AVAILIBILITY, CONSUMPTION AND PREFERENCE OF PREY IN JUVENILE STRIPED BASS *(Morone saxatilis)* IN THE HUDSON RIVER

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Striped bass (*Morone* saxatilis) is ecologically and socially an important fish in the Hudson River. Understanding factors related to the growth and survival of the juvenile life stage is important because these factors ultimately influence recruitment. Feeding behavior is one such factor. Past studies of diet composition of juvenile striped bass in the Hudson River have not explored prey availability. We investigated prey consumption of striped bass young-of-the-year and benthic macroinvertebrate abundances at three Hudson River locations on two dates. Dipteran larvae (family Chironomidae), decapod shrimp (*Crangon septemspinosa* and *Palaemonetes* spp.), amphipods (Oedicerotidae and Gammaridae), and polychaete worms (*Nephtys* spp. were found to be the most important diet components, whereas oligochaete and polychaete worms, dipteran larvae, and isopods (*Cyathura polita*) were found to be the most abundant macroinvertebrates. Values of the niche overlap index indicated that prey consumption differed spatially and temporally; and feeding largely occurred during day versus night. Macroinvertebrate abundances tended to differ more widely on a spatial rather than a temporal scale. Analysis showed decapod shrimp and dipteran larvae to rank among the highest in diet preference. When decapod shrimp were not available, preference rankings were shuffled and amphipods were most preferred. Abundance, size, color, and behavior are possible factors in juvenile striped bass diet preference.

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INTRODUCTION

Striped bass are important economically, recreationally, and ecologically in the Hudson River. Presently, adult populations are high and are likely substantially impacting ecological interactions within the river. Understanding the factors influencing adult population abundance is vital both for managing striped bass and for predicting the species' impact on other organisms.

Important to recruitment into the adult stock is juvenile survival. Juvenile survival depends upon foraging success, diet quality, and ultimately, condition and growth (Werner et al. 1984). Predation by larger fish can be a major source of juvenile mortality. By growing faster, juvenile fish can decrease the risk of predation (Juanes and Conover 1994; Buckel et al.1999). In addition, faster growing juveniles may be better able to survive over winter (Hurst and Conover 1998). Thus, variation in juvenile foraging efficiency may affect year-class strength (Stevens et al. 1985) and recruitment.

The Hudson River estuary is an excellent environment for investigating juvenile striped bass feeding habits. Juveniles are abundant and integral in the trophic interactions (Rathjen and Miller 1957; Gardinier and Hoff 1982; Pace et al. 1993; Dunning et al. 1997; Buckel et al. 1999). The lower portion of the river, in particular, has been cited as an important nursery area (Dey 1981; McKown and Young 1992; Dunning et al. 1997).

Recently, young-of-the-year (YOY) striped bass diets have been investigated within the Haverstraw Bay region of the river (Jordan and Juanes 1999; Howe and Juanes 2000). Schmidt (1993) investigated juvenile striped bass feeding in Manitou marsh and found different diet compositions than found in the Haverstraw Bay studies. The spatial extents of these recent studies were limited, however, and none examined prey availability. These studies did reveal, however, that habitat differences are important when considering juvenile feeding. In other systems, habitat differences have been shown to affect striped bass growth rates (Wainwright et al. 1996) and may explain higher abundances in certain areas (Boynton et al. 1981).

Prey availability likely is an important parameter driving differences in habitat quality. Assessment of available prey frequently accompanies studies of larval striped bass survival (Limburg et al. 1999; Robichaud-LeBlanc et al. 1997; Bennet et al. 1995), probably because plankton tows are relatively simple additions to the methodology. Despite their importance as a prey base for juvenile striped bass, sampling of benthic and epibenthic fauna of estuaries is often difficult and is therefore infrequent. One exception for the Hudson River is Haley (1999) who used trawls and benthic grabs to explore invertebrate prey available for sturgeon. No work, however, has been conducted on prey availability for Hudson River juvenile striped bass.

