Report of the
Study Group on Integration of Economics, Stock Assessment and Fisheries Management (SGIMM)

by correspondence

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Contents

Executive Summary

Ecosystem based fishery management has moved beyond rhetorical statements calling for a more holistic approach to resource management, to implementing decisions on resource use that are compatible with goals of maintaining ecosystem health and resilience. Coupled economic-ecological models are a primary tool for informing these decisions. Recognizing the importance of these models, the Study Group on Integration of Economics, Stock Assessment and Fisheries Management (SGIMM) has been formed to explore alternative modelling approaches that bring the multiple disciplines of economics, ecology, and stock assessment into integrated ecosystem models. This year the group has not physically met, but worked through correspondence and through two special theme sessions at international conferences. The first session was held at the World Fisheries Congress (WFC) in Edinburgh, Scotland, 7–11 May 2012. The session "Sustainable Fisheries: Ecological – Economic Modelling Tools to be used in integrated fish stock and fisheries management" focused on the biological parts of the models. The second session "Coupled Economic-Ecological Models for Ecosystem-Based Fishery Management: Exploration of Trade- offs Between Model Complexity and Management Needs" at the conference of the International Institute for Fisheries Economics and Trade (IIFET) from 16 to 20 July 2012 in Dar es Salaam, Tanzania, highlighted the economic components of coupled models in presentations and a panel discussion.

Within the presentations and discussions it was envisaged to compare fully integrated, highly detailed and dynamic economic-ecological models such as Atlantis to models that may be less detailed or not fully dynamic or integrated. Although economic and ecological systems are inherently complex, models are abstractions of these systems incorporating varying levels of complexity depending on available data and the management issues to be addressed. The objective of the IIFET session was specifically to assess the pros and cons of increasing model complexity to incorporate linkages between ecosystem components and processes. While more complex ecosystem models may provide greater insight into how management decisions and human actions propagate through the ecosystem and impact the value of ecosystem services, the resources and information required to develop and parameterize them is greater and these models tend to require trade-offs such as inability to quantify uncertainty or model human behaviour as accurately as can be done with models of individual fisheries. Where the WFC session had a high variety of different models, the IIFET session focused primarily on management issues that are of a longer-term strategic nature such as the implications of climate change, fundamental regime change, or the role of forage species in an ecosystem.

The approaches presented are either further developments of the models and methods included and partly reviewed in the previous SGIMM reports or represent new models. The presented models at the special sessions under WFC in May 2012 and under IIFET in July 2012 will be included in the model review table and matrix developed under ICES SGIMM. This appendix is being distributed to the additional model developers who are asked to fill in the table for their respective model, approach or method. This will facilitate the continuous development of this review table and extensive coverage of this of existing models and further model developments. The objective of the meeting of the study group next year is to summarize all these models, discuss the approaches, and explore future work within ICES with the potential aim of an extended survey and review paper.

1 SGIMM Terms of Reference

The Study group worked by correspondence in 2012 with the following Terms of Reference:

a) Evaluate further the world wide state-of-the-art in integrating economic (modelling), stock assessment and fisheries management plans relevant for ICES; In this context develop further the suggested Model Performance and Characteristics Matrices and Model Summaries reviewing each of the relevant models both in scientific, advisory and management context;

a) Develop further existing integrated frameworks, models and methods on case specific basis for integrated bio-economic modelling of fisheries, and test and discuss their general utility with respect to general implementation in ICES fisheries and scientific evaluation of fisheries and stocks;

b) Discuss and identify functions for economic dynamics (parameters) needed to be integrated into the models and frameworks;

c) Identify further the data and information required as well as expertise needed for integrated bio-economic modelling of fisheries and application of socio-economic evaluation methods on short and long term basis;

d) Identify platforms and multi-disciplinary fora (fisheries biology (ecology), economy, sociology) to develop, link and use ecological-economic modelling tools to be used in scientific evaluation and advice on integrated fish stock and fisheries management; Hereunder develop further the cooperation with IFET on this.

2 General approach

To set the sessions into the larger context and to give an overview of the work envisaged, an introductory presentation was held at both sessions.

2.1 Integrated ecological–economic modelling – status, progress and wider future perspectives

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Fisheries are economic activities, which are dependent on and interact with the ecosystem in which they take place. Management decisions are driven not only by changes in the environment but the economic activity itself. The impact of fisheries on the marine ecosystem and vice versa can only be assessed and predicted using integrated ecological-economic models, which incorporate the feedback of the ecosystem on the fishery and vice versa. This evaluation tools needed will be even more integrated and complex if not only target species of the fisheries are of concern, but also other ecosystem components and processes - e.g. protected habitats, protected species, productivity, biodiversity, trophic cascading or ecosystem services like water clearance. A further step in integrated management evaluation would be to include interactions between the fisheries catch sector and other sectors on a regional scale.

Special sessions at the World Fisheries Conference (WFC) in May 2012 and the IIFET Conference in July 2012, which were arranged and organized in cooperation with the ICES SGIMM, focused on examples of integrated ecological-economic models and evaluation tools addressing both the dynamics in the fisheries system and the ecosys-

tem. This includes fisheries and ecosystem-based management evaluation frameworks and models with varying levels of complexity of the ecosystem and the fishery and socio-economic systems that increase the understanding of the feedback between the systems. The sessions included presentations and abstracts ranging from theoretic analyses to applied models and implemented management strategy evaluations. The level of complexity of the models was considered in relation to the different types of management advice needed in present fisheries management.

The sessions address, in association with ICES SGIMM the need and tendency, globally and in the ICES areas, to move from single fish stock evaluation and management advice to more integrated and holistic assessment and fisheries management and on recent developments of tools and models that can perform:

1) Integrated multi-stock-multi-fisheries bio-economic evaluation and fisheries management evaluation involving i) multi-stock biological evaluation and ii) economic fleet and fisheries (metier) based evaluation which often also integrates the fisheries technical interactions and mixed fisheries aspects, and iii) broader scale multi-sector socio-economic and regionalized evaluations.

2) Integrated broader ecosystem impact evaluation on a regional basis involving i) Ecosystem and multi-species based evaluation of biotic components and biological interactions and impacts, ii) Environmental pressures and impacts (abiotic components and pressures), and iii) Harvesting pressures and fishery impacts including technical interactions.

The ICES Study Group on Integration of Economics, Stock Assessment and Fisheries Management (ICES SGIMM 2011–2013) aims to explore the technical basis and possibilities for integrating and linking biological and economic models (especially at stocks and fisheries levels) further into management advice which covers:

- exploration of needs for additional developments and knowledge;
- potential for implementation in ICES considering progress in model development worldwide.

So far the study group has evaluated status and progress and reviewed several integrated ecological-economic models and approaches and made a synoptic review matrix characterizing the models and approaches and their usefulness, forces and limitations. The associated theme sessions at World Fisheries Conference (WFC) in May 2012 have included presentations and extended abstracts of scientific progress and developments for several models, methods and approaches worldwide. The second associated theme session to ICES SGIMM held under the July 2012 Conference of the International Institute of Fisheries Economics and Trade (IIFET) provided presentations and panel discussion of further needs for these models:

- highlighting the economic component of coupled models;
- focusing on pros and cons of increasing model complexity;
- evaluating the level of detail needed to capture realism sufficient for management decisions and considerations of trade-offs between using fully integrated and highly detailed dynamic models or less integrated, simpler, or static models.

