Diet and Population Metrics of the Introduced Blue Catfish on the Altamaha River, Georgia

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Abstract: Blue catfish (*Ictalurus furcatus*) were first detected in the Altamaha River, Georgia, during an access creel survey in 2005 and subsequently in 2006 during annual ictalurid sampling. Introduction of this species in the Altamaha River is believed to have occurred via escape from normal upstream reservoir releases from Lake Sinclair and Lake Oconee. Relative abundance, as indexed by electrofishing catch rate (fish per hour), has increased from 2.9 ± 1.0 SE in 2006 to 38.8 ± 8.2 SE in 2011. The size of blue catfish captured ranged from 56 to 820 mm total length and 0.001 to 7.7 kg. Using otoliths obtained in 2010 ($n = 214$), age of fish ranged from 0 to 6 yrs, which indicated a relatively young population. The catch-curve analysis resulted in an instantaneous mortality rate (Z) of 0.75. Despite concerns of blue catfish predation on native fishes and mussels, a diet analysis of blue catfish ($n = 257$) obtained in 2010 revealed that diets of fish in all size groups were dominated by the introduced Asiatic clam (*Corbicula fluminea*). This study describes a recently introduced blue catfish population in an Atlantic coastal plain river and provides insight on possible ecological effects during the early phases of establishment. These results offer an early status assessment of the invasion dynamics before the system has had time to reach a new equilibrium state.

Key words: age, diet, growth, mortality, relative abundance

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The blue catfish (*Ictalurus furcatus*) is considered the largest ictalurid catfish in North America (Graham 1999). As a result of their growth potential, angling for these catfish has become popular (Graham 1999). The most recent angling world record, exceeded 64.9 kg (J. Vitek, International Game Fish Association, personal communication) and was taken from John H. Kerr-Buggs Island Lake, Virginia, in June 2011. Non-indigenous occurrences of this species are common and have resulted from intentional stocking of waterbodies for food and/or sport (Guier et al. 1984) as well as unintentional flooding of private waterbodies (Metee et al. 1996). Currently, blue catfish are found in 29 states with populations established in the Mississippi River Basin, as well as the Atlantic, Pacific, and Gulf coastal slope drainages (Graham 1999).

Georgia's only native population of blue catfish is found in the Coosa River located in the northeastern corner of the state (Glodeck 1980), but they have also been found in Lake Sinclair (Georgia Department of Natural Resources, GADNR), Lake Oconee (Homer and Jennings 2011), and the Chattahoochee (Dahlberg and Scott 1971), Flint (GADNR), Satilla (GADNR) and Savannah rivers (GADNR). Blue catfish were first detected in the Altamaha River, Georgia, during creel surveys in 2005 and subsequently in 2006 in annual standardized ictalurid sampling (GADNR unpublished data). Introduction of this species in the Altamaha River is believed to have occurred via escape from normal releases from upstream reservoirs; blue catfish were first detected in gillnet surveys on Lake Sinclair in 1996 and Lake Oconee in 1997 (Homer and Jennings 2011). The source of these populations is unknown, but illegal stockings by the public are suspected (Chris Martin, GADNR personal communication).

Biologists are beginning to witness the potential effects of blue catfish introductions across the Atlantic slope drainages. For instance, range expansion and population increases of blue catfish in the Chesapeake Bay watershed directly coincided with concurrent declines in the abundance of native white catfish (*Ictalurus catus*) (Schloesser et al. 2011). The potential of introduced blue catfish populations to reduce native fish abundances in the Altamaha River is unknown. However, flathead catfish (*Pylodictis olivaris*), have been established in this system since the late 1980s (Kaeser et al. 2011), resulting in declines of native bullhead (*Ameiurus* spp,) and sunfish (*Lepomis* spp.) species (Thomas 1993). Furthermore, there is concern that flathead catfish predation may be having adverse effects on anadromous fish restoration programs (Guier et al. 1984, Brown et al. 2005, Pine et al. 2005, Flowers et al. 2011). Homer and Jennings (2011) suggested that the introduction of blue catfish and flathead catfish into Lake Oconee could have led to declines in the native catfishes because of predation or competition for resources.

