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CENTER FOR AQUATIC ECOLOGY

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FACTORS INFLUENCING LARGEMOUTH BASS RECRUITMENT: IMPLICATIONS FOR THE ILLINOIS MANAGEMENT AND STOCKING PROGRAM

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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 completed our examination of the most reliable and cost-effective method for mass-marking fingerling largemouth bass. Fin clips, fin clip-cauterization, and freeze branding were examined for long-term retention on 100-mm largemouth bass. Fin cauterization had the longest retention time, followed by fin clipping and then freeze branding. Identification of fin clips and fin cauterization were 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 fall when bass have darker external coloration. We found no differences in growth rates between fish with these three different marks. During this segment, we completed evaluating seasonal variability (fall vs. spring) in mark retention for freeze brands and found that seasonal variation in largemouth bass color does influence readability. Freeze brands are difficult to read in the second fall after stocking, but are easily visible in the subsequent seasons, including both spring and fall. The best mark for use in various situations will vary with management objectives. Choices of mark will vary with number of fish to mark and associated cost of marking as well as the reason for marking fish. Freeze brands will be best if the number of fish and costs of marking are high and if the interest is in long-term survival (after the second fall). If early survival is the focus and recovery of marks in the first and second fall is important, fin clips with cauterization will be the best choice followed by fin clips.

Supplemental stocking is a widely used management tool for increasing the standing stock of an existing population. In Job 101.2, survival of stocked largemouth bass fingerlings varied considerably across lakes, ranging from 0 to 7.5 stocked fish per hour of electrofishing during the fall of 2004. Six and eight inch bass were larger than the other bass in the lake at the time of stocking. These fish however, experienced lower growth rates after stocking and were similar in size to other bass in the lake shortly after stocking. 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 to reduce mortality. Predation rates on stocked fish were low among all sizes of stocked fish. Two-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 larger than two inches were found in similar relative abundances and at similar mean size from the first summer after stocking throughout the following seasons. Cost analysis will

be conducted in subsequent segments in order to make recommendations on which size of fish should be stocked in Illinois impoundments.

The relative survival of intensively and extensively reared largemouth bass varied between lakes. However, few fish were recaptured and larger efforts must be put into sampling in order to accurately assess which rearing strategy yields 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.

The objective of Job 101.3 is to evaluate the survival and reproductive success of stocked largemouth bass to the resident population. To determine the contribution of stocked fingerling to a population, fingerlings were produced at the Little Grassy Fish Hatchery with the MDH B2B2 allele as a genetic tag. These genetically tagged fingerling were then stocked into six study lakes. Once these fish reached sexual maturity, it is possible to assess their reproductive success and recruitment to the population by comparing the pre-stocking MDH B2 allele frequencies with the post-stocking MDH B2 allele frequencies. Young-of-the-year produced in 2003 and 2004 were collected from each of the six study lakes and their allele frequencies determined for the MDH B2 allele. Although it is still early to fully evaluate the effects of stocking, four of the six lakes do show an increase in the MDH B2 allele. Further yearly sampling is needed to fully evaluate the long-term impacts of stocked fingerlings in these populations and to fully assess the costs and benefits of largemouth bass stocking programs.

In Job 101.4, we assess the importance of a variety of abiotic and biotic factors on largemouth bass recruitment. This segment covers recruitment of the 2004 year-class and associated environmental conditions in the 12 study lakes. Prey abundance was very variable among and within lakes during the growing season. Similar to previous segments, we observed a great deal of variation among the 12 study lakes in young of the year (YOY) density and recruitment. Survival of YOY largemouth bass to the fall was negatively correlated to gizzard shad abundance and positively correlated with post-spring density of juvenile bluegill. First-year growth of largemouth bass was negatively related to YOY bass density. In general, overall recruitment to age-1 was lower than average for 2004, and early densities of YOY bass were a good indicator of differences in year class strength among the 12 lakes. From 2000-2004, both July and peak densities of YOY bass were the two most reliable indicators of differences in recruitment among the 12 study lakes. However, these early indexes of recruitment were not as reliable when examining within single lakes over time. A multiple linear regression model for the 2004 year-class significantly related recruitment to age-1 to YOY total length in the fall and density of larval Lepomis. For 2000-2004, the abundance of bluegill, as either larvae (TL $\leq$ 15 mm) or juveniles (15 mm $\leq$ TL $\leq$ 60 mm), has been a consistent indicator of differences in largemouth bass recruitment among the 12 study lakes. Gizzard shad may indirectly influence bass recruitment through a negative effect on bluegill abundance.

In Job 101.5, nest-guarding male largemouth bass were subjected to catch-and-release angling as well as simulated tournament angling and abandonment rates were assessed for each angling practice. Our results show that competitively angled males abandon their nests at a rate of 90 percent, while catch-and-release males abandoned at a 33 percent rate. Due to the high abandonment rate of competitively angled males, a conservative recommendation would be for anglers to consider alternative tournament formats during the reproductive season for largemouth bass in lakes with poor or declining recruitment. Additional research will be required to determine the population consequences of these practices.

Tournaments were attended during 2004 and 2005 in order to assess the proportion of male and female bass angled during the spawn and post-spawn season. Data from 2004 and 2005 were combined with previous years data and analyzed. Males were caught more often in most tournaments and there was no difference in proportion of males caught between spawn and post-spawn tournaments. In addition, we interviewed anglers to assess the level of culling and the number of sub-legal fish caught. Angler surveys as of 2005 showed that few fish are being culled from tournament catch and culling is not skewing estimates of male to female sex ratios of caught fish.

Competitive angling events often require that fish be held in live wells for extended periods of time until the fish are brought to the weigh-in. As a result, a number of techniques have been suggested to reduce stress and thus maximize survival when fish are held in live wells. Addition of ice, water conditioners, and antibacterial treatments (including salt) are the most common. Therefore, we compared initial and delayed mortality of largemouth bass that had been confined to live wells that contained ice, salt, salt and ice or recirculated/aerated lake water. Dissolved oxygen levels in the live wells were high regardless of the live well additive; however, water temperature oscillated during the course of the day as a result of the addition of ice to live wells. Initial mortality was generally low being less than 3%. However, delayed mortality was generally higher for fish subjected to live well additives compared to those fish that just had circulated aerated lake water. Delayed mortality was highest for fish subjected to ice, followed by salt and ice, and the salt only treatment. The effect of live well additives tended to be exacerbated with higher lake water temperatures and increases in size of largemouth bass. We recommend that participants in competitive angling events refrain from adding water conditioners such as salt or ice to live wells. Instead we recommend that participants operate live wells in a to ensure fresh lake water throughout the competition.

In Job 101.6 a portion of Clinton Lake that has been closed to fishing was sampled to determine the effects of the refuge on largemouth bass populations. Electrofishing and seine samples yielded higher CPUE for adult and juvenile largemouth bass inside the refuge compared to control sites outside the refuge. Some increase in the number of largemouth bass has also been observed throughout the lake. Sampling will continue at Clinton Lake in order to monitor largemouth bass populations for changes relative to the establishment of the refuge.

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 useful when evaluating supplemental stocking programs. The choice of a particular fish marking technique depends primarily on the scope of the management question. An ideal mark should be inexpensive, easy to apply, have long-term retention, and have minimal impact on the health of the fish. In some instances, short-term marks can provide sufficient information to address management questions. However, in most cases, it is important to identify marked fish throughout their lifetime. In Illinois, freeze branding (Mighell 1969) is 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 this variability can compromise the quality of recapture data, it is important that a relatively long-term mark be identified.

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 clip with cauterization, and (3) freeze branding. Fin clips were obtained by removal of the right pelvic fin. Removing the left pelvic fin 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 ponds (1/3 acre) at a total density of 250 fish/pond. In case fish lost their mark, 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 were measured and assessed each spring and fall from May 1999 through March 2004. Seasonal differences in fish coloration can make it difficult to detect freeze brands, which has raised some concerns with this marking technique. Therefore, in November 2003, we initiated an evaluation of seasonal variability in visibility of freeze brand marks. We marked 100 fingerling bass

(137 mm, TL) with vertical and horizontal freeze brands. Seasonal readability was assessed in spring 2004 and was completed in fall 2004.

FINDINGS: In the long-term pond experiments (1999-2004), fin cauterization was the longest lasting mark followed by fin clip and freeze brand marks (Figure 1-1). Whole fin regeneration for fish marked with fin clips (10.4%) was greater than that for fish marked with fin cauterized clips (5.3%) during the six years. Fin clips and fin cauterized marks had considerable amounts of fin regrowth that made them less desirable than freeze brand marks. Fin cauterized marks had 20% less fin regrowth than fin clips. 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. 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. Fish grew to similar lengths over the 6-year period regardless of the three marking techniques. The removal of a fins (fin clip $\bar{x}$ = 293 mm, TL; 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.

In the short term experiment (2003-2004), vertical and horizontal freeze brands (96%) were both very readable during the spring, but less so in the fall (78%). Of those marks that were determined to be poor, two were horizontal and two vertical. Variability in juvenile largemouth bass color does appear to significantly influence readability in the second fall after stocking, but not at other times of the year.

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 efforts that wish to reduce mortality, fin clip marks (with or without cauterization) 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. Although all three marks had good retention freeze brand marks resulted in the most discrete and reliable means for largemouth bass identification. The speed and low cost that freeze brands afford suggest that this is the best method for long-term marking of 4" largemouth bass in some situations.

Freeze branding can be used to mark a large number of largemouth bass quickly, and they are discernable over a long time period, except in the first and second fall periods. In our study the majority of indistinguishable freeze brand marks occurred in the first two falls, after which the majority of remaining marks were readily distinguishable. These indistinguishable marks can most likely be attributed to the branding process resulting from insufficient tissue contact time with the branding iron bar and/or inadequate bar temperature coupled with a slightly darkened integument during colder months in the fall. In order to ensure adequate scarring we suggest that the tissue contact the branding bar for at least two seconds. In addition, freeze brands on juvenile largemouth bass develop as dark marks and therefore should be applied vertically to lightly pigmented areas. Consideration should also be given to the hazards of working with liquid nitrogen that require strict safety precautions. Liquid nitrogen must be carried outside of the passenger compartment of vehicles and requires the use of specialized containers and transfer devices.

