HABITAT VARIATION AND THE DIET, GROWTH, AND CONDITION OF JUVENILE STRIPED BASS (*MORONE SAXATILIS*) IN THE MID-HUDSON RIVER ESTUARY

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Striped bass are an economically and recreationally valuable fish found along the Atlantic coast. In recent years, there has been an increase in the striped bass populations. Juvenile striped bass, although potentially critical to determining year class success, remain poorly studied. The objective of this study was to investigate the feeding habits and growth of juvenile striped bass along a fine spatial scale. The New York State Department of Environmental Conservation (NYSDEC) collected approximately two hundred fifty-four fish from four sites representing different habitat types located around the Haverstraw Bay region of the Hudson River. These fish were collected over five dates in the late summer and fall of 1998. We determined the diet and estimated the condition of each fish. We then compared those findings to habitat data to discern if trends existed. The results showed that diet did differ among the sites investigated, but that there were no significant differences in condition across sites. These results suggest that scale is an important consideration for certain aspects of early life history in juvenile striped bass.

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INTRODUCTION

Recruitment success in many fish populations is contingent on the survival of the earliest life stages (Peterman1988). Recruitment variability of fishes is especially evident in estuaries because of the large numbers of larvae and juveniles concentrated within these systems (e.g., Newberger and Houde 1995). Size-linked mortality makes growth and diet particularly important for survival of early life stages (Werner and Gilliam 1984). Although many studies have focused on the effects of large-scale spatial and temporal fluctuations on the growth, diet, and survival of fishes (Limburg 1996a; Wainwright et al. 1996), we know little about small-scale variation within an estuary.

The Hudson River estuary provides an excellent opportunity to examine the relationships of small-scale habitat variation with growth and diet of juvenile striped bass (*Morone saxatilis)* for two important reasons. First, striped bass, a commercially and recreationally valuable resource, is abundant in the Hudson River. In particular, the lower portion of the river is an important nursery for juveniles (Dey 1981; McKown and Young 1992; Dunning et al. 1997). Secondly, the Hudson River is a temperate system that experiences seasonal and spatial fluctuations in physical and biotic factors (Cooper et al. 1988). These fluctuations are likely to create a number of variable habitats within the lower portion of the river. Although there has been little investigation of small-scale habitat variation of juvenile striped bass in the Hudson River, the dynamics of the estuarine environment likely impact their population.

Striped bass are integral in the trophic interactions within the Hudson (Rathjen and Miller 1957; Gardinier and Hoff 1982; Pace et al. 1993; Dunning et al. 1997; Buckel 1997). After a severe decline, population sizes have increased dramatically in recent years (Field 1997). This increase will likely affect the ecological interactions in the portions of the river that the juveniles use and may cause possible shifts to new habitats. Prior research showed that juveniles prefer certain habitats (e.g., estuarine, shallower, more saline, etc.) over others (Dey 1981; Boynton et al. 1981; Wainwright et al. 1996).

Responses to habitat change may appear in the diets and growth of individuals. Diet may vary because of differential prey availability among habitats. Combined with altered ecological interactions, these diet changes could affect growth of juvenile fishes.

