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Report of the Workshop on operational EwE models to inform IEAs (WKEWIEA)

26-30 November 2018

Barcelona, Spain

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CIEM Conseil International pour l'Exploration de la Mer

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Executive summary

The first Workshop on operational EwE models to inform IEAs (WKEWIEA) met from the 26th to the 30th of November 2018 in Barcelona, chaired by Maciej T. Tomczak (Sweden), Maria Angeles Torres (Spain) and Eider Andonegi (Spain). The main goal of WKEWIEA was to identify, analyse and provide light on the potential use of ecosystem models to inform the scientific advice currently provided by ICES. The workshop focused on Ecopath with Ecosim (EwE) models as accepted by the ICES Secretariat, since EwE is the most widely used ecosystem modelling tool across ICES integrated ecosystem assessments (IEA) regional groups.

The group was composed by a variety of experts, including ecosystem modellers, ecosystem researchers and people closely related with or with a deep knowledge of the ICES advisory process (people that actively participate in providing advice on fishing opportunities and also in fisheries and ecosystem overviews).

Different works were presented during the workshop, some providing a general overview of the way EwE models have and/or are being used for solving management and policy related issues, and others showing practical examples how existing models could be used to inform current and future generations of Ecosystem Overviews (EOs). Additionally, discussions focused on the need of a well-accepted and documented protocol that establishes the basis about the requirements of these ecosystem models in order for them to be used to inform various parts of ICES advice, including fishing opportunities.

The main recommendations provided by WKEWIEA to the ICES community are to: i) develop a key run and quality protocol for using EwE models to inform IEAs and ICES advice (together with the Working Group on Multispecies Assessment Methods (WGSAM)); ii) adopt EwE and equivalent models in the ToRs of the ICES IEA regional groups; iii) provide advice for IEA expert groups about indicators from EwE models to be used in IEAs for the state of different ecosystem components; iv) provide some guidelines about the visualization of products (e.g. trade-offs or links quantification). Additionally, WKEWIEA strongly recommends setting up a series of workshops to continue working on how to make EwE (and other ecosystem models) operational for ICES advice, starting with a next workshop in 2019 to deal with the inter-comparability of EwE models to inform IEAs. Intersessional meetings will also be held to organize our work and strengthen the links with other ICES working groups identified as key by the group for achieving these goals.

1 Opening of the meeting

The first meeting of the **Workshop on operational EwE models to inform IEAs (WKEWIEA**) was opened at 13.00 pm on 26th November and adjourned on 30th November 2018, chaired by Maciej Tomczak (Sweden) and Eider Andonegi (Spain) with the apologizes from the third chair, Maria Angeles Torres (Spain) for not been able to physically attend the meeting. Nevertheless, Maria Angeles worked and supported the chairs by correspondence during the whole process. The meeting was attended by 18 participants representing 10 different countries. A full participants list is found in Annex 1.

2 Adoption of the agenda

A preliminary agenda was presented to the group and was adopted with minor changes that are contained in the agenda shown in Annex 2.

3 Terms of reference

The **Workshop on operational EwE models to inform IEAs (WKEWIEA)** needed to address the two tasks in the Terms of Reference described below:

a) Explore the practicalities of integrating information from existing Ecopath with Ecosim and Ecospace models

b) Explore their utility towards informing IEA in ICES areas – explore their potential to inform ICES products such as the Ecosystem Overviews, as an integral part of the ecosystem advice

Several presentations were organized (see the agenda) to get a global context on how EwE models could be used to inform IEAs, and hence ecosystem and fisheries related advice in ICES. All the presenters were asked to showcase their EwE-related work, and to reflect on how that work could be useful to inform IEAs and general ICES advice.

4 Progress report on ToRs and workplan

4.1 Building the working framework

During the first day, aiming at stablishing a common working framework for all participants, the chairs presented the motivation for the workshop. The WS was conceptualized during consecutive WGEAWESS meetings and shared with other IEA groups in ICES to analyse the interest of the whole community, and was contextualized in the framework of the ICES advice and current development of relevant science (i.e. WKDEICE), providing some starting point for following discussions during the week.

Iñigo Martinez from the ICES Secretariat presented how ICES is working to provide ecosystem advice since 2016. See the summary of his talk below:

4.1.1 ICES Ecosystems Overviews: Development and Rationale

By Iñigo Martinez (ICES Secretariat)

The ICES strategic plan highlights the importance of providing the evidence for EBM. Three main outputs are provided to support EBM: advice on fishing opportunities, fisheries overviews, and ecosystem overviews (EOs). All these three products should be considered together to have a complete picture of the ICES advice with the fisheries as the main activity and hence EBFA.

The ICES environmental advice is relatively new and needs to be provided in context for the scope and the framework to be understood, with a correct interpretation by recipients (see outputs from WKECOFRAME2, 2018). ICES environmental advice needs to be consistent with other pieces of ICES Advice and needs to be evidence based, transparent and legitimate.

The ecosystem overviews objective is to provide a concise, up-to-date, evidence-based overview of each of the ICES ecoregions and is divided in 5 main sections:

1. Ecoregion description: boundaries and management
2. Key signals within the environment and ecosystem
3. Top pressures on the ecosystem
4. State of ecosystem components
5. Climate change (2018)

The ecosystem overviews currently use qualitative methods to identify and focus on the top five priority pressures and associated human activities that can be locally managed within each ecoregion. They thus put fishing activities into the context of the trends and status of the marine ecosystem as a whole. EOs also try to highlight consequences of trade-offs between objectives.

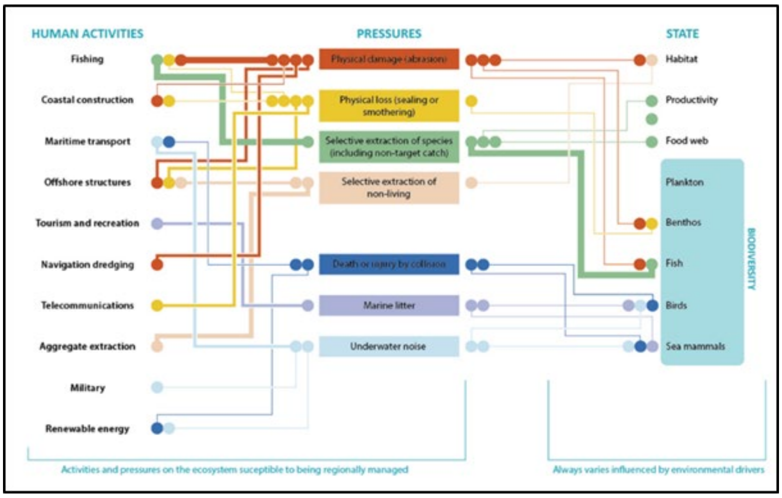

Figure 4.1.1.1. Example of ecoregion overview main diagram with the major regional pressures, human activities, and ecosystem state components. Climate change affects human activities, the intensity of the pressures, and some aspects of state, as well as the links between these.

So far ICES has developed EOs for seven Ecoregions; Bay of Biscay and Iberian Coast, Greater North Sea, Celtic Seas, Barents Sea, Norwegian Sea, Icelandic waters and Baltic Sea: http://www.ices.dk/community/advisory-process/Pages/Ecosystem-overviews.aspx

Current overviews use qualitative methods based on knowledge from across the ICES network combined with the quality assurance and advice drafting experience. However, a new generation of overviews with more quantitative methods to further assess these pressures are currently being developed. These new overviews will reinforce the online application, consider social and economic objectives an incorporate ecosystem services and not only pressures.

There would be also stronger expectations for data provision and access to underlying data for the future ICES ecosystem overviews (see FAIR principles for data). Therefore, data supporting new products are expected to (1) have a Digital Object Identifier (DOI) (2) conform to ISO standards, and (3) refer to international standards and units. Data access rights must be clear, and could include a data usage license (ref. to the ICES data policy) and links to download with internationally recognized download formats. All data should be accompanied by a clear vocabulary and auxiliary data (manuals and protocols) that describe the methods used or referenced by weblinks.

In addition, ICES is implementing a Transparent Assessment Framework (TAF: taf.ices.dk) that links data inputs with decision-making and models to data outputs. This framework should assure archiving, transparency and reproducibility in the long term.