Preference is defined as active selection of particular prey (Juanes 1994). Work in some systems has demonstrated that adult striped bass may show preference for certain prey components (Matthews et al. 1988; Stevens 1969), in contrast to the common view that adults feed opportunistically (Boynton et al. 1981). These contrasting views may be explained by habitat differences: the former studies were conducted in fresh water and the latter in an estuary. It is unknown whether Hudson River juveniles feed randomly or with preference. Knowledge of feeding mode may explain differences in feeding such as the near lack of amphipods found in the diets of Manitou Marsh striped bass YOY by Schmidt (1993), in contrast to their historical predominance as a prey item elsewhere (Howe and Juanes 2000; Jordan and Juanes 1999).

OBJECTIVES

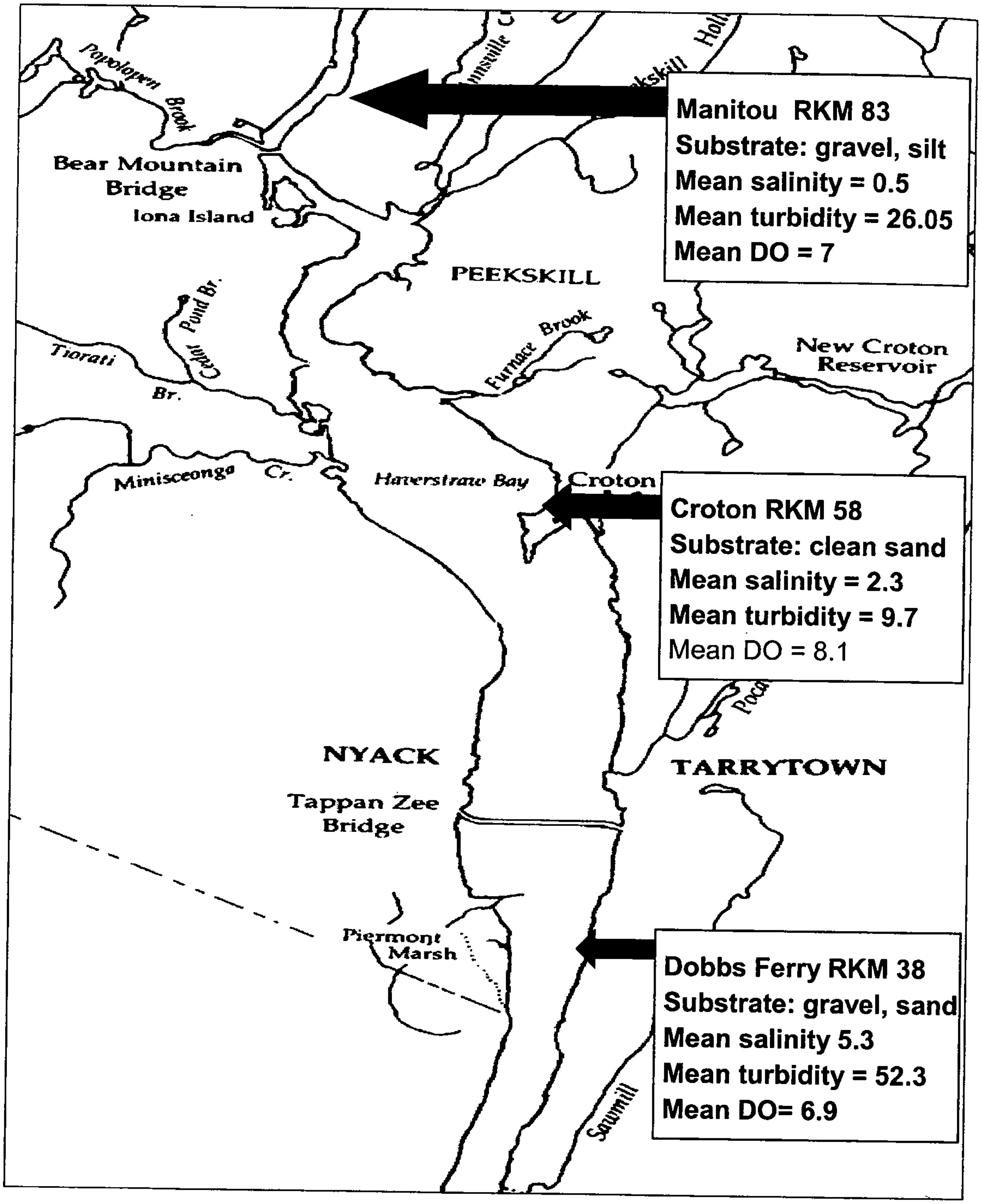
The objectives of this study were: (1) to compare feeding habits of YOY striped bass on diel and spatial scales; (2) to assess the invertebrate community available as prey; and (3) to investigate feeding preference with juvenile (young-of-the-year) striped bass in the Hudson River estuary.