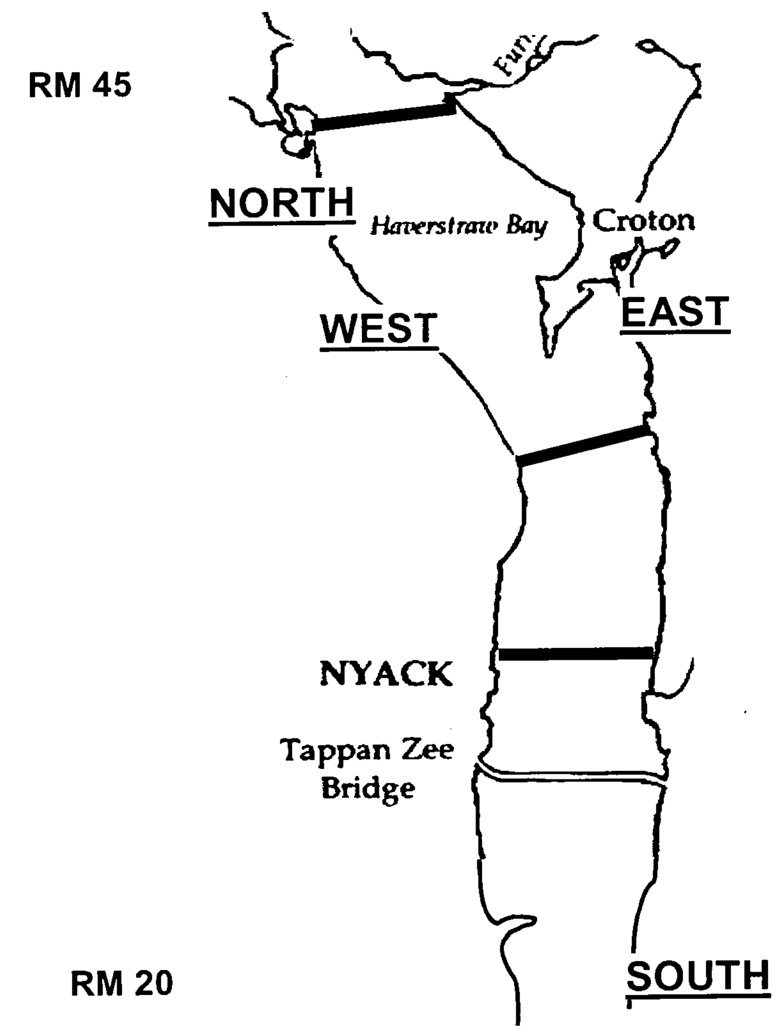
OBJECTIVES

The objectives of this study were to quantify the diet and growth of juvenile striped bass along four distinct habitats to determine if small-scale variations exist within the lower portion of the Hudson River. Differences in diet and growth were then correlated with habitat features and physical characteristics of the four sites.

METHODS

The area studied was the Haverstraw Bay region of the lower Hudson River Estuary (Figure 1), a productive nursery for striped bass (McKown and Young 1992). The New York State Department of Environmental Conservation (NYSDEC) selected four collection sites between river mile 20 to river mile 45 in an effort to maximize habitat diversity. Three sites were located around the Haverstraw Bay and one site was located just south of the bay (Figure 1). The sites differed in both physical and biotic characteristics, including substrate composition, salinity, and vegetation cover.

Figure 1. Map of the Haverstraw Bay region of the lower Hudson River with the location of our four sites indicated. Approximately 20 river miles lie between the north and south sites.



The NYSDEC collected fish with a 61-meter beach seine during its 1998 survey operations. The crew sampled on a bi-weekly basis from mid-July to early November. Approximately 15 juvenile striped bass from each site on each of five dates were preserved in a 10% buffered formalin solution. This yielded 254 fish for this study.

We measured the standard length, SL (± 0.01mm) and wet weight, WW (± 0.01 g) of each individual collected. We then removed the stomach of each fish. Stomach contents were weighed both individually in terms of prey type and as a whole. The contents were then identified to the lowest taxa possible (following Weiss 1995, and Merritt and Cummins 1996).

Prey consumption was summarized using two indices as described by Hyslop (1980). The first index is percent frequency occurrence, i.e., the number of stomachs in which a prey item occurred expressed as a frequency of the total number of stomachs containing food. The second index is percent wet weight, i.e., wet weight of a prey item in the stomach expressed as a percentage of total wet weight of all food items in the stomach.

We computed diet overlaps between sites using two indices of niche overlap: Percent overlap and simplified Morisita (Krebs 1989). Both indices compare a single pair of sites per calculation. Percent overlap is found using $P_{jk} = [\sum_{i-n} (\text{minimum } p_{ij}, p_{ik})]100$ and simplified Morisita is given by $M_{jk} = [2 \sum_{i-n} p_{ij}p_{ik}] / \sum_{i-n} p^2_{ij} + \sum_{i-n} p^2_{ik}$. For both formulae, n = the total number of prey types used by striped bass at a given pair of sites; p_{ij}, p_{ik} = percent wet weight of prey type i for sites j and k, respectively. We deemed diet overlap "considerable" if the calculated values exceeded 60% for the former index and 0.6 for the latter (Krebs 1989). Lastly, we looked at feeding success as measured by the mean weight of prey found in fish stomachs (Boynton et al. 1981). We produced this mean by summing the weight of all prey items for each site over all five dates.

