A Novel Perspective on Recruitment and Productivity in Atlantic Striped Bass

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Introduction: Fishes that engage in wide-ranging migratory movements may exhibit intrapopulation spatial structure, where differences in vital population rates among groups can impact overall population dynamics and influence how species respond to environmental stochasticity and anthropogenic pressures. Variable growth and recruitment rates during early-life stages may reflect divergent responses to environmental fluctuations and result in differences in productivity between groups[4]. High levels of intrapopulation connectivity and enhanced synchrony in response to external stressors can result in depressed productivity; conversely, asynchrony can have a stabilizing effect, particularly over large spatial scales. Demographic diversity may therefore confer stability and resilience by mitigating population-level responses to disturbance and unfavorable environmental conditions[3,7].

The coastal migratory population of Atlantic striped bass (*Morone saxatilis*) is comprised of distinct spawning aggregates from Chesapeake Bay, Delaware Bay, and the Hudson River but is currently managed as a single stock. Recent declines in spawning stock biomass for Atlantic striped bass have been attributed to lower abundances of juvenile fish coast-wide, despite the production of individual strong year classes among different natal areas. The relative contributions of each watershed to the coastal stock are partially dependent on year-class strength of individual component stocks, location, and season[2]. However, the link between variable recruitment observed in these major producing areas and the dynamics of the coast-wide population remain largely unexplored. The objective of this study was to identify the level of synchrony evident in recruitment among major nurseries in the Chesapeake Bay, Delaware Bay, and the Hudson River over a 40-year period, 1983-2022, and explore whether intrapopulation spatial structure can inform drivers of population productivity in this species.

Methods: Catch data of age-0 striped bass from four fishery-independent surveys were used to generate time series of recruitment from major estuarine producing areas in the Hudson River, Delaware Bay, and Chesapeake Bay between 1983 and 2022 (Table 1). Generalized linear mixed models (GLMMs) were used to create an annual index of relative abundance for each region, where recruitment was defined as the relative abundance of age-0 striped bass in each survey. Year was included in all models to ensure estimation of annual abundance, and several covariates reflecting abiotic conditions at the time of catch (e.g., temperature, salinity, and tidal stage) were evaluated to account for seasonal and spatial variation in catchability and abundance within individual regions. Sampling station was included as a random effect to account for the fixed station design in each individual survey. Dynamic factor analysis (DFA), a multivariate, dimension-reduction technique[10], was then applied to identify

Table 1. Data used to generate recruitment indices from major producing areas for *M. saxatilis*

Region	Data Years	Source
Hudson River	1985-2022	NYDEC Hudson River Beach Seine Survey
Delaware Bay	1987-2022	NJDEP Delaware River Seine Survey
Chesapeake Bay	1983-2022	MDDNR Juvenile Striped Bass Survey
		VIMS Juvenile Striped Bass Seine Survey

common trends across the four recruitment time series and detect the effects of external factors on those common trends. The relationship between individual indices of abundance was assessed through "loadings" within the DFA model; if individual indices related to a trend in the same way, this might suggest similar patterns in recruitment, whereas contrasting relationships could indicate opposite patterns in recruitment. DFA employs a two-stage model selection process: first, the number of common trends (1, 2, or 3) and the covariance structure are identified; then, the best combination of covariates to explain the common trend is selected. Four factors hypothesized to impact year-class strength in this species across the Mid-Atlantic region were investigated: spawning stock biomass, two climate indices (the North Atlantic Oscillation, NAO; and the Atlantic Multidecadal Oscillation, AMO), and a final variable that captured the magnitude and duration of coastal marine heat waves[6]. In both GLMMs and DFA, model selection was conducted using information theoretic approaches[1] and graphical diagnostics.

Results: Model-based indices of annual abundance for age-0 striped bass from each producing area were highly variable. The underlying patterns in regional recruitment from 1983-2022 were best represented by three common trends (Fig. 1) with a diagonal/equal variance-covariance matrix (i.e., equal variance between indices, no covariance). The selected DFA model included the winter NAO index (DJFM) and the cumulative annual intensity of marine heat waves as drivers of common trends in recruitment. Loadings of each recruitment index to each common trend allow us to visualize the strength and directionality of those relationships; common trend #1 best represents recruitment in the Hudson River, where common trends #2 and 3 best describe recruitment in the Delaware and Chesapeake Bay (Fig. 2). On all trends, significant loadings (>0.2) for each producing area are positive, indicating that recruitment is similar between those regions (Fig. 2). An examination of the effect of each covariate on striped bass recruitment suggested that a higher incidence of heat waves in the coastal ocean resulted in generally lower recruitment, especially in the Hudson River. The effect of the NAO was mixed, but we detected a significant negative effect on recruitment in Virginia.