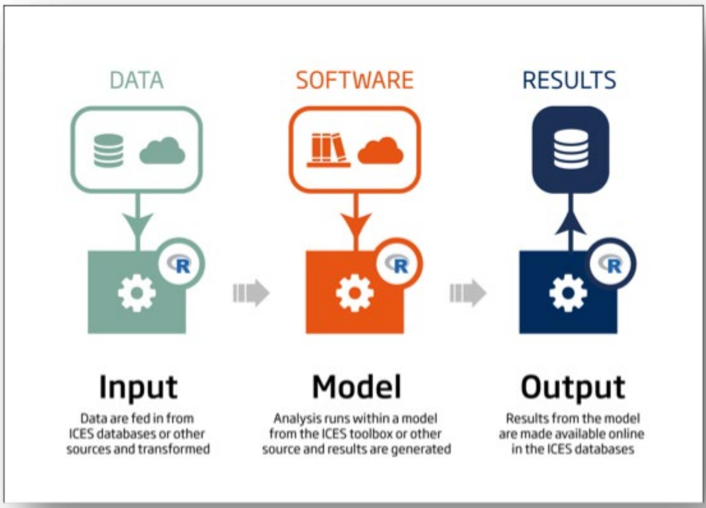

Figure 4.1.1.2. Transparent Assessment Framework (TAF) conceptual model.

During the following two days, different works were shown by the workshop participants. Some examples demonstrated how EwE models were being used to address management related issues in a global and/or regional scale, showing cases from both ICES and non-ICES international areas.

The summaries of those talks (following the order of the agenda) are shown in the subsections below.

Section 4.2 contains the bulk of presentations that aimed to provide an overview of how ecosystem models in general and EwE models in particular are being used to address management and policy related issues. Section 4.3 contains presentations focused on providing considerations, recommendations and potential alternatives about the use of ecosystem models. Section 4.4contains presentations that detail practical examples where EwE models have been applied for EU-ICES areas and how they could be used to inform existing Ecosystem Overviews. Finally, section 4.5 presents other potential ways of using EwE models to inform advice were shown, dealing with different issues such as including the spatial dimension using Ecospace, incorporating fisher's knowledge in EwE models and also the use of geographically-nested ecosystem model to support MPAs related issues.

4.2 How are EwE and other ecosystem models used to support management and policy related issues?

4.2.1 Are ecosystem models used for management and policy?

By Villy Christensen (University of British Columbia)

There is widespread interest in and demand for models of aquatic ecosystems, and this presentation showed an overview of how ecosystem models are used for management and policy based on a review focused on the most widely used ecosystem model type, Ecopath with Ecosim (EwE). There are around 500 published - EwE models, and many of these are available for download in an online database - (www.Ecobase.Ecopath.org). The review evaluated the current status of using EwE for management and policy and was structured around seven topics, (1) fisheries management, focused on evaluation of ecological, economic and social factors and trade-offs, and for setting and evaluation of reference points, and increasingly as operating models for Management Strategy Evaluation (MSE); (2) fishing regulations, where development of STECF Multi Annual Plans, evaluations of the EU Landing Obligation and other bycatch studies are of interest; (3) indicators, with focus on the EU Marine Strategy Framework Directive; (4) evaluations of the fisheries sector, notably value chain analysis describing economic and social factors throughout the supply chain to the consumers; (5) spatial management, which includes development of MSE frameworks as operational tools for ecosystem based management, and applications aimed at developing toolboxes for evaluating impact of nuclear reactor incidences on seafood; (6) environmental impact assessments are a focus of much development, and includes evaluations of impact of dams, marine renewable energy, and major infrastructure; and (7) climate change research, based on coupling of physical, biogeochemical and foodweb models climate change, or linking to Earth System models to evaluate potential impacts of climate change, which impacts policies through IPBES, IPCC, Fisheries Management Councils, a.o.

4.2.2 A modelling framework for the Mediterranean Sea ecosystem in support of EU policies

By Chiara Piroddi (JRC, European Union)

The Marine Strategy Framework Directive (MSFD) is foreseeing that all EU Member States take the necessary measures to maintain or progressively achieve Good Environmental Status (GES) in the marine environment by year 2020. In recent years, the JRC has delivered to the Commission scientific and technical support to the implementation of the Marine Strategy Framework Directive (MSFD). As part of this initiative, in particular, the development of models aiming at helping the evaluation and implementation of policies conductive of achieving GES in the different European basins. Under this framework, this presentation showed the Marine Modelling Framework (MF) developed at DG JRC with the aim of providing policy-support to EU initiatives dealing with the environmental status of EU regional seas. The general structure of the MF was presented as well as a schematic representation on how such tools could be used, through modelled derived indicators, in the MSFD policy evaluation cycle (selected descriptor/criteria were presented and linked to the modelled derived indicators). A general overview of current implementations and progress of these approaches at EU scale was shown, together with some specific examples of present and past applications of the MF for the Mediterranean Sea, which was the first regional sea of being assessed by JRC.

4.2.3 Using EwE models for management issues – the US example

By Howard Townsend (NOAA)

National Marine Fisheries Services (NMFS) uses a range of ecosystem models for living marine resource management. The primary reason to use ecosystem modeling is to systematically and simultaneously evaluate multiple factors affecting LMRs. Models

are used in a holistic, EBFM context as well as to inform single-species management issues (Table 4.2.3.1).

Table 4.2.3.1. Different use of ecosystem models in the EBFM and classic FM context.

EBFM Context	Informing single species management
To systematically catalogue information for an ecosystem and thereby systematically identify data gaps	To predict LMR species responses to a range of management options

To explore hypotheses of how the ecosystem, ocean, trust spp., and fisheries behave	To predict LMR species responses to climate change, oceanography, esp. with respect to distribution
To systematically evaluate relativity of risk	To provide mass balance constraints to stock-assessment, Protected Resource model outputs
To quantitatively evaluate social, economic, and ecological trade-offs among different management options	To constrain Stock assessment ACL outputs with real-world limits of total system production
To predict human behavior responses, especially fleet dynamics, with respect to ecosystem change	To produce multi-model ensembles and account for uncertainty associated with model structure
To conduct scoping and feasibility exercises with stakeholders, esp. with qualitative network modelling	To predict LMR species responses to a range of mgt options
To conduct quantitative testing aspects of IEAs	To predict LMR species responses to climate change, oceanography, esp. with respect to distribution

Most NMFS centers have simpler ecosystem models (e.g. multispecies surplus production), some have very complex models (e.g. Atlantis or other end-to-end models). Virtually every science center has used Ecopath for ecosystems within their purview. Many centers use EwE as one of suite of ecosystem models with the purpose of accounting for uncertainty associated with model structure. For example, the Alaska Fisheries Science Center uses EwE, along with other models of varying complexity, to evaluating fishing management strategies under different climate scenarios. The Northwest Fisheries Science Center has used Ecopath, along with an Atlantis Model and a Model of Intermediate Complexity, to evaluate effects of sardine fisheries on predators. These are just a few examples of the ways NMFS is beginning to include information from ecosystem models into living marine resource management.

Specifically, for Integrated Ecosystem Assessments (IEAs) within NMFS, ecosystem models can inform the IEA process (Figure 4.3.2.1) by:

1. Synthesizing available data to help us understand and assess system dynamics,
2. Scenario tests of the risk of key species to top-down or bottom-up mediated stressors, and
3. Scenario tests of the effectiveness and trade-offs of management strategy alternatives.

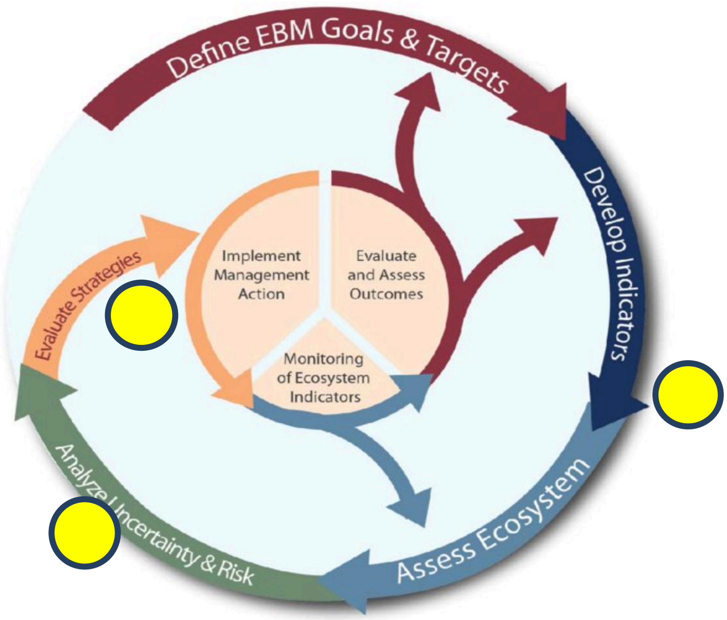

Figure 4.3.2.1. Integrated Ecosystem Assessments loop diagram (modified from www.noaa.gov/iea)

In addition to complex, data-driven ecosystem models, NMFS IEAs have been increasingly making use of qualitative, conceptual models to understand the driver, pressures and states of the ecosystem. The process for developing these conceptual models involves stakeholder input. The stakeholder involvement in model development process enables managers, stakeholders and scientists/modelers to develop a shared understanding of important social and biophysical processes in a n ecosystem. This approach has been useful in incorporating socio-economic aspects of ecosystems that often are not readily quantifiable, thus providing a more complete picture of the social-ecological system in NMFS regions.