We used age-length regressions to estimate the growth rate for each collection site and collection date. Age of the juveniles was estimated by examining the daily increments or rings on the otoliths of the inner ear (Jenkins et al. 1993; Panella 1971). The use of otoliths to obtain a daily age record has been validated for juvenile striped bass (Secor et al. 1991).

We removed both sagittal otoliths from each fish. A single otolith was mounted and polished following the methods of Secor et al. (1991). We used image analysis software (Optimas 6.0, Optimas Corp., Seattle Washington) to enhance the images of the otoliths. We found, however, that despite being buffered, the formalin did not perform adequately as a storage medium for the otoliths. Their condition varied and no apparent pattern relating to age or mass could be ascertained. Damages included cavities, eroded edges, and undetectable incremental rings. The age-length regressions were not significant and yielded low coefficients of determination ($p > 0.05$ in all cases, $R^2 = 0.06$ on average). We therefore decided to use condition as an indirect measure of growth rate variation (Busacker, et al. 1990).

We quantified differences in condition following two methods. First, we used Fulton's index of condition (K) (Busacker, et al. 1990- = weight/(length)^3). Site differences in K were determined using analysis of variance (ANOVA). Next, we generated length-weight regressions for each site. All slopes did not differ significantly from 3.0 ($p = 0.12$), thus we used analysis of covariance to test for differences in intercepts.

Physical characteristics (i.e., dissolved oxygen, air and water temperature, and salinity), and habitat characteristics (i.e., substrate, percent vegetation cover, vegetation type, and striped bass abundance) were measured by the NYSDEC. Care was taken to equalize seining effort. A standard air thermometer and a YSI Model 85 hydrolab were used to measure salinity, temperature, and dissolved oxygen (± 1.0). The NYSDEC visually estimated the substrate type, dominant vegetation, and percent cover (± 25%). We analyzed these data to discern if any trends existed among the four sites. The sites are designated north, west, east, and south (Figure 1).

Lastly, we compared the physical and habitat characteristics, and condition diet indices to assess whether small-scale spatial variation was evident among these parameters. We were unable to divide the striped bass data sets by date because of low sample sizes. Temporal differences, therefore, were not considered in this study.

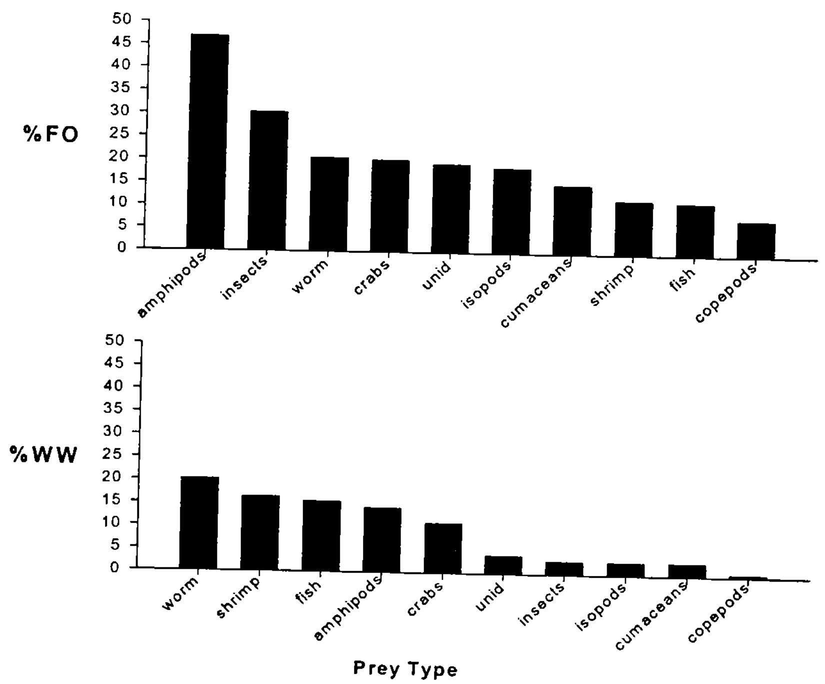
RESULTS

We analyzed data from 254 juvenile striped bass. On average the TL of the juveniles was 57.3 ± 10.9 mm and the average WW was 4.0 ± 2.3 g. Of these, 231 fish (91%) had stomach contents. We found at least eight different orders of prey in the juvenile diet (Table 1). Overall, amphipods (mostly *Gammarus* spp.) were the most frequently occurring prey items (47%) (Figure 2). Dipteran larvae (30%), annelid worms (21%), and crabs (20%) constituted the next most frequently occurring prey items. In terms of percent wet weight, however, annelid worms (mostly *Nereis* spp.) had the greatest importance (20%) (Figure 2). Shrimp (16%) and fish (16%) also constituted a large proportion of the diet by wet weight. Of all stomachs, 19% contained unidentifiable contents (unid), totaling 4% of stomach content wet weight.