Introduced blue catfish may also have a negative effect on the rare Altamaha spiny mussel (*Elliptio spinosa*) as well as other mussels in the system. Blue catfish are opportunistic, omnivorous feeders (Graham 1999) that can be highly piscivorous but also frequently eat fishes, invertebrates, crayfishes, clams, snails, and mussels (Brown and Dendy 1961, Perry 1969, Graham 1999). A recent feeding ecology study by Eggleton and Schramm (2004) concluded that introduced zebra mussels (*Dreissena polymorpha*) were important diet components of blue catfish in the lower Mississippi River. Similarly, introduced blue catfish consumed exotic Asiatic clam (*Corbicula fluminea*) in California reservoirs (Richardson et al. 1970, Dill and Cordone 1997) and in the Cape Fear River in North Carolina (Fuller et al. 1999). Jolley and Irwin (2003) found blue catfish <500 mm TL in the tailwaters of the Coosa River, Alabama, favored mollusks.

Age, growth, and mortality information for introduced blue catfish populations in Georgia rivers do not exist, but Homer and Jennings (2011) reported age and growth data for an introduced blue catfish population on Lake Oconee, Georgia. This population, which was sampled with gillnets in 2008 and 2009, had a mean total length (TL) of 330 mm and a mean weight of 468 g; ages ranged from 0 to 8 years, and the largest fish recovered in the study was 740 mm TL and 5.1 kg (Homer and Jennings 2011). Sex-specific growth information was not reported, but other studies have found this species to exhibit sexually dimorphic growth, with male blue catfish growing faster than females (Holley 2006). Recently, Greenlee and Lim (2011), measured growth of four introduced blue catfish populations in Virginia tidal rivers and found that mean total length at age-10 varied considerably from 416 mm TL in the Rappahannock River to 675 mm TL in the James River.

Our objectives were to describe the population dynamics and diet composition of introduced blue catfish in the Altamaha River. Specifically, we wanted to 1) use annual ictalurid electrofishing survey data for the Altamaha River to evaluate trends in the relative abundances of catfish species, 2) quantify basic population parameters including age, abundance, size structure, condition, growth, and mortality information of blue catfish in this system, and 3) describe the diet of the blue catfish population.

Methods

Study Area

The Altamaha River is the largest Atlantic slope drainage in Georgia and originates at the convergence of the Ocmulgee and Oconee rivers in southeastern Georgia (Figure 1). The watershed comprises roughly 35,224 km^2 (Sammons and Maceina 2009), and is composed of hardwood forests, cypress swamps, planted slash pine monocultures, and agricultural land which give the river a muddy, sediment-like appearance (Sehlinger and Otey 1980). The river flows generally southeast across the coastal plain for 221 km before emptying into the Atlantic Ocean near Darien, Georgia.

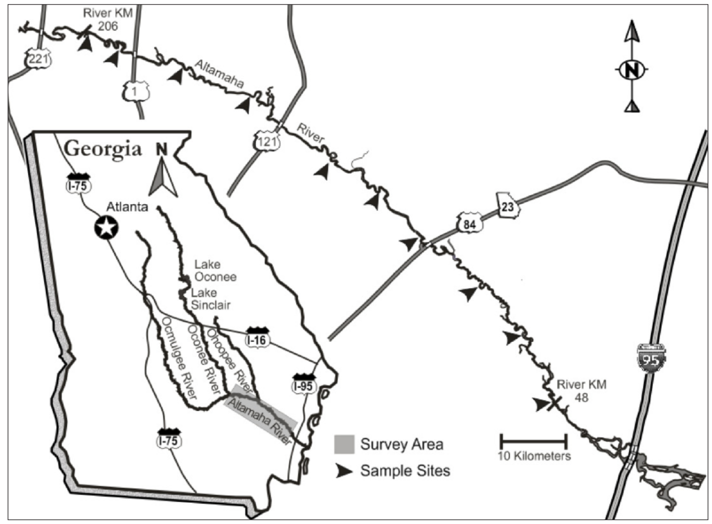

Figure 1. Locations of standardized sampling sites on the Altamaha River, Georgia, that were sampled for all ictalurids during the period 2006–2011.

