INVESTIGATING INTERACTIONS BETWEEN CHANNEL CATFISH AND OTHER SPORT FISHES IN ALABAMA'S STATE PUBLIC FISHING LAKES

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INVESTIGATING INTERACTIONS BETWEEN CHANNEL CATFISH AND OTHER SPORT FISHES IN ALABAMA'S STATE PUBLIC FISHING LAKES

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THESIS ABSTRACT

INVESTIGATING INTERACTIONS BETWEEN CHANNEL CATFISH AND OTHER SPORT FISHES IN ALABAMA'S STATE PUBLIC FISHING LAKES

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Channel catfish *Ictalurus puntatus* is a popular sportfish maintained by annual stocking in Alabama's State Public Fishing Lakes. Channel catfish may negatively affect bluegill *Lepomis macrochirus* and largemouth bass *Micropterus salmoides* populations in these systems through direct and indirect effects of competition or predation. I sought to determine if channel catfish were becoming overly abundant in Alabama's State Public Fishing Lakes via stockpiling and if they were negatively affecting other sportfish populations.

Using a variety of gears, I sampled channel catfish, largemouth bass, and bluegill in twelve Alabama State Public Fishing Lakes from 2006-2007 that contained variable channel catfish abundances and population size structures. From these data, population statistics were calculated and compared to investigate potential relationships which may be associated with channel catfish negative effects. Four of these lakes (two with high channel catfish abundance and two with low channel catfish abundance) were sampled more intensively, including quarterly samples of diet of each fish species, to determine the potential for competition between species and to quantify channel catfish piscivory. From diet data, bioenergetics models were used to predict total annual consumption of average channel catfish and largemouth bass populations in a typical Alabama State Public Fishing Lakes.

Relative weights of channel catfish and bluegill were positively correlated, but channel catfish and largemouth bass relative weights were not related. Growth was not correlated between species, but latitude had an effect on growth of all species. No strong trends were found relating catfish abundances or population structures with any other sportfish population statistics. Channel catfish and bluegill diets were moderately similar, with little seasonal or among lake variability in similarity. Channel catfish and largemouth bass diets were dissimilar across all seasons in all lakes. Within a species, diet similarity was high among lakes. Percent of empty stomachs within a species also did not vary among lakes. From bioenergetics models, a typical channel catfish population was predicted to consume 32 kg/ha of fish (82% *Lepomis* sp. by number) annually, compared to 241 kg/ha of fish (77% *Lepomis* sp. by number) by a typical largemouth bass population.

I found no evidence to indicate channel catfish were negatively affecting bluegill and largemouth bass populations in most of Alabama’s State Public Fishing Lakes.

Because of the moderate similarity in diets between channel catfish and bluegill, the potential exists for competition between these species when prey resources are limiting. However, current stocking and exploitation rates in most lakes appeared to maintain channel catfish abundances below a level at which this may occur. One possible exception was in Marion County Lake, which had low bluegill CPUE, largemouth bass growth and condition, and extremely high channel catfish stocking rates. However, in all other study lakes, channel catfish piscivory appeared low enough to preclude any predatory (on bluegill) or competitive (with largemouth bass) negative effects on other sportfish. Current channel catfish stocking rates could probably be marginally increased to improve angler catch rates without causing any negative effects on other sportfish, although given the recent decline in number of anglers visiting Alabama’s State Public Fishing Lakes, this may not be necessary.

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INTRODUCTION

Catfishes *Ictalurus* spp. are a popular sport fish throughout North America. Michaletz and Dillard (1999) found that over 60% of surveyed agencies in the US and Canada rated catfish as being moderately or highly important to anglers. In a survey of Alabama anglers, catfish were rated as one of the top four targeted species, as well as the favorite fish to eat (Wright et al. 2003). This study also found that catfish angling in Alabama had increased in popularity over the previous 20 years. As popularity of catfish among anglers has increased, so has a desire to stock catfish in small (less than 100 hectare) impoundments. Dauwalter and Jackson (2005) found that 28 states offered specific recommendations for stocking channel catfish *Ictalurus punctatus* in small impoundments.

Nearly all channel catfish reproduction in small impoundments may be consumed by piscivorous fish (Marzolf 1957; Krummrich and Heidinger 1973; Spinelli et al. 1985); therefore, restocking is necessary to maintain populations. Typically, channel catfish of at least 200 mm total length are stocked into systems with established largemouth bass *Micropterus salmoides* populations, as fish of this size are large enough to avoid predation (Krummrich and Heidinger 1973).

The relatively high natural survival of stocked channel catfish in small impoundments makes stocking rate one of the most important factors in controlling their population size. Lakes in Iowa that were stocked at rates between 125-250 catfish fingerlings per hectare had nearly twice the biomass of smaller catfish and higher total standing stocks than lakes stocked at a rates ranging from 25 to 125 fingerlings per hectare (Hill 1984). Shaner et al. (1996) determined that biomass of channel catfish stocked, along with angler effort, explained 68% of the variation in the number and 56% of the weight of channel catfish harvested in Alabama's State Public Fishing Lakes. In a five year period from 1986-1990, 52-92% of all stocked channel catfish were harvested in an Illinois lake (Santucci et al. 1994). As these studies suggest, angler harvest combined with stocking rates are the two most important factors controlling channel catfish density, biomass, and harvest in small impoundments.

When overstocked and/or underharvested, channel catfish populations can become overabundant in small impoundments. Channel catfish growth in small impoundments can be negatively related to their density and, therefore, rate of stocking (reviewed in Hubert 1999), demonstrating situations where intraspecific competition is important. Evidence of interspecific competition, specifically with bluegill *Lepomis macrochirus*, also has been found. Both channel catfish and bluegill rely heavily on macroinvertebrates as a food source (Werner et al. 1983; Schramm and Jirka 1989; Hubert 1999), and at high abundances channel catfish can reduce macroinvertebrate abundance (Michaletz et al. 2005). Competition between channel catfish and bluegill was suspected in an Iowa lake in which biomass of benthic invertebrates was very low (10 kg/ha) (Mitzner 1989), and both species showed poor growth and condition. The average weight of bluegill and redear sunfish *Lepomis microlophus* in the first year after stocking was about 30% less in Alabama ponds stocked with 370 channel catfish per hectare than in ponds with 125 per hectare (Crance and McBay 1966). Michaletz (2006a) found a prevalence of macroinvertebrates in the diets of both bluegill and channel catfish smaller than 400 mm. This, in addition to a similarity of positively selected prey taxa between the two groups, suggested that catfish may compete with bluegill if food resources became limiting. Michaletz (2006b), found little evidence of competition between bluegill and channel catfish in experimental pond studies, but found consistently poor bluegill size structure and growth rates in lakes with high channel catfish catch-per-unit-effort.

Further, channel catfish competition with bluegill could have indirect influences on other piscivores, such as largemouth bass, by reducing the amount of prey available to these predator fish (as shown for the indirect effects of gizzard shad-bluegill competition on largemouth bass, DeVries and Stein 1992). As channel catfish grow, they become increasingly piscivorous (Bailey and Harrison 1948; Ware 1967; Busbee 1968; reviewed in Hubert 1999). This piscivory by catfish may lead to competitive interactions between channel catfish and largemouth bass, which typically are highly piscivorous in small impoundments (Hackney 1975). In addition, as many as 30-40% of channel catfish stocked in sport fishing ponds can become uncatchable by anglers, or “hook-shy” (Masser et al. 1993). As a result, a portion of the population may be large, piscivorous individuals that contribute little to the fishery and can have significant negative impacts on other fish populations.

In Alabama, sunfish in the genus *Lepomis*, are among the most-preferred fish groups targeted by anglers (Wright et al. 2003), and thus interactions between channel catfish and bluegill have important implications for anglers. Managers need to assess the costs and benefits of stocking channel catfish into small impoundments if their population-level consumptive demand could negatively influence bluegill populations. The effects of an increasing trend towards largemouth bass underharvest and over population in many small impoundments combined with catfish overabundance in these systems may result in a demand for forage species production that exceeds capacity.

In this study, I attempted to determine if channel catfish were negatively affecting bluegill and/or largemouth bass populations in Alabama's State Public Fishing Lakes. I quantified sport fish population statistics in selected Alabama State Public Fishing Lakes with variable channel catfish stocking rates and compared growth, condition, and size structure among sport fish and with channel catfish stocking and harvest rates in an effort to identify relationships among species. I predicted that if channel catfish were competing with bluegill or largemouth bass, then these species' population statistics would be negatively related to channel catfish abundance. To investigate seasonal trends, I quantified diets of channel catfish, bluegill, and largemouth bass throughout the year in lakes that had high or low channel catfish abundance and stockpiling and estimated diet overlap between channel catfish and bluegill and between channel catfish and largemouth bass to determine the degree of similarity in diets between these species. I also compared diets within species among lakes to determine if a species' prey selectivity changed based on channel catfish abundance. I predicted that if channel catfish were competing with either bluegill or largemouth bass, then differences in prey selectivity would be evident based on channel catfish abundance. Lastly, from diet data, as well as estimates of population size, I used bioenergetics models to predict annual consumption by channel catfish and largemouth bass in a typical Alabama State Public Fishing Lake.

STUDY SITES

The Alabama Department of Conservation and Natural Resources (ADCNR) manages Alabama State Public Fishing Lakes in twenty counties throughout the state (Figure 1). The State Lakes program was initiated in the late 1940s to provide quality fishing at an affordable price in areas of Alabama that lack sufficient natural waters to meet public needs (Turner 2002). Lakes range in size from 5-74 hectares (mean = 34) and in 2007, received a total of 145,110 angler visits (ADCNR unpublished data). Largemouth bass, bluegill, and channel catfish dominate most fish communities, with redear sunfish *Lepomis microlophus,* green sunfish *Lepmois cyanellus,* warmouth *Lepomis gulosus*, golden shiner *Notemigonus crysoleucas*, gizzard shad *Dorosoma cepedianum*, threadfin shad *Dorosoma petenense*, crappie *Pomoxis* spp., mosquitofish *Gambusia affinis*, grass carp *Ctenopharyngodon idella*, brown bullhead *Ameiurus nebulosus*, and white catfish *Ameiurus catus* also present in some lakes. Channel catfish are stocked yearly between November and February, and in 2007 lakes received an average of 140 channel catfish/ha at an average size of 250 mm (ADCNR unpublished data). Lakes are managed using typical pond management approaches, including fertilization, liming, and bass harvest (20-30 kg/ha targeted annually) to maintain good fishing opportunities for largemouth bass, *Lepomis* spp., and channel catfish.

METHODS

Broad sampling

I sampled a suite of Alabama State Public Fishing Lakes in the fall of 2006 and 2007 to quantify sport fish population statistics, as well as to collect abiotic data on these lakes. Ten lakes were originally selected for this portion of the study to include lakes with differing channel catfish stocking (Table 1) and exploitation (Table 2) rates, as well as across the latitudinal gradient of Alabama. Lakes chosen for sampling in fall 2006 were Barbour, Bibb, Clay, DeKalb, Fayette, Lamar, Lee, Marion, Pike, and Walker County Lakes. In 2007, Crenshaw, Madison, and Monroe County Lakes replaced Bibb, Lamar, and Marion County Lakes in the sampling design.

Dissolved oxygen ($mg \cdot L^{-1}$; YSI Model 51 B meter) and temperature (°C) profiles were taken at 1 m intervals from the surface to the bottom at the deepest part of the lake. Secchi depth was measured, and a sample of water was collected and returned to the lab to determine chlorophyll-a concentration and turbidity. Chlorophyll-a concentration was determined by using an Aquafluor Handheld Fluorometer, and a MicroTPW Turbidimeter was used to quantify turbidity. Other information recorded was vegetation abundance, time of day, and cloud cover.

In 2006, two ten-minute daytime electrofishing transects were conducted along the shoreline within each lake. Three fifteen-minute transects were conducted in 2007 to increase sample sizes. Sites were randomly selected in an attempt to reduce site specific bias and include a mixture of habitat types and depths. All largemouth bass, crappie, bluegill, and other *Lepomis* spp. were collected, along with any channel catfish that were shocked. Total length (mm) and weight (g) were recorded for each individual. Up to 30 individuals of each species were placed on ice and returned to the lab, where saggital otoliths were removed, cleaned, stored dry, and aged by independent readers. Individuals were subsampled from across the size distribution collected for each species.

Because electrofishing can be less effective for sampling channel catfish in small impoundments than some other techniques (personal observation; see also Santucci et al. 1999), tandem hoop nets and fyke nets were used to collect channel catfish. In fall 2006, five fyke nets baited with 3-4 kilograms of cheese trimmings were set for 1-3 nights per lake. Due to low and highly variable channel catfish catch rates from fyke nets in fall 2006, tandem hoop nets (76-cm-diameter frames; 25-mm-bar measure mesh) were used in fall 2007. Tandem hoop nets (three hoop nets tied front-to-back in a series) have been successfully used to sample channel catfish in Missouri (Michaletz and Sullivan 2002) and Iowa (Flammang and Schultz 2007). Four series were baited with 2 kg of soybean meal and set at randomly-selected locations parallel to shore in 1-2 m depths for two nights (approximately 36 hours) per lake. Soybean meal has been found to produce equal or higher catch rates than cheese trimmings depending on time of year (Flammang and Schultz 2007), and is cheaper and less offensive to handle than cheese trimmings. Total length (mm) and weight (g) were recorded for all channel catfish collected, and up to 30 individuals from across the size range collected were returned to the lab where otoliths were removed as described in Buckmeier et al (2002), cleaned, and stored dry.

