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Leveraging multiple hierarchical models to assess critical oceanographic drivers of forage fish distribution and availability in the Northeast US Continental Shelf ecosystem

Small pelagic forage fish are a critical prey resource within marine food webs, linking primary production and zooplankton to upper trophic level predators, such as seabirds, seals, and cetaceans. Forage fish surface aggregations represent a concentrated source of available prey for surface- and shallow-foraging marine predators, and are often patchily distributed within their broader species distributions. In some cases, we know which environmental factors affect the distributions of individual forage fish species, but inferences from broad-scale single species models may not be well-correlated with marine predator foraging behavior. Further, we lack an understanding of which features drive forage fish community distribution and aggregating behavior at the scale where many marine predators interact with their prey. We used a series of hierarchical models in a Bayesian framework to examine the roles of a common suite of oceanographic variables in driving distributions and aggregations of forage fish. Specifically, we applied a joint species distribution model to estimate the probability of occurrence of the forage fish community from bottom trawl survey data collected biannually across the U.S. Northeast Continental Shelf (NES) ecosystem. Then, we developed a spatial conditional autoregressive model to both jointly and independently assess the importance of oceanographic variables on forage fish aggregation abundance and size from digital aerial survey data collected at two survey sites within the NES ecosystem. The independent model proved to be the most appropriate for these data as responses of aggregation density and size to environmental covariates were not always aligned. Our results suggest that drivers of distributions vary by species, but depth, sea surface temperature, and sub-mesoscale eddies are consistently important factors. Although these variables influence the abundance and size of aggregations, salinity and mixed layer depth are also significant factors for the occurrence of aggregations. In combination, these models help us determine the availability of forage fish to marine predators at relevant scales. Additionally, this project is a step forward in understanding how to analyze digital aerial surveys of subsurface biota like forage fish and represents a novel application for spatial models.