Historical discharge at Doctortown, Georgia, has ranged from 40 to 8,495 m^3/sec, with a mean annual discharge of approximately 383 m^3/sec (USGS 2011; water data gauge No. 02226000), located near Highway 84 (Figure 1). Besides blue catfish, catfish present in the Altamaha River include brown bullhead (*Ameirus nebulosus*), channel catfish (*I. punctatus*), flathead catfish, white catfish, and yellow bullhead (A. nebulosus). Common species other than catfish found in the river include American shad (*Alosa sapidissima*), hickory shad (*A. mediocris*), gizzard shad (*Dorosoma cepedianum*), threadfin shad (*D. petenense*), American eel (*Anguilla rostrata*), spotted sucker (*Minytrema melanops*), striped mullet (*Mugil cephalus*), black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmodies*), longear sunfish (*L. megalotis*), redbreast sunfish (*L. Auritus*), redear sunfish (*L. microlophus*), and warmouth (*L. gulosus*).

Fish Collection and Population Metric Analyses

Boatmounted, low-frequency (18 Hz), pulsedDC electrofishing equipment was used to sample catfishes at 10 fixed sampling stations annually in July from 2006–2011 (Bonvechio et al. 2011; Figure 1). Average widths of the river at the 10 sampling sites were between 137 and 156 m and flows were typically low. Each station was sampled in a downstream direction where the deep, riveted, undercut bank was targeted for 1 hour, and a chase boat was used to increase sampling efficiency (Daugherty and Sutton 2005). All catfish were collected at each station; however, for the purposes of this study only blue catfish were used for analyses.

Relative abundance estimates (mean number of fish per hour) of blue catfish were obtained each year from 2006 to 2011. Because of low water, the station located 4 km upstream from highway 121 was eliminated in 2011 (Figure 1). Catch rates were log-transformed to stabilize variances and mean catch rates were compared among years using a mixed-model ANOVA (SAS Institute 2000). The sampling station was considered a fixed variable in the mixed model. Means were separated among years using the LSMEANS procedure (SAS Institute 2000). A Kendall tau correlation analysis was also conducted to determine if a significant trend in mean catch rate was observed during the study period.

To quantify size structure, all blue catfish were measured to the nearest mm total length (TL) and weighed to the nearest g. In July 2010, almost all blue catfish collected were sacrificed for age and growth analysis. After recording length and weight measurements, fish were placed on ice in the field and transported to the laboratory where lapilla otoliths were extracted (Long and Stewart 2010). Similar to Nash and Irwin (1999), otoliths were set in crystal bond and a grinding procedure described by Maceina (1988) was used to prepare the otoliths for reading. Two independent readers estimated the age of each fish by counting annuli on the otoliths (Nash and Irwin 1999, Sakaris et al. 2006, Long and Stewart 2010). Any disagreement in age between readers was resolved by a third reader following the methods of (Bonvechio and Bonvechio 2006). Ultimately, 214 of 257 fish were aged. The other fish were not aged because of otolith loss during extraction ($n = 23$), poor clarity or otherwise unreadable ($n = 18$), and reader disagreement ($n = 2$).

The instantaneous (Z) and total (A) rates of annual mortality were estimated using weighted catch-curves (Ricker 1975, Slipke and Maceina 2000). An age-length key was used to assign ages to unaged fish (Ricker 1975). Based on the age-frequency, blue catfish were assumed to recruit to the gear at age 1, and catch-curve analysis was conducted using age 1 and older fish (SAS Institute 2000). Genders were combined for estimating mortality.

