessel over time". However, stability of TACs is no guarantee for economic survival, if prices are low (e.g. NS plaice). Also, there are many species without a TAC.

R: Hence, we changed the original indicator "TAC development per vessel over time" into an indicator related to direct effort control, i.e., the indicator is now "harvest development per vessel over time", which is driven by effort.

Descriptor for efficiency

Additional indicators were suggested for efficiency: TACs, number of vessels, gross turnover in tons per vessel. We have included any aspect that refers to competitiveness? But there is confusion about our use of terminology. Also, there is a need to explain the method of calculating the measures that are incorporated in the model, e.g. efficiency, rentability, profitability.

Some stakeholders expressed concerns about the efficiency measures (i.e. indicators). High profitability may lead to underutilization of less profitable resources (e.g. a move from 100 to 50 trawlers in Norway over 10 years' time). Why do we not consider CPUE?

R: Due to the complexity of the whole model, the individual components are still quite simple. The economic pillar is static, and the components do not include feedbacks.

Business scale is important.

Resource rent versus profits: fishers see fish as a private resource compared to it being a resource for society as a whole.

R: In our modelling, resource rent is included, we look at the total product.

Effort costs are measured differently for different fleets and métiers.

R: We are trying to apply different effort costs depending on métiers.

Does the variable fuel prices drive changes in profitability such that predicting profit is mainly an exercise in predicting fuel costs?

R: We could easily provide other output, e.g. landings per effort unit.

(c) Social pillar

General

Cultural value is missing as a descriptor or indicator.

R: It is difficult to quantify it therefore we cannot include it. We could make narratives.

There is nothing on import-export.

R: We are not comparing the EU to the rest of the world but rather to the fisheries sector itself. Thus we are concentrating on evaluating fisheries on the first hand basis, not including import-export.

Descriptor of community viability

The indicator number of employment is not considered sufficient.

R: We did discussthis when we chose the indicators. It is currently not possible to include other indicators, due to lack of data or knowledge. Indirect fisheries employment (e.g. in the gear, boat construction, canning sectors) is taken into account through multipliers.

Instead of "working places" it would be better to say "jobs" or "firms", because "working places" is ambiguous. Both are good indicators and number of different firms can be argued to be a truly social indicator while straight employment is really economic. Both could be used with number of different firms (or rather a gini coefficient of fishing income over firms) being an indicator of community viability and number of jobs (perhaps also something measuring compensation levels as that is really job attractiveness) being an indicator of job attractiveness.

R: At the moment it is not deemed feasible to include data on jobs or firms and to include the distributional issue. Hence we prefer the more undefined term "working places" for the moment.

Community viability is both an economic and social issue. It could be interesting to score the social/ cultural importance of fishing in coastal communities, where fishing is still important for the identity of a town and its economic contribution.

R: Indirectly we take this into account through employment in the coastal communities and the size of the communities, for the different scenarios.

It was suggested to move "number of working places" down to the job attractiveness descriptor, and then use "% of fishers active in fishermen's association" or something similar as an indicator of community viability.

Add to community viability the indicator "ability of fishers to shift to alternative fishing opportunities/ other marine-related employment".

R: This is a valid comment, but here we have utilised a different approach.

Descriptor of job attractiveness

The following indicators should be added: port facilities quality, resource availability, landings, number of other vessels which practise the same fishing, turnover for one species, number of employment.

R: The indicator income per fisherman has been included.

Expensive capital inputs (large vessels, costly quotas) are barriers to recruitment to the fishing sector.

R: We have no indicator and do not know of one that takes account of this. Also, we cannot consider anything concerning the improvement/certification of young fishers' education, as no indicator exists.

Descriptor of food security

Why have you not included any indicator/ metric here? The UK government is interested in food security. The indicator would be harvest.

R: We do not have a stuiable indicator available here yet. We acknowledge that it is an important descriptor but we do not currently know how to measure it.

2.3 Comments/suggestions concerning the management scenarios

General comments

In general, our choice of scenarios was perceived as relevant. Opinions differed with respect to the question whether a particular scenario should be removed, modified or an additional one added.

The stakeholders could see the usefulness of the scenarios as a tool to check whether it is possible to balance the different ecological, economic and social objectives against each other in the management process that comes.

Nonetheless, we need to make clearer the connection between the 3-pillar framework (the "tree") and the scenarios. Which indicators in the "tree" should or do provide input to the scenarios; which can be output?

Specific comments

The proposed scenarios created confusion. It was criticized that there is an imbalance, with three scenarios for the environmental pillar (1,2,3), and just one each for the social (4) and economic (5) pillars.

R: In fact, in scenario 1 no emphasis is given to either one of the pillars. Scenario 2 assumes that the ecological pillar sets the boundaries for the rest. Scenario 3 is the scenario with the best balance between all three pillars. Therefore, we assume that the confusion arose due to the language used. We rephrased our scenario description, where appropriate, trying to be as clear as possible.

Originally, in the GES scenario description, we included the phrase, "no loss of species is accepted", taken from previous work in the GES working groups. This was not considered realistic and not natural. Species appear and disappear; dynamics/variability is natural. We should take into account the natural dynamics in populations and ecosystems and be more interested in the new species that are coming than in trying to keep the old state. Not all changes are man-induced.

R: This is relevant but we cannot incorporate such potential changes in our scenarios. However, the explanatory text of the GES scenario was .

The usefulness of the " Maximizing profits" scenario was emphasised, as it ensures good jobs and safe capital gear (vessels). It also feeds into the creation of other productive entities in coastal communities, as well as cultural values.

Suggestions for alternative scenarios

- A scenario combining the maximum employment scenario (maintaining coastal communities, especially in regions highly dependent on fisheries) with the GES scenario.
    R: We could combine the GES scenario with the employment scenario, but the aim here was to show extremes.
- A scenario without any technical measures, to show the effect of fisheries management and policy on the ecosystem.
- A scenario to investigate the effect of fishing on seafloor integrity

- A scenario on reversing the burden of proof; e.g. changes in fishing fleets in Norway create more responsibilities for fishers.
- Suggestion to focus more on maximum sustainable mortality, i.e., taking into account that not all fish is actually landed (discards). Many countries have discard surveys. We can distinguish between discards and landings, and hence we should be able to say something about total mortality.
- A scenario on discards and land-based waste of food recourses (e.g. reduction vs consumption fisheries; scenarios that reduce discards).

