Population Changes of Sportfish Following Flathead Catfish Introduction in the Satilla River, Georgia

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Abstract: A standardized sampling dataset collected from 1991–2007 on the Satilla River, Georgia, was used to document changes in bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and redbreast sunfish (*L. auritus*) populations after the introduction of flathead catfish (*Pylodictis olivaris*). Repeated measures ANOVA was conducted incorporating a control area, where flathead catfish abundance is extremely low, and a flathead area, where flathead catfish have become well established, for both before (1991–1995) and after (1996–2007) flathead invasion. The analyses revealed that the mean log-transformed electrofishing catch per hour ($\log_{10}$–CPH) of redbreast sunfish and largemouth bass decreased significantly in the flathead area but not in the control area following flathead introduction. Mean $\log_{10}$–CPH of largemouth bass between 150–299 mm TL increased in the control area but remained unchanged in the flathead area. No other significant differences in trends were found for bluegill or other size groups of these sport fishes between areas following flathead introduction ($P > 0.10$). Our analyses suggest that establishment of flathead catfish in the Satilla River may have contributed to observed declines in some sportfish populations in the Satilla River. Long-term data sets like the standardized sampling events examined can prove to be valuable management tools for fisheries biologists when assessing the potential effects of an introduced species on a system.

Key words: ANOVA, flathead catfish, largemouth bass, redbreast sunfish, relative abundance, Satilla River.

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Many studies have documented declines in native fish populations where the piscivorous flathead catfish (*Pylodictis olivaris*) has been introduced (Guier et al. 1984, Quinn 1988, Marsh and Brooks 1989, Barr and Ney 1993, Thomas 1993, Bart et al. 1994, Cailteux and Dobbins 2005, Sakaris et al. 2006). Thomas (1993) reported declines in the Altamaha River, Georgia, sportfishes including redbreast sunfish (*Lepomis auritus*) and native bullhead (*Ameirus sp.*) populations as a result of flathead catfish invasion. The proliferation of flathead catfish has also been implicated as a contributing factor to declines in the native spotted bullhead (*Ameiurus serracanthus*) in the Appalachicola River and concerns have been addressed for other north Florida rivers where flathead catfish have been introduced (Cailteux and Dobbins 2005).

The flathead catfish is an apex predator, so direct predation on native fishes can be a driving mechanism causing shifts in sportfish populations and fish community composition. The piscivorous nature of the flathead catfish has been well documented (Minckley and Deacon 1959, Hackney 1965, Guier et al. 1984, Barr and Ney 1993, Thomas 1993, Ashley and Rachels 2000, Weller and Robbins 2001, Pine et al. 2005). Flathead catfish diet analysis on the Satilla River from 1996–1997 revealed 30% by number of all prey items consisted of sunfish ($N = 208$) (Georgia Department of Natural Resources [GDNR], unpublished data). Weller and Robbins (2001) compared the diets of introduced flathead catfish in several southeastern U.S. rivers and found that food habits depend on the available forage base. In the Altamaha River, Georgia, centrarchids, including sunfish species (*Lepomis* spp.), were the dominant prey item (by weight) found in flathead catfish stomachs, followed by ictalurid species (Weller and Robbins 2001). In another study, centrarchids were found to be the most abundant prey fish consumed by the introduced flathead catfish in Byllesby Reservoir, an impoundment of the New River, Virginia, and it was estimated that up to 35% of centrarchids are consumed by this species in this system each year (Barr and Ney 1993). Centrarchids also comprised significant portions of flathead catfish diets in other systems (Turner and Summerfelt 1970, Pine et al. 2005).

Flathead catfish do not appear to be gape limited and can therefore have a large effect not only on recreationally-important sportfishes, but on the riverine fish community structure as a whole. Slaughter and Jacobson (2008) found that no size of bluegill (*L. macrochirus*), largemouth bass (*Micropterus salmoides*), or gizzard shad (*Dorosoma cepedianum*) would preclude predation by flathead catfish; thus the flathead catfish is one of the least gape-limited freshwater piscivores. A variety of forage species was also observed in the diets of flathead catfish collected in six Oklahoma reservoirs and these species varied throughout the year depending on when they inhabited reservoir bottom habitats where flathead catfish are found (Turner and Summerfelt 1970). Thus, as reported

