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Incorporating species interactions in a statistical catch-at-age model of the Georges Bank fish community

Kiersten L. Curti[1,2], Jeremy S. Collie[1], Christopher M. Legault[2], Jason S. Link[2]
(1) Graduate School of Oceanography, University of Rhode Island, USA; (2) National Marine Fisheries Service, Northeast Fisheries Science Center, USA; Presenter contact details: National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543, USA, Kiersten.Curti@noaa.gov

Summary

An ecosystem approach to fisheries requires the quantification of predation mortality by accounting for the interactions among fished species. Georges Bank, a historically important fishing ground within the Northeast U.S. Continental Shelf ecosystem, has undergone extensive changes in community dynamics and ecosystem structure over the last half century, promoting an ecosystem approach. The goal of this work is to incorporate species interactions into a statistical multispecies catch-at-age model of nine fish species. This model incorporates commercial catch, fishery-independent survey catch, and food habits data to estimate predation parameters, fishing rates, initial abundances and annual recruitment. We statistically estimated both the magnitude and temporal trends in predation mortality rates experienced by prey species. Mackerel, herring and silver hake experienced the greatest mortalities due to predation. For these species, biomass losses due to predation generally exceeded annual landings. Goosefish was the most important predator, followed by cod and silver hake, and consumption of modeled fish generally followed patterns in prey abundance. However, these results were sensitive to assumptions regarding the consumption rate of goosefish. Overall, this work further demonstrates the strong impact of predation on Georges Bank fish community dynamics and provides a tool for statistically estimating the mortality due to predation.

Introduction

Georges Bank is part of the Northeast U.S. (NEUS) Large Marine Ecosystem, which has experienced marked changes in ecosystem structure and is currently experiencing ecosystem overfishing as well as potential sequential depletion of resources (EcoAP 2009). As a consequence, there has been considerable discussion about establishing an ecosystem approach to fisheries. Multiple studies have demonstrated that predation is a dominant source of mortality (e.g. Tsou and Collie 2001), and an ecosystem approach requires the quantification of predation mortality. Additional tools are needed to examine food-web structures and species interactions with the same statistical rigor as those models currently used to inform fisheries management. To meet this goal, we developed a multispecies statistical catch-at-age model of nine Georges Bank fish species (Figure 1).

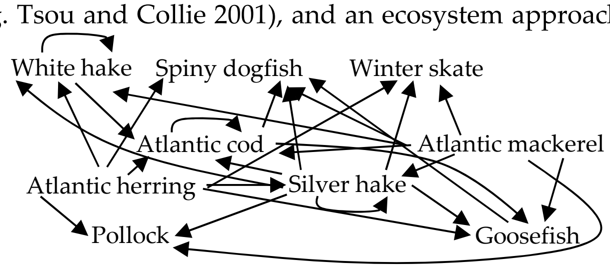

Figure 1. Predation interactions between the nine modeled species. The arrows point from prey to predator.

Materials and Methods

The formulation of the multispecies model builds upon that of multispecies virtual population analysis (MSVPA, Helgason and Gislason 1979). Total natural mortality was partitioned into the mortality due to predation and residual natural mortality, such that total mortality was quantified as the sum of fishing, predation and residual natural mortality rates. Predation mortality was based on prey suitability coefficients, which incorporated both the size preference and species preference of a predator. Species preference (prey vulnerability) coefficients were estimated for each species interaction and incorporated all differences in food selection not attributable to size. Predator size-preference was estimated outside of the model. Age-specific predation mortality was estimated as a function of age-specific suitable prey biomass, total predator and prey biomasses, and per-capita predator consumption rates estimated outside of the model using the gastric evacuation model (e.g. Tsou and Collie 2001).

A key difference from MSVPA is the statistical estimation of model parameters and recognition that the observed data contain measurement error. Estimated model parameters included initial age-specific abundances, annual recruitment, age-specific fishery and survey selectivity coefficients, and species preference parameters.

Results and Discussion

Predation mortality rates (M2) were strongly size-dependent, whereby M2 generally decreased with increasing age (Figure 2). Goosefish, cod and white hake were both intermediate prey and predator species, exhibiting maximum predation rates between 0.18 (goosefish) and 0.43 (cod). For these intermediate prey species, the M2 rates of the oldest age classes were approximately zero, such that fishing was the dominant source of mortality for these age classes. As a consequence, the fishery landings for these three prey species were greater than the biomass consumed by modeled predator species. In contrast, mackerel, herring and silver hake experienced the greatest mortalities due to predation, with maximum predation mortality rates of 0.62 for mackerel, 1.01 for herring and 1.58 for silver hake (Figure 2). For these principal prey species, the oldest age classes were still exposed to predation. For silver hake, the biomass consumed was over three times the magnitude of the landings in each year. For mackerel and herring, the losses due to predation generally exceeded annual landings; however, there was at least one year for each prey species in which landings exceeded predation losses. Goosefish was the most important predator, likely due to its high consumption rate, followed by cod and silver hake. However, the ranking of dominant predators, M2 rates of cod, mackerel and silver hake, and relationships between biomass consumed and landings were sensitive to the assumed rate of goosefish consumption, demonstrating the importance of accurately estimating consumption.

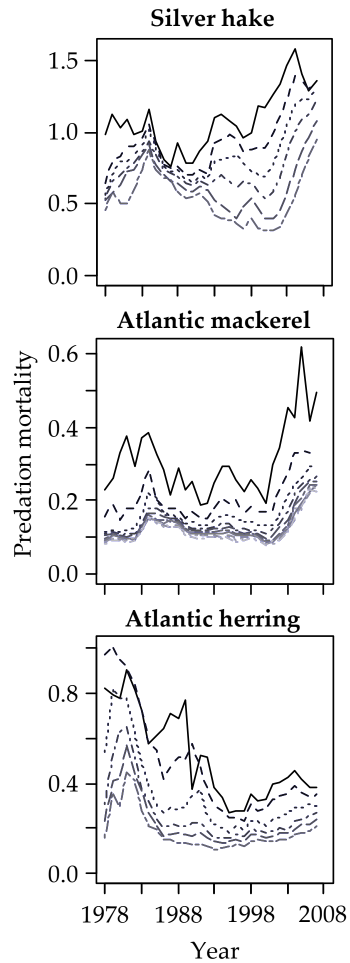

Figure 2: Predation mortality rates for the primary prey species. Each line represents an age class from age-1 (black) to age-10 (light grey).

While sensitivity to dataset weights and initial parameter estimates was apparent, this work demonstrates that the statistical estimation of species-specific predation mortality rates within a complex ecosystem such as Georges Bank is feasible. Consistent with previous multispecies modeling efforts on the NEUS Continental Shelf, the multispecies statistical catch-at-age model developed in this study demonstrates the strong impact of predation on community dynamics.

References

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