2.4 List of persons who provided feedback, by country

Interviewing institute	Name of interviewee	Occupation / relationship to fisheries management
IFM, DK	Douglas Kongshøj Wilson	Colleague at IFM, has participated in/coordinated numerous EU research projects
IFM, DK	Christian Olesen	Director Danish Pelagic PO
IFM, DK	Aukje Coers	Pelagic RAC, executive secretary
IEO, ES	José Ramón Fuertes Gamundi	ARVI (Vigo harbour Ship-owners' Cooperative)
Uni Brest, FR	Benoit Guerin	SWW RAC member, general secretary
Uni Brest, FR	Benoit Figarede	SWW RAC member, AGLIA Grand Littoral Atlantique Association
Uni Brest, FR	Marie Sebire	SWW RAC member
IMARES, NL	Ton IJlstra	Dutch ministry (LNV / EL&I)
IMARES, NL	Dr. Tammo Bult	IMARES, Head of fisheries department
Uni Tromso, NO	Ian Kinsey	Coastal fisherman, active in Norwegian Fisherman's Association
Uni Tromso, NO	Tor Are Vaskinn	Norwegian Fishing Vessel Owner's Association (Fiskebåtredernes Forbund), Tromsø office
Uni Tromso, NO	Guri Kristin Hjallen Eriksen	Norwegian Ministry of Fisheries and Coastal Affairs, section: Ocean and Coastal Resources
IPIMAR, PT	António Shiappa Cabral	ADAPI General Secretary and Distant Waters RAC; Fleet Segment: Multispecies Bottom trawl
IPIMAR, PT	Cristina Moço	Fleet Segment: Artisanal fleet
CEFAS, UK	Paul Dolder	Department for Environment, Food and Rural Affairs, Sea Fisheries Conservation

IEO, ES	Javier Garat Pérez (contacted, no feedback received)	CEPESCA (Spanish Fishing Confederation): FEOPE: Spanish Federation of Fishing organisations; FEABP: Spanish Federation of fishing ship-owners; ONAPE: National organisation of fishing associations
IEO, ES	Enrique Paz Setién (contacted, no specific feedback received)	Secretary of the Federation of Fisher Associations in Cantabria; Chairman of the anchovy working group of the SWW RAC region

Annex 3: Stakeholder comments (Dublin workshop)

Dublin, 3-4 November 2010

Contents

Stakeholder comments were recorded during the workshop and are summarised below. Responses or reaction from the MEFEPO team are included where appropriate (indicated by "R").

3.1 General comments

General comments

The MEFEPO project was considered to be very useful and timely.

MSFD

The workshop focussed around the MSFD and several comments related to this topic were received.

The stakeholders are aware and see the "MSFD-train" approaching. The challenge for the future is to integrate the MSFD in the CFP and/ or vice versa. The development of the CFP was compared to a crystal road. In contrast, the MSFD seems to have been developed in a rush, in the absence of the fishing industry and national ministries. This MEFEPO meeting, with presence of fishing industry, national ministries and NGOs was therefore considered novel ("surprising and very interesting").

How does an MSY approach (as suggested in the MSFD) fit in the EA? What if the MSY approach is going in a different direction that what an EA requires?

R: MSY boundaries are defined by other ecosystem components.

A limitation of fisheries models is the assumption that humans are rational operators and have complete information, and that based on this information they would make the correct decisions. However, in reality this assumption is almost always incorrect.

In fisheries and marine management, there are already several existing stakeholder bodies and management organisation (RACs, ACFA, OSPAR, HELCOM). Their roles need to be evaluated and re-formulated. There is no need for more than the existing bodies.

The regional dimension is re-emphasized in the MSFD. The importance of spatial planning was emphasised, in light of the increasing amount of new marine players/sectors. The fishing industry needs to develop a spatial strategy.

Pillar structure and importance of the pillars

Fundamental principles: The 3 pillars are not sufficient. The governance pillar is essential and missing. Without governance, the whole pillar structure collapses. Quality of governance is the main thing!

R: During the course of the workshop, there was agreement that governance cannot be just added as a fourth pillar; it is more like the glue that holdes the pillars together.

The MEFEPO team argued that governance has partly been included in our approach already, mainly through the choice of management scenarios: Each management scenario is somewhat based on an assumption with respect to the governance structures in place.

There was no consensus in the group on which of the pillars is the most important. It was stressed that the economic and social dimensions are necessary to reach robustness. Regional diversity needs to be recognized. Focussing only on models that maximise the economic outcome can be counterproductive in this respect. Several stakeholders called for the need to look in more depth at the economic measures. Economy is perceived as THE driving force to improve sustainability but the economic pillar seems to be the least sophisticated component in our models.

We should be creative, innovative, thinking of new shapes of the fishing sector, a completely different world. A diversified industry is regarded as the common goal. The fishing industry has the ability to innovate and is working on methods to improve fishing. Subsidies should be used to shift from the conventional management system to a new, innovative governance structure.

Fishers feel marginalised by bureaucracy and by other sectors, and small players in a large system alongside bureaucrats, scientists, large scale fishing companies. Fisheries are affected by ecological, economic, and social, aspects. Scientific advice is asked for from ICES.
How are the three pillars integrated?
R: We are trying to integrate the pillars by including the stakeholder preference weights into our analyses.

Regionalisation

In previous MEFEPO WPs, work focused on aspects of regionalisation of the CFP. Based on this work, different governance mechanisms that could be employed to deliver an ecosystem approach in line with the MSFD were presented to the stakeholders. The presentation focused on 3 models of regionalisation, based on modifications of the existing Regional Advisory Council's functioning, responsibilities and powers.
Stakeholders are looking for a formalised regional model
MS are more conservative, in terms of developing a pragmatic cooperative solution.
RACs are perceived as a level playing field and the body for governance but it was suggested to check how often advice from the RACs has been followed. The need to optimise the functioning of the RAC's was indicated.
There was no consensus concerning a reversal of the burden of proof. On the one hand it was asked, why does a modified management system need to be democratic? It was suggested that monitoring and management could be transferred to the industry. On the other hand, the fishing industry fears that the burden of proof will be too heavy for the industry, and it was suggest that the burden of proof should stay with the policy makers.
Implementation is an important aspect of governance.

Legal issues

There may be legal impediments, particularly in relation to provisions in the EU treaty (treaty of Rome). However, it was perceived that if there is the will to make changes, then there will be wasy to achieved change. Legal issues depend on the nature of powers that are delegated. In principle, essential legislation cannot be delegated. However, there is room for discussion and not everything is set in stone. There must be discussion on the detailed management decisions.
It was highlighted (by a lawyer in attednace) that it is necessary to distinguish between exclusive and shared competence in EU legislation. Conservation of marine biological resource (the CFP) falls under exclusive competence of the EU. However, it may be possible to delegate powers, even in areas of exclusive competence.