Consideration has been given to:

- resources and information required (knowledge base and data availability) to develop and parameterize the models;

- the trade-offs such as inability to quantify uncertainty or model human behaviour;
- the needs for management and management questions to be addressed;
- discussion of the longer term strategic nature of the model use and integration according to complexity and management needs.

An upcoming challenge from a wider perspective is to cover broader marine regionalized management evaluation and cross sector integrated marine management evaluation and spatial planning. Other sectors and societal groups also have significant use, benefit and exploitation of the sea and engage in activities that cover occupation of space for exploration and exploitation of the sea and seabed. This covers among other uses:

i) energy such as fossil resources in form of oil and other, renewable energy such as wind mill farms and wave energy;

ii) transport and infrastructure such as shipping and large marine constructions in form of bridges and tunnels;

iii) recreational use covering tourism, recreational fishery, etc.;

iv) area occupation in relation to defense and other military use;

v) sediment extraction;

vi) other.

These aspects need to be covered because there is increasing competition for use of the sea area and marine environment, i.e. competition for space and resources between sectors.

Regionalisation requires managing complex ecosystems and anthropogenic systems covering different sectors and must address multiple objectives including ecological and socio-economic criteria. Evaluation tools involving cross sector multi-disciplinary management evaluation are needed. The land based parts of the fishing sector and other sectors should be covered as well. Ecological, economic, social and institutional multi-disciplinary sustainability criteria and management objectives needs to be addressed at the regional scale when evaluating fisheries together with other important uses of the sea. Performance criteria and reference levels must be better defined in order to be integrated into management evaluation.

The multiple objectives and sustainability criteria can often be conflicting and it is necessary to develop systems to evaluate trade-offs in management. Ideally, the full system sustainability should be evaluated to enable managers to make informed decisions and to give a better overview and knowledge basis for making political decisions and choices.

With respect to spatial planning and marine management evaluation it is important to further develop spatially and seasonally explicit dynamic models operating with high resolution in time and space. Spatial models could properly address spatial and temporal co-occurrences of fisheries with the underlying harvested resources and their habitats with the purpose of better integrating the interlinked dynamics of both the resources and the economic exploitation. Spatial models should also encompass tools for testing so-called area-based management and the evaluation of concurrent utilizations of the sea (fisheries and other sectors). Similar to the fisheries scientific and advisory communities there exist scientific advisory communities for the other sectors, and it will be essential to establish contact and cooperation with those and enable integration here as well.

So far only relatively few integrated models are spatial explicit enabling broader marine management evaluation and spatial planning with scenario evaluation and comparison of trade-offs in management between the different sectors occupation of space and their importance with respect to economic and societal impact. Economic performance comparison will be a central issue here. Monetized value maybe the most useful and efficient common denominator to assess trade-offs. However, broader economic sustainability, given consideration of underlying ecological and energetic sustainability must also be evaluated.

3 Theme Session "Sustainable Fisheries: Ecological–Economic Modelling Tools to be used in integrated fish stock and fisheries management", at the World Fisheries Conference (WFC), Edinburgh, Scotland, 7–11 May 2012

3.1 PSA7.01: Humans - the missing jigsaw piece

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The dualism of nature and humanity has been engrained in western intellectual thought since the earliest of European records. This concept of humanity as separate to nature infuses thought and culture and even colours approaches to science and management. Much of science's success has been built on a reductionist foundation. Systems science is becoming more firmly established, but approaches to resource management often still retain a division between biophysical and anthropocentric with tenuous links bridging the divide; this is perhaps most evident in modelling. There is a long history of economically focused models and an equally long history of biophysical ones. End-to-end (or whole-of-system) models exist, and more are being constructed all the time, but they are typically still only used to build science foundations; their management uses still nascent. Nevertheless they have highlighted how management will continue to face a high risk of failure, or unintended consequences, unless the human jigsaw piece is explicitly integrated into analyses of the system. There are substantial challenges to modelling human behaviour, a greater proportion of "unknown unknowns" that can significantly impact upon system responses. Nevertheless continuing to omit the human dimension and focus only on stocks and habitats is like trying to drive a car through a paint-splattered windscreen; possible, but not advisable.

3.2 PSA7.02: Evaluating the trade-offs of conservation, economic, and social objectives across a range of fisheries management systems

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Fisheries management objectives are numerous–covering ecological, economic and social dimensions–and often conflicting. As conservation targets of exploited populations are typically near the quantities that maximize long-term sustainable yield, and greatest economic gains typically occur near (but slightly more conservative than) these same quantities, we should not necessarily expect trade-offs between conservation and economic objectives. However, these objectives may conflict with social objectives, especially job creation. It is often difficult (or at least ecologically or socially unacceptable) to sufficiently perturb a fishery to rigorously quantify the shape of the trade-offs among its component objectives. We approach this problem from a different angle and use meta-analysis to quantify the cross-fishery trade-offs among con-

servation, economic, and social objectives. We drew stock-level information from the recently-compiled RAM Legacy Stock Assessment Database, and constructed indicators of conservation objectives. We drew fishery-level information from a fishery management attributes database containing detailed socio-economic information, and constructed indicators of economic and social objectives. We merged these databases to quantify the trade-offs among competing objectives and identify particular management attributes that influenced the nature of these trade-offs. We observed a strong set of interacting objectives involving quota adherence (the ratio of catch to quota) as a conservation objective, return on management investment (the ratio of landed value to the total research and management budget) as an economic objective, and employment intensity (the ratio of harvesting jobs to landed value) as a social objective. As hypothesized, a win-win relationship was observed for quota adherence and return on management investment, but each of these objectives traded off with employment intensity. These trade-offs were strongly affected by ex-vessel prices and the proportion of research and management costs paid by industry. For valuable species, industry is willing to invest more in research and management costs; catches are maintained closer to quotas, and fisheries become more efficient so employment intensity decreases. These results confirm the hypothesis that while biological and economic objectives are largely compatible, there are significant trade-offs between job creation and either economic or biological performance.

3.3   PSA7.03: Exploring the ecological, social and economic implications of management decisions

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The European Union (EU) is committed to manage European fisheries within the structure provided by the Marine Strategy Framework Directive, based on productive fish stocks and healthy marine ecosystems which support economic and social sustainability. The proposals for the reform of the EU Common Fisheries Policy seek to deliver an ecosystem approach to fisheries management and to use this to reconcile the tension between fisheries productivity and environmental protection. In this paper we examine how the three pillars of sustainability may guide a formal analysis of these trade-offs, and be used to support development of integrated and holistic marine management. Through structured interaction with stakeholders (interviews and workshops) the Making European Fisheries Ecosystem Plans Operational (MEFEPO) project has developed Fisheries Ecosystem Plans (FEPs) for three European regional seas (North Sea, North West Waters and South West Waters) to support the transition to ecosystem based fisheries management. Central to the FEPs is an evaluation matrix that can be used to explore ecological, social and economic implications of different management strategies on ecosystem components. Collaboration across disciplines (fisheries scientists, ecologists, social scientists and economists) supported matrix development for case study fisheries within each region, while engagement with a broad range of stakeholders ensured the process had credibility which, in the longer term, is likely to increase management success. Application of the matrix approach raised concerns regarding the availability and suitability of data currently collected for the formal fishery advice process to support ecosystem based management. Management advice should be formulated collaboratively based on the best available evidence and implemented within an adaptive regime, responsive to new information and increased understanding. Ultimately management decisions will be made on the basis of overarching objectives (ecological, social and economic). Trade-offs among objectives are required; due to the nature of trade-offs it may not be possible to satisfy

all stakeholder groups simultaneously. However, the development and application of decision support frameworks such as that described here, can aid managers in making appropriate decisions based on the best available evidence.