METHODS

To accomplish these objectives, striped bass YOY and benthic macroinvertebrates were sampled in three locations within the Hudson River (Figure 1) estuary during two sampling events: July 31-August 1, and August 22-23. At each site, sampling occurred once during the day and once during the night.

Sites for this study were selected based on several criteria. First, we wanted to establish a somewhat greater spatial scale than used in previous studies (Howe and Juanes 1999). Second, despite this greater scale, the study needed to be confined to a region described as an important striped bass YOY nursery. Third, an attempt was made to maximize abiotic and biotic habitat differences. Fourth, approximately equal spacing between sites was deemed important. Finally, we needed shallow beaches with boat access and minimal obstructions for seining. The sites chosen include Dobbs Ferry in the south at approximately RKM 38, Croton Point at approximately RKM 58, and Manitou at approximately RKM 83 (Figure 1).

Figure 1: Map of the Hudson River indicating locations of the three sites used. Also indicated are physical conditions associated with the sites, including substrate composition, and salinity (ppt), turbidity (formazine turbidity units), and dissolved oxygen (DO, ppm) averaged over all visits.



Manitou RKM 83
Substrate: gravel, silt
Mean salinity = 0.5
Mean turbidity = 26.05
Mean DO = 7

Croton RKM 58
Substrate: clean sand
Mean salinity = 2.3
Mean turbidity = 9.7
Mean DO = 8.1

Dobbs Ferry RKM 38
Substrate: gravel, sand
Mean salinity 5.3
Mean turbidity = 52.3
Mean DO= 6.9

Fish samples were taken at each site by a 50 m beach seine. An attempt was made to confine sampling to the lowest tide possible. The seine was either set by boat or by foot and was retrieved by hand. Seining continued until 5 hauls were completed or 30 juvenile striped bass were captured. All collected fish were identified to species and counted. Total length (TL), standard length (SL), and weight to 0.01 g were measured on location. Heads were removed and stored in ethanol to safely preserve otoliths for possible later analysis. The bodies of fish were placed in formalin to preserve stomach contents. In the laboratory, stomach contents were identified and an index of relative importance (IRI) was calculated (Hyslop 1980). This index is given by IRI = (%N + %WW) x %FO, where N= number of prey, WW= prey wet weight, and FO= prey frequency of occurrence. We also applied analysis of variance (ANOVA) to compare stomach fullness (the amount of prey divided by predator weight), SL among the sites and dates, and fish body condition. As a measure of condition we used Fulton's K, where $K = \text{weight}/(\text{length})^3$ (Busacker et al. 1990).