Data availability and quality

It was suggested that qualitative and quantitative modelling approaches should be combined. In particular in the SWW region, where quantitative data is largely lacking. We should not just rely on the models, we need to combine and enhance understanding with qualitative data and justification.
Furthermore, we need to be more transparent about our approach: When and where is our approach based on qualitative and where on quantitative data?

Suggestion for future focus – the struggle with simplicity versus complexity

Stakeholders highlighted the struggle between the need for simplicity and the need for complexity in order to deliver useful results.
It was suggested that the models shouly be improved rather than increased.
We should work on improving data input, parameter assumptions, and verifying model structures. It was not conceived as promising to increase and further complicate our model by additional factors/ indicators.

Workshop considerations

The information that MEFEPO provided before the workshop was not considered to be sufficient. It was suggested to be more explicit next time about what we are doing and why. Approximately 10-12 pages with informative text were considered appropriate. Also, we should be clear about what we are going to do with the stakeholders' input.
The stakeholders indicated that they would like to provide feedback on the workshop through a feedback questionnaire.
R: The MEFEPO team prepared a feedback questionnaire and distributed it via email. The evaluation of the answers will be used to inform preparation and structuring the next MEFEPO workshop (WP6, April 2011).

3.2 Pillar specific feedback

Stakeholders expressed concerned as to whether or not the the economic and social descriptors and indicators utilised were the most relevant and suitable. Related to this, the questions "Are the models fit for purpose?". The models and outputs may look OK but do they reflect reality? It seems that we are missing proper indicators.

R: Our approach is based on the selection of indicators in the MSFD process to define GES but data availability remains a big problem. For many descriptors, we had to come up with our own indicators (although this is not to say that we invented our own proxies). We have probably not been clear enough in explaining our approach and the process. We need to put more effort into clear and transparent communication.

(a) Ecological pillar

General

It was suggested that marine litter could be included as this is a severe and important threat, stemming from both recreational and commercial activities.

R: We decided to follow the MSFD approach in defining GES. Marine litter has not been included as an indicator there. We do not want to change the underlying structure of the ecological pillar that has been thoroughly thought through by many marine experts.

Descriptor sea floor integrity

What scale and reference levels are we talking about? How many times trawled per year? Do we want no seabed disturbance at all?

The stakeholders rose a number of aspects that should be taken into account when dealing with seafloor integrity:

- The number of vessels operating in a specific area
- The speed of the vessel, when beaming
- Does static gear also have an impact?
- What exactly are we measuring?
- What is the reference level?
- What is the temporal scale?
- How many times can an area be trawled, per month, year, decade?

R: Other measures are possible. The selected indicator is "amount of disturbed sediment", based on the MSFD approach. Reference levels have to be decided and established by the EU MS in the MSFD process.

The selection of this indicator is based on the assumption that sea bed disturbance is bad/ unfavourable. Some stakeholders believed that this assumption is wrong. Some believe that ploughing the seabed is positive. Ploughing may be good for commercial fish. Reference was made to the plaice box in the North sea, where despite a beam trawl stop, the original ecosystem state did not come back.

R: There is now scientific consesnsus that trawling does not have a positive impact on the seafloor. Thus, the smaller the proportion ofseabed disturbed, the better.

There are differences in priorities: Why is the protection of seafloor necessary? It is a European obligation, under the habitat directive, to bring the seafloor in a shape that is favourable for commercial fish. It is thus not necessary to return to a pristine state of the seafloor.

R: The MSFD requires GES for the seafloor integrity. This does not necessarily imply a pristine state.

Technical comment: the number of descriptors per pillar is different.

(b) Economic pillar

General

It was suggested to look at the aggregate of vessels in a whole region instead of focussing on an individual vessel basis only.

R: Unfortunately this is not possible due to time limitations, .

Descriptor stability

This descriptor was considered to be important with regard to long-time security in fishing licences, in market stability, price stability/ fluctuations.
In general, the importance of the wealth of the entire sector was emphasized.

Descriptor efficiency / profitability

It was criticised that subsidies were not included in our framework.
In general, it was suggested to get rid of subsidies in fisheries. The fishing industry should become self-sufficient.

(c) Social pillar

General

How can the translation be made from fishing effort to social effects?
Cultural values are missing, but how can a value be put on tradition?

Descriptor job attractiveness

It was suggested to use “income in the sector” as indicator for the descriptor job attractiveness.
From a geographical perspective it was considered that looking at the number of people working on vessels was too limited,.
Several other descriptors/ indicators were mentioned to be related to job attractiveness:

- income (e.g. per unit effort)
- safety
- social status
- skills
- value of the industry to society.

Descriptor food security

Food security was perceived as an important indicator, but it should be wider than what our chosen indicator (maximum value of protein produced by the sea) suggests. It may be difficult to combine food quality with maximum yield.

R: We agree that focussing on protein value is a very simplified approach, but it is important, and it can be related to population growth.

We also need to include a scale aspect here, e.g. protein value over a time period. We could then optimise the output from the sea. Note that the wild fishery will still remain an important protein contributor.
Food supply, import export.

3.3 Comments/ suggestions concerning the management scenarios

General comments

It was realised, that ecological, economic and social objectives are not necessarily always conflicting.

Specific comments

It was considered essential to include employment on land (multiplier effect).

Suggestions for alternative scenarios

An employment scenario with decreasing employment at sea
A scenario with plenty of fish and few fishers

3.4 List of participants

NAME	ORGANISATION
1. Almudena Gómez	Confederación Española de Pesca (CEPESCA) (Spain)
2. Andrew Clayton	DEFRA (UK)
3. Antonnio Cabral	ADAPI - Associação dos Armadores das Pescas Industriais (Portugal)
4. Christian Olesen	Danish Pelagic PO (Denmark)
5. Cora Seip - Markensteijn	Productschap Vis (Netherlands)
6. Eibhlin O'Sullivan	Irish South and West Fish Producers Organisation (Ireland)
7. Ellen Kenchington	Department of Fisheries and Oceanography, Canada; Chair of MEFEPO Advisory Committee
8. Guri Eriksen	Advisor in the Ministry of Fisheries and Coastal Affairs, Ocean Resources and the Coast (Norway)
9. Ian Kinsey	Fisherman (Norway)
10. Jacques Pichon	ANOPROD (national organization of producers) (France)
11. Jonathan Moore	ClientEarth (UK)
12. Josephine Kelly	Department of Agriculture, Fisheries and Food (Ireland)
13. Lyndsey Dodds	Project PISCES (UK)
14. Marie Sebire	SWW RAC (France)
15. Melissa Pritchard	ClientEarth (UK)
16. Monica Verbeek (absent)	Seas at Risk (Belgium)
17. Poul Degnbol	Guest Speaker - Head of Advice, International Council for the Exploration of the Seas (ICES) (Denmark)
18. Sean O'Donoghue	Killybegs Fishermen's Organisation (Ireland)
19. Ton IJlstra	Ministerie van LNV, Directie AKV (Netherlands)
20. Willem Brugge	European Commission, DG MARE (Belgium)
21. Xoan Lopez	Federation of Galician Fishermen (Spain)