3.4 PSA7.04: Searching for the optimal fishing effort for swordfish by Kesennuma off-shore longline fishing in the post-tsunami recovery

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On 11 March, Kesennuma, which is one of the largest fishing ports in Japan, has been suffered devastated damages of Tsunami and post tsunami fire at the Great Tohoku Earthquake. Despite losing the most of fishing vessels, 18 out of 20 off-shore longline vessels survived because they were engaged in fishing activities away from the coast at the time of the tsunami. Now the rebuilding of this fishery is a key for the recovery of the economy of Kesennuma area.

This study empirically estimates a production (yield)-fishing effort (days of operation per trip) model for this fishery by combining a demand model for swordfish and an operating cost model. This integrated model is used to explore optimal fishing efforts for the profits, and sensitivies of profits to fuel price changes. The result demonstrates explicit differences among current average efforts (41 days per trip) and optimizing efforts for the maximum profits per trip (25 days per trip). The results also suggest that an increase in fuel price would lead to lesser maximum profit and constrict the range of efforts for positive profits.

3.5 PSA7.05: Ecological- economic multi-species management of the Baltic Sea fisheries: Tradeoffs between objectives in an ecosystem context

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The central Baltic Sea fish community is dominated by three species only, i.e. cod, herring and sprat. The fishery mainly consists of single species fisheries. However, fisheries are closely connected as there are strong ecological inter-connections between the species, i.e. predation by cod and competition between clupeids. Therefore, management measures taken for one species will inevitably affect the other species and its related fisheries. We developed and applied an age-structured ecological-economic multi-species optimisation model. This model offers the possibility to calculate optimal multi-species F-vectors for different management objectives. As a reference case, the maximum net present value of the combined fisheries is calculated. A weighting scheme in the objective function offers the possibility to calculate the actual costs of side conditions (as deviation from optimum), e.g. maintaining clupeid stocks above a limit biomass, or of maintaining a certain amount of profit in the single fisheries. This model, however, does not include an ecosystem perspective. Therefore, we combine the ecological-economic model with the central Baltic Sea food-web NEST model. The ecological-economic model calculates multi species fishing mortality vectors to achieve the management goals (or tradeoffs between different goals). The F-vectors are used to drive the NEST food-web model, which will predict the future development of the Baltic Sea ecosystem. This exemplary application and combination of models of different complexity allows a comparison and quantification of the risks that key indicators are negatively affected by management measures. This approach also allows taking future climatic variation into account.

3.6   PSA7.06: Towards the implementation of an integrated ecosystem fleet-based management of European fisheries

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The STECF (Scientific technical and economic committee of the European commission) experts working group on the "Development of the ecosystem approach to fisheries management (EAFM) in European seas" is requested to develop a pragmatic feasibility approach to provide some useful assessments and ecosystem advices in support of EAFM. We present here the main conclusions and the approach recently developed within this working group. We especially show that a fleet-based approach is the pathway to implement an effective AEFM. First, using the reference list of seven ecosystems defined by STECF in the Atlantic and Baltic Seas, a diagnostic on the health of each ecosystem is proposed based on: the reconstruction of long time-series of catch, the analysis of mean indicators or stocks trajectories derived from ICES stock assessment results, and the analysis of ecosystem indicators. Then, we present a fleet-based synthesis using indicators of both the ecological impact and the economic performances of the major fleets operating within each ecosystem. In particular, assessment diagrams show whether each fleet segment, on average, sustainably exploits the stocks. Although the method still needs improvements and results are preliminary due to the poor quality of available data, the analysis shows that simple indicators can be estimated and clearly highlight contrasts between fleet segments.

Such an approach contributes to progress from a stock-based to a fleet-based management. It could clearly be part of a framework used to determine which fleet segments would have to be reduced and which ones could be developed. Environmental assessments should also be used to guide management plans for fishing effort or to introduce positive or negative economic incentives in order to encourage fleets to improve their fishing practices.

Implementing EAFM is a task that has to be conducted in respect to -and in close collaboration with- the Marine strategy directive framework (MSFD), whose purpose is not (or not only) to ensure the good environmental status of ecosystems. On the other hand, EAFM aims to take into account not only ecological sustainability, but also economic profitability and social fairness. Its major objective (its specific value-added) is to analyse tradeoffs between ecology, economy and social aspects, the tree pillars of the sustainable development of fisheries.

3.7   PSA7.07: FLBEIA a Bio-Economic Simulation Toolbox

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FLBEIA (FL Bio-Economic Impact Assessment) is an R package build on top of FLR libraries. It provides a flexible and generic tool to conduct Bio-Economic Impact Assessments of harvest control rule based management strategies. As usual in a Management Strategy Evaluation (MSE) framework, the package is divided in two main blocks, the operating model (OM) and the management procedure model (MPM). In turn these two blocks are divided in 3 components. The OM is formed by the biological, the fleet and the covariables components and the MPM by the observation, the assessment and the advice components.

The model is multistock, multifleet and seasonal and uncertainty is introduced by means of montecarlo simulation. The algorithm has been coded in a modular way to

ease the checking and the flexibility of the model. The library provides functions that describe the dynamics of the different model components, under certain assumptions, and the user chooses which of the functions are used in each case specific model implementation. Furthermore, if in a specific case, for some of the components, the functions provided within FLBEIA do not fulfil the requirements, the user can code the functions that adequately describe the dynamics of those components and use the existing ones for the others. As the user can construct its own model, selecting existing submodels and constructing new ones, we define it as a toolbox more than as a model.

The package is being used in several case studies with very different peculiarities, from mixed fisheries fishing Hake in North Atlantic Western Watters to Seabream artisanal fisheries in the Gulf of Cadiz. In this work the main features of the simulation model and its application to representative case studies will be presented.

3.8 PSA7.08: Impact Assessments of fisheries management options using bio-economic models - experiences and paths for model improvements

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In the Common Fisheries Policy impact assessments are required for new management measures or management plans. Additionally, after three years the plans must be evaluated whether they achieved their goals regarding stock status and fishing mortality. The Scientific Technical and Economic Committee for Fisheries was asked to do some of these evaluations and impact assessments. Accordingly, in the first part of the paper an overview on the experiences of STECF are given. The problem with evaluation is often the lack of sufficient data, which are usually necessary for several existing bio-economic models; moreover, the models themselves are often insufficient. Therefore, models and especially the FishRent model, as one of the most advanced models for socio-economic evaluation of management options, has to be further developed. In fact, the main disadvantage of this model is the biological part, which so far does not nearly reflect the status quo of biological stock assessment models. Several current European research projects, including SOCIOEC on the socio economic impact assessment of management measures of the new CFP, contribute to the further development of this model. In the second part of the paper I will outline some paths for improvements and expected results of SOCIOEC.