4.3 Considerations and examples about the use of ecosystem models

4.3.1 Enhancing Europe's capability in marine ecosystems modelling for societal benefit

By Sheila Heymans (European Marine Board)

Marine ecosystem models are an important approach to: integrate knowledge, data, and information; improve understanding on ecosystem functioning; and complement monitoring and observation efforts. They also offer the potential to predict the response of marine ecosystems to future scenarios and to support the implementation of ecosystem-based management of our seas and ocean.

There are many marine ecosystem models, but there is no single model that can answer all policy questions, making it difficult to achieve a fully end-to-end (E2E) model. In each case the context, specific knowledge and scale need to be taken into account to design a model with the appropriate level of complexity. It is more practical to assemble several models in order to reach the full E2E spectrum. This requires a transdisciplinary approach and the inclusion of socio-economic drivers.

This Future Science Brief has identified the following research and development needs to improve model development as well as key recommendations to strengthen the marine ecosystem modelling capability:

- Collect and incorporate new data and information into marine ecosystem models;
- Model marine biodiversity and ecosystem services, based on critical understanding of marine ecosystems;
- Model changes in behaviour, based on understanding adaptive responses in marine organisms;
- Evaluate and reduce uncertainty in marine ecosystem forecasting; and
- Use new approaches in machine learning to enhance marine ecosystem models.
- Key recommendations to strengthen marine ecosystem modelling capability include:
- Enhance models by identifying crucial unavailable data, linking models to new and existing observations and data, and by strengthening links to data assimilation centers;
- Increase model predictability through coordinated model experiments and the ensemble approach;
- Develop a shared knowledge platform for marine models and support the development of next generation models;
- Make marine ecosystem models more relevant to management and policy by being more transparent about model limitations and the uncertainties in their predictions; including socio-economic drivers;
- Promoting co-design and dialogue between model developers and users; and
- Enhance trans-disciplinary connections and training opportunities.

4.3.2 Of Fish and Men: Integrated ecosystem assessments – Integrated fisheries management solutions

<u>By Rudi Voss (Kiel University)</u>

The world's fish stocks as well as the marine foodwebs they are embedded in, are increasingly under pressure, not only due to climate change effects, but also due to socio-economic development, leading to a worldwide increased demand for fish. One major reason is failing fisheries management, allowing for too generous catch opportunities, while disregarding ecological-economic feedback dynamics. New aspects of developing integrated, sustainable fisheries management solutions are needed. The work applies cutting-edge ecological-economic models based on newly available data that enable a necessary innovation in inter-and trans-disciplinary fisheries management. This research aims to improve 'on the ground' management applications in order to inform Integrated Ecosystem Assessments.

We use ecological-economic models of varying complexity to illustrate the importance of including socio-economic factors in Integrated Ecosystem Assessments – otherwise incomplete, or even simply false, conclusions might be reached. E.g. the application of a pure MSY strategy in a multispecies context (without any economic considerations) will result in economically AND ecologically disastrous outcomes (at least in the case study of the Baltic Sea).

Year-to-year management implicitly responds to short-term economic interests, and consequently, regularly resorts to tactical short-term rather than strategic long-term decisions. Using Baltic cod as a showcase, we introduce a new way of estimating management advice referred to as an 'ecologically-constrained Maximum Economic Yield' (eMEY) strategy, which takes into account ecological criteria as well as short- to medium-term economic costs. The eMEY approach aims at maximizing the economic benefits for the fishery as well as society (consumers), while safeguarding precautionary stock sizes. We find that application of eMEY advice results in less variable catches as compared to conventional management. Total allowable catches are dampened during high stock sizes, but importantly for the fishery, zero catch advice during phases of low stock size is avoided. Quantification and visualization of the costs of deviating from eMEY advice offers a transparent basis for evaluating decision-making outcomes. To foster the uptake of the eMEY approach, or other Integrated Advice, in current advice given by the International Council for the Exploration of the Sea (ICES) and the EU fishery management system, we suggest an easy-to-implement scheme of providing integrated advice, also accounting for economic considerations.

4.3.3 Qualitative modelling for assessing cumulative impacts on the North Sea ecosystem

The ICES North Sea IEA group (WGINOSE) is developing conceptual 'qualitative' models, using methods described by DePiper et al. (2017), for selected sub-regions of the North Sea. The strength of these modelling approaches is the ease with which they can be developed with stakeholders to identify the most important ecosystem components to assess from the perspective of the human dimension (e.g. types of activity, management objectives, target species and habitats) The direction and strength of ecosystem component interactions (or links) are again identified and agreed in consultation with stakeholders before running the models against an agreed set of scenarios or questions to be addressed. An example of a typical conceptual model structure and output in response to increasing fishing pressure from all fisheries, is shown in Figure 4.3.3.1 and 4.3.3.2.

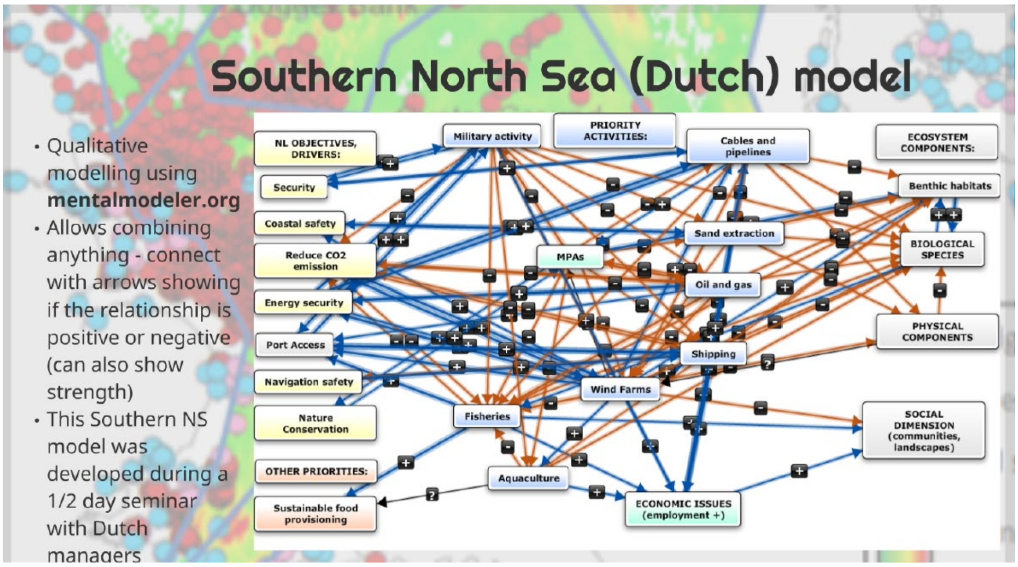

Figure 4.3.3.1. Conceptual ecosystem model developed in consultation with stakeholders for the Dutch sector of the Southern North Sea.

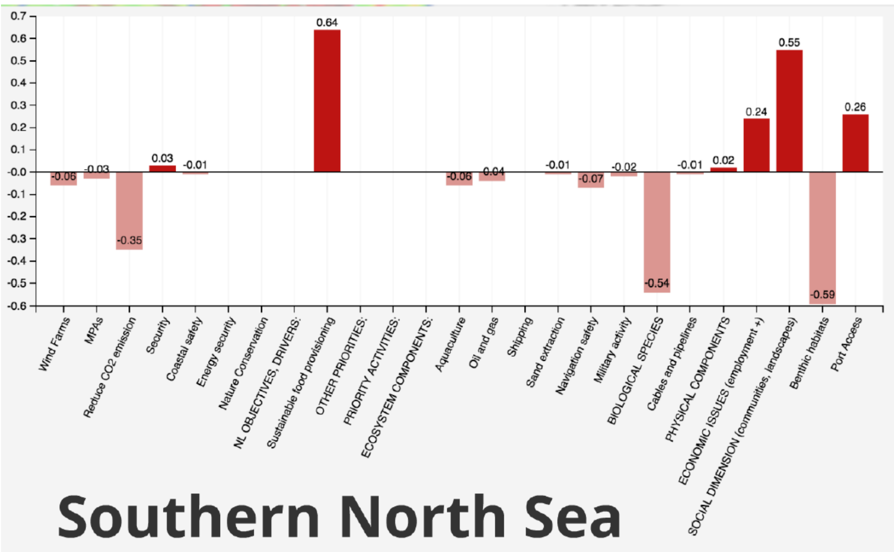

Figure 4.3.3.2. Model results for a scenario which increases fishing pressure for all types of fishing activity.

