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A conceptual framework for understanding the implications of and potential solutions for mismatches in scale of biological population structure and stock units.

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Summary

Research over the past decade focused on understanding the population structure of fish has revealed inconsistencies between the spatial extent of biological populations and the definition of stock units used in assessment and management. From a fisheries management perspective, stocks are assumed to be discrete units which can be exploited independently of each other. In reality, however, this assumption is often violated and may pose problems that affect fish resources, stock assessment, management, and fisheries. Here, we present a conceptual framework that describes approaches for improving the assessment and management process in situations wherein there is a mismatch between the scale of biological population structure and spatially-defined stock units.

Introduction

From a classic fisheries management perspective, single species advice is provided for individual stock units. It is assumed that stocks are discrete units and that specific stocks can be exploited independently of each other or that catches can be assigned to the stock of origin. Contemporary examinations of population structure that utilize advanced stock identification methods often reveal inconsistencies between the scale of biologically-defined fish populations and the existing spatially-defined scale of stock units used in assessment and management (e.g. Reiss *et al*. 2009). Violation of the unit stock assumption (i.e. misperception of the appropriate spatial scale of management) may pose problems affecting fish resources, fisheries, stock assessment and management.

In some cases, what is assumed to be a homogeneous stock may in fact be a mixed stock, composed of populations with unique demographics and dynamics (Cadrin and Secor 2009; Kell *et al*. 2009). Thus, the short-term recommendations, such as total allowable catch (TAC), and long-term strategy, such as biological reference points (e.g. B_{PA}, B_{lim}), and possible harvest control rules, produced from the single stock assessment may be inappropriate (Kritzer and Lui 2014). In this context, the harvest of a mixed stock, comprising unique populations of a single species, can potentially lead to overfishing less productive populations and under-fishing more productive populations (Cadrin and Secor 2009). Additionally, management units containing only a portion of a self-sustaining population can also pose problems for assessment and management of species (e.g. Frisk *et al*. 2008). Thus, understanding the spatio-temporal scale of population structure for a species in relation to management units is important

for accurate assessment and effective management. The goal of this study was to develop a conceptual framework that describes different scenarios of mismatch in scale between the biological structure of fish, the fishery, assessment and management units and alternative approaches, as well as their drawback and benefits, for dealing with this mismatch.

Materials and Methods

We present a conceptual framework that describes approaches for improving the assessment and management process in situations wherein there is a mismatch between the scale of biological population structure and spatially-defined stock units. The conceptual framework reflects best practices as well as highlighting concerns with maintaining the status quo and with implementing alternative approaches. We highlight case studies that demonstrate particular circumstances of spatial structure and stock exploitation. In suggesting alternative approaches to improve assessment and management we also consider practical limitations associate with changing monitoring, assessment, and management approaches.

Results and Discussion

There are a range of approaches to improve assessment and management in situations where a mismatch in scale occurs and the degree of spatial overlap between biological populations and mixed stock composition in the fisheries is an important determinant of the appropriate strategy. In scenarios of mismatch wherein biological units are effectively fished separately and historical data can be parsed to the appropriate unit, a revision of the existing stock unit may be most appropriate and practical approach to improve the accuracy of assessment and effectiveness of management. When there is spatial overlap of populations and a mixed stock fishery, the mixed nature of the data that informs stock assessment can potentially lead to an inaccurate perception of the fishery resource. Sophisticated tag-integrated models can account for mixing across stock boundaries, but these models are data intensive. Due to data limitations, splitting of stock unit data to achieve separate stock assessments for populations lumped into the same unit stock may not be possible. However, monitoring indices of abundance of populations is recommended if the goal is to conserve population structure. In these cases, alternative spatially explicit management tools (e.g. closures of spawning habitat) can be effective. The conceptual models developed here can inform the development of 'realistic' operating models and management strategy evaluations to quantitatively evaluating outcomes of alternative to stock assessment and management approaches.

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