3.9 PSA7.09: Transforming knowledge into quantitative modelling: Danish fishers respond to a web-based survey on dynamics in fuel consumption and fishing patterns

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Danish fishermen have provided information on dynamics in their fuel consumption, running costs, and fishing patterns via a web-based questionnaire. The developed questionnaire on fishing practices improves fisheries research and advice by supplementing detailed information to spatial modelling tools. These tools aim at integrating knowledge on spatial distribution and fuel consumption on individual vessel basis covering different fisheries with detailed information on spatial distribution of targeted stocks to evaluate the optimum fuel consumption and efficiency under increasing fuel costs and potential costs of displacement of effort. The energy efficiency (kg and value of fish per litre of fuel) of different fisheries was analysed by merging the questionnaire and logbook and VMS (vessel monitoring system) information.

Similar activity patterns from the respondents were detected by applying spectral clustering and social network analyses and compare those to the usual fleet-based classification. Furthermore, logic decision trees and conditional probabilities were established, where the fishermen must respond to a range of hypothetical conditions influencing their trip-decision. That is for example when do they decide to go fishing, why do they choose particular fishing grounds, when do they decide to stop fishing and go back to port, etc. Integration of these results into our recently developed spatially-explicit individual-based fishing vessel model (IBM) is essential in predicting how individual fishermen will adapt to dynamics in resource availability, increasing fuel prices, changes in regulations, and the consequences of various external pressures on harvested stock conditions.

Keywords: Area-based management; conditional probabilities; energy efficiency; fishermen's knowledge; classification tree; individual based bio-economic model; social network analysis; spectral clustering; underlying stock dynamics; web-based questionnaire.

3.10 PSA7.10: Predicting consequences of management measures on marine resources and local stakeholders through bio-economic modelling

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Because of anthropogenic pressures from various neighbouring countries, the Channel ecosystem has been damaged. To protect the ecosystem from further degradation, several management measures, including MPAs, are being implemented or considered on the French and English sides of the Channel. The effect of MPAs' size, design and location remains mostly unknown, causing great concern among local stakeholders and especially fishers. We applied ISIS-Fish, a spatial bio-economic marine ecosystem model representing fish stocks, fisheries management and exploitation, to ICES area VIId to assess the possible consequences of management measures and human perturbations on this ecosystem and on related human activities. Our work has two aspects: a methodological component for the development of methods for evaluating the robustness of the diagnosis of the impact of fisheries management scenarios in a context of uncertainty; and an operational component for validating the feasibility of using ISIS-Fish, in a context of assisting fisheries management decision making. We tried to ensure robustness through an iterative approach to modelling, progressively including only information with low uncertainty and keeping complexity to a minimum. Uncertainty is also taken into account by means of combinations of sensitivity analyses and info-gap simulations. Considering that fishers are an essential part of the local socio-ecosystem, our marine ecosystem model explicitly takes into account their behaviour as well as their sources of income and expenses to determine how they may be impacted by management measures.

3.11 PSA7.11: End-to-end ecosystem modelling of fisheries impacts in the North Sea

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Using and end-to-end ecosystem model of the North Sea spanning nutrients to birds and mammals, it is shown that maximum sustainable yield, and the corresponding harvesting rate, for demersal fish is conditional on harvesting rates for pelagic fish, and vice versa. The inter-dependence of yields from the different fishing sectors arises because of predator-prey interactions in the food web, and the effects permeate

the entire ecosystem. The model helps to identify the trade-offs between fishery sectors and other properties of the ecosystem, such as seabird or benthos production, that have to be considered in devising an overall harvesting strategy which meets sustainability criteria across the whole ecosystem.

3.12 PSA7.12: DPSIR framework and system dynamics: application to an integrated management model for artisanal fisheries of Northwest Spain

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Fisheries are complex systems that present a large number of interdependencies and interactions with different environmental, economic and social aspects. These interdependencies are even stronger in the case of artisanal fisheries, given their ecological, socioeconomic and cultural importance for the coastal areas where the activity takes place. In such context, it is necessary to develop new tools in order to improve decision-making processes and enhance environmental and socioeconomic sustainability of the artisanal activity. This paper presents an integrated management model, based on the DPSIR framework and Dynamic Systems simulation models, which tries to integrate all these dimensions into a unique tool.

This management model has been developed within PRESPO project, a European project that addresses the sustainable development of artisanal fisheries along the Atlantic Area. This case study focuses on the artisanal fleet from the west coast of Asturias, constituted by 119 vessels. Its activity is characterised by a great diversity in the fishing gears used, the sort of species caught and their relatively high economic value. Although the model is focused on the octopus fishery, it is complemented with other species highly relevant for the analysed fleet.

The model is defined by its multidisciplinary character: the DPSIR framework (Drivers, Pressures, State, Impacts and Responses) has been used to integrate multiple indicators according to different dimensions, such as socioeconomic, ecological, technological and institutional. This framework allowed the identification of key socioeconomic drivers affecting fishery exploitation and stock, environmental changes and potential policy responses. The System Dynamics approach was then used to model the current state of each fishery and to simulate the impact of different policy responses on fisheries' sustainability. The aim of the system dynamics model is to identify the main feedback mechanisms that influence the system behaviour.

The results obtained show that while individual responses may have undesired and unexpected outcomes, an integrated response combining some of these particular managerial actions would be much more effective to achieve pursued sustainability objectives. Therefore, it is essential to understand the aforementioned feedback mechanisms to achieve an integrated and sustainable management of artisanal fisheries.

3.13 PSA7.13: Implementing maximum economic yield in commercial fisheries using a prawn fishery as a case study

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Economists have long argued that a fishery that maximizes its economic potential will also usually satisfy its conservation objectives. Recently, maximum economic yield (MEY) has been identified as a primary management objective for Australian

fisheries. Globally, several fisheries have already started managing their fisheries towards MEY or some proxy thereof. However, first attempts at estimating MEY as an actual management target in a real multi-species fishery (the norm in most fisheries) have highlighted some substantial complexities generally unconsidered by fisheries economists. Some of the main issues and their implications highlighted during a 5-year implementation of an MEY target in an example Australian fishery are described. These include that unconstrained optimization using a bio-economic model, for which MEY is the management target, may result in effort trajectories that are not acceptable to industry or managers. Similarly, different assumptions regarding appropriate constraints result in different outcomes, each of which may be considered a valid way to achieve MEY. Finally, alternative treatments of prices and costs may result in differing estimates of MEY and associated effort trajectories. The way forward is shown to be extensive stakeholder engagement and an adaptive management approach, i.e. operationalizing MEY is not simply a matter of estimating numbers, but also requires strong industry commitment and involvement. For this to happen, all stakeholders need to have not only a broad overview of the basic concepts behind MEY, but also a reasonable knowledge of how one calculates MEY.