Annex 4: Different preference questionnaires (Dublin workshop)

In each questionnaire, we asked stakeholders for the following **background information**:

Nationality			
Disciplinary background		**Professional background**	
- natural sciences		- policy	
- social sciences		- science	
- economics		- industry	
- interdisciplinary		- NGO	
- other		- other	

1. In the first questionnaire, we asked the stakeholders to assign their preferences as a **weight** to the **descriptors.**

Please assign a weight between 0-100 to each of the descriptors, such that the weights sum up to 100

Indicator	**Weight**
- foodweb	
- sea floor integrity	
- biodiversity	
- commercial fish	
- efficiency	
- stability	
- community viability	
- job attractiveness	
- food security	
Sum	**100**

2. In the second questionnaire, we asked the stakeholders to assign their preferences as an **importance** score to the descriptors.

Please assign an importance score from 1-6 to each of the descriptors where 1= not important and 6 = very important.

Indicator	**Importance**
- foodweb	
- sea floor integrity	
- biodiversity	
- commercial fish	
- efficiency	
- stability	
- community viability	
- job attractiveness	
- food security	

3. In the third questionnaire, we asked the stakeholders to assign their preferences as a **weight** to the pillars.

Please assign a weight between 0-100 to each of the pillars, such that the weights sum up to 100

Pillar	**Weight**
Ecological	
Economic	
Social	
Sum	**100**

Annex 5: Dublin workshop feedback questionnaire

Making European Fisheries Ecosystem Plan Operational (MEFEPO)

WORKSHOP FEEDBACK

November 2010

Thank you for participating in the MEFEPO workshop in Dublin, 2nd/3rd November 2010. We hope that you found the workshop interesting and informative. We would be very grateful if you could take a moment to complete the workshop evaluation form below. Your comments will assist in planning for future workshops and work undertaken by the MEFEPO project.

Please complete the form and return via email to h.j.bloomfield@liv.ac.uk by **MONDAY 6th DECEMBER 2010**. Alternatively, if you would prefer to remain anonymous, please print the form and return via post to: Helen Bloomfield, University of Liverpool, Nicholson Building, Liverpool, L69 3GP, UK.

WORKSHOP CONTENT AND ORGANISATION
Scale: 1 – Strongly agree; 2 – Agree; 3 – Neutral; 4 – Disagree; 5 – Strongly disagree
Please provide feedback in the comments box

	1	2	3	4	5	Comments
1. The workshop location and facilities were appropriate and satisfactory	☐	☐	☐	☐	☐	
2. The information distributed in advance of the workshop was appropriate and sufficient to set the background for the workshop	☐	☐	☐	☐	☐	
3. The workshop material was presented in a clear and organised manner	☐	☐	☐	☐	☐	
4. The workshop material was presented at an appropriate level	☐	☐	☐	☐	☐	
5. The presenters responded to questions in an informative and satisfactory manner	☐	☐	☐	☐	☐	
6. The time allocated to presentations was appropriate	☐	☐	☐	☐	☐	
7. The time allocated to stakeholder input/activities was appropriate	☐	☐	☐	☐	☐	
8. The time allocated to stakeholder questions and discussion was appropriate	☐	☐	☐	☐	☐	
9. I have a good understanding of how our input will be utilised by the MEFEPO project	☐	☐	☐	☐	☐	
10. The workshop provided a useful opportunity for stakeholders to network with one another	☐	☐	☐	☐	☐	

GENERAL COMMENTS
11. Do you have any other comments regarding the workshop?
12. Do you have any other comments on the work being undertaken by the MEFEPO project?

The MEFEPO project is now in its final year, and over the next 10 months we will be producing project newsletters to inform all stakeholders on project progress. Details of project activities and reports that have been produced to date are available on our website (www.liv.ac.uk/mefepo); the website will be updated as new material becomes available.

If you know of any other stakeholders who might be interested in hearing about the MEFEPO project please provide their details in the form below.

Many thanks again for participating in the workshop and for taking the time to complete this form.

Best wishes,

The MEFEPO project team

Potential MEFEPO stakeholders

NAME	ORGANISATION	POSITION	EMAIL ADDRESS

Annex 6: Preference questionnaire test (Tromsø)

Summary results from the preparatory test in Tromsø

Table 1 The participants in the Tromsø-test by country and education background

Country Prof	Spain	Portugal	France	Nether- land	UK	Ireland	Denmark	Norway
Natural	1	1	2	3	1	1		
Economy								2
Social		1					1	

Table 2 Results from the Tromsø-test: average weights for the pillars

Pillar	Ecological	Economic	Social
average weight (st.dev)	44 (8,6)	28,5 (7,8)	27,5 (7,4)

Table 3 Results from the Tromsø-test: (i) average ranking; (ii) importance; and (iii) weights for the indicators

	food web	sea floor	bio div	comm. fish	effici-ency	stability	comm. viability	job attract	food sec
(i) ranking	5.93	4.21	5.29	6.57	4.14	3.35	2.57	2.5	4.64
(ii) importance	5.07	4.42	5.14	5.21	3.7	3.7	3.85	3.29	4.64
(iii) weight	15.4	11.6	15.1	16.4	8.1	7.65	5.82	6.18	12.93
(iv) weighted weight	10.5	8.5	10.3	11	11.5	11.8	6.7	6.6	12.9

The nominal values cannot be used to compared the preference order as different scales have been used (ranking from 1-9, importance between 1-6, and weights between 1-100), therefore we have to compare the preference order.