The consequences of different management scenarios can be readily evaluated with respect to non-target components of the ecosystem (Figure 4.3.3.2). However, confidence and reliability of the qualitative model outputs must be evaluated and supported through integration with quantitative modelling and assessment approaches. In this respect WGINOSE will couple its North Sea conceptual *MentalModels* with spatially comparable EwEs.

4.4 How could EwE models could inform next generations of Ecosystem Overviews – thoughts and examples

4.4.1 Natalia Serpetti: Western Coast of Scotland modelling in relation to Celtic Seas Ecosystem Overview

<u>**By Natalia Serpetti (SAMS)**</u>

This presentation was focused in three main topics:

1. Why MSY? Context - West of Scotland fisheries

This analysis was performed using two different modelling approaches. Ecopath with Ecosim (EwE NS and SH) and StrathE2E (by MH). Both models were used to assess the current state of MSY in this ecosystem: the major findings highlighted a strong reduction in fishing mortality from the 80’s (when pelagic and demersal stocks were in overfishing) to an under fished ecosystem on 2000’s.

This led to an increase of demersal biomass overall driven by a large increased of hake, saithe and flatfish, while other gadoids (cod, haddock and whiting) showed a continuous steady decline. Simulation from StratE2E showed that these trends caused a strong predation pressure on pelagic fish showing very low yields no related to fishing pressure. The yield curve for pelagic can be re-built only if the pelagic would be released by demersal predation pressure. EwE showed that also cod, whiting and haddock are crushed by predation pressure by saithe rather than fishing pressure.

Both models showed that to maximize the overall catches of pelagic domains we could fish twice as much the 2003-2013 baseline and up to ten times for the demersal domain, of course that will lead to a loss of biodiversity.

Currently the fishery has been managed under single stock assessment, however this approach does not take in consideration the predation pressure dictated by the food-web and the mix fishery issue. The demersal otter trawls catch all the main gadoids, so apply different fishing pressures for species caught by the same gear is not very applicable. For this reasons F at MSY were calculated across different methods (Surplus production model and EwE multispecies MSY plug-in) and compared with the baseline (F 2003-2013) and the fishing mortalities advised by stock assessment. Two more scenarios were also tested: one that look at the F MSY to maximize the catches of the demersal and pelagic overall domains (loosing biodiversity) and one scenario that represent a compromise which is taking in consideration an overall increase of fishing, but also an increase gear selectivity (reducing bycatches of juvenile gadoids by *Nephrops* trawler and spatially trying to avoid cod catches).

The overall comparison shows potential recovery of cod, whiting and haddock when a stronger fishing mortality for saithe was applied reducing the predation pressure of this predators over the other gadoids. Similar finding (no presented) have been found in the pelagic domain where an increasing fishing mortality for hake could lead to a reduction of predation pressure on pelagic group and an overall increase of their catches.

2. IPCC scenarios – Rising water temperature

This part of the presentation highlighted the importance of assessing the impact of ocean warming on sustainable fisheries management as warming water could have a strong impact on cold water species.

3. Impact of noise on harbour porpoise

Cetaceans groups was split into three sub-groups based on their sensitivity to noise sources: minke whales (low-frequency noise), harbour porpoise (high-frequency noise), dolphins (mid-frequency noise). Bottom-up and top-down spatial temporal data were coupled in Ecospace: top-predators data were supplied by Waggitt et al. (in prep) while depth integrated temperature and net primary were supplied by NEMO-ERSEM (Plymouth Marine Laboratory).

The new updated Ecospace model was used to assess the impact of noise on harbour porpoise.

4.4.2 Southern North Sea modelling in relation to North Sea Ecosystem Overview

By Moritz Stäbler (Leibniz Centre for Tropical Marine Research) and Miriam Püts (Thünen-Institute of Sea Fisheries)

1. Ecopath and Ecosim modelling of the southern North Sea

An Ecopath with Ecosim model was parameterized for areas IV b&c (WGSAM 2017; Stäbler et al. 2016; Stäbler et al. 2018). The model was fit to time-series of biomasses, catches and fishing efforts, and calibrated to stock–recruitment relationships of cod, plaice and sole. So far, applications of the model include a quantitative description of the structure and functioning of the foodweb in the model's base year, 1991 (Stäbler et al. 2018). The Ecosim model was used to check the feasibility of obtaining simultaneous 'pretty good yields' of cod, plaice, sole and brown shrimps. The compatibility of those multispecies MSYs with indicators of good environmental status was also addressed (Stäbler et al. 2016; Figure 1). A study investigating how multispecies MSYs of sole, plaice, cod and brown shrimp are affected by declines in system productivity, and by increasing populations of Grey seals and Harbour porpoises is under review (Figure 2).

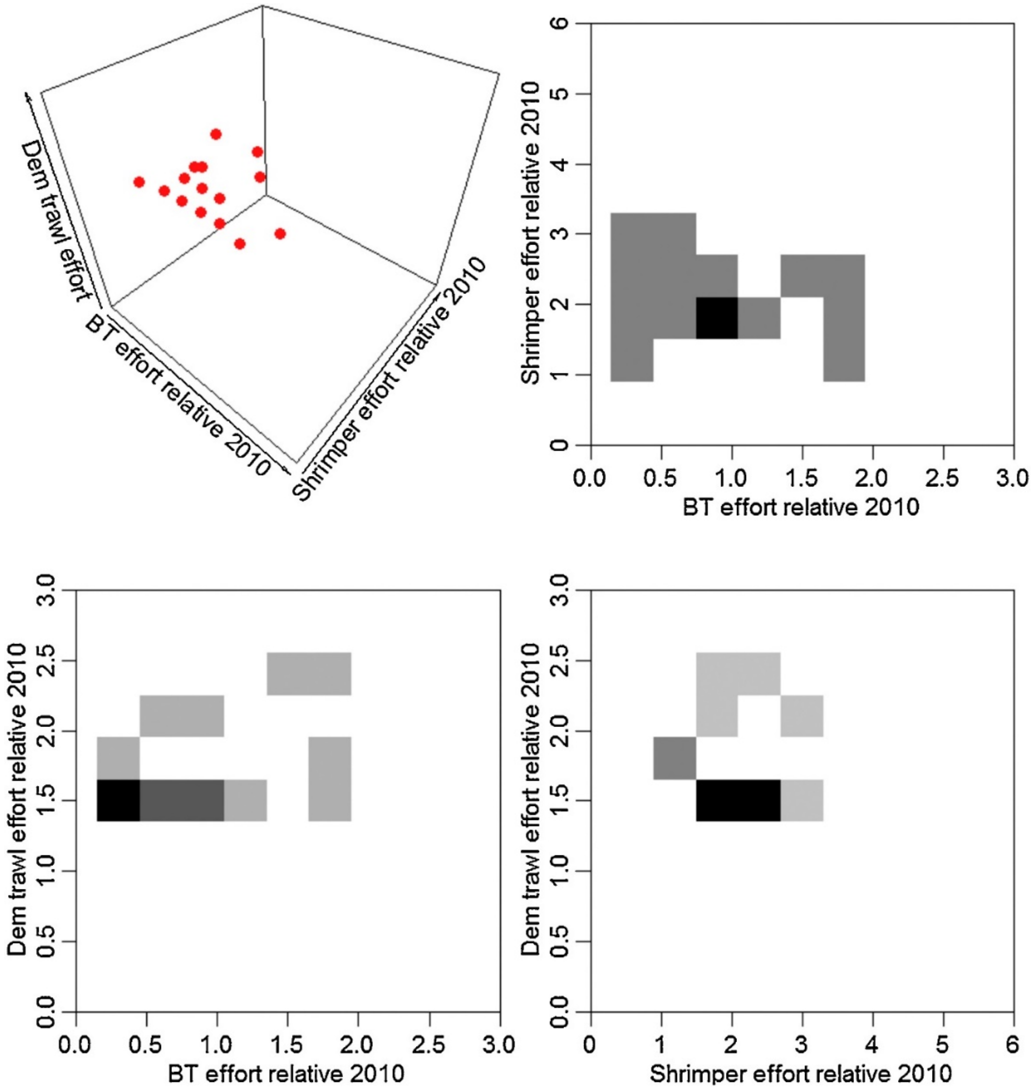

Figure 4.4.2.1: Fishing efforts of demersal, beam, and shrimp trawlers leading to simultaneous 'pretty good yields' of cod, plaice, sole and brown shrimp, while maintaining a proxy of Good Environmental Status. From Stäbler et al. 2016.

