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Prey resource use by bluegill and channel catfish in small impoundments

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Abstract Channel catfish, *Ictalurus punctatus* (Rafinesque), are commonly stocked into small impoundments that contain bluegill, *Lepomis macrochirus* Rafinesque, and these species may compete for food resources because both prey on macroinvertebrates. Prey selectivity and diet overlap of sympatric bluegill and channel catfish were evaluated in two small impoundments. Both fish species fed primarily on macroinvertebrates; but diet overlap between the species generally was not extensive because channel catfish consumed a more diverse array of foods, including more crayfish, fish and plant material. The use of foods other than macroinvertebrates increased as channel catfish grew larger. Bluegill also ingested large quantities of plant material at times, and ingestion of plants increased with fish size. Results of this study suggest that food competition between bluegill and channel catfish may occur when small channel catfish are abundant because, like bluegill, they feed almost entirely on macroinvertebrates and may reduce macroinvertebrate abundance. Thus, overstocking channel catfish in small impoundments managed for bluegill should be avoided.

KEYWORDS: bluegill, channel catfish, diet overlap, food habits, small impoundments, stocking.

Introduction

Channel catfish, *Ictalurus punctatus* (Rafinesque), are commonly stocked into small recreational fishing impoundments in the midwestern and southern United States to establish and maintain their populations (Michaletz & Dillard 1999). Without stocking, channel catfish abundance in these impoundments is usually low because of limited reproduction and predation on small channel catfish by largemouth bass, *Micropterus salmoides* (Lacepède), and other predators (Marzolf 1957; Krummrich & Heidinger 1973; Spinelli, Whiteside & Huffman 1985; Storck & Newman 1988). However, overstocking can cause high channel catfish abundance (Mitzner 1999), and some studies have reported reductions in growth and size structure of bluegill, *Lepomis macrochirus* Rafinesque, when channel catfish abundance was high (Crance & McBay 1966; Mitzner & Middendorf 1976; Mitzner 1989). These studies suggest that channel catfish may compete with bluegill for prey resources.

A prerequisite for competition between species is overlap in their use of prey and habitat resources. While channel catfish and bluegill are omnivorous, both commonly eat macroinvertebrates (Werner, Gilliam, Hall & Mittelbach 1983; Schramm & Jirka 1989; Hubert 1999; Olson, Paukert, Willis & Klammer 2003) and consequently may share prey resources. However, no published studies have examined diets of these two species concurrently in small impoundments; thus, the degree of diet similarity and overlap between these species remains unknown. Species with similar diets can coexist and reduce the potential for interspecific competition by using different habitats (Werner & Hall 1976, 1977; Werner, Hall, Laughlin, Wagner, Wilsmann & Funk 1977; Sale 1979). However, habitat partitioning in many small impoundments can be constrained by anoxia that occurs in the hypolimnion during summer stratification (Anderson, Reynolds, Lopinot, Hackney & Lockard 1978) that restricts fish to shallow water. Possibly because of this restriction, both channel catfish and bluegill are commonly found in shallow littoral areas in these impoundments (Michaletz & Sullivan 2002).

Extensive diet overlap between these species could explain reductions in growth and size structure of bluegill populations when channel catfish abundance is high (Crance & McBay 1966; Mitzner & Middendorf 1976; Mitzner 1989). At high abundances, channel catfish appear to reduce macroinvertebrate abundance

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(Michaletz, Doisy & Rabeni 2005), which may lead to prey shortages for bluegill and subsequent adverse effects on bluegill growth and population size structure. Information on prey consumption is necessary to interpret relations between channel catfish abundance and bluegill growth and size structure appropriately and, thus, determine desirable channel catfish stocking rates. Specific objectives were to determine prey selectivity and diet overlap of sympatric bluegill and channel catfish in two small impoundments that differed in the abundance of channel catfish.

