PRELIMINARY STUDIES OF LARVAL AND JUVENILE GIZZARD SHAD AND ATLANTIC MENHADEN IN THE HUDSON RIVER

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Gizzard shad (*Dorosoma cepedianum*) and Atlantic menhaden (*Brevoortia tyrannus*) are herrings that occur in the Hudson River. Gizzard shad are relatively new to the fish community and are able to switch feeding habits when resources become depleted. Atlantic menhaden are long-time components of the fish community and use the tidal river as a nursery. Both species have complex feeding habits. This report includes the locations and habitat descriptions of the sampling sites where these species were caught. I analyzed the stomach contents of larval and juvenile gizzard shad and juvenile menhaden. I also compared diet analysis results to stable isotopic ($\delta^{13}C$ and $\delta^{15}N$) compositions of muscular and stomach tissue of larval, juvenile, and adult gizzard shad and juvenile Atlantic menhaden collected from the Hudson River (39-238 km) during May- September. $\delta^{15}N$ revealed differences between detrital sources for juvenile gizzard shad and Atlantic menhaden. The $\delta^{15}N$ ratio of muscular tissue became more enriched as the location of sampling moved upstream. The life stages of gizzard shad separated out isotopically, reflecting the feeding habits, however, sampling was not controlled for geographic variation. Adult gizzard shad were collected from the Mohawk River whereas juveniles were only collected in the tidal Hudson. Further studies need to sample in open surface water for juvenile gizzard shad <38mm to better understand the trophic impacts on the Hudson River ecosystem. In addition, the variation in composition of detritus should be examined to detect the differences in quality of juvenile gizzard shad and Atlantic menhaden diets.

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INTRODUCTION

Dorosoma cepedianum (gizzard shad), is a relative newcomer to the Hudson River. In the 1980's gizzard shad were first noted in power plant entrainment surveys (K. Hattala, New York State Department of Environmental Conservation, pers. comm.). Since then, numerous sitings have occurred. Today, commercial American shad fishermen capture many gizzard shad adults in their nets. Gizzard shad larvae have also been entrained in power plant facilities, but few observations of subadults have been reported. This report describes a preliminary study to determine where subadult *D. cepedianum* occur in the Hudson River, what they are eating, and whether their diets reflect what they actually assimilate into somatic tissue.

The gizzard shad is predominantly a freshwater species, residing in lakes, reservoirs, and sluggish rivers; however, they tolerate brackish water (Smith 1995). In freshwater systems, particularly reservoirs in the mid-west and south, gizzard shad tend to be abundant and dominate the fish community (45% of fish biomass; Drenner et al. 1982) (Dettmers and Stein 1992, Yako et al. 1996). Larvae and young < 30 mm total length feed primarily on crustacean zooplankton, then at total lengths ≥30 mm switch to an omnivorous diet (Yako et al. 1996, Gu et al. 1996).

It was thought that gizzard shad > 38 mm shifted to detritivory, but research indicated that *D. cepedianum* consume zooplankton as it becomes available and that detritivory is in fact facultative (Yako et al. 1996, Stein et al. 1995). Prey selection by gizzard shad is determined by size and mobility (Cramer and Marzolf 1970, Drenner et al. 1982).

The implications of the gizzard shad shifting its diet may have profound effects on community structure. Stein et al. (1995) suggest that neither top-down nor bottom-up trophic pressures control *D. cepedianum*, because as zooplankton resources decline, it adjusts by feeding on benthic-detrital ooze or phytoplankton.

Young gizzard shad grow rapidly and are able to avoid predation by the end of their first year (Stein et al. 1995, Dettmers and Stein 1992, Gu et al. 1996, Mundahl and Wissing 1987). Not only does this strategy reduce their vulnerability to young piscivores, but in addition, by spawning early gizzard shad greatly reduce zooplankton resources. This, in turn, increases competition between obligate zooplanktivores (including early life history of piscivorous species), negatively affecting their growth and recruitment (Dettmers and Stein 1992, Kutkuhn 1958, Stein et al. 1995, Cramer and Marzolf 1970).