With reference to the 2016 ICES Greater North Sea Ecoregion Ecosystem Overview, the results found with the southern North Sea Ecosim model (sNoSe-EwE) can support coming rounds of the integrated ecosystem assessment as follows:

Table 1: Potential contributions to the ICES Greater North Sea Ecoregion Overview by Ecopath and Ecosim modelling of the southern North Sea (IV b&c) undertaken to date.

ICES Ecosystem Overview 2016	Potential contribution by southern North Sea EwE modelling
"Flatfish not included in multi-species models for the North Sea" (pg. 3)	Plaice and sole are focal functional groups in the sNoSe-EwE. Their representation in the model has been calibrated to ICES single species stock assessment.
"Harbour porpoise moved southwards" and "grey seals increasing" (pg. 3)	Implications of increased predation of marine mammals on target stocks is evaluated in Stäbler et al. (under review).

"Multispecies assessment models used to evaluate impact of fisheries and main predators on forage fish stocks" (pg. 5)	The sNoSe-EwE can serve as an additional tool to consider such multispecies interactions; and, other than SMS, includes Brown shrimp.
"Impacts on food-web" (pg. 6)	The 1991 representations of the total (Mackinson and Daskalov 2007) and the southern (Stäbler et al. 2018) North Sea deem the food-webs to be mature and resilient, compared to a global set of Ecopath models.
"Impacts on food-web" (pg. 6)	Safeguarding the Large Fish Indicator at levels above 0.3, and maintaining other, SSB based thresholds requires trade-offs in the multispecies MSYs (Stäbler et al. 2016).
"State of the Ecosystem: Food-webs" (pg. 12)	Flow from primary production through detritus into benthos is the dominant biomass flow in the (southern) North Sea (Stäbler et al. 2018).
"State of the Ecosystem: Productivity" (pg. 13)	Changes in system's productivity can have drastic effects on target stocks and yields (Stäbler et al., under review).

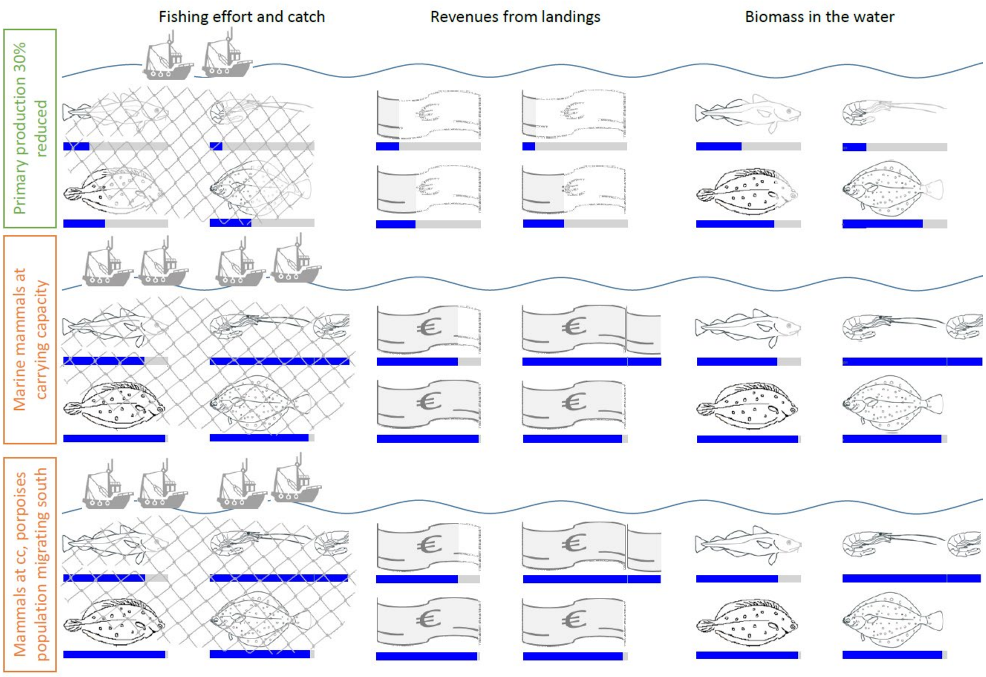

Figure 4.4.2.2: Southern North Sea Ecosim modelling results: Relative fishing efforts leading to multispecies MSY under changed ecosystem properties (30% reduced primary productivity, and marine mammal populations at carrying capacity); with respective catches, revenues from landings, and stock biomasses of cod, brown shrimp, plaice and sole (clockwise, starting top left) relative to baseline scenario. From Stäbler et al., under review.

1. Ecospace modelling of the southern North Sea

The Thünen Institute of Sea Fisheries is currently finalizing an Ecospace of the southern North Sea covering the ICES areas IV b and IV c. It is using the new spatial-temporal framework to dynamically implement habitat capacity maps for the majority of the functional groups. Studies on the effects of wind farms and designated marine protected areas are ongoing. This Ecospace has the potential to address several requirements for EOs, Advice and the MSFD. Consequences for the foodweb due to selective extraction of species will be analysed next to the identification of areas that are sensitive to change for commercial fish stocks and bycaught species. The effect of closed areas as alternative management measure to avoid the bycatch of certain species (i.e. choke species) under the landing obligation will be investigated. Additionally, the consequences of a reallocation of fishing effort due to windfarms and closed areas on indicators for e.g. biodiversity or abrasion can be evaluated. In the future IPPC scenarios will be implemented into the Ecospace model to test the effects of climate change on the ecosystem, the spatial distribution of fish stocks and the impact on spatial management.

Table 2: Potential contributions to the ICES Greater North Sea Ecoregion Overview by ongoing Ecospace modelling of the southern North Sea (IV b&c).

ICES Ecosystem Overview 2016	Potential contribution by southern North Sea EwE modelling
"Increase in the addition of new artificial hard substrate to the North Sea changed the biodiversity and productivity in local areas" (pg. 3)	Wind farms are implemented within sNoSe-Ecospace to test their effect on biodiversity within these areas
"Several of these elasmobranch species are now considered threatened or endangered by OSPAR and IUCN and are still caught as bycatch in fisheries" (pg. 3)	The effect of different spatial management options (e.g. closure of marine protected areas) on elasmobranch species are being tested
"Impact on foodwebs" (pg. 6)	Analysis of the effects of closed areas on the foodweb due to fishing effort reallocation
"Impact on foodwebs" (pg. 6)	Ongoing study of areas with high biodiversity that are sensitive to change
"Offshore wind farm development has started in the last decade with greater development planned for areas further offshore." (pg. 8) + "If the planned increase in power of wind farms … is established, the area occupied would be around 12 000 km^2, representing 1.6% of the total North Sea area" (pg. 9)	The effect of substrate loss due to artificial structures will be investigated as well as the impact of the non-fishing zones around these structures on commercially exploited species and their bycatch
"Over the last few decades, climate warming in the southern North Sea has been noticeably faster than in the northern North Sea" (pg. 14)	Different IPCC scenarios will be implemented to test the effect of climate change on the southern North Sea Ecosystem

4.4.3 Portuguese waters modelling in relation to Bay of Biscay and Iberian waters Ecosystem Overview

By Dorota Szalaj (University of Lisbon)

Modelling of Portuguese waters in the context of the Bay of Biscay and Iberian waters Ecosystem Overview, has been presented. Baseline static ecopath model, parameterized between 2006 and 2009 and developed by Veiga-Malta et al. (2018), was used to perform hindcast dynamic simulation between 1986 and 2017. Prior to the simulation, the ecopath model was adapted to year 1986. The model focuses mainly on pelagic component of the ecosystem because it was built with the objective to explain the drivers behind the Iberian sardine stock decline. The model was fitted to available time-series following the procedure proposed by Mackinson et al. (2009). It explained about 36% of variability in the data and the best fit model was achieved by including fishing, trophic effects and primary production anomaly as drivers. Because the analysis was focused on sardine, an improvement in the sardine fit, caused by each driver was quantified separately. The highest contributions for sardine fit improvement were obtained when fishing and trophic interactions were considered jointly, and here in contrary to the results related to the model treated as a whole, adding primary production anomaly did not improve the fit for sardine as it was a case for other species (e.g. rays, bogue, anchovy). These results aren't aligned with the literature that clearly linked sardine decline with environmental factors that affect sardine recruitment (Garrido et al. 2017; Malta et al. 2016). On the other hand, importance of trophic interactions and fishing as a drivers of sardine decline are also presented in the literature (Martins et al. 2013).