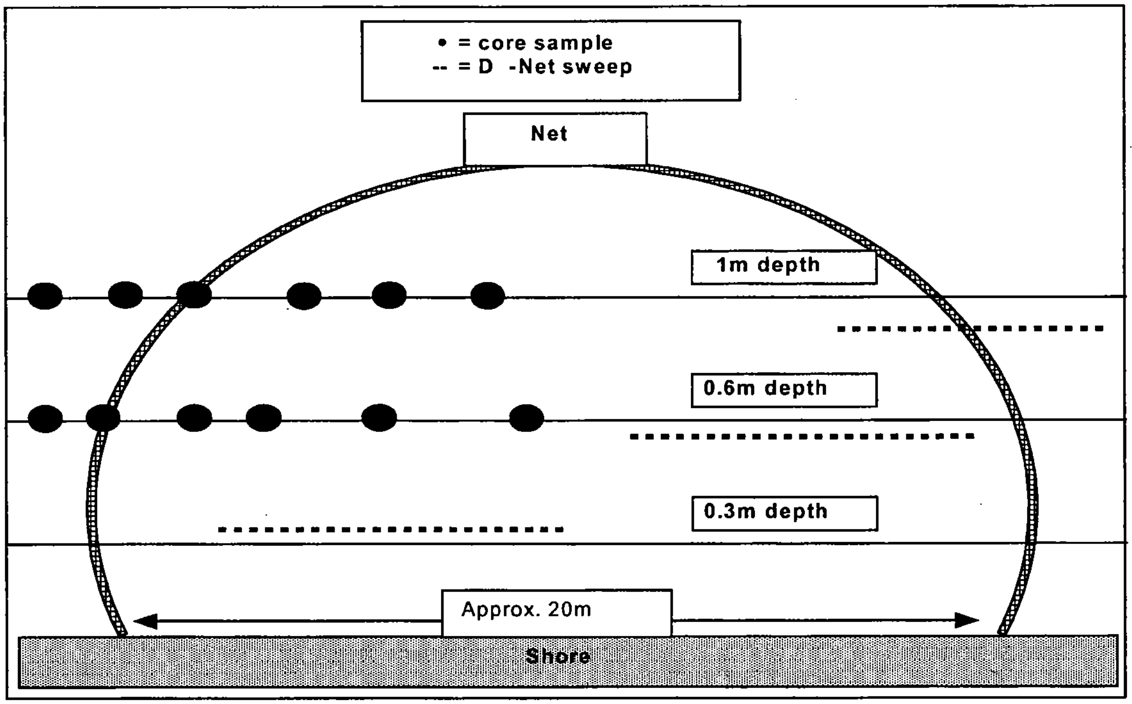
We computed diet overlaps between sites, dates, and diel phase using the simplified Morisita (Krebs 1989) index of niche overlap. This index compares a single pair of sites per calculation and is given by $M_{jk} = [2 \sum_{i\text{-}n} p_{ij}p_{ik}] / \sum_{i\text{-}n} p^2_{ij} + \sum_{i\text{-}n} p^2_{ik}$, where 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 Morisita values exceeded 0.60 (Krebs 1989). The simplified Morisita index was also used to compare prey availability by site, date, and diel phase.

Prey availability data were collected concurrently with the fish sampling using a D-framed sampling net and a sand auger following the protocol designed by Hicks

(1999). Two methods were used to adequately capture the array of epibenthic and benthic fauna that is potential juvenile striped bass prey (Howe and Juanes 2000). Sampling locations were randomly assigned along transects (Figure 2). The D-net was swept along the surface of the substrate following three transects. The flow through the net was monitored to quantify surface area swept. Average substrate surface area sampled by three sweeps was 3.6 m^2.

The auger was twisted into the substrate to a maximum depth of 8 cm. Depth varied because of differences in substrate composition and compaction. Twelve auger cores were taken totaling 0.18 m^2 of substrate surface area sampled.

Figure 2: Fish and invertebrate sampling design. Auger core locations were randomly selected. Transects began at a randomly selected location and subsequent transects occurred in deeper water. Where space allowed, seining and invertebrate sampling areas were adjacent.



Retrieved samples from both methods were placed into a # 30 soil sieve, rinsed, and then placed into labeled bags. Organisms were anaesthetized in carbonated water and then preserved in 10% buffered formalin. In the laboratory, the samples were sorted, counted, and identified following Weiss (1995) and Merritt and Cummins (1996).