Study area

Prey resource use by channel catfish and bluegill was evaluated in Blind Pony and Macon lakes during 1998–2000. Blind Pony (65 ha) and Macon (81 ha) lakes, located in central Missouri, USA, are shallow (mean depth < 5 m), moderately turbid (Secchi depths usually 0.5–1 m) impoundments that provide fisheries for largemouth bass, crappies, *Pomoxis* spp., bluegill and channel catfish. Channel catfish populations are maintained by annual stockings, because natural recruitment is non-existent. Gizzard shad, *Dorosoma cepedianum* (Lesueur), a potential competitor with bluegill (Aday, Hoxmeier & Wahl 2003; Michaletz & Bonneau 2005), was present in low abundance (< 20 fish h^{-1} of electric fishing, P. Michaletz, unpublished data) in Macon Lake and absent in Blind Pony Lake. Channel catfish was more abundant and grew faster in Blind Pony Lake than in Macon Lake (Table 1). Bluegill also grew faster in Blind Pony Lake, but the two impoundments had similar biomass per unit effort for bluegill (Table 1). Both impoundments are eutrophic, but Blind Pony Lake has higher nutrient concentrations and phytoplankton density (Table 1). Submerged vegetation was absent in Blind Pony Lake and scarce in Macon Lake. However, water willow, *Justicia americana* (L.), grew in about 15% of the shoreline and a few shallow coves were covered with fragrant water lily, *Nymphaea odorata* Aiton, in Macon Lake. Both impoundments thermally stratify at 2–4 m in June and destratify in September. Hypolimnia become anoxic, which forces fish to remain in the epilimnion for much of the growing season.

Materials and methods

Diets of channel catfish and bluegill were evaluated monthly from May to October for 3 years. Stomach samples were collected from channel catfish and bluegill captured by daytime electric fishing at haphazardly selected locations. Attempts were made to collect 20 stomach samples that contained food per month from each species. Channel catfish caught in overnight gill net sets were used to supplement electric fishing catches when necessary. All sizes of bluegill and channel catfish that were vulnerable to sampling, which included bluegills 40 mm total length (TL) and larger, and channel catfish 170 mm TL and larger were collected. Whole bluegills were retained for later food habit analysis. Plexiglass tubes (Van Den Avyle & Roussell 1980) were used to remove stomach contents from channel catfish. A squirt bottle was used to flush the stomach with water to facilitate removal of stomach contents. A flexible claw retriever (used in automobile repair for retrieving nuts and bolts) was also used to aid in removal of large prey (e.g. crayfish and fish). Whole bluegills and stomach contents of channel catfish were placed on ice and later frozen until they could be processed. In the laboratory, all organisms removed from the stomach were identified, counted and weighed (nearest 0.01 g) in aggregate. Mass of individual taxa was also determined directly

Table 1. Water quality and fish population characteristics in Blind Pony and Macon lakes. Catch per unit effort (CPUE) equals fish per h of night-time electric fishing for bluegill and fish per tandem hoop net fished for 3 days for channel catfish. Biomass per unit effort (BPUE) equals kg per h of night-time electric fishing for bluegill and kg per tandem hoop net fished for 3 days for channel catfish. For bluegill, CPUE and BPUE were grand means of May 1998, 1999 and 2000 data. For channel catfish, CPUE and BPUE were for May 2000 sampling only

Variable	Blind Pony	Macon	Source
Total phosphorus ($\mu g\ L^{-1}$)	94	50	J. Jones, unpublished data
Total nitrogen ($\mu g\ L^{-1}$)	1201	823	J. Jones, unpublished data
Total chlorophyll ($\mu g\ L^{-1}$)	37.5	23.9	J. Jones, unpublished data
Bluegill mean TL at age 4	157	137	P. Michaletz, unpublished data
Bluegill CPUE	205	357	P. Michaletz, unpublished data
Bluegill BPUE	16.9	16.7	P. Michaletz, unpublished data
Channel catfish mean TL at age 4	463	389	P. Michaletz, unpublished data
Channel catfish CPUE	83	11	Michaletz & Sullivan (2002)
Channel catfish BPUE	46.5	9.1	P. Michaletz, unpublished data

when possible. However, when mass of an individual taxon was below detection limits, mass was determined by visually estimating their portion of the total mass or a weighed portion (e.g. two or more taxa weighed in aggregate) of the stomach contents with the aid of average mass data for individuals of that same taxon from other stomach samples collected on the same date. Per cent mass for each prey taxon was computed for each individual fish and then averaged over all individuals for a sampling date and species. Mean per cent mass was used as an indicator of forage prevalence (Wallace 1981).

