Illinois Natural History Survey

Factors Influencing Largemouth Bass Recruitment: Implications for the Illinois Management and Stocking Program

Annual Progress Report

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EXECUTIVE SUMMARY: During the past segment, all activities outlined in the annual work plan were accomplished and within the specified budget. The goal of this study is to develop management strategies that maximize growth, recruitment, and harvest of largemouth bass *Micropterus salmoides* in Illinois impoundments. Largemouth bass are frequently stocked in many Illinois impoundments to compensate for variable recruitment. Even so, the long-term contribution of stocked fish to recruitment and harvest of natural bass populations is unknown and we are addressing these questions. Because stocking is only one of several management options for this species, it is critical that additional information on factors limiting recruitment processes be identified. In addition, information on the importance of rearing technique, size of stocked fish, forage base, cover, resident predators, physical-chemical conditions, and stocking stress in determining largemouth bass stocking success is needed to optimize use of hatchery produced fish.

In Job 101.1 we are attempting to determine the most reliable and cost-effective method for mass-marking fingerling largemouth bass. Fin clips, fin clip-cauterization, and freeze branding are being examined for long-term retention on 100-mm largemouth bass. Fin cauterization has had the longest retention time, followed by fin clipping and then freeze branding. Identification of fin clips and fin cauterization have been complicated by fin regrowth. Freeze branding does not have the problem of fin regrowth, but seasonal variation in appearance on the fish led to difficulty in identifying freeze brands in the spring when bass have darker external coloration. At this point, we have found no differences in growth rates between fish with these three different marks. During this segment, we began evaluating seasonal variability in mark retention and extended the long-term study of mark retention. These studies will be completed during the fall of 2004.

In Job 101.2 we are evaluating supplemental stocking which is a widely used management tool for increasing the standing stock of an existing population. In 2003 we stocked four sizes of largemouth bass in Woods Lake and Mingo Lake. These lakes were monitored throughout the year to assess differences in survival and growth. Initial stocking mortality was low among different sizes of stocked bass. Stocking mortality was related to temperature at the time of stocking suggesting stocking during cooler times of year can reduce mortality. Predation rates on stocked fish were low among all sizes of stocked fish. Four-inch fish experienced the highest level of predation and may be more susceptible to bass predation than other sizes of stocked largemouth bass. Despite initial differences in size and catch per unit effort (CPUE), all stocked bass except 2-inch fish were found in similar relative abundances and at similar mean size from the first summer after stocking throughout the following seasons. The exception was 2-inch bass, which did not occur in samples after the first spring after stocking. Cost analysis will be conducted that will incorporate data from previous and subsequent segments in order to make recommendations on which size of fish should be stocked in Illinois impoundments.

In segment 6, we also evaluated the relative survival of intensively and extensively reared largemouth bass. Survival of the two groups of stocked fish varied between lakes. In 2003 and 2004 samples, intensively reared fish showed higher survival in Walton Park Lake and Lake Shelbyville. Increased efforts must be put into resampling in order to accurately assess which rearing strategy is yielding the highest survival and

growth. Based on our results, the usefulness of supplemental stocking as a management strategy will vary by individual lakes. Additional research regarding the importance of predator and prey populations are needed to determine lake characteristics most favorable for stocking largemouth bass.

In Job 101.3 our objective is to evaluate the long-term contribution of stocked largemouth bass to the numbers of harvestable and reproducing adults. Although it is assumed that subsequent increases in standing stock are the direct result of stocking efforts, little data exist to either refute or support that idea. To track the potential contribution of stocked largemouth bass to an existing bass population, we stocked largemouth bass bred at the Little Grassy Hatchery specifically to be fixed for the MDH-B2B2 genotype. Prior to stocking, we evaluated the background frequency of the MDH-B1 and MDH-B2 alleles in the natural largemouth bass population of each study lake and verified that our experimental bass contained the MDH-B2B2 genotype. If stocked largemouth bass successfully reproduce in our study lakes, we should find an increase in the frequency of the MDH-B2 allele. We sampled young of the year (YOY) largemouth bass in Lake Shelbyville, Forbes, Murphysboro, Sam Parr, McLeansboro, and Walton Park in 2003 to determine if stocked fish were contributing to natural production within each lake. In Shelbyville, preliminary results suggest the frequency of the MDH-B2 allele was 18%, as compared to a background frequency of 15%. The remaining collections are currently being genetically identified to determine stocked fish contributions to these lakes. We will continue to collect YOY from these lakes in subsequent years to determine the contribution that these stocked fish have on these populations.

In Job 101.4, we assess the importance of a variety of abiotic and biotic factors on largemouth bass recruitment in order to both understand the mechanisms of recruitment of bass to age-1 and to develop indexes of bass recruitment for Illinois lakes. This segment covers recruitment of the 2003 annual cohorts and associated environmental conditions in the 12 lakes we have been monitoring over the last several years. Similar to previous segments, we observed a great deal of variation among the 12 study lakes in abiotic factors, such as total phosphorus and secchi depth, and biotic factors, such as the abundance of zooplankton and juvenile bluegill. Densities of young of the year (YOY) largemouth bass were especially variable during spring and summer. By fall, densities of YOY were more similar among lakes, but recruitment to age-1 was still variable. Spring water temperature was an important abiotic factor influencing differences among lakes in YOY bass abundance. YOY abundance in 2003 was not a reliable indicator of recruitment to age-1 the following spring. At this point in the study, early abundance of YOY largemouth bass has been significantly correlated with recruitment in only 2 out of 5 year classes. The abundance of important fish prey, mainly bluegill *Lepomis macrochirus*, has been a more consistent indicator of largemouth bass recruitment. Both the abundance and size structure of YOY bass at the end of the growing season was correlated with the abundance of larval fish and juvenile bluegill. Recruitment to age-1 was correlated with the density of zooplankton in the spring and juvenile bluegill during the summer and fall. Construction of multiple linear regression models of recruitment for the 2000 through 2003 annual cohorts further emphasized the importance of fish prey, with the abundance of either juvenile bluegill or Lepomis larvae appearing in all four models.

In Job 101.5 we are assessing the effect of angling on largemouth bass populations. One objective is to determine the effect of angling on nesting bass and to determine its effect on reproductive success, recruitment, and size structure. Highly turbid conditions during the spawning season prevented us from gathering useful data from our annual snorkel surveys in Lincoln Trail during 2004. In future seasons, we will continue our snorkel surveys of largemouth bass nests in order to measure habitat selection by male bass, nest predation, and brood abandonment rates. Data were collected from several tournaments during 2003 in order to assess the proportion of male and female bass angled during the spawn and post-spawn season. In 2003, we attended tournaments at Lake Mattoon (N = 2) and Lake Shelbyville (N = 2). Data from 2003 were combined with previous years data and analyzed. Males were targeted in most tournaments although there was no difference between spawn and post-spawn tournaments. Preliminary angler surveys as of 2003 suggest that few fish are being culled from tournament catch and therefore, culling is not skewing male to female ratios. These results will need to be confirmed in future samples. Angling has the potential to decrease short-term feeding, leading to lower growth rates, of largemouth bass. We assessed short-term feeding of largemouth bass subjected to simulated catch-and-release and competitive angling at three temperatures (22°C, 26°C, and 30°C). Temperature and angling practice interacted to decrease prey consumption by largemouth bass. Consumption by largemouth bass decreased linearly with increased temperature regardless of treatment. Mean number of fathead minnows *Pimephales promelas* consumed after 12 h was also related to angling type. Mean minnow consumption (± 1 SE) was lowest by fish that experienced a tournament (4.0 ± 0.5 minnows) followed by fish that were caught and released (6.5 ± 0.5 minnows) and controls (9.3 ± 0.5 minnows). Using multiple logistic regression and bioenergetics simulations, we predict decreased growth in fish subjected to competitive or catch-and-release angling events.

There are a number of potential options that can be used to help manage bass populations in Illinois, including harvest regulations, closed seasons, and spawning sanctuaries. In Job 101.6, we sampled largemouth bass in a closed area of Clinton Lake in order to determine the effects of a refuge on abundance and size structure of largemouth bass. Abundances of adult and juvenile largemouth bass were higher inside than outside the refuge. We will continue to monitor largemouth bass in Clinton Lake in order to measure potential changes in size and abundance due to the establishment of the refuge. With this series of experiments, we are working towards the ultimate goal of assessing the usefulness of various regulations and other strategies to manage bass recruitment and size structure.

Job 101.1 Evaluating marking techniques for fingerling largemouth bass

OBJECTIVE: To determine the most reliable and cost-effective method for mass-marking fingerling largemouth bass.

INTRODUCTION: The ability to reliably identify stocked fish is an essential component to successful population assessment. The choice of a particular fish marking technique depends primarily on the scope of the management question. In some instances, short-term marks can provide sufficient information to address management questions. Often times, however, it is important to identify marked fish throughout their lifetime. In Illinois, freeze branding (Mighell 1969) has been a commonly used method for mass-marking largemouth bass fingerlings. Although this technique permits marking large numbers of hatchery fish both quickly and inexpensively, long-term retention of freeze brands in centrarchids is variable (Coutant 1972). Because uncertainty about mark retention compromises the quality of recapture data by making the true contribution of hatchery fish unknown, it is important that a reliable, long-term mark is established. An ideal mark should be inexpensive, easy to apply, have long-term retention, and have minimal impact on the health of the fish.

Several marking techniques have the potential to produce long-term physical marks on largemouth bass. Fin clipping can permanently mark largemouth bass if all fin rays are carefully clipped at the point of attachment to the bone (Wydoski and Emery 1983). Partial or incomplete removal of fin rays, however, can result in fin regeneration and preclude our ability to identify stocked fish. Boxrucker (1982; 1984) used a combination of fin clipping followed by freeze cauterization of the wound to create a long-term mark on fingerling largemouth bass. This technique required more man-hours than fin clipping or freeze branding alone (Boxrucker 1982).

PROCEDURES: We evaluated the long-term retention rate associated with three different marking techniques for 4" largemouth bass. Marking techniques included (1) fin clipping, (2) fin cauterization, and (3) freeze branding. Fin clips were obtained by removal of the right pelvic fin. Removing both pelvic fins and 'freeze-branding' the wound with liquid nitrogen made fin cauterizations. Freeze branding was accomplished by holding fish for 2 s against a branding iron chilled to -190 °C with liquid nitrogen. Freeze brands were located on the left side of individual fish, just below the dorsal fin. Groups of fingerling bass with each mark (75-100 each) were then stocked into 3 outdoor ponds (1/3 acre) at a total density of 250 fish/pond. Fish used in these experiments were previously identified as either the1:1, 1:2, or 2:2 MDH-B genotype. At the beginning of the experiment, fish with known genotypes were assigned to a specific physical mark so that they could be genetically identified if marks disappeared or could not be positively identified in the field. Fingerling bass were stocked into ponds on December 14, 1998. Fish growth, differences in mark retention rates and percent regrowth among marking techniques have been measured and assessed every six months from May 1999 through March 2004. Seasonal differences in visibility of freeze brands have raised some concerns with this mark. In November 2003, we initiated an evaluation of seasonal variability of freeze brand marks. We marked 100 fingerling bass (137 mm, TL) with vertical and horizontal freeze brands. Seasonal readability was assessed in March 2004 and will be completed again in October 2004.

FINDINGS:

In the long-term pond experiments (4" fingerlings), fin cauterization was the longest lasting mark followed by fin clip and freeze brand marks (Figure 1-1). Fin clips and fin cauterized marks had considerable amounts of fin regrowth that made them less desirable than freeze brand marks. Through spring 2004, fin cauterized marks had 20% less fin regrowth than fin clips (Figure 1-2). Less fin regrowth in fin cauterized marks made them more obvious than fin clips and required less handling time to identify marks. Freeze brand marks were the most distinguishable and required the least amount of handling time to identify. Freeze brand marks were 7% less distinguishable during fall sampling ($\bar{x}$ = 93%) as compared to spring sampling ($\bar{x}$ = 100%) because of darker external fish coloration (Figure 1-3). Conversely, fin clips and fin cauterized marks ($\bar{x}$ = 100%) were distinguishable regardless of season (i.e., fish coloration).

Long-term growth appears to be unhampered by fin clips, fin cauterization, or freeze brand marks (Table 1-1). Fish have grown to a similar length over the 4-year period (March 2004) regardless of the three marking techniques. The removal of a pelvic (fin clip $\bar{x}$ = 293 mm, TL), or both pelvic fins (fin cauterized; $\bar{x}$ = 292 mm, TL) compared to freeze branding ($\bar{x}$ = 289 mm, TL) does not appear to impact foraging success or energy allocation.

Vertical and horizontal freeze brands (96%) were both very readable during the spring. Of those marks that were determined to be poor two were horizontal and two vertical. Variability in largemouth bass color in the spring does not significantly influence readability, but will need to be confirmed during fall sampling.

RECOMMENDATIONS: Short-term marking experiments reported previously suggest that OTC-marks are preferable over fin clips, fin cauterization, freeze brand, and photonic dye. However, this recommendation is based strictly on retention rates coupled with ability to mark large numbers of fish quickly. Specific scientific and management related objectives should be considered because OTC marked fish must be sacrificed for identification, which may not be acceptable for all applications. For those scientific and management endeavors that wish to reduce mortality, fin clip marks should be employed since they had comparable retention rates as OTC.

Long-term marking results suggest that freeze brand marks are more distinguishable and take less handling time to identify than fin clips and fin cauterized marks. This in conjunction with better growth rates during the first year as well as the speed and low cost that freeze brands afford suggest that this is the best method for long-term marking of 4" largemouth bass. We will continue to sample these marked fish at 6-month intervals and evaluate growth rates, long-term mark retention, and ease of readability to determine if these results hold true as these largemouth bass continue to increase in size and age. The seasonal variability to mark visibility for freeze branded fish is potentially problematic and will need to continue to be assessed. We will continue to monitor the seasonal variability in freeze brand marks place vertically and horizontally on largemouth bass until October 2004. These combination of long-term experiments will allow us to estimate loss rate for the most common physical marks used on largemouth bass.

Job 101.2. Evaluating various production and stocking strategies for largemouth bass.

OBJECTIVE: To compare size specific survival and growth among different sizes of stocked largemouth bass fingerlings and to compare various rearing techniques.

INTRODUCTION: Supplemental stocking of largemouth bass Micropterus salmoides is a commonly used management tool for increasing population size. Benefits of supplemental stocking include either increasing harvest rates and reproductive potential, or increasing the number of predators to control an overabundant forage population. However, in order for these positive benefits to occur, stocked fish must contribute to the natural population. Numerous studies have examined either introductions of different genetic stocks of largemouth bass (Rieger and Summerfelt 1978; Maceina et al. 1988; Mitchell et al. 1991; Gilliland 1992; Terre et al. 1993) or introductions of largemouth bass into ponds (Dillard and Novinger 1975; Modde 1980; Stone and Modde 1982). Surprisingly, few studies have examined the factors influencing success of supplemental stocking of largemouth bass. The few studies that have examined the contribution of stocked largemouth bass to a natural population, examined only one (Lawson and Davies 1979; Buynak and Mitchell 1999) or two lakes (Boxrucker 1986; Ryan et al. 1996). Given that lakes are highly variable, examining stocking evaluations in only one or two lakes limits our ability to make generalizations.

Factors influencing stocking success may include predation, prey availability, and abiotic variables (Wahl et al. 1995). Predation from older age classes of largemouth bass may be especially important given that they have been shown to prey heavily on other species of stocked fish (Wahl and Stein 1989; Santucci and Wahl 1993) and are highly cannibalistic (Post et al. 1998). The availability of appropriate sized prey has also been shown to be important to survival of stocked fish for other species (Fielder 1992; Stahl and Stein 1993). Finally, abiotic factors such as water temperature at time of stocking may contribute to stocking success. High water temperatures at time of stocking may increase stocking stress and subsequent mortality (Clapp et al. 1997). Determining which of these factors is most important to stocking success has important implications for deciding the appropriate locations and times to stock.

Previous stocking evaluations conducted in the Midwest have often examined species that do not naturally reproduce in the recipient water body (e.g. muskellunge Esox masquinongy, Szendrey and Wahl 1996; walleye Stizostedion vitreum, Santucci and Wahl 1993). Largemouth bass, however, reproduce naturally in most Midwestern reservoirs, and therefore stocking occurs in addition to an existing population of reproducing fish, although reproduction may be somewhat limited. The number of natural fish produced during the year of stocking may influence stocking success through competitive interactions for food and habitat. Because native largemouth bass may out compete stocked largemouth bass, a large natural year class may decrease stocking success in an individual lake. Conversely, stocked largemouth bass may do well in years with high natural recruitment because they are potentially influenced by the same variables.

In addition to stocking bass in appropriate lakes, the size of largemouth bass fingerlings produced by Illinois hatcheries and timing of their release into recipient populations could greatly affect the success of largemouth bass stocking efforts. New or rehabilitated lakes in Illinois are often stocked with two-inch fingerlings, however, most supplemental stockings occur in the fall with four-inch fingerlings. In addition, some recent programs in Illinois have used eight-inch fingerlings to stock populations in the spring. Advantages of the latter strategy include being able to stock the same age fish after a weak year-class has been identified and potentially higher survival of larger stocked fish. Disadvantages include increased cost and hatchery space required to rear larger fish.

Differences in rearing method (e.g., intensive raceway versus extensive ponds) of the largemouth bass fingerlings may also influence growth and survival. Largemouth bass raised on commercial food pellets have been shown to grow better when stocked into rearing ponds than those fed a diet of fathead minnows (Hearn 1977). A number of Illinois reservoirs and impoundments are stocked with largemouth bass raised extensively in nursery ponds. These and other lakes can also be stocked using largemouth bass raised at state hatcheries. The relative merits of these two rearing techniques are being assessed as part of this study.

PROCEDURES:

Size Specific Stocking

We evaluated the success of four size groups of stocked largemouth bass in two lakes in 2003 (Mingo and Woods, Figure 2-1). Largemouth bass were stocked as small fingerlings (50 mm) in July, medium fingerlings (100 mm) in August, large fingerlings (150 mm) in September and advanced fingerlings (200 mm) in October (Table 2-1). Each size group was given a distinctive mark for identification during subsequent sampling. Small fingerlings were immersed in oxytetracycline (OTC), while larger fingerlings were marked with distinctive fin clips.