Fin cauterization and fin clip marks were good as a long term marking method that lasted for at least six years. Fin cauterized clips tended to exhibit slightly less fin regeneration. Fin regeneration adds considerable time to fish identification and additional stress by prolonging air exposure. Unfortunately, minor variations exist in fin clipping techniques among workers. If these variations result in incomplete removal of the fin at its insertion at the pelvic girdle regeneration, will most likely occur and may result in misidentification. Fin clips performed on fish that have been anesthetized (e.g. with MS-222) may lessen the amount of incomplete fin clips. Fin clips may add considerable time to complete, particularly if cauterization is employed, resulting in additional monetary costs associated with labor.

Our results suggest that freeze branding had good retention rates and more importantly were readily distinguishable when properly applied. In addition, freeze branding appears to the least labor intensive and thus the most cost effective means to mass mark large numbers of juvenile largemouth bass. Freeze brands will work for assessment of long-term survival, but will be less effective in the first two falls after stocking for assessments of short-term survival. Fin cauterization and fin clips proved to be effective for marking juvenile largemouth bass. However, additional time is required to mark and in the field to distinguish regenerated fins compared to fins that had not been clipped. We suggest using fin clips only for marking small numbers of fish when time allows careful attention to making complete clips.

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 to enhance existing largemouth bass populations. Supplemental stocking efforts are directed at increasing harvest rates and reproductive potential, or restoring the fisheries predator/prey balance. 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 management recommendations for a wide variety of lakes statewide.

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 Sander vitreum, Santucci and Wahl 1993). Largemouth bass, however, reproduce naturally in most Midwestern lakes and impoundments, and therefore supplemental stocking programs are directed at enhancing existing populations where reproduction may be 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 due to lake conditions that are cause high bass survival such as high prey availability and water temperature.

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 late summer or 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 stocking the same age fish after a weak year-class has been identified and potentially higher survival rates associated with stocking larger 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 2004 (Charleston and Homer, 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 pelvic fin clips.

Following stocking, we evaluated the importance of stocking stress, physicochemical properties, predation, and prey availability, on the stocking success 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 checked after 24 and removed after 48 hours and the number of live and dead fish was 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. Predator diets were examined daily until they were found to contain no stocked bass on two consecutive sample dates.

Long term survival and growth was also assessed for the different sizes of stocked bass. Largemouth bass were collected through two spring and two fall electrofishing samples. Bass were collected, measured for total length and clips were identified. Catch per unit effort and mean length were compared among the two, four, six, and eight inch bass and native bass. Differences in the survival and growth of stocked fish were examined using a repeated measures ANOVA to test for differences in CPUE and mean total length through time.

Rearing Technique

The effects of rearing techniques on growth and survival of stocked largemouth bass were evaluated in lakes Shelbyville, Jacksonville and Walton Park in 2004. 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 where they 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 a 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. In 2004 Charleston and Homer were stocked with the four different sizes of largemouth bass (Table 2-1). The only observed mortality (Charleston 48%; Homer = 2%) occurred during the two-inch stockings. The two-inch fish were stocked at the highest temperature of all the stockings (Charleston = 27.5°C; Homer = 29.1°C; Table 2-1). This is consistent with the findings in previous reports where temperature at the time of stocking seems to affect survival of the newly stocked bass. Predation on stocked bass could also 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. Examinations of all predator diets revealed that the two-inch stocking was the only size group that experienced predation as no four, six, or eight-inch fish were observed (Table 2-2). Two-inch fish had the poorest stocking success in 2004 due to initial stocking mortality and high predation pressure.

Unclipped young of year largemouth bass were collected to examine for OTC marks. These fish have not yet been processed so survival and growth cannot be estimated for two-inch stocked bass at this time. In 2004, four inch-bass had the lowest survival of all stocked bass greater than two inches (Table 2-3). Charleston had few four-inch fish surviving until spring and no four-inch fish were recaptured at Homer in the spring. The four-inch bass grew at a similar rate as the natural bass in both lakes. This is similar to previous years where four-inch bass were similar in size to the natural bass and exhibited similar growth (Figure 2-2). CPUE of six-inch bass was higher than four-inch fish in the fall, but low over winter survival of six-inch bass resulted in similar CPUE in the spring. Like previous segments, six-inch fish were larger than natural and four inch fish in both lakes at the time of stocking (Table 2-3). Eight-inch bass were stocked in the spring and again similar to previous segments had a higher spring CPUE than other stocked and natural bass in both lakes (Figure 2-3), however by subsequent fall samples the densities had dropped to low numbers similar to other sizes of stocked largemouth bass.

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 patterns that occurred across all study lakes that were stocked with different sizes of bass. When six-inch bass were stocked, they were significantly larger in size than that achieved by earlier stocked 2 and 4-inch bass as well as natural bass in the lakes. These six-inch fish were also larger than those stocked as four-inch fish going into the first winter (Figure 2-2). This suggests there is a potential for size specific mortality over winter. The following spring however, there was little to no difference in bass size. Similarly, eight-inch bass stocked in the spring were significantly larger in size than their cohorts, but by the summer were similar in size. All sizes of stocked bass as well as the natural bass were similar in length going into the second winter. Although there are inherent size differences at stocking, lags in growth occur shortly after, perhaps as a result of the transition from hatchery conditions to the wild. There were few differences in size 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. CPUE of six-inch fish was significantly greater than the four and eight inch stocked bass in the first fall after stocking (Figure 2-3), probably because little time had passed since they were stocked. As a result, 6-inch bass were higher in abundance going into the first winter than 2 and 4-inch size groups. Over winter survival was extremely low for 6-inch bass. 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. 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 Shelbyville and Walton Park in the fall of 2004 while extensively reared fish were more abundant in Jacksonville (Table 2-4). No stocked fish were recaptured in the following spring at Shelbyville. Jacksonville and Walton Park had few or no fish recaptured in the spring of 2005. This is similar to observations in previous segments where variation is high between lakes and no one rearing technique produced higher survival. Due to the variability between lakes and years, and the low level of survival for both intensively and extensively reared bass it is difficult to determine which rearing strategy performs the best at this point.

RECOMMENDATIONS: Survival of the different sizes of stocked fish varied initially, but was 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 were evident between the 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 acclimation period where hatchery bass need to adjust to feeding on natural prey resources. It may take some time for minnow fed hatchery bass to become efficient at feeding on naural prey fish, primarily bluegill available in stocked lakes. Feeding experiments and diet analysis of stocked and native bass were continued in 2004. These experiments 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. Two-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. Stockings for this job were concluded in 2005 and future efforts will focus on assessing the survival and growth of the previously stocked bass through time. Because there is little difference in size, abundance and stocking mortality for different sized bass at this point, 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. 2004 was the final year of stocking these fish. In future segments, we will continue to follow the fish stocked in 2004 and earlier years to observe any differences in long-term survival and growth. 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, and these in addition to Walton Park, Murphysboro, Mcleansboro, Sam Parr, Forbes, and Shelbyville in 1999.

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 2004 by boat electroshocking to determine if the frequency of the MDH B2 allele has increased through reproduction of the stocked fish. These sample efforts will document the contribution of stocked fish to the reproductive population.

FINDINGS: The original largemouth bass fingerlings stocked into each lake were analyzed to determine if the fingerlings have all had the MDH B2B2 genotype. All samples analyzed from the original stocking were 100% MDH B2B2 genotype with the exception of fingerlings stocked into Lake Shelbyville in the summer of 2001. In that case, 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.

The background frequencies of largemouth bass 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 3-1a). 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.

Preliminary sampling of largemouth bass began in 2002. By 2003 all stocked fish should have reached maturity and all lakes were sampled for YOY in 2003 and in 2004 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 3-1b). In four of the lakes the MDH B2 allele frequencies have increased (8 to 26%). In the other two lakes, frequencies have remained the same, or fluctuated slightly. McCleansboro Lake had a higher frequency MDH B2 allele from the pre-stocking sample, and therefore the effects of stocking may not be clear. Because of its large size, assessing the contribution of stocked fish in Lake Shelbyville may take a longer period before a change in allele frequencies can be determined.

RECOMMENDATIONS: Genetic frequencies from YOY spawned from largemouth bass stocked with the MDH B2 allele have increased in four of the study lakes. It is too early to evaluate the affects of stocking in McCleansboro Lake and Lake Shelbyville. Sampling should continue in each of the study lakes during the post-spawning months. Efforts should be made to collect adequate sample sizes, to remove any sampling error when calculating allele frequencies.

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 that have reached 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 in natural populations should be important to recruitment due to the size-dependent 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 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 attempts to address 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 2004 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). AC electrofishing (240 V, 8-12 Amps) 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 2004, 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 (Forbes, Lincoln Trail, Paradise, 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 at least 200 organisms from the two most abundant taxonomic groups were counted. Organisms from all other taxanomic groups were also counted in those subsamples. 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 spring zooplankton density (excluding nauplii copepods and rotifers), Lepomis larvae, post-spring density of juvenile bluegill (TL $\leq$ 60 mm), and benthos (combined density of amphipods, chironomidae, hemiptera, zygoptera, and ephemeroptera). The amount of recruitment variation explained by the model was estimated with an adjusted R^2.

FINDINGS: In 2004, YOY largemouth bass densities (Figure 4-1) and sizes (Figure 4-2) were highly variable among the 12 study lakes. Peak densities of YOY ranged from $0.004/m^2$ to $2.13/m^2$. The highest densities of YOY largemouth bass were found in Ridge, Sterling, and Walnut Point, while the lowest abundances of YOY were in Dolan and Shelbyville (Figure 4-1). YOY largemouth bass total length at the end of the growing season varied from 79 mm (Sterling) to 138 mm (Dolan) and was negatively correlated with peak density (Spearman; r = -0.68; P = 0.01). Number of YOY largemouth bass surviving to the end of the growing season was positively correlated with peak density of YOY (Spearman; r = +0.62; P = 0.03). Abundances in June, July, and August were also early indicators of among-lake differences in YOY surviving to fall (Table 4-1). Across 5 year-classes, the most reliable early indicators of YOY largemouth bass abundance at the end of the growing season were peak and July densities (Table 4-1). However, these early indexes of fall abundance more consistently predict among lake differences, with fewer significant correlates of fall abundance within lakes, across years (Table 4-2). Peak reproductive activity occurred during late April in Forbes and Lincoln Trail and in early May in Paradise and Woods.