Atlantic menhaden (*Brevoortia tyrannus*), a marine herring, is an important component of the fish community in the Hudson River. After spawning on the coast, young menhaden move into the Hudson River estuary and use it as a nursery. Typically, menhaden were found in southern brackish areas of the river; however, in recent years menhaden have been captured as far north as Albany (R. Schmidt, Simons Rock College, pers. comm.).

B. tyrannus and *D. cepedianum* both switch as juveniles from zooplankton to detritus feeding. As stated above, gizzard shad are facultative detritivores. Juvenile menhaden feed mostly on zooplankton, and as adults are herbivores and detritivores, but may still feed on zooplankton (Maryland Department of Natural Resources).

Stable isotope analysis (SIA) is a research tool that can provide information on element cycles in ecosystems, and serving as a means of tracing ecological processes. In most ecological studies, stable isotope composition is expressed in terms of δ (del) which are parts per thousand (‰) from the standard, ($R_{sample}/R_{standard}$ - 1) x 1000 (Peterson and Fry 1987, Limburg 1998). For this study $\delta^{13}C$ and $\delta^{15}N$ ratios were used. The ratios of carbon stable isotopes (^{13}C:^{12}C) elucidate the indirect sources of energy and matter. Nitrogen stable isotope ratios (^{15}N:^{14}N) reveal the relative position of organisms in the food web. The combined use of stable isotope analysis and a diet study provides more complete information on a species' food resource and trophic status, than does a diet study alone.

The difference in stomach content and muscle tissue are to be expected by a 3.5‰ shift towards the heavier isotope ^{15}N up the food chain because ^{14}N tends to be lost (Fry 1991). Nitrogen undergoes more fractionation than carbon (Fry 1991), due to its greater involvement in various metabolic processes (e.g., excretion). The percent composition of elemental (vs. isotopic) nitrogen and carbon for juvenile menhaden and gizzard shad may reflect differences in food quality.

In this project, I surveyed most of the extent (39km-238km) of the tidal Hudson to determine where gizzard shad and menhaden were found, and I compared their diets. By the method of SIA, I could examine trophic relationships among species and life stages, examine differences in stable isotope signals along the Hudson River, and relate my results to other research. Also in this project, Atlantic menhaden are compared to gizzard shad. Atlantic menhaden are a long-term component of the Hudson River fish fauna, whereas gizzard shad are recent invaders. Because of trophic similarities, I compared their diets and assimilation of C and N in order to assess the potential for competition.

METHODS

Twenty-one sites were sampled from May 2000-September 2000 along the tidal Hudson River, Figure 1. Three of the sampling locations were larval sampling sites and the rest were juvenile beach seine sites.

Larval Sampling

Larval sampling began in May 2000 and continued through July 2000 for a total of thirteen sampling events. A one meter, 500-micron mesh, 0.5-meter diameter plankton net was used to sample larval gizzard shad. Five major tributaries of the Hudson River were investigated: Esopus Meadows, Wappinger Creek, Fishkill Creek, Roundout Creek, and Moodna Creek. Esopus Meadows and Fishkill Creek were abandoned as sites due to the location of dams, which were too close to the Hudson River. Ten samplings were conducted between 9:00 and 18:00 hrs and 20:00 and 24:00 hrs. The procedure for sampling was as follows: depending on flow velocity, the plankton net was weighted with 5-10 pounds (window sash-weights), and lowered into the tributary from a bridge with the opening of the net facing into the current. The net was allowed to fish for 20-minute intervals. Duration of sampling was shorter when flow velocity was high. The samples were preserved in 70% ethanol and brought back to the laboratory for processing.

Precipitation during summer 2000 was high, which made sampling difficult and flushed many larval fish out of the tributaries into the Hudson River.