Table 4 Results from the Tromsø-test: preference order for the indicators

	food web	sea floor	bio div	comm. fish	effici-ency	stability	comm. viability	job attract	food sec
(i) ranking	2	5	3	1	6	7	8	9	4
(ii) importance	3	5	2	1	7	7	6	9	4
(iii) weight	2	5	3	1	6	7	9	8	4
(iv) weighted weight	5	7	6	4	3	2	8	9	1

The results from the weighting of the pillars presents a similar trend to that demonstrated for weightings, rankings and importance values of the indicators. The average weightings for the pillars demonstrated preference for the ecological pillar, with the economic and social pillars having similar weights (Table 2). Correspondingly, the four ecological indicators were given the highest average weights, and the economic and social indicators were assigned lower weights (Table 3). Overall, the social indicators, with the exception of food security, were assigned the lowest weights. Hence, respondents' weighting of the pillars and of the indicators belonging to the pillars is consistent.

Overall, there was agreement among preference orders from each of the three methods. The only exception is for the indicator community viability, which was ranked as number 6 out of the 9 indicators according to the importance-method, but 9 out of 9 according to the weighting-method. For all other indicators the difference in ranking is not more than one (e.g. preferred as number 3 out of 9 instead of as number 2 out of 9).

Effects of a difference in number of indicators per pillar

We were interested in examining whether the fact that the three pillars encompass a different number of indicators affected the results in terms of the order of preferences, therefore we compared the weights the respondents attached to the pillars with the sum of the weights attached to the indicators belonging to that pillar. When indicator weights are aggregated for the ecological pillar, they summed to a number higher than the weight that was assigned to the ecological pillar alone (58 and 44 respectively). For the economic pillar it was the other way around, i.e. the sum of the weight of the indicators was lower than the weight attached to the pillar (15.75 and 28.5 respectively). For the social pillar the aggregate of the indicators weight and the weight assigned to the pillar, were comparable (26 and 27.5 respectively).

Thus, the economic pillar was underrepresented in the selection of indicators due to the fact that only 2 economic indicators were used compared to 4 indicators for the ecological pillar. Underrepresentation could be corrected by multiplying each of the nine indicators with a parameter expressing the weight assigned to the pillar to which they belong, relative to the aggregate of the weights assigned to all indicators belonging to that pillar, i.e. the economic indicators are scaled upwards whereas the ecological indicators are scaled downwards. The results of this procedure are given in the last rows of Tables 3 and 4 above.

The results presented in Table 4 demonstrate that the iindicator weights crucially change the order of the preferences compared to the uncorrected order preference, and food security is now given the highest priority and the two economic indicators are preferred to all the 4 ecological indicators. Given this effect on the preference order we had to decide which method to use: the simpler method without correcting for different numbers of indicators or the method where we correct for different number of indicators?

We decided not to correct for the different number of indicators belonging to each pillar as we considered the weighting (ranking or assigning importance) of pillars and indicators as two separate and independent exercises. First, we wanted to ask the respondents about their preferences regarding the overarching aims of the fisheries management, represented by the three pillars. Secondly, we wanted to ask about the preference of 9 indicators, representing different aspects of the fisheries, and we wanted this to be independent of the preference test of the pillars. Thus, at the stakeholders workshop we undertook two surveys; one which collected data on preferences on the overarching pillars and one which collected data on 9 separate indicators, independent of whether these represent ecological, economic or social aspects of the fisheries' activities.

The three techniques for deriving stakeholder preferences gave relatively similar results in terms of the order of the indicators but there appeared to be differences in terms of the ease of completing questionnaires. The results received from stakeholders indicated that the ranking was the most difficult technique to apply, as 2 respondedns did notresponse to the ranking request and one responded but assigned the same rank to two or more of the indicators. With respect to assigning importance to the descriptors many of the stakeholders attached high importance to almost every descriptor. Of course it is possible to perceive that all descriptors are important but asking stakeholders to assigning values to each descriptor and requiring the aggregate of the values to equal 100, requires stakeholders to make trade-offs between the descriptors.

Appendix 7: North Western Waters methods

This appendix provides a description of the development and parameterisation of the multi-species model applied in the NWW case study. As stated in the main report (Section 4.2) the main steps in the analysis and scenario evaluation can be broadly described as:

- Abundance: calculate abundance at size per ICES statistical rectangle on the basis of the Cefas quarter 4 Western Ground Fish Survey (Q4WGFS) and the French EVHOE survey. Abundance at size converted to abundance at age by cohort splitting with species-specific von Bertalanffy growth curves.
- Mortality: calculate total international mortality (landings + discards) per species at age on the basis of English and Welsh discard observer database records scaled to total international effort and subsequently scaled to reported ICES landings data.
- Estimate F at age: Fs calculated from the estimated abundance and mortality on the basis of rearranging the standard catch equations.
- Establish species-specific ‘per-recruit’ models: species-specific models set up on the basis of life-history relationships that allow necessary parameters to be calculate on the basis of taxonomic affinity and L_{max}.
- Develop relative recruitment multipliers: on the basis of survey estimates of juvenile abundance calculate relative recruitment multipliers to allow whole community YPR, and associated values, to be calculated from multiple YPR models.
- Run comparative scenarios: run scenarios under a range of different metier-specific fishing efforts to examine effects of different effort control management regimes on the descriptors of environmental, social and economic performance of the fishery.

7.1 Abundance estimates

The raw survey abundance estimates per ICES rectangle were calculated via the swept area method, based on the trawl wing swept area, using the average catch per unit effort (CPUE) per species per length normalised to half hour tow durations. The focus of the analysis was on rare species that are often only intermittently encountered in survey hauls. To increase the sampling effort upon which the estimates were based abundance estimates were calculated from the mean average CPUE from all survey hauls made per rectangle over the period 2007-2009 in both the Q4WGFS and EVHOE surveys. Linear interpolations were applied to estimate abundance in ICES rectangles with no coverage in the surveys used in the analysis. The analysis covered all demersal fish in ICES VII f,g,h that occurred in both the survey and commercial fishing records with a maximum length (L_{max}) greater than 25cm (Table 7.1).