Abiotic (Table 4-3) and biotic variables (Table 4-4) potentially important to YOY largemouth bass growth and survival varied among lakes and time of year. Secchi depth transparency varied from 0.46-2.81 meters, and spring water temperature ranged from 18.4-25.4 degrees Celsius (Table 4-3). Transparency was negatively related to chlorophyll *a* concentration (Pearson; r = -0.69; P = 0.01), and lakes with the highest total phosphorus concentrations had the highest chlorophyll *a* concentrations (Pearson; r = +0.72; P = 0.008). Proportion of lake area that was vegetated was generally low among the study lakes (Table 4-3). Inshore density of crustacean zooplankton was very high and variable among lakes with averages ranging from 34.7 individuals/L to 1484/L (Table 4-4). Crustacean zooplankton was most abundant in spring and early summer (Figure 4-3) and was positively correlated with spring water temperatures (Pearson; r = + 0.63; P = 0.03). Benthos density was lowest in Forbes and highest in Walnut Point (Table 4-4). Larval fish abundance also varied among lakes, with average values ranging from 0.21/m^3 to 32.2/m^3 (Table 4-4). Timing of peak larval abundance varied among lakes, with some lakes showing multiple peaks over time (Figure 4-4). Dorosoma and Lepomis species typically make up the largest proportion of larval fish sampled in the study lakes. Abundance of Lepomis larvae was positively correlated with density of crustacean zooplankton in the spring (Pearson; r = +0.77; P = 0.004). The post-spring density of juvenile bluegill (TL $\leq$ 60 mm) and the abundance of gizzard shad in the fall were both positively related to the previous densities of their respective larvae (Lepomis: Spearman; r = +0.70; P = 0.01; Dorosoma: Pearson; r = +0.76; P = 0.004). Gizzard shad are not present in three of the 12 study lakes (Lincoln, Ridge, Walnut), and in the other 9 lakes, gizzard shad catch per unit effort ranged from 5.37/hr to 1739/hr (Table 4-4). Among lakes, average density of juvenile bluegill ranged from 0.014/m^2 to 3.87/m^2 (Table 4-4). Over time, juvenile bluegill abundance was highly variable, sometimes exhibiting multiple peaks in abundance (Figure 4-5). Post-spring density of juvenile bluegill was negatively correlated with gizzard shad catch per unit effort (Spearman; r = -0.71; P = 0.01). The abundance of YOY largemouth bass surviving to the end of the growing season was negatively correlated with the density of larval shad (Spearman; r = -0.63; P = 0.03) and the abundance of post-larval gizzard shad (log-transformed; Pearson; r = -0.71; P = 0.01). In contrast, fall abundance of YOY largemouth bass was positively related to post-spring density of juvenile bluegill (Spearman; r = +0.67; P = 0.02).

Largemouth bass recruitment to age-1 varied among the 12 study lakes (Figure 4-6) and was generally lower than average recruitment in the period 1999-2004 (Figure 4-7). Recruitment strength was positively correlated with YOY densities throughout the previous growing season (Table 4-1) and with fall abundance of YOY (Spearman; r = +0.76; P = 0.005). Across 5 year-classes, the most consistent correlations between YOY densities and recruitment to age-1 were July, September, and peak densities (Table 4-1). For the 1999 cohort, recruitment strength was correlated with October density of YOY bass (Spearman; r = +0.62; P = 0.04) and marginally correlated with peak density of YOY (Spearman; r = +0.55; P = 0.09). Fewer correlations between early YOY density and recruitment to age-1 existed within lakes among six year-classes (Table 4-5). June, July, and peak densities of YOY largemouth bass were the only abundances significantly correlated with recruitment to age-1 (Table 4-5). For the 2004 year-class, recruitment was most closely correlated with both post-spring density of juvenile bluegill (Spearman; r = +0.68; P = 0.02), peak density of YOY bass (Spearman; r = +0.65; P = 0.02), and density of larval Lepomis (log transformed; r = +0.73; P = 0.007). Post-spring density of juvenile bluegill was not significant (α = 0.15) in the stepwise selection procedure, therefore the linear regression model related recruitment of the 2004 year class to density of larval Lepomis, peak density of YOY largemouth bass, and fall size structure of YOY (adj. R^2 = 0.90; P < 0.0001).

RECOMMENDATIONS: During the time period 2000-2004, and July and peak monthly (varies year by year) density of YOY largemouth bass has been the most reliable indicator of bass recruitment to the end of their first growing season. However, these early indexes of year class strength have been more reliable in distinguishing among lakes in a given year than among years within a given lake. Fortunately, among lake comparisons are most important for making stocking decisions.

Based on our results thus far, July seining would provide the best index to be used in making stocking descitions on a particular lake. From 1999-2004, a similar pattern was observed for correlations between YOY density and abundance of bass recruited to age-1. 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 2004. The abundance of either larval Lepomis (TL $\leq$ 15 mm) or juvenile bluegill (TL $\leq$ 60 mm) 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. Indirect effects of the aquatic community may also influence recruitment. Gizzard shad abundance was negatively related to both the density of juvenile bluegill, an important prey species, and to the number of YOY largemouth bass surviving to the fall. YOY bass size at the end of the growing season explained part of the recruitment variation among lakes; therefore, size-specific mortality of YOY may have been important in determining year class strength. Intraspecific competition may have reduced YOY bass growth, because sizes were lower in lakes where the density of YOY was high. Peak abundance of YOY bass also accounted for a significant portion of among-lake variation in recruitment in 2004. Peak density of YOY is typically found early in the growing season and therefore is likely to represent the degree of reproductive success occurring in each lake.

The significant influence of multiple variables on largemouth bass recruitment points out the relatively complex mechanisms responsible for recruitment variation of largemouth bass populations. We will need data from additional year classes to examine these complex relationships. 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. 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: Removal of spawning males by angling have unknown effects on largemouth bass reproductive success. In the spring, male largemouth bass (*Micropterus salmoides*) build solitary, highly visible (depending on water clarity) saucer-shaped nests in the substrate in order to court and spawn with females (Kramer and Smith 1962; Pflieger 1966; Coble 1975). Once spawning is completed, females leave the nesting area and the male remains to provide all parental care of the developing offspring, a period that may last four or more weeks (Ridgway 1988). While male bass are providing parental care for their broods, they are extremely aggressive (Ridgway 1988) and, therefore, highly vulnerable to many angling tactics (Neves 1975; Kieffer et al. 1995). Even though this vulnerability has never been assessed accurately, many fisheries management agencies have invoked closed fishing periods, catch-and-release regulations, and various length and harvest limits in different combinations in an effort to enhance or promote bass reproduction and recruitment (see Schramm et al. 1995). This strategy of maximizing reproductive success by protecting successful spawning bass from angling assumes that there is a positive relationship between reproductive success and recruitment. Our objective here is to quantify the effects of angling on the reproductive success of largemouth bass.

Male largemouth bass experience reduced levels of food consumption while providing parental care (Kramer and Smith 1962; Pflieger 1966; Coble 1975). Therefore, the spawning season has negative effects on parental males fitness, characterized by a decrease in energy store and somatic growth. The quality of post swim-up parental care provided is influenced by the energy reserves of the nesting male (Ridgway and Friesen 1992). As a result, an energetically costly activity, such as being captured by angling, could result in a decreased ability of that male to provide continued parental care (Kieffer et al. 1995) and negatively impact offspring survival. Furthermore, Phillip et al. (1997) have confirmed that angling of nesting bass, even on a catch-and-release basis, results in increased brood predation and male abandonment rates. Therefore, it is likely that substantial catch-and-release angling for nesting bass would have negative effects on reproductive success. Because female largemouth bass preferentially spawn with the largest males, those males will have the largest broods. Also, those males with the largest broods will defend their nest more aggressively, making them susceptible to anglers. We would also expect these fish to be targeted by anglers during tournaments. During competitive angling events, fish are held in livewells, for several hours in some instances, and then transported to a central location where they are subjected to the weigh-in procedure. One objective of our study is to better assess the impact that competitive angling and catch-and-release angling have on the reproductive success of largemouth bass.

Competitive tournament fishing for black bass in the United States has grown rapidly over the past several years. Most of these angling events, although catch and release, require the fish be held in live wells for extended periods of time until they are brought to the weigh-in. As a result, a number of techniques have been attempted to reduce stress and thus maximize survival when fish are held in live wells. Addition of ice, water conditioners, and antibacterial treatments (including salt) are the most common.

In response to the need for quantitative evaluation of both the biological effects of competitive angling, a number of papers have been published on the effects of retaining black basses in live wells. Live well additives have significant influence on physiological processes. For example, Cooke et al. 2000 examined the effects of live well additives on cardiac recovery times of smallmouth bass. Their results indicated that for fish held individually, the use of salt and commercial conditioner more than doubled the time for cardiac parameters to normalize following angling compared to control fish. Heightened metabolic activity exhibited by largemouth bass resulted from the addition of the live well additives during the time that fish were also dealing with the recovery from exercise and oxygen debt after angling. Cooke et al. (unpublished data) also examined individual largemouth bass that were subjected to an ice treatment. This study indicated that as a fish cools, heart rate decreases; however, as soon it is placed back into warmer water (e.g., released back into the lake) its heart rate dramatically increases and remains elevated for at least four hours after return. Thus, subjecting fish to live well additives (i.e. salt baths and chilling) during competitive angling events may prolong recovery rates of fish and thus may add additional stress that may increase initial and delayed mortality.

Given the results of these studies we examined live well additives to determine if they could reduce initial and delayed mortality following angling tournaments. We compared initial and delayed mortality of largemouth bass that had been confined to live wells that contained ice, salt, salt and ice, or recirculated/aerated lake water.