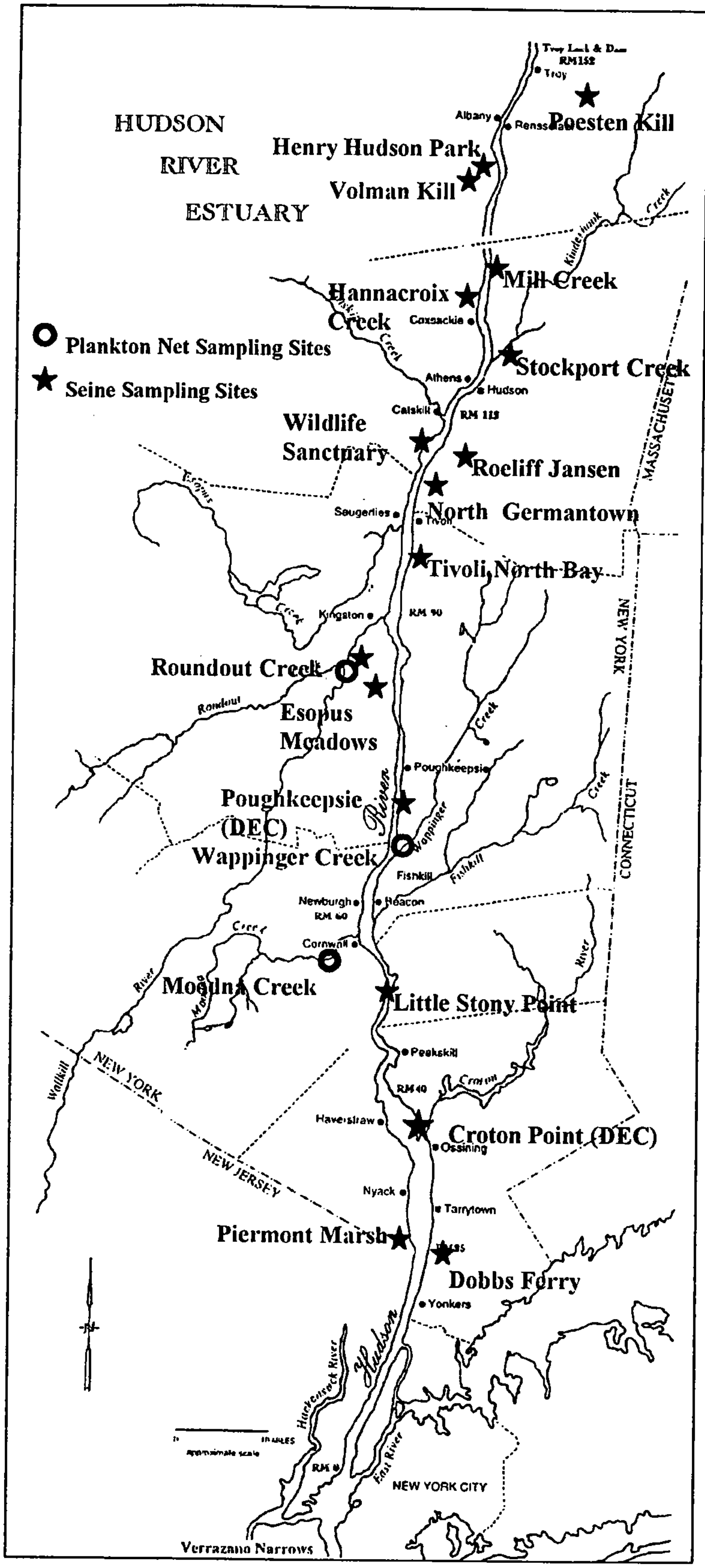


Figure 1. Map of plankton net and beach seine sampling sites in the tidal Hudson River and its tributaries from June-September 2000.

