Seasonal Food Habits of Introduced Blue Catfish in Lake Oconee, Georgia

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Abstract: Blue catfish (*Ictalurus furcatus*) are native to the Coosa River drainage in northwest Georgia but have been widely introduced outside of this range including Lake Oconee, a 7677-ha impoundment on the Oconee River in central Georgia. Blue catfish abundance and growth rates have increased dramatically since their introduction in Lake Oconee, but their food habits are unknown. Therefore, food habits of blue catfish in this impoundment were determined by examining the stomachs of 808 specimens in the reservoir's upper and lower regions across all seasons from summer 2012 to summer 2013. Diet was summarized using the Relative Importance of specific prey by weight. In the upper region of the reservoir, Asian clams (*Corbicula fluminea*) were the dominant prey item during the summer (75.7%), fall (66.4%), and winter (37.6%); whereas crappie (*Pomoxis* spp.) was the dominant prey item in the spring (38.7%). Asian clams also were the dominant prey items in the lower region during the fall (68.4%), winter (33.9%), and spring (36.4%). Blue catfish seemed to feed opportunistically on seasonally abundant prey items in both the upper riverine and lower lacustrine portions of the reservoir. Of the many sportfishes in the reservoir, only crappie was an important prey item, and then only in the upper region during the spring. Our results do not support concerns that blue catfish are an apex predator that would decimate the sportfish assemblage in this recently colonized reservoir.

Key words: diet, relative importance, prey accumulation curves, invasive species

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The blue catfish (*Ictalurus furcatus*) is the largest of the freshwater catfishes in North America and its native range historically spanned from the Ohio River drainage into Belize (Graham 1999). Because of its large size, blue catfish is an important species for commercial, recreational, and predator-control purposes within the United States (Graham 1999, Michaletz and Dillard 1999, U.S. Fish and Wildlife Service and U.S. Census Bureau 2001). As a result, it has experienced widespread introduction nationally (Graham 1999, Higgins et al. 2006). In Georgia, blue catfish are native to the Coosa River drainage in the northwestern part of the state (Glodeck 1980) but have been widely introduced outside of this range (Bonvechio et al. 2011, Homer and Jennings 2011). Blue catfish were first discovered in the Oconee River system about 20 years prior to this study: they were documented in Lake Sinclair in 1996 and Lake Oconee in 1997 (Homer and Jennings 2011). Subsequently, they spread downstream into the Altamaha River, and their abundance and growth rates increased dramatically throughout the system (Bonvechio et al. 2011, Homer and Jennings 2011, Homer et al. 2015).

Because of their widespread introduction into many water bodies and their presumed highly predatory behavior, blue catfish have had negative effects on native aquatic communities (Wilcove and Chen 1998, Lodge et al. 2000, Jelks et al. 2008). For example, increases in blue catfish population sizes have been correlated with declines of native white catfish (*Ictalurus catus*) in the Chesapeake Bay watershed (Schloesser et al. 2011) and in Lake Oconee, Georgia (Homer and Jennings 2011). The direct mechanisms for the decline of white catfish in these systems are unknown, but Schloesser et al. (2011) postulated that competition between blue catfish and white catfish for prey resources may have contributed to the documented declines. Literature pertaining to the feeding ecology of both native and introduced blue catfish populations is growing and suggests that mollusks are an important prey item for blue catfish in southern rivers (e.g., Jolley and Irwin 2003, Eggleton and Schramm 2004, and Bonvechio et al. 2011). However, further research examining the dynamics between introduced blue catfish populations and their native prey species would be beneficial for determining the trophic role of the species in any given ecosystem (*sensu* Schloesser et al. 2011).

In this paper, we describe the seasonal diets of a recently introduced population of blue catfish in Lake Oconee, Georgia. Initially, this population grew rapidly, with CPE in Georgia Department of Natural Resources standard gill net surveys increasing from 0.2 fish net night^{-1} in 1997 to 28.5 fish net night^{-1} in 2011, but it seemed to have stabilized (~18 fish net night^{-1} in 2016). Information about its trophic role is lacking. The objectives of this study were to: 1) document the seasonal diets of introduced blue catfish in Lake Oconee, Georgia, and 2) determine if the introduced blue catfish prey heavily on native sportfish species.