A two stage catchability correction was applied to the raw survey abundance data. The first stage applied a comparative gear catchability (CGC) correction, and the second stage an absolute abundance catchability correction. The CGC correction was implemented correctly for the catchability of the survey gear, a GOV otter trawl, relative to other gears. This procedure compared the CPUE per species at length of different gears fishing in similar locations at similar times, the data sets considered were the Q4WGFS and EVHOE surveys, the beam trawls used in the CEFAS Western Channel bean trawl survey, and data from commercial beam and otter trawl fisheries from the England and Wales discard observer program. All the species covered in the analysis were categorised by ‘species type’ based on general body form and behaviour (Table 7.2); data on relative catch at length for all species within a species group were combined. For each species group and length class the gear with the highest catch rate was assumed to give a sample of the ‘true’ abundance, and the relative CPUE of the other gears calculated as a proportion of this (Appendix figure 1). This allowed proportional catchability at length of the GOV to be calculated for each species group (Fig. 7.2). The raw survey abundance estimates per species at length were raised by the calculated CGC scaling factor. Where there was only a very small, or no catch, in the GOV survey data compared to the other datasets this generated extremely high abundance multipliers; to avoid subsequent unrealistically high abundances estimates the maximum

CGC abundance multiplier was capped at 200. Once the CGC correction had been applied abundance at length was converted to abundance at age by cohort splitting.

Table 7.1 Characteristics of species included in the analysis. The species group refers to the species groups listed in Table 7.2.

Code	Species Name	Common name	Lmax	Teleost / Elasmobranch	Species Group
BIB	*Trisopterus luscus*	whiting-pout	54	T	4
BLL	*Scophthalmus rhombus*	brill	71	T	3
BLR	*Raja brachyura*	blonde ray	119	E	8
CDT	*Callionymus lyra*	common dragonet	35	T	7
COD	*Gadus morhua*	cod	122	T	4
COE	*Conger conger*	european conger eel	247	T	2
CUR	*Leucoraja naevus*	cuckoo ray	84	E	8
DAB	*Limanda limanda*	dab	59	T	3
DBM	*Galeus melastomus*	blackmouthed dogfish	73	E	2
DGN	*Scyliorhinus stellaris*	nurse hound	159	E	2
DGS	*Squalus acanthias*	spurdog	120	E	4
ECR	*Torpedo nobiliana*	common electric ray	115	E	8
ESB	*Dicentrarchus labrax*	bass	79	T	4
GAG	*Galeorhinus galeus*	tope shark	189	E	4
GFB	*Phycis blennoides*	greater forkbeard	65	T	7
GUG	*Eutrigla gurnardus*	grey gurnard	48	T	7
GUR	*Aspitrigla cuculus*	red gurnard	62	T	7
GUS	*Trigloporus lastoviza*	streaked gurnard	39	T	7
HAD	*Melanogrammus aeglefinus*	haddock	81	T	4
HKE	*Merluccius merluccius*	hake	118	T	4
JOD	*Zeus faber*	john dory	63	T	4
LBI	*Lepidorhombus boscii*	four spot megrim	47	T	3
LEM	*Microstomus kitt*	lemon sole	67	T	3
LIN	*Molva molva*	common ling	191	T	2
LSD	*Scyliorhinus canicula*	lesser spotted dogfish	86	E	2
MEG	*Lepidorhombus whiffiagonis*	megrim	67	T	3
MON	*Lophius piscatorius*	anglerfish (monk)	149	T	7
MUR	*Mullus surmuletus*	red mullet	53	T	2
PLA	*Hippoglossoides platessoides*	long rough dab	43	T	3
PLE	*Pleuronectes platessa*	plaice	69	T	3
POD	*Trisopterus minutus*	poor cod	45	T	4
POK	*Pollachius virens*	saithe	104	T	4
POL	*Pollachius pollachius*	pollack	98	T	4
PTR	*Raja microocellata*	painted ray	99	E	8
RBM	*Helicolenus dactylopterus*	blue-mouth redfish	47	T	4
SDR	*Raja montagui*	spotted ray	98	E	8
SDS	*Mustelus asterias*	starry smooth hound	125	E	4
SHR	*Leucoraja fullonica*	shagreen ray	114	E	8
SKT	*Dipturus batis*	common skate	180	E	8
SLI	*Molva macrophthalma*	spanish ling	64	T	2
SMH	*Mustelus mustelus*	smooth hound	151	E	4
SOL	*Solea solea*	sole	67	T	1
SOS	*Pegusa lascaris*	sand sole	46	T	1
TBR	*Gaidropsarus vulgaris*	three-bearded rockling	52	T	2
THR	*Raja clavata*	thornback ray	107	E	8
TUB	*Chelidonichthys lucerna*	tub gurnard	67	T	7
TUR	*Psetta maxima*	turbot	86	T	3
WAF	*Lophius budegassa*	white-anglerfish	102	T	7
WHG	*Merlangius merlangus*	whiting	68	T	4
WIT	*Glyptocephalus cynoglossus*	witch	57	T	3

Table 7.2 Species group definitions and parameters for the CGC correction multiplier at length; where the multiplier at length $=1/\left(1+exp^{-(a+b.l+c.l^2)}\right)$. The multiplier species is the ICES assessed species used for the absolute abundance multiplier (see text).

Species group	Description	a	b	c	min length (cm)	max length (cm)	Multiplier Species
1	Predominantly buried in sediment	-1.936	-0.067	-0.004	2	55	SOL
2	Predominantly on the seabed- fusiform	-2.698	-0.014	0.000	2	222	PLE
3	Predominantly on the seabed- flat	0.227	-0.202	0.002	3	128	PLE
4	Predominantly close to the seabed, but not on it	2.110	0.104	-0.007	3	117	COD
5	Midwater species with some seabed association	2.729	-0.025	-0.001	2	160	COD
6	Pelagic	na	na	na			
7	Predominantly on the seabed- lumpiform	-3.700	0.014	-0.001	1	132	PLE
8	Predominantly on the seabed- flat Elasmobranch	-5.657	0.077	-0.001	12	128	PLE

Later in the analysis estimated F per species per age class was calculated from the estimated survey abundances and catch at age (see below). The calculated Fs were compared with the Fs from ICES assessments for the assessed stocks in the region (Appendix table 3), this revealed significant disparity between the estimates of Fs in this analysis and the ICES assessments. For the species covered by ICES assessments the survey abundance estimates were corrected so that the resultant Fs matched the ICES assessments. The absolute catchability correction multiplier of the ICES assessed stocks in each species type were applied across all species in the group. Where none of the species in the group was covered by an assessment, the multiplier for the species showing the closest 'behaviour' was applied.