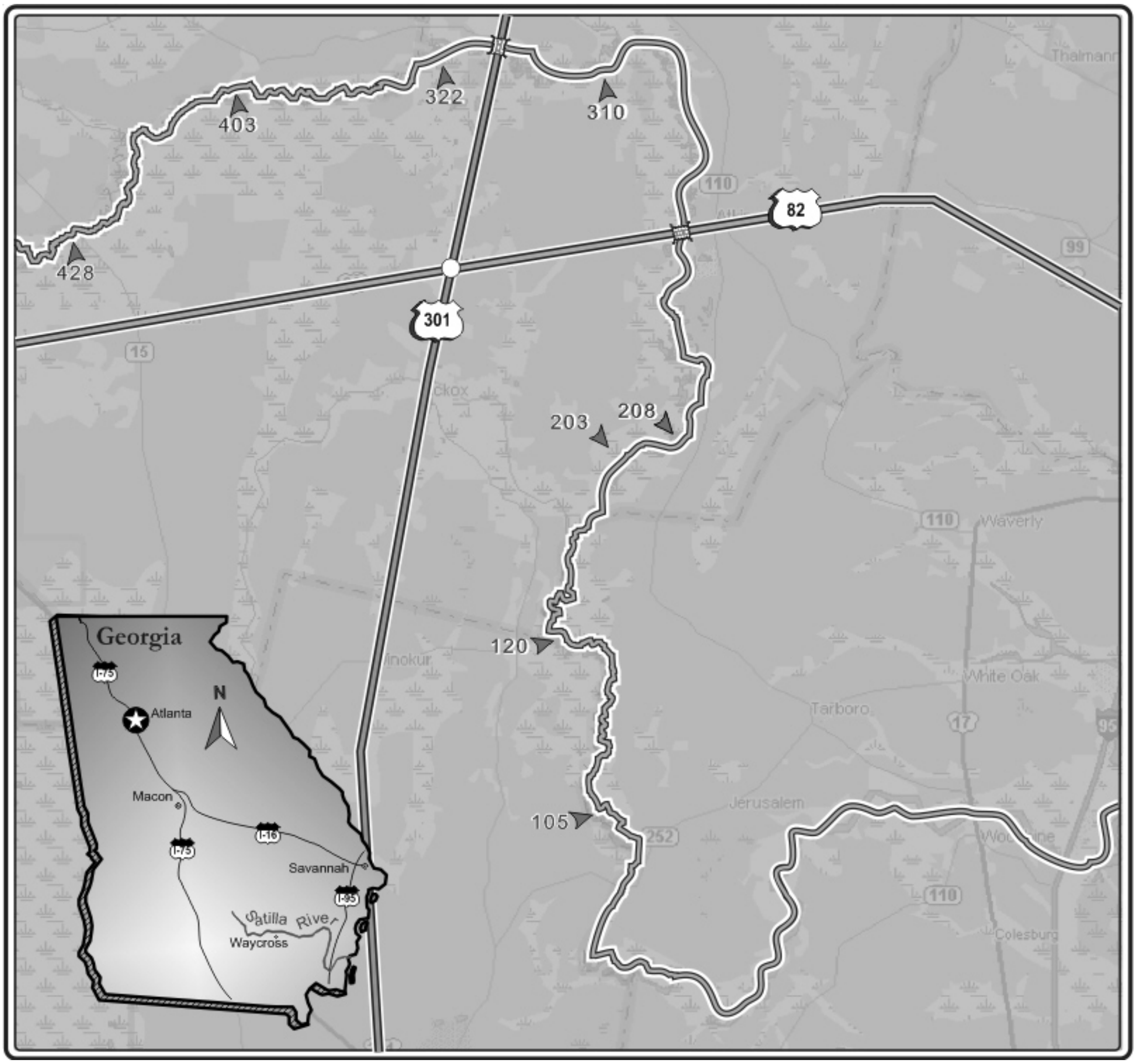

Figure 1. Standardized sampling sites locations on the Satilla River, Georgia. Four fixed sites located below U.S. Highway 82 were designated as flathead area locations and were numbered 208, 203, 120 and 105. Four fixed sites above Highway 82 were designated as control area locations and were numbered 428, 403, 322 and 310.

by Pine et al. (2005), flathead catfish not only have large consumption rates, but they exhibit little selectivity for prey type or size.