Following stocking, we evaluated the importance of stocking stress, physicochemical properties, predation, and prey availability, on the growth and survival of the different size groups of stocked largemouth bass. We estimated initial stocking mortality by placing 30 fish into each of three floating mesh cages. Largemouth bass were taken directly from the hatchery truck and placed immediately into the cages. Cages were 3 m deep and 1 m in diameter and were placed in at least 3 m of water. The cages were removed after 24 or 48 hours and the number of live and dead fish were counted. Predation on stocked bass was estimated by sampling predator diets. Potential predators were collected by electrofishing and diets were examined by tubing and the number of stocked bass as well as size and type of prey were recorded. Stocked lakes were electrofished for predator diets daily until no stocked bass occurred in predator diets on two consecutive sample dates.

Rearing Technique

The effects of rearing techniques on growth and survival of stocked largemouth bass were evaluated in lakes Jacksonville, Shelbyville and Walton Park in 2003. Extensively reared bass were produced at the Little Grassy Fish Hatchery where they were held in ponds and fed on minnows until stocking. Intensively reared bass were produced at the Jake Wolf Fish Hatchery. Intensively reared fish were held inside the hatchery in 265 L concrete tanks and fed commercially produced pellets until stocking. Each fish was given a distinct pelvic fin clip for future identification of rearing technique.

Fish were transported from the hatchery in oxygenated hauling tanks to the recipient lakes. Hauling time ranged between 0.5 to 3 hours. Fifty largemouth bass were measured (nearest mm) and weighed (nearest g) before stocking on each date. Fish were released near shore at a single location at each lake. Attempts were made to stock largemouth bass at a rate of 60 fish per hectare, however rates varied by individual lake due to varying success of rearing ponds and hatchery production.

Growth and survival of stocked largemouth bass was determined in the fall and spring by sampling during the day with a 3-phase AC electrofishing boat. Three shoreline transects on each lake were shocked for 0.5 h each on each sampling date and all largemouth bass were collected, measured, weighed, and examined for clips. Catch per unit of effort (CPUE) was calculated as the number of stocked fish collected per hour and was used as a relative measure of survival across lakes. Growth was estimated using the mean size of bass at the time of sampling.

FINDINGS: In this segment, we examined growth, survival and mortality of different sizes of largemouth bass. Unmarked young of year largemouth bass were collected to examine for OTC marks. These fish have not been processed at this time so survival and growth can not yet beestimated for two-inch stocked bass. Four inch-bass had the lowest survival of all stocked bass (Table 2-2). No four-inch bass were recaptured in Woods Lake and Lake Mingo had low numbers of recaptured four-inch bass in both spring and fall (7 and 1 bass/hr respectively). The four-inch bass in Mingo also had a smaller mean size in fall than natural and other stocked bass at the time of recapture (Figure 2-2). This differs from previous years where four-inch bass were similar in size to the natural bass and exhibited similar growth (Figure 2-3). CPUE of six-inch bass was higher than four-inch fish in the fall, but low over winter survival resulted in similar CPUE in the Spring. Unlike previous segments, six-inch fish were smaller than natural fish in both lakes at the time of stocking. The size difference was small, however, and recaptured six-inch bass were similar in size to the natural fish in the spring samples. Eight-inch bass were stocked in spring and sampling occurred shortly after stocking. Eight-inch bass had a higher CPUE than both other stocked and natural bass in both lakes. This was similar to previous segments where eight-inch bass had the highest abundance in the spring (Figure 2-4), however by subsequent fall samples the densities had dropped to low numbers similar to other sizes of stocked.

Sources of mortality at the time of stocking varied between lakes (Table 2-1). Mortality related to stocking stress was high for two-inch fish in Woods Lake (17% mortality in cages) yet no mortality was observed for two-inch fish at Mingo. The high mortality of two-inch bass in Woods may be due to high water temperature (28 ° C). Lake temperature at the time of stocking has played a role in determining observed stocking mortality. All mortality observed in previous years in mortality cages took place at temperatures over 23 ° C (Figure 2-5). Mortality was low for 4-inch fish on both lakes and no mortality was observed for six and eight inch bass. No stocking mortality has been observed for 8-inch bass throughout the duration of the study. Eight-inch bass stockings all took place in the spring when water temperatures were cooler and had not yet reached 23 ° C and may be the cause of the low mortality observed.

Predation on stocked bass could reduce overall survival if levels are high. Smaller bass may be more vulnerable to predation and may have a higher potential mortality. Predation on stocked largemouth bass was primarily by adult largemouth bass populations present in the study lakes. Northern pike, channel catfish, and white crappie also preyed on stocked largemouth bass, but in very limited amounts due to the low abundance of these fish in the study lakes. As a result, largemouth bass were examined as the main predators of stocked bass. Lake Mingo had higher predation rates than Woods Lake for both two and four-inch bass (Table 2-3). Lake Mingo has a more abundant bass population than Woods (CPUE 114/hr, 39/hr respectively) and the potential for predation is higher. No predation was observed on six and eight-inch bass in either lake.

There is a good deal of year-to-year variation in survival and growth of stocked largemouth bass. This variation makes it important to look at general trends that occurred over all stockings and lakes that were stocked with different sizes of bass. Six-inch bass were stocked at a larger size than the 2 and 4-inch bass as well as natural bass in the lakes (Figure 2-3). There were also few size differences going into the first winter, with 6-inch stocked fish larger than those stocked as 4-inch fish, followed by the 2-inch size of stocked fish. This suggests there is a potential for size specific mortality over winter. The following spring however, size differences no longer existed between all of the size groups and natural bass. Eight-inch bass were stocked in the spring at a larger size than all other bass at that time but by the summer the size difference no longer existed. All sizes of stocked bass as well as the natural bass were of similar length going into the second winter. Although there are initial size differences at stocking, lags in growth occur shortly after, perhaps as the bass go from foraging in hatchery conditions to the wild. There were few differences in growth after the first year so we must examine other factors that may influence stocking success.

Survival also differed among the size groups of stocked fish. Six-inch fish tended to be present in the highest abundance in the first fall after stocking (Figure 2-4), probably because little time had passed since they were stocked. As a result, 6-inch bass were in higher abundance going into the first winter than 2 and 4-inch size groups and unclipped natural bass. Over winter survival was extremely low for both 2 and 6-inch bass and somewhat higher for the 4-inch size group. In the spring very few 2-inch fish were recaptured in electrofishing samples and 6-inch bass were observed at similar catch per unit effort as 4-inch fish. Winter survival was generally high, however natural fish in the spring are observed at a much higher relative abundance. Eight-inch fish were stocked in the spring and as a result were recaptured during spring electrofishing samples at a higher abundance than other sizes of stocked fish. However, a short time after stocking, CPUE during the summer months for 8-inch bass had declined to a similar level as 4 and 6-inch bass. Also, no 2-inch fish were recaptured at any of the lakes after the first spring following stocking. Overall survival was low for all stocking sizes and a majority of fish in electrofishing samples of older ages were naturally produced fish. This pattern is consistent over the following seasons and CPUE for the 4, 6, and 8-inch fish remained low at around 2 to 3 bass per hour of electrofishing. In the future, population estimates will be calculated to determine the total number of each size that we observe in the adult population.

Rearing techniques:

Survival of intensively reared fish was higher than extensively reared fish in all lakes that were stocked in 2003 (Table 2-4). This is different than what has been observed in the previous segments where variation is high between lakes and no one rearing technique produced higher survival. No stockings occurred in Lake Jacksonville due to use of the rearing pond for smallmouth bass in 2003. This lake will be included in future segments. In previous years in Jacksonville, intensively reared fish also had a higher CPUE than extensively reared largemouth bass in fall and spring electrofishing samples. No extensively reared bass were recaptured in Walton Park in the fall or the spring while intensively reared bass were observed in both seasons. Lake Shelbyville had similar numbers of recaptured intensive and extensive bass in the fall but only intensive fish were recaptured in the spring although they were at low numbers. Due to the variability between lakes and years, it is not apparent if one rearing technique has an advantage over the other at this point. Continued stockings must occur in order to make a management recommendation.

RECOMMENDATIONS: Survival of the different sizes of stocked fish were initially different, but were similar after the second spring following stocking. Similarly, there were some differences in sizes of bass through the first fall and winter, but after the first spring, no size difference remained between the different sizes of stocked fish. In particular, a lag in growth occurred for the 6 and 8-inch fish after stocking and despite being larger initially, they were soon similar in size to the natural population. This may be due to an acclamation period where hatchery bass adjust to feeding on natural prey resources. The study lakes have primarily bluegill forage and it may take some time for minnow fed hatchery bass to become efficient at feeding on different prey fish. Feeding experiments and diet analysis were initiated in 2003 and will be completed in future segments in order to examine the factors that cause the observed growth lag. Mortality due to temperature stress and predation was low for all sizes of stocked fish. Four-inch fish were found in higher numbers in predator diets and may be more vulnerable to bass predation than other sizes. In order to determine how many fish are lost to predation, population estimates should be analyzed and diet data used in order to estimate the total number of stocked bass that are consumed after stocking. Temperature related mortality was also low across all sizes of stocked fish in all study lakes. All observed mortality in cages occurred at a temperature higher than 23 ° C. Stocking at times of year when temperatures are cooler or stocking a size of bass that is available during cooler temperatures may reduce stocking mortality and increase the survival of stocked bass. Because there is little difference in size, abundance and stocking mortality for different sized bass, there is no clear preferred size to stock. Before a recommendation can be made about stocking size, hatchery costs for producing the fish must be considered. In future segments, we will examine cost-benefit relations to recommend a particular size of bass to stock in Illinois lakes.

Results from comparisons between intensive and extensive stocked fish were not consistent across lakes, suggesting the need for further exploration of the effectiveness of the two techniques. Comparisons of these two techniques will be conducted again in Walton Park, Shelbyville, and Jacksonville in 2004. Attempts will also be made to supplement shocking efforts in order to increase sample size and recapture a larger number of stocked bass to better represent survival of fish from the two rearing techniques. Sampling will also be conducted in future segments to follow the long-term survival of the largemouth bass reared using different techniques.

Job 101.3 Assessing the long-term contribution of stocked fish to largemouth bass populations.

OBJECTIVE: To evaluate the long-term contribution of stocked largemouth bass to the numbers of reproducing and harvestable adults.

INTRODUCTION: Many species of fish, including both largemouth and smallmouth bass, are cultured in hatcheries for release into lakes and streams in an effort to establish new or supplement existing populations. Although it is assumed that subsequent increases in the standing stock are the direct result of those stocking efforts, little data exist to either refute or support that idea. Furthermore, if the stocking effort does indeed increase the standing stock of adult bass, it remains unclear how that increase could or would impact the level of reproduction and recruitment in subsequent generations. Both largemouth and smallmouth bass likely home back to natal areas to spawn (Philipp, and Ridgway, personal communication), therefore it is possible that introduced bass may not compete successfully with resident bass for optimal spawning sites or may simply make poor choices in selecting nesting sites on their own. Under either of these scenarios, the level of reproductive success of stocked bass would be lower than that of resident bass. Preliminary results of largemouth bass stocked into Clinton Lake during 1984 (Philipp and Pallo, unpublished results) indicated that survival of the stocked fish to at least age 4 was good (approximately 8-10% of that year class), however those individuals made no discernable contribution to any later year classes. To justify continued stocking efforts for largemouth bass in Illinois, it is important to determine the actual contribution that stocked fish make to bass populations. The objective of this job is to compare the survival and reproductive success of stocked bass to resident bass. In this way, we can assess the costs and benefits of the bass stocking program in a long-term timeframe.

PROCEDURES: Largemouth bass to be stocked in each selected study lake were those produced at the Little Grassy Hatchery bred specifically to be fixed for the MDH-B2B2 genotype as a genetic tag. These fish were stocked directly into a target lake, while others were first introduced into rearing ponds near the target lake before being stocked. Six study lakes were stocked and sampled; Lake Shelbyville and Forbes Lake beginning in 1998 through 2003, and these in addition to Walton Park, Murphysboro, Mcleansboro, Sam Parr, Forbes, and Shelbyville in 1999-2003.

Prior to actual stocking, samples of fish from the hatchery rearing ponds were sampled, and protein electrophoretic analysis (Philipp et al., 1979) was used to determine if those fish had the MDH B2B2 genotype. Also prior to stocking, a sample of naturally produced largemouth bass were collected from each study lake and analyzed to determine the inherent background frequency of the MDH-B locus. YOY from the six lakes were sampled in 2003 to determine if the frequency of the MDH B2 allele has increased through reproduction of the stocked fish. The fish stocked into these lakes should be sexually mature and should begin and continue to reproduce. Sample efforts will continue over the next several years to document the contribution of stocked fish to the reproductive population.

FINDINGS: Largemouth bass fingerlings stocked into each lake have been analyzed to determine if the fingerlings have all had the MDH B2B2 genotype. All samples analyzed have been 100% MDH B2B2 genotype with the exception of fingerlings stocked into Lake Shelbyville in the summer of 2001. Five of the fifty fingerlings that were analyzed had the MDH B1B2 genotype and not the MDH B2B2 genotype; therefore a correction factor will have to be used to analyze future samples from Lake Shelbyville.

Background frequencies of LMB from four of the six study lakes have less than 20% of the individuals with the MDH B2B2 genotype. The exceptions were Forbes and McCleansboro (Table 3-1). The higher frequency of the MDH B2 allele from McCleansboro is potentially problematic and may make this lake difficult to use in determining the contribution of stocked fish to recruitment.

Largemouth bass stocked into all six lakes should be sexually mature and reproducing. We collected YOY from these lakes in 2003 to determine if the frequency of the MDH B allele has changed as a result of the stocked fish spawning and passing on the MDH B2 allele (Table 3-1). To date, only young of the year from Lake Shelbyville have been analyzed and are not adequate to make recommendations.

RECOMMENDATIONS: Genetic frequencies from YOY that have been collected from all six study lakes during 2002/2003 as well as those that will be collected in subsequent years will need to be analyzed to determine if the stocked fish are contributing to the overall reproductive success within each lake. The prediction is that if the stocked fish are contributing we should observe an increase in the MDH B2 allele as more stocked fish mature and contribute to the reproductive success.

Job 101.4. Evaluating factors that influence largemouth bass recruitment in Illinois.

OBJECTIVE: To determine important mechanisms affecting largemouth bass recruitment in Illinois impoundments and develop recruitment indices for management.

INTRODUCTION: Largemouth bass *Micropterus salmoides*, similar to other fish species, experiences variable recruitment among populations and years (Jackson and Noble 2000). In general, reproductive capacity of the adult population (Ricker 1954; Rutherford 2002), food availability during the larval life stage, and predation on early life stages (Houde 1987) are general mechanisms of fish recruitment. With slight modifications, these three hypotheses could apply to the specific case of largemouth bass recruitment.

The reproductive behavior of largemouth bass potentially complicates any relationship between spawning stock and recruitment. Besides spawning, largemouth bass reproductive behavior includes nest construction, courtship, and brood defense. Typically, spawning stock is the abundance of all fish of a specific age or size range associated with sexual maturity. However, for a species with courtship, territoriality, and parental care, a much smaller fraction of mature fish may be responsible for the majority of surviving young of the year (YOY), therefore, typical estimates of spawning stock may inadequately assess the reproductive capacity of the adult population (Raffeto et al. 1990). Furthermore, conditions (e.g., temperature) and human behaviors (e.g., angling) that affect nest success influence reproductive output and, potentially, recruitment (Philipp et al. 1997; see also Job 101.5).

An important factor in the environment of any developing YOY fish is the availability of food. Ultimately, food availability within a given system is driven by its productivity. The reliance of larval fish on zooplankton is often the critical relationship influencing recruitment strength (Hjort 1914). With fish species that are primarily piscivorous as adults, such as largemouth bass, a successful transition from invertebrate to fish prey during the first year of life could be critical for future survival and success (Mittelbach and Persson 1998). The availability of both invertebrate prey during the earliest life stages and vulnerable fish prey are likely to be important for the consistent and timely development of piscivory (Olson 1996). The growth advantage gained by a switch to piscivory should be important to recruitment due to the size-dependant nature of YOY mortality.

Size-dependent mortality of YOY may be especially important for largemouth bass recruitment due to either selective predation on smaller bass or size-specific winter mortality. Predation often exacts a heavy toll on YOY fishes, potentially influencing recruitment strength (Houde 1987). Typically, the most important form of predation on YOY largemouth bass is cannibalism by earlier hatched individuals and largemouth bass from previous year classes (Post et al. 1998; Parkos and Wahl 2002). Predation pressure may also influence mortality of YOY largemouth bass during their first winter, when they are dependent on their bodies' lipid reserves for survival (Miranda and Hubbard 1994; Ludsin and DeVries 1997). Winter mortality may the most important recruitment bottleneck for YOY largemouth bass, but no evidence for this relationship has been previously found for Illinois populations (Fuhr et al. 2002).

Despite the importance of identifying the processes operating during the early life stages of largemouth bass that influence recruitment to age-1, these mechanisms remain largely unknown. The current study addresses this critical gap in knowledge by monitoring multiple largemouth bass populations and their associated aquatic communities across multiple years. By monitoring over several years, our study encompasses variable environmental conditions and recruitment levels. Identification of important mechanisms and indexes of largemouth bass recruitment will guide management of sustainable largemouth bass populations and aid in prioritization of stocking efforts for lakes less likely to produce strong year classes.

PROCEDURES: We sampled 12 reservoirs in 2003 to assess the influence of various factors on largemouth bass recruitment. Eight reservoirs were sampled every two weeks, while the remaining four impoundments were sampled monthly from May to October. The lakes chosen for this study varied in surface area, latitude, and trophic state. In addition, we chose lakes with poor, medium, and good largemouth bass recruitment.

Shoreline seining and electrofishing was used to assess largemouth bass YOY abundance and recruitment. Seining was conducted using a 9.2-m bag seine pulled along the shoreline at fixed transects. All fish species were counted and up to 50 fish from each species were measured to total length (mm). In six lakes (Forbes, Lincoln, Lake of the Woods, Paradise, Ridge, Walnut), we saved thirty YOY largemouth bass from each sample date for diet and age analyses. Electrofishing was used to collect YOY largemouth bass in the fall after they were too large to be effectively sampled by seining. Electrofishing the following spring was used to estimate recruitment to age-1. Based on otolith-derived ages, all largemouth bass from fall to the following spring that were less than or equal to 150 mm total length were considered to belong to the same year class. In the spring of 2003, we used weekly electrofishing to determine the abundance of spawning largemouth bass in order to estimate the timing of peak spawning activity in four lakes (Lincoln Trail, Paradise, Ridge, Woods). Each adult bass was sexed and checked for reproductive condition (immature, running, spent). Spring electrofishing was also used to estimate the abundance of potential predators on largemouth bass YOY.

