Ecosystem Variability and Estuarine Fisheries: A Synthesis

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Objectives

- Synthesize the physical, chemical, and biological data, collected in Chesapeake Bay during 1995-2000 as part of the Trophic Interactions in Estuarine Systems (TIES web site) project (funded as part of the National Science Foundation's Land Margin Ecosystem (LMER) program).
- Provide ecological forecasts to agencies involved in Chesapeake Bay fisheries management
- Extend products and approaches developed to benefit management in a broad class of estuaries.

Overview

The comprehensive data products and forecasting tools being produced require an interdisciplinary synthesis of physical, chemical, and biological data collected at numerous spatial and temporal scales with a variety of technologies (e.g., acoustics, CTDs, OPCs, ADCPs, remote sensing). During 2005, spatially-explicit bioenergetics-based modeling was conducted to assess habitat suitability for Chesapeake Bay fishes during spring, summer, and fall 1996-2000. One model focused on bay anchovy, the dominant zooplanktivore in Chesapeake Bay and a primary forage species, and the other on striped bass, the dominant predator in this system. In both models, we used a spatially explicit approach to explore how temperature, food availability and dissolved oxygen influenced habitat suitability of these species, as measured by growth rate potential (i.e., the expected growth of an individual of known size under a suite of known habitat conditions). Overall, our modeling suggested that oxygen availability can severely reduce habitat suitability of bay anchovy in Chesapeake Bay during summer by limiting access to important zooplankton resources that appear to use the low-oxygen zone as refuge. This phenomenon was particularly evident in the deep, mid-region of the Bay, where about two-thirds of the water column became severely hypoxic (< 2 mg/l) during summer. Habitat suitability for striped bass also was low deep-water habitat, relative to shallow-water habitat, in mid-portions of the Bay, owing to hypoxia in deeper waters.

Results

Bay Anchovy Modeling Exercise

Bay Anchovy. Maps of adult bay anchovy growth rate potential (GRP; surrogate measure of habitat suitability) have been generated for Chesapeake Bay during Spring, Summer, and Fall 1996, 1999, and 2000 along the entire latitudinal extent of the Bay. Although some interannual variation in the distribution of habitat quality was evident, some striking generalizations could be drawn:

- **Spring** (Figure 1, top four panels): Growth rate potential (habitat quality) was greatest during spring across the entire Bay, owing primarily to high zooplankton biomass that was accessible to bay anchovy because of well-oxygenated waters (› 3 mg/l) throughout most of the water column. In fact, ›90% of the modeled cells (cell dimensions: ~ 1 km x 1-m depth) had a positive habitat suitability value (i.e., a potential for positive growth; GRP › 0) during spring 1996, 1999, and 2000.
- **Summer** (Figure 1, middle four panels): Habitat quality was typically lowest during summer, especially in the deep, mesohaline (mid-portion) of the Bay, owing to reduced oxygen availability (‹ 3 mg/l). This reduction in habitat quality was evident despite optimal temperatures for bay anchovy growth. Although ample zooplankton (prey) resources existed in the mesohaline region of the bay, they were typically unavailable to bay anchovy; the highest levels of zooplankton prey occurred in deep, hypoxic waters, which were not suitable for high levels of bay anchovy consumption (dissolved oxygen levels ‹ 3 mg/l are stressful to bay anchovy). Thus, reduced oxygen availability may indirectly limit bay anchovy growth by reducing access to prey resources during summer. Indeed, observed distributions of bay anchovy during summer (as measured by hydroacoustics) closely matched the observed distribution of dissolved oxygen (and hence, GRP), thereby supporting our model's predictions. Further, when the model was run without any oxygen effects on bay anchovy foraging during summer, average bay anchovy GRPs were significantly higher because of heightened access to zooplankton prey. Ultimately, these results indicate that dissolved oxygen availability may severely limit production potential of bay anchovy during summer months, which in turn, may have ramifications for higher predators (e.g., striped bass, bluefish). Importantly, habitat quality for bay anchovy during summer can be variable. For example, during 1996 and 2000, the number of cells with positive GRP was typically low during summer (‹ 51%), whereas the clear majority of cells (88%) had a positive GRP during 1999 (Table 1). Thus, factors (e.g., nutrient loading, temperature, wind) that influence the spatial extent of oxygen availability also can indirectly influence habitat quality for bay anchovy growth.
- **Fall** (Figure 1, bottom four panels): Habitat quality for bay anchovy tended to be intermediate during fall months as a result of enhanced oxygen availability in bottom waters relative to summer, but lower zooplankton biomass relative to spring. Similar to summer observations, inter-annual variability in GRP was evident during fall. For example, owing to delayed fall mixing, anoxia was still prevalent during fall 2000 sampling, which in turn, caused ~30% of the modeled cells to have a negative growth potential (Table 1).