Considering the best fit model, few future projection scenarios, testing various levels of fishing mortality on sardine, have been performed. The results showed that by 2080 sardine biomass will recover up to the level from 1986 when fishing will maintain on current level or lower. Moreover, sardine biomass increase will be still observed even if fishing pressure will increase up to 50%. On the other hand, an increase of fishing mortality above 50% will impair sardine recovery and might even cause its collapse. The next step is a quantification of the impact that tested sardine fishing mortality scenarios might have on the ecosystem. Also, performing simultaneously the same simulation but with conventional stock assessment method will be an interesting avenue to explore, in order to see if ecosystem model results are aligned with the conventional stock assessment methods.

4.5 Other potential uses of EwE to inform ecosystem advice

4.5.1 Benefits of MPA networks in the Western Mediterranean Sea: a geographically-nested ecosystem modelling approach

By Marta Coll (ICM-CSIC)

In this presentation a geographically nested ecosystem modelling approach developed to assess the ecological and fisheries benefits of MPA networks in the Western Mediterranean Sea was shown. The study showed the implementation of the nested approach to quantify the benefits (to ecosystems and fisheries) of the establishment of MPA networks in the Western Mediterranean Sea. To develop the work, the Ecopath with Ecosim (EwE) foodweb modeling approach was used to develop spatial-temporal local, sub-regional and regional models representing areas with different levels of protection. For three Mediterranean MPAs, Cerbere-Banyuls, Cap de Creus and Medes Islands, nine models (three for each MPA) representing the three different management zones were developed: Fully Protected Area (FPA), Partial Protected Area, and Unprotected area. Then three models representing each MPA zone integrating the different management schemes were built. Afterwards, a sub-regional model including the three MPAs and their surroundings to describe the whole MPA network were constructed. Finally, a model covering the W Mediterranean included current general MPA dynamics. The nested modelling approach allowed to: (1) characterize the structure and functioning of MPA zones and identify differences between zones and between MPAs, (2) assess the regional effects of local MPAs, (3) quantify temporal changes, and (4) explore alternative MPA spatial configurations to promote fisheries sustainability in the region, accounting for stakeholders suggestions. Results highlighted the ecological importance of FPAs, although their benefits are local due to their small size. Current MPAs showed small differences with each other in terms of ecosystem structure and functioning. The study highlighted that a significant increase in the level of protection (and enforcement) is needed to get benefits on fisheries at the regional level. This study represents a baseline for the development of further management scenarios of MPA networks in the W Mediterranean and their assessment.

4.5.2 Incorporating fisher's knowledge AND uncertainty analyses into the development of ecosystem models

By Jacob Bentley (SAMS)

1. WKIrish: operationalizing ecosystem models for integrated ecosystem assessment of the Irish Sea

1.1. Ecopath

Under WKIrish, Ecopath with Ecosim (EwE) was used to construct a foodweb model of the Irish Sea Ecosystem representative of 1973, aiming to underpin the drivers of ecosystem change to inform integrated ecosystem assessment. The modelled foodweb includes 41 functional groups, ranging from detritus and plankton to seabirds and mammals, with a well-defined fish component. (Figure 4.5.2.1). The model's diet matrix was constructed using information held in DAPSTOM (integrated DAtabase and Portal for fish STOMach records) (Pinnegar, 2014) for fish functional groups, and from scientific literature for the mammal, seabird and invertebrate groups. Diet information was also added based on knowledge provided during WKIrish4, where stakeholders designed individual foodwebs for cod, haddock, plaice, *Nephrops*, rays and whiting. We followed recommended best practice methods (Heymans et al., 2016) and ecological rules of thumb (Link, 2010) for ensuring that ecological realism was maintained in the models structure and function. The Irish Sea model includes eight fishing fleets (beam trawl, otter trawl, *Nephrops* trawl, pelagic nets, gillnets, pots, dredge, and longlines) which reflect those deemed most important by fishers during the WKIrish4 workshop. Landings and discards for 1973 were allocated to fleets using data from ICES and the Scientific, Technical and Economic Committee for Fisheries (STECF). For an in-depth description of the methods and parameters used to build the Irish Sea Ecopath model, see the published technical report (Bentley et al. 2018a).

1.2. Ecological indicators

The Ecopath model of the Irish Sea has been used to develop state indicators which reflect the structure and function of the foodweb (Bentley et al., 2018b). During this process we designed a new approach which incorporates diet uncertainty into the estimation of indicators, enabling stronger ecological inferences which are crucial to management (Figure 4.5.2.2).

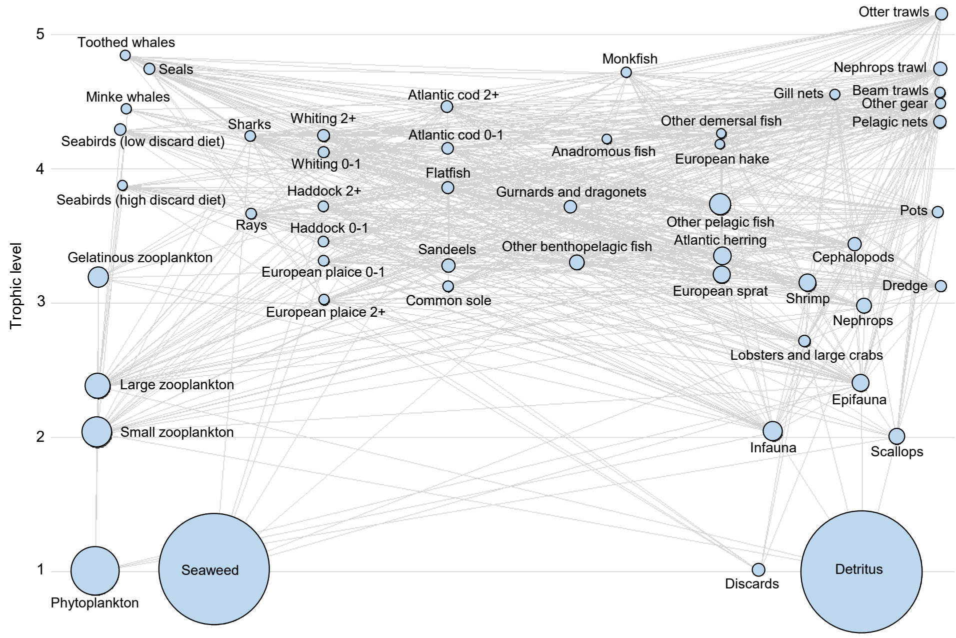

Figure 4.5.2.1. Energy flow and biomass diagram for the Irish Sea Ecopath foodweb model. Functional groups and fleets are represented by nodes, the relative size of which denotes their estimated biomass in the ecosystem in 1973. Lines represent the flow of energy and the y-axis denotes the trophic level.

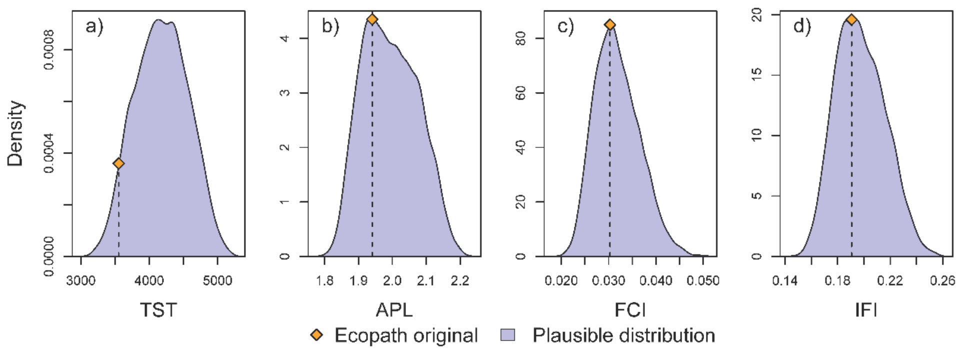

Figure 4.5.2.2. Probability density plots showing original estimates and distributions of foodweb indicators for the Irish Sea using data guided uncertainty: (a) Total system throughput (TST), (b) Average path length (APL), (c) Finns Cycling Index (FCI) and (d) Indirect Flow Intensity (IFI). Figure taken from Bentley et al., (2018b).