Prey resources were estimated by sampling benthic invertebrates, zooplankton, larval fish, and small forage fish. Benthic invertebrates were sampled at six sites in each lake during June and August by using a modified stovepipe sampler. The benthos was sieved through a 250-µm sieve bucket and preserved in ETOH and rose bengal. Invertebrates were sorted, identified, and measured at the lab. Zooplankton was collected at four offshore and four inshore sites with a 0.5-m diameter zooplankton net with 64-µm mesh. Samples were either taken from the thermocline or from the bottom (if the lake was not stratified) to the surface. Zooplankton samples were preserved in 4% Lugol's solution and returned to the lab for processing. Zooplankton subsamples were counted until 200 organisms from two taxonomic groups were counted. Body size was measured on 30 individuals from each species from two of the inshore and two of the offshore sites. Larval fish were sampled at six sites on each lake by pushing a 0.5-m diameter push net with 500-µm mesh. The larval net was mounted to the front of the boat and pushed for 5 minutes along the shoreline and 5 minutes offshore. Larval fish were preserved in ETOH for later sorting and identification. Forage fish were collected by shoreline seining as described for YOY largemouth bass.

Physical and chemical variables potentially important to largemouth bass recruitment were sampled in each of the study lakes. In June and August, aquatic vegetation was identified and mapped in each lake to estimate the amount of vegetation cover. Water level was monitored throughout the spring and summer. Water temperature and dissolved oxygen was measured at 1-m intervals using a YSI oxygen meter. In addition, thermographs were placed into four lakes to record water temperature at 2-hour intervals throughout the year. Water samples for chlorophyll-*a* and total phosphorus were collected using an integrated tube sampler lowered to twice the secchi depth. Chlorophyll-*a* was estimated fluorometrically with an acetone extraction, and total phosphorus was determined by measuring sample absorbance with a spectrophotometer after an acid molybdate extraction.

A stepwise selection procedure was used to construct a multiple linear regression model from those variables that were significantly correlated with largemouth bass recruitment at the $\alpha = 0.10$ level. Correlation analyses consisted of either Pearson correlations, or if the data was non-normally distributed, Spearman correlations. The significance level necessary for entry into the multiple linear regression model was $P = 0.15$. Diets from YOY largemouth bass in four lakes (Forbes, Lake of the Woods, Lincoln Trail, and Walnut Point) were used to focus prey availability variables onto more specific values than overall availability of all taxa in a general prey category, such as zooplankton. The amount of recruitment variation explained by the model was estimated with an adjusted R^2. The same approach was used to construct multiple linear regression models for previous year classes in order to determine if any variables are consistently important to recruitment of largemouth bass to age-1.

FINDINGS: In 2003, YOY largemouth bass densities (Figure 4-1) and sizes (Figure 4-2) were highly variable among the 12 study lakes. YOY densities peaked in either June or July and ranged from $0.58/m^2$ to $0.04/m^2$. In Lincoln, Paradise, Ridge, and Woods, YOY peak densities were found to occur, on average, 33 days after peak reproductive activity. Abundance of YOY largemouth bass as early as May was correlated with densities of YOY at the end of the growing season (Spearman; $r = +0.63$; $P = 0.03$). YOY largemouth bass total length at the end of the growing season varied from 81 mm to 126 mm. Abiotic (Table 4-1) and biotic variables (Table 4-2) potentially important to YOY largemouth bass growth and survival varied among lakes and time of year. Inshore density of zooplankton exhibited multiple peaks over time (Figure 4-3) and varied among lakes from 114 individuals/L to 27.9/L (Table 4-2). Larval fish abundance also varied among lakes, and was highest in Lincoln, Paradise, and Walnut (Figure 4-4). Among lakes, average abundance of juvenile bluegill ranged from 0.004/m2 to 6.6/m2 (Table 4-2). Over time, juvenile bluegill abundance was very variable, sometimes exhibiting multiple peaks in abundance, especially in Ridge Lake where bluegill were extremely abundant (Figure 4-5). Mean density of juvenile bluegill was positively correlated with secchi depth (log transformed; $r = +0.69$) and negatively correlated with gizzard shad catch per unit effort (log transformed; $r = -0.78$).

The abundance and size structure of YOY largemouth bass was related to the availability of fish prey and water conditions. YOY densities during the growing season were not correlated with average values of total phosphorus, chlorophyll *a*, secchi depth, zooplankton, benthos abundance, or larval fish densities (Table 4-3). Abundances of

YOY largemouth bass were positively related to both spring water temperatures and juvenile bluegill (TL $\leq$ 60 mm) abundance (Table 4-3). Peak densities of YOY were also positively correlated with average spring water temperature (Pearson correlation; $r = +0.70$; $P = 0.01$) and juvenile bluegill density (Spearman correlation; $r = +0.58$; $P = 0.05$). Fall total length of YOY largemouth bass was positively correlated with larval fish abundance (larval density log-transformed; $r = +0.58$; $P = 0.05$) and negatively correlated with secchi depth (secchi depth log-transformed; $r = -0.63$; $P = 0.03$).

YOY largemouth bass diets changed from predominately zooplankton in the spring to primarily fish through the summer and fall (Figure 4-6). Benthic macroinvertebrates were consumed throughout the first growing season. Amphipods, chironomids, ephemeroptera, hemiptera, and zygoptera comprised 75% of benthos biomass in YOY bass diets. Based on these patterns of diet utilization, examination of recruitment relationships included zooplankton abundance in spring and excluded nauplii copepods and rotifers (Figure 4-6B). Benthos abundance consisted of amphipods, chironomidae, hemiptera, zygoptera, and ephemeroptera because of their importance in YOY diets. Juvenile bluegill and larval Lepomis were the most common fish found in YOY largemouth bass diets, and therefore, were used to represent the availability of fish prey. Based on changes in YOY diets over time, we focused on juvenile bluegill abundances after spring when more than 50% of YOY largemouth bass were piscivorous (Figure 4-6A).

Largemouth bass recruitment to age-1 was found to be variable among the 12 study lakes (Figure 4-7), with recruit abundance ranging from 1/hr to 23/hr. YOY densities were not a reliable indicator of year class strength because largemouth bass recruitment was not correlated with abundance of YOY at any point the previous year (Spearman; $P > 0.05$). Recruitment was correlated with post-spring density of juvenile bluegill (log transformed; $r = +0.64$; $P = 0.03$), and weakly correlated with spring density of zooplankton ($r = +0.51$; $P = 0.09$). Recruitment was not significantly correlated with total phosphorus, secchi depth, spring temperature, larval Lepomis density, gizzard shad abundance, spawning stock size, benthos density, fall total length of YOY largemouth bass, piscivore abundance, vegetation cover, or peak abundance of YOY bass ($P > 0.05$). Spring density of zooplankton was not significant ($\alpha = 0.15$) in the stepwise selection procedure, therefore the linear regression model only related recruitment of the 2003 year class to abundance of juvenile bluegill (Figure 4-8; adj. $R^2 = 0.35$).

Multiple linear regression models for previous year classes consisted of post-spring density of juvenile bluegill in combination with either chlorophyll *a* (2000 year-class; adj. $R^2 = 0.78$) or spring zooplankton abundance (2001 year class; adj. $R^2 = 0.43$). None of our measured variables were correlated with recruitment of the 1999 and 2002 year-classes ($P > 0.05$). After allowing the stepwise procedure to select from all possible variables for these two year-classes, we were only able to produce a model for the 2002 year-class that related recruitment to the density of Lepomis species larvae. However, the recruitment variability explained by this model was low (adj. $R^2 = 0.16$). The abundance of juvenile bluegill was found in all models that explained a significant amount of recruitment variation among lakes.

RECOMMENDATIONS: During the time period 1999-2003, abundance of YOY largemouth bass has not been a reliable indicator of bass recruitment. Environmental variables may prove to be more dependable as an early indicator of largemouth bass year class strength. Food availability has been correlated with YOY largemouth bass abundances and recruitment from 2000 to 2003. The abundance of small fishes, such as either larval fish or juvenile bluegill, has been the most consistent correlate of recruitment. YOY bass diets have helped us to focus food availability correlations onto the important prey types during each appropriate portion of YOY largemouth bass ontogeny. Warming trends in the spring also appear to influence YOY largemouth bass abundance. Indirect effects of the aquatic community may also influence recruitment. Gizzard shad was negatively related to the abundance of juvenile bluegill, an important bass prey species and a common correlate of recruitment.

Future expansions of analyses will include water level, vegetation cover, and hatch time. In 2003, water level was not found to vary much within and among most of the 12 study lakes. Over time, water level may vary more within lakes, allowing for a more rigorous examination of potential correlations between recruitment and water level. No correlations between vegetation cover and recruitment have been found yet, but our sample size is still small. In future reports, the vegetation cover from more lakes will be added to the analysis. The timing of YOY largemouth bass hatches should influence the availability of prey for each hatch cohort and subsequent recruitment. Determination of hatch timing from otolith daily rings will enable us to examine this important question.

The significant influence of multiple variables on largemouth bass recruitment points out the relatively complex mechanisms responsible for recruitment variation in these fish. As more year classes are added to our data set, we will be able to determine if specific factors consistently influence recruitment across years or if the pattern is more variable. With a larger data set, we will also expand our multivariate analysis to include examination of lake-specific factors affecting recruitment over time. Due to the potential importance of fish size for first year survival, future reports will address the influence of multiple factors on YOY largemouth bass growth rates. Better understanding of the factors that control largemouth bass recruitment will enable us to make recommendations for effective management actions to enhance this valuable fishery.

Job 101.5 Assessing the impact of angling on bass reproductive success, recruitment, and population size structure.

OBJECTIVE: To assess the level of angling for nesting bass in Illinois and to determine its impact on reproductive success and annual recruitment, as well as to determine how much long term exploitation of Illinois bass has changed the size structure of those populations.

INTRODUCTION: Largemouth bass are a popular, commonly sought sportfish throughout North America. Because of the continued growth in popularity of angling for this species (Holbrook 1975; Shupp 1979; Schramm et al. 1991a,b; Quinn 1996), concerns still remain about the effects that angling practices may have on black bass fisheries (Holbrook 1975; Shupp 1979; Wilde et al. 1998). Examinations of largemouth bass response to recreational (i.e., catch-and-release) and competitive angling have shown substantial mortality rates (see Wilde 1998), physiological changes (Gustaveson et al. 1991; Cooke et al. 2002b; Suski et al. 2003), and reproductive impairments (Philipp et al. 1997; Ostrand et al. In Press). Identifying the effects of capture and handling stress on largemouth bass reproduction is important given the continued growth in popularity of angling, including the common practice of catch-and-release (Quinn 1996) and competitive angling events (Gustaveson et al. 1991; Schramm et al. 1991a,b; Wilde et al. 1998).

Male largemouth bass and smallmouth bass experience reduced levels of food consumption while providing parental care (Kramer and Smith 1962; Pflieger 1966; Coble 1975), therefore, this period in the reproductive cycle is characterized by a continual decrease in energy storage and somatic growth. The quality of post-swim parental care provided is influenced by the energy reserves of the nesting male (Ridgway and Friesen 1992). As a result, any energetically costly activity, such as the type of exhaustive exercise experienced during angling, could result in a decreased ability or willingness of that male to provide continued parental care (Kieffler et al. 1995) and thus, negatively affect offspring survival. Furthermore, angling efforts tend to disproportionately target that portion of the male bass population that is most productive (i.e., larger males with higher mating success).

Accurate prediction of the effects of angling on largemouth bass growth is difficult. Previous studies with other species have been conducted in either saltwater environments (striped bass, Diodati and Richards 1996; Stockwell et al. 2002) or at cool temperature regimes (smallmouth bass, Clapp and Clark 1989) that cannot be easily applied to largemouth bass. Bioenergetics models of striped bass subjected to angling predicted decreased growth of 13 to 30%, depending on number of captures and level of decreased feeding associated with capture (Stockwell et al. 2002). However, decreased feeding after the angling event was estimated, rather than based on actual observations. High recapture rates have been documented in largemouth bass (up to 21 times per year, Burkett et al. 1986), suggesting decreases in feeding and growth may be greater than previously estimated in other species. Environmental conditions present during summertime bass angling (e.g., high temperatures) combined with stressful angling practices (especially competitive angling) may reduce feeding rates and seasonal growth of largemouth bass.

PROCEDURES: Snorkel surveys were conducted on April 22 and 28, 2004, and May 5, 2004 in Lincoln Trail. These surveys are used to assess the extent of largemouth bass spawning activity, nesting site selection by spawning males, and the effects of angling and electrofishing on nesting success. Twelve sites have been monitored each spring since 1999, except in 2002 due to high turbidity. Similar to 2002, high turbidity prevented us from being able to accurately survey bass nesting in Lincoln Trail in 2004.

Throughout the spawn and post-spawn period, we monitored bass tournaments at Mill Creek, Lake Mattoon, Forbes Lake, and Lake Shelbyville to determine if nesting males were more at risk from anglers than either non-nesting males or females. The total length, sex, and reproductive condition of each fish brought to weigh-in was recorded. In 2003 we began interviewing anglers at weigh-ins to determine if anglers were culling fish and influencing sex ratios observed at the conclusion of the tournaments. Previous data collected from tournaments showed that females angled were on average larger than males. This may produce skewed sex ratios at tournaments towards larger females as anglers culled out smaller males. Angler interview questions included the number of fish that were culled and the number of sub-legal fish that were caught and released.

To assess the effects of angling on feeding rates, we collected adult largemouth bass (mean total weight ± 1 SE = 444 ± 20 g) from central and southern Illinois lakes by electrofishing. Fish were held within a recirculating water system consisting of 24 tanks (0.6 m^3) with common settling tanks, biofilters, and temperature control unit. Water turnover rates of approximately 12 times/d were consistent among tanks. Fish were held at natural photoperiods (12L:12D) for at least six weeks and fed fathead minnows *Pimephales promelas* ad libitum. Fish were considered acclimated to the test tanks when they fed readily for at least two weeks prior to experimentation. After a 48-h starvation period, fish were subjected to one of the following treatments: control, simulated catch-and-release, or simulated tournament.

Fish subjected to the simulated catch-and-release angling treatment were netted, held underwater for 5 sec and hooked (Z-bend Texas Rig Worm Hook, Model L7095BP, Eagle Claw, Inc., Size 4/0) through the lower jaw. Fish were then chased for 60 s to simulate angling exhaustion (Cooke et al. 2002b), netted, measured and weighed during a 120 s air exposure (a duration shown to cause physiological disturbance; Cooke et al. 2002b), and then released back into their tanks. Fish in the simulated tournament were treated in the same way except they were then placed into a 75 L livewell for 4 h at a density of five fish per livewell. Livewell water temperatures were held within ± 0.02°C (±1 SE) of test temperatures with dissolved oxygen levels (mean ± 1 SE) of 3.15 ± 0.13 mg/L. Livewells had 5 min water flushes every 15 min in combination with a livewell disturbance (i.e. water agitation, opening lid) every 1 h to simulate wave action and culling. Fish were then removed from the livewell and given a 10 s air exposure before being held for 120 s in a plastic weigh-in bag (0.66 m x 0.86 m) containing about 7 L of water. Fish lengths and weights were taken exposing individuals to air for 120 s to simulate the weigh-in and fish transport back to the lake before they were released into their respective tanks. Physiological disturbances associated with the simulated angling we used have been shown to mimic disturbances observed during actual angling practices (C. Suski, Queen's University, personal communication). Control fish were left undisturbed in the tank.

Immediately after treated bass were returned to their tanks, fathead minnows (N = 10, mean weight ± 1 SE = 1.17 ± 0.03 g) were introduced into each tank and consumption was recorded as the number of minnow prey consumed in each tank up to 48 h. All treatments were replicated at each of the three acclimation temperatures (21.5 ± 0.03°C, 26.3 ± 0.05°C and 30.1 ± 0.04°C). Temperatures were chosen to represent the range that largemouth bass could experience across spring, summer, and fall in mid-temperate latitude lakes. We compared feeding rates of largemouth bass subjected to catch and release and tournament angling practices to controls across the three temperatures. We also used multiple logistic regression to assess the effects of temperature, catch-and-release, and tournament treatments on largemouth bass feeding. We fit the multiple logistic response function:

$$Y_i = e^{(\beta' X i)}/1 + e^{(\beta' X i)}$$

where, Y_i = probability of prey consumption, $\beta' Xi = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$, β_o = regression intercept, β_1 = regression slope, and X_j = independent variables (temperature, catch-and-release, and tournament treatments) (Neter et al. 1996). We assessed the significance of the logistic regression models using a full/reduced model likelihood ratio χ^2 test (Table 5-1; SAS 1999). We then used the logistic model to predict consumption values at various temperatures for use in the bioenergetics simulations.

Using the Hanson et al. (1997) Fish Bioenergetics 3.0 software, we estimated loss of weight due to delays in feeding caused by angling. Energy densities of largemouth bass and fathead minnow prey were estimated at 1,000 cal/g (Rice et al. 1983; Garvey et al. In press). We adjusted the model for two days after fish capture by reducing daily energy intake in the energy balance equation to approximate reduced feeding due to catch-and-release or tournament angling events relative to controls. Temperatures (range = 16.8 to 32.3 °C) used in the model were obtained using Hobo Temperature Loggers (Onset Computer Corp.) placed 1-m below the surface of Stephen Forbes Lake, Marion County, Illinois (22 May 2002 to 3 October 2002; 38° 42' 50.0 N, 88° 44' 55.0 W). We used initial weight (444 g) and final weight (510 g) of control fish for the 135-d model simulation period to represent average growth of an age-4 largemouth bass (Perry et al. 1995). To assess reduced growth of largemouth bass related to type of angling (i.e., catch-and-release or competitive event), we subjected bass in the model from zero to twelve captures over a season, values within the range of number of captures over a season observed by Burkett et al. (1986).

FINDINGS: Sampling of largemouth bass fishing tournaments were conducted in 2003/2004 in Lake Shelbyville (N=2) and Lake Mattoon (N=2) and were combined with data collected in previous years. Tournament anglers in the spring do appear to target spawning bass. The percentage of bass that were reproductively active ranged from 66% to 100% of all fish captured (Table 5-1). A majority of both male and female bass sampled in spring tournaments had signs of spawning activity (ripe, running, swollen pore, and fin erosion). A higher proportion of males were angled in all lakes during the spawning period except Shelbyville. This would imply that spawning males are targeted in disproportion to females. Males however are also captured at higher proportions in tournaments in the post spawn period and a higher proportion of males were caught during the post-spawn period in Forbes, Shelbyville, and Mattoon Lakes.