Table 1: Diet description for the total of all juvenile striped bass sampled. Included are the diet indices, percent frequency of occurrence (%FO) and percent wet weight (%WW).

Prey	Lowest taxa possible	%FO	%WW
Amphipoda			
	Gammarus spp.	43.7	13.3
	Unidentified amphipods	3.1	0.83
Decapoda			
Brachyura	Unidentified crabs	20.1	11.0
Caridea	*Crangon* spp.	4.7	5.6
	Palaemonetes pugio	2.4	5.8
	Pandalidae	0.4	1.5
	Small unidentified shrimp (<5mm)	1.6	2.1
	Large unidentified shrimp (>5mm)	2.8	1.3
Annelida			
	Nereis spp.	12.6	15.2
	Unidentified polychaete	5.5	4.7
	Unidentified annelid	1.2	0.2
Isopoda			
	Cyathura polita	10.6	3.9
	Unidentified isopod	7.9	0.8
Fish			
	Anchoa mitchilli	3.1	9.9
	Morone spp.	0.8	5.1
	Other fish	1.6	1.2
	Fish eggs	1.2	0.3
	Fish scales	4.7	0.0
Diptera			
	Chironomids and other larvae	30.3	3.0
Copepoda			
	Unidentified copepods	7.9	0.1
Cumacea			
	Unidentified cumaceans	14.9	2.9
Unidentified			
	Unidentified remains	19.3	4.0

Figure 2: Graphical representations of the two diet indices, percent frequency of occurrence (%FO) and percent wet weight (%WW). The prey items have been grouped into prey types. Note that the orders of importance of the prey types differ for the two indices.



When examining the percent frequency occurrence data by site, we found that amphipods appeared most commonly in stomachs of fish captured in the north site (Figure 4). South site fish ingested annelid worms more often than fish elsewhere. Dipteran larvae were highly prevalent in fish from the north as well as the west sites. Prey consumption appeared most even in fish from the east site.

We found the simplified Morisita to be a more conservative measure than the percent overlap (Table 3). For the percent overlap index, all pairs except the west-south pair showed less than considerable overlap. With the simplified Morisita, only the east-north and the north-south pairs yielded less than considerable overlap. Both indices reported the east-north pair to have the least overlap.

Figure 3. Frequency of occurrence index (%FO) compared among sites. Data are summed over all five collection dates.