Juvenile Sampling

Juvenile sampling began July 2000 and continued through September 2000. Eighteen sites were sampled with a 6 meter, 5 mm mesh knotless seine with a 1.25x1.25x1.25 meter bag in the center. The technique of pulling the seine varied with terrain and space limitations; the seine was pulled parallel, in a J-curve, or perpendicular to the shore. All species captured were noted and subsequently released, except menhaden and gizzard shad (preserved in 70% ethanol or frozen).

Adult Collection

Normendeau Associates provided adult gizzard shad. Five adults were collected in the Mohawk River at Lock 6 between Cohoes and Vischers Ferry.

Diet Analysis

Juvenile menhaden and gizzard shad stomachs were dissected and their contents examined. Exterior (body shape and morphometrics) and interior (gut length and color of peritoneum) characteristics determined the species. Larvae of *D. cepedianum* were identified using the *Fishes of Delaware* key (Wang et al. 1979). Adult *D. cepedianum* stomach contents were not analyzed because of poor preservation. I measured, weighed, and analyzed stomach contents for all fish.

Stable Isotope Analysis

Larval and juvenile menhaden, and juvenile and adult gizzard shad, were analyzed for $\delta^{13}C$ and $\delta^{15}N$ stable isotopes. Larvae and juveniles were dried whole excluding the entire digestive tract (removed and dried separately). A 2.5cm^3 section of dorsal muscle tissue was removed from adult fish for analysis. Larval and juvenile samples were pooled. All samples were dried for 3-4 days at 60°C, and then placed in a dessicator. After cooling, samples were ground up into a powder, placed into vials, and sent for analysis to the Mass Spectrometry Lab at the University of Alaska at Fairbanks.

RESULTS

Geographical distribution of gizzard shad

The sites were divided into three reaches: upper, mid, and lower Hudson River. Sites varied in substrate type (sandy to rocky), aquatic vegetation (either *Trapa natans* or *Vallisneria americana)*, number of beach seine hauls, and whether they were located on the Hudson River proper or a tributary (Table 1). Many other species were captured Table 2 lists all the species.

Table 1. Date of sampling, location (kilometers from mouth), name of tributary or nearest city where sampled, substrate type and presence/absence of vegetation for beach seine sampling (July-September) in the tidal Hudson River and its tributaries.

Date sampled	Site Category	River KM	Location (# of sites)	Location Type	Substrate Type	Vegetation
08/16	Upper	238	Poesten Kill (2)	Tributary	Cobble	
08/16	Upper	218	Henry Hudson Park(3)	Beach	Rocky	
08/16	Upper	217	Volman Kill (1)	Tributary	Mud	
08/10	Upper	209	Hannacroix Creek (2)	Tributary	Rocky	
07/26,08/10	Upper	198	Mill Creek (3)	Tributary	Sandy	
09/21	Upper	185	Stockport Creek (4)	Tributary	Sandy	
09/21	Upper	180	Coxsackie (10)	Beach	Sandy/Rocky	X
08/10	Upper	177	Wildlife Sanctuary (1)	Tributary	Mud	
08/11	Upper	174	Roeliff Jansen (3)	Tributary	Rocky	X
07/21,07/26	Upper	172	North Germantown(10)	Beach	Sandy	X
07/21	Middle	158	Tivoli Bay (3)	Beach	Rocky	X
08/10	Middle	145	Roundout Creek (6)	Tributary	Sandy	
07/26	Middle	135	Esopus Meadows (4)	Beach	Rocky	X
08/08	Middle	111-121	Poughkeepsie (5)	Beach	Rocky/Sandy	
07/26	Middle	101	Little Stony Point (7)	Beach	Sandy/Rocky	
08/22	Lower	64-58	Croton Point (10)	Beach	Sandy/Rocky	X
07/19	Lower	40	Piermont Marsh (4)	Beach	Mud/Rocky	
07/26	Lower	39	Dobbs Ferry (4)	Beach	Sandy	

Table 2. Non-target species captured in beach seine samples (July-September) in the tidal Hudson River and its tributaries. The Hudson R. is divided into three sections (upper (170-245km), mid (100-169km), and lower (0-99km)) kilometers from mouth.