Channel catfish otoliths were processed for aging as outlined in Secor et al. (1991). Otoliths were imbedded in an epoxy solution and sectioned, after the epoxy was allowed to cure, with a low-speed diamond wheel saw (Model 650 – South Bay Technology, San Clemente, CA), taking a thin transverse section of the core. All other species' otoliths were read whole. Un-aged fished were assigned ages based on age-length keys for each species within each lake using Fisheries Analyses and Simulation Tools (FAST; Slipke and Maciena 2006). Mean length-at-age (MLA) was calculated for each species and age combination as the mean length of individuals at time of collection.

Relative weight was calculated for individual fish as an estimate of condition (Wege and Anderson 1978). Mean relative weight was calculated for each species within each lake. Proportional stock density (PSD; Anderson and Neumann 1996) was calculated for each species in each lake. Catch-per-unit-effort (CPUE) for largemouth bass and bluegill was calculated as the number of fish collected per hour in electrofishing transects.

Channel catfish stocking and harvest data were obtained for each lake (ADCNR, unpublished data). Average number stocked per hectare per year and relative annual exploitation (number harvested in year *x* / number stocked in year *x*) were calculated from the previous seven years of data (oldest channel catfish collected was age-7) for 2006 and 2007.

Data from 2006 and 2007 were pooled. Pearson correlation coefficients were calculated (SAS Institute 2003) between variables for five general analyses:

1) Mean relative weights among all pairwise species comparisons

2) Growth, measured as mean length-at-age-2, among all pairwise comparisons of species

3) Channel catfish stockpiling, measured as the percent of channel catfish collected over two years old, versus sportfish population statistics

4) Channel catfish stocking versus sportfish population statistics.

5) Channel catfish exploitation versus sportfish population statistics.

To reduce the number of tests run, only mean length-at-age-2 (MLA-2) for each species were used for growth comparisons, but MLAs within a species were generally strongly correlated. Lakes in which a relatively high amount of natural channel catfish reproduction was found (i.e., >20% of all channel catfish collected were younger than the age at which channel catfish are stocked; Table 3) were excluded from analyses involving MLA-2s, as naturally spawned channel catfish exhibited more rapid growth than stocked channel catfish and thus skewed MLA-2s in those lakes.

In those cases where latitude had a significant effect on MLA-2s, and therefore could mask relationships of MLA-2s with other variables, multiple regression (SAS Institute 2003) was used to determine if other variables were related to MLA-2s after holding for the effect of latitude using the equation:

$$\text{MLA-2} = b_0 - b_1\text{LAT} \pm b_2\text{VAR}$$

where MLA-2 is the mean length-at-age-2 of the species of interest, LAT is latitude, and VAR is the additional variable to be examined.

Focused sampling

Four lakes (Barbour, Clay, Lee, and Pike County lakes) were selected for additional sampling to quantify seasonal changes in interactions between channel catfish and other sport fishes. From preliminary sampling, lakes were classified as having either high or low channel catfish abundance and stockpiling based on differences in catch among those lakes (Table 4). Sampling began in September 2006, and occurred every other month beginning in February 2007. All sampling trips were conducted between late-afternoon and nighttime.

Abiotic data were collected as in the broad sampling. In addition, water temperature (°C) at 2 m was recorded every two hours in each lake using temperature loggers (Onset HOBO H8 logger). Electrofishing surveys were conducted until 30 largemouth bass (five individuals in each of six size groups derived from length-frequency data) were collected. Total length (mm) and weight (g) were recorded for largemouth bass, and food items were removed using acrylic tubes (Van Den Avyle and Roussel 1980), after which the fish were released back into the lake. Largemouth bass stomach contents were placed in plastic bags, put on ice, and returned to the lab, where they were frozen and stored until processed. All bluegill shocked during electrofishing surveys were collected, and a subsample of up to 30 individuals (five individuals in six size groups) of each species were placed on ice and returned to the lab where their stomachs were removed, placed in vials, preserved in 95% EtOH, and stored until processed.

Channel catfish diets were obtained by collecting individuals via electrofishing, hook-and-line (jugging), and gill netting. A total of 40 jugs with hooks set at 1-6 m depths (based on dissolved oxygen and temperature profiles) were baited with frozen shad and set upon arrival at the lake. Jugs were fished 2-4 hours while abiotic and electrofishing surveys were conducted. Additionally, two 38 m long and 1.8 m tall experimental gill nets (five 7.6 m panels with 25.4, 38.1, 50.8, 63.5, and 76.2 mm bar mesh) were set during each sampling trip beginning in February 2008. Gill nets were set on the lake bottom perpendicular to shore and were fished 2-3 hours. Total length (mm) and weight (g) were recorded for all channel catfish, and their diets were removed and stored using the same methods as for largemouth bass.

To quantify diets, stomach contents were placed in a dish and viewed under a dissecting microscope. Prey items were identified to the lowest taxa possible (species or genus for fish, family or order for invertebrates). Length measurements recorded from zooplankton (body length) and macroinvertebrate items (e.g., head width, carapace length, total length) were converted to total dry biomass using regression equations from published literature (Smock 1980; Sage 1982; Culver et al. 1985; Leeper and Taylor 1998, Benke et al. 1999; Sabo et al 2002; Lailvaux et al 2004). Dry biomass was converted to wet biomass using ratios presented by Bottrell et al (1976) for zooplankton and Sage (1982) for macroinvertebrates. Fish, bryozoans, and decapods were converted directly to wet biomass from regression equations determined from this study and from Norris (2007). Prey items that were identified in a diet but on which measurements were unable to be taken (i.e. absence of measureable parts) were assigned a mean weight value of that prey item from other diets for the corresponding species and sampling date combination. Prey items were categorized into one of the following prey types: Bryozoa, caddisfly, Ceratopogonidae larvae, Chaoboridae larvae, Chironomidae larvae, crayfish, Crustacea, other dipteran, fish egg, fish, other macroinvertebrate, mayfly larvae, Odonata larvae, snail, or zooplankton. Percent biomass for each prey item was computed for each individual fish and then averaged over all individuals for a sampling season and species. Sampling seasons were classified as fall (September 1 – November 30), winter (December 1 – February 28), spring (March 1 – May 31), and summer (June 1 – August 31). Diet overlap was calculated using Schoener's index (Schoener 1971):

$$C_{xy} = 1 - 0.5(\sum | p_{xi} - p_{yi} |)$$

where C_{xy} is the overlap between species x and species y, p_{xi} is the proportion of prey type i used by species x, and p_{yi} is the proportion of prey type i used by species y. Index values range from 0 to 1, with 0 indicating no overlap and 1 representing complete overlap. Overlap values were calculated within a species among the four lakes, as well as seasonally between channel catfish and bluegill, and between channel catfish and largemouth bass. Proportions of empty stomachs found were compared within a species among lakes and among sampling gears for channel catfish using Chi-squared analysis.

Bioenergetics Modeling

Annual food consumption demands of channel catfish and largemouth bass were estimated with the generalized bioenergetics model and software by Hanson et al (1997) described as:

$$C = (R + A + S) + (F + U) + (B + G)$$

where C is consumption, R is respiration, A is active metabolism, S is specific dynamic action, F is egestion, U is excretion, B is somatic growth, and G is gonad production. Consumption and respiration are temperature and size dependent and egestion and excretion are functions of consumption. With temperature and fish size, the energy budget of each species was solved to estimate the amount of food that must be consumed to produce observed growth. Physiological parameters required to conduct bioenergetics modeling were taken from Rice et al (1983) for largemouth bass and from Blanc and Margraf (2002) for channel catfish.

All data were pooled from across the four lakes sampled for diets to generate a "typical" state lake, which was assumed to be 40 hectares in size. For the age-1.5 channel catfish cohort, simulations began on December 1 (corresponding to an approximate date of stocking typically found in the state lakes) and ran through September 31. For the age-0 largemouth bass cohort, simulations began on April 1 (corresponding to an approximate spawning date of largemouth bass in the state lakes) and ran through September 31. Simulations were run for 365 days from October 1 to September 31 for all other cohorts. Diet proportions (insect, crustacean, fish, zooplankton, other) were calculated seasonally for each cohort within each species.

Annual mortality for each species was estimated using weighted catch curve analysis in FAST. For channel catfish, cohort sizes were based on initial population density and subsequent mortality. Initial population density was set at 5,000, which was based on an average stocking density of 125 individuals per hectare typically found in the state lakes. For largemouth bass, cohort sizes were extrapolated from age-frequency, mean weight-at-age, and mortality estimates so that the total population biomass of largemouth bass in the system would be equal to 2,829 kg (based on density estimates from Swingle 1950). Above age-5.5 for channel catfish and age-6.5 for largemouth, cohort initial population sizes were less than 0.05% of the original population number; therefore simulations were ended at those age groups. To calculate start and end weights for each cohort, predicted mean length-at-age was first calculated using the von Bertalanffy (1938) growth equation based on mean lengths-at-age at capture for each species:

$$\mathrm{TL}_t = \mathrm{TL}_\infty (1 - e^{-K(t + t_0)}),$$

where TL_t is mean total length (mm) at age t, TL_∞ is the theoretical maximum total length, K is the growth rate, and t_0 is the theoretical time when length equals 0. Mean length-at-ages were then converted to mean weight-at-ages using length-weight regressions for each species.

RESULTS

Broad sampling

A total of 568 bluegill and 521 largemouth bass were collected in electrofishing transects in 2006, of which 213 bluegill and 263 largemouth bass were sacrificed for aging. From fyke nets, a total of 157 channel catfish were collected, of which 127 were sacrificed for aging. In 2007, a total of 3,289 bluegill and 1,251 largemouth bass were collected in electrofishing transects, with 365 bluegill and 359 largemouth bass being sacrificed for aging. From hoop nets, 1,083 channel catfish were collected in total, of which 272 were sacrificed for aging.

Because channel catfish were stocked at age-1 during the winter, all stocked fish would be age-2 or greater at the time of my fall sampling. Evidence of natural reproduction (individuals less than age-2) was found in four of the ten lakes sampled in 2007 (Table 3), and accounted for a substantial percentage of the total catch in two of the lakes (Barbour and Monroe County lakes). The average length of age-0 channel catfish in these lakes were all greater than 200 mm, thus these individuals were large enough to avoid predation (Krummrich and Heidinger 1973) and therefore recruit into the population. While no evidence of natural reproduction was found in 2006, the presence of both age-0 and age-1 individuals in Barbour and Monroe County lakes indicated that natural reproduction occurred in consecutive years, and the lack of finding individuals less than age-2 in 2006 may have been due to small sample size.

Relative weights: Mean relative weights of bluegill and channel catfish were positively related ($r = 0.58$, $P = 0.02$; Table 5). Largemouth bass mean relative weights were not related with bluegill mean relative weights nor with channel catfish mean relative weights ($P > 0.05$).

Growth: All species' MLA-2s were negatively related to latitude ($P < 0.05$; Table 6; Figure 2). Channel catfish and bluegill MLA-2s were positively correlated ($r = 0.89$, $P < 0.01$), but after accounting for the effect of latitude in the multiple regression equation, this relationship was no longer significant ($P > 0.05$).

Channel catfish stockpiling: The percentage of channel catfish collected over two years old was not related to any bluegill or largemouth bass population statistics ($P > 0.05$; Table 7).

Channel catfish stocking: Channel catfish, bluegill, and largemouth bass population statistics were not related to channel catfish stocking rate ($P > 0.05$, Table 8).

Channel catfish exploitation: Channel catfish relative exploitation was not related to any channel catfish or bluegill population statistics ($P > 0.05$; Table 8). However, channel catfish relative exploitation was negatively correlated with largemouth bass MLA-2 before accounting for the effect of latitude ($r = -0.71$ $P < 0.01$); after accounting for the effect of latitude in the multiple regression equation, the two were no longer significantly related ($P > 0.05$).

Focused sampling

A total of 966 bluegill, 186 channel catfish, and 1,064 largemouth bass diets were analyzed from all four lakes. All bluegill and largemouth bass were collected via electrofishing, as were 48 channel catfish. Additionally, 87 channel catfish were collected via jugging, and 51 were collected via gill netting. Frequency of empty stomachs did not vary by sampling method (Table 9); therefore all channel catfish diets were pooled regardless of sampling gear by which they were captured. For channel catfish and largemouth bass, frequency of empty stomachs did not vary among lakes (Table 10), but frequency of empty stomachs differed among the four lakes for bluegill (χ^2 =19.81; P = 0.0002).

Bluegill primarily consumed insects throughout the year (Figure 3), but increased the proportion of zooplankton consumed in the winter and spring. Channel catfish primarily consumed insects throughout the year (Figure 4). Largemouth bass primarily consumed fish throughout the year (Figure 5), but increased the proportion of insects and crustaceans consumed in the winter and spring. As bluegill increased in size, they consumed a smaller proportion of zooplankton and higher quantities of insects (Figure 6). Channel catfish became increasingly piscivorous with size in three of the four lakes, but still primarily consumed insects throughout all sizes (Figure 7). Of the 11 fish found in channel catfish diets, 9 were either bluegill or unidentifiable *Lepomis* species, and 1 was a largemouth bass. Largemouth bass primarily consumed fish throughout all sizes, and their consumption within size groups were more variable among lakes (Figure 8).

Bluegill diets were highly similar among the four lakes, with an average overlap of 0.73 (Figure 9). Largemouth bass diets also were highly similar among the four lakes, with an average overlap of 0.77 (Figure 10). Channel catfish diet similarities showed more variability between lakes and among lake comparisons (Figure 11), with similarities ranging from 0.43 to 0.79. Bluegill and channel catfish diets within lakes were moderately similar with an average overlap of 0.50, and showed no seasonal trends in similarity (Figure 12). Largemouth bass and channel catfish diets were dissimilar within each lake across all seasons (average overlap = 0.17; Figure 13).