To combine organism counts from the two methods, counts for each taxon found in the auger samples were multiplied by the ratio of the D-net sample surface area for the cruise over the auger surface area. Numbers in each taxon were then summed for the two methods. To make these numbers comparable among cruises, they were divided by the respective D-net sample surface area. This result is an abundance estimate for 1 m^2.

Striped bass diet composition was compared to invertebrate availability using preference assessment software (PREFER, v5.1, Pankratz, 1994). The program performs calculations described in Johnson (1980). PREFER tests the hypothesis that all components are equally preferred and compares components using the multiple comparison procedure of Waller and Duncan (1969).

RESULTS

The substrate at Manitou consisted of coarse gravel and railroad fill, along with considerable organic sediment; Croton Point substrate was densely packed, clean sand with smooth pebbles toward the high tide mark; sand with moderately coarse gravel and patches of organic sediment comprised the substrate at Dobbs Ferry. On average, salinity was highest at Dobbs Ferry and lowest at Manitou; dissolved oxygen (DO) was highest at Croton Point and lowest at Dobbs Ferry; and turbidity was highest on average at Dobbs Ferry and lowest at Croton Point (Figure 1).

Overall, we analyzed data from 212 juvenile striped bass. Total length (TL) averaged 42.4 ± 8.25 mm and WW averaged 1.6 ± 1.12 g. Stomachs of 171 fish (81%) contained food. We found at least 10 different orders of prey in the juvenile diet (Table 1). Dipteran larvae (mostly chironomids, class Insecta) comprised 66.3% of total IRI, Caridea (shrimp, order Decapoda 16.0%, and Amphipoda 12.3%). Fish comprised 3.1%. Polychaeta, Isopoda, and Copepoda comprised 1.2%, 0.8%, and 0.4%. Brachyura (crabs, order Decapoda), Mesogastropoda (snails), Xiphosurida (horseshoe crabs), and adult insects were uncommon stomach contents. Unidentifiable contents occurred in 2% of stomachs, totaling 3% of total wet weight.

Table 1: Prey consumed by striped bass YOY. %FO = percent frequency of occurrence, %WW = percent wet weight; N = number of individuals consumed; %N = percent of the total number of individuals consumed represented by a given taxon; IRI = index of relative importance (IRI = (%N + %WW) x %FO); and %IRI = percent of the total IRI represented by a given taxon. Unidentified stomach contents were not used in the IRI calculations.

Consumed Prey	% FO	% WW	N	% N	IRI	%IRI
Diptera (Class Hexapoda)	48.24	14.65	1817	77.15	4428.48	66.30
Decapoda (Caridea)	33.53	26.75	118	5.01	1065.09	15.95
Amphipoda	51.76	9.45	150	6.37	819.21	12.27
Fish	6.47	31.78	11	0.47	208.72	3.12
Phylodocida (Class Polychaeta)	8.24	8.83	14	0.59	77.60	1.16
Isopoda	15.29	2.00	32	1.36	51.40	0.77
Copepoda	2.35	2.99	205	8.70	27.51	0.41
Decapoda (Brachyura)	1.18	0.40	3	0.13	0.62	0.01
Mesogastropoda (Snails)	1.76	0.07	3	0.13	0.36	0.01
Xiphosurida (Horseshoe crab)	0.59	0.10	1	0.04	0.09	0.00
Insecta (Adult Terrestrial)	0.59	0.01	1	0.04	0.03	0.00
Unidentified	2.94	2.94				

The simplified Morisita index values of niche overlap (Table 2) indicate that in general diets differed between sites both months (0.02-0.37). Diet overlap between months by site was moderate to considerable (0.32-0.76), with the exception of the Croton night samples (0.02). Overlap between day and night samples varied greatly across sites and months, ranging from 0.02 (August Croton Point) to 0.91 (July Croton Point).

