Ecosystem Models for Fisheries Management: Finding the Sweet Spot

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Summary

The recent push towards ecosystem-based fisheries management has motivated considerable development, implementation, and testing of ecosystem models. We present in this paper the required characteristics of ecosystem models and issues that need to be addressed, especially the challenge of increasing complexity. In this paper, we illuminate the characteristics, capabilities, and short-comings of the various modeling approaches being proposed for ecosystem-based fisheries management. We identify key ecosystem needs in fisheries management and indicate which types of models can meet these needs. Incorporating ecosystem considerations requires moving from the single-species models used in stock assessments, to more complex models that include species interactions, environmental drivers, and human consequences. Ecosystem models have been playing strategic roles by providing an ecosystem context for single-species management decisions. However, conventional stock assessments are being increasingly challenged by changing natural mortality rates and environmentally-driven changes in productivity that are observed in many fish stocks. Thus, there is a need for more tactical ecosystem models that can respond dynamically to changing ecological and environmental conditions.

Fishery Ecosystem Models

The advent of an ecosystem-based approach dramatically expanded the scope of fisheries management, creating a critical need for new kinds of data and quantitative approaches that could be integrated into the management system. Ecosystem models are needed to codify the relationships among drivers, pressures and resulting states, and to quantify the trade-offs between conflicting objectives. Depending on management needs, moving from single-species management to an ecosystem basis means that the complexity of models can develop in four main ways: by adding population structure, environmental influences, trophic interactions, and human interactions. Adding complexity to models requires compromises: for example, to include additional component species, the models of each species have in some cases been simplified from age-structured to logistic or bioenergetic models. Increased availability and resolution of environmental data has permitted the development of mechanistic models representing the relationship between the environmental and the biological responses at appropriate spatial and temporal scales. An ecosystem approach requires more complete economic accounting because it makes the trade-offs among competing resource uses more explicit. With this increasing model complexity, model fit can improve, but parameter uncertainty increases. Along the complexity continuum there is a "sweet spot" at intermediate complexity that balances model bias with parameter uncertainty (Fig. 1). Finding the sweet spot depends on effort, cost, and data to construct the models as well as the key scientific questions asked or management policies being considered.

Use of Ecosystem Models in Fisheries Management

Ecosystem models can be used for strategic or tactical purposes, with the output of strategic models providing context for tactical management decisions. Complex ecosystem models can also be used as operating models in management strategy evaluations. Models of intermediate complexity, which incorporate the important ecosystem components with strong links, will ultimately be most useful to specify harvest guidelines. Among other considerations, they need to be statistically fit to data and account for structural uncertainty (e.g., predator functional responses). Precautionary and dynamic approaches exist for determining multispecies biological reference points. In an ecosystem context, the concept of maximum sustainable yield can be replaced with multispecies sustainable yield—the region of harvest rates within which all species are maintained at sustainable levels. Methods exist to visualize the consequences of different combinations of harvest rates within this sustainable region.

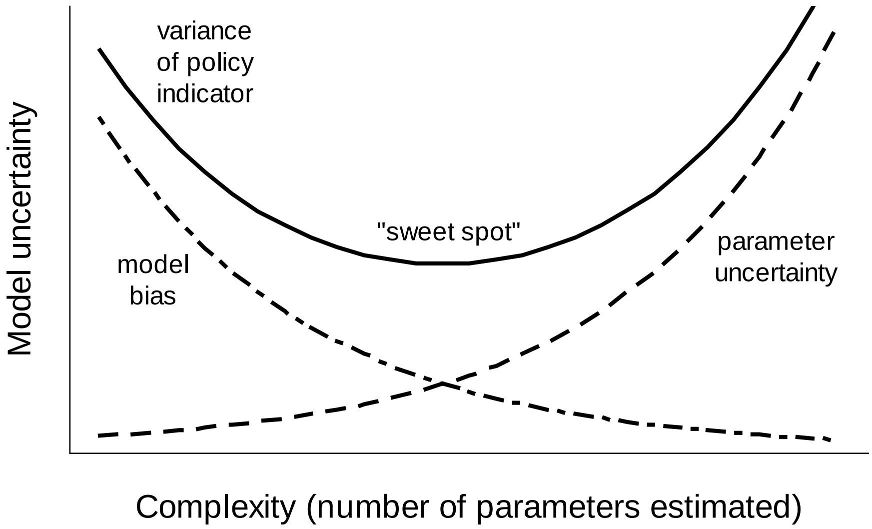

Figure 1. A schematic view of the way in which model bias declines and parameter uncertainty increases with increasing model complexity. The variance of key policy indicators is the product of these two sources of error and therefore has a minimum at an intermediate level of complexity (adapted from Walters 1986).

Existing Applications to Management

Ecosystem models are increasingly being used to inform management by providing system-level context, and in some cases, for strategic management analyses. However, the use of ecosystem models in tactical decision-making in fisheries management has been slow to develop because the uncertainties in model outputs do not allow sufficient confidence for specific management decisions and because getting new methods fully incorporated into the regulatory structure of marine fisheries management is difficult. There are increasing numbers of examples where single-species methods have been expanded to include the effects of other species (mortality rates) and environmental influences on recruitment. Age-structured, multispecies models are presently being used to provide tactical advice in the Baltic Sea, Barents Sea, and elsewhere. But there is a large gap from these enhancements of single-species analyses to a full ecosystem-based evaluation. Facilitating the adoption of ecosystem models in fisheries management requires critial evaluations of different model forms and independent reviews of these approaches. Finding the sweet spot of minimal uncertainty will accelerate the use of ecosystem models for strategic analyses and generate momentum for their greater use in tactical decision-making.

References

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