Bioenergetics Modeling

Proportion of maximum consumption values (p-values) for channel catfish ranged from 0.52-1.09, and for largemouth bass ranged from 0.36-0.62 (Appendix H). Where calculated p-values exceeded 1, p-values were set to 1 for bioenergetics runs. Total annual population-level consumption by channel catfish in a 40 hectare lake was estimated at 21,727 kg, of which 20,233 kg were insects, 1,283 kg were fish, 118 kg were crustaceans, 2.2 kg were zooplankton, and 92 kg were other prey (Table 11). Overall consumption was highest in the age-1.5 cohort (10,279 kg), but consumption of fish was highest in the age-3.5 cohort (505 kg). Total annual population-level consumption by largemouth bass in a 40 hectare lake was estimated at 12,760 kg, of which 9,653 kg were fish, 2,257 kg were insects, 810 kg were crustaceans, 7.3 kg were zooplankton, and 32 kg were other prey (Table 12). Overall consumption was highest in the age-1.5 cohort (3,433 kg), as was consumption of fish (2,689 kg).

DISCUSSION

Past declines of other sportfish in some of Alabama's State Public Fishing Lakes when channel catfish abundances were high (Jack Turner, ADCNR, personal communication) suggested that either competition or predation by channel catfish in these systems might be important interactions. Other studies suggested that channel catfish need to be highly abundant to reduce size structure and abundance of bluegill (Crance and McBay 1966, Michaletz 2006b), and only after these negative effects on bluegill occurred would I expect to see negative effects on largemouth bass via reduced prey availability. However, at the densities currently maintained in most of the lakes I studied, I did not detect any evidence of these negative interactions. Below I step through the evidence to support this conclusion.

Channel Catfish and Bluegill

Michaletz (2006b) found evidence of intraspecific competition in channel catfish stocked at high densities in experimental ponds, with no evidence of interspecific competition between channel catfish and bluegill. Thus, intraspecific competition in channel catfish populations in small impoundments would probably occur at densities below the level at which negative effects on bluegill would occur. I found no evidence of intraspecific competition in channel catfish at densities currently maintained in study lakes. For example, in fall 2007, two of the highest channel catfish mean relative weights were found in Barbour County Lake (Wr = 99.8) and Lee County Lake (Wr = 99.6), which were both classified as high channel catfish abundance from ADCNR sampling. Channel catfish condition, length-at-age, and population size structure were not related to their stocking or exploitation rates, indicating that factors other than channel catfish density affected these population statistics at the range of channel catfish densities currently maintained in the lakes. Mosher (1999) found that abiotic factors such as precipitation, runoff, and fertility of the watershed were correlated with channel catfish growth.

No evidence was found to suggest that channel catfish and bluegill were competing in focused sampling study lakes. The moderate overlap in diet between these species indicated that if prey resources were limiting, these two species may compete. However, several observations suggest that was not occurring. The percentage of empty stomachs did not differ significantly among lakes for channel catfish, and though they did for bluegill, the population with the highest percentage of empty stomachs occurred in a lake with relatively low channel catfish abundance (Pike County Lake), indicating that something other than channel catfish abundance caused this phenomenon. If these species were competing, I would expect to see a higher proportion of empty stomachs in lakes with high channel catfish abundance, as less prey would be available. In addition, bluegill diets were highly similar among the four lakes, and while there was more variability in channel catfish diets among lakes, this variability was also not related to channel catfish abundance. For example, the highest similarity in channel catfish diets was between Lee and Pike County lakes, two lakes with differing channel catfish abundances. If competition was occurring between these species, I would expect to see more dissimilarity in diets between lakes with differing channel catfish abundances, as competing populations would be expected to shift their diet composition due to limiting prey resources.

Results from a consideration of population statistics also showed little evidence of channel catfish and bluegill competition. Mean relative weights of bluegill and channel catfish were positively related. Relationships between other bluegill population statistics and channel catfish stockpiling, stocking, or exploitation rates were not significant, indicating that these bluegill population statistics varied independent of channel catfish abundance. While bluegill CPUE was extremely low (18 fish/hr) in Marion County Lake, which experienced extremely high stocking rates, growth and condition of catfish and bluegill were not poor in the lake, suggesting that competition between and within species did not occur. Michaletz (2006b) only found evidence of competition between channel catfish and bluegill (i.e., poor bluegill size structure and growth rates) in lakes where channel catfish CPUE (as an indicator of channel catfish abundance) exceed 200 fish/tandem hoop net series.

Predation by channel catfish on bluegill appears to be relatively low. While channel catfish became increasingly piscivorous as they grew, and the majority (82% by number) of these prey fish items were bluegill or *Lepomis* sp., the proportion of these large, more piscivorous channel catfish in the population was not related to any bluegill population statistics, indicating that this piscivory was not affecting bluegill populations. This was supported by my bioenergetics modeling, which predicted a typical channel catfish population to consume 32.1 kg of fish per hectare annually, a relatively low number, especially when compared with largemouth bass fish consumption (241 kg/ha), the majority (77% by number) of which also were bluegill or *Lepomis* sp.

Channel Catfish and Largemouth Bass

No evidence was found to suggest that channel catfish and largemouth bass were competing in most study lakes. Diets between these species were relatively dissimilar, suggesting a low potential for competition. Largemouth bass diets were highly similar among lakes, indicating that differences in channel catfish abundance among lakes did not affect largemouth bass prey selectivity.

Results from broad sampling also showed no evidence of channel catfish and largemouth bass competition in most lakes. Mean length-at-age-2 and mean relative weights between these species were not related. Because channel catfish became increasingly piscivorous with size, populations with a higher abundance of large individuals may have more of an effect on largemouth bass populations through competition; however, no relationships were found between largemouth bass population statistics and the percent of large channel catfish (over two years old). No relationships were found between largemouth bass population statistics and channel catfish stocking or exploitation rates, indicating that these largemouth bass population statistics varied independent of channel catfish abundance.

In Marion County Lake, however, largemouth bass showed some evidence of negative effects related to catfish stocking rates. Relative weight and MLA-2 of largemouth bass were the lowest of all the lakes sampled. This, combined with the low CPUE of bluegill, suggest that the high channel catfish stocking rates in Marion County

Lake may have negatively affected largemouth bass growth and condition by reducing prey abundance, possibly through predation. Average channel catfish stocking rates in Marion County Lake (458/ha) were well beyond the range of average stocking rates found in all other Alabama State Public Fishing Lakes (79-279/ha), as this lake is managed specifically for high channel catfish yield. No evidence of negative effects of channel catfish was found in all other study lakes.

A typical channel catfish population was predicted to consume 32.1 kg of fish per hectare annually, compared to 241 kg/ha of fish annually by a typical largemouth bass population (77% *Lepomis* sp. by number). The relatively low additional consumption by channel catfish apparently had little effect on largemouth bass in most lakes. Also, only 9% (by number) of the prey fish items consumed by channel catfish were largemouth bass, so channel catfish consumption of largemouth bass in these systems appears to be minimal.

Effect of Latitude

Differences in growth related to latitude within a geographic region have been previously documented for largemouth bass (Bennett 1937; Ball 1952; Clugston 1964; Stone and Modde 1982; Belk and Houston 2002) and bluegill (Modde and Scalet 1985; Tomcko and Pierce 2001; Belk and Houston 2002), but had not been noted for channel catfish in the wild (Hubert 1999; Belk and Houston 2002). Latitude (or most likely, the differences in temperature related to latitude) was the most important factor I looked at affecting channel catfish growth in Alabama’s State Public Fishing Lakes, because intra- or interspecific competition did not appear to occur (i.e., little to no resource limitation) and other abiotic factors among lakes were relatively similar. Relationships between largemouth bass and bluegill MLA-2 and latitude were weaker than for channel catfish, indicating that factors other than temperature have stronger effects on their growth in these systems.

Bioenergetics Modeling

Bioenergetics simulations were run for an "average" channel catfish population, and in lakes with lower than average annual mortality and therefore greater abundances of large channel catfish, total annual consumption of fish by these channel catfish populations may be greater than my estimates. The level at which this predation would begin to have negative effects on other sportfish is unknown, but given that none of the lakes I sampled showed negative effects related to the abundance of large channel catfish, even those theoretically greater consumption rates that may occur in some lakes still would probably not be large enough to cause negative effects on other sportfish under stocking rates in most lakes. One possible exception may have been Marion County Lake, in which the exceptionally high channel catfish stocking rates may have resulted in high enough channel catfish abundances that their population-level consumption of bluegill may have reached a level at which it negatively affected largemouth bass.

The unreasonably high proportion of maximum consumption values for the age-1.5 and -2.5 channel catfish cohorts indicated that a systematic error may exist in the model for smaller channel catfish. Also, if prey energy density values used in this study (Appendix G) were lower than what naturally occurred in the environment, namely for insects, model runs would predict greater consumption rates to achieve observed growth, thereby inflating the proportion of maximum consumption value. This error would have a greater effect on smaller channel catfish cohort p-values, because these fish consumed higher proportions of insects than did larger channel catfish. However, given that my goal was to estimate annual consumption of fish, and that smaller channel catfish were less piscivorous than larger channel catfish, these errors probably would not significantly alter my overall population-level estimate of fish consumption by channel catfish.

MANAGEMENT IMPLICATIONS

The exceptionally high channel catfish stocking rates in Marion County Lake may have reduced bluegill abundance, causing poorer growth and condition of largemouth bass. In all other study lakes, I found no evidence of negative effects on bluegill or largemouth bass by channel catfish. However, some conditions I found could facilitate channel catfish stockpiling and overabundance even in those lakes with lower channel catfish stocking rates than occurred in Marion County Lake.

While it is unknown what factor or factors allowed for natural reproduction to occur successfully in some lakes, this should be closely monitored, as channel catfish populations in lakes in which natural reproduction occurs are more likely to become overabundant, due to stocking supplementing a potentially self-sustaining population. If natural reproduction is consistent in these lakes, stocking rates should be reduced or eliminated to lower the potential for stockpiling, and to reduce unnecessary expenditures related to stocking. Currently, the ADCNR monitors channel catfish populations in Alabama's State Public Fishing Lakes with trot line sampling; however age-0 channel catfish are not susceptible to this gear (Michael Holley, ADCNR, personal communication). Hoop nets were the only sampling gear I used that collected age-0 channel catfish. Therefore, I recommend that the ADCNR consider annual or semiannual hoop net sampling in Alabama's State Public Fishing Lakes following the procedures used in this study to monitor the presence and magnitude to which channel catfish natural reproduction occurs.

Because of the strong effect of temperature on growth combined with the positive relationship between channel catfish length and piscivory, negative effects on other sportfish due to this piscivory could occur more rapidly in southern latitudes than in northern latitudes. Therefore, channel catfish stockpiling should be monitored more closely in southern lakes. Largemouth bass and bluegill growth also was related to latitude, and appropriate management strategies among regions of the state may vary based on these differences in fish growth related to latitude.

Current channel catfish stocking rates in most of Alabama’s State Public Fishing Lakes appear to be maintaining densities below a level at which they would negatively affect bluegill and largemouth bass populations. The trend of declining stocking rates since 2000 (Figure 14) likely has reduced channel catfish abundances below a level at which these negative effects would occur. The overall number of angler visits has steadily declined since 1992 as well (Figure 15). As a result, the decline in stocking rates has roughly tracked the decline in number of anglers so that catch rates are similar to past levels (Figure 16). However, if improved angler catch rates are desired, channel catfish stocking rates could probably be marginally increased to improve angling success without causing any significant negative effects on other sport fish.

TABLES

Table 1. Average channel catfish stocking rates from 1998-2007 in the twelve Alabama State Public Fishing Lakes sampled in this study, and associated coefficient of variation (CV).

Lake	N stocked / ha	CV (%)
Marion	458	32
Pike	216	28
Madison	205	32
Fayette	179	15
Lee	162	42
Crenshaw	164	40
Clay	163	28
Lamar	150	43
Monroe	149	54
Barbour	141	33
Walker	134	24
DeKalb	129	26

Table 2. Average channel catfish relative annual exploitation from 1998-2007 in the twelve Alabama State Public Fishing Lakes sampled in this study, and associated coefficient of variation (CV).

Lake	Exploitation (%)	CV (%)
Marion	130	39
Walker	97	32
Lamar	90	34
Fayette	87	33
Pike	77	38
DeKalb	74	31
Clay	72	28
Monroe	63	34
Lee	63	33
Madison	61	50
Crenshaw	48	49
Barbour	45	32

Table 3. Number and percent of channel catfish less than age-2 collected from tandem hoop net sampling in fall 2007, and their associated mean total lengths.

Lake	Total N	N < Age-2	% < Age-2	Mean TL Age-0	Mean TL Age-1
Barbour	230	78	33	258	490
Clay	187	0	0	-	-
Crenshaw	0	0	-	-	-
Dekalb	113	0	0	-	-
Fayette	144	1	0.7	210	-
Lee	42	0	0	-	-
Madison	85	0	0	-	-
Monroe	41	26	63	304	473
Pike	24	0	0	-	-
Walker	217	1	0.5	205	-

Table 4. Channel catfish catches and lake classifications from ADCNR summer 2004 trotline sampling.

	Barbour	Lee	Clay	Pike
N	82	73	22	28
% > 508 mm	59%	62%	9%	4%
Abundance Classification	High	High	Low	Low
Stockpiling Classification	High	High	Low	Low

Table 5. Pearson correlation coefficients (r), p-values (P), and number of observations (N) for relationships between mean relative weights (Wr) of channel catfish (CAT), bluegill (BGL), and largemouth bass (LMB).

	BGL Wr			LMB Wr		
	r	P	N	r	P	N
CAT Wr	0.58	0.02	16	0.17	0.52	16
BGL Wr				0.15	0.52	19

Table 6. Pearson correlation coefficients (r), p-values (P), and number of observations (N) for mean length-at-age-2 (MLA-2) and latitude relationships for channel catfish (CAT), bluegill (BGL), and largemouth bass (LMB).