Table 2: Simplified Morisita index values of niche overlap comparing both prey consumed and prey available by month, diel phase, and site. Asterisk indicates considerable overlap.

Comparisons	Consumed	Available
July		
Dobbs Day X Croton Day	0.12	0.30
Dobbs Day X Dobbs Night	0.46	0.07
Croton Day X Croton Night	0.91*	0.97*
August		
Dobbs Day X Croton Day	0.12	0.31
Dobbs Day X Manitou Day	0.02	0.35
Croton Day X Manitou Day	0.37	0.25
Dobbs Day X Dobbs Night	0.21	0.82*
Croton Day X Croton Night	0.02	0
Manitou Day X Manitou Night	0.45	0.93*
July X August		
Dobbs Day 1 X Dobbs Day 2	0.32	0.37
Croton Day 1 X Croton Day 2	0.76*	0.59
Dobbs Night 1 X Dobbs Night 2	0.56	0.43
Croton Night 1 X Croton Night 2	0.02	0

Mean fish body condition ($K = \text{weight}/(\text{length})^3$ was significantly higher in July (1.97) than in August (1.78), but did not differ significantly by diel phase or by site (ANOVA, general linear model, N=212, F=17.35, 1.84, and 1.74, respectively; $p<0.001$, p = 0.059, and p = 0.067, respectively). Mean stomach fullness was significantly higher in July (1.54) than in August (0.89); it was significantly higher during the day (1.56) than at night (0.69); but it was not significantly different among sites (ANOVA, general linear model, N=210, F=9.5, 14.22, and 1.86, respectively; p=0.002, p<0.001, and p=0.159, respectively). Mean standard length was significantly greater in day-captured fish (43.99mm) than in night-captured fish (40.81mm), but it did not differ significantly by month or site (ANOVA, general linear model, N=212, F =8.09, 0.08, and 0.17, respectively; p=0.005, 0.771, and 0.841, respectively).

Overall, oligochaete worms were found to be the most abundant invertebrate group (Table 3), followed in order by polychaete worms (mostly Nephtyidae, *Nephtys* spp.), dipteran larvae (mostly Chironomidae, *Cryptochironomus*), Isopoda (mostly *Cyathura polita*); Amphipoda (Oedicerotidae, Gammaridae, and Aoridae), Caridea (*Palaemonetes* spp. and *Crangon septemspinosa*), Cumacea, and Brachyura (*Callinectes sapidus* and Xanthidae). Comparing prey available using the simplified Morisita's index, we found that by site within months overlap was moderate, with values ranging from 0.25-0.35. Overlap by diel phase within site and month was very high for July at Croton Point (0.97) and for August at Dobbs Ferry (0.82) and Manitou (0.93), however, overlap was extremely low in July at (0.07) and in August at Croton Point. These last two results may reflect tidal differences: the night samples in the pairs were collected near high tide. Comparisons between months within site and diel phase showed moderate overlap ranging from 0.37-0.59, with the exception of the Croton Point night pair. The index value here was 0.0, possibly also reflecting the previously noted tidal phenomenon.

Table 3: Benthic macroinvertebrate abundance per 1m^2 by taxon, site, month, and diel phase. Not listed are snails (family Hydrobiidae) and clams (mainly family Sphaeridae). In bold are the site/month/diel phase combinations used in the preference analysis.