Common Name	Latin Name	Upper	Mid	Lower
American eel	*Anguilla rostrata*	X	X	X
American shad	*Alosa sapidissima*	X	X	X
Atlantic menhaden	*Brevoortia tyrannus*	X	X	X
Atlantic needlefish	*Strongylura marina*		X	X
Banded killifish	*Fundulus diaphanus*	X	X	
Blueback herring	*Alosa aestivalis*	X	X	X
Blue crab	*Callinectes sapidus*	X	X	X
Bluegill sunfish	*Lepomis macrochirus*	X	X	
Bullhead	*Ictalurus nebulosus*	X		
Carp	*Cyprinus carpio*		X	X
Crevalle jack	*Caranx hippos*			X
Fluke	*Paralichthys dentatus*			X
Goby (sp.)	*Gobiosoma sp.*			X
Hogchoker	*Trinectes maculatus*			X
Largemouth bass	*Micropterus salmoides*	X	X	
Pumpkinseed sunfish	*Lepomis gibbosus*		X	
Redbreast sunfish	*Lepomis auritus*		X	
Silverside	*Menidia sp.*		X	X
Smallmouth bass	*Micropterus dolomieui*		X	
Spottail shiner	*Notropis hudsonius*	X	X	X
Striped bass	*Morone saxatilis*	X	X	X
Tessellated darter	*Etheostoma olmstedi*	X	X	X
White perch	*Morone americana*	X	X	X
White sucker	*Catostomus commersoni*	X	X	
Yellow perch	*Perca flavescens*		X	

Larval *D. cepedianum* were captured at three locations (Table 3), and mostly at night. Juvenile gizzard shad were not captured on any of my sampling expeditions. In late August, a crew from the Region 3 (New Paltz) Office of New York Department of Environmental Conservation (New Paltz DEC) caught ten juvenile gizzard shad (Table 4). These locations had similar habitat as the sites I sampled before and after the DEC sampled (Table 1). Most of the gizzard shad were caught near Newburgh. Young-of-year *B. tyrannus* were caught in great abundance at three locations, Piermont Marsh (40km), Peekskill/Croton Point area (64km-58km) and North Germantown (172km).

Table 3. Date of capture, tributary name, kilometers from mouth and number of larval gizzard shad captured during plankton net sampling (June-July). * denotes night sampling.

Date	Location	River Kilometer	Number of Larval Gizzard shad caught
6/21/00	Roundout Creek	145	3
7/12/00*	Wappinger Creek	108	5
7/12/00*	Moodna Creek	93	1

Table 4. Date of capture, location of nearest city, kilometers from mouth and number of juvenile gizzard shad captured by New Paltz Department of Environmental Conservation crew in the tidal Hudson River.

Date	Location	River Kilometer	Number of Juveniles
9/20/00	Albany	223	2
9/19/00	Poughkeepsie	111	1
8/24/00	Newburgh	95	5
9/18/00	Newburgh	90	2

Diet Analysis

All nine larval gizzard shad stomachs were empty. Juvenile *D. cepedianum*, provided by New Paltz DEC, stomachs contained fine dark brown detritus, some visible plant material, but no traces of animal material. Adult gizzard shad stomach contents were unidentifiable. Juvenile *B. tyrannus* (n=50) stomach contents primarily contained fine dark brown detritus. Eleven individuals from Piermont and the Peekskill/Croton Point area contained a small unidentified organism. Table 5 summarizes diet analysis.

Table 5. Species, stage, sample size, and stomach contents for diet analysis.