In the first year of angler interviews and reported in previous segments, we have thus far only surveyed 5 anglers to determine if they were culling smaller male fish from their creel during the spawn. Of the five anglers surveyed, only one had a captured a limit of fish. No anglers had culled any fish from their creel. Observations from previous tournaments are consistent with the surveys in that there are few anglers that catch enough bass to allow them to cull. Several of the anglers surveyed caught and released sub-legal fish. If they are reproductively active fish, there may be some implications to nesting success related to catch and release angling.

Angling practices and temperatures interacted to decrease largemouth bass prey consumption after capture. Mean prey consumption decreased with increased temperature (Figure 5-1). Mean prey consumption at 12 h was highest for control fish followed by catch-and-release and competitively angled fish (Figure 5-2). Using estimated feeding rates obtained from the multiple logistic model, bioenergetics simulations predicted lower growth for fish that experienced reduced feeding associated with multiple angling events (Figure 5-3). Lower final weights were predicted by the bioenergetics model for tournament-angled fish than for catch-and-release angled fish.

RECOMMENDATIONS: In 2004, we were unable to survey largemouth bass nests due to low visibility during the spawning season. In future seasons, we will continue snorkel surveys during largemouth bass nesting in Lincoln Trail, as long as conditions are favorable for accurate data collection. During these surveys, we will continue our measurements on nest abandonment, habitat selection by nesting males, and nest predation. Furthermore, we will expand our sample size for our examination of the potential influence of angling on nest abandonment by parental males and the influence of habitat type, predation pressure, and parental male aggression on nest success.

In conjunction with our angling experiments, we will continue to monitor bass tournaments in order to assess if reproductively active males are being preferentially caught. Data from three of the four lakes examined suggests that this may be the case during both spring tournaments and the post-spawning period. Preliminary information provided by tournament angler surveys suggests that the culling and release of smaller males for larger females is minimal and not skewing sex ratio numbers. Sample sizes are very small thus far for these surveys and future segments will focus on increasing sample sizes of angler surveys to determine the effects of culling. Using this data, we will be able to make predictions about how angling will affect recruitment of largemouth bass.

Water temperature and angling practices are major determinants of the degree of sublethal stress experienced by fish. Physiological disturbances and mortality rates of fish increase with water temperature and the degree of stress experienced during the angling event (Gustaveson et al. 1991; Kieffer 2000; Cooke et al. 2002b; Suski et al. 2003). Similarly, we found lower feeding rates after angling at warmer water temperatures. It is unlikely that the loss of energy in individual largemouth bass due to angling would cause mortality, but our model simulations suggest declines in food consumption could affect growth rates.

Anglers should focus on minimizing the handling of fish to reduce any potential effects of angling on feeding and growth of largemouth bass. Efficiently landing and unhooking fish in order to return them to the water in a timely manner will minimize the effects of catch-and-release angling on largemouth bass. During competitive events, anglers should quickly unhook fish and place them in the livewell, and maintain good livewell conditions during the confinement period. Weigh-ins should be conducted as efficiently as possible, reducing handling times throughout the entire competitive event. Angling when water temperatures are not at their extremes (i.e. spring or fall, early morning or evening) may also allow fish to more quickly recover from the angling event and begin feeding with minimal effects on growth. Anglers should take a proactive approach in maintaining quality fish handling practices during both recreational and competitive angling to minimize effects on largemouth bass feeding rates and growth.

Job 101.6 Evaluating the impact of harvest regulations on largemouth bass recruitment in Illinois.

OBJECTIVE: To develop a model to evaluate the effects of various angling scenarios and pressures on Illinois bass recruitment and size structure.

INTRODUCTION: Largemouth bass can be vulnerable to anglers while spawning and the success of the spawn may depend on stress the fish undergoes during this period. This has sparked a recent controversy in anglers whether or not bed fishing (angling fish off the nest) is detrimental to bass populations.

Our recent research (Job 101.5) suggests that angling largemouth bass off the nest can cause the fish to abandon the nest, which results in the failure of the nest to produce offspring. Many states have implemented closed seasons or spawning refuges, which are closed to fishing in an attempt to alleviate this problem. It is unclear if these management techniques are appropriate for Illinois reservoirs.

Clinton Lake is an approximately 5000-acre lake that is operated as both a power plant cooling lake and a recreational lake. In the fall of 2001, a portion of the lake adjacent to the Clinton Lake Power Plant was closed to boaters and anglers permanently. This closed area provides a refuge for largemouth bass from angling. The refuge may be beneficial to largemouth bass, by increasing spawning success and decreasing fishing mortality. We will use this opportunity to begin to evaluate the success of a fish refuge in increasing numbers and size structure of the largemouth bass population.

PROCEDURES: Population abundance and size structure of largemouth bass were assessed in Clinton Lake using spring and fall electrofishing and seining in 1999-2004. Samples collected during 1999 – 2001 represent pre-refuge During the fall of 2003, two electrofishing transects and two seine hauls were performed inside the refuge. Three transects were also electrofished and seined outside of the refuge. Sites outside of the refuge were located adjacent to and approximately 2 and 4 lake miles from the refuge. Fish were identified to species and total length was recorded. Catch per unit effort (CPUE) was then calculated as the number of fish per hour of AC electrofishing. Seining was conducted using a 9.2-m bag seine pulled along the shoreline at fixed transects. All fish were counted and up to 50 fish were measured for each species. All largemouth and smallmouth bass collected inside the refuge were given an upper caudle fin clip in order to determine if fish in the refuge move into adjacent areas of the lake.

FINDINGS: Mean CPUE for largemouth bass in Clinton Lake from 1999 through 2004 were 25.5 fish per hour of electrofishing. This is lower than most of our study lakes, which have a range of CPUE from 20.9 to 67.3 fish per hour. As a result, there is the potential for an increase in abundance of largemouth bass in Clinton Lake from implementation of the refuge. Sampling at sites inside the refuge in 2003 yielded a much higher CPUE than sites outside the refuge as well as samples taken before the refuge was closed (Table 6-1). This suggests that bass may be more abundant inside the refuge due to the elimination of fishing pressure. This data however is based on two sample dates in one year. More data is required to verify that CPUE is consistently higher inside the refuge. CPUE from seines was lower for all fish in the refuge than in the remainder of the lake. CPUE for bass however was twice as high in the refuge than in the remainder of the lake. The refuge may be positively influencing young-of-year largemouth bass recruitment. Continued assessment of young-of-year bass is required in order to assess if the refuge is increasing natural recruitment in Clinton Lake. No clipped fish were observed in electrofishing or seine samples taken outside of the refuge. This implies that there is little or no movement of fish from the refuge to the open portion of the lake. This is also based on a low sample size and must be supplemented in future segments.

RECOMMENDATIONS: We will continue to monitor largemouth bass abundance and size structure in Clinton Lake through the next several years. Sampling will continue at sites both inside and outside of the refuge. At this time there are low sample sizes due to limited access to the refuge immediately after closing. We will continue gaining access to the refuge once in the spring and fall of each year. In future segments, we will also analyze electrofishing and seine CPUE data for young of year bass production in order to determine if closing the refuge is affecting natural reproduction and recruitment.

There are many potential harvest regulations that can be used to manage bass populations, including size limits, closed seasons, and spawning refuges. Each of them can have a different impact on the population, either by affecting size structure or numbers. Some regulations have the potential to impact recruitment more than others, but right now, we cannot make accurate predictions. Other management options include habitat, prey, and predator manipulations. As part of the next segment, we will develop an adaptive study that will involve the use of experimental management on some state lakes, coupled to the FAS Lakes and Creel databases. As a first step, we will establish a statewide team of fisheries biologists to design a large-scale study (involving multiple state lakes) that will assess the usefulness of various regulations and other strategies to manage bass population recruitment and size structure.

Job 101.7. Analysis and reporting.

OBJECTIVE: To prepare annual and final reports summarizing information and develop management guidelines for largemouth bass in Illinois.

PROCEDURES and FINDINGS: Data collected in Jobs 101.1-101.6 were analyzed to develop guidelines for largemouth bass regarding stocking and management techniques throughout Illinois.

	Segment 6	
Job	Proposed cost	Actual cost
Job 1	$29,510	$29,510
Job 2	$64,921	$64,921
Job 3	$44,264	$44,264
Job 4	$64,921	$64,921
Job 5	$50,166	$50,166
Job 6	$11,804	$11,804
Job 7	$29,510	$29,510

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Table 1-1. Growth rates for 4" largemouth bass marked with fin clips (FC), freeze brands (FB), or fin cauterization (FCFB). Seventy-five fin clipped, 100 freeze brand, and 75 fin clip cauterized fish were stocked into three 0.3-acre ponds on 14 December 1998 and sampled every subsequent spring and fall. Unidentifiable fish were recognized by their respective genotype: fin clipped (1:1), freeze brand (1:2), and fin clip cauterized (2:2).

	Growth Rate (g/d)		
Date	Fin clip	Freeze brand	Fin cauterization
12/14/98 to 5/27/99	0.10	0.09	0.10
5/27/99 to 10/26/99	0.19	0.23	0.22
10/26/99 to 3/20/00	0.05	0.05	0.03
3/20/00 to 11/2/00	0.38	0.30	0.41
11/2/00 to 3/15/01	0.08	0.08	0.10
3/15/01 to 10/18/01	0.04	0.05	0.06
10/18/01 to 3/12/02	0.18	0.18	0.18
3/12/02 to 10/16/02	0.76	0.66	0.78
10/16/02 to 3/19/03	0.05	0.07	0.06
3/19/03 to 10/22/03	0.15	0.26	0.19
10/22/03 to 3/18/04	0.07	0.09	0.03

Table 2-1. Comparison of stocking success of four sizes of largemouth bass in Lakes Charleston and Homer, 2003 and 2004. Catch per unit effort (CPUE) is measured as the number of fish per hour of AC electrofishing during the fall and following spring. Each size class was given a distinct mark for future identification. Stocking mortality was estimated by holding bass in 3 mesh cages and counting the number of dead after 48 hours.

Lake	Stock	Date	Stocking TL (mm)	Number Stocked	Stocking Density (#/ha)	Temperature at Stocking (°C)	Stocking Mortality (%)
MINGO	2	07/22/03	56	8500	123	26	0
	4	08/19/03	115	4250	62	29	2
	6	09/23/03	158	2550	37	21	0
	8	04/21/04	205	1600	23	18	0
WOODS	2	07/22/03	56	1400	127	28	17
	4	08/19/03	115	700	64	29	2
	6	09/23/03	158	280	25	21	0
	8	04/21/04	205	150	14	18	0

Table 2-2. Comparison of survival among three sizes of stocked and naturally produced largemouth bass. Catch per unit effort (CPUE) is the mean from electrofishing samples performed in the fall of 2003 and spring of 2004. CPUE is reported as number of fish per hour of AC electrofishing. Two inch fish have not yet been processed for OTC marks.

Lake	Stock	Fall Size (mm)	Fall CPUE (#/hr)	Spring Size (mm)	Spring CPUE (#/hr)
MINGO	2	-	-	-	-
	4	131	7	146	1
	6	162	39	168	4
	8	NA	NA	201	26
	Natural	189	114	194	21
WOODS	2	-	-	-	-
	4	-	0	-	0
	6	180	20	160	5
	8	NA	NA	201	20
	Natural	188	39	157	13

Table 2-3. Comparison of predation on different sizes of stocked bass. All potential predators were examined for diets and percent of predators with stocked bass in the diets was reported.

Lake	Size	Stomachs Examined	Stomachs full	Stocked LMB observed in Diet	Percent of predators with stocked LMB in diet
MINGO	2	67	43	16	24
	4	25	16	2	8
	6	24	11	0	0
	8	1	0	0	0
WOODS	2	35	10	1	3
	4	32	6	0	0
	6	9	1	0	0
	8	2	0	0	0

Table 2-4. Largemouth bass stocking summaries for lakes Shelbyville, and Walton Park. Intensively reared bass were raised in raceways while extensively reared bass were raised in ponds. Catch per unit effort (CPUE) is based on the number of fish collected per hour of daytime AC electrofishing in fall and spring months.

Lake	Stock	N	Fall TL +/- SE (mm)	Fall CPUE (#/hr)	Spring TL (mm)	Spring CPUE (#/hr)
Shelbyville	Intensive	8800	130 +/- 0	0.7	164 +/- 0	0.7
	Extensive	35000	115 +/- 0	0.7	-	0.0
	Native	-	139 +/- 8.8	18.3	145 +/- 12.8	9.0
Walton Park	Intensive	625	137 +/- 9.6	2.7	147 +/- 2.0	1.3
	Extensive	625	-	0.0	-	0.0
	Native	-	124 +/- 8.3	12.7	145 +/- 23.4	2.0

Table 3-1. Background frequencies of largemouth bass MDH B2:B2 genotype determined from Little Grassy Fish Hatchery and six lakes in Illinois prior to stocking (1998 to 2001). Post-stocking collections are the number of individuals taken from each of the six lakes in Illinois during 2002-03 to determine MDH B2 allele frequency after stocking.

Source	Pre-Stocking Genotypes (N)			Pre-Stocking Allele Frequencies		Post-Stocking YOY Collected(N)	
				1	2	2002	2003
Little Grassy Fish Hatchery	1/1 (0)	1/2 (05)	2/2 (262)	0.05	0.95	100	100
Forbes	1/1 (81)	1/2 (49)	2/2 (28)	0.67	0.33	98	94
McCleansboro	1/1 (23)	1/2 (34)	2/2 (32)	0.45	0.55	105	87
Murphysboro	1/1 (80)	1/2 (12)	2/2 (06)	0.88	0.12	108	112
Sam Parr	1/1 (75)	1/2 (16)	2/2 (10)	0.82	0.18	107	100
Shelbyville	1/1 (158)	1/2 (45)	2/2 (08)	0.86	0.14	100	66
Walton Park	1/1 (66)	1/2 (11)	2/2 (08)	0.84	0.16	73	101

Table 4-1. Average values of total phosphorus (TP; µg/L), secchi depth (m), spring temperature (°C), and aquatic vegetation cover in spring (% of lake area) in 12 study lakes in Illinois during 2003.

Lake	TP	Secchi	Spring temp	Vegetation
Clinton	143	0.67	18.7	-
Dolan	216	0.48	18.8	-
Forbes	157	0.74	19.1	-
Lake of t. Woods	156	0.77	18.5	0.28
Lincoln Trail	73	1.56	19.7	0.19
Paradise	327	0.42	18.3	0.03
Pierce	107	0.87	19.6	0.22
Ridge	151	0.78	20.5	-
Shelbyville	131	0.9	18.7	-
Sterling	73	1.62	19.1	0.25
Walnut Point	177	0.91	20	0.05
Woods	194	0.47	17.6	0

Table 4-2. Average values of chlorophyll *a* (μg/L), total zooplankton (N/L), benthos (N/m^2), total larval fish density (N/m^3), juvenile bluegill abundance (N/m^2), and gizzard shad CPUE (N/hr) in 12 study lakes in Illinois during 2003.

Lake	Chloro	Zoop	Benthos	Larval	J. Blg	Gz Shad
Clinton	36.3	27.9	12979	6.26	0.08	94.5
Dolan	50.3	41.3	6070	1.64	0.35	21.3
Forbes	23.9	46.5	1378	6.09	0.23	76.7
Lake of t. Woods	20.1	62	20364	5.7	0.79	37
Lincoln Trail	16.6	31.5	7644	23.1	3.14	0
Paradise	57	65.2	9899	34.8	0.12	117
Pierce	21.2	93	10712	5.1	2.33	69
Ridge	32.2	114	13407	1.2	6.6	0
Shelbyville	9.43	88.9	945.5	2.88	0.004	377
Sterling	12.8	44.1	4110	0.41	0.083	19
Walnut Point	40.5	62.8	19218	26.5	3.08	0
Woods	41.1	46.5	7514	8.34	0.18	266

Table 4-3. Pearson correlation coefficients for the relationships between the mean densities of YOY largemouth bass (log transformed; N/m^2) during 2003 and average values of spring water temperature (°C), total phosphorus (log transformed; TP; μg/L), chlorophyll *a* (μg/L), secchi depth (log transformed; m), spring zooplankton (N/L), benthos (N/m^2; taxa selected in diets only), larval Lepomis species (log transformed; N/m^3), and post-spring density of juvenile bluegill (log transformed; TL $\leq$ 60 mm; N/m^2). * is $P \leq 0.05$ and ** is $P \leq 0.01$.

Month	Spring Temp	TP	Chlorophyll	Secchi Depth	Spr Zoopl	Benthos	Larval Lep	Juv BLG
May	0.62*	0.07	0.13	-0.05	0.05	-0.23	-0.07	0.64*
Jun	0.31	-0.11	-0.05	0.07	-0.49	-0.29	0.06	0.25
Jul	0.74**	-0.03	0.09	0.16	0.36	-0.36	0.28	0.8**
Aug	0.36	0.11	0.2	0.1	0.17	-0.22	0.57	0.41
Sep	0.75**	-0.05	0.03	0.15	0.16	-0.47	0.22	0.78**
Oct	0.65*	-0.08	0.03	0.3	0.18	-0.39	0.4	0.68*

Table 5-1. Logistic regressions describing consumption, temperature, and time for controls and fish subjected to simulated catch-and-release and simulated competitive angling. Intercepts (β_o), regression slopes for predictor variables time (β_1), temperature (β_2), and time*temperature (β_3), and likelihood ratio (χ^2) value with associated degrees of freedom (df) and p-values (*P*) are presented for each regression equation.

Treatment	β_o	β_1	β_2	β_3	χ^2 (df)	*P*
Control	0.2877	0.5427	0.0063	-0.0116	856.4 (3)	< 0.01
Catch-and-release	0.6306	0.1550	-0.0957	-0.0008	923.9 (3)	< 0.01
Competitive	-2.7586	0.5470	-0.0298	-0.0151	1214.4 (3)	< 0.01

Table 6-1. CPUE (#/hr) for largemouth bass in Clinton Lake captured through AC electrofishing. The refuge was closed in 2001 and sampling on the closed portion began in fall of 2003.