PROCEDURES:

Effects of catch and release and tournaments on nesting success: Snorkel surveys were used to assess bass spawning activity, nest site selection by males, and the effects of angling on nesting success in Lincoln Trail Lake. Snorkeling began on April 18th and continued through May 11, 2005. Six transects have been monitored from 1999 to 2005. Each nest we locate was given a nest tag and an egg score (1-5). The water depth of the nest was recorded as well as the developmental stage of the offspring. Habitat within a 4m x 4m area around the nest was mapped, making note of substrate, cover and potential nest predators. A visual length estimate of the guarding male was noted as well as the presence or absence of a hook wound. For a subsample of nests, the male was chased off the nest for a five-minute interval where we could observe nest predation while the male was absent. The number of predators in the nest were recorded, as well as their size and amount of time spent in the nest. Also, the number of times the male had to be chased off the nest during the five-minute interval was recorded as a measure of aggression.

To examine the effects of angling on nest abandonment, nests were divided into three treatments - catch-and-release, tournament, and controls with no angling. Males were removed from the nest by snorkelers using a six-foot fishing pole rigged with five feet of monofilament and tied to a treble hook. The treble hook was held above the nest in order to initiate a strike. If the fish was not aggressive enough to strike, it was then snagged on the lower jaw. Catch and release males were held for a two-minute air exposure and released 10m from the nest. Tournament males were immediately placed into a holding tank for two hours. After two hours had elapsed, the fish were placed in a weigh-in bag with 7L of water for two minutes and then exposed to air in an open cooler for two minutes, to simulate a typical weigh-in. Tournament fish were then released 1 km from their nesting site. All angled fish were given an upper caudal clip. The next day, all nests were checked for abandonment by snorkeling. Presence of the male at each nest was noted and eggs remaining in the nest were scored once again.

Tournament monitoring: 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. We also 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. We used these data in an attempt to determine if culling was influencing sex ratios of bass weighed in during the spawning season.

Live well additives: We contacted tournament organizers and conducted a field experiment during July and August to determine if largemouth bass mortality decreased as a result of live well additives. For this first experiment, tournaments were chosen that had manageable numbers of participants (< 50 boats) and were at locations near cooperating marinas where holding net pens could be secured for 5 days. Participants were given appropriate live well additives and given instructions on live well operation. All anglers were instructed to flush and aerate live wells as they would normally. Individuals within the salt treatment were instructed to add noniodized salt to make a 0.5 percent solution at the onset and half way through the tournament (@ 4 hours). Those with ice were instructed to fill live wells and then add an appropriate amount of ice to cool the water approximately 5 °C and then adding additional ice about every two hours. The final treatment group added salt and ice following similar time lines. Following the weigh-in, fish were given a unique fin clip designating their respective live well and treatment, measured, and placed in holding nets. Initial mortality was recorded and delayed mortality was assessed by checking the net pens daily for 5 days.

These first experiments were conducted during late July and August, typically the hottest time of the year in Illinois. Because water temperature is positively related to tournament associated mortality we conducted a laboratory experiment to examine if the effect of live well additives on initial and delayed mortality was the same at cooler temperatures. In this second experiment, fish were chased manually for 90 s, exposed to air for 60 s, moved to live wells and held at a density of three fish per live well for eight hours. Live wells were circular tanks (0.91 m, diameter) that contained 100 L of water and one of four treatments, control, noniodized salt, ice, or salt and ice. Live wells were flushed and aerated and fish were exposed to a series of disturbances including brief air exposures and manual disturbances to simulate the addition of fish, wave action, culling, and other live well disturbances. At the termination of live well retention, fish were held in a water-filled bag to simulate the movement of fish from the boat to the weigh-in site. The contents of the bag were then emptied into a laundry basket, to simulate weigh-in. Fish were then weighed and measured and placed into holding tanks. Initial mortality was noted. Delayed mortality was monitored for 5 days.

Since larger largemouth bass suffer higher post release mortality than smaller largemouth bass we conducted a third experiment by conducting two simulated tournaments using experimental ponds at the Sam Parr Biological Station. Fish were angled and placed in live wells that contained one of the four treatments (control, noniodized salt, ice, and salt and ice). All live wells were flushed and aerated. Throughout experiment, fish were exposed to a series of disturbances including brief air exposures and manual disturbances to simulate the addition of fish, wave action, culling, and other live well disturbances. At the termination of live well retention, fish were held in a water-filled bag to simulate the movement of fish from the boat to the weigh-in site. The contents of the bag were then emptied into a laundry basket to simulate weigh-in. Fish were then weighed and measured and placed into holding tanks. Initial mortality was noted and fish were monitored for delayed mortality for 5 days.

FINDINGS:

Effects of catch and release and tournaments on nesting success: Based on our data, tournament angling has a detrimental effect on individual largemouth bass reproductive success. Of the bass we subjected to a simulated tournament, about 90 % of them chose to abandon. Catch-and-release males abandoned at a rate of 32% while the control males abandoned at a low rate of 3.4% (Figure 5-1). Our study, along with others (Philipp et al. 1997), provides evidence that angling of nesting bass has a negative effect on that individuals' reproductive success. Although there has been no correlation between individual reproductive success and recruitment, it is important to realize that removal of parental males from the nest could result in decreased largemouth bass recruitment.

Fish subjected to competitive angling had a much higher abandonment rate than those fish subjected to catch-and-release angling (Figure 5-1). This is most likely due to the fact that the longer the male is away from the nest, the more likely nest predation will occur. Previous work has shown that bass will return to the nest following both catch and release and tournament angling and that abandonment occurs when the eggs have been depleted (egg score reduced to low levels). Furthermore, the degree of nest predation that occurs during the males' absence also plays a role in the decision to abandon.

Tournament monitoring: In this segment, sampling of largemouth bass fishing tournaments were conducted in 2004/2005 in Lake Shelbyville (N=2), Mill Creek (N=1), 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 than females were angled in all lakes during the spawning period except Shelbyville. This would imply that spawning males might be targeted more than females. However, the proportion of males to females captured in post spawn tournaments is similar to tournaments during the spawning period.

During 2004 and 2005 tournaments, 59 angler surveys were conducted to determine if they were culling smaller male fish from their creel during the spawn. The mean number of bass weighed in by interviewed anglers was 2.7 (SE=0.27). Only eight of the 59 anglers caught a limit of fish and none had culled any bass. Observations from previous tournaments were consistent with these surveys in that there were few anglers that catch enough legal sized bass to allow them to cull. Most of the anglers surveyed caught and released sub-legal fish. The mean number of short bass released was 8.3 (SE=0.90). It appears tournament bass anglers handle about two times the number of bass that they weigh in. If these fish are reproductively active, there may be some implications to nesting success as related to catch and release angling.

Live well additives: In the first experiment examining live well additives in tournaments, dissolved oxygen levels in the live wells did not approach anoxic levels (range = 6 - 8 mg/l) regardless of the live well additive. Water temperatures in the live wells gradually increased throughout the day reaching their highest level at weigh-in (Figure 5-2). This gradual increase in temperature was similar to lake surface water temperatures. Water temperatures in the live wells that had ice fluctuated compared to controls and those with only salt. As ice was added temperatures decreased and rose as the ice melted and live wells were flushed and aerated. In the ice only treatment temperatures dropped an average of 3.5 °C whereas in the salt and ice treatment temperatures dropped an average of 3 °C. Thus fish that are captured early during a tournament will be subjected to oscillating temperatures during the course of the day potentially increasing physiological disturbance, prolonging physiological recovery, and thereby increasing the probability of delayed mortality.

In the first set of field experiments, initial mortality was less than 3% for the two tournaments. Mortality was generally higher for fish subjected to live well additives compared to those fish that were confined to live wells that had circulated aerated lake water (Figure 5-3). Delayed mortality increased for fish subjected to ice, followed by salt and ice, and the salt only treatment.

Results from the second experiment in the laboratory suggest that temperature may be more important to survival than live well additives. Fish used during the second experiment were of equal size as those caught during tournaments in the first experiment. Water temperatures were significantly cooler during the laboratory experiment as compared to the first experiment. We observed no initial or delayed mortality regardless of live well additive when fish we subjected to sublethal tournament stress at these cooler water temperatures (Figure 5-4).

The results from the third experiment suggest that smaller largemouth bass caught in a tournament and subjected to live well additives are less likely to succumb to mortality than larger fish. Fish in the third experiment were significantly smaller than those caught in tournaments for the first experiment; however, the water temperatures were similar between the two experiments. There was no initial mortality observed regardless of live well additive. Only four of the smaller largemouth bass exhibited delayed mortality (Figure 5-5). Delayed mortality for this experiment was similar to that observed during the first experiment. One individual died in the salt and ice treatment and three fish died in the salt treatment four days after the tournament.

RECOMMENDATIONS: Male largemouth bass that were exposed to a simulated tournament had very high nest abandonment (90%) compared to catch and release and control fish. These results suggest nest abandonment of tournament caught fish can be expected to be very high. Conditions during actual tournaments are often more severe than we simulated, with longer duration in livewells, longer air exposure during weigh-ins, and greater release distance from the nest. A major question that remains is what the population level consequences of springtime angling might be on largemouth bass populations. Not all nesting male bass are caught, and the number of successful nests needed to maintain a population is unknown. In the meantime, until these questions can be answered some techniques for reducing stress during springtime tournaments would be helpful. Previous work has suggested the weigh-in as the most stressful component of a tournament. Tournament anglers should be encouraged to minimize air exposure during weigh-ins and release fish as close to capture location as possible. The majority of bass tournaments will likely be conducted on lakes with strong or adequate recruitment. In situations where recruitment in a lake is poor or declining, additional precautions might be warranted to minimize effects of tournaments on recruitment. These alternative-angling practices may take several different forms. For instance, refuge areas on a lake can be closed off to fishing. These refuge areas have been shown to increase black bass nesting success (Suski et al. 2002). We are currently examining the potential effects of refuges to increase recruitment in Job 101.6. Tournaments could also move to a catch-and-release format. These angling practices also reduce reproductive success (Philipp et al. 1997), but not to the extent of competitively angled fish. Fish could either be measured or weighed immediately after capture and then released. This method is more commonly known as a paper tournament and have been used successfully for some tournaments.

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 estimates. Sample sizes are very small thus far for these surveys and future segments will focus on increasing sample number of angler surveys to determine the effects of culling. Additional research to determine the implications of angling bass from the nest on the overall bass population and year class strength are needed. These data would allow predictions about how angling may affect recruitment of largemouth bass.