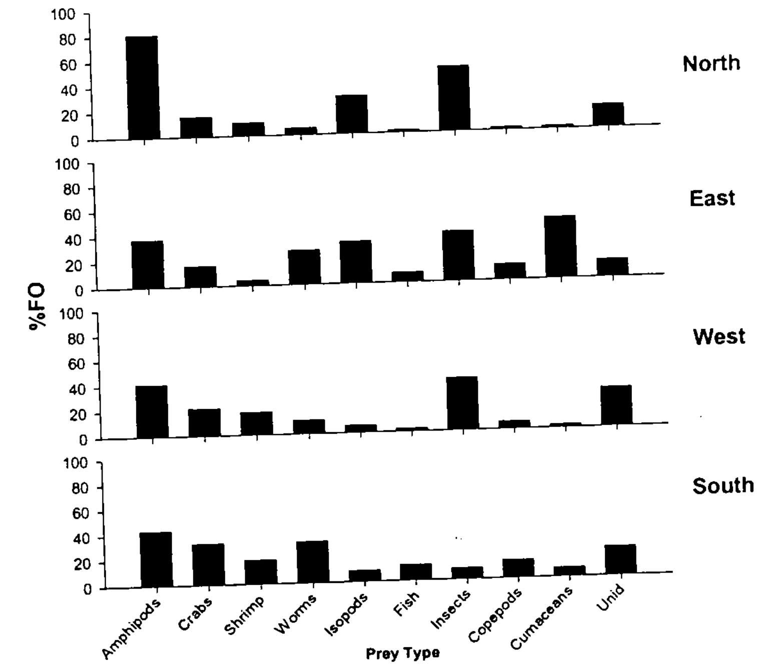


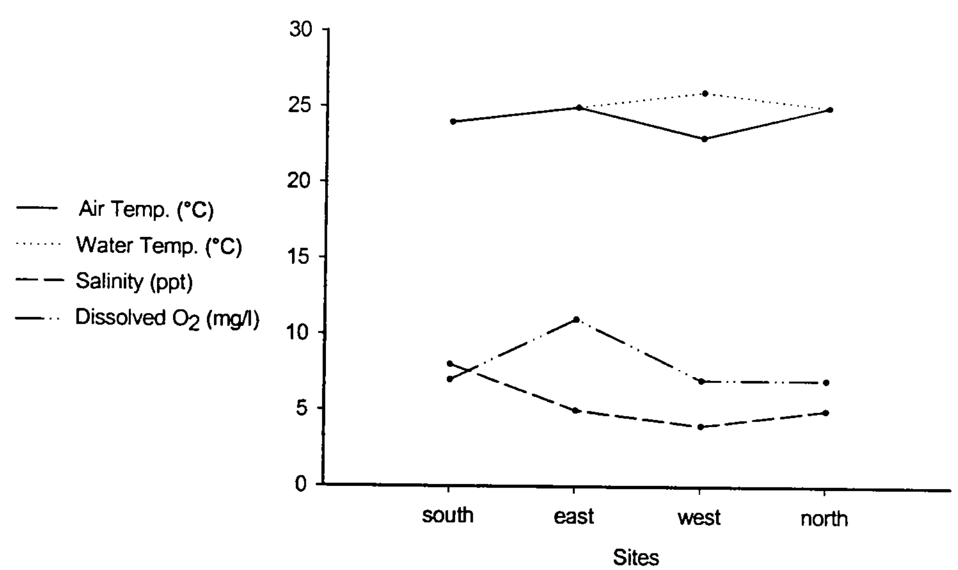
Table 2. Percent overlap and simplified Morisita indices comparing all possible pairs of sites. Diet data were combined for the five dates. Note that the simplified Morisita appears to be a more conservative index. Starred values indicate those that are below 0.6 or 60%.

Site	Percent Overlap	Simplified Morisita
West and east	59.93*	0.75
West and south	62.38	0.77
West and north	55.61*	0.72
East and south	56.32*	0.82
East and north	31.18*	0.35*
North and south	32.04*	0.39*

The results from the analysis of covariance testing for differences in intercept (p = 0.20) and the analysis of variance testing for differences in Fulton's condition K (p = 0.12) indicate that differences in condition did not exist across sites. We then compared feeding success and although the mean weight was slightly higher for the east site, the results from ANOVA indicate that the mean weight of prey did not differ significantly among sites (p = 0.09).

The physical and chemical characteristics of the sites show only slight differences. Air and water temperatures varied little among the sites over the five dates (Figure 3). Salinity was lowest at the northern region of the bay, and dissolved oxygen was highest at the east site. As only single data values were taken at each of the sites, we were not able to statistically compare differences.

Figure 4. Salinity (ppt), water temperature (°C), air temperature and dissolved oxygen (mg/l) at the four sites. Data are averaged over the five collection dates.



Sites differed substantially in substrate type and vegetative cover (Table 2). The south site had no vegetation and a muddy bottom. The north and west sites both had sandy type bottoms and moderate vegetation cover, predominantly filamentous green

algae and Eurasian milfoil (*Myriophyllum spicatum*), respectively. The east site had the most vegetation cover, predominantly water celery (*Valisneria americana)*, and a muddy-rocky bottom. The east site had the greatest number of bass captured over the entire season, while the other three sites had about equal numbers captured over the season. Capture effort was similar at all sites.

Table 3. Habitat characteristics. These descriptions were summarized by NYSDEC for the season. Catch refers to the total number of bass captured at that site over the season.

site	substrate	% cover	vegetation type	catch
south	muddy	0	none	200
east	mud/rock	25-50%	*Valisneria* spp.	295
west	sandy	<25%	*Myriophyllum* spp.	205
north	sand/rock	<25%	filamentous algae	195

DISCUSSION

The results of our study indicate that small-scale (within 15 river miles) habitat variation exists within the Haverstraw Bay region of the Hudson River estuary. We found that some differences in juvenile striped bass (age-0) diet existed across the four sites designated in this study. We found, however, no differences in condition (K) among these four sites coinciding with these differences in diet.