Year	Control		Refuge	
	Spring	Fall	Spring	Fall
1999	19.8	24.5	56.0	24.0
2000	32.4	8.0	18.0	2.4
2001	26.0	48.7	10.0	22.0
Refuge Closed 9-11-01				
2002	8.5	43.0	-	-
2003	21.5	22.7	-	116.0

Figure 6-2. Catch per unit effort from seine hauls in 2003 taken from the main lake and inside the refuge. CPUE is measured as number of fish per square meter.

	Seine CPUE (#/m^2)			
	Control		Refuge	
	Spring	Fall	Spring	Fall
All Fish	0.42	0.44	-	0.27
LMB	0.01	0.004	-	0.008

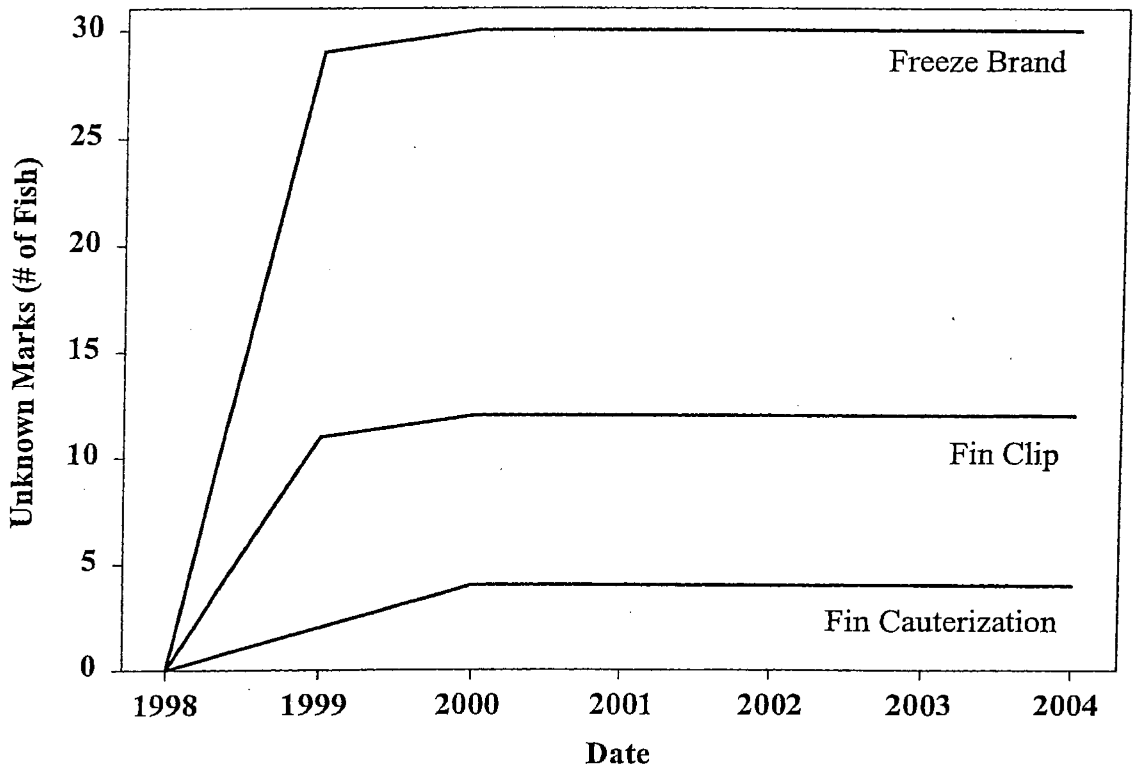

Figure 1-1. Cummulative number of 4" largemouth bass with unrecognizable marks sacrificed and identified by 1:1 (Fin Clip), 1:2 (Freeze Brand), or 2:2 (Fin Cauterization) MDH-B genotype for each date sampled.

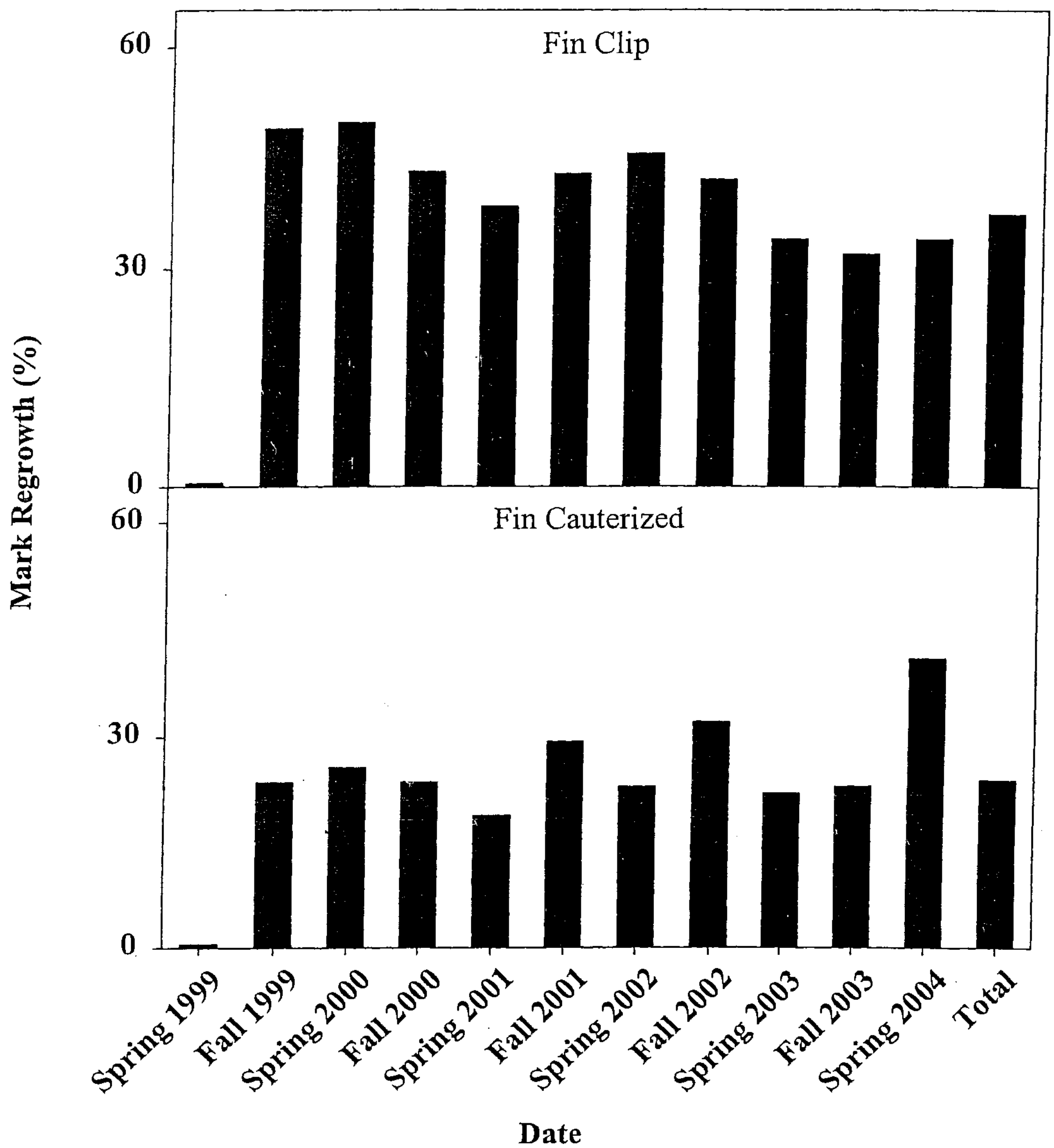

Figure 1-2. Average mark regrowth (%) for fin clip and fin cauterized marked 4" largemouth bass through time. Total denotes experiment wise average (%) regrowth for fin clip and fin cauterized marks.

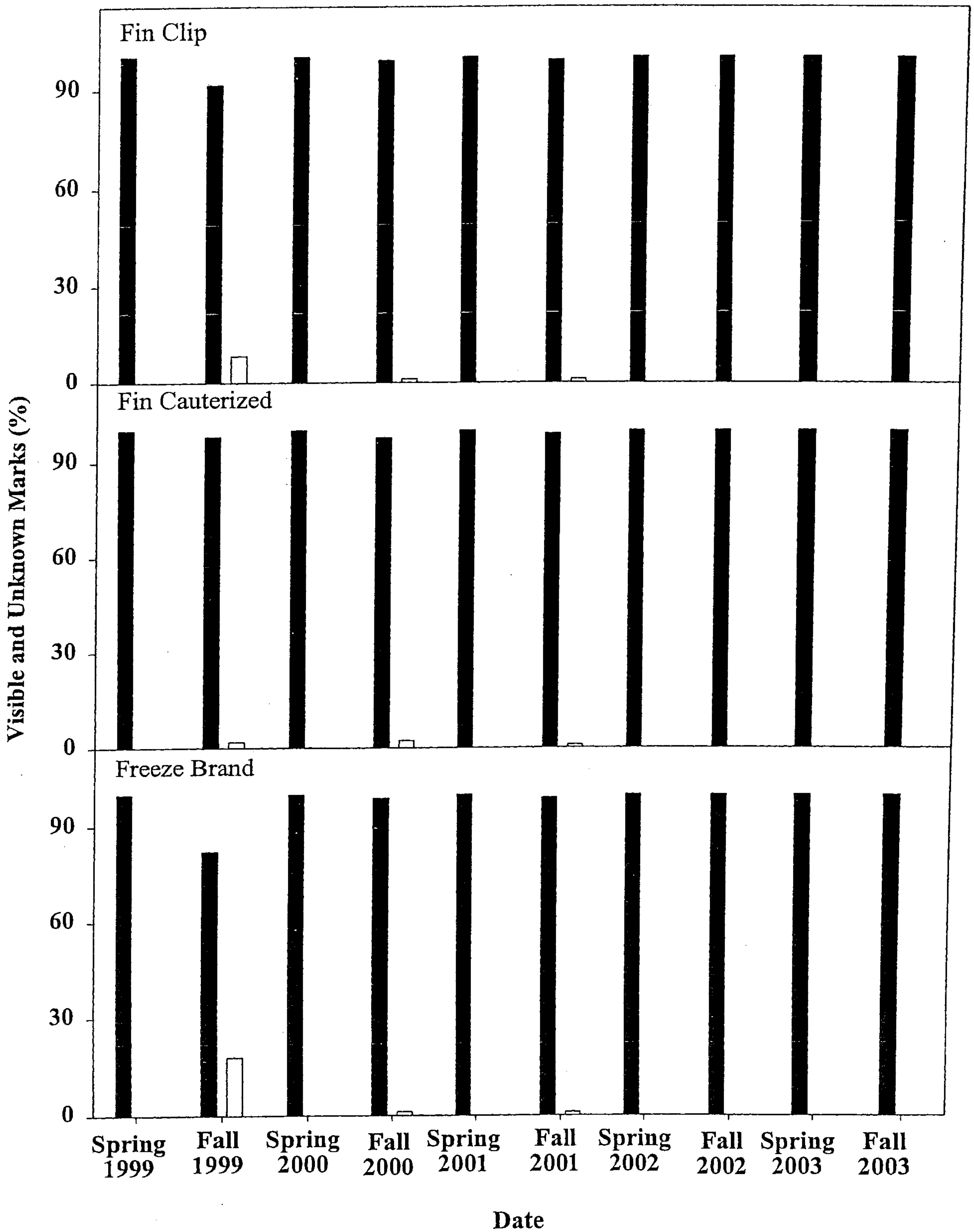

Figure 1-3. Percent of visible marks (dark bars) and those that were undiscernable (light bars) and identified by gentic markers for fin clip, fin cauterized, and freeze brand marks sampled seasonally.

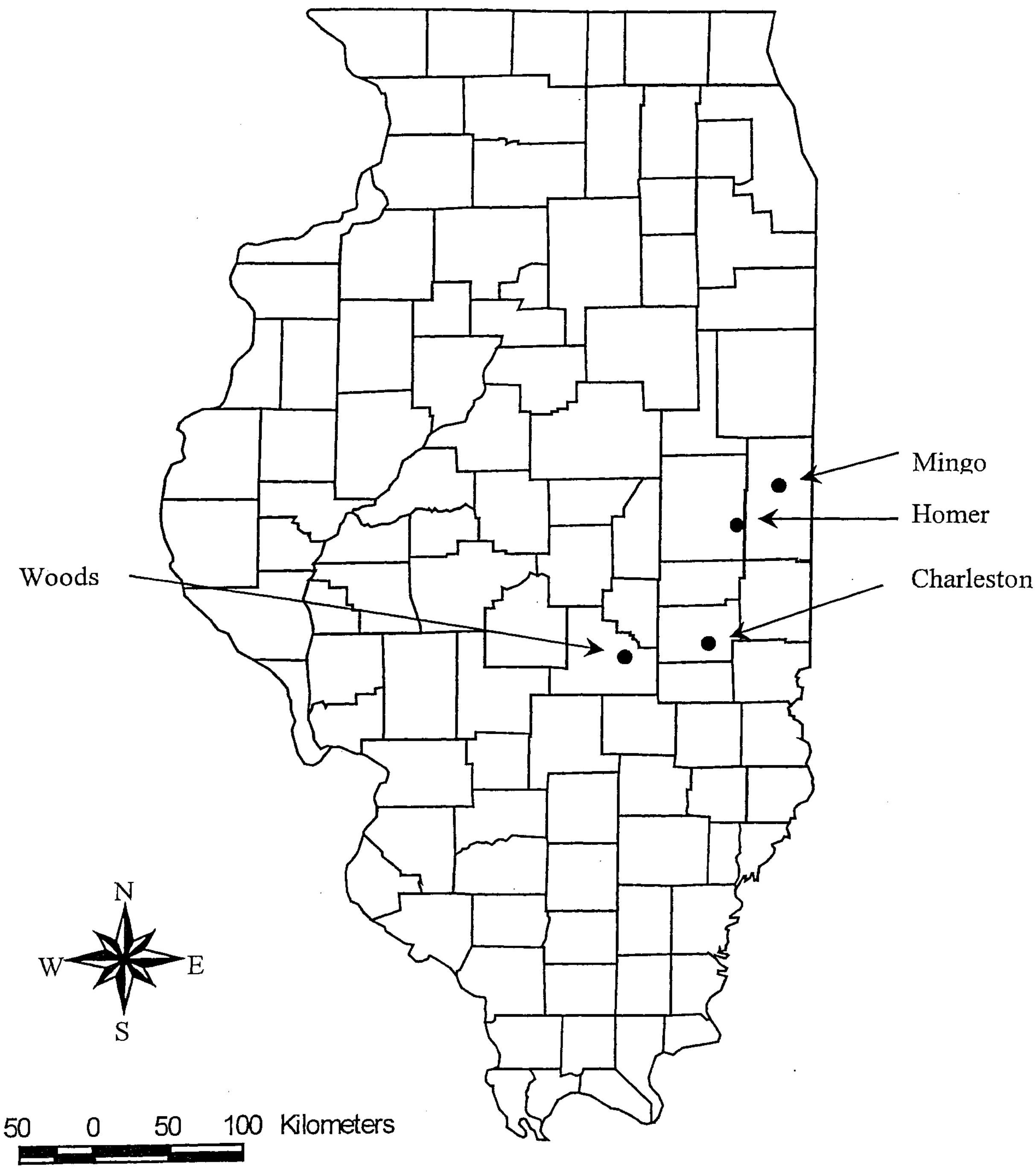

Figure 2-1. Location of 4 lakes in Illinois stocked with four sizes of fingerling largemouth bass in 1999 – 2004.

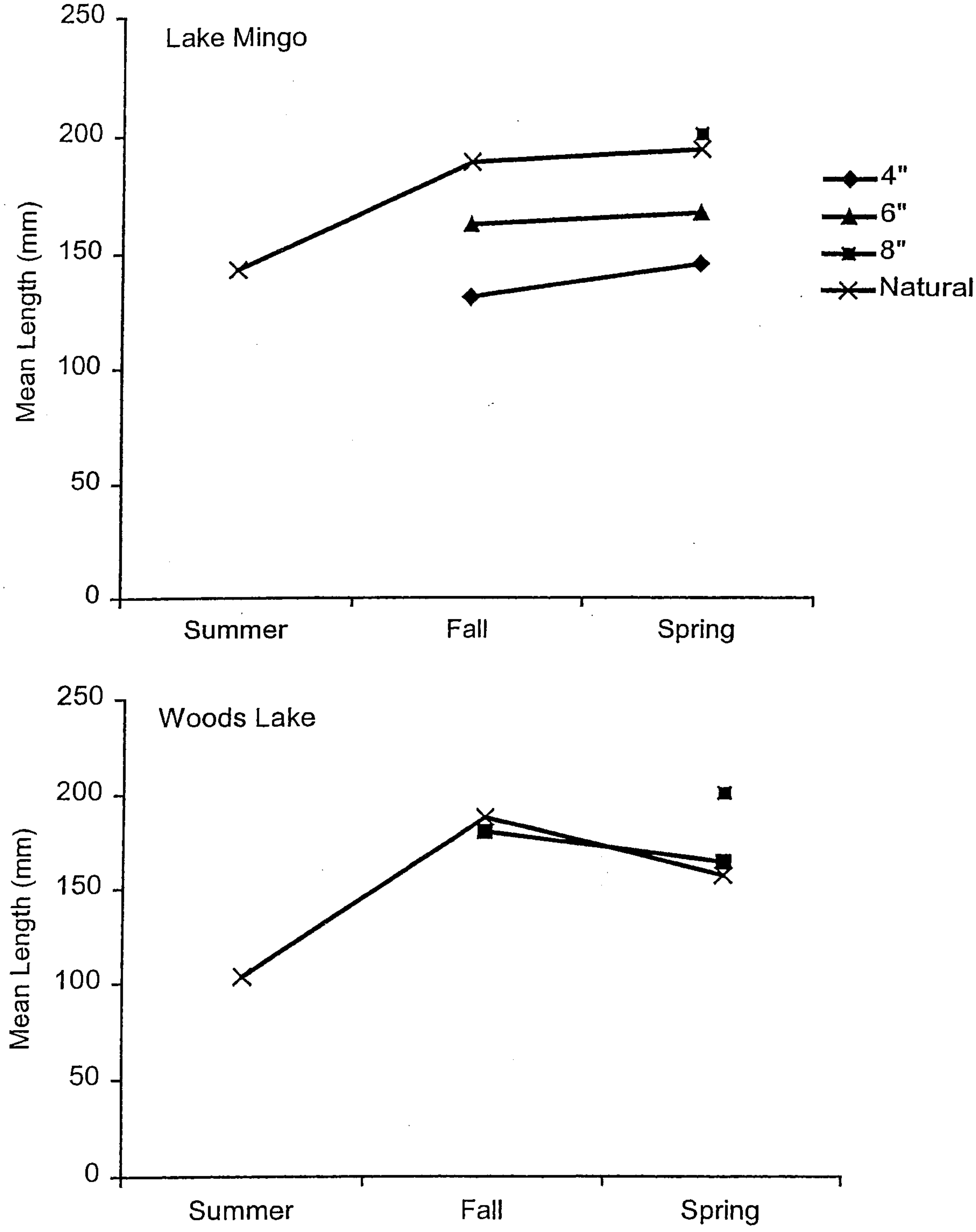

Figure 2-2. Growth of stocked and natural largemouth bass following introduction in Woods Lake and Lake Mingo during 2003 and 2004. Mean length of fish of each stock was determined from recapture during AC electrofishing.