3.14 PSA7.14: EcoTroph: a trophic-level based ecosystem model to assess fishing impacts and fisheries interactions

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EcoTroph is a simple trophic-level based ecosystem model which allows users to simulate the biomass trophic spectrum of an ecosystem (i.e. the distribution of ecosystem's biomass across trophic levels), under various fishing scenarios. Using the Southern Benguela upwelling ecosystem and the Guinea ecosystem as cases of study, we showed that the EcoTroph model provides efficient tools to build diagnoses of the fishing effects on ecosystems, taking into account the direct fisheries impacts on targeted species as well as the indirect impacts through the food web. In both cases an EcoTroph model was derived from a pre-existing Ecopath model and was used to simulate increasing or decreasing fishing efforts, for the whole fishing activity or for some specific fisheries. We showed that in both ecosystems the current fishing effort levels led to full exploitation of higher trophic levels, confirming and generalizing previous single-species assessment results. The global fishing impact appeared higher in the Guinean ecosystem, where a larger fraction of the food web is currently targeted. In the Benguela ecosystem we simulated two scenarios highlighting how the small pelagics fishery is impacting the food chain in a very different way from the hakes fishery. It especially appeared that the small pelagics fishery may induce an important decrease in the biomass at all trophic levels of the ecosystem, therefore impacting all other fisheries. Then, applying EcoTroph to the Guinean ecosystem, we distinguished the effects of the artisanal fishery from those of the industrial fisheries. We showed that, as these fisheries are targeting rather different groups, they do not impact each other much. Nevertheless, the industrial fishery has the strongest impact on the high trophic levels and thus is responsible for most of the negative impacts on the trophic biodiversity within this ecosystem.

3.15 PSA7.15: Effect of zoning on the sustainability of small-scale fisheries in San Miguel Bay, Philippines

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Philippines' Republic Act 8550 of 1998 divided its national water into city or municipal waters (MW) and provided jurisdiction to its respective local government to protect the rights of fisherfolk (local fisherman) on its preferential use. This is to achieve food security, provide protection of fishery resources and to protect the rights of the fisherfolk. This study aims to find the real situation of the fisherfolk, know the effect of zoning/ delineation to the local fisheries sector, and to find the most suitable condition for the sustainability of San Miguel Bay (SMB) in terms of environment, economy, and society using various analytical tools. The xy coordinates of the MW boundaries of the four (4) municipalities within San Miguel Bay, namely; Cabusao, Calabanga, Tinambac and Sipocot, were plotted and the fishing areas for 5 km, 10 km and >10 km but not more than 15 km distance from the coastline were calculated using Geographical Information System (GIS). The social effect of zoning/delineation was assessed using Contingent Valuation Method (CVM). The catch per unit effort (CPUE) in kg/hour and kg/trip was calculated for Calabanga. Preliminary results shows that Calabanga has a bigger area of 188.4 km2 for 1304 fisherfolk compared to its three neighboring municipalities namely; Cabusao: 1108 fisherfolk/49.3 km2, Sipocot: 235 fisherfolk/44.2 km2, and Tinambac: 541 fisherfolk/115.7km2. Majority of respondents belong to below poverty line monthly income of USD 114.34, and are willing to pay for an annual fishing fee of less than USD6.86 and a monthly intermunicipal fishing fee of not more than USD 2.29. Except from Cabusao, majority do not support commercial fishing within municipal waters and believes that there's still a competition between local and commercial fisheries in spite of delineation. The monthly CPUE of Calabanga from March–November 2008 is slightly lower than the monthly CPUE of SMB from March–November 2002. Also, the 2008 mean CPUE of Calabanga is lower than the previous mean CPUE of SMB (1980/1981,1992/1993 and 2002) in spite of being one of the major fish producers within SMB municipalities. Further studies on stock assessment, optimization and simulations of possible scenarios will be done using Ecopath with Ecosim (EwE) and General Algebraic Modeling System (GAMS) in order to find the most suitable condition to ensure that fisheries in SMB will be sustainable in the next decades.

3.16 PSA7.16: Singing the fisheries blues: I ain't got no data, what am I going to do

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When fisheries practitioners in developed countries think of fisheries management they generally take for granted that data exist to support it. They expect to find time series of catch and effort, and biological information, all synthesized in stock assessments. The exceptions we label "data-poor" fisheries tend to be low in volume and value. Outside this "world", hundreds if not thousands of fisheries exist, running to millions of tonnes of production, for which few data and, quite possibly, no reliable data exist. Despite the intense contrast between these two worlds, the recommended approach to research and management is often the same. Many fisheries rely on catch and effort data that is often incomplete, poorly recoverable or misleading for other reasons such as hyperstability in abundance indices; reliable data are quite possibly beyond reach on timescales critical to the fishery. So, we propose an alternative, fish-

ing mortality (*F*) based approach to support management of these fisheries. Estimating *F* is not trivial but a variety of approaches (tagging, depletion experiments, swept area analysis, catch curves) make it feasible in most fisheries. Once Fnow is known, comparison with reference or target values (*Ftarget*) commonly associated with sustainable fisheries and "pretty good yields" is possible; such target values can be estimated for most fish stocks given only simple growth information, as is available in Fishbase. The ratio of *Fnow* to *Ftarget* provides managers a clear message about how much fishing is advisable relative to the current level of fishing. Harvest control rules typically call for changing *F* in relation to current biomass relative to the biomass that would produce MSY (i.e. in relation to *B/Bmsy* or *B/Bunfished*). However, these ratios are probably not possible to estimate for most data-poor fisheries. It is much more potent for sustainability to move toward easily-known, sustainable *F* values than to attempt to manage in relation to unobtainable biomass ratios. Additionally, the same relatively simple data needed to provide estimates of target fishing mortality rates can also be used to inform policy changes aimed at reducing growth overfishing (improvement in yield per recruit).

3.17 PSA7.17: Assessing the effects of moving to maximum economic yield effort level in the western rock lobster fishery of Western Australia

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The western rock lobster (*Panulirus cygnus*) fishery has been facing significant economic pressure from increasing costs, lower prices as well as predicted reduced catches due to low recruitment. A maximum economic yield (MEY) assessment estimated the fishing effort that would maximise the net present value of profits over 2008/2009 to 2013/2014 was about 50–60% reduction of 2007/2008 effort. The assessment accounted for fixed vessel costs and the variable pot lift cost. An important component of this assessment was the use of puerulus settlement time series that provided a reliable predictor of recruitment to the fishery 3–4 years later. This can be contrasted to most MEY assessments that would use an average catch-effort relationship rather than taking into account the expected recruitment. This predictive ability has been particularly useful as there has been a period of unusually low puerulus settlements over the five years (2006/2007 to 2010/2011) including the lowest two settlements in the 40-year time series. Due to the low settlements, substantial management changes were implemented in 2008/2009 and 2009/2010 (44 and 73% reduction in nominal fishing effort, respectively compared to 2007/2008) to maintain the breeding stock at sustainable levels by having a significant carryover of legal lobsters into future years of lower recruitment. These effort reductions provided a unique opportunity to assess the economic impact of a fishery moving to an MEY effort level over two years. The CPUE increased from 1.1 kg/pot lift in 2007/2008 to 1.7 and 2.7 in 2008/2009 and 2009/2010, respectively. These CPUEs were much higher than the expected levels (1.2 and 1.1, respectively) if the 2007/2008 effort had been maintained in these two years. The vessel numbers declined by 14 and 36% in 2008/2009 and 2009/2010, respectively, compared to 2007/2008. The fishery profit increased by AUS$13 and 49 million for 2008/2009 and 2009/2010, respectively, compared to that estimated if the 2007/2008 effort level had continued. This assessment demonstrates the economic benefits of fishing at a level close to that estimated for MEY under an input management regime. The management decision-rule framework is currently based on having the egg production above a threshold reference level to ensure sustainability and now a target reference point based on MEY principles is also being considered.