Gammarid amphipods were the most frequently occurring prey item in the total sample. This result concurs with findings of previous juvenile diet studies conducted within the Hudson (Jordan and Juanes 1999, Gardinier and Hoff 1982) and in other estuaries (Boynton et al. 1981). Since amphipods are among the most abundant invertebrates in the Hudson River during the summer months (Gladden et al. 1988), striped bass are likely feeding as generalists. Annelid worms were the most important items in wet weight overall, but at none of the sites individually. We found greater number of prey types in the juvenile diet particularly, soft-bodied prey, planktonic prey, and dipteran larvae in our study compared to a previous study examining fish collected from 1994-1997 (Jordan and Juanes 1999). This diet difference could be attributed to possible differences in prey availability or more likely to difference in preservation method: Jordan and Juanes (1999) used frozen samples, whereas our fish were fixed in formalin. Apparently, this decreased the amount of unidentifiable and decomposed stomach contents.

The site at which the most fish were captured per-unit-effort, the east site, appears most different from the other sites. At the east site, the Croton River empties into the Haverstraw Bay. The substrate is heterogeneous and the site is the most heavily oxygenated and vegetated. Water celery (*Valisneria americana)* is the dominant macrophyte.

In terms of diet, the east site fish show the greatest evenness in prey type and the highest mean feeding success. The percent overlap index indicated little overlap among most of the sites. In comparison, the simplified Morisita provided more conservative estimates and indicated only that the north and south and the north and west sites had little overlap in diet.

Prey availability has been shown to change with time in a single season. For example, in the Hudson River the upriver prey availability tended to decrease in the north

during the fall (Limburg 1996b). A limitation in our study is that temporal differences in diet were not considered because of small sample sizes.

The variation in diet found among the four sites is probably best explained by differences in prey availability. We would expect greater abundance of polychaete annelid worms in the southern, more saline habitats, and conversely, we would expect more insect larvae in the less saline north. Our expectation coincided with prey consumption patterns across sites, suggesting a generalist feeding strategy. In addition, gammarid amphipods were very common in the diet, and are known to be abundant in the Hudson River (Gladden et al. 1988). Other investigations also suggest that juvenile striped bass adopt a generalist feeding strategy (Boynton et al. 1981, Robichaud-LeBlanc et al. 1997). It must be noted, however, that statements about juvenile feeding strategy cannot be definitively made without data on prey availability.

Though diet differences did exist among the four sites, we did not find differences in condition among the fish. This might suggest that striped bass juveniles move throughout the region. Adequate movement could neutralize possible impacts of differences in physical characteristics, habitat features, or prey availability among sites.

In addition to movement, energetic issues could underlie the absence of effect on condition. Assuming other influences on energetics (e.g., water temperature, salinity, etc.) equal, energetic qualities of prey were possibly insufficient to alter condition or growth. Certain prey items, such as other fish, are likely to alter growth, and thus condition more substantially (Dutta 1994). For example, juvenile bluefish experienced differences in condition when fish dominated their diets compared to periods when invertebrates dominated their diets (Friedland et al. 1988). Piscivorous diets also led to higher growth rates than invertebrate diets (Juanes and Conover 1994). Striped bass have been reported to switch to piscivory when they reach lengths of 100-140 mm (Gardinier and Hoff 1982, Rulifson and McKenna 1987).

Other studies of juvenile striped bass year class strength indicate that food availability and growth are key in ensuring survival into adult stages. Limburg et al. (1999) found that within the Hudson cohorts associated with regions of higher food availability were better represented into the next year. The authors suggested that biotic controls predominate in predicting recruitment success. Boynton et al. (1981) suggested that salinity, however, could act as an indicator of what prey types are likely to be found in the juvenile diet. Haloclines have also been associated with regions of growth rate variation of juveniles (Wainwright et al. 1996).

In conclusion, small-scale habitat differences can be correlated with differences in diet of juvenile striped bass in the Hudson River estuary. The east site in particular had the greatest number of juveniles captured and the most evenness in prey consumed. Future investigations should continue to consider small-scale variation in life history parameters of juvenile fishes. Adding factors including movement of juveniles within the Hudson River and prey availability would further elucidate the habitat-juvenile relationship.

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