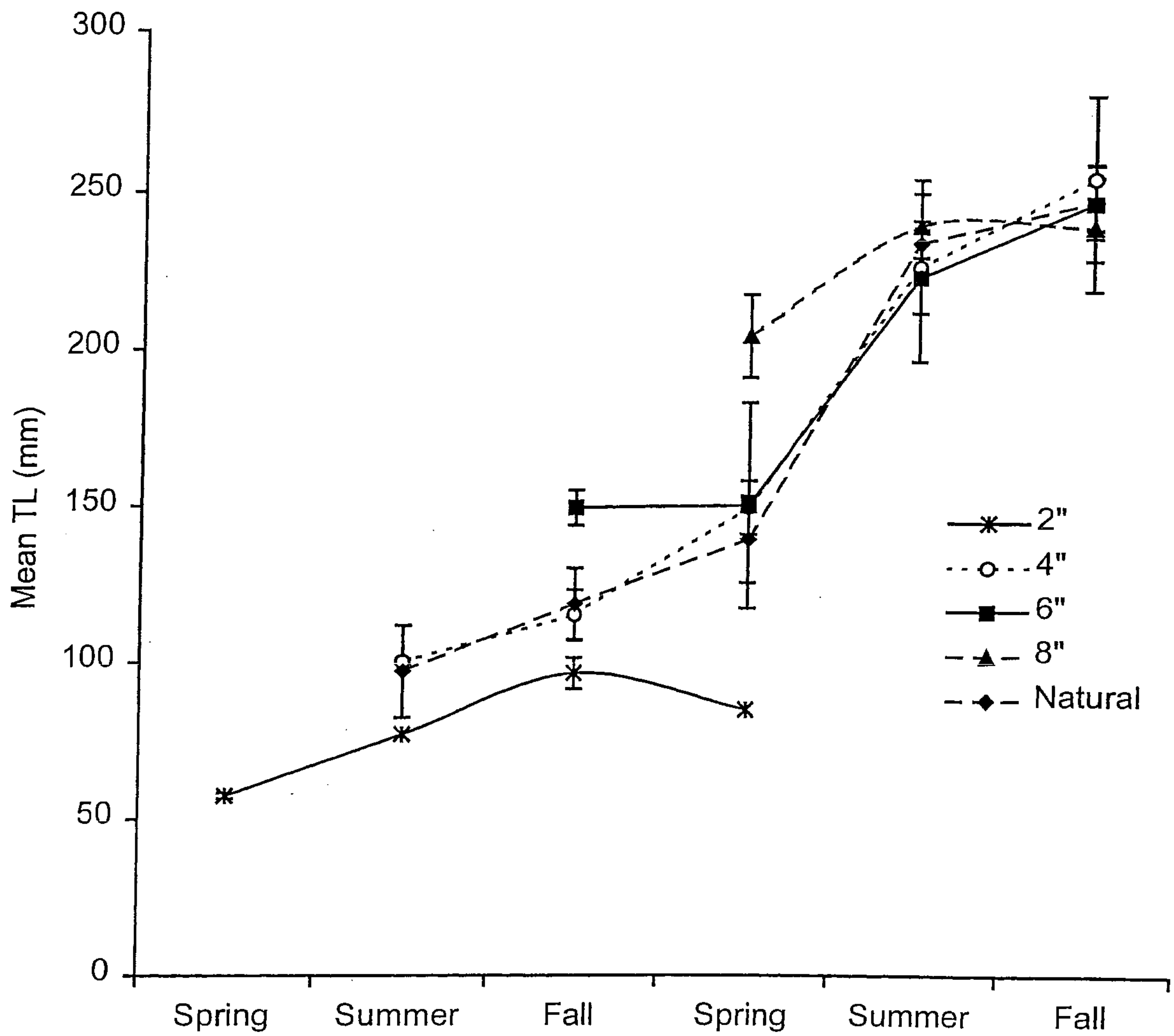

Figure 2-3. Mean growth through time of different sized largemouth bass after stocking in 4 reservoirs during 1998-2003. Values are mean total length (mm) +/- 1SE in each season following stocking.

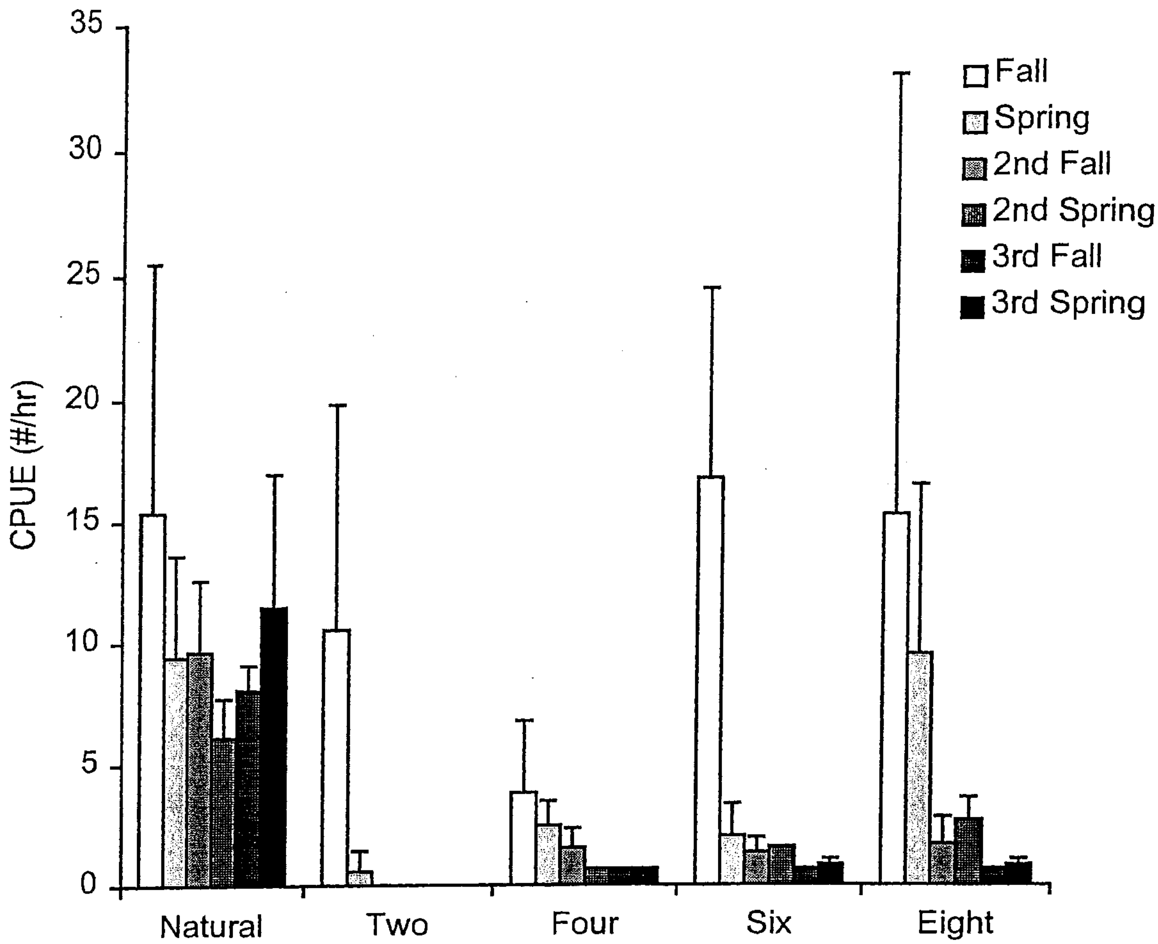

Figure 2-4. Catch per unit effort (CPUE) through time for different sizes of stocked largemouth bass in 4 reservoirs in 3 years during 1998-2003. Catch per unit effort is the number of fish per hour of AC electrofishing.

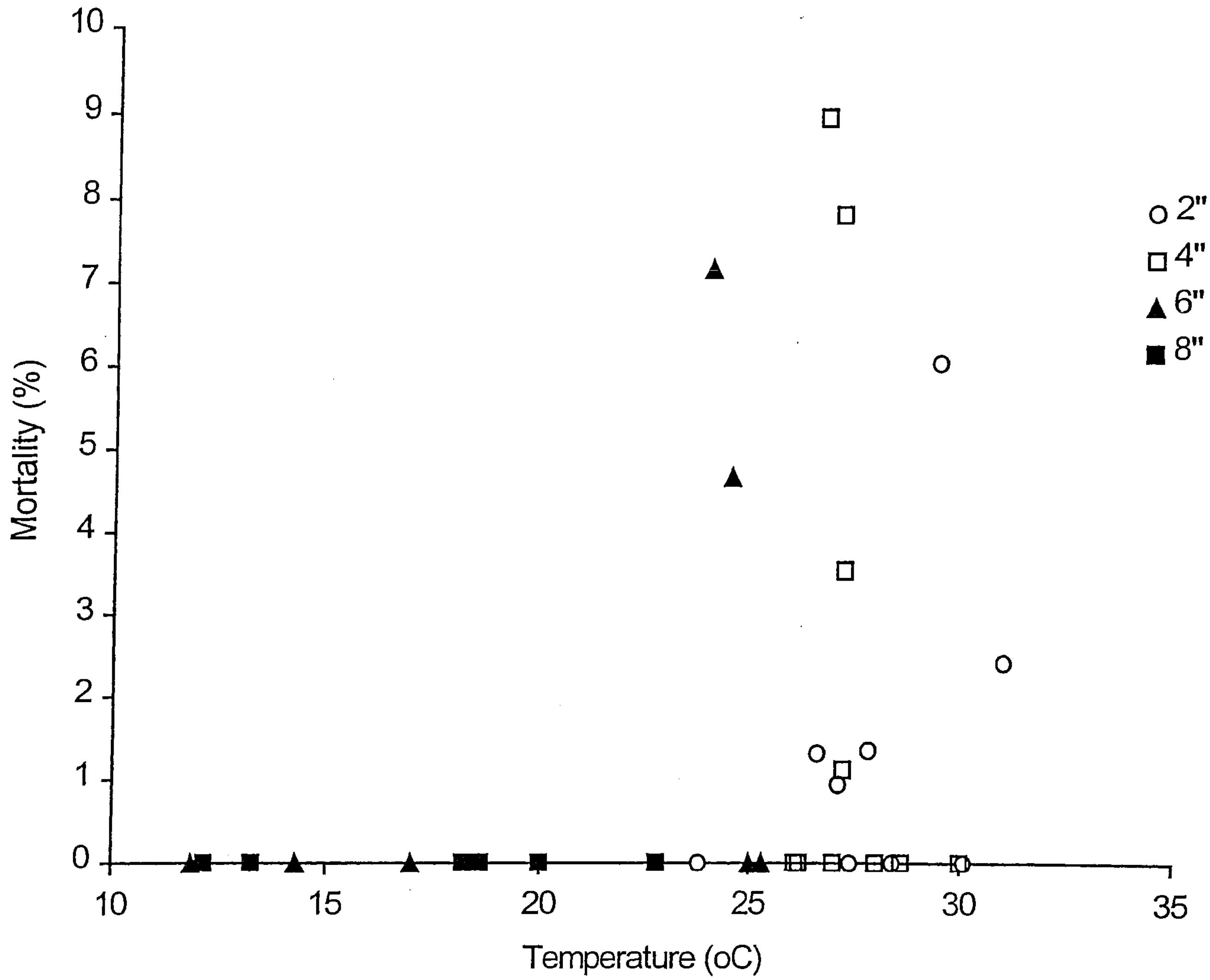

Figure 2-5. Relationship between mortality at stocking and temperature. Stocking mortality was estimated by holding bass in 3 mesh cages and counting the number of dead after 48 hours. Temperature is the lake surface temperature at the time of stocking.

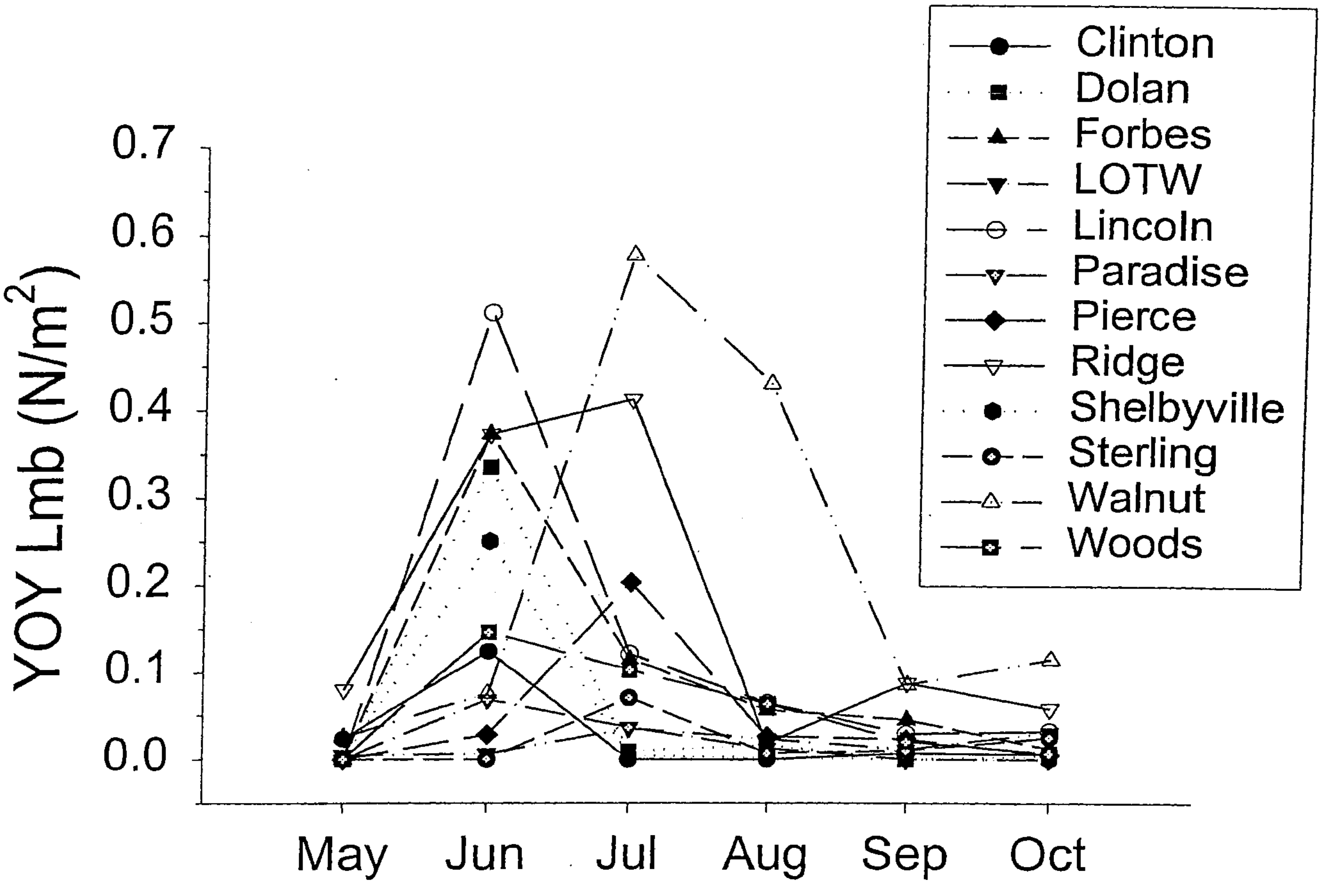

Figure 4-1. Average monthly young of the year (YOY) largemouth bass densities (N/m^2) for 12 study lakes in 2003. Largemouth bass were collected with a 9.2-m bag seine from 4 stations in each lake. Closed symbols represent lakes with gizzard shad, whereas, open symbols represent lakes without gizzard shad.