Diet Determination and Analysis

During otolith removal, stomachs were excised from blue catfish, and contents were removed and identified to the lowest possible taxon. Fish were grouped into three length groups (≤ 300 mm TL, 301–599 mm TL, and ≥ 600 mm TL), and diet data were summarized by length group, as well as across all length groups. Diets were described by frequency of prey occurrence in the diet (O_i), proportion of prey in diet by number (N_i) and by weight (W_i) for each group. Diet composition was described using the Relative Importance (RI) index, which is designed to reduce biases associated with using a single measure of diet (Chipps and Garvey (2007).

Results

Electrofishing catch rates (fish per hour) of blue catfish increased throughout the study period, from 2.9 ± 1.0 SE in 2006 to 38.8 ± 8.2 SE in 2011 ($r = 0.733$; $P = 0.039$; Figure 2). Similarly, mean catch rates were lowest in 2006, 2007 and 2008, intermediate in 2009, and highest in 2010 and 2011 ($F = 52.03$, df = 5, 43, $P < 0.0001$).

Between-reader agreement for aged blue catfish was 97.6%, and of the five disagreements, all but two were resolved by a third independent reader. Blue catfish ages ranged from 0 to 6 years. The catch-curve analysis for ages 1 to 6 resulted in an instantaneous mortality rate (Z) of 0.75, which conferred a total annual mortality rate (A) of 47% ($P = 0.021$, $r^2 = 0.77$). Mean TL mm, estimated from the age-length key for ages 1 to 6 was 210 ± 2.5 SE ($n = 128$), 307 ± 8.8 SE ($n = 41$), 421 ± 12.6 SE ($n = 47$), 521 ± 12.4 SE ($n = 34$), 472 ± 26.8 SE ($n = 3$), and 610 ± 37.8 SE ($n = 8$), respectively. The length-frequency distribution over the period 2006–2011 indicated that the size structure of blue catfish is skewed towards smaller fish, but larger fish (> 600 mm TL) were more commonly collected as the population aged (Figure 3).

Diet Composition

A total of 257 blue catfish stomachs from the Altamaha River were examined, and 193 (75.1%) of these fish contained food items. Asiatic clam was the dominant diet item in blue catfish, regardless of size class, with RI values ranging from 77 to 99 (Table 1). Diets of blue catfish <600 mm were especially dominated by Asiatic clams; however, diets of larger blue catfish were somewhat more varied with American eel and the "other" category (composed of organic material, sunflower seeds, and corn) being second and third, respectively, in RI values for that size fish. However, the overall sample size of that size class was small ($n = 9$).

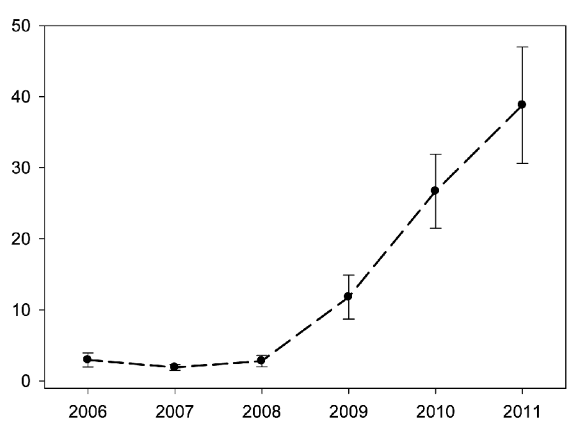

Figure 2. Electrofishing catch-per-effort (CPE) of blue catfish collected from the Altamaha River, Georgia, from 2006 to 2011. Points are mean CPE and error bars are +1 standard error.