In addition to direct predatory effects on sportfishes and other native fishes, flathead catfish may also affect riverine fish community structure through competition for resources. Ecological modeling conducted by Pine et al. (2007) using data collected on a coastal North Carolina river indicated that flathead catfish would likely decrease the biomass of other piscivores due to competition for prey resources.

Flathead catfish were first found in the Satilla River, Georgia, in 1996, likely from an illegal stocking near Hickox, Georgia. Mean electrofishing catch rates of flathead catfish throughout the river have increased over time, ranging from 1.1 to 40.3 fish/hr and averaging 16.7 fish/hr from 1996 to 2007, since their introduction (GDNR, unpublished data). An access creel survey conducted during the same time period also showed declines in effort and catch of some sportfishes including redbreast sunfish thus adding to the biologists' concern that flathead catfish may be affecting the sportfish populations of the Satilla River (GDNR, unpublished data). As a result, a study was initiated to evaluate trends in the sportfish populations on the Satilla River, Georgia, following the introduction of the flathead catfish. Our objectives were to analyze a standardized sampling data set and determine if electrofishing catch rates (i.e., relative abundances) and size structures have changed for three sportfish populations (i.e., bluegill, largemouth bass, and redbreast sunfish) following flathead catfish introduction.

Study Area

The Satilla River originates in Southeast Georgia near the town of Fitzgerald and flows 225 miles to the Atlantic Ocean at St. Andrew's Sound (Figure 1). The watershed is composed of cypress swamps, lowlands, and planted pine ecosystems resulting in a tannic-acid, blackwater stream with a pH of 4.5 to 6.0 (Sandow et al. 1974). Development along the flood plain is very limited due to highly fluctuating water levels. The primary substrate is sand, but there are a few scattered sandstone outcroppings and rubble patches.

Methods

Bluegill, largemouth bass, and redbreast sunfish were collected in the Satilla River, Georgia, at eight fixed standardized sampling locations (Figure 1). In an effort to examine potential differences in sportfish population characteristics following flathead catfish introduction, four standardized sampling sites above Highway 82 were selected and analyzed as a control area, due to the low relative abundance of flathead catfish in these areas. Flathead catfish catch rates in this area have ranged from 0.14 to 2.95 fish/h but averaged 0.57 fish/h between 1996–2007 (GDNR, unpublished data). The four samples sites below Highway 82 were selected as the flathead area along the river where flathead abundance has become high (GDNR, unpublished data) (Figure 1). GDNR flathead catfish catch rates in the flathead area have ranged from 1.3 fish/hr to 47.5 fish/h and averaged 20.5 fish/h during the same period. One hour electrofishing transects for sportfish were performed at each of the eight sample locations, which included Nimmer's Fish Camp (3116N 8204W; Station 428), Herrin Landing (3117N 8201W; Station 403), upstream of Highway 301 boat ramp (3117N 8158W; Station 322), Forks of the River Hunt Club (3118N 8154W; Station 310), Satilla Estates (3108N 8152W; Station 208), Old Barn Hunt Club (3107N 8154W), Still Lake Fish Camp (3103N 8156W), and a river reach north of the Burnt Fort Boat Ramp (3058N 8154W) (Figure 1). Electrofishing surveys for sportfish were conducted annually in the spring and were completed within one-month. All sportfish were collected with electrofishing gear similar to Thomas (1993). Electrofishing surveys for flathead catfish were conducted in the summer with gear similar to Weller and Robbins (2001). Although pedal time during flathead catfish sampling was recorded for each individual stretch of the river, effort was not standardized by time (i.e., unlike one hour per transect during the sportfish samples).