We recommend that participants in competitive angling events refrain from adding water conditioners such as salt or ice to live wells. Instead we recommend that participants operate live wells in a manner that ensures fresh lake water throughout the competition. Live well additives may sublethally stress fish that when coupled with the weigh-in process may result in higher delayed mortality than simply aerating and flushing live wells as much as possible. Our experiments indicate that subjecting largemouth bass to live wells that are chilled or have low concentrations of salt during tournaments will most likely result in an increase (or no improvement) in delayed mortality during summer months. Additions of salt or ice to live wells during tournaments that are conducted during the early spring or late fall, when water temperatures are relatively low, will also most likely have no effect on delayed mortality.

Although our results are consistent with previous studies that report delayed recovery in basic physiological processes with live well additives, they are counter intuitive given salts common use in aquaculture settings. Salt has been and is commonly used during handling and transport in an attempt to maintain homeostasis and thus maximize survival. While the use of salt during periods of stress may result in better osmoregulatory balance or lower the risk of fungal infections this may not be the case for larger fish that have been exposed to successive acute stressors such as during a tournament. Efforts have been undertaken by anglers, tournament organizers, and fisheries managers to reduce initial and delayed tournament mortality. Our results suggest the use of live well additives in increasing survival is minimal. Temperature or the time of year tournaments are conducted and bass size are more important in determining mortality.

Job 101.6 Evaluating the impact of harvest regulations and other management strategies 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 1999-2005. Samples collected during 1999 – 2001 represent pre-refuge. In this segment, electrofishing transects and seines hauls were performed in the spring and fall of 2004 and the spring of 2005. Two, thirty minute electrofishing transects and two seine hauls were performed inside the refuge on each sampling date. 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 caudal 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 2001 was 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 through 2005 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 numbers are increasing in the refuge due to the elimination of fishing pressure. This data however is based on few sample dates in a limited number of years. More data is required to verify that CPUE is consistently higher inside the refuge or if the refuge is contributing to increased numbers of bass throughout the lake.

Seine data has shown some increases in the catch of young of year largemouth bass throughout the lake and refuge after the refuge was closed. In the spring of 2005 we observed a large number of young of year bass in the main lake, however no young of year were collected inside the refuge. The total number of fish captured in seine samples also appears to have increased after the refuge was closed. The refuge may be positively influencing young-of-year largemouth bass recruitment. With the increased number of adult bass in the refuge, we would expect to see an increase in young of year production. 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. It is important to evaluate if the refuge is influencing the remainder of the lake in order to determine if the closing areas for fishing can be used as a management tool for bass populations on a lake wide scale. These results are 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.

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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, 2004 and 2005. 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	Number Stocked	Stocking Density (#/ha)	Temperature at Stocking (C)	Stocking Mortality (%)
Charleston	2	7/13/2004	15,000	132	27.5	48
	4	8/18/2004	7,000	62	24.4	0
	6	8/19/2004	3,000	27	24.3	0
	8	4/25/2005	1,500	13	14.7	0
Homer	2	7/13/2004	4,000	125	29.1	2
	4	8/18/2004	2,000	63	24.1	0
	6	8/19/2004	800	25	24	0
	8	4/25/2005	400	13	13.6	0

Table 2-2. 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 are reported.

Lake	Size	Stomachs Examined	Stomachs Full	Percent of Predators with Stocked LMB in Diet
Charleston	2	93	48	10.4
	4	12	7	0
	6	10	6	0
	8	-	-	-
Homer	2	126	45	4.4
	4	67	45	0
	6	52	23	0
	8	-	-	-

Table 2-3. 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 2004 and spring of 2005. CPUE is reported as number of fish per hour of AC electrofishing. Two-inch fish have not yet been processed for OTC marks.

Lake	Size	Fall				Spring			
		CPUE	St Err	Mean Length	St Err	CPUE	St Err	Mean Length	St Err
Charleston	Four	1.00	1.00	120.0	-	0.33	0.33	125.0	-
	Six	7.50	4.50	163.4	4.0	1.67	0.33	167.0	4.0
	Eight	Not Stocked Until Spring		Not Stocked Until Spring		9.00	9.00	207.0	2.6
	Natural	3.50	0.50	99.6	8.1	1.67	0.33	125.2	7.8
Homer	Four	2.17	1.17	120.2	4.4	0.00	0.00	No Recaptures	
	Six	2.67	2.67	152.6	3.2	1.00	0.33	152.0	17.0
	Eight	Not Stocked Until Spring		Not Stocked Until Spring		1.67	1.67	209.6	4.3
	Natural	7.67	0.33	127.8	8.9	6.34	3.00	127.9	6.8

Table 2-4. Largemouth bass stocking summaries for lakes Shelbyville, Jacksonville, 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	Number Stocked	Fall		Spring	
			CPUE	Mean TL (mm)	CPUE	Mean TL (mm)
Shelbyville	Intensive	8,800	1.0	155.0	0.0	-
	Extensive	35,000	0.0	-	0.0	-
	Natural	-	8.3	175.4	5.5	191.7
Jacksonville	Intensive	5,000	0.0	-	0.0	-
	Extensive	15,000	3.0	161.7	1.3	168.8
	Natural	-	12.3	129.5	4.3	167.8
Walton Park	Intensive	625	3.5	196.4	0.3	220.0
	Extensive	625	0.9	154.8	0.7	165.0
	Natural	-	2.5	168.8	6.7	107.6

Table 3.1. Background frequencies (pre-stocking) of largemouth bass MDH B2:B2 genotype determined from Little Grassy Fish Hatchery and six lakes in Illinois prior to stocking from 1998 to 2001 (Table 3.1a). Post-stocking collections are the number of individuals taken from each of the six lakes in Illinois during 2003 and 2004. Post Stocking allele frequencies are calculated for the MDH B2 allele for each of the six lakes from both the 2003 and 2004 collections (Table 3.1b).

Table 3.1a

SOURCE	PRE-STOCKING GENOTYPES (N)			PRE-STOCKING ALLELE FREQUENCIES	
	1/1	1/2	2/2	1	2
FORBES	81	49	28	0.67	0.33
MCCLEANSBORO	23	34	32	0.45	0.55
MURPHYSBORO	80	12	6	0.88	0.12
SAM PARR	75	16	10	0.82	0.18
SHELBYVILLE	158	45	8	0.86	0.14
WALTON PARK	66	11	8	0.84	0.16

Table 3.1b

SOURCE	POST-STOCKING YOY COLLECTED		POST-STOCKING ALLELE FREQUENCIES 2003		POST-STOCKING ALLELE FREQUENCIES 2004	
	2003 *N*	2004 *N*	1	2	1	2
FORBES	94	125	0.59	0.41	0.58	0.42
MCCLEANSBORO	87	100	0.53	0.47	0.49	0.51
MURPHYSBORO	112	87	0.73	0.27	0.8	0.2
SAM PARR	100	101	0.77	0.23	0.63	0.37
SHELBYVILLE	66	209	0.73	0.27	0.86	0.14
WALTON PARK	101	31	0.8	0.2	0.58	0.42

Table 4-1. Spearman correlation coefficients for the relationships between peak density and mean densities of YOY largemouth bass (N/m^2) during the months of their first growing season with the abundances of both YOY largemouth bass at the end of the growing season and bass recruited to age-1 the following spring (N/hr). * is $P \leq 0.05$, ** is $P \leq 0.01$, and *** is $P \leq 0.001$.

Year	Sample period	fall YOY Lmb	recruits
2000	May	0.26	0.2
2000	June	0.59	0.54
2000	July	0.81**	0.67*
2000	August	0.58	0.56
2000	September	0.55	0.63*
2000	October	0.2	0.4
2000	peak YOY Lmb	0.79**	0.65*
2001	May	0.51	0.38
2001	June	0.56	0.63*
2001	July	0.46	0.67*
2001	August	0.53	0.62*
2001	September	0.41	0.76 *
2001	October	0.36	0.54
2001	peak YOY Lmb	0.45	0.60*
2002	May	0.74*	0.5
2002	June	0.78**	0.2
2002	July	0.88***	0.49
2002	August	0.89***	0.44
2002	September	0.84**	0.39
2002	October	0.58	0.15
2002	peak YOY Lmb	0.82**	0.31
2003	May	0.14	0.18
2003	June	0.23	0.09
2003	July	0.73*	0.41
2003	August	0.64*	0.46
2003	September	0.71*	0.39
2003	October	0.63*	0.28
2003	peak YOY Lmb	0.76*	0.29
2004	May	-	-
2004	June	0.62*	0.68*
2004	July	0.58*	0.65*
2004	August	0.63*	0.66*
2004	September	0.46	0.58*
2004	October	0.37	0.58*
2004	peak YOY Lmb	0.62*	0.65*

Table 4-2. Spearman correlation coefficients for the relationships between mean YOY largemouth bass densities (N/m^2) with abundance of YOY largemouth bass at the end of the growing season (N/hr). * is $P \leq 0.05$.

Lake	May	June	July	August	September	October	peakYOY
Clinton	-0.35	0.1	0.34	0.31	-0.3	-0.21	0
Lincoln	0.41	0.6	0.9*	0.8	0.9*	0.56	0.7
Paradise	0.35	-0.21	0.1	0.1	0.35	0	0
Pierce	0.73	-0.29	0.21	0.05	0.21	0.05	0.05
Ridge	0.05	0.7	0.9*	0.9*	0.2	0	0.9
Shelbyville	-	0.35	0.8	0.89*	-0.71	-	0.8
Walnut	0.21	0.1	0.6	0.8	0.6	-0.5	0.6
Woods	0.71	0.05	0	-0.6	-0.021	0.5	0.1

Table 4-3. 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 2004.

Lake	TP	Secchi	Spring temp	Vegetation
Clinton	71.9	0.68	18.8	-
Dolan	114	0.43	24.0	0.01
Forbes	31.3	0.56	19.8	-
Lake of t. Woods	28.6	2.81	19.8	0
Lincoln Trail	< 1	1.39	24.5	0.16
Paradise	172	0.49	21.5	0.12
Pierce	71.3	0.78	18.4	0.14
Ridge	6.97	1.25	25.4	-
Shelbyville	< 1	1.14	21.1	-
Sterling	17.2	1.86	23.9	0.14
Walnut Point	17.2	0.86	21.2	0.09
Woods	51.8	0.46	23.8	0

Table 4-4. 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 2004.