Methods

Study Area

The study was conducted from June 2012–June 2013 on Lake Oconee, which is located in central Georgia (33º 21′ 0″ N, 83º 9′ 25.2″ W) on the Oconee River (Figure 1). Lake Oconee was formed in 1979 when Wallace Dam was constructed on the Oconee River for hydro-electric power and recreational activities (Homer and Jennings 2011). At full pool, Lake Oconee covers 7677 ha and has 605 km of shoreline, with a maximum depth of 27.8 m and a mean depth of 6.4 m. The upper region is shallower and possesses more riverine habitat types than the lower region, which is much deeper and more lacustrine. The reservoir supports popular fisheries for many species including striped bass (*Morone saxatilis*), white bass (*M. chrysops*), hybrid striped bass (*M. saxatilis* × *M. chrysops*), largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), blue catfish, black crappie (*Pomoxis nigromaculatus*), white crappie (*P. annularis*), and sunfishes (*Lepomis* spp).

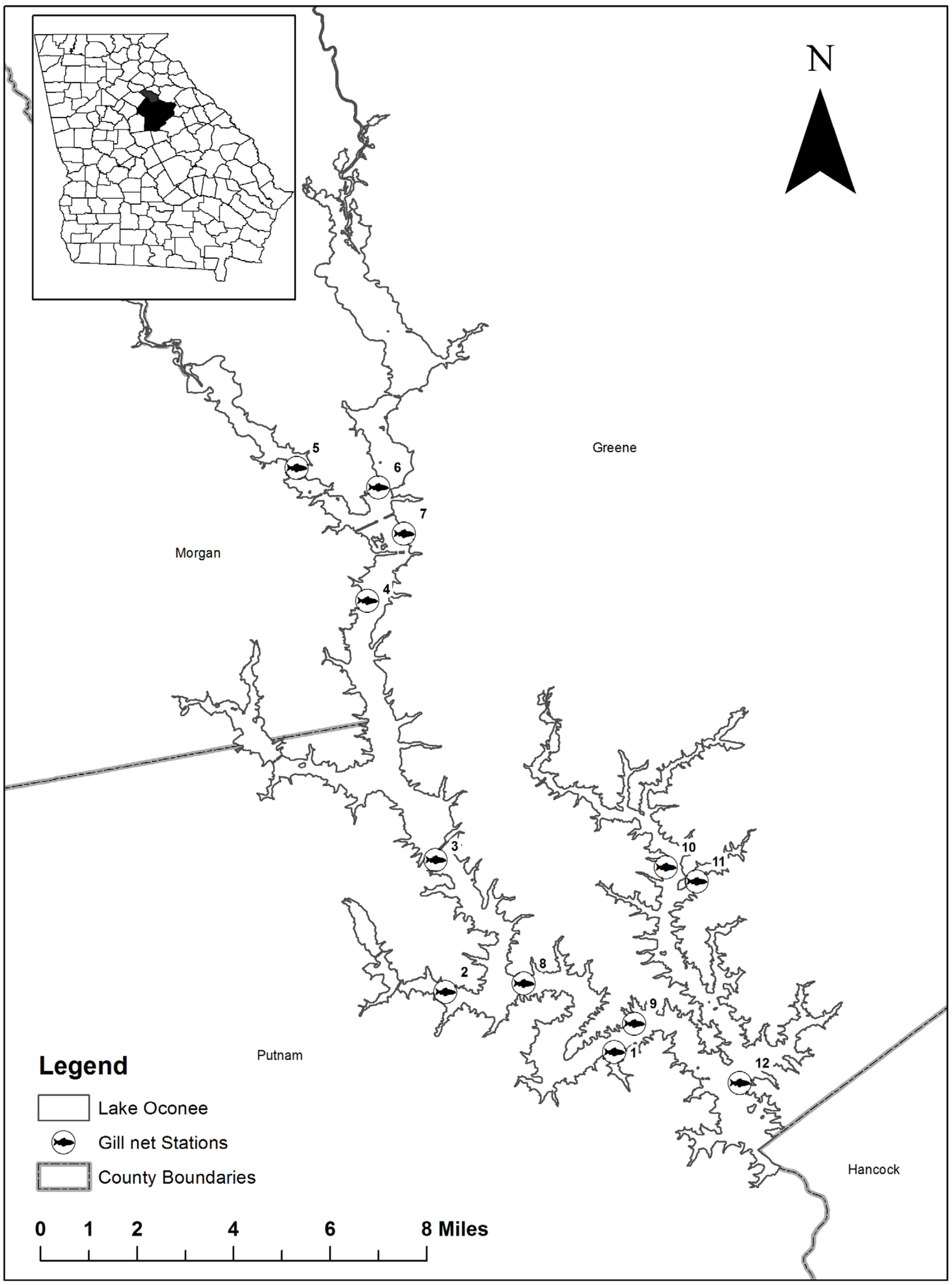

Figure 1. Map showing the location Lake Oconee and the 12 Georgia Department of Natural Resources standardized sampling stations sampled with gillnets during June 2012–June 2013. (Reprinted with permission from Homer et al. 2015)

Fish Sampling

Fish sampling occurred at 12 Georgia Department of Natural Resources standardized sampling stations that spanned the reservoir and varied in habitat type (Figure 1). Sites were further stratified into upper ($n = 7$) and lower ($n = 5$) regions to account for the expected longitudinal variation in productivity and morphometry typically found in reservoirs (Siler et al. 1986). All sites were sampled monthly with single-panel sinking gillnets (30.4 m long by 1.8 m deep) fished overnight. Each net consisted of a single panel of mesh consisting of either 50.8 mm ($n = 2$), 76.2 mm ($n = 2$), or 101 mm ($n = 2$) mesh. One net was randomly assigned to a station, and sampling of all the stations usually occurred over 2–3 d. Seasonal periods were determined based on mean (±95% CI) water temperatures: summer (June, July, August—mean = 30.2 °C ± 2.34); fall (September, October, November—mean = 24.8 ± 1.62); winter (December, January, February—mean = 15.5 ± 1.98), and spring (March, April, May—mean = 22.1 ± 2.40). Once