Catch per hour (CPH, fish/h) for bluegill and redbreast sunfish <150 mm total length (TL), 150–202 mm TL, >203 mm TL, and all fish sizes combined was determined by site and year. In addition, CPH of largemouth bass <150 mm TL, 150–299 mm TL, ≥300 mm TL, and all fish sizes combined was determined by site and year. We included different size groups to determine if flathead catfish introduction may have been associated with shifts in select portions of these populations. Repeated measures analysis of variance (ANOVA) was used with the PROC MIXED procedure (SAS Institute 2000) to test for differences in mean CPH of the different size groups of the three species between pre-and post-flathead introduction within the control and flathead areas. The CPH data were $\log_{10}$ transformed to meet assumptions of the ANOVA. Sample sites were nested within years as the subject in the analysis by area (flathead vs. control) and period (pre- vs post-flathead introduction) as the fixed effects. The area * period interaction was also included in the model and, if significant, the LSMEANS procedure was used to determine which areas differed between periods. For this analysis, the years 1991–1995 were treated as pre-flathead invasion and 1996–2007 were considered post-flathead invasion. For the flathead area, only redbreast sunfish data were collected in 1991, but in all subsequent years (1992–2007) all three sportfish species were targeted. For the control areas, only redbreast sunfish data were collected in 1991 and 1993, but all three sportfish species were targeted in all other years. Most of the time, four electrofishing transects were performed and analyzed for each time period (pre vs post) and area (flathead vs control) except in 2003, 2004, and 2007, when, because of access issues, only three electrofishing transects were conducted for bluegill and largemouth bass at the post-flathead areas. As a result, station 105 was not sampled for largemouth bass or bluegill in 2004 and 2007 and station 120 was not sampled for largemouth bass or bluegill in 2003. For this analysis, a difference was considered significant if $P < 0.05$.

Results

Mean $\log_{10}$–CPH of redbreast sunfish decreased following flathead introduction (1996 to 2007). Before the flathead catfish introduction (1991–1995), annual mean CPH for all redbreast sunfish in the flathead area ranged from 38 to 177 fish/h and averaged 125.2 fish/h, whereas following flathead introduction (1996–2007) it ranged from 9 to 73 fish/h and averaged 54 fish/h (Figure 2, Table 1). For the control areas, before flathead catfish introduction (1991–1995), annual mean CPH for all redbreast sunfish ranged from 112 to 305 fish/h and averaged 229.9 fish/h, whereas following flathead introduction (1996–2007) it ranged from 32 to 241 fish/h and averaged 135.7 fish/h (Figure 2, Table 1). Repeated measures ANOVA revealed that mean log-transformed electrofishing catch per hour (CPH) of all redbreast sunfish collected decreased significantly in the flathead area (LSMEANS; $t_6 = -5.20$; $P = 0.002$) but not in the control area (LSMEANS; $t_6 = -1.57$; $P = 0.168$) following flathead introduction. However, no significant differences were observed in the trend of mean $\log_{10}$–CPH of different size groups of redbreast sunfish between periods for the two areas (area*period interaction; $F_{1,6} = 0.15 - 2.43$; $P > 0.05$); i.e., both areas exhibited a similar increase, decrease, or no change in $\log_{10}$–CPH between the pre and post flathead introduction periods. Interest-