Differences in the proportion of macroinvertebrates in the diets (all taxa combined) among seasons and between impoundments for each species were tested with a repeated-measures mixed linear model (PROC MIXED, SAS Institute 1999); forage prevalence data were arcsine-square root transformed and compared among sampling periods and impoundments using impoundment, month and the interaction between impoundment and month as fixed effects and year as a random-block effect. Significant effects in the model were further analysed by comparing least-square means using *P*-values adjusted by the Tukey–Kramer method and significant interaction terms were further analysed using the SLICE option (LSMEANS statement, SAS Institute 1999).

The prevalence of foods in the diet may vary with size of the predator and this may influence diet overlap between species. Kruskal–Wallis tests were used to determine if the mean per cent mass of plants or fish in the diets varied with predator size using 50-mm TL groups for bluegill and 100-mm TL groups for channel catfish. For these analyses, predators were pooled over all sampling dates for each impoundment.

Diet similarity between bluegill and channel catfish was assessed using Mantel tests (Sokal & Rohlf 1995; Manly 1997; Legendre & Legendre 1998). This test compares the degree of similarity in diets among fish within a species with the degree of similarity in diets between fish species. For these tests, food habit data for each fish species were pooled into spring (May and June), summer (July and August) and autumn (September and October) to increase sample sizes and reduce the number of tests. Food items were grouped into chironomids, other dipterans, mayflies, caddisflies, odonates, megalopterans, other insects, zooplankton, snails, pelecypods, crayfish, fish, plants (algae and vascular plants) and other organisms. Bray–Curtis distance matrices of fish diet data (per cent mass of prey items per individual fish) were constructed using PopTools (Hood 2003) and converted to similarity matrices. These similarity matrices were then used to compute Mantel tests using the randomisation (Monte Carlo test) method with 9999 runs (PC-ORD, McCune & Mefford 1999). Significant Mantel tests indicated that bluegill and channel catfish diets were significantly different.

To evaluate prey selectivity, benthic macroinvertebrates were sampled concurrently with fish collections for food habit analysis. An Ekman grab sampler (23 × 23 cm) was used to collect benthic invertebrates at 10 randomly selected sites in the littoral zone in each lake. Benthic invertebrates were not collected from the limnetic zone because they are not available to predators for most of the growing season because of hypoxia. Macroinvertebrates were preserved in 10% formalin and later identified to order or family and counted.

Macroinvertebrate prey selection was quantified for channel catfish and bluegill using the linear index of food selection (Strauss 1979). Prey categories for this analysis were chironomids, chaoborids, ceratopogonids, caddisflies, pelecypods, mayflies, megalopterans and oligochaetes. These prey categories were chosen because they were either common in the environment, in fish stomachs or both. The linear index of food selection is defined as

$$L_i = r_i - p_i$$

where r_i = the proportion (by numbers) of prey item i in the fish's diet and p_i = the proportion of prey item i in the environment (Ekman grab samples). The index ranges from −1 to 1 with positive values indicating positive selection and negative values indicating negative selection. A value of 0 indicates neutral selection.

Results

Diets

For each monthly sample, a broad range of sizes of fish were collected for each species. For bluegill, TL typically ranged from about 60 mm to over 170 mm; mean TL ranged from 93 mm (October 1999 for Blind Pony Lake) to 148 mm TL (September 1999 for Blind Pony Lake). For channel catfish, TL typically ranged from about 300 to 600 mm; mean TL ranged from 385 mm (May 1999 for Blind Pony Lake) to 499 mm TL (October 1998 for Blind Pony Lake). Channel catfish were difficult to capture with electric fishing and gill netting; consequently, <20 individuals with food contents were collected most months (Fig. 1).

Both bluegill and channel catfish fed mainly on macroinvertebrates in both impoundments, but channel catfish diets were more diverse and included more