Species	Stage	Sample size	Stomach contents
D. cepedianum	Larval	9	empty
D. cepedianum	Juvenile	10	detritus w/ plant material
D. cepedianum	Adult	1	unidentifiable
B. tyrannus	Juvenile	50	detritus (n=11 w/ small organism)

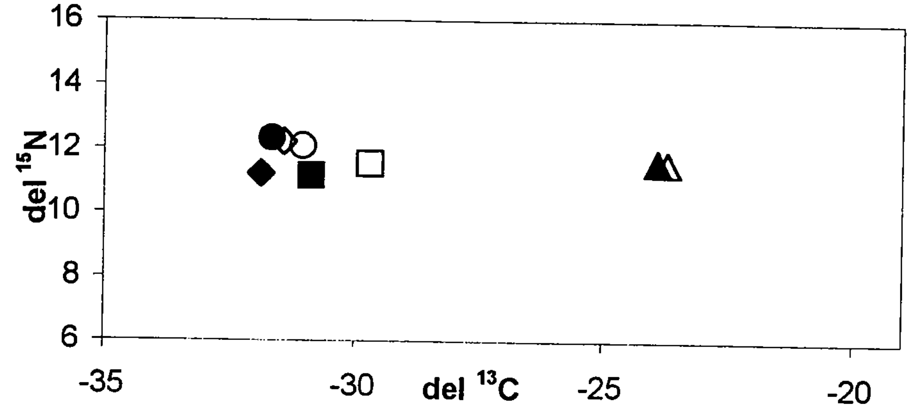
Stable Isotope Analysis

Larval, juvenile, and adult *D. cepedianum* and juvenile *B. tyrannus* fish muscle tissue and stomach contents were analyzed for $\delta^{13}C$ and $\delta^{15}N$ stable isotope ratios. Table 6 lists date sampled, species, stage, locations, average length (mm), and the number of fish pooled per sample. Carbon and nitrogen stable isotope ratios were used to determine if gizzard shad and menhaden somatic tissues are similar to what was present in their stomachs. The $\delta^{13}C$ and $\delta^{15}N$ ratio data for juvenile gizzard shad somatic tissue and stomach contents were close, indicating that assimilation reflects material observed in the guts (Figure 2). In Figure 2, the designations "Newburgh24" and "Newburgh18" indicate two different sampling dates and size classes. Newburgh24 gizzard shad were sampled on 24 August 2000 and the mean total length of 68.2mm. Newburgh18 gizzard shad were sampled on 18 September 2000 and the mean total length was 112.5 mm.

Table 6. Date of capture, species, stage, kilometers from mouth, name of tributary of closest city to sampling location, average total length and number of fish pooled that were analyzed for C and N stable isotopic ratios. #Five adult samples were analyzed separately.

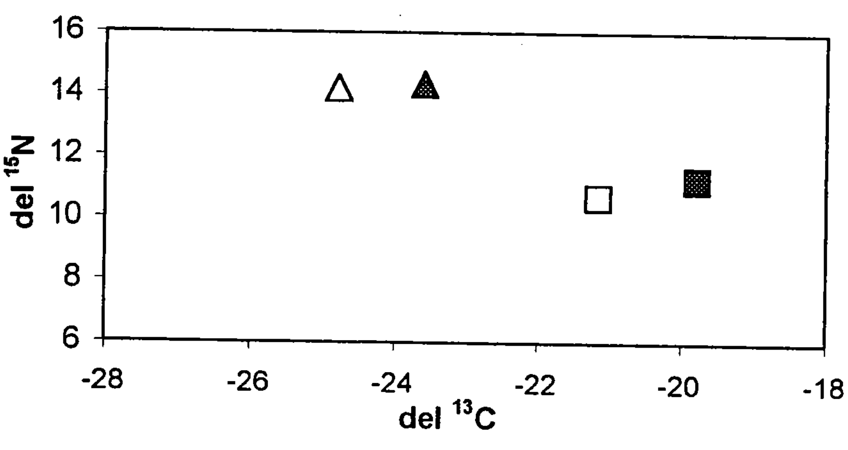
Date sampled	Species	Stage	River Km	Location(s)	Number Pooled	Average Total Length (mm)
06/21 07/12 07/12	*Dorosoma cepedianum*	Larvae	145 108 93	Roundout Creek Wappinger Creek Moodna Creek	9	4.99
09/20	*Dorosoma cepedianum*	Juvenile	224	Albany	3	67
09/19	*Dorosoma cepedianum*	Juvenile	111	Poughkeepsie	1	71
08/24	*Dorosoma cepedianum*	Juvenile	95	Newburg 8/24	5	68.2
09/18	*Dorosoma cepedianum*	Juvenile	90	Newburg 9/18	2	112.5
06/01	*Dorosoma cepedianum*	Adult	227	Albany	1#	385.8
07/26	*Brevoortia tyrannus*	Juvenile	172	North Germantown	10	53
07/19	*Brevoortia tyrannus*	Juvenile	40	Piermont Marsh	10	47.9