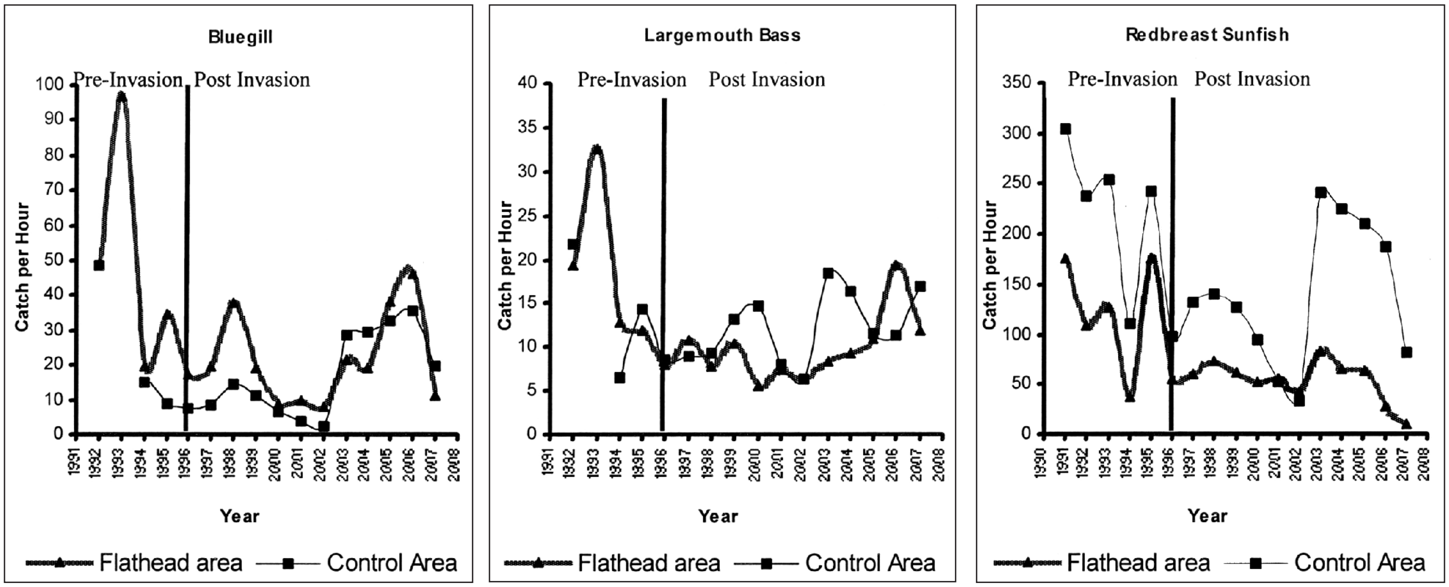

Figure 2. Mean catch per hour of bluegill (left panel), largemouth bass (middle panel) and redbreast sunfish (right panel) collected during spring 1991–2007 on the Satilla River, Georgia. Data was collected from eight fixed electrofishing sites by Georgia Department of Natural Resources personnel. Four fixed sites located below U.S. Highway 82 were designated as flathead areas and four fixed sites above U.S. Highway 82 were designated as control areas. Samples were not collected in 1991 and 1993 for bluegill and largemouth bass at the control areas. Samples were also not collected in 1991 for bluegill and largemouth bass at the flathead areas.

Table 1. Mean + SE electrofishing catch per hour (fish/h) of bluegill, largemouth bass, and redbreast sunfish in the Satilla River. Bluegill and largemouth bass were sampled annually from 1992 through 2007, except they were not sampled in 1993 at the pre-control sample sites. Redbreast sunfish were sampled annually from 1991 through 2007. The abbreviation *n* indicates the number of electrofishing transects. Most of the time, four electrofishing transects were performed and analyzed for each area and year except in 2003, 2004, and 2007, when only three electrofishing transects were conducted for bluegill and largemouth bass at the post-flathead areas.

Species, years sampled, *n*, and total length	Pre-flathead area	Pre-control area	Post-flathead area	Post-control area
Bluegill				
Years	1992–1995	1992, 1994,1995	1996–2007	1996–2007
n	16	12	45	48
<150	7.1 + 2.2	8.7 + 2.5	9.0 + 1.4	7.8 + 1.3
150–202	24.7 + 9.6	10.9 + 4.0	5.8 + 0.1	5.9 + 0.9
>203	18.8 + 6.5	4.4 + 1.6	7.2 + 1.0	3.3 + 0.6
All fish	50.0 + 16.0	24.0 + 6.5	21.7 + 2.4	17.1 + 2.2
Total collected	801	289	977	822
Largemouth bass				
Years	1992–1995	1992, 1994, 1995	1996–2007	1996–2007
n	16	12	45	48
<150	0.3 + 0.1	2.8 + 1.8	0.6 + 0.1	1.3 + 0.3
150–299	7.2 + 1.6	4.9 + 1.5	4.8 + 0.5	4.8 + 0.5
≥300	11.7 + 3.7	11.7 + 2.9	4.2 + 0.4	5.8 + 0.6
All fish	19.1 + 5.0	19.3 + 3.0	9.7 + 0.7	11.9 + 0.9
Total collected	307	231	435	560
Redbreast sunfish				
Years	1991–1995	1991–1995	1996–2007	1996–2007
n	20	20	45	48
<150	50.1 + 8.9	88.2 + 14.0	37.1 + 3.3	74.2 + 7.9
150–202	44.4 + 5.8	88.2 + 11.1	10.5 + 1.4	40.0 + 4.7
>203	30.8 + 5.2	53.6 + 7.2	6.3 + 1.0	21.5 + 3.4
All fish	125.2 + 14.1	229.9 + 18.3	54.0 + 4.4	135.7 + 12.2
Total collected	2,504	4,598	2,429	6,363

ingly, similar numbers of redbreast sunfish were obtained in five years of sampling ($N = 2{,}504$, 1991–1995) before flathead invasion compared to 12 years of sampling ($N = 2{,}429$, 1996–2007) after flathead invasion for the flathead area (Table 1).