1.1. Ecosim

The Ecosim model of the Irish Sea runs from 1973 to 2016. To affect a change in the biomass and catch trends of functional groups over time, the model requires time-series of drivers, such as fishing effort, fishing mortality or environmental change. Ideally, each fishing fleet will have its own effort time-series but available series covering the full extent of the model were only available for three of the eight fleets: beam trawl, otter trawl, and *Nephrops* trawl. During WKIrish4 stakeholders provided effort trends for beam trawl, otter trawl, *Nephrops* trawl, pelagic net, gillnet, pot, dredge and longline fleets. The fishing effort trends fishers provided showed good agreement with scientific estimates for vessels using beam trawl, otter trawl, *Nephrops* trawl and pelagic gears. However, when incorporated into the Irish Sea Ecosim model they caused multiple stock collapses due to the magnitude of change they exerted on the system. Under the assumption that stakeholders' trends were more accurate than their suggested magnitude of change, trend magnitudes were adjusted using a Bayesian approach to find the magnitudes which led to better reconstructions of historic trends. Following this, the model performed best when driven by a combination of trends from data (beam, otter *Nephrops*) and stakeholders' knowledge (pots, pelagic. Gill, dredge, long-line) (Figure 4.5.2.3).

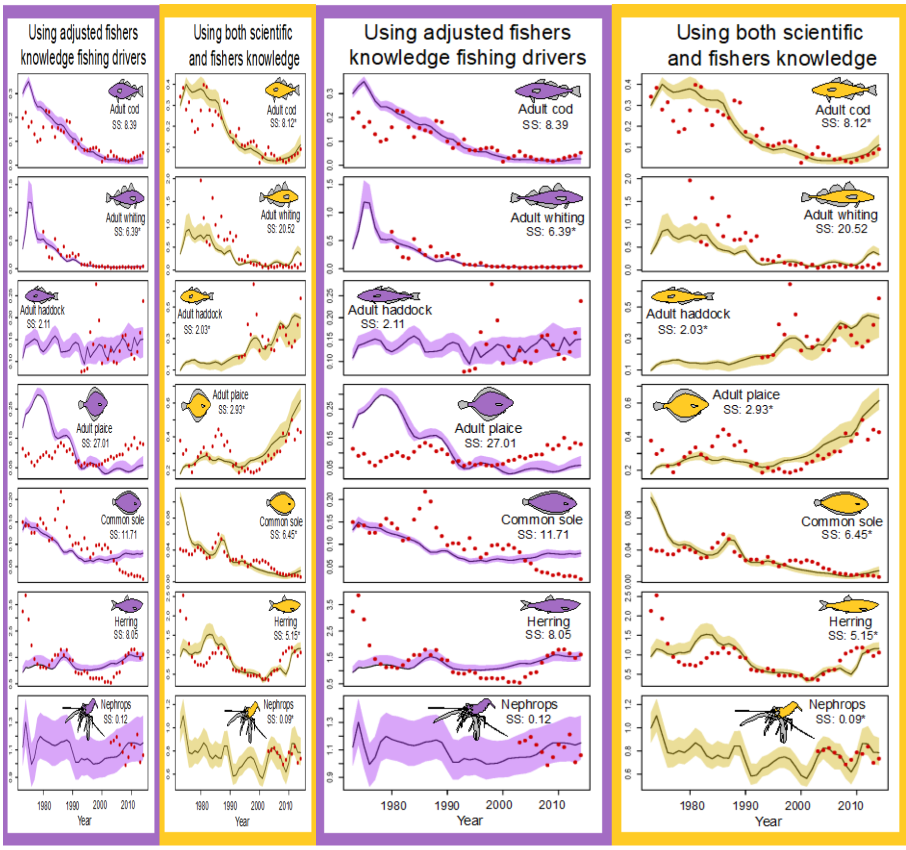

Figure 4.5.2.3. Biomass trends for the commercially important stocks in the Irish Sea EwE model. Solid lines indicate model predictions and dots represent observed data. Predictions are surrounded by 95% confidence intervals calculated using a Monte Carlo approach, generating 1,000 models within the range of plausible input estimates. Model predictions were generated using four sources of fishing effort data: 1) Scientific knowledge, 2) fishers' knowledge, 3) adjusted fishers' knowledge, 4) hybrid knowledge.

Through a fitting procedure the model estimates a primary production anomaly for phytoplankton to improve the statistical fit of simulated trends to observed data. The trend estimated for the Irish Sea model negatively correlates with the North Atlantic Oscillation Index (NAO).

1.1. Updates from WKIrish5

While the model in its current state is applying this environmental trend to phytoplankton to enact bottom-up change, hypotheses derived from environmental indicator analysis suggest the system is more likely driven by changes in secondary production. Work is therefore ongoing to ensure the direct impact of environmental change is applied in a realistic way. Through an external review of the models parameterization, recommendations were made for the alteration of a select few parameters (i.e. diets and production rates) prior to a key run assessment to be held in October 2019.

2. Ecosystem indicators to inform quota setting (stemming from WKIrish5-report in prep)

Ecosystem models quantify the cumulative impact of fishing and system productivity on stock trends, often concluding that it is a combination of both which drive stock dynamics. It would therefore be valuable to find ways to incorporate indicators of system productivity into the quota setting advice process. As discussed by WKIrish, ecosystem information could be used to suggest where to sit within the Fmsy range. For example, if the ecosystem indicator is in positive phase, and the ecosystem information suggests this will not have a negative impact on other stocks, the advice should be to remain in the upper limit of Fmsy. Whereas if the ecosystem indicator is in negative phase, the advice should be to remain in the lower limit of Fmsy as a precautionary approach (Figure 4.5.2.4).

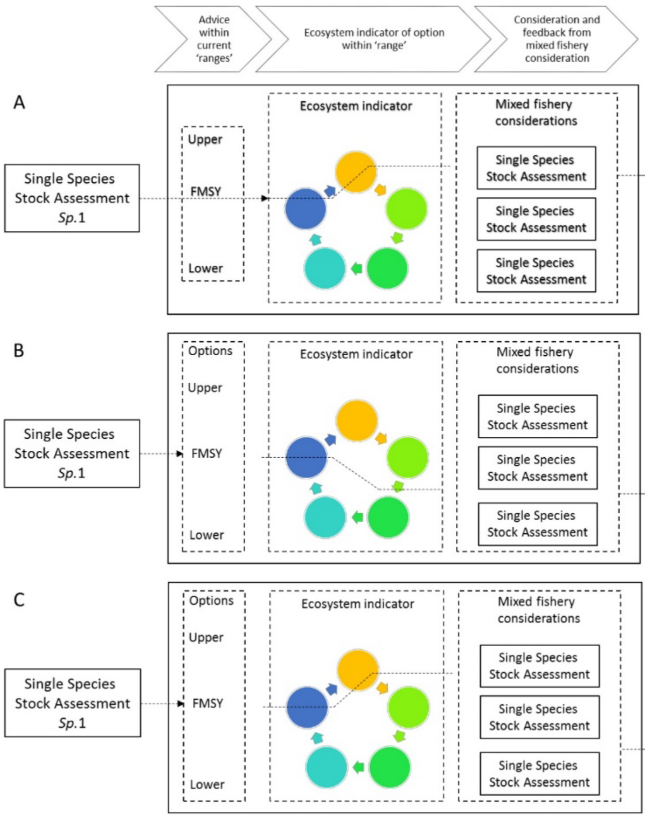

Figure 5.4.2.4. Ecosystem indicators to inform quota setting (figure credit: Mathieu Lundy, WKIrish): A: Ecosystem indicator suggests upper part of range and mixed fishery consideration supports that this with not have a negative impact on other stocks: keep advice in 'upper range'. B: Ecosystem indicator suggests lower part of range – should be used as a constraint in mixed fisheries assumptions: keep advice in 'lower range'. C: Ecosystem indicator suggests upper part of range but mixed fishery consideration suggest this would negatively impact other stocks: shift advice to 'lower range'.