In summary, it appears that reduced oxygen availability can limit habitat quality (as indexed by GRP) for bay anchovy, primarily during summer and occasionally during fall. Most affected are deep, mesohaline waters of the mid-Bay. Habitat quality in the shallower upper and lower reaches of the bay, as well as the surface waters of the mid-Bay, tended to be high (positive GRP), regardless of season. Ultimately, these results suggest that efforts to minimize hypoxia might have a positive effect on important zooplanktivorous prey species such as bay anchovy.

Table 1: Summary statistics of adult (age-1+) bay anchovy growth rate potential, a measure of habitat quality, in Chesapeake Bay during spring, summer, and fall, 1996, 1999, and 2000. The sample size (N), mean (X), standard deviation of the mean (SDx), and median (M) are presented for each cruise, as is the percentage of grid cells with a positive growth rate potential for each cruise (%pos).

	Spring			**Summer**			**Fall**		
Statistic	**1996**	**1999**	**2000**	**1996**	**1999**	**2000**	**1996**	**1999**	**2000**
N	2627	3010	2949	3349	3486	2302	2343	2454	2455
X	0.017	0.019	0.020	0.002	0.021	0.004	0.014	0.023	0.008
SD_X	0.009	0.009	0.010	0.017	0.016	0.014	0.008	0.012	0.011
M	0.018	0.019	0.019	-0.008	0.018	0.000	0.013	0.025	0.008
%pos	92	97	99	29	88	51	97	97	73