captured, each fish was placed in a 1:1 ice to water slurry to be euthanized (Blessing et al. 2010). When euthanization was complete, the specimens were transported to a laboratory at the University of Georgia, Warnell School of Forestry and Natural Resources, for processing. In the lab, the fish were weighed to the nearest kg, measured to the nearest mm (total length) and stomachs excised. The stomachs were fixed with 10% formalin for three days before being stored in ethanol (Jolley and Irwin 2003).

Stomach Content Analysis

Standard diet assessment procedures were used to process the fish stomachs which were surgically opened and stomach contents removed. Empty stomachs and full stomachs were counted and listed separately (Jearld and Brown 1971). Stomach contents were identified to the lowest taxon possible (Manooch 1973, Jolley and Irwin 2003). Diet items were quantified by enumerating the frequency of occurrence of each prey item, numerical proportion of each food item, and the proportion of wet mass weight (g) of each species group (Jearld and Brown 1971, Manooch 1973, Jolley and Irwin 2003).

Blue catfish diet data were grouped by season and region for analyses. The Relative Importance index (RI) of prey mass was used to evaluate the diet of the sampled fish between regions and among seasons. The RI is recommended for gut contents analysis when determining the relative importance of predator populations on prey (Chips and Garvey 2007).

Prey accumulation curves (PAC) were used to determine if sample sizes of the diet data for blue catfish from each region and season combination were sufficiently large for an adequate description of the diet. A PAC is a graphical tool used to determine if a sample size of stomachs is adequate to base conclusions about the diet of a specific species (Cook and Bundy 2010). The PAC is composed of two variables that compares the number of prey items against the number of stomachs sampled. The rate at which new prey items are identified decreases as more stomachs are examined. At a certain point on the graph, identification of new items will cease and the graph will reach an asymptote, which indicates that the sample size is adequate and a conclusion on the diet of a species can be drawn (Cook and Bundy 2010).