4.5.3 Recent developments of EwE with special focus on Ecospace

By Jeroen Steenbeek

This presentation showed the most recent developments to the EwE software, with particular focus on spatial-temporal modelling with Ecospace. The recent introductions of the spatial-temporal data framework and the habitat foraging capacity model have turned Ecospace into an integrated, time-dynamic foodweb and species distribution model. Added flexibility in the consideration of Marine Protected Areas has improved the applicability of EwE for policy advice, as has the addition of consider system-wide impacts of parameter uncertainty through Ecosampler. Ecotracer, the contaminant tracing module of EwE, has been revamped and has seen a few new recent applications. Last, the addition of detailed discards management has enabled EwE to better address policy impacts, such as the common fisheries policy, onto marine foodwebs. Also presented was the recent integration of EwE into the Marine Spatial Planning Challenge 2050 serious game, where policy-makers become aware of possible ecological consequences of planned developments.

4.6 General remarks – current and further use of ecosystem models to support integrated advice

The focal point of the WK was the potential of using EwE models to inform ICES products such as the Ecosystem Overviews, as an integral part of the ecosystem advice. Several approaches and examples of using EwE were identified as useful to support IEA (see above), e.g. to inform quota setting (see WKIrish5), exploring trade-offs, MSFD indicators and supporting stakeholders' interactions. As agreed at the WK EwE allows quantification of links between activity-pressure and state relevant for (Figure 3) and interactive version of EO's. That could be done as a sensitivity analysis on external forcing on main pressures included in the model. In most cases main ecosystem pressures (relevant for foodweb dynamic) was identified at the existing EO's and bringing the EO's from fully descriptive to semi - quantitate. WKEWIEA identify that models, expert and required skills are available for most of ICES areas.

WGSAM could be a common platform, to develop models, on the other hand regional IEA group are the place where synthesis, analysis and model runs need to be performed and deliver information for EO's. However, at the operational level, EwE modelers does not establish yet thematic platform to work on specific EwE-EO's related issues i.e Expert Group' or series of WK, what would be required and recommended. It's possible to deliver quantification of links between activity-pressure and state within 3 years perspective but a number of conditions need to be fulfilled to accept model runs. WKEWIEA suggests that before using EwE models, the model quality protocol and key-runs need to be developed to implement Transparent Assessment Framework (TAF) and FAIR data principles in to publish models. Models for a number ICES ecoregions are already publish and described (in case of North Sea and Central Baltic ICES key runs exist). Right now, number of models exist as simulations of ecosystem dynamic, providing solid scientific results. Implementing model quality protocol and key-runs should improve reproducibility and transparency.

Because of EO's format …"will not include advice on management options and trade-offs when meeting targets for state of the environment, as this would usually require a tailored, and often extensive, analysis in the main body of the advisory text" (WKECOVER), group supports progress towards the delivery of integrated advice as a next generation of integrated product ICES, not as a descriptive format of EO's, but in the direction where capacity of ecosystem models could be used to support IEA.

WKEWIEA identified and suggest steps to be done as follow:

1) Develop methods for using EwE as a modeling approach for Regional IEAs. Use existing ICES regional EwE models (as outline in the summaries by Serpetti, Stäbler,

Bentley, etc.) to inform Ecosystem Overviews. This work would be done by regional seas working groups/IEA groups.

2) Designate WGSAM as the review group for EwE models (and other ecosystem modeling approaches) for providing ecosystem information. WGSAM would ensure best practices for EwE models are being implemented and establish key runs.

3) Establish an EwE/Ecosystem Modeling workgroup that a) works with existing models and regional seas working groups/IEA groups to explore other options for informing ecosystem approaches to management and b)supports regional seas working groups/IEA groups in developing additional regional EwE/ecosystem models.

These recommendations are suggested for a long-term period. Recommendation 1 could take 2-3 years. After existing models had been refined and information from them tailored for Ecosystem Overviews, WGSAM would review these example cases to ensure the models were developed using best practices, best available science, and provide appropriate information for ecosystem overviews. When this has been established for existing models and the information taken up by appropriate ICES management bodies, WGSAM could then be designated as the review group for future models and updates to existing models (Recommendation 2). Once this process for using EwE models for informing Ecosystem Overviews is established, ICES could move forward with Recommendation 3.

Annex 1: List of participants

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Annex 2: Agenda

Final agenda for WKEWIEA

Monday 26th of November

13:00 Arrival of participants

13:15 Welcome word from Marta

13:30 Welcoming and presentation of the workshop, the agenda and the WK participants (Eider Andonegi)

14:00 Presentations of EOs by ICES secretariat (Iñigo Martinez): main goals and use for advice. Open discussion.

16:00 Coffee break

16:30 Presentation about idea of using EwE models for Advice - seating scene (Maciej Tomczak)

18:00 Closing the day

Tuesday 27th of November

09:00 Presentations on uses of modelling to inform ecosystem advice

- Villy Christensen: The use of EwE models for advice
- Chiara Piroddi: A modelling framework for the Mediterranean Sea ecosystem in support of EU policies
- Howard Townsend: Using EwE for management issues – the US example

11:00 Coffee break

11:30 Continuation of presentations

- Sheila Heymans: Enhancing Europe's capability in marine ecosystems modelling for societal benefit
- Rudi Voss: How to use using economic aspect for IEA/ICES advice
- Andrew Kenny: Qualitative modelling for assessing cumulative impacts on the North Sea

13:00 Lunch break

14:00 Discussions and report writing

16:00 Coffee break

18:00 Closing the day

Wednesday 28th of November

09:00 Presentations on uses of modelling to inform ecosystem advice

- Natalia Serpetti: Western Coast of Scotland modelling in relation to Celtic Seas

  Ecosystem Overview

• Moritz Stäbler and Miriam Püts: Southern North Sea modelling in relation to

North Sea Ecosystem Overview

• Dorota Szalaj: Portuguese waters modelling in relation to Bay of Biscay and Iberian

waters Ecosystem Overview

11:00 Coffee break

11:30 Continuation of presentations

• Marta Coll: Benefits of MPA networks in the Western Mediterranean Sea: a geographically-nested ecosystem modelling approach

• Jacob Bentley: Incorporating Fisher's Knowledge and Uncertainty Analyses into the Development of Ecosystem Models

• Jeroen Steenbeek: A more generic overview of recent developments in Ecospace

13:00 Lunch break

14:00 Discussions and report writing

16:00 Coffee break

16:30 Discussions and report writing

18:00 Closing the day

19.30 Meeting dinner

Thursday 29th of November

09:00 Summary discussion and subgroup work

11:00 Coffee break

11:30 Subgroup work

13:00 Lunch break

14:00 Subgroup work and report writing

16:00 Coffee break

16:30 Report writing

18:00 Closing the day

Friday 30th of November

09:00 Wrap up and general conclusions

11:00 Coffee break

11:30 Wrap up and general conclusions

13:00 Meeting closure

Annex 3: WKEWIEA2 terms of reference for the next meeting (Draft)

The second **Workshop on operational EwE models to inform IEAs (WKEWIEA2**), chaired by Maciej T. Tomczak (Sweden) and Eider Andonegi (Spain), Maria Angeles Torres (Spain) will meet in Stockholm. 2019 (data and time need to be agreed) to:

a) Perform practical examples of integrating information from existing EwE models from ICES areas for next generations of Ecosystem Overviews

b) Perform trial version of using EwE models at IEA framework to support EBFM

c) Discuss and shape quality protocol and key run requirements for EwE models used for policy exploration and advice frameworks.

Annex 4: Recommendations

Recommendation	Adressed to
1. Develop key-run protocol for using EwE models for IEAs and advice	WGSAM (WGIPEM)
2. Review approach and provide feedback	ACOM/SCICOM + IEASG
3. IEA regional groups adopt EwE and equivalent models into their ToRs	ACOM/SCICOM + IEASG and IEA regional groups
4. Establish next workshop(s) for Intercomparability of EwE models for IEAs	ACOM/SCICOM
5. Provide advice about indicators from EwE modesl to be use in IEAs for the state of different ecosystem components	WGBIODIV
6. Guidelines about the visualization of the trade-offs	ICES secretariat

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Annex 6: Acknowledgements

The chairs of WKEWIEA want to thanks all the participants for being part of this interesting experience and specially Villy Christensen and Marta Coll for supporting them in the organization of this workshop and for providing them with the required facilities Thanks for hosting this meeting with such an enormous enthusiasm and for making our work a lot easier.