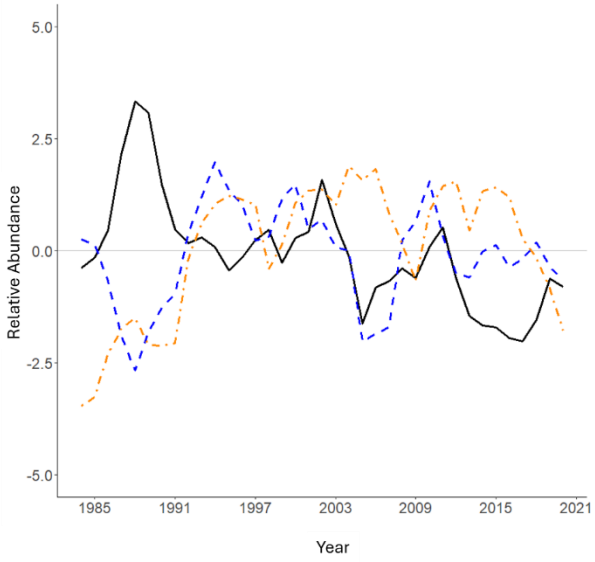

Fig. 1. DFA model reflecting three common trends (C.T) in striped bass recruitment between 1983-2022. (C.T. #1=black; C.T. #2=blue, C.T.#3=orange)

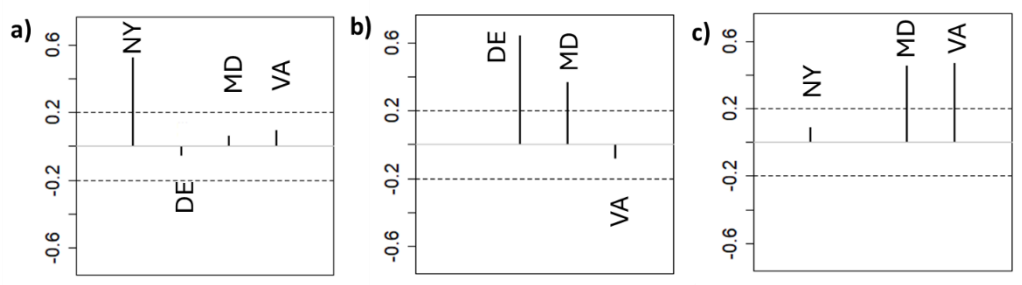

Fig. 2. Loadings of each recruitment index on (a) common trend (C.T.) #1, (b) C.T. #2, and (c) C.T. #3. Factor loadings in the DFA model are unitless.

Discussion: Among major producing areas for Atlantic striped bass, recruitment exhibits high interannual variation, which is characteristic of fishes that utilize estuarine nursery areas[2]. Within the DFA framework, we observed a gradual decline in striped bass recruitment in the Hudson River throughout the study period following a peak in the late 1980's. Comparatively, recruitment in the Delaware and Chesapeake Bays was low in the late 1980's, increased in the early 1990's, then varied until about 2013-2015. Together, all three trends reflected the decline in adult abundance observed over the past decade. While sufficient numbers of adults are needed to maintain production, environmental variability during early life stages is also known to impact recruitment[8]. Recruitment in the Hudson River appears to have been negatively impacted by marine heat waves throughout this study period. This may be due to genetic differences between populations along the Atlantic coast[9], where fish in a more northern region are more sensitive to acute warming events. Climate variability on regional scales can lead to fluctuations in weather patterns and hydrologic conditions that may result in variable recruitment success in different areas. In Chesapeake Bay, we observed higher relative recruitment at negative values of the winter NAO. A negative NAO phase corresponds to cooler temperatures and increased precipitation, which have both been shown to support strong striped bass recruitment in this region[5].

This study provides early evidence of possible asynchrony in Atlantic striped bass recruitment across major producing areas in the Mid-Atlantic region. Over the past 40 years, we observed peaks in recruitment from different areas during different years. However, positive loadings between areas on multiple common trends indicate that low abundance in one area and high abundance in another are unlikely to occur within a given year. Variable recruitment rates between these intrapopulation components can influence how this species may be responding to environmental change on a regional, coastwide scale. The response of individual areas to each driver provides support that striped bass recruitment has a synchronous response to an acute, short-term stressor, but a more varied response to longer-term climate trends.

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Applicant: Rachel L. Dixon
Advisor: Mary C. Fabrizio

10 July 2024

Selection Committee
2024 Best Student Presentation Award
American Fisheries Society

Dear Committee,

As Rachel Dixon's Ph.D. advisor at the Virginia Institute of Marine Science (VIMS), I write to support her application for the Best Student Presentation Award and to confirm that her research is at a stage appropriate for this award. Her presentation titled, 'A Novel Perspective on Recruitment and Productivity in Atlantic Striped Bass,' is based on a completed study of synchrony in recruitment of this iconic species. She is currently drafting a manuscript for submission, and I expect that she will have submitted the paper for journal review by the time of the Annual AFS meeting in September. This work comprises one of the chapters of her dissertation, "Recruitment Dynamics of Chesapeake Bay Fishes: Implications for Population Productivity."

Sincerely yours,

Mary C Fabrizio

Mary C. Fabrizio, Ph.D.
Professor of Marine Science
Fellow, American Fisheries Society

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