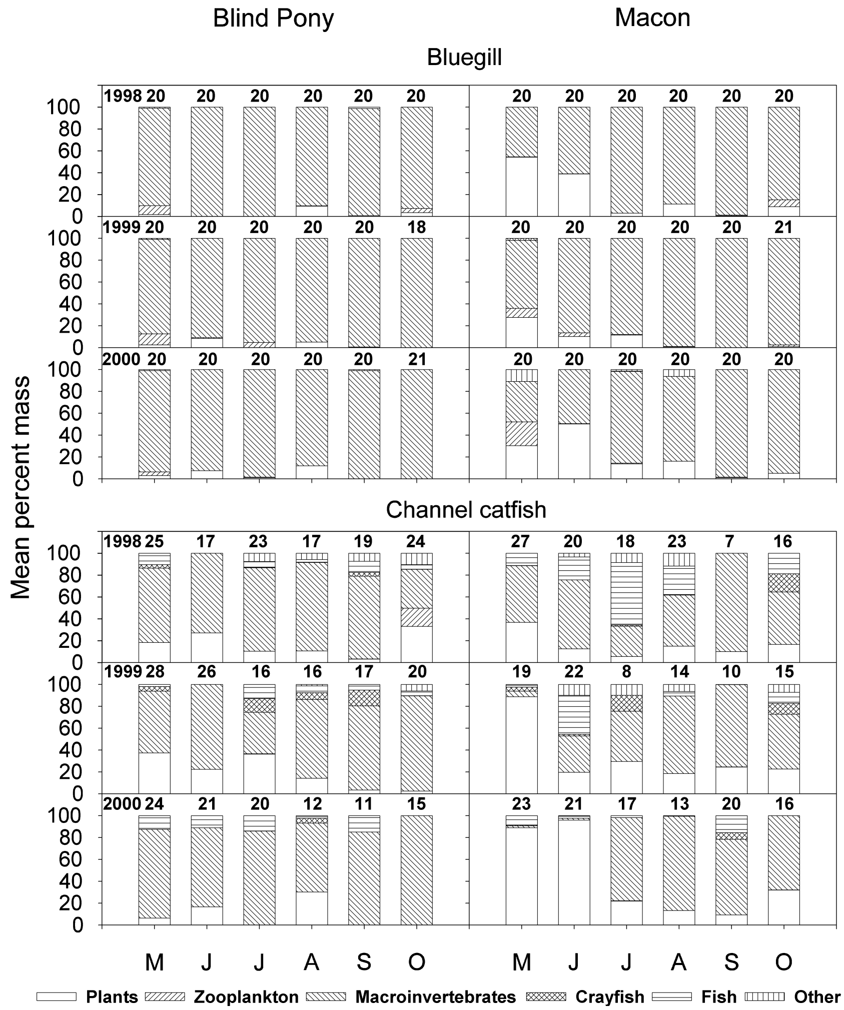

Figure 1. Mean per cent mass of food items found in bluegill and channel catfish collected from Blind Pony and Macon lakes during May through October, 1998–2000. The number on the top of each bar indicates the number of fish examined that contained food.

plants, crayfish and fish, especially in Macon Lake (Fig. 1). Seasonal and impoundment differences in macroinvertebrate prevalence in diets occurred for both fish species. Month and the impoundment × month interaction were significant (all $P < 0.0034$), but impoundment and year were not significant (all $P > 0.07$) in mixed linear models for both species. Further analysis revealed that macroinvertebrate prevalence in bluegill diets was significantly greater ($P < 0.0001$) in Blind Pony Lake than in Macon Lake during May and June. Similarly, channel catfish diets contained a greater proportion of macroinvertebrates ($P < 0.0001$) in Blind Pony Lake than in Macon Lake during May and June. Chironomids were the most commonly consumed macroinvertebrate by both bluegill (63% of macroinvertebrate biomass consumed) and channel catfish (52% of macroinvertebrate biomass). Other macroinvertebrates common in fish diets were mayflies, caddisflies and chaoborids. With the exception of chaoborids in channel catfish diets (12% of macroinvertebrate biomass consumed), none of these prey were more than 8% of the macroinvertebrate biomass consumed by either fish species. Zooplankton was mostly eaten by bluegill in the spring and was rarely ingested by channel catfish (Fig. 1). Both bluegill and channel catfish sometimes ingested substantial amounts of plant material, particularly in the spring in Macon Lake. The contribution of plant material to the diets of both bluegill and channel catfish increased with fish size in both impoundments (Fig. 2; Kruskal–Wallis test, all $P \leq 0.0005$). Fish also increased in dietary prevalence with size of channel catfish in both impoundments (Kruskal–Wallis test, both $P < 0.04$). Prey fish