Annual mean CPH for all largemouth bass in the flathead area from 1992, 1994, and 1995 ranged from 12 to 33 fish/h and averaged 19.1 fish/h, whereas following flathead introduction (1996–2007) the catch rates ranged from 6 to 19 fish/h and averaged 9.7 fish/h (Figure 2,Table 1). For the control areas, before flathead catfish introduction annual mean CPH for all largemouth bass ranged from 6 to 22 fish/h, and averaged 19.3 fish/h, where as following flathead introduction (1996–2007), catch rates ranged from 6 to 19 fish/h and averaged 11.9 fish/h (Figure 2, Table 1). The area*period interaction term was not significant for either largemouth bass >300 mm or <150 mm TL ($F_{1,6} = 0.06\ 0.70$; $P > 0.43$). Thus, the flathead and control areas showed a similar trend in mean $\log_{10}$–CPH of largemouth bass between the two periods for these size groups. However, for largemouth bass between 150–299 mm TL, the control area exhibited an increase in mean $\log_{10}$–CPH, but the flathead area remained unchanged (LSMEANS; t6 = –0.37; $P = 0.724$). For all largemouth bass combined, mean $\log_{10}$–CPH did not change for the control site ($t_6 = -0.06$; $P = 0.957$), but for the flathead site, mean $\log_{10}$–CPH declined significantly ($t_6 = -3.98$; $P = 0.007$).

Annual mean CPH for bluegill in the flathead area from 1992, 1994, and 1995 ranged from 20 to 97 fish/h and averaged 50 fish/h, whereas following flathead introduction (1996–2007) the catch rates ranged from 9 to 46 fish/h and averaged 21.7 fish/h in the flathead area (Figure 2,Table 1). For the control areas, before flathead catfish introduction (1992, 1994, and 1995), annual mean CPH for bluegill ranged from 8 to 49 fish/h and averaged 24.0 fish/h, whereas following flathead introduction (1996–2007) it ranged from 2 to 36 fish/h and averaged 17.1 fish/h in the control areas (Figure 2, Table 1). For mean $\log_{10}$–CPH for all bluegill, as well as for the different size groups of bluegill, the area*period interaction term was not significant ($F_{1,6}$=0.68 to 3.72; P=0.102 to 0.442). Thus, for all comparisons, mean $\log_{10}$–CPH either decreased for both areas or remain unchanged between the pre and post flathead introduction periods.

Discussion

Our results suggest that the introduction of the non-native flathead catfish may have negatively affected sportfish populations in the Satilla River. Similar to an earlier study (Thomas 1993), we observed significant declines in the abundance and/or size structure of redbreast sunfish and largemouth bass populations between the time periods evaluated (pre- and post-flathead introduction). Other studies have also documented declines in native riverine fish populations following flathead introduction including the abundance of ictalurids and redbreast sunfish (Guier et al. 1984, Bart et al. 1994, Ashley and Rachels 2000). Although we are unable to identify the mechanisms underlying observed changes in the sportfish populations in the Satilla River, we hypothesize that these differences were due in part to direct predation by flathead catfish and competition with flathead catfish for available prey resources.

Direct predation by flathead catfish on native fishes and competition for resources may influence riverine fish community structure with the greatest effect presumably immediately following introduction. Introduced flathead populations have been found to exhibit more rapid growth rates than native populations (Sakaris et al. 2006) and even at low densities may exhibit predation pressure that can negatively impact native fish populations (Pine et al. 2005). Direct predation by flathead catfish has been implicated as the cause of declines in native fish populations in several Georgia and North Carolina rivers (Guier et al. 1984, Thomas 1993, Bart et al. 1994, Ashley and Rachels 2000). On the Satilla River in 1996 and 1997, direct predation by flathead catfish on centrarchids including bluegill, largemouth bass, and redbreast sunfish was directly observed in diet analysis (GDNR, unpublished data). Weller and Robbins (2001) documented redbreast sunfish in the diets of flathead catfish introduced into the Altamaha River, Georgia. Centrarchids also comprised significant portions of flathead catfish diets in other systems (Turner and Summerfelt 1970, Barr and Ney 1993, Pine et al. 2005).