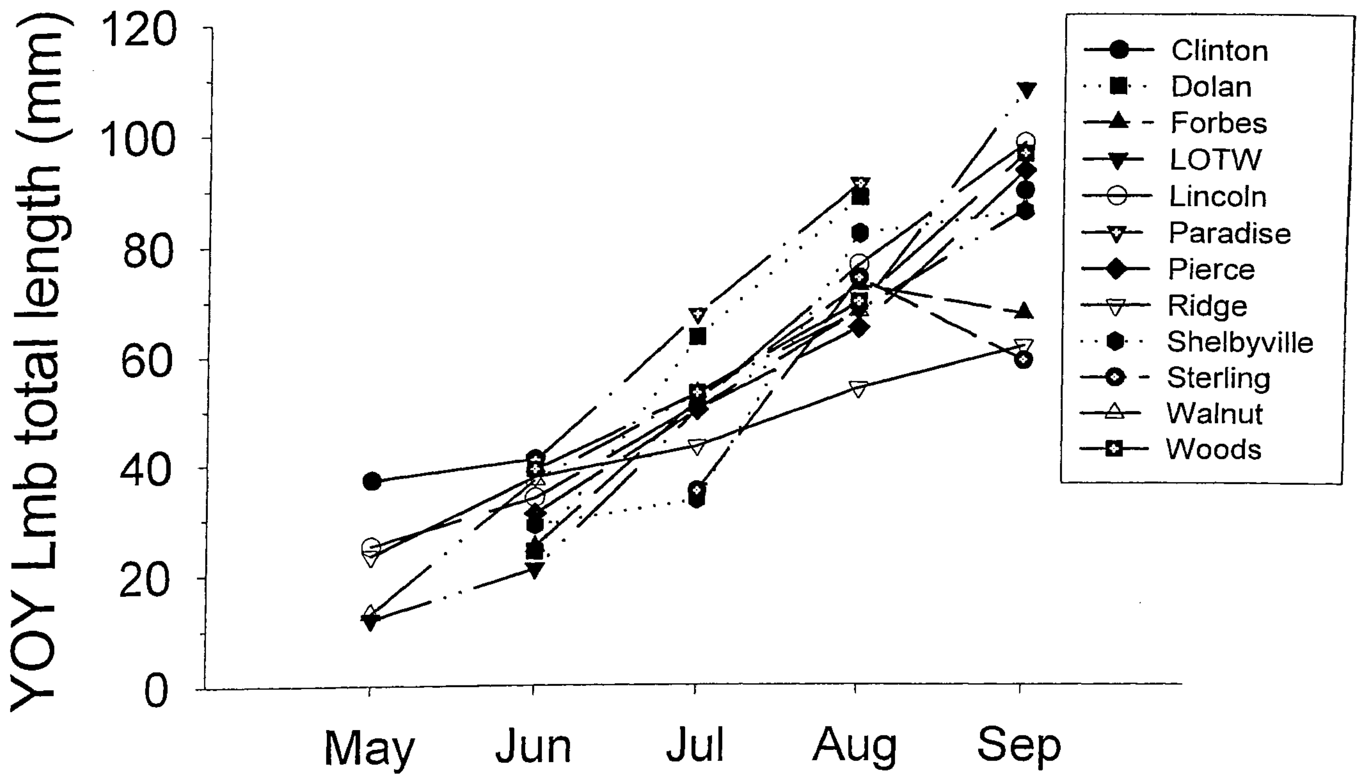

Figure 4-2. Average monthly total lengths (mm) of young of the year largemouth bass collected from 12 study lakes in 2003. Largemouth bass were collected with a 9.2-m bag seine from 4 stations on each lake. Open symbols represent lakes with no gizzard shad.

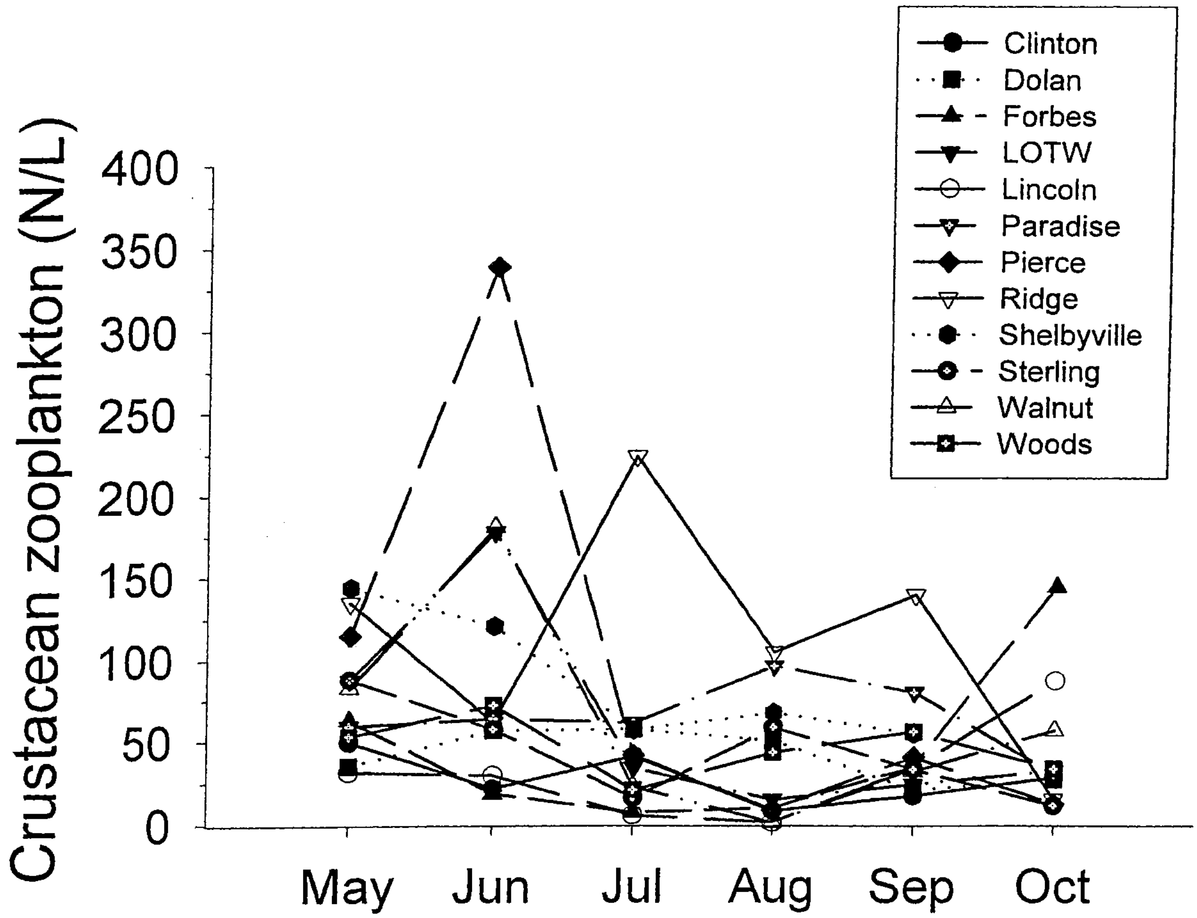

Figure 4-3. Average monthly densities of inshore crustacean zooplankton (N/L) in 12 studylakes in 2003. Inshore zooplankton samples were collected with a 0.5-m diameter zooplankton net with 64-µm mesh pulled from 1-m depth to the surface. Open symbols represent lakes without gizzard shad.

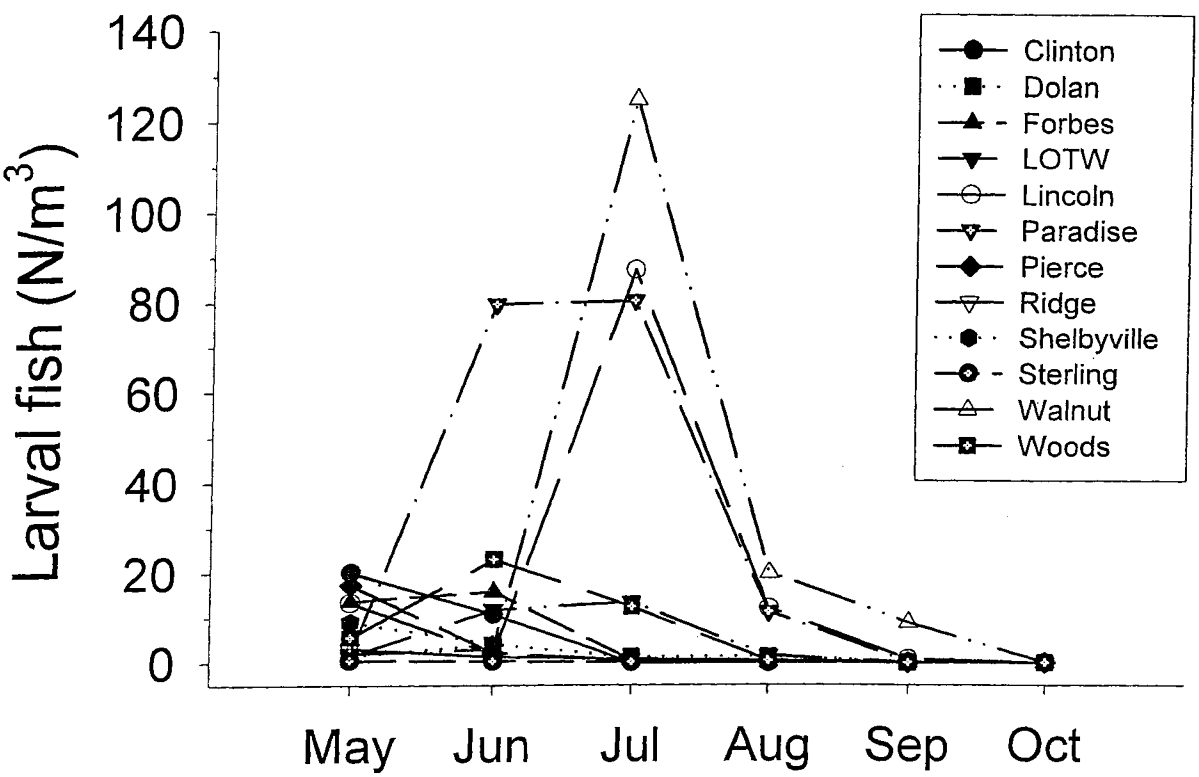

Figure 4-4. Average monthly densities of larval fish (N/m^3) in 12 study lakes during 2003. Larval fish were collected at six sites by pushing a 0.5-m diameter push net with a 500-µm mesh for 5 minutes inshore and 5 minutes offshore. Closed symbols represent lakes with gizzard shad and open symbols represent lakes without gizzard shad.

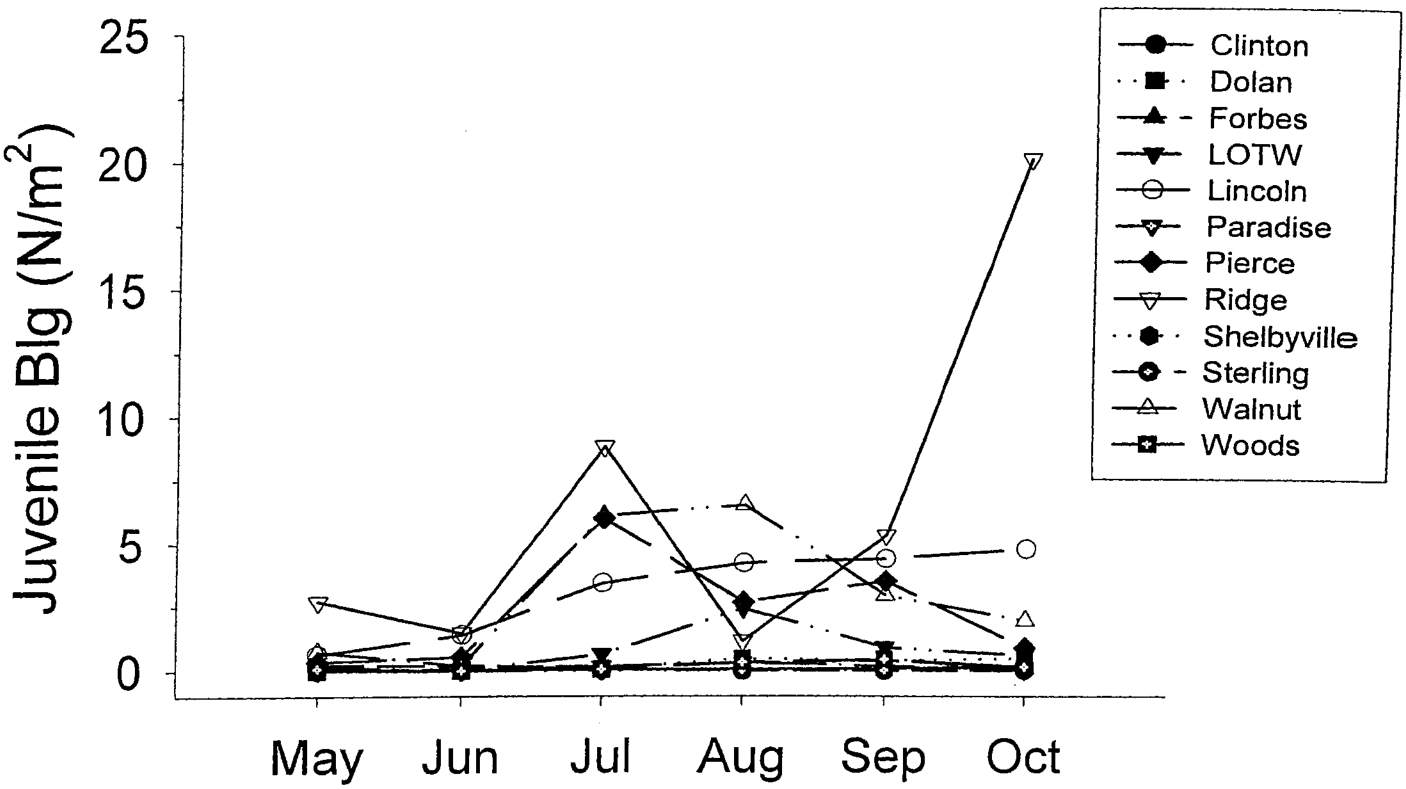

Figure 4-5. Average monthly densities of juvenile bluegill (Blg TL $\leq$ 60 mm; N/m^2) in 12 study lakes in 2003. Bluegill were collected with a 9.2-m bag seine pulled at four fixed stations in each lake. The lakes represented by open symbols do not contain gizzard shad.

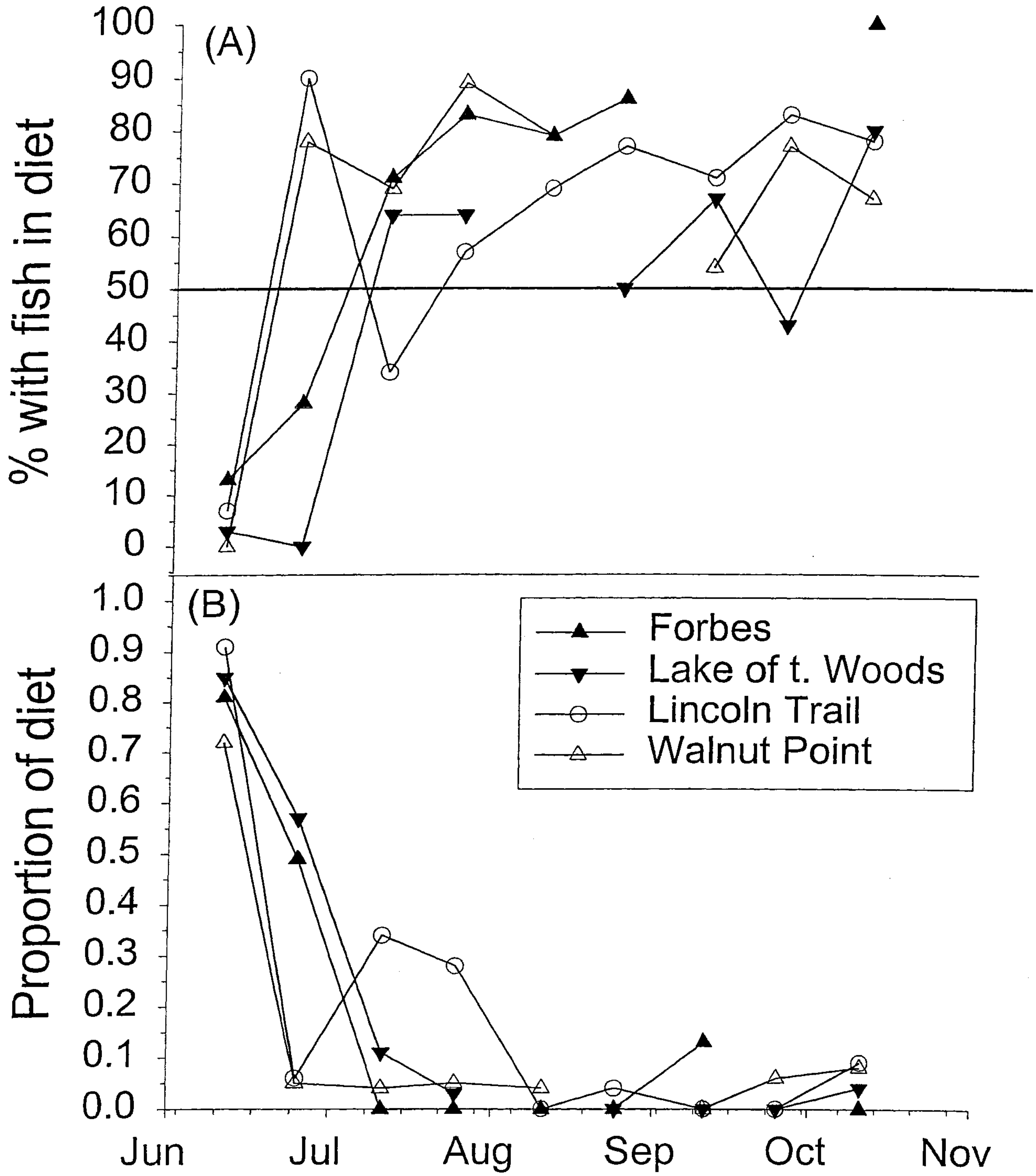

Figure 4-6. YOY largemouth bass diets in selected study lakes. (A) Percent of YOY largemouth bass with fish in their diet and (B) proportion of diet biomass that consisted of zooplankton. The horizontal line in panel (A) represents the percentage above which YOY bass are considered piscivorous. YOY largemouth bass diets were examined every other week from 30 fish collected with a 9.2-m bag seine.