Table 1. Stomach contents of three length groups of blue catfish from the Altamaha River in July 2010. Diet categories were: Asiatic clams, Chironomidae (larvae only), Coryalidae (larvae only), Odonata (larvae only), Orthoptera (larvae only), freshwater mussels (native, family Unionidae), freshwater prawn (introduced, family Palaemonidae) unidentified insects (unid. insects), *Alosa* spp. (river herrings), American eel, catfishes (family Ictaluridae), unidentified fishes (unid. Teleostei), and other (e.g., corn, seeds, organic material). N_i=% Proportion by number, W_i= % Proportion by weight, O_i= Frequency of Occurrence, RI_i = Relative Importance Index. n/a = index could not be calculated due to low values.

	n = 257 *24.9% empty* All size classes				*n* = 147 *26.5% empty* <300				*n* = 101 *24.8% empty* 301–599				*n* = 9 11.1% empty >600			
Categories	N_i	W_i	O_i	RI_i	N_i	W_i	O_i	RI_i	N_i	W_i	O_i	RI_i	N_i	W_i	O_i	RI_i
Invertebrates																
Asiatic clam	64.6	87.9	54.7	99.0	57.8	95.1	45.4	98.8	75.2	94.5	68.4	99.1	55.6	63.1	50	77.4
Chironomidae	12.5	<0.1	17.2	n/a	20.4	<0.1	26.9	n/a	2.0	0.1	5.3	0.1	0.0	<0.1	0	n/a
Coryalidae	3.1	<0.1	4.2	n/a	2.0	<0.1	2.8	n/a	5.0	<0.1	6.6	n/a	0.0	<0.1	0	n/a
Odonata	0.4	<0.1	0.5	n/a	0.7	0.3	0.9	<0.1	0.0	<0.1	0.0	n/a	0.0	<0.1	0	n/a
Orthoptera	1.6	<0.1	2.6	n/a	2.7	0.6	4.6	0.2	0.0	<0.1	0.0	n/a	0.0	<0.1	0	n/a
Freshwater mussel	0.4	0.04	0.5	<0.1	0.0	0.0	0.0	<0.1	1.0	0.1	1.3	<0.1	0.0	0.0	0	0.0
Freshwater prawn	3.5	1.0	4.7	0.3	2.0	1.0	2.8	0.1	5.0	1.3	6.6	0.4	11.1	0.0	12.5	1.8
Unid. insects	1.9	<0.1	2.6	n/a	2.7	<0.1	3.7	n/a	1.0	<0.1	1.3	n/a	0.0	<0.1	0	n/a
Fishes																
Alosa spp.	0.4	0.0	0.5	<0.1	0.7	0.3	0.9	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0	0.0
American eel	0.8	7.6	1.0	0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	<0.1	22.2	35.3	25	18.7
Catfishes	2.3	0.7	3.1	0.1	2.0	0.3	2.8	0.1	3.0	1.0	3.9	0.1	0.0	0.0	0	0.0
Unid. Teleostei	5.1	0.5	3.1	0.2	5.4	1.7	4.6	0.5	4.0	0.3	1.3	<0.1	0.0	0.0	0	0.0
Other																
Other	3.5	1.8	5.2	0.3	3.4	0.7	4.6	0.3	4.0	1.7	5.3	0.3	11.1	1.6	12.5	2.1

