# Theme Session F Report 2024

## New avenues for incorporating ecosystem processes in models used for fisheries management

Conveners: Nis Sand Jacobsen (Denmark), Tobias Mildenberger (Denmark), Margaret Siple (USA)

**Session synopsis**

Theme session F gathered researchers interested in the development and evaluation of models and harvest control rules for ecosystem-based fisheries management (EBFM). The call for papers was issued based on a current need for incorporating external effects into EBFM, with particular focus on model developments, tools, and their application in marine ecosystems. We asked presenters to consider how to include ecosystem processes in the models used for management, how we can implement EBFM when we lack information about stock status or parameter values, and how we can use simulation to address those questions. Specifically, we invited contributions on methods for incorporating ecosystem processes in closed-loop simulations, development of multispecies models to inform EBFM, ecosystem-based simulation and assessment frameworks suitable for data-poor systems and mixed fisheries, and evaluation and communication of trade-offs related to ecosystem function or processes.

There were 18 talks and 8 posters in this session. Presentations were categorised into four subsessions based on their principal focus: 1) ecosystem models, 2) models with a focus on multispecies interactions, 3) models accounting for mixed fisheries, and 4) data and tools. Posters were not separated by topic, but addressed theoretical models fitted to data from the field, assessing the forecasting ability of climate models, engaging communities and stakeholders to address management needs, and using recreational fishery data in models used for management. We convened the session by having presenters share their work in each of the four categories above and concluded the subsessions with an audience Q&A and discussion with the presenters as panellists.

The theme session included a wide range of models of varying complexity, as well as multiple examples of applying management scenarios to more complex frameworks (including, for instance, predation or bottom up forcing), than what is currently applied in global fisheries management.

The posters and presentations in the sessions led to interesting discussions regarding state-of-the-art ecosystem models, the use and efficacy of using advanced models for management strategy evaluation (MSE), and the importance of including natural mortality in assessment models, as well as in forward projections. Speakers in this session introduced tools that can be used in the development or advancement of existing reference points. Many of the modelling approaches introduced in this session can also be used to advance ICES advice for carrying out MSE with ecosystem considerations, carrying out assessments, and reviewing ecosystem status. One way to advance ecosystem-based fisheries management is to evaluate the performance of current management procedures in light of changing environmental conditions and other ecosystem components and processes not accounted for in current assessments.

**Subsessions**

The first subsession included presentations concerning ecosystem models, as well as a presentation that investigated differences in spatial observation and productivity models. These presentations explored the complexities of using ecosystem-based management and stock assessment models across different fisheries and ecosystems. A recurring theme was the challenge of accurately

modelling species dynamics and interactions, particularly in cases where data, such as fishery age composition or catchability, are mis-specified. Several studies, including those on northern anchovy and Atlantic cod, highlighted how errors in key parameters could lead to assessment error and bias, affecting stock management strategies. Models like Atlantis, StrathE2E, and GADGET were employed to simulate species interactions, fishing impacts, and ecosystem dynamics, often integrating environmental factors such as climate and predation. The talks also addressed the importance of harvest control rules (HCRs) and precautionary approaches, balancing fishing mortality with ecosystem health, as seen in studies on the California Current and North Sea herring. As ecosystems become more dynamic due to climate change, these studies emphasise the need for adaptive, multi-species management frameworks that can integrate ecological, biological, and fishery data, while accounting for broader ecosystem shifts. The use of models to explore different scenarios and their strategic application could pave the way for more flexible and sustainable fisheries management in the future. The Q&A for this subsession highlighted the need to investigate more broadly the input from physical models (e.g., ROMS), as well as the utility of "shortcut" versus "full" MSEs when using models that have a long run time, such as the end-to-end models. Finally, we discussed the implementation of these models in tactical versus strategic applications.

The presentations in the multispecies category highlighted natural mortality, density dependence, and predator-prey dynamics. One study highlighted that simplified assumptions about processes like natural mortality and density dependence for Norwegian Spring-Spawning herring can lead to ineffective harvest control rules (HCRs), particularly when these factors vary over time. Another study examined the impact of increasing grey seal populations in the North Sea, emphasising the need to include top-level predators in multispecies models to better understand their effect on fish stock mortality. A separate investigation revealed that multispecies interactions, such as mackerel predation on herring larvae, can significantly influence recruitment dynamics and affect the performance of current HCRs, suggesting that current management strategies may not be precautionary enough for these species, interactions. Lastly, advancements in Stock Synthesis (SS3) models were presented, showcasing new capabilities to explicitly model predator-induced mortality, offering a more nuanced way to assess predator-prey relationships in stock assessments. Together, these studies demonstrate the need for more robust, multispecies management frameworks that account for ecological variability and interactions to improve fisheries management outcomes. The Q&A in the multispecies category steered largely towards reference points and how they vary based on inter- and intraspecific dynamics. Additionally, the implementation and practical calculation of time varying reference points was also discussed.

The mixed fisheries presentations highlight advancements in EBFM through various modelling approaches. One study emphasised the need for integrating predator-prey interactions, environmental processes, and technical factors in a mixed fisheries model to operationalize EBFM in the North Sea. Another focused on the challenges of managing mixed fisheries, especially under climate change, proposing simulations incorporating climate-driven impacts on fish stocks in the Bay of Biscay. A separate study discussed the development of a fishery ecosystem plan for Georges Bank in the Northeast U.S., testing stock complex management and control rules using a prototype MSE. Across these studies, the incorporation of multispecies dynamics, climate impacts, and ecosystem-level advice was shown to improve management strategies, suggesting pathways forward for EBFM implementation. Here we discussed model ensembles, and model differences in EBFM application, as well as choosing the appropriate model for the question.

In the final category ("data/tools'') several studies were presented that aimed to enhance fisheries management through innovative methodologies. One study introduced a new integrated modelling system designed to support advanced stock assessments and ecosystem analysis. Another explored the potential of spatial indicators to assess fish stock status, utilising data-rich stocks for validation purposes. In a different study, a socio-ecosystem-based MSE approach was employed to align stock

management with biodiversity conservation and economic considerations. Additionally, research on deep-water fisheries highlighted the risks of overexploitation and evaluated various management strategies for stock recovery. Furthermore, a collaborative project focused on integrating environmental, ecological, and socioeconomic data into stock assessments to facilitate more comprehensive management. Collectively, these efforts underscore the increasing emphasis on ecosystem-based fisheries management and the necessity of addressing complexity and uncertainty in decision-making processes.

**The way ahead and relevance for ICES and advice**

This theme session collected state-of-the-art knowledge on the incorporation of ecosystem processes in MSE, stock assessment, and EBFM in general. The focus was on modelling approaches with particular emphasis on development of models with several trophic components. The presentations addressed several of the questions we originally posed and demonstrated that this area of research is rich and rapidly developing. The recommendations from this session are to enhance the use of auxiliary (to individual stocks) ecosystem information in order to navigate towards EBFM, to use existing frameworks to evaluate and improve models and reference points used for management, and to continue to identify important climate drivers and species interactions so that they can be meaningfully incorporated in the models used for management.