	CAT MLA-2			BGL MLA-2			LMB MLA-2		
	r	P	N	r	P	N	r	P	N
Latitude	-0.90	<0.01	14	-0.69	0.01	14	-0.61	0.01	16
CAT MLA-2				0.89	<0.01	11	0.34	0.30	11
BGL MLA-2							0.03	0.93	11

Table 7. Pearson correlation coefficients (r), p-values (P), and number of observations (N) for relationships between bluegill (BGL) and largemouth bass (LMB) population statistics and percent of channel catfish (CAT) collected over two years old.

BGL	CAT % > 2 years				LMB	CAT % > 2 years		
	r	P	N			r	P	N
CPUE	-0.45	0.08	16		CPUE	0.14	0.62	16
Wr	0.18	0.50	16		Wr	0.07	0.78	16
PSD	0.15	0.60	14		PSD	0.57	0.83	16
MLA-2	-0.08	0.79	13		MLA-2	-0.18	0.57	13

Table 8. Pearson correlation coefficients (r), p-values (P), and number of observations (N) for relationships between channel catfish (CAT), bluegill (BGL), and largemouth bass (LMB) population statistics and channel catfish stocking and exploitation rates.

	N Stocked/ha			% Harvested		
	r	P	N	r	P	N
CAT Wr	-0.05	0.85	16	0.12	0.65	16
CAT % > 2 years	0.09	0.75	16	0.33	0.20	16
CAT MLA-2	-0.01	0.99	14	-0.45	0.10	14
BGL CPUE	-0.45	0.06	19	-0.29	0.22	19
BGL Wr	0.11	0.65	19	-0.14	0.55	19
BGL PSD	0.32	0.21	17	0.41	0.10	17
BGL MLA-2	0.47	0.09	14	-0.43	0.13	14
LMB CPUE	-0.22	0.37	19	0.16	0.52	19
LMB Wr	-0.22	0.37	19	-0.26	0.29	19
LMB PSD	-0.10	0.68	19	-0.25	0.29	19
LMB MLA-2	-0.49	0.06	16	-0.69	<0.01	16

Table 9. Frequency of occurrence of empty stomachs in channel catfish in four lakes and with all four lakes pooled, and associated Chi-squared statistics.

Lake	Electrofishing	Jugging	Gillnetting	Chi-Sq	P
Barbour	12.5%	38.5%	16.7%	2.26	0.33
Lee	45.5%	20.9%	21.4%	2.86	0.24
Clay	10.0%	21.1%	0.0%	0.54	0.76
Pike	10.5%	25.0%	0.0%	1.08	0.58
All	18.8%	24.1%	15.7%	1.51	0.47

Table 10. Frequency of occurrence (%) of empty stomachs in bluegill, channel catfish, and largemouth bass in four lakes, and associated Chi-squared statistics.

Species	Barbour	Lee	Clay	Pike	Chi-Sq	P
Bluegill	6.0	6.2	5.4	15.0	19.81	<0.01
Channel Catfish	24.2	24.4	13.9	14.3	2.78	0.43
Largemouth Bass	18.1	22.3	21.9	23.0	2.38	0.50

Table 11. Predicted annual consumption of five prey types (in kg) consumed by channel catfish cohorts in a 40 hectare lake.

Age Group	Fish	Crustacean	Insect	Zooplankton	Other	Total
1.5	331.62	0.74	9,945.71	0.84	0.32	10,279.23
2.5	250.36	116.75	8,143.94	1.37	77.52	8,589.95
3.5	505.01	0.03	1,543.22	0	10.35	2,058.62
4.5	150.35	<0.01	460.02	0	3.10	613.49
5.5	45.63	<0.01	139.63	0	0.94	186.21
Total	1,282.97	117.52	20,232.52	2.21	92.23	21,727.50

Table 12. Predicted annual consumption of five prey types (in kg) consumed by largemouth bass cohorts in a 40 hectare lake.

Age Group	Fish	Crustacean	Insect	Zooplankton	Other	Total
0	715.33	10.35	345.40	1.90	10.41	1,083.40
0.5	2,494.77	63.83	524.22	0.58	2.19	3,085.59
1.5	2,689.35	159.29	583.93	0	0	3,432.56
2.5	1,749.00	267.72	371.36	2.22	8.76	2,399.06
3.5	1,022.61	157.54	219.75	1.33	5.33	1,406.55
4.5	552.86	85.47	119.58	0.73	2.95	761.58
5.5	286.05	44.31	62.11	0.38	1.55	394.39
6.5	143.04	22.19	31.13	0.19	0.78	197.32
Total	9,653.01	810.70	2,257.48	7.33	31.97	12,760.45

FIGURES

Lake	Number
Barbour	1
Clay	2
Lee	3
Pike	4
Crenshaw	5
DeKalb	6
Fayette	7
Lamar	8
Madison	9
Marion	10
Monroe	11
Walker	12
Bibb	13
Chambers	14
Coffee	15
Dale	16
Dallas	17
Escambia	18
Geneva	19
Washington	20

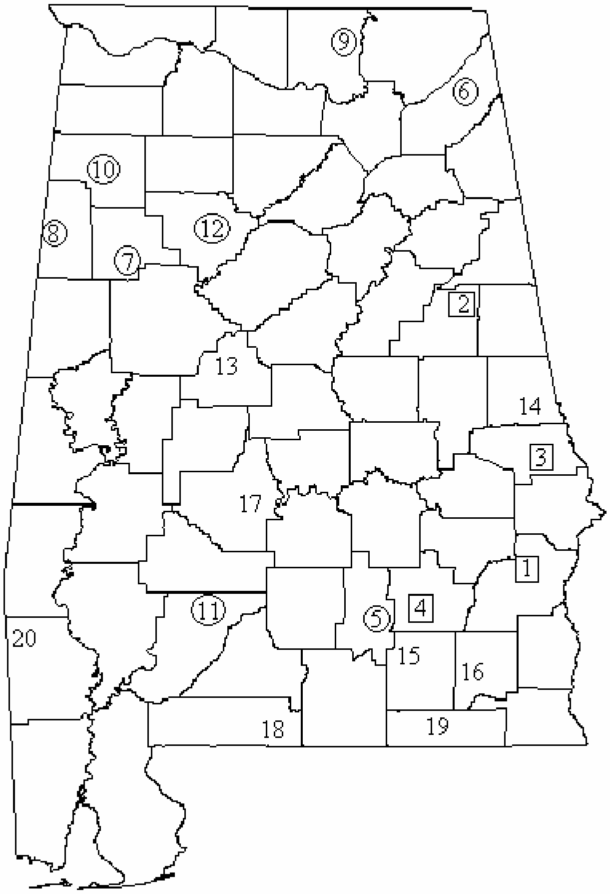

Figure 1. Locations of Alabama’s State Public Fishing Lakes. Boxed numbers indicate lakes sampled for both population statistics and diets, circled numbers indicate lakes sampled for population statistics only, and all other lakes were not sampled in this study.

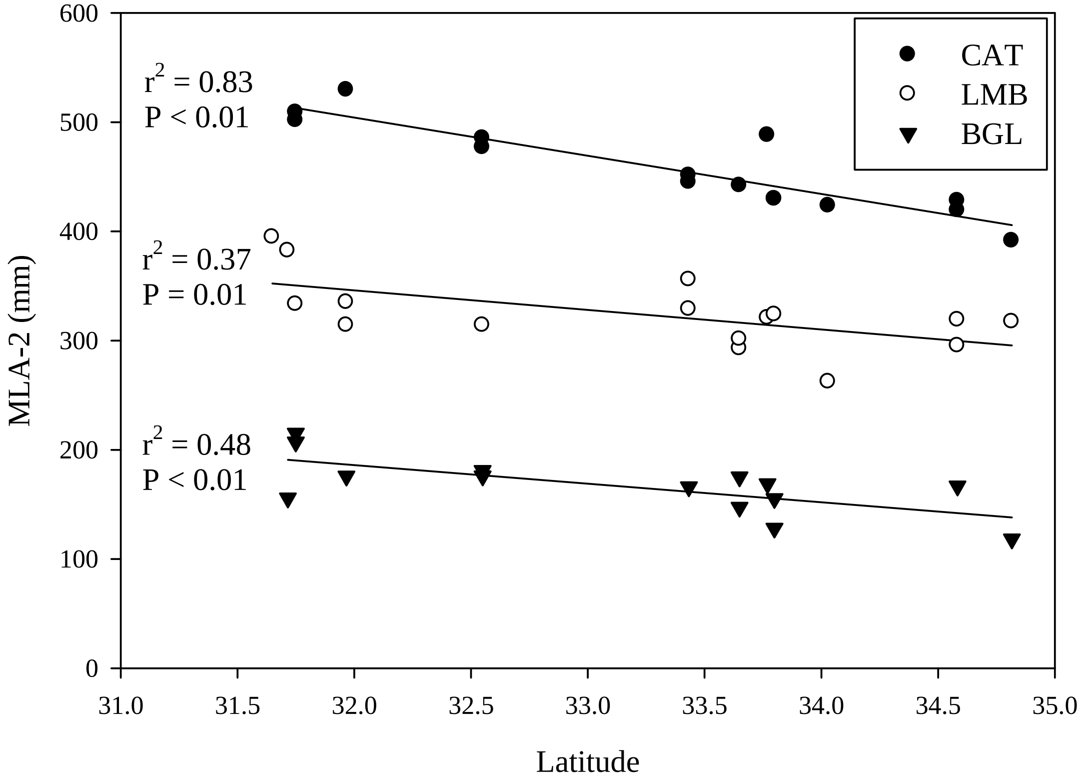

Figure 2. Relationships between channel catfish (CAT), largemouth bass (LMB), and bluegill (BGL) MLA-2 and latitude.

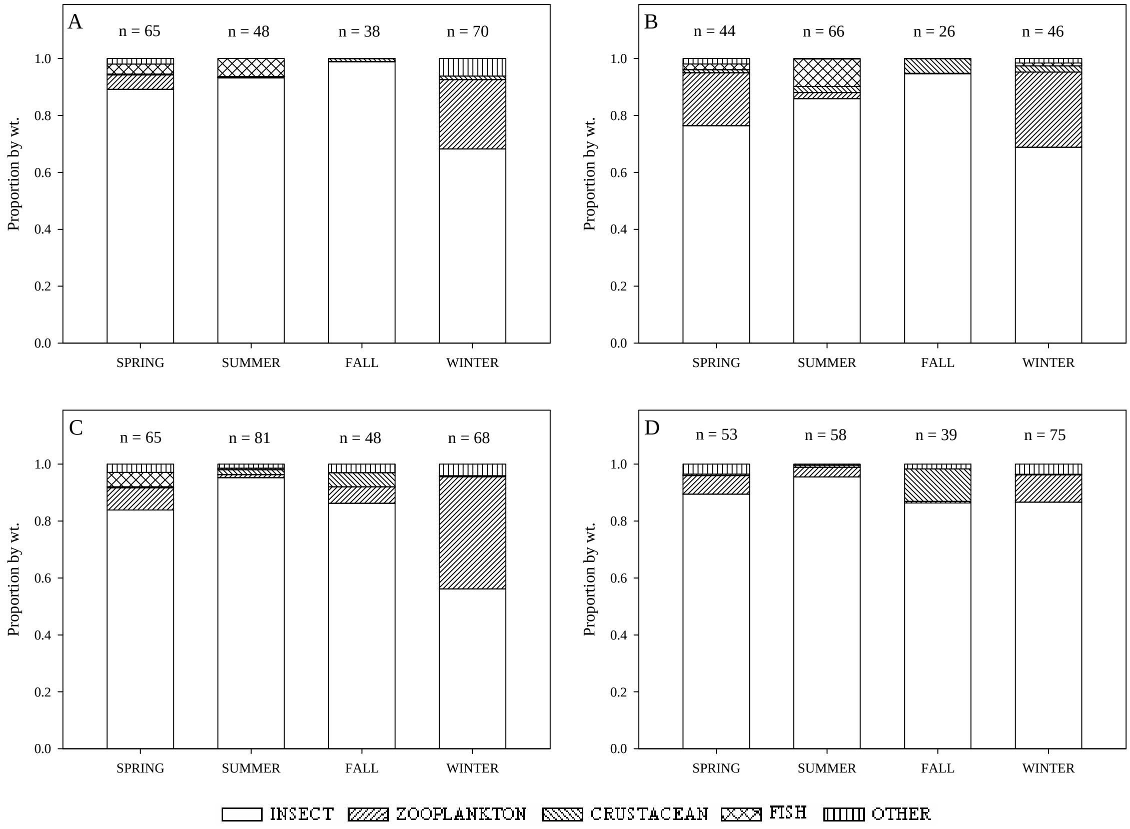

Figure 3. Proportion by weight of food items found seasonally in bluegill collected from Barbour (A), Lee (B), Clay (C), and Pike (D) County Lakes. The number on the top of each bar indicates the number of fish examined that contained food.