Results

Fish Catch and Stomach Data Summary

A total of 808 blue catfish was caught and stomachs analyzed for diet content. Fish ranged in length from 150 to 1050 mm TL and weights ranged from 20 g to 19.5 kg (Figure 2). A total of 304

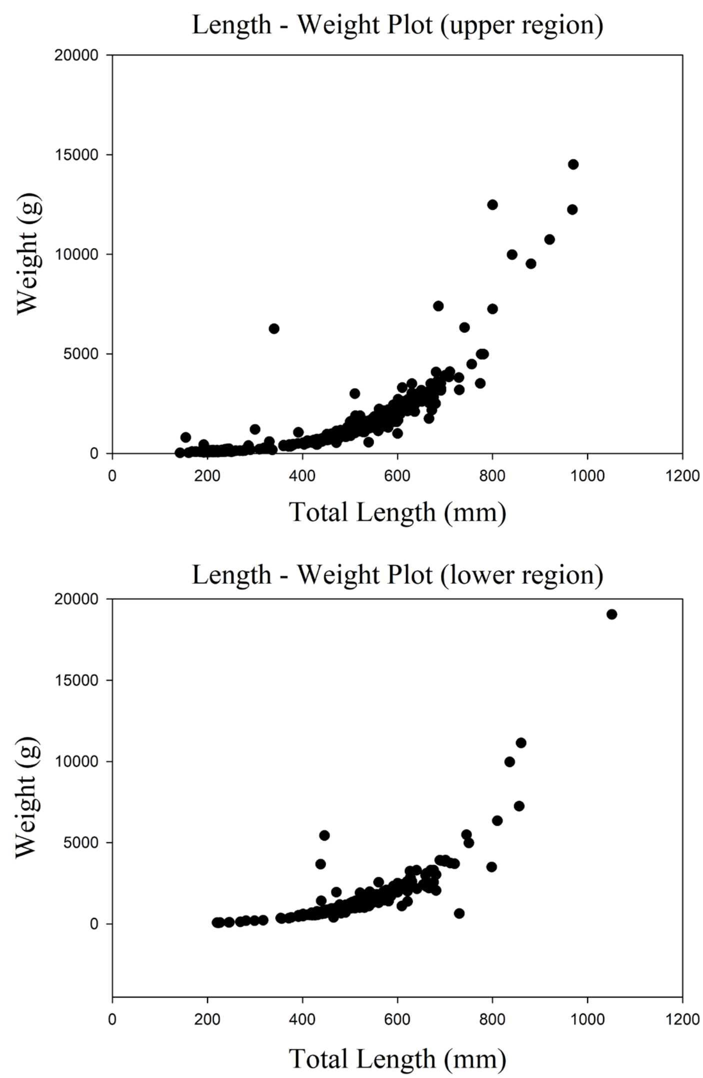

Figure 2. Length-weight scatter plot of the blue catfish from the upper ($n = 504$; top) and lower ($n = 304$; bottom) regions of Lake Oconee, Georgia, June 2012–June 2013.