4 Theme Session "Coupled Economic-Ecological Models for Ecosystem-Based Fishery Management: Exploration of Trade-offs Between Model Complexity and Management Needs", at the IIFET conference, 16–20 July 2012

4.1 A coupled model of the Gulf of Maine lobster, herring and groundfish fisheries

Dan Holland, Sigrid Lehuta

The productivity and resilience of fisheries are subject to a multitude of dynamic and interrelated influences that arise from complex coupling of fish populations with the natural and human systems of which they are a part. With few exceptions, fisheries are managed independently, ignoring important natural and human linkages among them. The biological productivity, sustainability and consequently human benefits of ostensibly separate fisheries may be substantially increased if these linkages are better understood and if this understanding can be applied to management. The American lobster, Atlantic herring and Northeast multispecies groundfish fisheries in the Gulf of Maine are subject to an array of natural and human linkages, but these linkages have not been systematically studied. We use a range of bioeconomic models of varying complexity and realism to explore the implications that the linkages amongst these fisheries have for joint management. Our approach to studying and modeling the coupled system of fisheries is to build up from the knowledge base and models that are a legacy of the single-species approach to fisheries management that has prevailed to date, rather than attempt to construct original complex ecosystem models. While ecosystem models that attempt to characterize and quantify the overall food web in the ecosystem are useful in developing a qualitative understanding of the overall ecosystem, they are limited by major gaps in information and computational constraints. A fruitful middle ground is to build multi-fishery models incorporating single-species models that are connected by the important natural and human linkages among them.

4.2 Age-Structured Ecological-Economic Multi-Species Models for Baltic Sea Fisheries

Martin Quaas, Rudi Voss, Jörn Schmidt, Olli Tahvonen

Biologists have criticized traditional biomass models in fishery economics for being oversimplified. Biological stock assessment models are more sophisticated with regard to biological content, but rarely account for economic objectives. Recently, age-structured models of fish stocks have increasingly been used in fisheries economics, but applications have so far mainly been limited to single-species settings. Here, a multi-species age-structured optimization model will be presented for the Baltic that comprises the three economically most important stocks, cod, herring, and sprat, and the effects of predator-prey relationships between these stocks. The optimization model not only studies economically efficient management (using the Kaldor-Hicks criterion), but also studies distributional effects by studying Pareto-efficient allocations in the absence of compensation payments between fleets. It is shown that the distributional effects of economically efficient management can be large, and that, on the other hand, addressing distributional issues, or ecosystem considerations, can be very costly.

4.3   Decision-support for ecosystem-based fishery management in the context of marine spatial planning: regional economic impact models, model outputs, and tradeoff measures

Porter Hoagland, Di Jin

The implementation of ecosystem-based fisheries management (EBFM) requires the development of new analytic tools to integrate environmental, ecological, and socio-economic data from various sources; to capture explicit interactions among ecosystem components; and to simulate and evaluate the effects of alternative management options. We are developing a computable general equilibrium (CGE) framework that models coastal and marine resource sectors linked to the output of a marine food web model. The framework can be used to examine the interactions among different components of a coastal economy and alternative realizations of the structure of a marine food web (Jin *et al.* 2012). We illustrate our framework with two examples from New England fisheries: (1) a basic model with five industry sectors, including agriculture, manufacturing, commercial fishing, seafood processing, and other (an aggregate of all other industries); and (2) an expanded nine-sector model, including four non-fishing sectors and five fishing sectors characterized by gear type: lobster (pot), trawl, scallop (dredge), gillnet, and other. The integrated framework can be used to develop "what-if" type policy simulations for many important issues faced by coastal and ocean managers (e.g., marine spatial planning and climate change impact assessments). Through comparative analyses, we show how economic and distributional tradeoffs among alternative policy options can be assessed by examining changes in metrics of interest to marine resource managers, including a measure of economic surplus.

4.4   Ecopath-based simulation and optimization of management options for the Eastern Gulf of Mexico reef fish fishery

Sherry Larkin, Sergio Alvarez, Jake Tetzlaff, Mike Allen, Carl Walters, Bill Lindberg, Bill Pine

Ecological and economic tradeoffs of recently proposed reef fish management actions were assessed using the Ecopath with Ecosim (EwE) and Ecospace software. The model has 70 biomass pools (e.g., detritus, primary producers, invertebrates, fish, dolphins, sea birds), including multiple age-classes of key species. After mass-balancing, the model was driven using observed fishing mortality from 13 fleets (4 recreational, 9 commercial) and foraging behaviour was adjusted to fit the model to historic abundance and catch trends. The mixed trophic impacts routine was used to identify the most influential groups in the system (i.e., recreational private boats, small mobile epifauna and sardines-herring). The initial simulation extended the status quo 20 years and examined the impact of: 1) rebuilding gag grouper, 2) reducing longline effort, 3) increasing baitfish harvests and 4) alternative closed areas. Results highlight changes in biomass through both competition and predation within the food web. Next, fishing effort is optimized to maximize a weighted four-criterion objective function (profit, jobs, stock size, ecosystem structure). Tradeoff frontiers between profits and reef fish biomass arise. Results indicated the status quo of over-fished gag grouper is sub-optimal but policies being considered should move the system closer to the frontier. Sensitivity analysis on the recreational and commercial prices reveals a stable frontier. Lastly, Ecospace predicts spillover effects from marine protected areas (MPAs) that benefit key species and fleets, however, negative effects of lost fishing grounds and subsequent concentration of effort occurs. Results indicate that MPAs would need to be relatively large in order to be effective at preventing overfishing.

4.5 Including human dimensions in integrated marine ecosystem models: Australian examples

Olivier Thébaud, Beth Fulton, Trevor Hutton, Rich Little, Sean Pascoe, Ingrid Van Putten

With international efforts to develop ecosystem-based management of ocean uses, there has been a growing call for the development of integrated assessment tools, including the design of models which can be used to identify possible futures and evaluate alternative management strategies. Along with this, there is increasing recognition that such models should include explicit representations of human behaviour and its drivers, as this is key to understanding the potential responses to economic, ecological and regulatory changes. The presentation will use examples from Australia to illustrate the diversity of approaches and domains of application in which such modelling can be developed, and discuss some of the key issues which need to be considered in developing these models. Examples will include whole-of-system models, such as Atlantis in the Australian South-East Fishery and multiple use applications of the In Vitro platform in North-Western Australia, as well as the highly spatial multi-species and multi-fleet Effects of Line Fishing Simulator in the Great Barrier Reef and Ningaloo Reef (Western Australia).

5 Session Discussion IIFET Session

The panel discussion was structured in the way that all panellists had the chance to answer the questions posed by the audience to get the whole range of views.