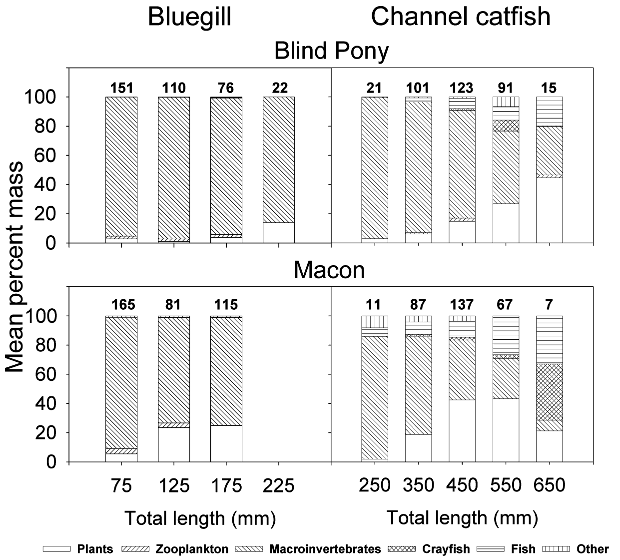

Figure 2. Mean per cent mass of food items found in 50-mm total length classes of bluegill or 100-mm classes of channel catfish collected from Blind Pony and Macon lakes during May through October, 1998–2000. The number on the top of each bar indicates the number of fish examined that contained food. Numbers on x-axis represent midpoints of each length category.

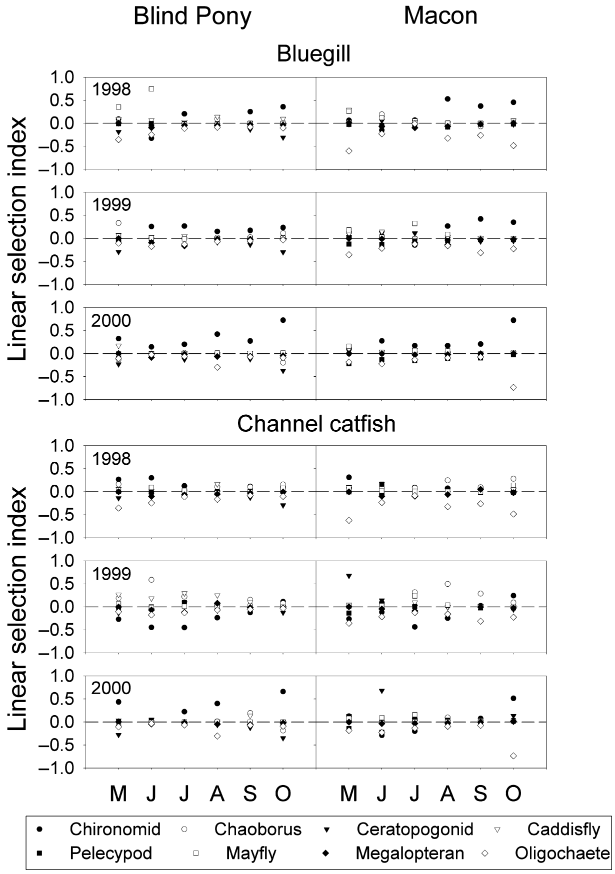

Figure 3. Mean linear selection index values (Strauss 1979) for macroinvertebrate taxa consumed by bluegill and channel catfish during May through October in Blind Pony and Macon lakes during 1998–2000. The dashed horizontal line at $y = 0$ indicates neutral selection.

consisted mainly of bluegill in Blind Pony Lake and bluegill and gizzard shad in Macon Lake.

Prey selectivity

Bluegill and channel catfish selected similar macroinvertebrate taxa in both impoundments (Fig. 3). Both fish species commonly preferred chironomids and caddisflies and avoided pelecypods, megalopterans and oligochaetes. However, during spring and summer of 1999, channel catfish appeared to negatively select chironomids in both impoundments. Chaoborids were also commonly selected by channel catfish. Mayflies and ceratopogonids were mostly consumed in proportion to their abundance by both fish species. There were no consistent seasonal trends in prey selection by either fish species, nor were there consistent differences among impoundments.

Diet overlap

Diet overlap among bluegill and channel catfish usually was not great because channel catfish consumed a more diverse array of foods. Diets of bluegill and channel catfish were most similar when both species fed almost exclusively on macroinvertebrates. These instances occurred during summer 1998, autumn 1999 and summer and autumn of 2000 in Blind Pony Lake (Table 2).