Site	Month	Diel	Amphipoda	Caridea	Brachyura	Polychaeta	Oligochaeta	Isopoda	Diptera	Cumacea	Total
Dobbs	**July**	**Day**	**21.5**	**5.1**	**0.3**	**43.6**	**0.0**	**0.5**	**1.8**	**0.0**	**72.7**
Dobbs	July	Night	0.0	5.4	0.0	0.0	6.5	0.4	0.0	0.0	12.3
Croton	**July**	**Day**	**0.5**	**0.0**	**0.0**	**5.4**	**0.0**	**21.9**	**90.5**	**0.0**	**118.4**
Croton	July	Night	7.5	0.6	0.0	10.8	0.0	16.2	55.8	0.0	91.0
Dobbs	**Aug.**	**Day**	**9.9**	**0.3**	**0.5**	**37.9**	**92.3**	**21.7**	**0.0**	**0.0**	**162.5**
Dobbs	**Aug.**	**Night**	**61.7**	**3.2**	**0.0**	**97.8**	**81.2**	**49.5**	**0.0**	**0.0**	**293.5**
Croton	**Aug.**	**Day**	**8.1**	**0.0**	**0.0**	**37.9**	**0.0**	**96.3**	**45.7**	**1.6**	**189.5**
Croton	Aug.	Night	0.0	0.3	0.0	0.0	893.7	0.0	0.0	0.0	894.0
Manitou	Aug.	Day	3.2	0.0	0.0	5.3	25.3	0.6	11.1	0.0	45.5
Manitou	Aug.	Night	15.1	0.0	0.0	10.8	176.7	5.9	19.5	5.4	233.5
Total			127.4	14.9	0.8	249.7	1275.7	213.1	224.4	7.0	2112.9

Five site/month/diel phase combinations provided sufficient prey consumption and striped bass sample size to conduct preference analysis (Table 4). All but one was a daytime sample. Probabilities for the F statistic produced in testing the null hypothesis that all diet components were equally preferred was <0.001 in all 5 analyses. Caridea ranked highest in preference in the 3 Dobbs Ferry analyses, 2nd highest in preference at Croton in August, but was not a prey item at Croton Point in July. Amphipoda was highest in preference at Croton Point in July, but ranked 3rd in all other analyses. Diptera ranked highest in preference at Croton Point in August, but ranked 2nd or 3rd in all other analyses in which it appeared as a prey component. Polychaeta ranked lowest in the 3 Dobbs Ferry analyses, but Isopoda ranked lowest in preference in the 2 Croton Point analyses.

Table 4: Preference rankings of prey types by site and date. Asterisk indicates a night sample. Site/month/diel phase combinations with extremely low prey consumption or small striped bass sample size were excluded from preference analysis. Also reported are F statistics associated with the test of H_o: all components are equally preferred. Probabilities of all values presented are <0.001.

Site		**Croton**	**Croton**	**Dobbs**	**Dobbs**	**Dobbs***
Month		July	August	July	August	August
	1	Amphipoda	Diptera	Caridea	Caridea	Caridea
	2	Polychaeta	Caridea	Diptera	Diptera	Isopoda
Rank	3	Diptera	Amphipoda	Amphipoda	Amphipoda	Amphipoda
	4	Isopoda	Polychaeta	Polychaeta	Brachyura	Polychaeta
	5		Isopoda		Isopoda	
	6				Polychaeta	
F		90	171	125	437	173

DISCUSSION

Overall, Caridean shrimp appears to be the most preferred prey component of striped bass YOY in the Hudson River. This may be related to generally larger body size, but feeding inefficiencies presented by other groups may also contribute to active selection of Caridea by striped bass YOY. Such inefficiencies may lower the ratio of energy gained from a food item over the energy used in pursuit and consumption of that item; or they may represent costly uses of stomach space. For example, many chironomids found in the macroinvertebrate sampling inhabited sand tubes. Many ingested polychaete worms contained considerable sand. *Cyathura polita*, the only significant isopod prey component, is dorso-ventrally flattened and its coloration closely mimics sand, potentially causing them to be difficult for striped bass YOY to locate and ingest. This may render *C. polita* energetically expensive to pursue.

Coloration and size of prey types may interact and thereby influence preference. Oligochaetes were extremely common yet were never consumed. These worms were generally reddish brown, similar to the substrate. Polychaetes, which were consumed, were often green. Polychaetes, however, tended to be not only physically larger but could also appear larger because of parapodia movement. Most dipteran larvae captured and ingested were bright green but of similar size as oligochaetes. Diptera ranked highly in preference.