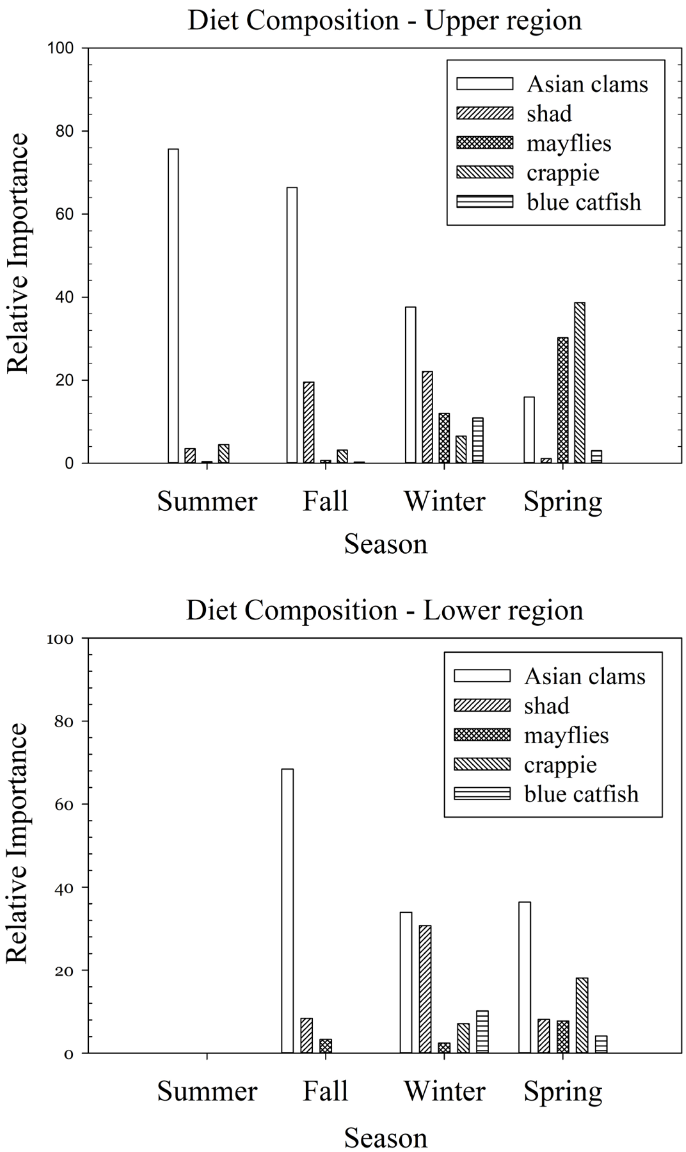

Figure 3. Relative importance of the top five prey items in the diet of blue catfish sampled from upper (top) and lower (bottom) of Lake Oconee, Georgia, from June 2012–June 2013. The lower region was not sampled during summer.

(57% with contents) blue catfish stomachs was collected from the lower region and 504 (55% with contents) stomachs were collected from the upper region. A total of 452 (56%) stomachs contained prey items, and the stomach fullness percentage varied from a high of 71% to a low of 51% across seasons. Prey accumulation curves determined that sample sizes were sufficiently large to draw diet content conclusions for all seasons and regions. Twenty different prey items were identified at least to order; there was one category for unidentified prey. The highest diversity of prey encountered was 14 different items from a single stomach. Prey breadth varied seasonally (Figure 3) and was comparable between upstream (12 total items) and downstream (14 total items) regions of the lake.

Diet Analysis

Lower Region Seasonal Diet.—Blue catfish diet shifted and diversity increased seasonally from predominantly Asian clams in the fall to a mix of clams and piscine prey in the winter and spring. The dominant prey items (RI) identified for the fall were Asian clams (68%), shad (*Dorsoma* spp.; 8%), flies (7%), unidentified prey (8%), and mayflies (Ephemeroptera; 3%; Table 1). The dominant prey items for winter were Asian clams (33%), shad (30%), blue catfish (10%), crappie (7%), striped bass or striped bass hybrids (4%), channel catfish (4%), detritus (2%), and mayflies (2%; Table 1). Dominant prey items for the spring were Asian clams (36%), crappie (18%), channel catfish (10%), shad (8%), mayflies (7%), detritus (6%), and blue catfish (4%; Table 1).

Upper Region Seasonal Diet.—Blue catfish diet also varied seasonally in the upper region of the lake, shifting from predominantly Asian clams (in the summer and fall to a more diverse diet of Asian clams, fishes, and insects in the winter and spring (Table 1). The dominant prey items (RI) for the summer were Asian clams (75%), unidentified prey (7%), crappie (4%), stoneflies (*Plecoptera* spp.; 4%), and shad (3%). Dominant prey items for the fall were Asian clams (66%), shad (19%), detritus (6%), and crappie (3%;

Table 1. Food items in stomachs of blue catfish ($n = 453$) and their Relative Importance (RI; weight) by season and region from Lake Oconee, Georgia, 2012–2013; Up = Upper Region, Low = Lower Region.

	Summer		Fall		Winter		Spring	
Prey Items[a]	**Up**	**Low**	**Up**	**Low**	**Up**	**Low**	**Up**	**Low**
Insects								
Diptera	0.35	N/A	0.17	7.38	1.42	0.55	0.00	0.33
Ephemeroptera	0.37	N/A	0.64	3.31	12.00	2.43	30.22	7.45
Plecoptera	4.00	N/A	0.02	0.25	0.03	0.12	0.00	0.02
Fish								
Dorsoma spp.	3.50	N/A	19.53	8.40	22.07	30.73	1.11	8.14
I. punctatus[b]	0.00	N/A	0.45	2.47	0.00	4.00	0.00	10.77
I. *furcatus*[c]	<0.01	N/A	0.31	0.00	10.89	10.16	3.03	4.17
Pomoxis spp.	4.46	N/A	3.13	0.00	6.50	7.11	38.68	18.11
Morone spp.[d]	0.00	N/A	1.97	0.00	0.00	4.88	4.84	2.24
C. carpio[e]	0.00	N/A	0.00	0.00	0.00	0.40	0.00	3.46
Mollusks								
C. fluminea[f]	75.68	N/A	66.41	68.43	37.61	33.93	15.91	36.39
Unionidae	0.00	N/A	0.03	0.00	0.00	0.00	0.01	1.26
Miscelleanous								
Detritus	1.80	N/A	6.02	0.52	2.86	4.13	3.31	6.59
Unidentified	7.88	N/A	0.85	8.63	2.12	1.49	2.85	1.00

