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Using indices of ecosystem dynamics within spatio-temporal habitat models to estimate single-species shifts in distribution and abundance

Author: James T Thorson

Abstract

Climate change, fishing activities, and other processes are driving shifts in community biomass and productivity for all marine ecosystems. There is a growing suite of ecosystem indicators to measure community changes, but these indices are rarely included in the statistical models used for index standardization and stock assessment that inform single-species management of catches. I therefore demonstrate a new two-stage approach to integrate ecosystem and habitat information into single-species stock assessment and management. First, this approach involves a multispecies generalization of empirical orthogonal functions (EOFs). EOFs are widely used by oceanographers to summarize physical measurements at basin scales, and I generalize EOFs to summarize the zero-inflated, spatially unbalanced, and multispecies data that are common for biological sampling. Second, this approach extracts the dominant annual index from the multivariate EOF and includes it in a single-species habitat model, using a spatially-varying coefficient model to estimate the preferred habitat associated with a positive or negative phase of that ecosystem index. I demonstrate both steps with 37 years of bottom-trawl sampling data from the Eastern Bering Sea using a vector autoregressive spatio-temporal (VAST) model and publicly available software. Specifically, the multispecies EOF estimates an annual index that is highly correlated with cold-pool extent. Using cold-pool extent in a spatially varying coefficient standardization model explains substantially more variance than local bottom temperature in isolation. I conclude that existing multispecies habitat models can be used to summarize ecosystem variability within index standardization models used for single-species management.

Keywords:
Spatio-temporal model; VAST; spatially varying coefficient; ecosystem indicator

Contact author:
James Thorson. Habitat and Ecosystem Process Research program, Alaska Fisheries Science Center, National Marine Fisheries Service, NMFS, NOAA, DOC; Email: James.Thorson@noaa.gov