Discussion

Macroinvertebrates dominated the diets of bluegill and channel catfish in both study impoundments. Chironomids were most frequently consumed and preferred by both fish species, but caddisflies and mayflies were also common in diets. Macroinvertebrates were prevalent prey for all sizes of bluegills and zooplankton was relatively uncommon, similar to findings for other midwestern and southern lakes (Schramm & Jirka 1989; Olson *et al.* 2003). As channel catfish grew larger they exhibited diet shifts similar to those observed in other studies (Bailey & Harrison 1948; Ware 1967; Mathur 1971; Tyus & Nikirk 1990). Macroinvertebrates were most prevalent for smaller (< 400 mm TL) channel catfish with other foods

Table 2. Results of Mantel tests (standardised Mantel statistic, *r*) comparing prevalence of food consumed by bluegill and channel catfish from Blind Pony and Macon lakes during 1998–2000. Mantel tests with *P*-values ≤ 0.0028 (Bonferroni adjustment, 0.05/18 tests = 0.0028) indicate that diets of bluegill and channel catfish were significantly different

	Spring		Summer		Fall	
Year	*r*	*P*	*r*	*P*	*r*	*P*
Blind Pony						
1998	0.27	0.0001	0.01	0.09	0.14	0.0001
1999	0.25	0.0001	0.32	0.0001	0.04	0.007
2000	0.06	0.001	0.02	0.03	0.02	0.05
Macon						
1998	0.08	0.002	0.34	0.0001	0.18	0.0001
1999	0.24	0.0001	0.18	0.0001	0.15	0.0001
2000	0.26	0.0001	0.10	0.0003	0.13	0.0001

including fish, crayfish and plants becoming more prevalent as channel catfish grew larger.

Estimates of preferences of macroinvertebrate prey by bluegill and channel catfish may be biased in at least two ways. First, only the macroinvertebrate portion of the fish diets was compared with estimates of macroinvertebrate abundance; consequently 'preferred' macroinvertebrate prey may not be preferred in comparison with other non-macroinvertebrate prey. Secondly, the abundance estimates of macroinvertebrate taxa derived from Ekman grab samples were assumed to reflect the availability of prey to the fish. This may be valid for channel catfish that are primarily benthic foragers (Weisberg & Janicki 1990), but bluegill may feed in vegetation and in open water in addition to near or on the substrate (Werner & Hall 1974, 1976; Werner, Mittelbach & Hall 1981; Schramm & Jirka 1989). Therefore, it is possible that the relative abundances of macroinvertebrate prey available to bluegill may differ from the abundances estimated from Ekman grab samples. However, vegetation was not abundant in the impoundments and limnetic prey such as zooplankton were not common in bluegill diets, indicating that these foraging strategies may have been uncommon. Also, most bluegills were collected in areas that lacked vegetation. Ekman grab samples may have provided a reasonable estimate of prey availability because estimated prey selectivities were similar to those previously reported for bluegill (Schramm & Jirka 1989).

Both bluegill and channel catfish ingested large quantities of algae, especially in the spring in Macon Lake. Whereas channel catfish has been previously reported to ingest algae and other plant material (Ware 1967; Mathur 1971; Tyus & Nikirk 1990), no published studies have documented this for bluegill. Because stomachs sometimes contained several grams of algae it is unknown if algae were ingested incidentally while foraging for macroinvertebrates or intentionally ingested. If algae and other plant material had been excluded from the diet analysis, macroinvertebrates would have accounted for a much greater proportion of the diets of both bluegill and channel catfish during the spring in Macon Lake, and diet overlap between the fish species would have been greater.

The prevalence of macroinvertebrates and similarity of positively selected taxa suggests that channel catfish may compete with bluegill if food resources become limiting. Although this study found no evidence of competition despite the greater abundance of channel catfish in Blind Pony Lake, negative effects on bluegill populations have been associated with high densities of channel catfish in other lakes (Crance & McBay 1966; Mitzner & Middendorf 1976; Michaletz 2006). Results of this study suggest that food competition is most likely to result from high densities of smaller channel catfish, because like bluegill, these smaller channel catfish feed mostly on macroinvertebrates, and may reduce macroinvertebrate abundance (Mitzner & Middendorf 1976; Michaletz *et al.* 2005). Thus, overstocking of channel catfish should be avoided especially in lakes managed for bluegill.

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