a. Items encountered infrequently and whose relative importance was <0.01 include crustaceans (Daphnia, Amphipods, Decapods), worms (Oligocheates, Polycheates), flies (Tricoptera, Dixidae), leaches (Hirudinea), and beetles (Coleptera).
b. *Ictalurus punctatus*
c. *Ictalurus furcatus*
d. *Morone saxatilis*
e. *Cyprinus carpio*
f. *Corbicula fluminea*

Table 1). Dominant prey items for the winter were Asian clams (37%), shad (30%), mayflies (12%), blue catfish (10%), and crappie (6%; Table 1). In the spring, the dominant prey items were crappie (38%), mayflies (30%), Asian clams (15%), striped bass and hybrid striped bass (4%), and detritus (3%; Table 1).

Discussion

Seasonal Diets

Invasive blue catfish in Lake Oconee could best be characterized as an omnivorous, opportunistic predator, which is similar to the tropic role described in studies of native blue catfish populations (Darnell 1958, Minckley 1962, Perry 1969, Davis 1979). Blue catfish exhibit consistent diet shifts throughout the year, presumably feeding opportunistically on abundant prey (McMahon 1983, Stoeckel et al. 1997, Moser and Roberts 1999, Grist 2002, Magoulick and Lewis 2002, Jolley and Irwin 2003, Eggleton and Schramm 2004, Bonvechio et al. 2011). This pattern was observed in Lake Oconee as well, and the shifts seemed to be related to seasonal prey abundances. Further, diet breadth (i.e., number of items in the diet) was much narrower during the summer when Asian clams (the most important prey during most of the year) are typically more abundant compared to the winter and spring when they were less abundant (Mattice and Dye 1976, Lucy et al. 2012). Thus, the seasonal abundance of the various prey items in the stomach of blue catfish in the reservoir seemed to reflect local prey abundances in the upper and lower regions of the lake.

The overnight gillnet sets used to sample blue catfish in this study could have influenced the number of stomachs with contents and the type of gut contents found, especially during the warmer months. However, our sampling produced over 400 stomach with contents, and the resulting prey accumulation curves indicated our sample size was adequate to describe blue catfish diet in each season by region combination in the reservoir.

Important Prey Items

A wide variety of prey items ($n = 20$) were encountered in the stomachs of blue catfish in both regions of Lake Oconee. However, only a few specific prey items comprised most of the prey encountered in any given stomach and all stomachs overall (Table 1). These prey items were Asian clams, shad, crappie, mayflies, and blue catfish, and their relative contribution to the regional and seasonal diet of blue catfish in Lake Oconee varied considerably as described below.

Asian clams.—In Lake Oconee, Asian clams were the major resource for blue catfish in both regions of the reservoir throughout the year, and their relative importance was highest in the summer and lowest in the winter and spring. Bonvechio et al. (2011) also reported large amounts of Asian clams from the stomachs of blue catfish sampled in the Altamaha River, Georgia, during July 2010. This consumption pattern in Lake Oconee was consistent with the spawning of the clams that enables them to reach their highest abundances during the summer and early fall seasons (Bagatini et al. 2007). Because of the high densities achieved during spawning, Asian clams often experience population declines (or die offs) caused by degraded habitat conditions at the spawning site (Bagatini et al. 2007). Further population declines occur during the winter because Asian clams do not survive extreme cold temperatures (Mattice and Dye 1976, Lucy et al. 2012). These declines in the abundance of Asian clams in late fall and winter are reflected in the notable decline in the Asian clam importance in blue catfish diets during winter (33%) and spring (36%).