Figure 2. Stable isotope ratios plotted $\delta^{13}C$ versus $\delta^{15}N$ (‰) for juvenile gizzard shad muscle tissue (solid symbols) and stomach tissue (open symbols). Symbols represent the different locations where juvenile gizzard were captured: Albany (diamonds), Newburgh18 (triangles, 18 denotes date 09/18 of capture), Newburgh24 (circles, 24 denotes date 08/24 of capture), and Poughkeepsie (squares).



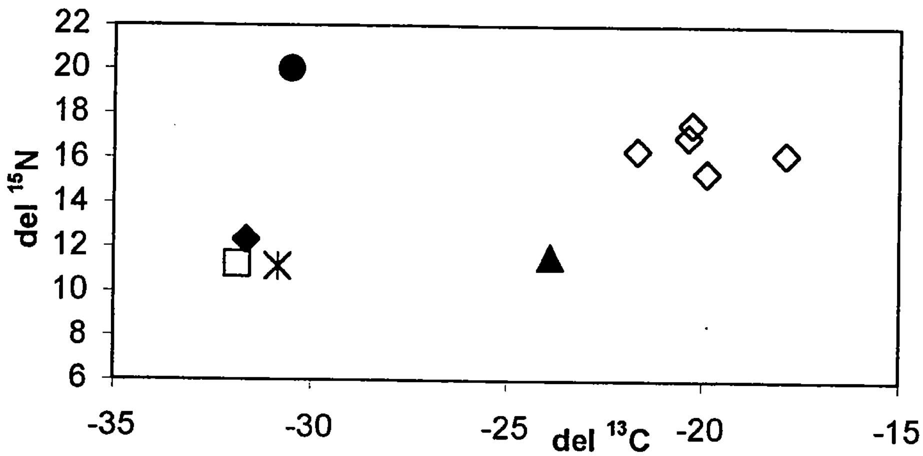
A close correspondence was observed between Atlantic menhaden muscle tissue and stomach contents (Figure 3). $\delta^{13}C$ ratios are depleted in ^{13}C in the northern site (Germantown) compared to Piermont, reflecting the freshwater signal (Limburg 1998). Conversely, $\delta^{15}N$ ratios are enriched in ^{15}N (the heavier isotope) at Germantown, agreeing with observations of Limburg (1998) and Caraco et al. (1998).

Figure 3. Stable isotope ratios plotted $\delta^{13}C$ versus $\delta^{15}N$ (‰) for juvenile Atlantic menhaden muscle tissue (solid symbols) and stomach tissue (open symbols). Symbols represent the different locations where juvenile menhaden were captured: Piermont marsh (squares) and North Germantown boat launch (triangles).



The $\delta^{13}C$ and $\delta^{15}N$ isotopic ratios revealed differences between juveniles, adults and larvae, providing evidence that juveniles feed on alternative parts of the food web compared with larvae and adults. Gizzard shad juveniles collected at Newburgh on 18 September ("Newburgh18") have an average total length greater than other juveniles (Table 3). These fish are also ^{13}C enriched. Although there is a distinct separation between all life stages (Figure 4), this study did not control for geographic location. Most notably, the adults were collected from the Mohawk River where $\delta^{15}N$ and $\delta^{13}C$ appear to be different than in the Hudson, when identical fish species and life stages are compared (K. Limburg, SUNY-ESF, pers. comm.). Larvae are more enriched in $\delta^{15}N$ and depleted in $\delta^{13}C$ compared to juveniles and Mohawk River adults.