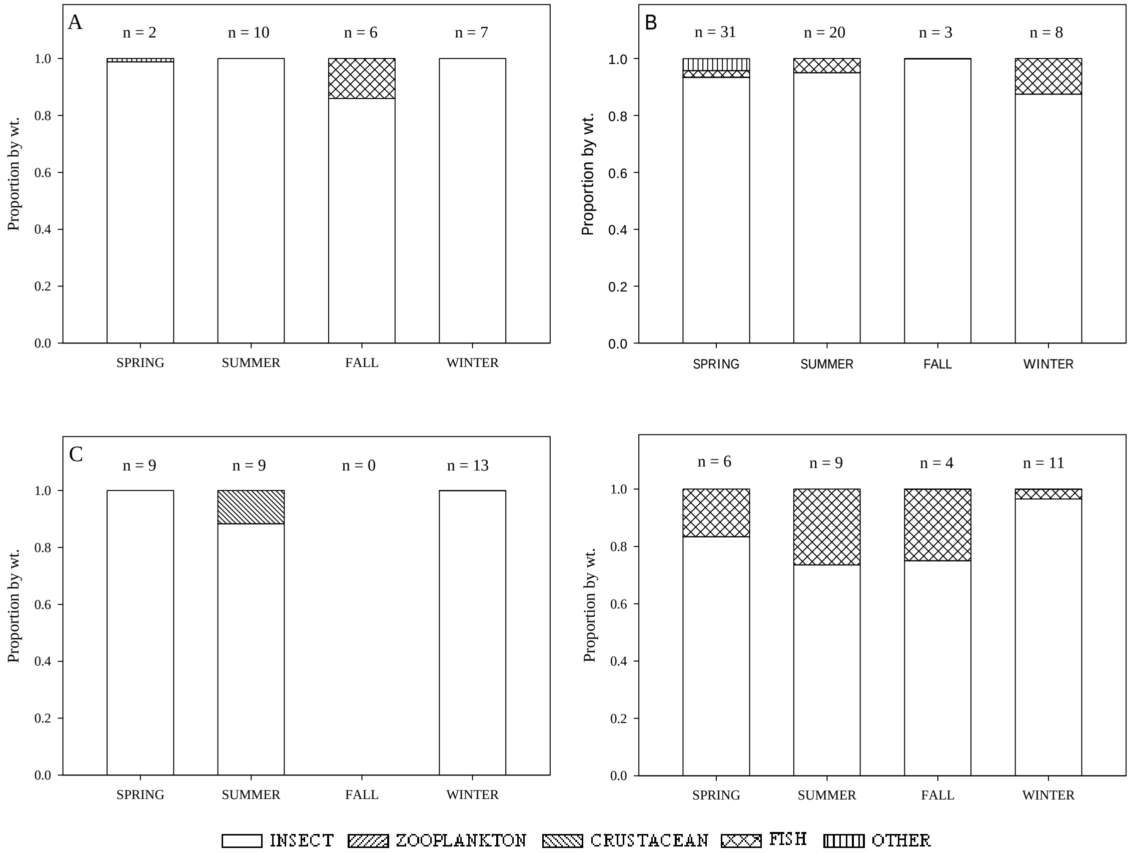

Figure 4. Proportion by weight of food items found seasonally in channel catfish collected from Barbour (A), Lee (B), Clay (C), and Pike (D) County Lakes. The number on the top of each bar indicates the number of fish examined that contained food.

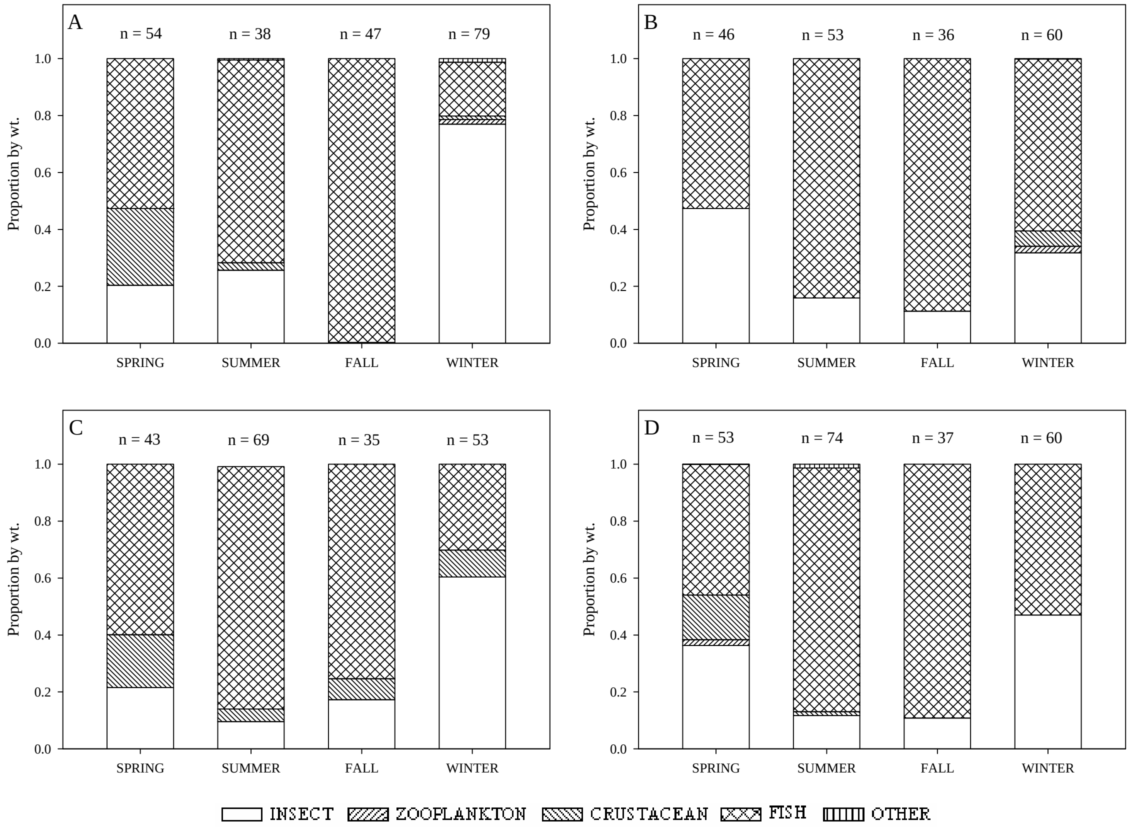

Figure 5. Proportion by weight of food items found seasonally in largemouth bass collected from Barbour (A), Lee (B), Clay (C), and Pike (D) County Lakes. The number on the top of each bar indicates the number of fish examined that contained food.

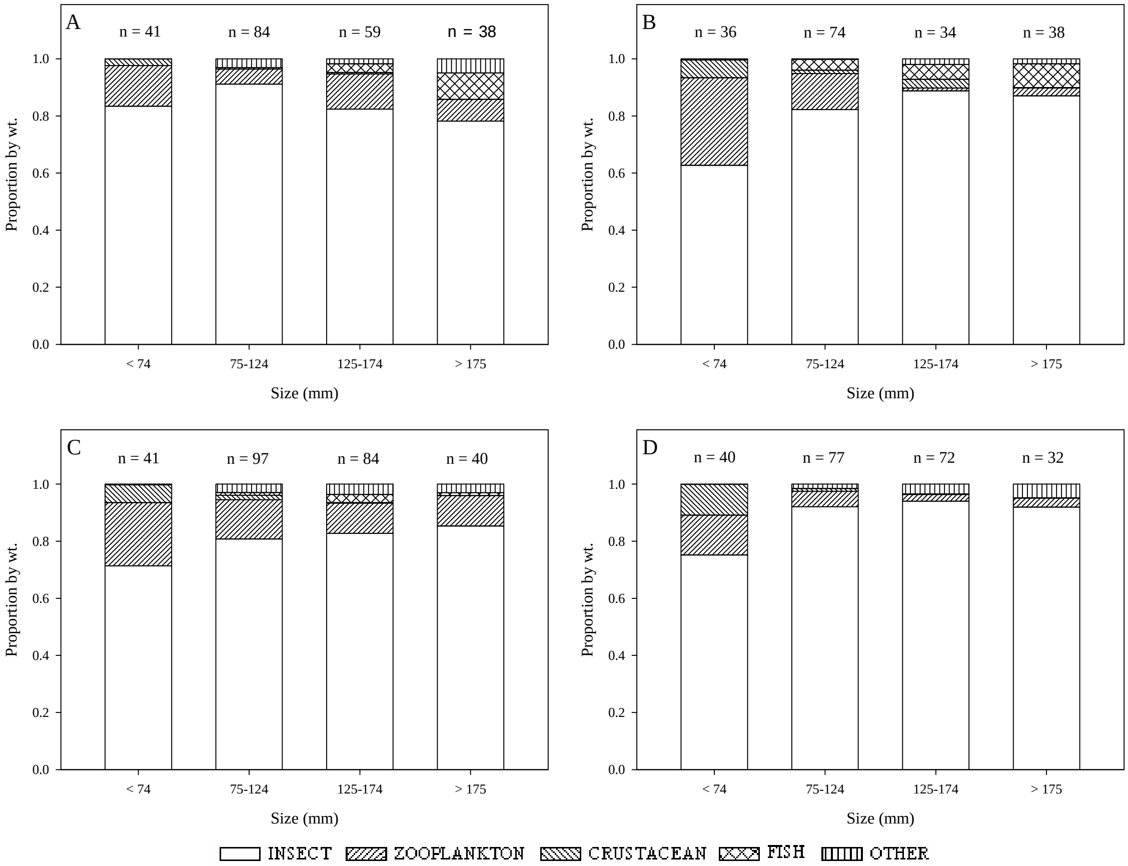

Figure 6. Proportion by weight of food items found in four bluegill size groups collected from Barbour (A), Lee (B), Clay (C), and Pike (D) County Lakes. The number on the top of each bar indicates the number of fish examined that contained food.

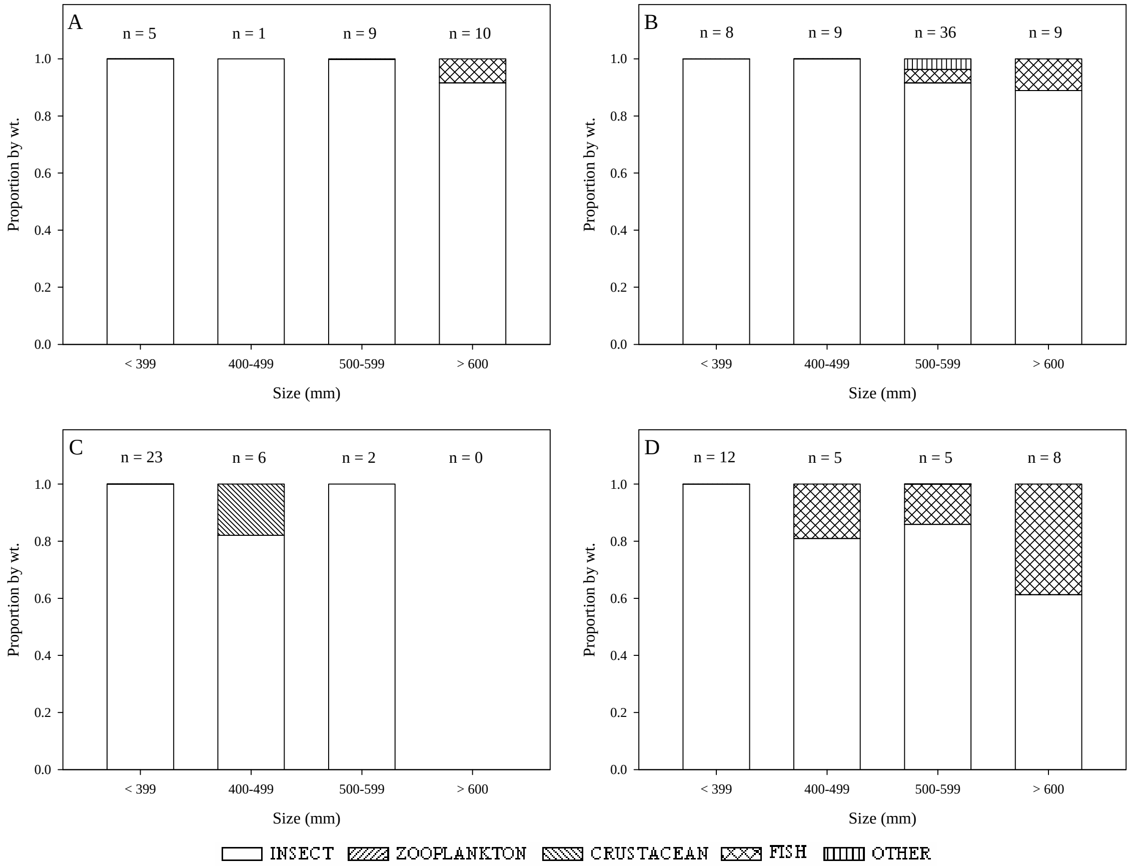

Figure 7. Proportion by weight of food items found in four channel catfish size groups collected from Barbour (A), Lee (B), Clay (C), and Pike (D) County Lakes. The number on the top of each bar indicates the number of fish examined that contained food.