5.1 Struck by the range, in which economics is included in the different models: what dictated the choice for the different models

5.1.1 Porter Hoagland

Our modelling approach has a history, dating back to an early effort to develop an Input-Output (I/O) model to help understand the scale and distribution of economic impacts to New England coastal communities from the implementation of fishery management measures in the US Northeast Region (MPC 2000). This kind of effort was called-for in the 1996 revision to the Magnuson-Stevens Act, known as the Sustainable Fisheries Act. Because of mathematical similarities to the marine food web models that were under development for the US Northeast fisheries, it was natural to try to link the I/O model to a food web, therefore creating a type of model that could help with ecosystem-based management (Jin *et al.* 2003). From this effort, we moved towards the development of a Computable General Equilibrium (CGE) model in order to be able to measure the welfare effects of either fishery management regulations or changes in the ecological system (Jin *et al.* 2012; Hoagland and Jin 2011).

5.1.2 Sherry Larkin

A basic Ecopath model was already developed and mass-balanced so we were able to take advantage of previous model building efforts on the biological side. However, the role of economics in the broader Ecopath with Ecosim (EWE) platform is limited. It works similar to an I/O model, and the economic parameters are held constant even throughout long-run simulations. We have been able to further explore the use of optimizations that involve tradeoffs among four diverse objectives for the fishery and those have been well-received but it still suffers from the use of fixed parameters.

5.1.3   Dan Holland

The development was driven by the research interests of the scientists involved in the project and by funding possibilities. The project was designed in response to a call for proposals from the US National Science Foundation for interdisciplinary research on couple natural and human systems. The researchers felt that a middle ground approach, between single species models and foodweb models, that focused on human and natural linkages between key fisheries would be a useful and novel way to improve understanding and management of these fisheries and a practical step toward ecosystem management that would also be appealing to the funding agency.

5.1.4   Rudi Voss

The development was clearly driven by the personal background of the people involved. The start was to overcome the hesitation of biologists to include economic considerations into their models. To ease the communication, especially with stock assessment scientists, the model was structured in a similar way as the stock assessment models (e.g. age structured), also using the same input data.

5.1.5   Olivier Thébaud

The starting point was the need to answer specific questions, which people asked. The move came partly from biologists, and the development was also driven by the background of the people involved.

5.2   Coming from live-stock economics: There is still a lack of integration of real feedback from the economic system to the ecological system. Any ideas of how to tackle this?

5.2.1   Porter Hoagland

The CGE model that we have developed is fundamentally a static representation of the economy. We use biomass inputs from linked ecological models to assess the economic effects. There are a few CGE models that have been designed to allow dynamic feedbacks. The incorporation of feedbacks is mostly a task for future research, but the development of reliable CGE approaches will be difficult due to model complexity and the practical aspects of model balancing.

5.2.2   Sherry Larkin

In the EWE model it is possible to restrict landings by certain sectors, for example, by requiring that the harvest be profitable, which would then affect fishing effort on certain species. The group is looking for possibilities to incorporate endogeneity in the prices and costs in the optimization and simulation routines where the biology and economics interact but has no progress to report at this time.

5.2.3   Dan Holland

The group wants to build in feedbacks, but wants to concentrate on micro-scale feedbacks. The feeling is that a full-feedback model will unreasonably increase the uncertainty, because medium or even long term projections of economic behaviour are highly uncertain and would add disproportionately to the uncertainty, which is already inherent in ecological models.

5.2.4 Rudi Voss

Totally agrees with Dan, especially with respect to the high uncertainty of ecological models and the difficulty to perform sensitivity analyses due to high computational demands of complex ecosystem models.

5.2.5 Olivier Thébaud

The incorporation of full feedback also depends on the use of the model, e.g. in Australia some people want to develop feedback models for strategic outlook taking into account interactions between multiple sectors of the economy, including those related to the mining boom, and the ecosystem.

5.3 Some of the ecological models used for the coupled approach are highly complex and the need for at least multispecies models is clear. However there might be the risk of not including important species within the ecosystem, especially if they are not of commercial value: Is there a susceptibility of the models to different degrees of complexity?

5.3.1 Rudi Voss

For some regions, e.g. the Baltic Sea, there are already different models with different degrees of complexity available. A working group within the International Council for the Exploration of the Sea (ICES) has used a set of different models with the same input data (where possible) to explore the uncertainty around the different models (ensemble modelling approach). However a challenge is the hesitation of the political side to adopt this approach. They still go for the single model approach.

5.3.2 Comment from the audience

Another perception is that there is national or international pressure already there, but institutions are not well prepared to step beyond single stock assessments and advice.

5.3.3 Porter Hoagland

It would be interesting to use one economic model to assess different levels of the aggregation of species. One could initialize the model with historic data to get an idea of whether it is sensitive to alternative species aggregations. Preliminary results from our CGE framework reveal that welfare estimates can differ when assessing increases (due to fishery regulations) in the biomass of two species independently in comparison to assessments of such changes simultaneously. This result is due undoubtedly to the current structure of the CGE framework.

5.4 If you want to use the models, you need to evaluate the robustness of the model: how do you approach this?

5.4.1 Dan Holland

Both the Ecopath and the Atlantis models are tuned with time series data. However, when the models are forced with dramatic changes in the system to explore the reaction a real validation or even sensitivity analysis is difficult, because of the high computational demands of running the models and the fact that scenarios and outcomes are typically outside the range of historical data with which to validate.

5.4.2   Olivier Thébaud

Agrees with respect to Atlantis. It is not possible to perform a full sensitivity analysis, thus one has a look at the major assumptions and explore potential outcomes of selected scenarios, as well as try to get the processes right. It would be interesting to develop ensemble-modelling approaches for economic process models, but he is not aware of an existing study.

5.4.3   Sherry Larkin

As mentioned in the presentation, we approached the model building process with the need for the model to pass a credibility test, expose they key underlying issues, address how the model could be useful to management and become an operational tool. This was accomplished by holding a series of workshops for scientists (economists, ecologists and biologists) and policy makers. These workshops were invaluable for ground-truthing some of the inputs and ensuring the outputs were reasonable. We were also able to use some of the system summary statistics (e.g., primary production, total system throughput, ascendency, etc.) to compare our EWE model with others that have been developed for other regions. A validation might be difficult for some of the data for the economic models because sufficient data is not always accessible for all the sectors that may need to be modelled. However, the model could be used to identify the parameters that (when changed) produce significant changes in results (i.e., sensitivity analysis). The benefit of such an analysis is that the results can be used to identify were future data collection efforts should be improved; these models take a lot of data and resources are scarce so we see this as a valuable use for these models.

5.5   What about societal or economic scenarios or regimes? Are the time scales or dynamics similar and what are the time scales of the models?

5.5.1   Olivier Thébaud

You can for example consider this at the process level, e.g. technical changes or changes related to expected future trends in global market. One example of this is the Northern Prawn fishery where changes in future input and output price levels have been factored into the evaluation of possible strategies towards achieving Maximum Economic Yield.

5.5.2   Dan Holland

The time scale can be different in different models and one has to be aware that there is not a single generic model which fits all purposes, but specific models are built for answering specific questions.