Sandow et al. (1974) documented 24 Satilla River redbreast sunfish nests and noted they were located in the main stem of the river and were always associated upstream of some form of natural obstruction (i.e., a log, stump or tree root). As a result, Sandow et al. (1974) described the redbreast sunfish affinity for cover during the day was similar to the flathead catfish who also spend the day in cover (Robinson 1977, Skains 1992) provided by woody debris. So we hypothesize that the habitat preference overlap may predispose largemouth bass and redbreast sunfish to higher rates of predation.

Although direct predation by flathead catfish has been identified as the primary mechanism behind observed changes in sportfish populations, fish community shifts may also occur due to competition for resources. A model constructed by Pine et al. (2007) found that exploitation of flathead catfish would have a large positive response on native piscivore groups. They suggested this response was due to interspecific competition of available prey resources between these groups and flathead catfish. Thus, through direct predation and competition, the flathead catfish could have a potentially large effect on riverine fish communities.

Significant differences in the catch of different size groups of these sportfishes were rarely observed. This was not surprising given the lack of gape limitations (Slaughter and Jacobson 2008) and the random feeding habits exhibited by flathead catfish (Pine et al. 2005). Flathead catfish do not appear to select for species or size (Pine et al. 2005) thus the prey types consumed is dependent upon the available forage base. This may explain why the diets of flathead catfish vary by system and throughout the year in a particular system (Turner and Summerfelt 1970, Weller and Robbins 2001, Pine et al. 2005).

Although flathead predation is one of the density-dependent factors influencing the relative abundance of redbreast sunfish and largemouth bass in the Satilla River, there are density independent factors that can influence relative abundance estimates (Everhart and Youngs 1981, Sigler and Sigler 1990, Royce 1996). Besides, predation (Guier et al. 1984, Quinn 1988, Marsh and Brooks 1989, Barr and Ney 1993, Thomas 1993, Bart et al. 1994), reductions in redbreast sunfish populations have been attributed to pesticide contamination of the water (Davis 1972), loss of suitable habitat (Davis 1972), and angler overexploitation (Sandow et al. 1974). Furthermore, stream flow is considered a major variable that affects the abundance and distribution of many riverine species (Resh et al. 1988, Power et al. 1995). Sammons and Maceina (2009) reported that from 1997 to 2005, central and southern Georgia followed a typical pattern of wet and dry years, with 1999–2001 characterized by dry conditions and 1997, 2002, 2003, 2004, and 2005 by wet conditions. However, there was no discernable pattern in CPH of sportfish species with water conditions in these years (i.e., CPH was not significantly higher or lower during wet years or dry years). Other factors can influence electrofishing catch rate, including fish behavior, fish size, fish species, population density, sampling crew, water clarity, water conductivity, water level, water temperature, and weather conditions (Hardin and Connor 1992, Hilborn and Walters 1992, Reynolds 1996, Bayley and Austen 2002). Thus, although flathead catfish predation may be a key component in the declining abundances of redbreast sunfish and largemouth bass, the limited scope of this study (i.e., one river examined) and the influence other density-independent and density-dependent factors may have reduced our ability to identify other confounding effects that may have contributed to the observed trends.

The lack of significant differences found with relative abundance or size structure among bluegill sunfish in the Satilla River may have resulted because of protracted spawning periods (Metee et al. 1996). Bluegill are habitat generalists, so when environmental conditions become favorable within a given year a successful spawn can occur. Furthermore, being habitat generalists, their susceptibility to flathead predation may be much lower than the largemouth bass or redbreast sunfish. Largemouth bass habitat preferences include stumps, tree roots, dead trees, and other woody debris (Miller 1975, Wheeler and Allen 2003), while redbreast sunfish frequent sand and fine gravel areas as well as woody debris (Davis 1972). All of these habitats describe locations where one would expect predation by the flathead catfish to be high.

Long-term data sets like the standardized sampling events examined in this study can prove to be valuable management tools for fisheries biologists when assessing the potential changes of an introduced species on a system. Specifically, changes in the native fish population following the introduction of a top-level piscivore can be monitored with a long-term data set. Along with strong public support to rid the Satilla River of flathead catfish, the results of this study support the ongoing management program to remove flathead catfish from the Satilla River in an effort to buffer the potential negative effects on redbreast sunfish and largemouth bass populations. Future research efforts should focus on identifying the underlying mechanisms behind the observed trends in sportfish populations and on assessing the ecological effects of flathead catfish on riverine fish community structure.

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