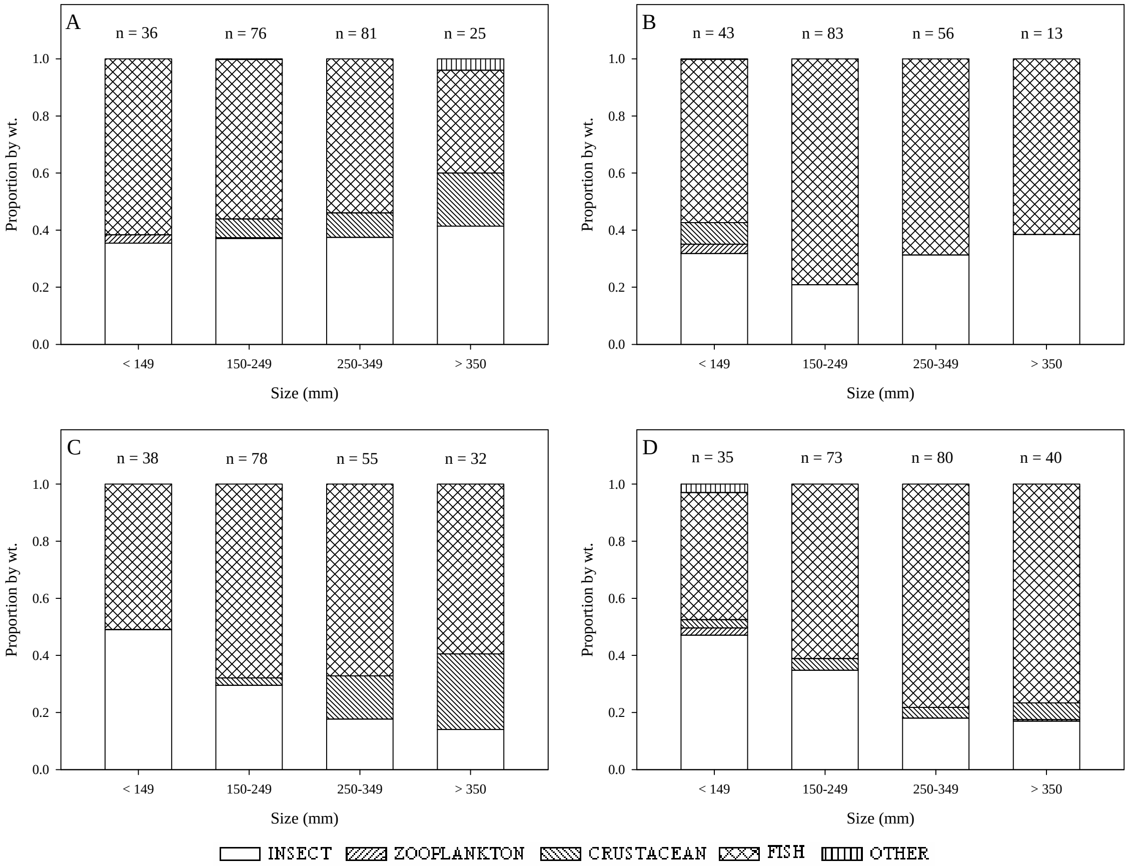

Figure 8. Proportion by weight of food items found in four largemouth bass size groups collected from Barbour (A), Lee (B), Clay (C), and Pike (D) County Lakes. The number on the top of each bar indicates the number of fish examined that contained food.

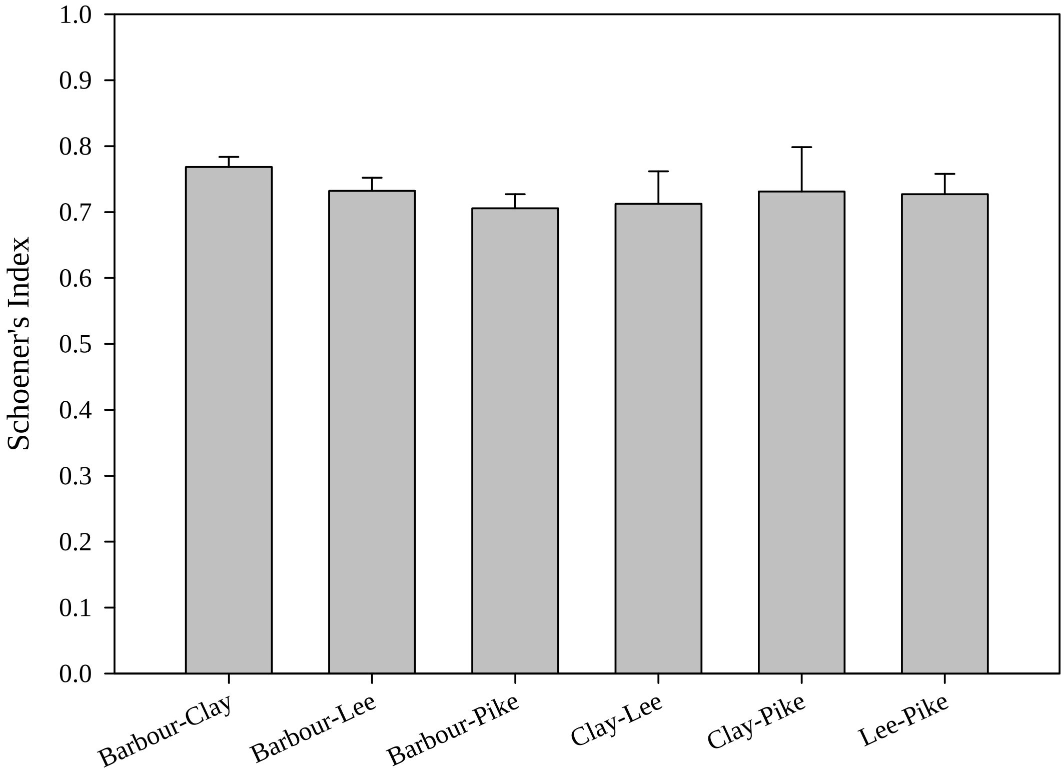

Figure 9. Schoener’s index values for pairwise lake comparisons of bluegill diets. Error bars indicate seasonal variation in diet similarity.

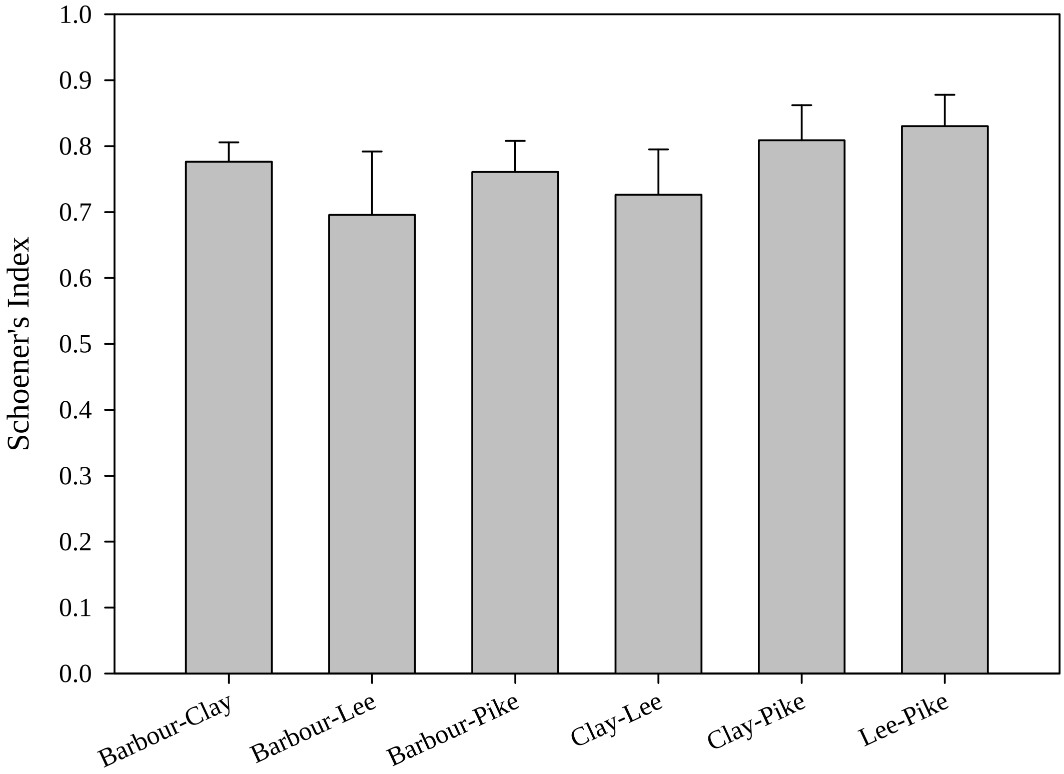

Figure 10. Schoener’s index values for pairwise lake comparisons of largemouth bass diets. Error bars indicate seasonal variation in diet similarity.

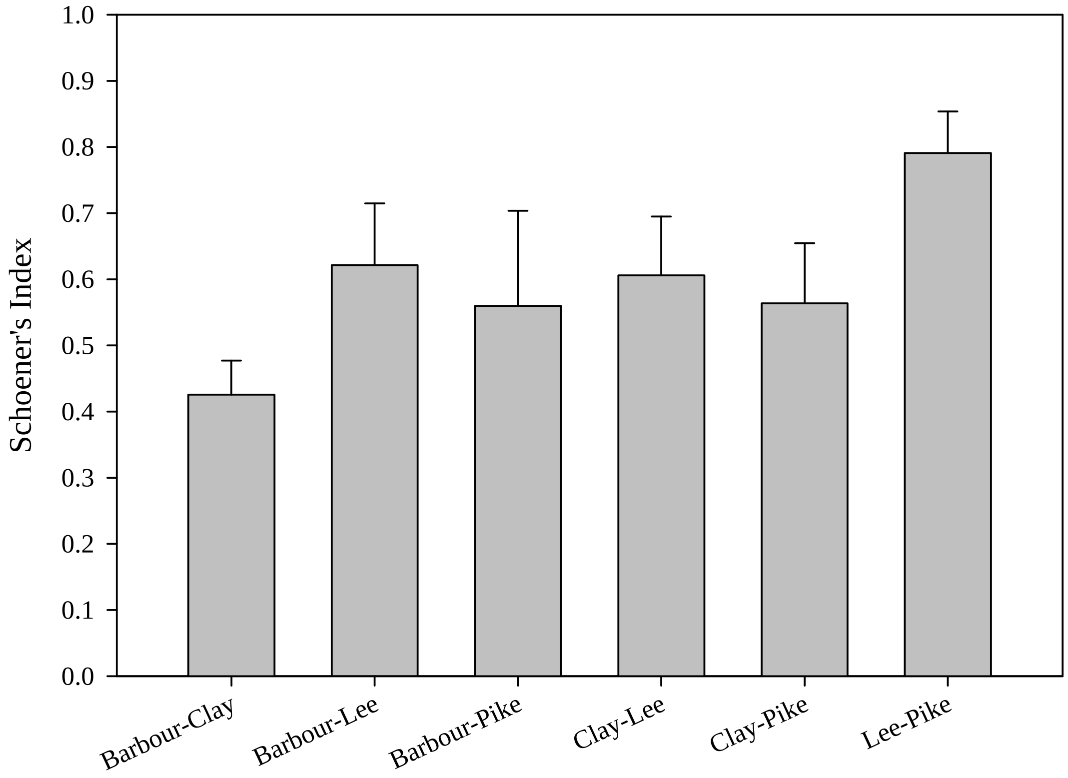

Figure 11. Schoener’s index values for pairwise lake comparisons of channel catfish diets. Error bars indicate seasonal variation in diet similarity.

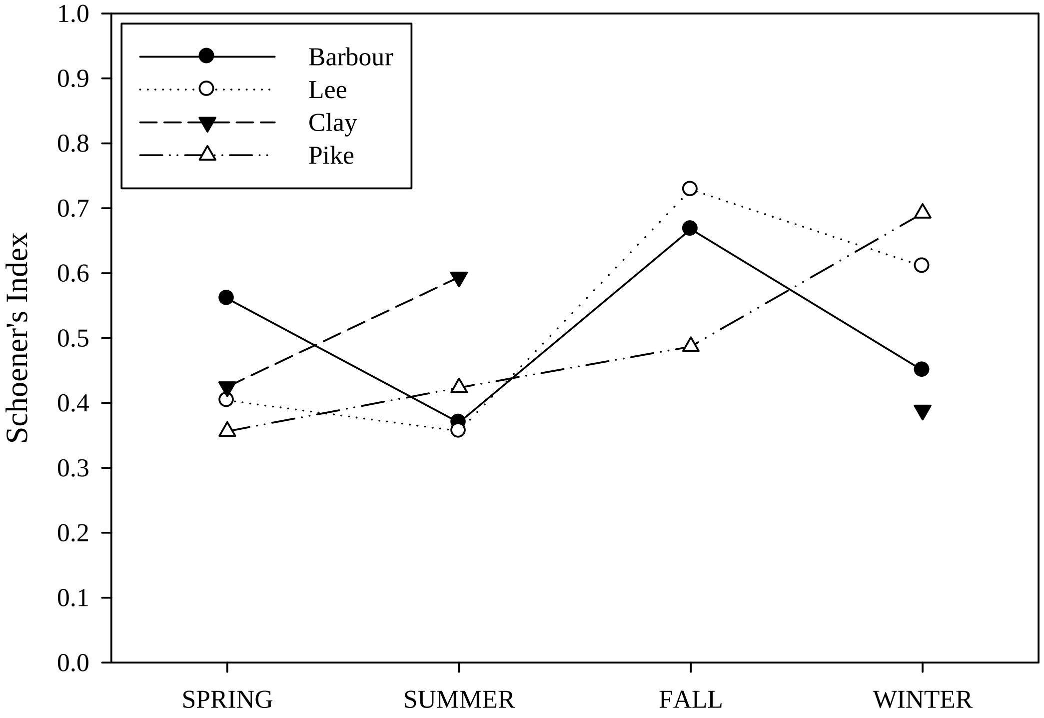

Figure 12. Schoener’s index values for channel catfish and bluegill within each sampling season in four Alabama State Public Fishing Lakes.