Lake	Chloro	Zoop	Benthos	Larval	J. Blg	Gz Shad
Clinton	31.6	351	1747	5	0.059	373
Dolan	40	34.7	1201	2.38	0.056	14
Forbes	20.3	81.1	351	2.86	0.705	28.3
Lake of t. Woods	18.7	514	8097	24.3	0.311	50.7
Lincoln Trail	18.6	434	4072	9.05	3.87	0
Paradise	47	501	1911	11	0.376	86.7
Pierce	24	418	4603	71	1.59	72.4
Ridge	11.8	559	2093	3.41	3.61	0
Shelbyville	8.5	340	1747	4.15	0.014	1739
Sterling	4	367	1132	0.21	0.111	5.37
Walnut Point	34.4	1484	17418	32.2	2.08	0
Woods	33.1	328	3608	4.45	0.258	100

Table 4-5. Spearman correlation coefficients across 6 year-classes (except Dolan, where N = 5) for the correlations between mean and peak YOY largemouth bass densities (N/m^2) with the abundance of largemouth bass recruited to age-1 the following spring (N/hr). * is $P \leq 0.05$ and ** is $P \leq 0.01$.

Lake	May	June	July	August	September	October	peakYOY
Clinton	-0.13	-0.12	-0.03	-0.56	-0.26	-0.52	-0.43
Dolan	-	0.90*	0.87*	0.68	0.69	-0.15	0.90*
Forbes	0.13	-0.31	0.49	-0.64	-0.71	0.40	-0.31
Lincoln	0.23	0.77	0.54	0.71	0.20	0.49	0.94**
Paradise	0.13	0.89*	0.81*	0.71	-0.15	0.43	0.93**
Pierce	0.39	0.41	0.37	0.09	0.49	0.54	0.60
Ridge	0.27	0.94**	0.20	0.14	0.31	0.14	0.83*
Shelbyville	-	-0.54	0.43	-0.40	0.40	-	0.20
Sterling	-	0.35	0.48	0.12	0.30	-0.24	0.48
Walnut	0.64	0.49	-0.09	0.60	-0.09	0.31	0.49
Woods	0.13	-0.23	-0.14	-0.43	-0.75	-0.58	-0.31

Table 5-1. Number of fish surveyed, sex ratios, average total length, and percent spawning bass from tournament catches on Mill Creek, Lake Mattoon, Lake Shelbyville, and Steven Forbes Lake during spawn and post-spawn periods from 1999 to 2005. Percent spawning are reported for males, females, and all fish caught. TL refers to the total length of the fish.

Lake	Season	N	% Male	Female TL (mm)	Male TL (mm)	Male Running (%)	Female Running (%)	Total Running (%)
Forbes	Spawn	61	57.4	453	407	54.3	80.8	65.6
	Post	32	62.5	399	439			
Mattoon	Spawn	70	58.6	454	409	73.2	100.0	84.3
	Post	45	60.0	411	385			
Mill Creek	Spawn	118	66.1	422	364	100.0	100.0	100.0
	Post	63	42.9	407	386			
Shelbyville	Spawn	145	42.1	431	382	91.8	91.7	93.0
	Post	236	49.6	424	408			

Table 6-1. Catch per unit effort (#/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	24.4	56.0	24.0
2000	32.4	5.5	18.0	0.0
2001	26.0	48.7	10.0	22.0
	Refuge Closed 9-11-01			
2002	8.3	38.0	-	-
2003	21.5	23.8	-	87.5
2004	20.7	28.3	42.0	146.0
2005	27.2	-	32.0	-

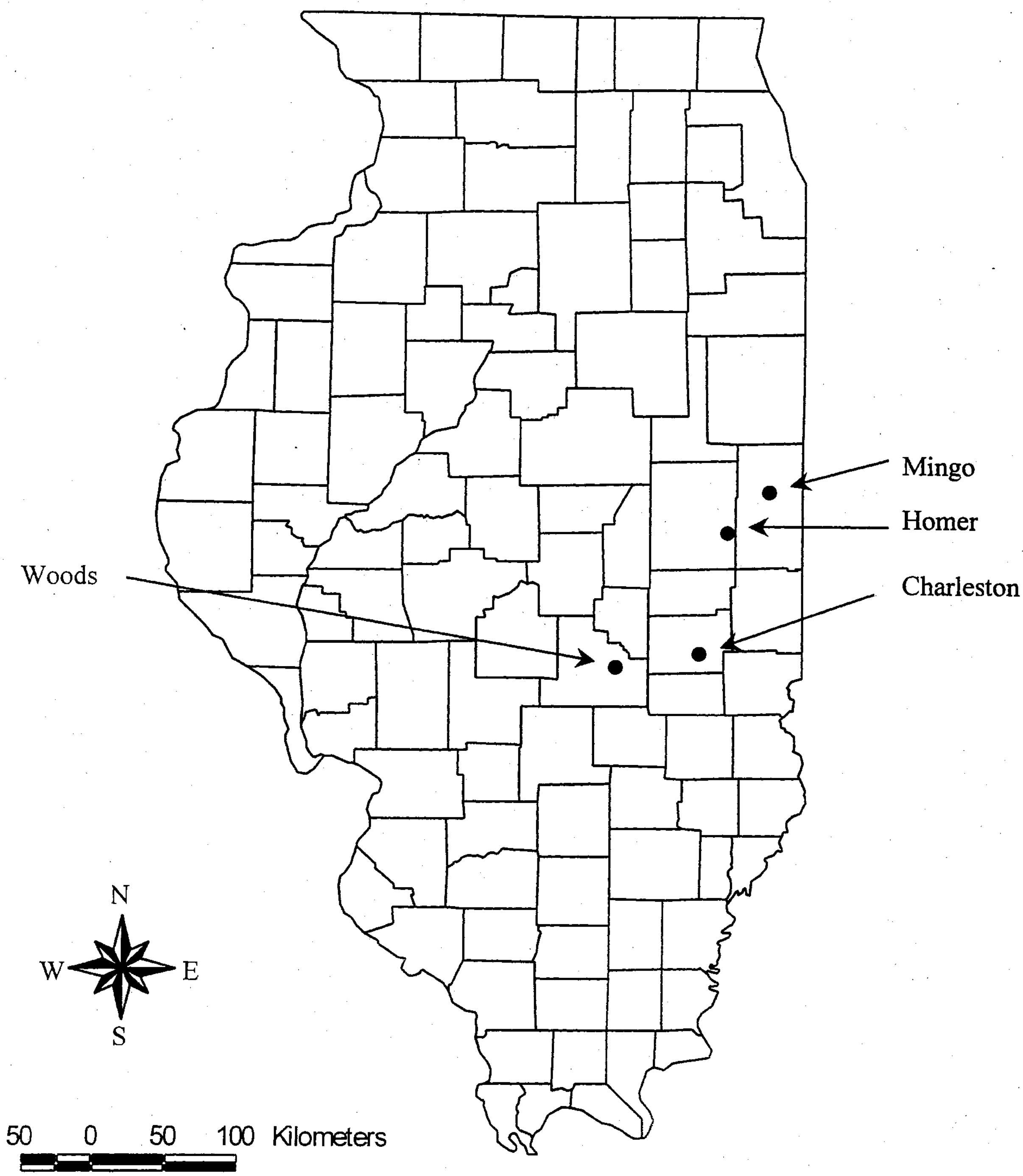

Figure 2-1. Location of 4 lakes in Illinois stocked with four sizes of fingerling largemouth bass in 1999 – 2005.

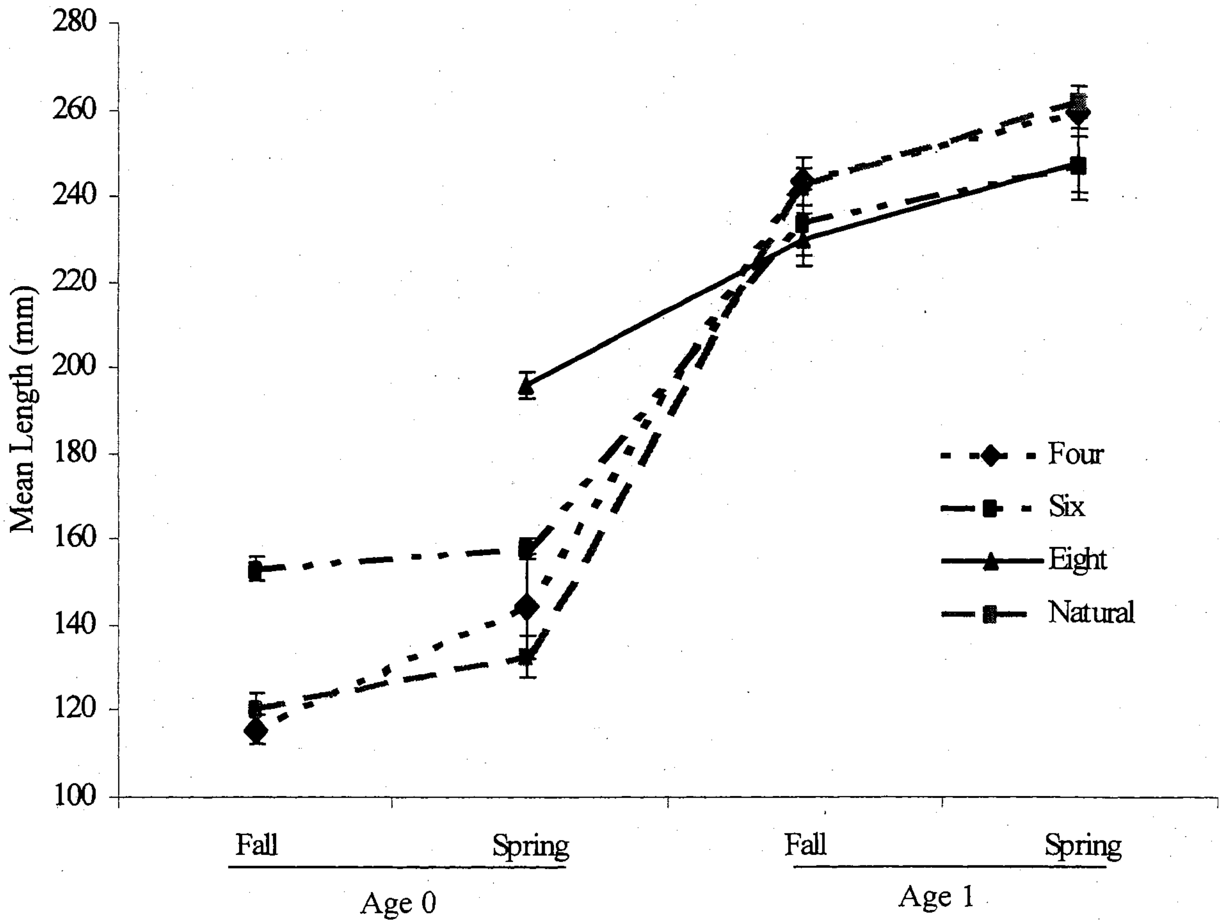

Figure 2-2. Mean growth through time of different sized largemouth bass after stocking in 4 reservoirs during 1998-2005. Values are mean total length (mm) +/- 1SE in each season following stocking.