Shad.—Differences in consumption rates of shad were observed between the upper and lower lake regions during fall and spring, and the relative importance of shad to blue catfish during these seasons was much lower than the relative importance during winter in both regions. Shad were the second most important diet item in blue catfish winter diets in both regions, and the relative importance were similar. The relatively larger representation of shad in diets of lower region blue catfish diet may reflect the seasonal movement patterns of these species. Shad are intolerant of rapid changes in temperature (Jester and Jensen 1972), and they overwinter in the deepest regions of the lake where temperatures are constant throughout the winter (Schael et al. 1995). Likewise, blue catfish overwinter and restrict their movement to the deepest parts of reservoirs or lakes as well (Jordan and Everman 1923, Pflieger 1975). Therefore, shad and blue catfish overwintering patterns overlap temporally and spatially and may explain the increased shad relative importance in blue catfish diet in winter relative to other seasons.

Crappie.—Crappie were a common diet item in both regions of the lake during the spring when they were the most important (38%) prey item in the upper region of the lake and the second most important (18%) prey item in the lower region. Crappie were nominally important (4–7%) in the diet of blue catfish during the summer, fall, and winter in upstream region and during the winter in the downstream region. Crappie aggregate in large schools prior to spawning in the spring and spawn in shallow water near submerged structures (Etnier and Starnes 1993, Mettee et al. 1996). The springtime increase in the importance to crappie in the diet of blue catfish in Lake Oconee may be reflective of crappie seasonal distribution in the reservoir; spawning aggregations in the shallow upper region of the lake may explain why crappie were eaten more by blue catfish there compared to those found in the deeper, lower region of the reservoir.

Mayflies.—Mayflies were most important in the upper region of the reservoir during the winter and spring and slightly less important in the lower region during fall, winter, and spring. However, regardless of the season or location, the importance of mayflies in blue catfish diets were only relatively high in the upper part of the reservoir during the spring, probably during their spring emergence (Elliott 1972, Brattian and Nagell 1981, Sivaramakrishnan et al. 2000). Further, almost all of the mayflies found in stomachs we examined were in their nymph stage or sub-imago stage, which further supports our contention that blue catfish preyed opportunistically upon **the mayfly annual** spring hatch and emergence from the bottom of the reservoir. Mayflies were not as important during other periods of the year, as is evidences by their lower relative importance scores during the summer, fall, and winter.

Blue catfish.—Cannibalism occurred among blue catfish in Lake Oconee, but only during the winter (10%) and even less so in the spring (3%–4%) in both regions of the reservoir. This predation pattern seems to occur only during the coolest part of the year when other prey have become scarce. Overall, cannibalism was rare for blue catfish in Lake Oconee. Likewise, literature documenting cannibalism among blue catfish is rare, with most references only referring to blue catfish as an opportunistic feeder that may eat fish, as available (e.g., Etiner and Starnes 1993, Mettee et al. 1996).

Summary

Blue catfish were first detected in Lake Oconee in 1997 and are now naturalized in the system. Blue catfish in Lake Oconee appeared to feed opportunistically on whatever was seasonally abundant in both the upper riverine and lower lacustrine portions of the lake. They fed primarily on Asian clams in the summer and switched to mostly fish in the winter (shad) and spring (crappie). Insects (e.g., mayflies) also were an important prey item in the spring. Accordingly, diet breadth was narrowest in the summer and widest during the winter and spring.

Our results documented only limited instances when blue catfish preyed on sportfishes or native mussels. For example, of the many sportfish in the lake, only crappie were moderately important in the diet of blue catfish and then only in the shallow upstream region where crappie aggregated in large numbers to spawn during spring. This feeding pattern on crappie seems opportunistic, a feeding pattern ascribed to blue catfish by others (e.g., Etnier and Starnes 1993, Mette et al. 1996). There were a few instances when other sportfish (e.g., striped bass) and a few native mussels (total of four for the study) were found in blue catfish stomachs, but those instances were infrequent and the relative importance of those species was negligible. Accordingly, we view concerns about blue catfish being an apex predator that would decimate populations of the many sportfishes and native mussels in the reservoir as unfounded. Further, we hypothesize that blue catfish may be similarly opportunistic predators in other systems where they are invasive.

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