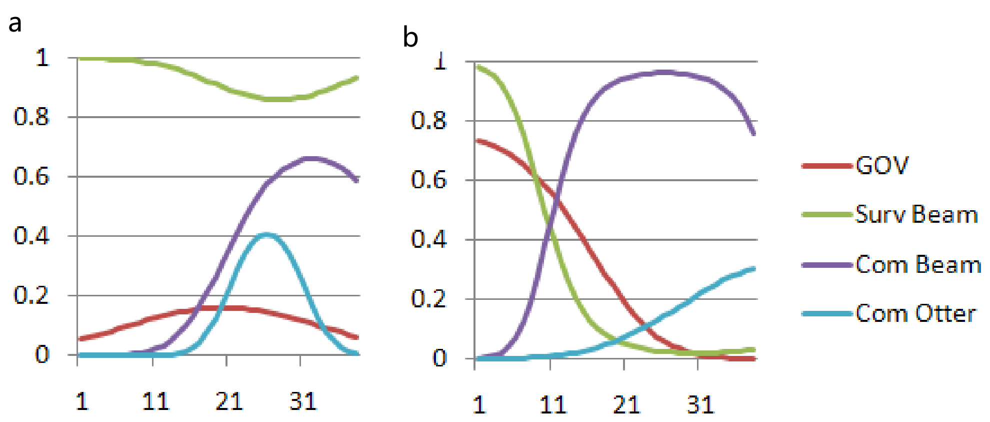


Fig. 7.1 Example outputs of comparative CPUE at length for a) bib, and b) plaice.

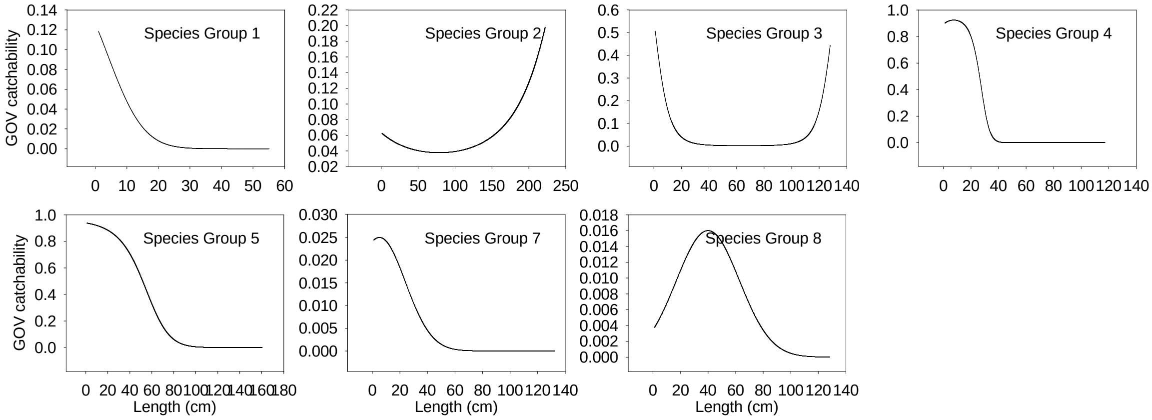


Fig. 7.2 GOV catchability per species group.

The data used for calculation of total mortality (see below) was not available in a spatially disaggregated format; the final abundance estimates were aggregated across the study region.

7.2 Mortality estimates

The analysis required total mortality (landings + discard mortality) in numbers by age class; international landings statistics only provide landings by weight and no international estimates of discarding are available covering all species in this analysis. The only available information on landings by size class and discards by size class was the CEFAS held English and Welsh discard observer program records database (DDB). To estimate total mortality at age the following procedure was followed: observed landings and discards per species by length class by metier in the DDB were raised to a raw estimate of total international landings and discards by raising these values to the total international effort. The metier classification applied was beam trawlers, otter trawlers, nephrops trawlers, and gill & trammel nets. Total international effort was taken from the STECF effort database collected under the cod recovery plan. No Spanish effort data is included in the STECRF effort database; Spanish effort data was provided by F. Velasco (IEO, Spain). Cohort splitting was applied to the estimates of landings and discards to convert to estimates by age class. Species specific correction multipliers for total landings and discards calculated by scaling age aggregated landings data to the Eurostat/ICES total reported catch by species and these multipliers were then applied to un-aggregated landings and discards estimates. Some of the landings data is listed under different species names and at different levels of taxonomic resolution to the DDB records. The follow conversions were applied to the Eurostat/ICES data to harmonise the records with the DDB records:

Balistidae to *Balistes carolinensis* (TRF)

Bothidea to *Arnoglossus imperialis* (ISF)

Dicentrarchus spp to *Dicentrarchus labrax* (ESB)

Gaidropsarus spp to *Gaidroparus vulgaris* (TBR)

Gaelus spp to *Galeus melastomus* (DBM)

Labridae to *Labrus mixtus* (CUW) and *Labrus bergylta* (BNW) using a 50:50 split (J Ellis pers comm.)

Lepidorhombus spp. to *Lepidorhombus whiffiagonis* (J Ellis pers comm.)

Lophidae, *Lophius americanus* and Lophuis spp to *Lophius piscatorius* (MON) and *Lophius budegassa* (WAF), split according to ratio of total MON and WAF landings data for 2008 from ICES WG Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (VII+VIII), MON: 24601/ WAF: 7574

Molva spp to *Molva molva* (LIN)

Mullus to *Mullus surmuletus* (MUR)

Mustelus spp to *Mustelus asterias* (SDS)

Raja batis to *Dipturus batis* (SKT)

Raja fullonica to *Leucoraja fullonica* (SHR)

Raja naevus to *Leucoraja naevus* (CUR)

Raja spp, Rajidae, Rajiformes split amongst rays and skates proportional to Eurostat/ICES reported catches by species.

Scyliorhinidae & Scyliorhinus spp. split amongst *Scyliorhinus canicula* (LSD), *Scyliorhinus stellaris* (DGN) & *Gaelus melastromus* (DBM) proportional to Eurostat/ICES reported catches by species.

Solea lascaris to *Pegusa lescaris* (SOS)

Squalus spp to *Squalus acantia* (DGS)

Squalidea to *Squalus acantia* (J Ellis pers comm.)

Triakidae to mustelus asterias (Jim pers comm.)

Triglidea to *Aspritigula cuculus* (GUR), *Trigloporus Lastoviza* (GUS), *Eutrigla Gurnardus* (GUG) and *Chelidonichthy lucerna* (TUB) proportional to Eurostat/ICES reported catches by species.

Raja circularis to *Raja microocellata* (PTR) (J Ellis pers comm.).

It was assumed that there was an 80% discard mortality rate to convert total discards to mortality from discarding. This provided mortality estimates due to landings and discards by species by age class by metier.

Table 7.3 ICES stock assessments covering the study region.