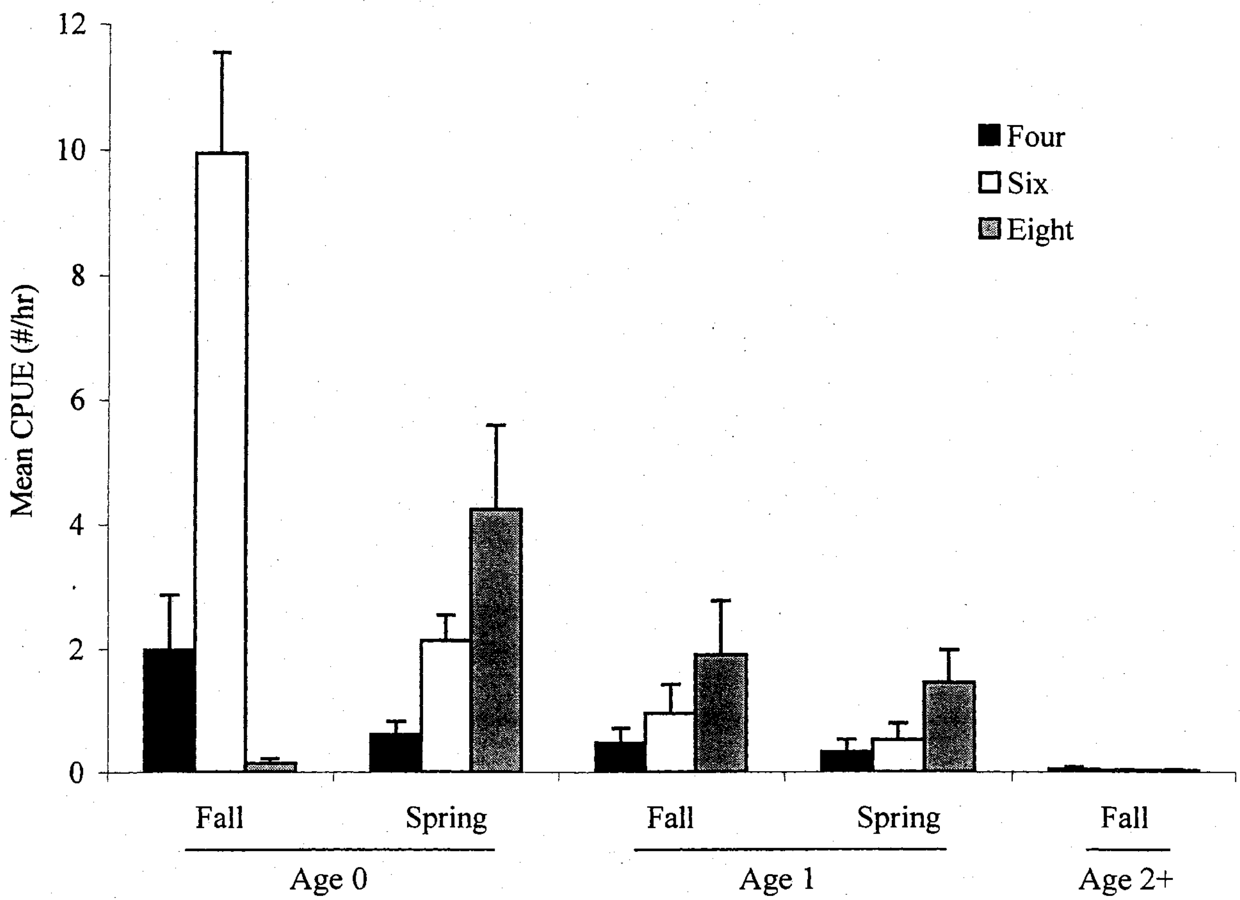

Figure 2-3. Catch per unit effort (CPUE) through time for different sizes of stocked largemouth bass in 4 reservoirs in 1998-2005. Catch per unit effort is the number of fish per hour of AC electrofishing.

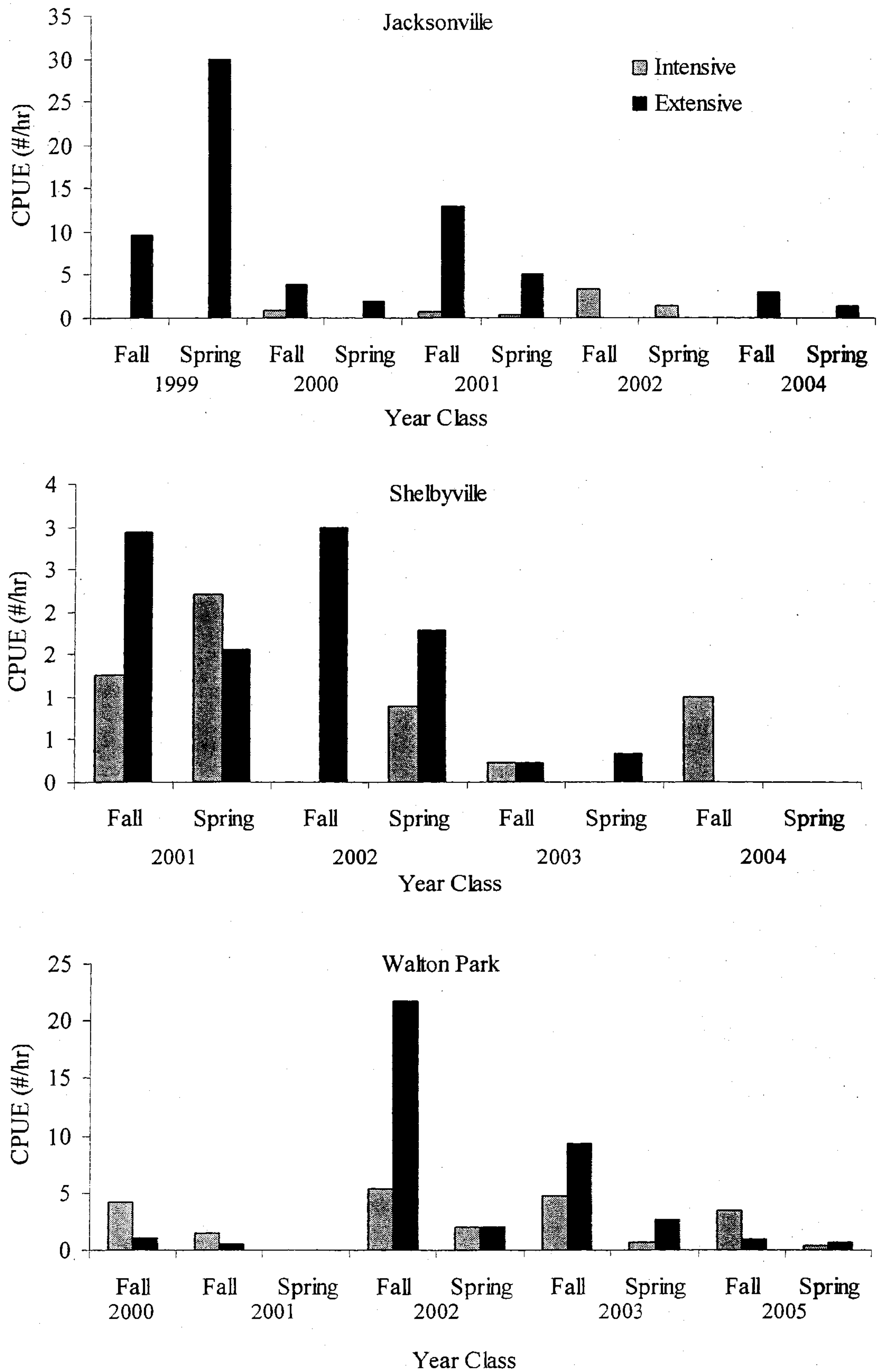

Figure 2-4. Catch per unit effort (CPUE) through time for different sizes of stocked largemouth bass in 4 reservoirs in 3 years during 1998-2005. Catch per unit effort is the number of fish per hour of AC electrofishing.