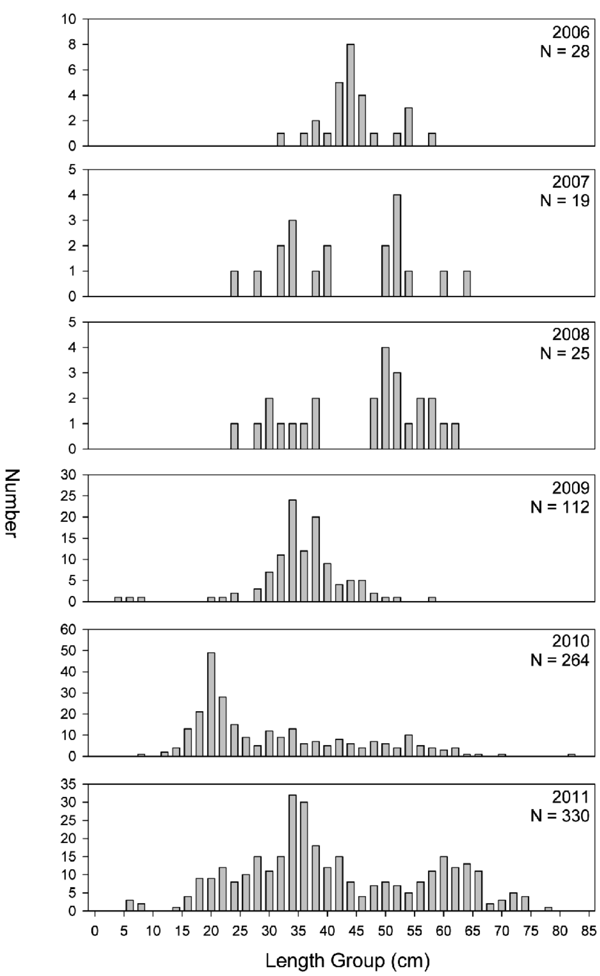

Figure 3. Length-frequency distributions (2-cm length groups) of blue catfish collected in the Altamaha River, Georgia, from 2006 to 2011. Notice the varying scales on the Y-axes.

Discussion

Introduced flathead catfish populations in Georgia rivers tend to display rapid growth rates (Sakaris et al. 2006, Bonvechio et al. 2011, Kaeser et al. 2011) and prey heavily on native fish species (Weller and Robbins 1999). Piscivory by this species has led to notable declines in native centrarchid panfish (e.g., redbreast sunfish) and ictalurid (e.g., bullhead) species in some Georgia rivers (Thomas 1993, Bonvechio et al. 2009). Recently, Homer and Jennings (2011) documented rapid shifts in the gillnet catch of white catfish to blue catfish in Lake Oconee, Georgia. They suggested predation or competition by the introduced blue catfish and flathead catfish in Lake Oconee may have led to declines in the native catfishes such as the white catfish. There is also evidence that blue catfish may have displaced native white catfish and snail bullheads (*Ameiurus brunneus*) in Lake Norman, North Carolina (Grist 2002). Similar declines have been noted with white catfish in Virginia rivers after blue catfish introduction (Schloesser et al 2011). However, data collected thus far do not indicate that native catfish abundance is declining in the Altamaha River (T. Bonvechio, unpublished data) although expansion of the blue catfish population is likely still ongoing, and ecological effects may be more evident in the future.

There are many factors that could be influencing increasing blue catfish catch rates in the Altamaha River, including fish behavior, fish size, fish species, population density, sampling crew efficiency, water clarity, water conductivity, water level, water temperature, and weather conditions (Hardin and Connor 1992, Reynolds 1996, Bodine and Shoup 2010). We attempted to eliminate many of these factors of variation in our sampling by standardizing methods, specifically the seasonal differences in capture efficiency (Buckmeier and Schlechte 2009), by sampling during the same time of year. Catch rate increases could also be attributed to increased efficiency of the same electrofishing crews through experience on the river and learning what constitutes good blue catfish habitat within the fixed transects during the course of this data series (Hardin and Connor 1992). Spatial segregation with regard to habitat preference among blue catfish can influence relative abundance and size structure evaluations (Bodine and Shoup 2010, Bodine et al. 2011). Although habitat preference was not directly measured in this study, the authors observed blue catfish displaying a high affinity for large woody debris associated with the outside bends of the river in deeper water (< 3m).

Our study found few age classes of blue catfish present in the Altamaha River; this result is similar to those of Homer and Jennings (2011) for Lake Oconee, Georgia (ages 0 to 6 in our study vs ages 0 to 8 in their study). Also, length-frequency distributions were similar between the studies, with a relatively small maximum size being found in samples from both studies (820 mm TL vs 740 mm TL). These data suggest that the blue catfish population in the Altamaha River is relatively young and healthy, with similar population characteristics as observed for the upriver population in Lake Oconee (Homer and Jennings 2011).