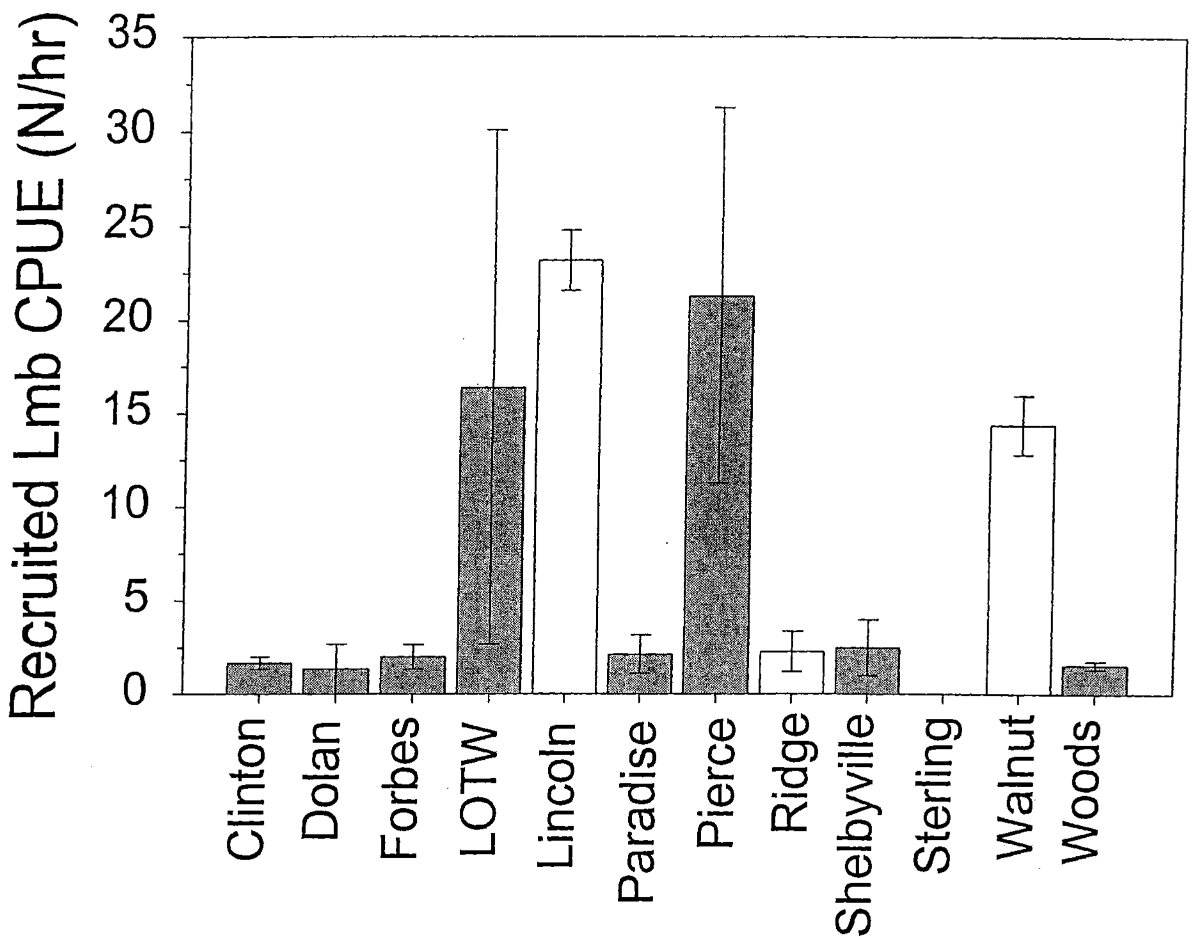

Figure 4-7. Average catch per unit effort (CPUE; N/hr + 1 SE) of largemouth bass recruited to age-1 for 12 study lakes in spring of 2004. Fish were collected in the spring by using A.C. electrofishing along three shoreline transects for a 0.5 hour each. Open bars represent the lakes without gizzard shad.

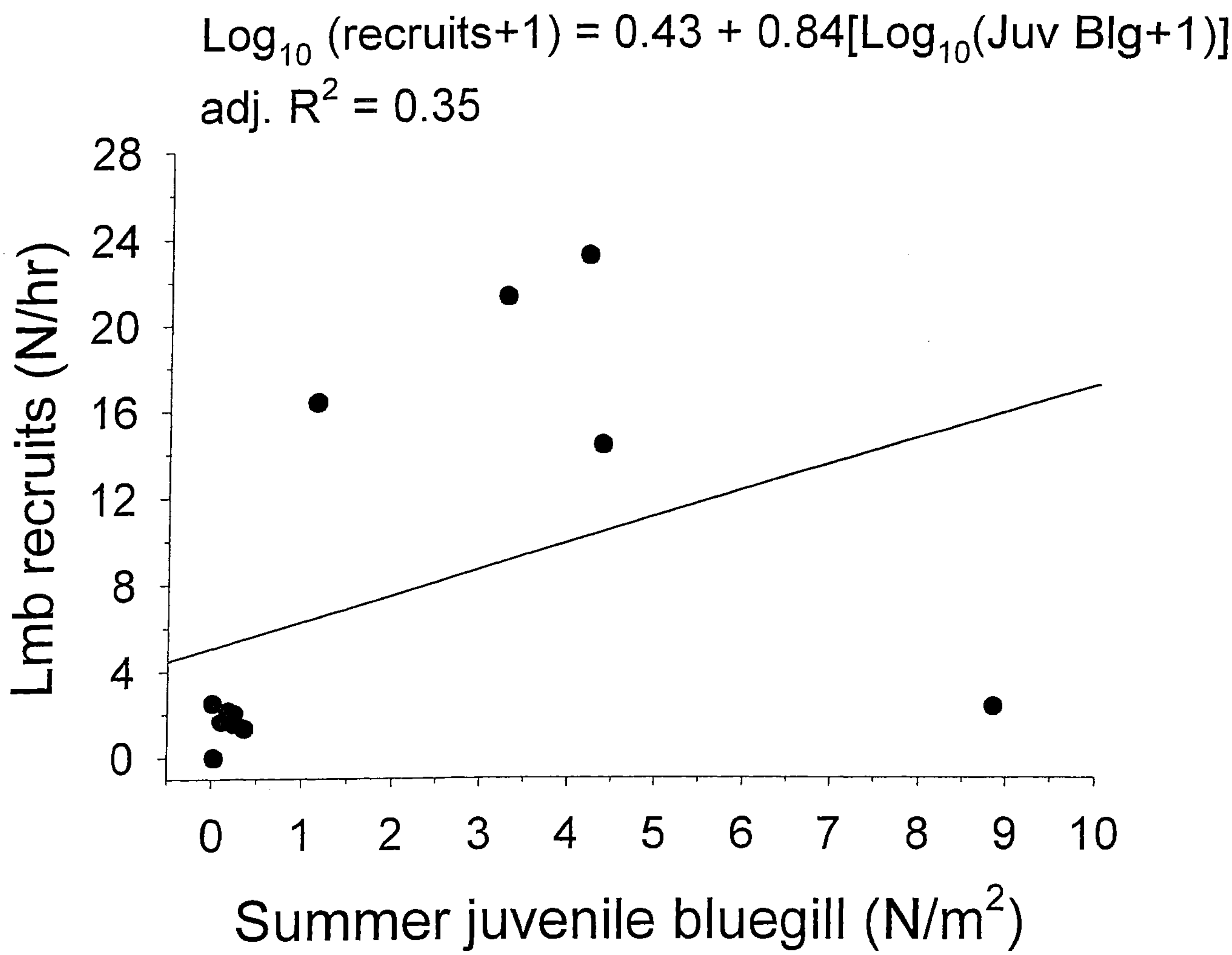

Figure 4-8. Linear regression of largemouth bass recruits on post-spring density of juvenile bluegill from 12 study lakes in the summer of 2003.

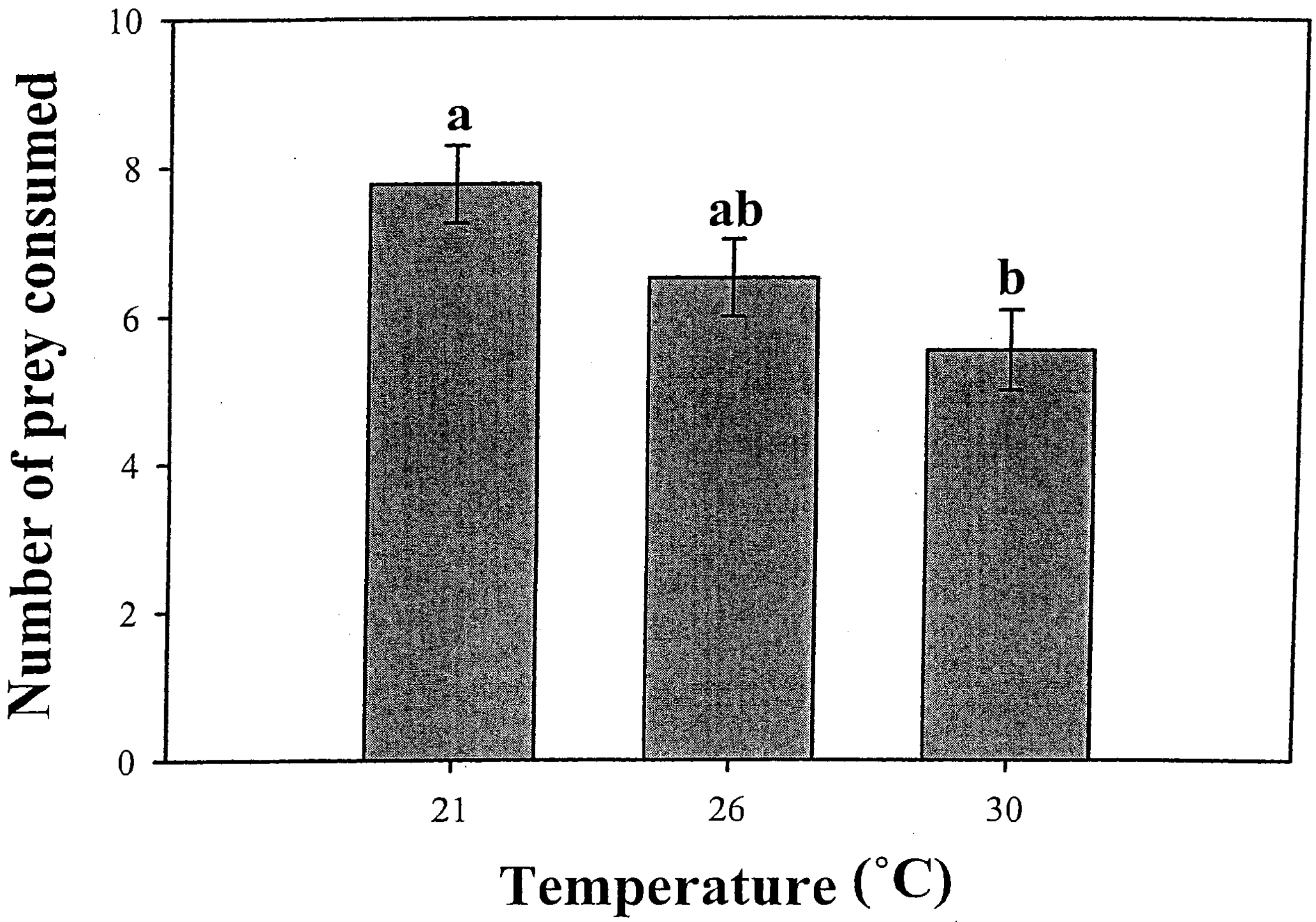

Figure 5-1: Mean consumption (# of prey) at 12-h for fish held at 21, 26, and 30 °C. Error bars represent $\pm$ 1 SE with differing letters representing significant differences ($P \leq 0.05$) in mean consumption.

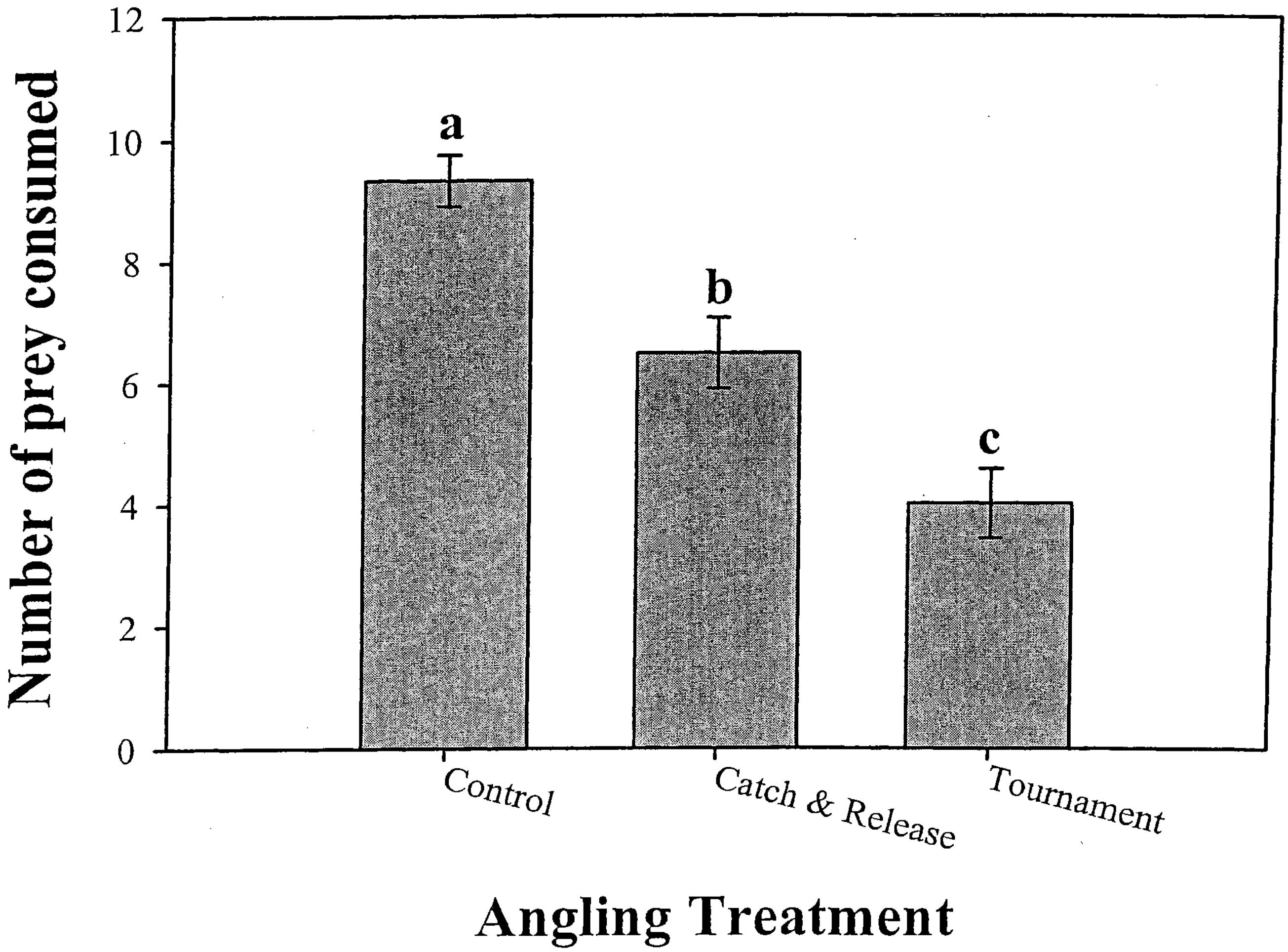

Figure 5-2. Mean consumption (# of prey) at 12-h for controls and fish subjected to simulated catch-and-release and tournament angling. Error bars represent ± 1 SE with differing letters representing significant differences ($P \leq 0.05$) in mean consumption.

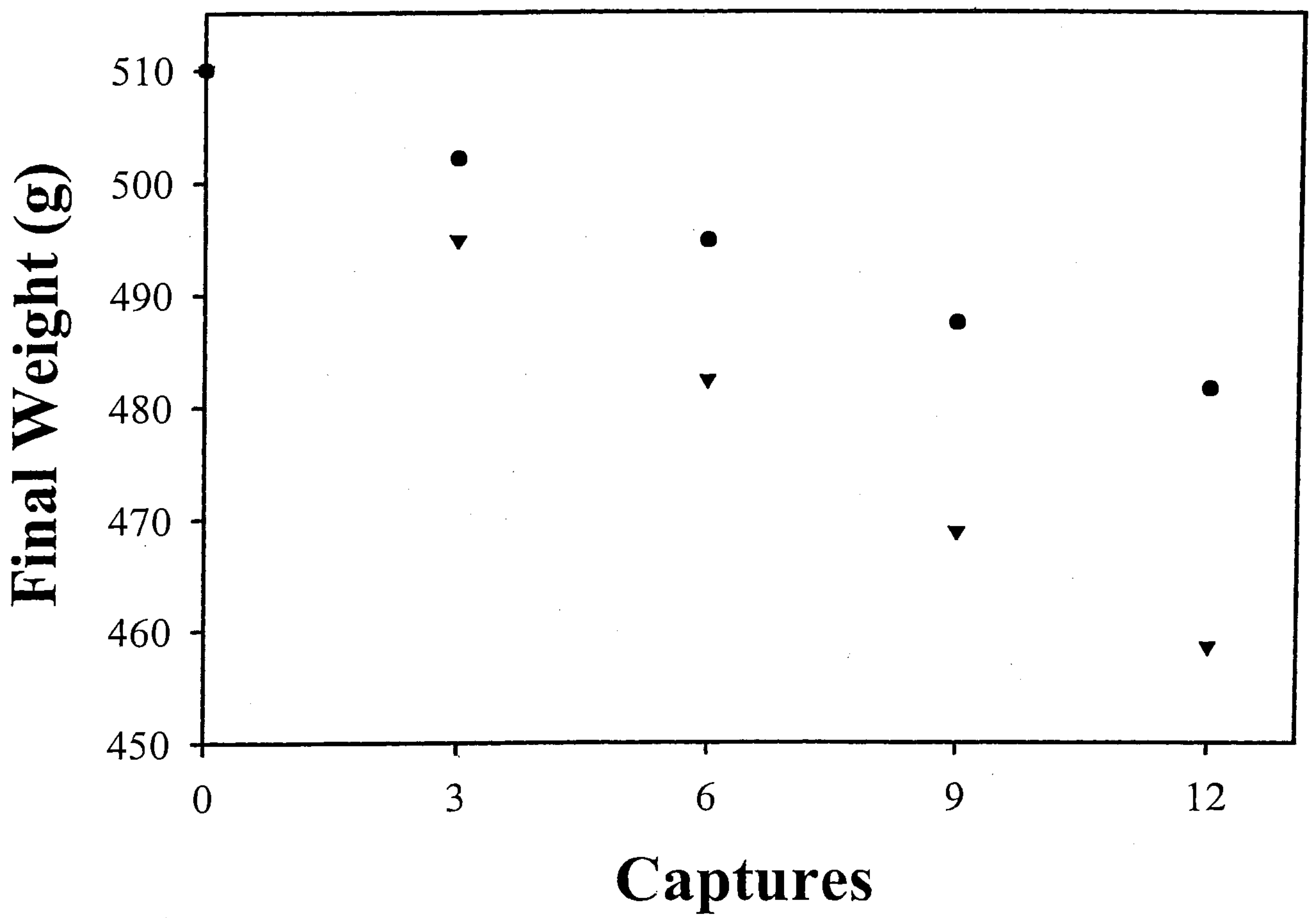

Figure 5-3. Predicted final weights derived from bioenergetics simulations for largemouth bass subjected to either catch-and-release (circles) or competitive angling (inverted triangles) from zero to twelve times through the 135-d simulation period.