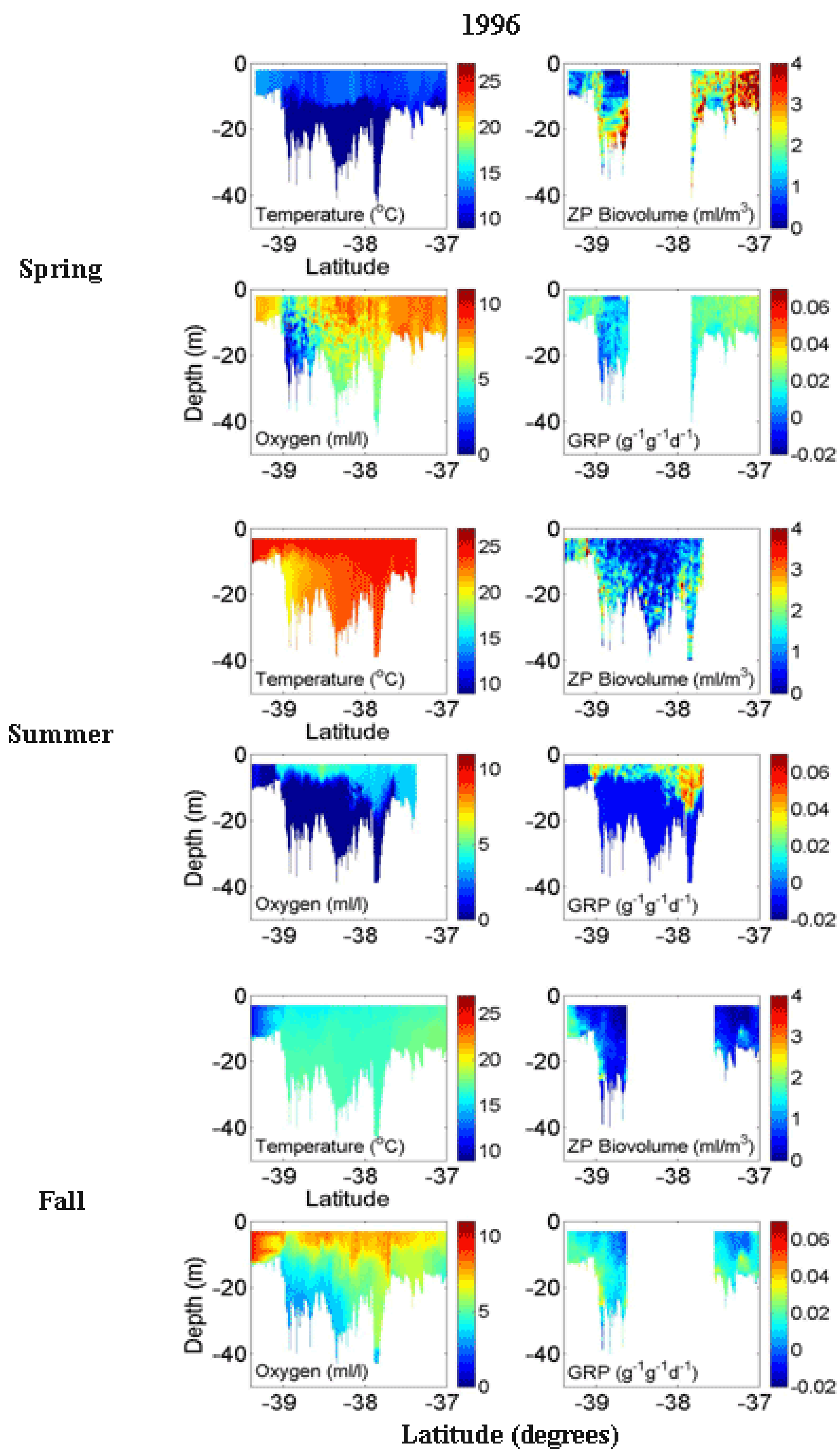

***Figure 1**: Maps of temperature, dissolved oxygen, and zooplankton biovolume (biomass), and growth rate potential (GRP), a measure of habitat quality, in Chesapeake Bay during spring (top*

four panels), summer (middle four panels), and fall (bottom four panels) of 1996. Only results from daytime cruises are shown because 1) bay anchovy feed primarily during daytime, and 2) zooplankton distributions during nighttime are not reflective of actual availability, owing to diel vertical migration behavior.

Data Processing and Analysis Progress

- Completed processing all axial transects from Chesapeake Bay during spring, summer, and fall 1996, 1997, and 2000
- Completed processing all lateral transects conducted during summer and fall in these years (some spring transects also have been processed).
- li›Processed all acoustics data associated with midwater trawling trawls conducted during 1995-2000. Compiled all physical and lower trophic level data associated with acoustics data.
- Generated surface and vertical-profile maps of distributions of relative fish biomass across the bay
- Explored multivariate statistics and spatially-explicit bioenergetics modeling to examine how habitat availability (e.g., temperature, oxygen, food) influences the distribution and growth rate potential of Chesapeake Bay fishes
- A full bioenergetics-based growth rate potential model has been developed for bay anchovy (results presented at the annual American Fisheries Society meeting during August 2004), as well as for striped bass.

Products

Presentations

Ludsin, S.A., X. Zhang, L.W. Florence, M.R. Roman, and S.B. Brandt. 2003. *A multi-scale analysis of factors that influence spatial distributions of Bay Anchovy in Chesapeake Bay*. American Fisheries Society, Quebec City, Canada.

Florence, L.W., S.A. Ludsin, W.C. Boicourt, M.R. Roman, and S.B. Brandt. 2003. *Effects of the Chesapeake Bay hydraulic control point on zooplankton and Bay Anchovy distributions*. American Fisheries Society, Quebec City, Canada.