Age and growth analysis revealed that the introduced blue catfish population in the Altamaha River has rapid growth rates that far exceed native populations. For example, blue catfish in the Altamaha River can exceed 720 mm TL in six years (e.g., one individual 820 mm TL and 7.7 kg), which is much quicker than has been reported for other populations. Ten years are required for a blue catfish to reach 675 mm TL in the James River, Virginia (Greenlee and Lim 2011). Blue catfish reached approximately 760 mm TL in 10 years on Lake Wilson, Alabama (Holley et al. 2009), and 12 years in Lake Texoma, Oklahoma (Mauck and Boxrucker 2004). Although sample sizes of large fish from the Altamaha River were low, this young blue catfish population has demonstrated fast growth.

Our mortality estimates may be slightly biased because older fish were not encountered in our samples; as a result, our estimate ($Z = 0.75$) is probably a fairly representative rate for a population without fish older than age 6. Thus, published estimates of instantaneous rate of annual mortality (Z) for older populations of this long-lived catfish are much lower than those found in this study. Holley et al. (2009) constructed two mortality curves: one for fish from ages 4 to 10 and one for ages 10 to 25, because survival was estimated to be higher in older fish ($Z = 0.218$) than younger fish ($Z = 0.495$). They further speculated that differential mortality was occurring with size and age. This may be a consideration in the future for blue catfish on the Altamaha River, as the population reaches equilibrium and fish attain older ages.

Published blue catfish age and growth studies based on otoliths are rare (Greenlee and Lim 2011). Recently, Greenlee and Lim (2011) found that Z ranged from 0.208 to 0.323 for four introduced blue catfish populations in Virginia tidal rivers. Boxrucker and Kuklinski (2006) reported that mean Z for seven Oklahoma blue catfish reservoir populations was 0.315. Although the estimate of mortality on the introduced blue catfish population in the Altamaha River was higher than what was found in those studies, it is similar to the rate of mortality found for the introduced flathead catfish population in the Satilla River, Georgia ($Z = 0.74$; Bonvechio et al 2011). However, lower mortality estimates have been reported for introduced flathead catfish populations in Georgia rivers, with estimates of Z ranging from 0.20 to 0.60 (Sakaris et al. 2006, Kaeser et al. 2011). Also, Kwak et al. (2006) reported low mortality rates ($Z = 0.170$ to 0.221) for three North Carolina introduced flathead catfish populations.

Blue catfish food habits examined in this study were similar to what has been reported in the literature for this species. Regardless of size class or diet measure used, the most dominant prey item in this study was introduced Asiatic clam. Furthermore, another important prey item found in the diet was the freshwater prawn (*Macrobrachium rosenbergii*), which has also been introduced into the Altamaha River. Thus the introduced blue catfish in the Altamaha River preyed heavily on other non-native, invertebrates or mussels. These results are similar to what has been found in other studies of introduced blue catfish (Richardson et al. 1970, Dill and Cordone 1997, Fuller et al. 1999).

Blue catfish are a successful invader that has established a foothold in the Altamaha River and continues to expand. Data from this study suggests that blue catfish are primarily feeding on introduced species such as the Asiatic clam instead of species of conservation concern like the rare Altamaha Spiny mussel. Thus, the potential for blue catfish to adversely affect management and restoration of anadromous species such as the American shad and other sensitive and rare species appears to be low. However, these results are merely a snapshot of early invasion dynamics in a system that has not yet reached a new equilibrium (Homer and Jennings 2011). Loftus and Kushlan (1987) reported a common phenomenon among introduced species, where an explosive population increase is witnessed followed by a rapid decrease as the population reaches equilibrium in its new environment. Generally, information on the the trophic interacations and food web dynamics caused by the introduction of blue and flathead catfish on Atlantic slope systems is lacking; as a result, many questions remain unanswered (Greenlee and Lim 2011). Thus, further efforts to assess the effects of blue catfish on the ecology of the Altamaha River system would benefit from continued monitoring of the growth, dietary patterns, and population demographics to ensure that restoration efforts for other species remain unaffected by this invader.

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