5.6   How are you planning to incorporate non-market values

5.6.1   Porter Hoagland

In theory, we could incorporate non-market economic values into the CGE framework, and the diagram in our presentation indicates that such values might be incorporated naturally into consumer utility functions. Note that the existing linkage to the ecological model assumes that fish yields are a priceless input to the production of seafood. Assigning a price to the harvest of fish implies that the production function at the front end of the CGE model would need re-specification, possibly requiring a change in its constant elasticity of substitution form, and leading to a necessary rebalancing of the model. David Finnoff and John Tschirhart at the University of Wyo-

ming have been working along these lines, incorporating, for example, protected species in what they refer to as a "general equilibrium ecosystem model" for Alaska's Bering Sea (Finnoff *et al*. 2012).

5.6.2 Sherry Larkin

It is possible to give species, which are not commercially exploited (e.g., seabirds and dolphins), a non-market value in Ecopath. When entered as non-market values, the values are included in calculations of the total value of the ecosystem. However, these non-values are not considered in the optimizations that evaluate tradeoffs between various fishery objectives (even the ones designed to capture social values and ecosystem strength).

5.6.3 Rudi Voss

It is possible to build in constraints, e.g. a minimum stock size of a prey species for sea birds or marine mammals.

5.6.4 Olivier Thébaud

It is possible to calculate the shadow values associated with the protection of species or areas with no commercial value, using the model, and then to use these values in assessing the performance of alternative management strategies.

5.7 Given the complexity of the models and results, it is more and more difficult to communicate the results, but there is increasing space for interpretation and discussion. How to deal with this?

5.7.1 Sherry Larkin

They had stakeholder discussions on the model inputs and results (including those designed to capture uncertainty in the point estimates) and it was obvious which graphs and tables were most confusing and which were most important and helpful. That process was extremely helpful in being able to better communicate what the model can and cannot do. With respect to what the model cannot do, or which it is not suited to addressing, that was our biggest challenge. For example, the model should not be used to address allocation issues between fishing fleets due to the use of total values based on fixed parameters (versus marginal values that would be a better tool for determining the movement of use between sectors).

5.7.2 Dan Holland

They have not tried so far to get in discussions with stakeholder, but it is well understood that communicating uncertainty is an important issue.

5.7.3 Olivier Thébaud

As the models tackle increasingly complex systems and multiple-use issues, there is a need to communicate simulation outcomes across a growing range of dimensions, taking into account uncertainty and potentially diverging views on what is important to consider. There is a need to invest research efforts in this part of ecological-economic modelling as well.

6 Outlook and Future Challenges

The Study Group will have its next meeting in 2013 and will summarize and extend the work of the first two years. A survey is planned to extend the range of the model

set already collected. On this basis the group will discuss which types of models are or can be best used in the ICES context with respect to advice and strategic research in the near future. The group will also comment on further needs of initiatives following SGIMM to explore and promote integrated approaches, methods and models in the ICES area related to research and advice, given the global experiences. This will also include discussions on the need to further link to existing expert groups like the integrated assessment working groups.

The presentations on the theme sessions this year have again shown the large variety of model approaches, which still need to be gathered within the review matrix. The theme sessions, especially the special session at the IIFET, have also been successful in attracting new members, especially economists, to the group. A key challenge is and will be to attract participation of ecological and economic modellers. However, the recent international discussions including the sessions associated to SGIMM show that integrated models will be central tools and methods in future management evaluation and thus, the work of this group will continue to be relevant and informative.

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Annex 2: SGIMM draft resolution for the next meeting

The **Study Group on Integration of Economics, Stock Assessment and Fisheries Management** (SGIMM), chaired by Jörn Schmidt, Germany, J. Rasmus Nielsen, Denmark, and Eric Thunberg, USA, will meet in Copenhagen, Denmark, DATE [TBA] 2013 to:

a) Evaluate and review further the world wide state-of-the-art in integrating economic (modelling), stock assessment and fisheries management plans relevant for ICES; In this context develop further the suggested Model Performance and Characteristics Matrices and Model Summaries reviewing each of the relevant models both in scientific, advisory and management context;

b) Develop further existing integrated frameworks, models and methods on case specific basis for integrated bio-economic modelling of fisheries, and test and discuss their general utility with respect to general implementation in ICES fisheries and scientific evaluation of fisheries and stocks;

c) Discuss and identify functions for economic dynamics (parameters) needed to be integrated into the models and frameworks;

d) Identify further the data and information required as well as expertise needed for integrated bio-economic modelling of fisheries and application of socio-economic evaluation methods on short and long term basis;

e) Identify platforms and multi-disciplinary fora (fisheries biology (ecology), economy, sociology) to develop, link and use ecological-economic modelling tools to be used in scientific evaluation and advice on integrated fish stock and fisheries management; Hereunder develop further the cooperation with IFET on this.

f) Comment on the need of follow up initiatives like SGIMM to explore and promote integrated approaches, methods and models in the ICES area, research and advice, given global experiences. This should also include the discussion of linking to other ICES expert groups, like the integrated assessment working groups.

SGIMM will report by 15 August 2013 (via SSGRSP and SSGSUE) for the attention of SCICOM and ACOM.

Supporting Information

Priority	There is an increasing demand for coupled ecological and economical models in advice giving bodies and review of their development level, characteristics and performance. However, the possibilities to coordinate the expertise of economists, sociologists, and ecologists to develop and evaluate further bio-economic models and management evaluation frameworks is not fully used yet. The goal will be to further couple economic and sociological expertise directly with the ecological understanding within ICES to enhance the quality of fisheries assessment and the value of the advice.
Scientific Justification	The incorporation of bio-economics in fisheries assessment might lead to a better result and an enhanced communication with fisheries industry, fishermen, managers and other stakeholders as the advice could be made on the basis of a deepened understanding of: • the economic and sociological incentives of fishermen and industry; • the bio-economic interaction between different fisheries and both

	biological and economical consequences of different management scenarios;
	• and transaction costs of different policies coupled with the existing sound biological knowledge within ICES.
	Further scientific overview and evaluation of performance, characteristics and scientific and advisory implementation of the models is necessary in order to advice on implementation.
	The workshop will directly feed goals 3 and 5 of the ICES action plan: "Evaluate options for sustainable marine-related industries, particularly fishing and mariculture" and "Enhance collaboration with organisations, scientific programmes, and stakeholders (including the fishing industry) that are relevant to the ICES goals".
	The possibility to incorporate economics and socio-economics directly into the scientific advice and further develop the models and their integration scientifically would enhance the acceptance of the advice on stakeholder level and to "…deliver the advice that decision makers need…"
Resource Requirements:	No specific resource requirements beyond the need for members to prepare for and participate in the meeting
Participants	Interested scientists, economic modellers, ecological modellers, SCICOM members, ACOM members, Assessment group members, stock assessment experts (as well as selected stakeholder observers, e.g. RACs and managers)
Secretariat Facilities	Sharepoint, secretariat support for reporting
Financial:	None
Linkages to Advisory Committees:	The incorporation of economy in fisheries advice should be of basic interest to ACOM and the general scientific overview and further development of interest to SCICOM
Linkages to other Committees or Groups:	Assessment groups (ACOM). Scientific methods to enable Integrated Marine Management across sectors and implementing an Ecosystem Based Approach to Fisheries Management has significant scientific focus and is relevant for ICES SCICOM and several ICES groups hereunder.
Linkages to other Organisations:	Contact and agreement on scientific collaboration has been established with the International Institute of Fisheries Economics and Trade (IIFET).