Figure 4. Stable isotope ratios plotted $\delta^{13}C$ versus $\delta^{15}N$ (‰) for adult (open diamonds), juvenile and larvae (solid circle) gizzard shad. Other symbols represent juvenile gizzard shad captured at different locations in the tidal Hudson R.: Albany (open square), Newburgh18 (solid triangle, 18 denotes date 09/18 of capture), Newburgh24 (solid diamond, 24 denotes date 08/24 of capture), and Poughkeepsie (star).

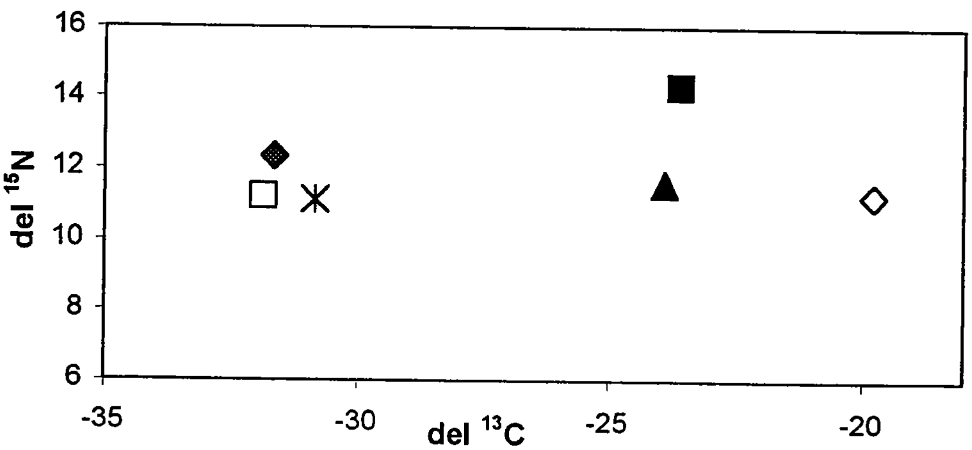


From visual inspection Atlantic menhaden and gizzard shad contained similar detrital material in their stomachs, but their $\delta^{13}C$ and $\delta^{15}N$ ratios differ considerably, excluding the Newburgh18 data point, which groups together with the menhaden data

(Figure 5). Piermont menhaden are more enriched in ^{13}C isotope (reflecting the salinity gradient), but the nitrogen isotopic ratios for both species are closer, ranging from 11.13‰ to 14.3‰.

The $\delta^{13}C$ data reveals significant differences in food composition for yoy gizzard shad and yoy menhaden (excluding "Newburgh 18" yoy gizzard shad) (ANOVA, $p<0.01$). In addition to differences due to the weak salinity gradient, the $\delta^{13}C$ may be due to different origins of the detritus, for example, the detritus gizzard shad feed upon may be derived from phytoplankton and/or terrestrial material, whereas the detritus Atlantic menhaden feed upon may be derived from submerged aquatic vegetation and associated epiphytes.

Figure 5. Stable isotope ratios plotted $\delta^{13}C$ versus $\delta^{15}N$ (‰) for juvenile gizzard shad and Atlantic menhaden. Symbols represent different locations within the tidal Hudson R and different species. Atlantic menhaden: Piermont Marsh (open triangle) and North Germantown boat launch (solid square). Gizzard shad: Albany (open square). Newburgh18 (solid triangle. 18 denotes date 09/18 of capture). Newburgh24 (solid diamond. 24 denotes date 08/24 of capture). and Poughkeepsie (star).



Differences of carbon and nitrogen composition between all stages and species considered may also be illustrated through percent composition comparisons. The differences of percent carbon concentrations show that adult gizzard shad contain more