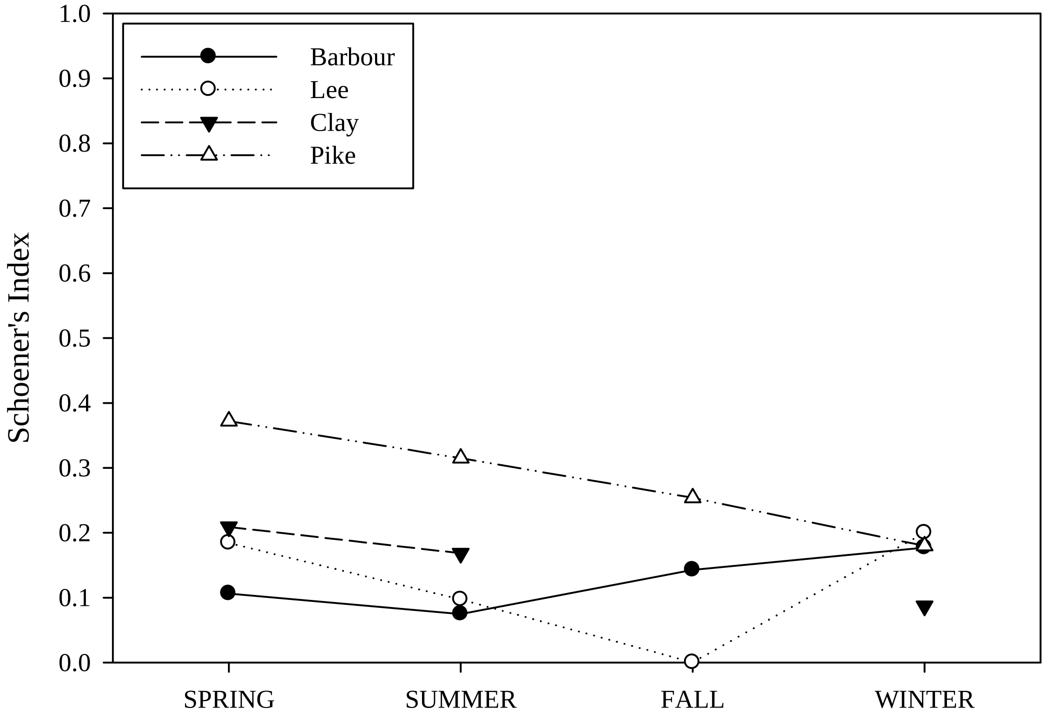

Figure 13. Schoener’s index values for channel catfish and largemouth bass within each sampling season in four Alabama State Public Fishing Lakes.

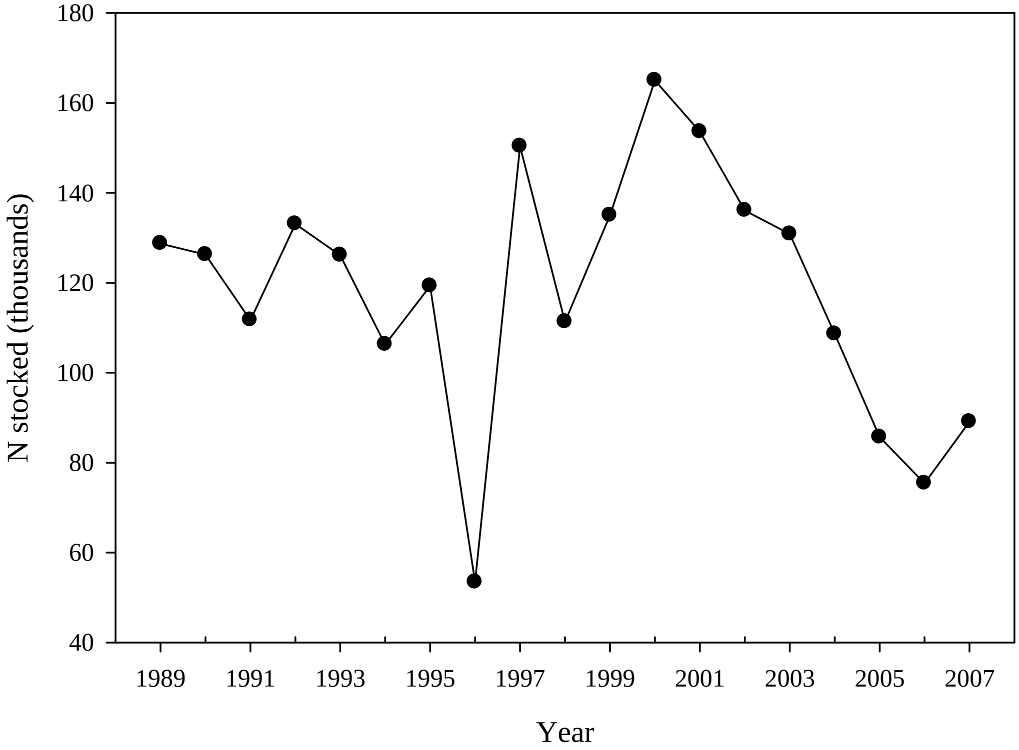

Figure 14. Total number of channel catfish stocked in Alabama's State Public Fishing lakes from 1989-2007.

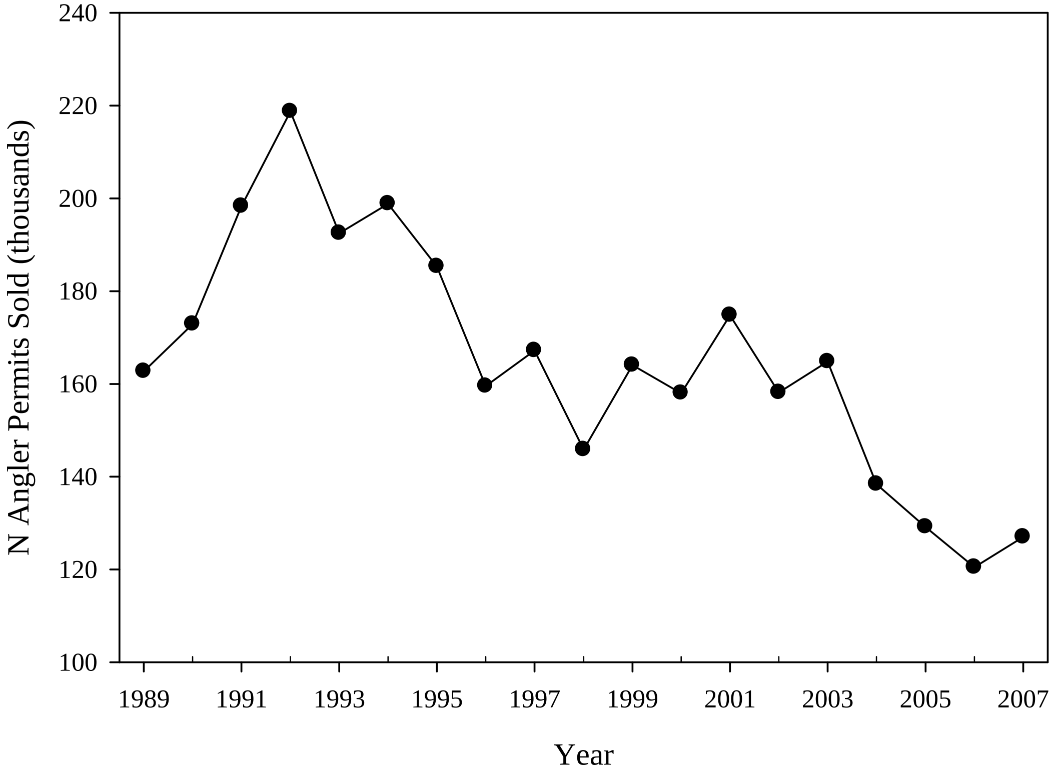

Figure 15. Total number of angler permits sold in Alabama’s State Public Fishing lakes from 1997-2007.

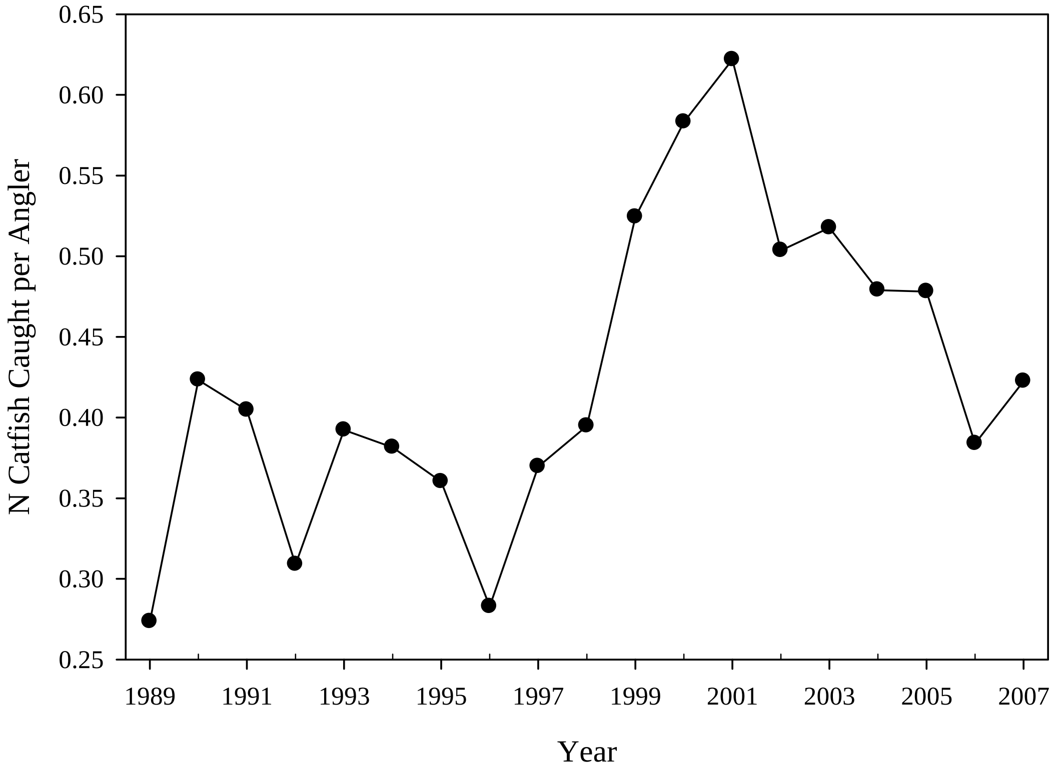

Figure 16. Number of channel catfish caught per angler in Alabama's State Public Fishing lakes from 1997-2007.

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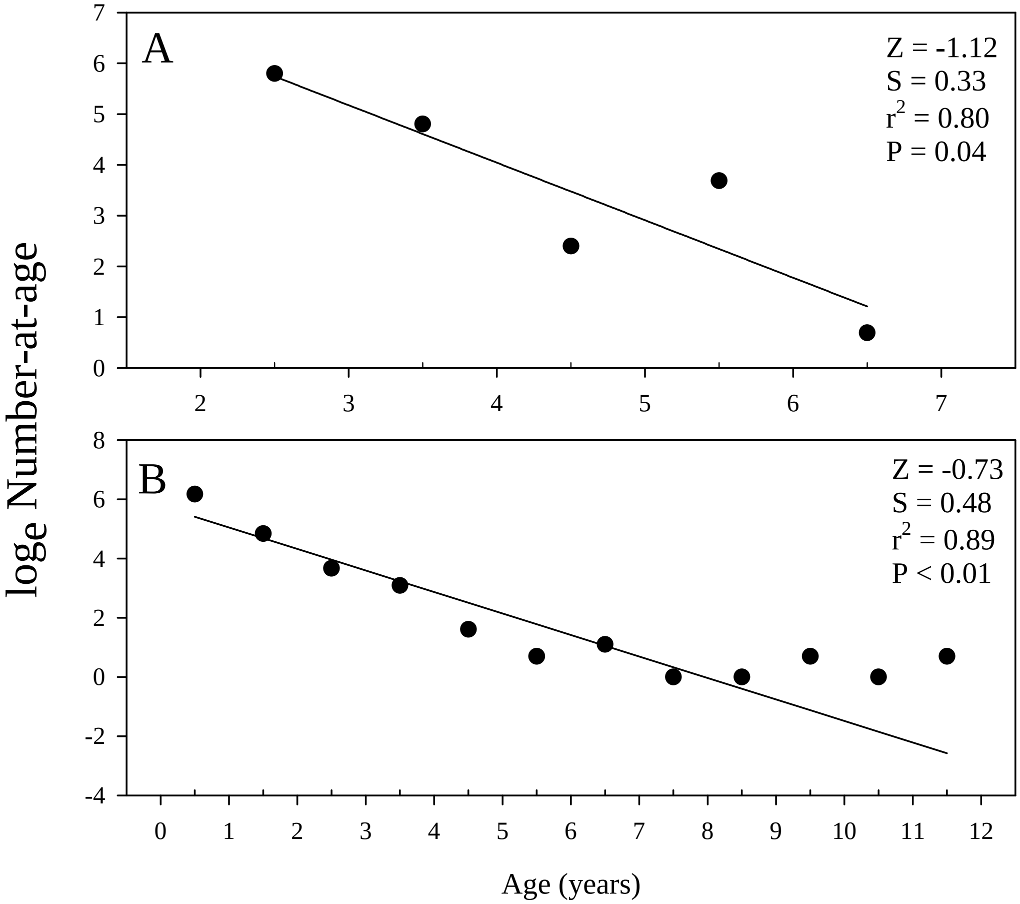
APPENDICES

Appendix A. Number of channel catfish collected in fyke nets and number of nights nets were set in fall 2006.