Species	Common name	Assessment region	Age classes	2007 smoothed F	Assessment correction multiplier
Pleuronectes platessa	Plaice	VII f,g	3-6	0.4067	0.2
Solea solea	Sole	VII f,g	4-8	0.274	3.25
Gadus morhua	Cod	Vii e-k	2-5	0.6707	0.25

Table 7.4 Life-history relationships used to define the parameterisation of the age-structured population models from L_{max}.

Function	Unit	Relationship	Source
Asymptotic length	cm	$L_{inf} = \exp(0.044 + 0.9841 \times \text{Log}_{10}(L_{max}))$	Froese & Binohlan (2000) equation 5.
Weight	g	$W_t = 0.01 \times L_t^3$	Gislason et al (2008) equation 14.
Natural mortality rate	year^{-1}	$M_t = 0.1+1.71 \times L_{inf}^{0.8} \times L_t^{-1.66}$	Gislason et al (2010) equation 8, parameters from key run for demersal species, Table 2.
Teleosts			
von Bertalanffy k	year^{-1}	$k = 3.07 \times L_{inf}^{-0.64}$	Gislason et al (2008) table 1 for demersal species
Length at first maturity	cm	$L_{mat} = 0.64 \times L_{inf}^{0.95}$	Gislason et al (2008) table 1 for demersal species
Elasmobranchs			
von Bertalanffy k	year^{-1}	$k = -0.17 \times \text{Log}(L_{max}) + 0.97$	Frisk et al (2001) equation in caption for fig 6.
Length at first maturity	cm	L_{mat} $0.7 \times L_{max} + 3.29$	Frisk et al (2001) equation in caption for fig 1.

7.3 Estimation of F at age

F per species per age was calculated from the landings at age data and the survey abundance data by applying the standard catch equations to give:

$$L_{s,a} = \frac{F_{s,a}}{F_{s,a} + M_{s,a}} \cdot \frac{N_{s,a}}{e^{-\partial F_{s,a} - \partial M_{s,a}}} \cdot (1 - e^{-F_{s,a} - M_{s,a}})$$

and solving to within 1% of the estimated total mortality due to landings and discards, where $L_{s,a}$ is the landings of species s at age a, $M_{s,a}$ is the natural mortality of species s at age a, $F_{s,a}$ is the fishing mortality for species s at age a, δ is the proportion of the way through the year when the survey occurs and $N_{s,a}$ is the survey abundance of species s at age a. Natural mortality at age for each species was calculated according to the life history relationships described in section 3.2.1.4 below.

For some species and age classes there was a reported catch, but no records of the species occurring at that age in the survey datasets. In these instances F at age was estimated according to the following rules:

If there was no catch below the 'missing' age class the first F was used

If there was no catch above the 'missing' age class the last F was used

Otherwise F was taken as the midpoint between the first age classes above and below the 'missing' age class(es) for which an F was calculated.

The maximum age of many species in the per-recruit models (see section 3.2.1.4) was greater than the maximum age of fish found in either the survey or catch data. To allow the per-recruit models to be run Fs had to be defined for these older age classes. Fs for older age classes were defined as the mean F for the last 2 age classes for which there are records in both the survey and DDB data sets.

7.4 Establishing 'per-recruit' models

Examining the impact of fishing the conservation status of fish species requires that the current status of stocks is compared against reference values; this was implemented by application of per-recruit models. Per-recruit models were chosen over fully dynamic age structured models due to the uncertainty that exists over stock-recruit relationships for well studied species, let alone wide range of less studied species considered in this analysis. Parameterisation of age structured per-recruit models requires estimates of asymptotic length, the von Bertalanffy K parameter, and weight, natural mortality and maturity at age. To set up population models for the wide range of species included in this analysis species specific parameterisation was based on life-history invariants. This allowed models to be parameterised on the basis of L_{max} and taxonomic affiliation; whether species are teleosts or elasmobranchs. The current region L_{max} of species was defined on the basis of the largest recorded specimen of each species recorded in the catch (DDB) and survey (Q4SWGFS, EVHOE) datasets used in the analysis. The life-history relationships used are given in Table 7.4.

7.5 Relative recruitment multipliers:

To allow calculation of total yield and landings value on the basis of the multiple YPR models a relative recruitment multiplier had to be applied to each species to scale YPR to absolute abundance. This was calculated by selecting the age class, between 1 and 5 yrs, with the largest number of individuals and then back calculating to the implied numbers at age 0, apart from DGN where all age classes were assessed as no individuals less than 5 yrs were found in the survey. This fitting looked across several age classes, rather than just using numbers at age 1, due to the low and variable catchability of young age classes.

Values

Species specific monetary value per unit landed weight were taken from the UK iFish landings database. The records for 2009 were analysed and the unit value calculated by diving the total recorded landed (first sale) value and dividing by total recorded landed live weight. Where direct species attributions were not possible the following substitutions were used:

DBM and DGN were assigned values of SYX (dogfish)

LBI and MEG were assigned values of LEZ (megrim)

GUS and TUB were assigned values of GUX (gurnards and latchet)

SLI assigned values of LIN (ling)

POD and CDT were assigned values of BIB.

Cephalopods

Cephalopod population dynamics were not modelled in the underlying biological models due to the difficulty of implementing biological models for cephalopods. However due to their significant contribution to landings value crude representation of cephalopods was included in the model. Cuttlefish and squids were treated independently, all cuttles were assumed to be *Sepia officianalis*, all squids assumed to be *Loligo vulgaris*. Cephalopod catch was assumed to be linearly related to effort, with a limit of a maximum increase of 30% on the 2008 catch based on Royer (2002; 2006) conclusions that cephalopod catches were near their maximum limits. Cephalopod catch was split between beams and otters on the basis of the DDB catches multiplied up to total international levels. The total catch of each was taken from the ICES landings records.

Individual species fits

The selection of effort patterns leading to management scenario optimisations was initially driven by a few species showing wildly unrealistic dynamics that dominated the indicator responses. The following fits were subjectively applied to these species to bring their catches within =/- 100% of ICES reported landings.

BIB recruitment reduced by 500, F's scaled from 4.62 to 1.
JOD F's all scaled to reduce max to 1.2 from 3.384 and recruitment reduced by 2000
Reduce beam trawl discard F on WHG to 0.25 and increase recruit multiplier by 100.
Reduce CUR recruit multiplier by 3.
Reduce SOS recruit multiplier by 5.
COD discard F at 1 reduced to 0.2, recruit multiplier reduced by 10.
SKT F at ages >13 held at F age 13, recruit multiplier reduced by 5.

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