Prey preference may also be influenced by the interaction of color and behavior. Oligochaetes were largely captured in the D-net samples and polychaetes largely in the auger samples. This would suggest that oligochaetes might be physically more available to fish than polychaetes, given that the D-net samples the substrate to a lower depth than the auger. Oligochaetes unlike polychaetes, however, were collected in higher numbers at night than during the day. More rapid gut evacuation of oligochaetes may explain their lack in striped bass stomachs, however, an oligochaete entangled on a piece of fishing line that one fish that ingested (removed from analysis) was perfectly preserved.

Differences in stomach fullness, but similar prey abundances, between day and night indicate that striped bass YOY forage more successfully during the day. An exception is the fish collected at Dobbs Ferry in August. This site has considerably less tree cover than the other sites and is partially lit by nearby street and park lights. Foraging in light would allow the fish to employ color discrimination to enhance prey capture efficiency.

Prey captured by striped bass YOY in this study appears to curiously depart from what previous studies might predict. First, Diptera emerged as extremely important from this study, but was a relatively minor component to virtually absent in past studies (Howe and Juanes 2000; Jordan and Juanes 1999; Gardiner and Hoff 1982). Amphipoda, the prey component reported in these earlier studies as perhaps the most important for striped bass YOY in the Hudson River, ranked third this year. Caridea became more important than in the past, and the importance of Polychaeta declined markedly from that found in Howe and Juanes (2000) and Jordan and Juanes (1999). Unfortunately, no prey availability data for previous years exist, however, it seems likely that prey availability would factor heavily in this inter-year variation.

A long-term study of the macroinvertebrate community of the Hudson River is needed. Yearly variation in striped bass diet may reflect fluctuations intrinsic to the food web or the macroinvertebrate community may be responding to larger scale biotic or abiotic trends within the river. Even subtle, temporary changes in prey relative abundances may have important implications for striped bass YOY diets.

An abundance threshold may exist which triggers active pursuit of a prey component by striped bass YOY. This abundance threshold may differ among prey types according to factors such as size, encounter rate, capture ease, and handling time. Caridean shrimp, for example, may be pursued at much lower abundances than dipteran larvae because of their larger size and greater independence from the substrate.

Differing in Caridea and Diptera abundance, the August day samples at Dobbs Ferry and Croton Point showed otherwise moderate overlap in prey available. Prey consumed, however, showed little overlap. This trend was seen throughout the study and supports the hypothesis that striped bass YOY do exhibit diet preference. Diet preference, or prey consumption that is disproportionate to prey availability, may result if one or more particular components, such as Caridea or Diptera in this study, is sufficiently abundant.

Assessing preference is problematical and some aspects of the methodology used in this study bear discussion. No precedent could be found for combining invertebrates collected by two seemingly divergent methods into measures of relative abundance. Both methods in this study, D-net and sand auger, in essence removed a layer of substrate and all organisms contained therein that were unable to escape. Generally, a sand auger core penetrated deeper than the D-net, but this varied by substrate. Because surface area was more constant than volume in the auger cores and because the substrate surface is where prey are most likely to be found, surface area was used rather than volume to equalize effort. Additionally, using D-net to auger volume ratio to extrapolate abundances of prey found in the auger presents greater risk of exaggeration than using surface area. All prey types were captured by both methods. Ratios of D-net to auger core capture rates of some types, for example Caridea, Amphipoda, and Diptera, paralleled the difference in surface area. Isopoda and Polychaeta, however, appeared poorly represented in the D-net samples. In fact, only 2 polychaetes were netted. Without the auger cores and subsequent extrapolations, striped bass YOY preference for isopods and polychaetes would likely have been grossly exaggerated.

A potential weakness in any preference study surrounds the ability to accurately reflect availability for a given species. Although Johnson (1980) claims that the use of ranks in his method addresses concerns about faithfully determining resource availability, even accurate abundant assessments may not reflect true availability. For example, it may be that physical conditions, such as turbidity or substrate composition differentially