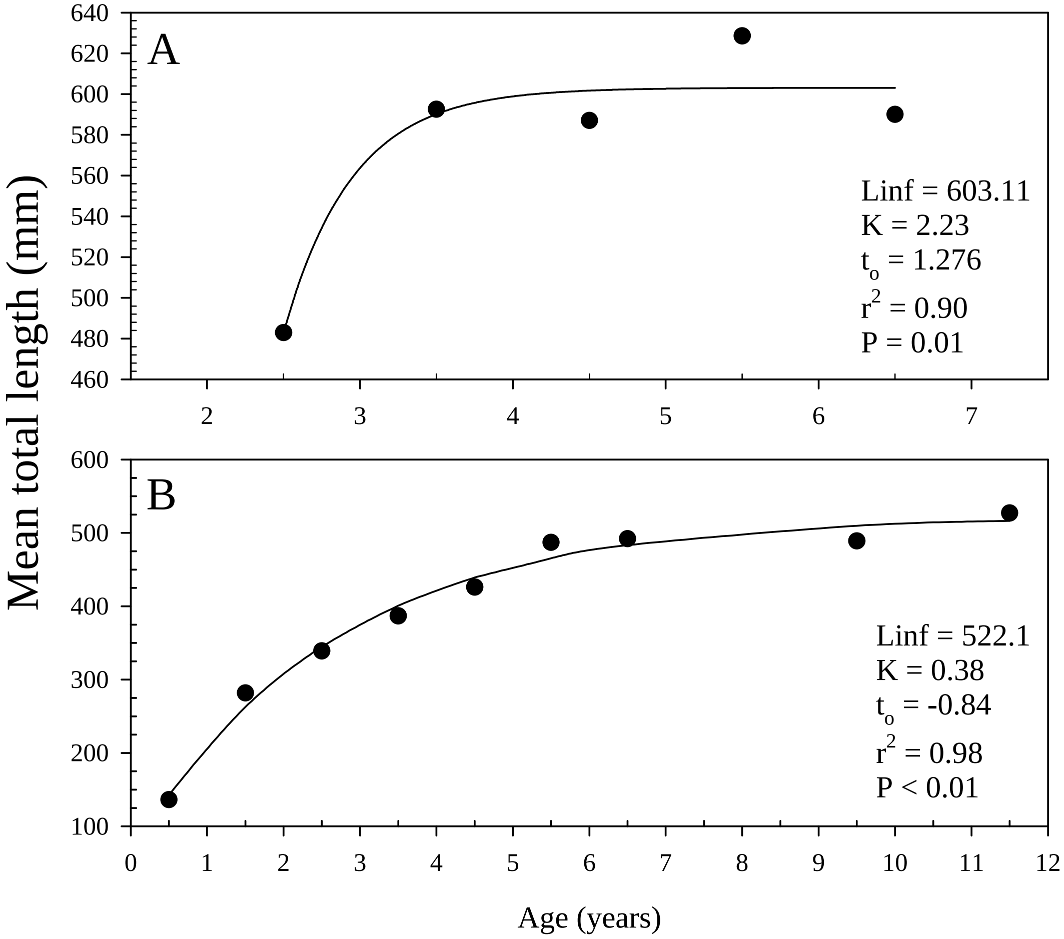
Lake	Net 1	Net 2	Net 3	Net 4	Net 5	Total	Net-Nights
Barbour	0	0	0	1	0	1	3
Clay	6	0	3	0	3	12	3
DeKalb	0	0	1	2	0	3	2
Fayette	0	0	0	0	0	0	1
Lamar	0	0	0	8	0	8	1
Lee	0	1	0	8	3	12	1
Marion	0	2	0	0	6	8	1
Pike	8	1	0	39	2	50	2
Walker	0	21	0	0	30	51	1

Appendix B. Number of channel catfish collected in front (F), middle (M), and back (B) hoop nets set in tandem in fall 2007.

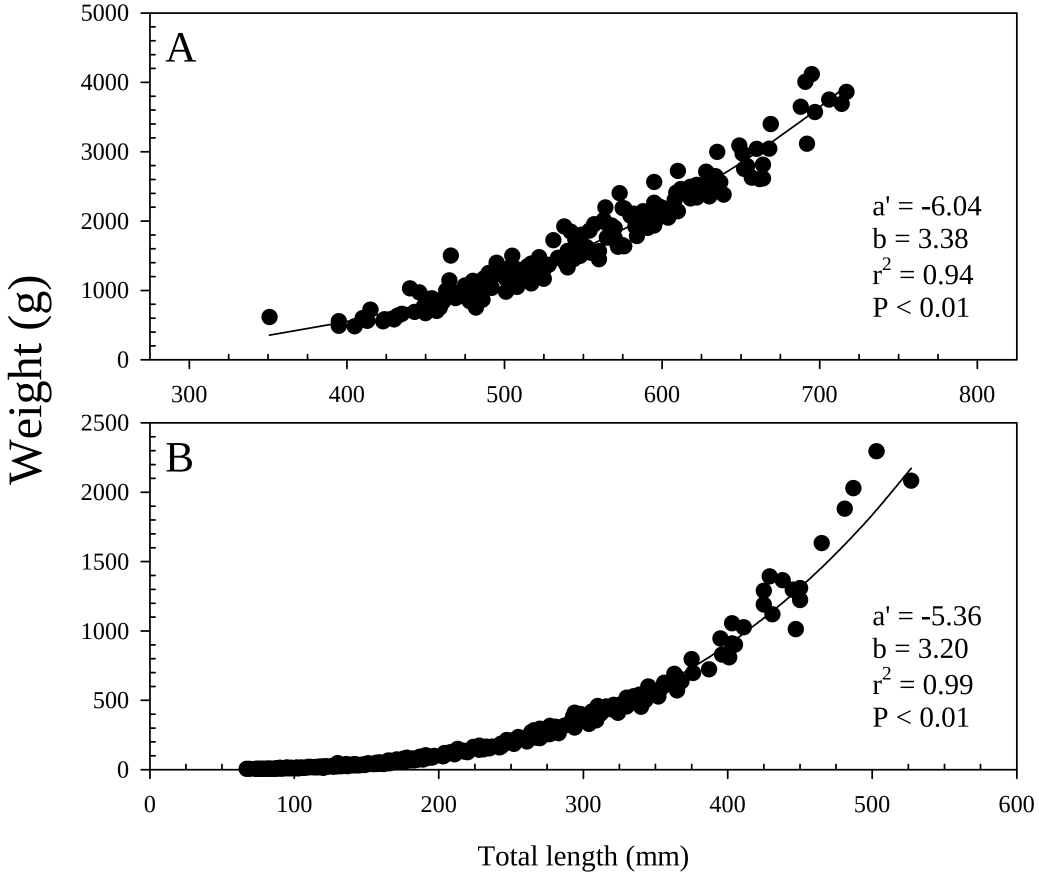
Lake	Tandem 1			Tandem 2			Tandem 3			Tandem 4			Total
	F	M	B	F	M	B	F	M	B	F	M	B	
Barbour	3	13	43	13	22	39	22	21	23	10	12	9	230
Clay	36	18	6	1	6	14	4	18	0	7	25	52	187
Crenshaw	0	0	0	0	0	0	0	0	0	0	0	0	0
DeKalb	2	8	31	6	2	12	3	5	4	11	12	17	113
Fayette	11	10	9	8	8	37	13	14	15	7	7	5	144
Lee	4	14	1	0	2	4	2	2	7	0	2	4	42
Madison	8	19	12	0	0	1	3	9	14	6	2	7	81
Monroe	0	19	0	0	0	0	3	4	2	2	5	6	41
Pike	1	4	2	1	0	2	3	3	6	0	2	0	24
Walker	2	30	21	4	8	23	28	18	8	29	46	0	217



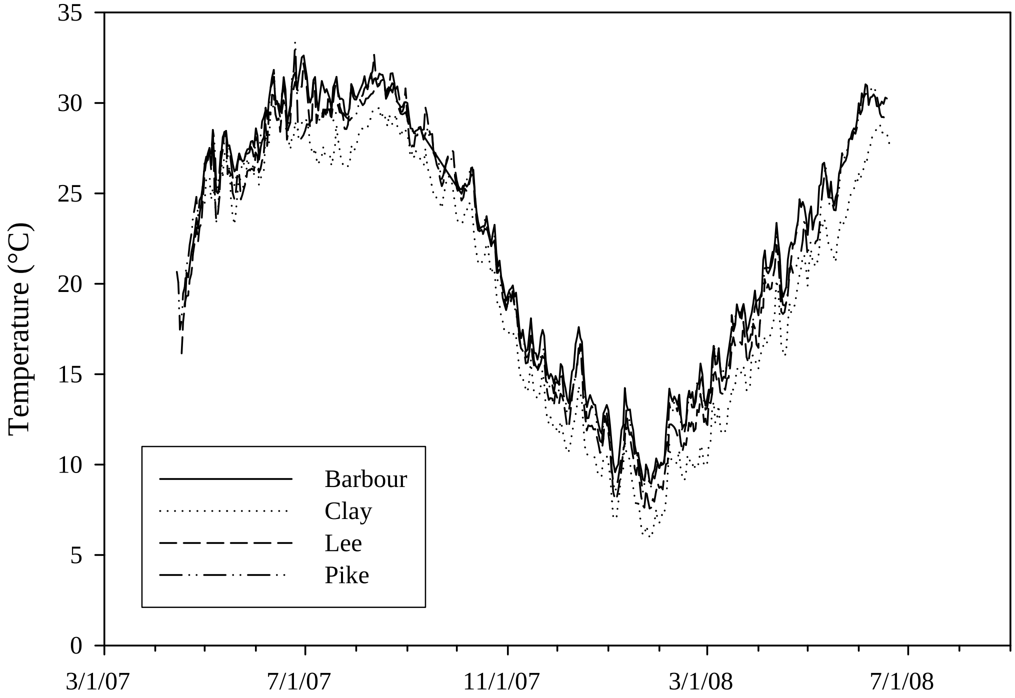
Appendix C. Weighted catch-curve regression and associated statistics for (A) channel catfish and (B) largemouth bass pooled from fall 2006 and 2007 sampling in Barbour, Clay, Lee, and Pike County lakes.



Appendix D. von Bertalanffy growth curve coefficients for (A) channel catfish and (B) largemouth bass pooled from fall 2006 and 2007 sampling in Barbour, Clay, Lee, and Pike County lakes.



Appendix E. Length to weight relationship and associated statistics for (A) channel catfish and (B) largemouth bass pooled from fall 2006 and 2007 sampling in Barbour, Clay, Lee, and Pike County lakes.



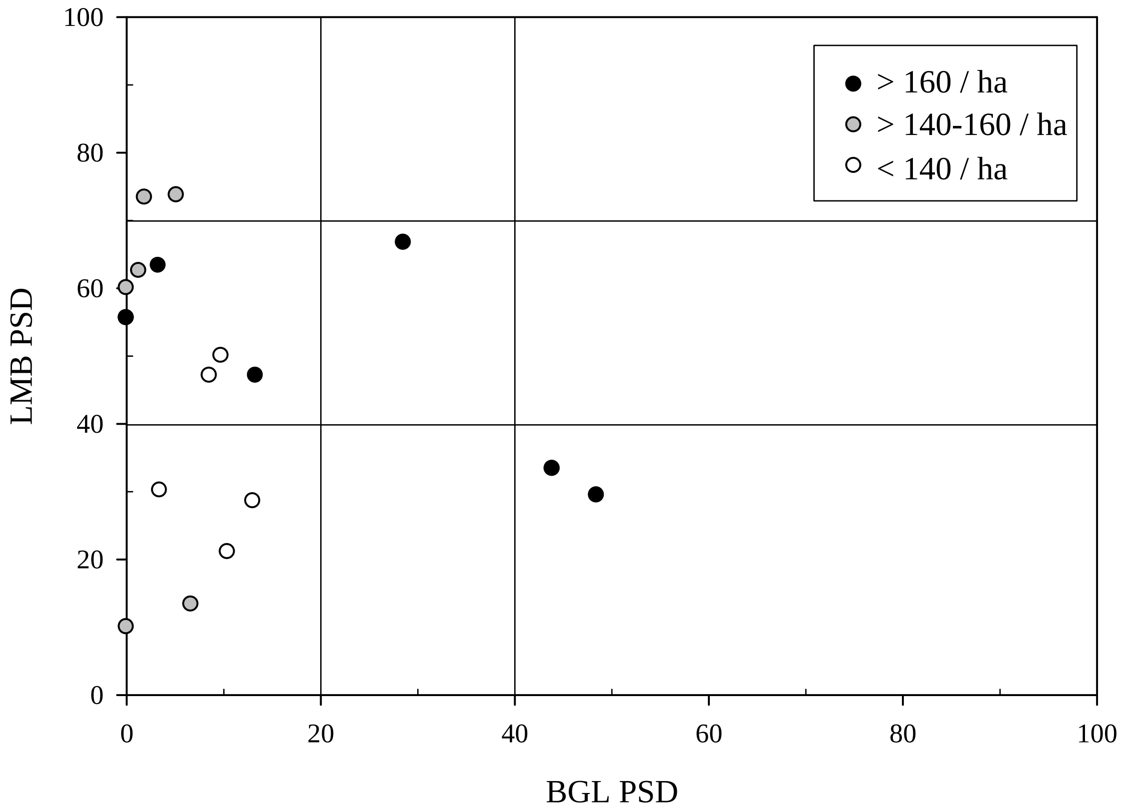
Appendix F. Mean daily water temperatures obtained from data loggers which were averaged across lakes and used in bioenergetics modeling.

Appendix G. Wet weight energy values (j/g) of prey items used for channel catfish (CAT) and largemouth bass (LMB) in bioenergetics analysis.

	Energy density (j/g)		
Prey type	CAT	LMB	Source
Crustacean	3,786	3,786	Brey 2001
Fish	4,286	4,286	T. Farmer (unpublished)
Insect	2,505	2,971	Brey 2001
Zooplankton	2,721	2,721	Brey 2001
Other	1,847	1,847	Schindler et al. 1971

Appendix H. Initial population numbers, start weights, and p-values (proportion of maximum consumption) from bioenergetics models for channel catfish and largemouth bass. P-values were derived from bioenergetics simulations (*fitted P-values greater than 1 were set to 1 for simulations)

	Channel catfish			Largemouth Bass		
Cohort	Initial population	Start wt (g)	P-value	Initial population	Start wt (g)	P-value
age 0				7483	1	0.62
age 0.5				5377	33	0.48
age 1.5	5000	227	1.09*	2601	233	0.47
age 2.5	1969	956	0.94	1258	557	0.43
age 3.5	602	1995	0.55	608	904	0.40
age 4.5	184	2142	0.52	294	1212	0.38
age 5.5	56	2158	0.52	142	1460	0.37
age 6.5				68	1649	0.36



Appendix I. Largemouth bass (LMB) PSDs plotted against bluegill (BGL) PSDs calculated from fall sampling, with shades representing groups of channel catfish stocking rates.