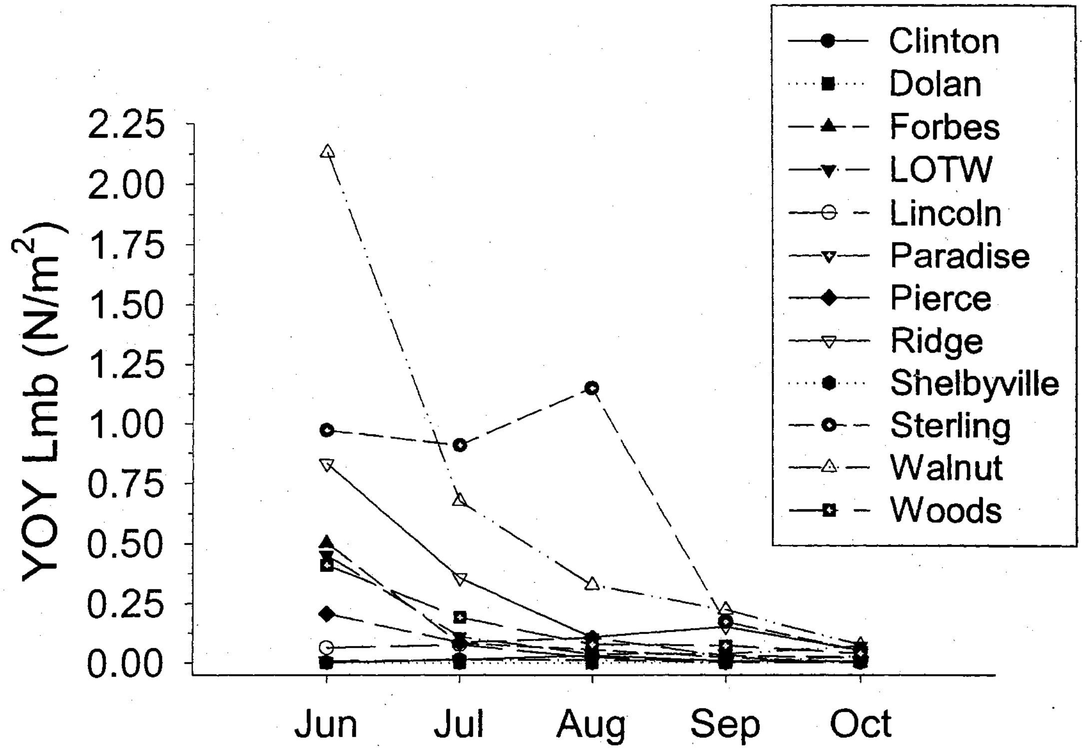

Figure 4-1. Average monthly young of the year (YOY) largemouth bass densities (N/m^2) for 12 study lakes in 2004. Largemouth bass were collected with a 9.2-m bag seine from 4 stations in each lake. Closed symbols represent lakes with gizzard shad, whereas, open symbols represent lakes without gizzard shad.

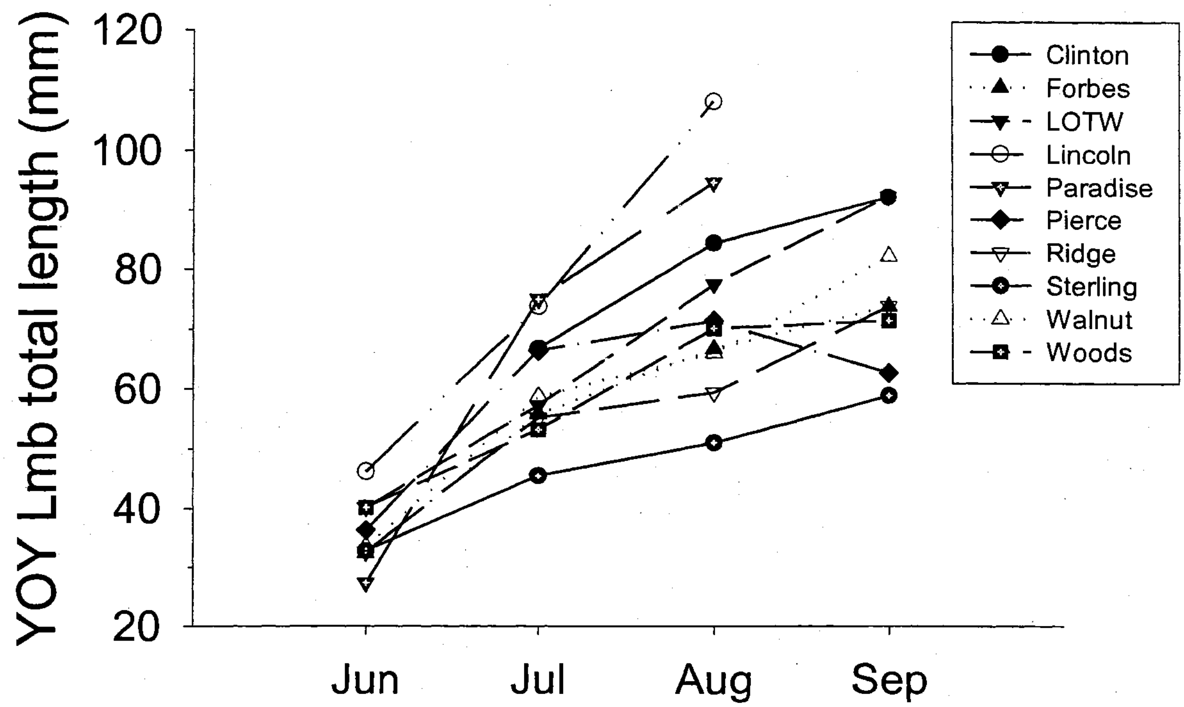

Figure 4-2. Average monthly total lengths (mm) of young of the year largemouth bass collected from 12 study lakes in 2004. Largemouth bass were collected with a 9.2-m bag seine from 4 stations on each lake. Open symbols represent lakes with no gizzard shad.

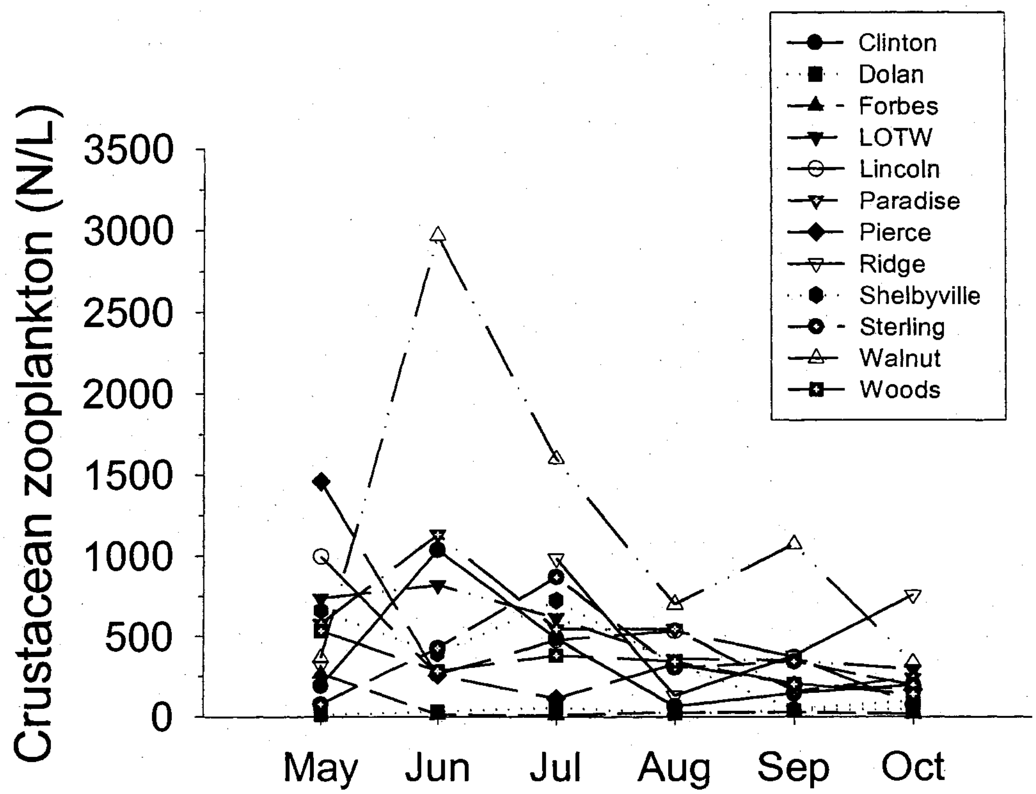

Figure 4-3. Average monthly densities of inshore crustacean zooplankton (N/L) in 12 study lakes in 2004. Inshore zooplankton samples were collected with a 0.5-m diameter zooplankton net with 64-µm mesh pulled from 1-m depth to the surface. Open symbols represent lakes without gizzard shad.

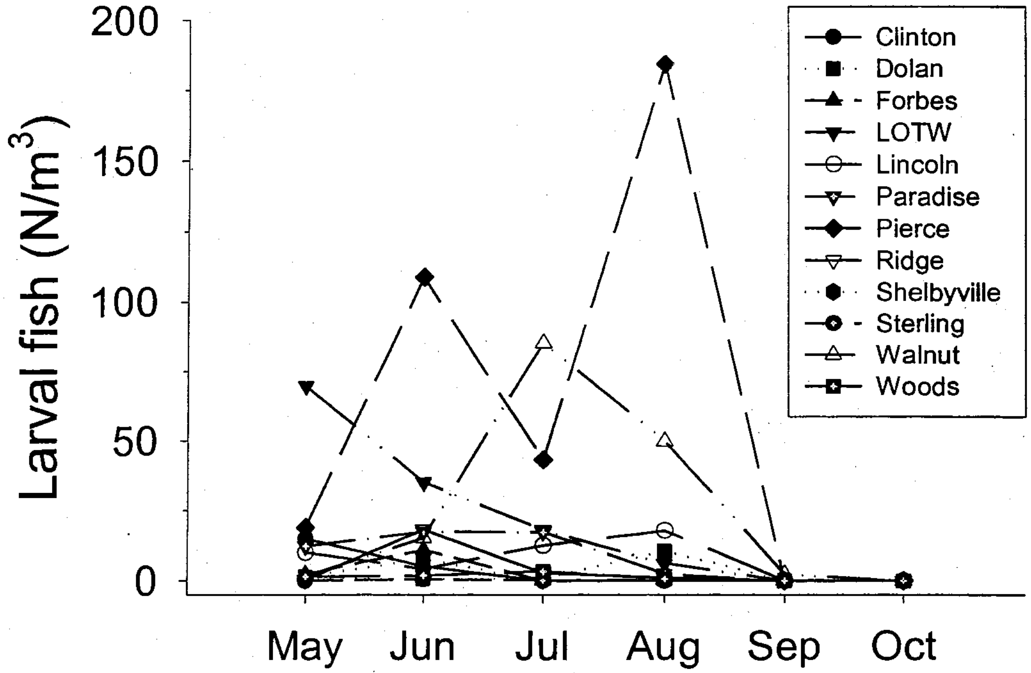

Figure 4-4. Average monthly densities of larval fish (N/m^3) in 12 study lakes during 2004. Larval fish were collected at six sites by pushing a 0.5-m diameter push net with a 500-µm mesh for 5 minutes inshore and 5 minutes offshore. Closed symbols represent lakes with gizzard shad and open symbols represent lakes without gizzard shad.

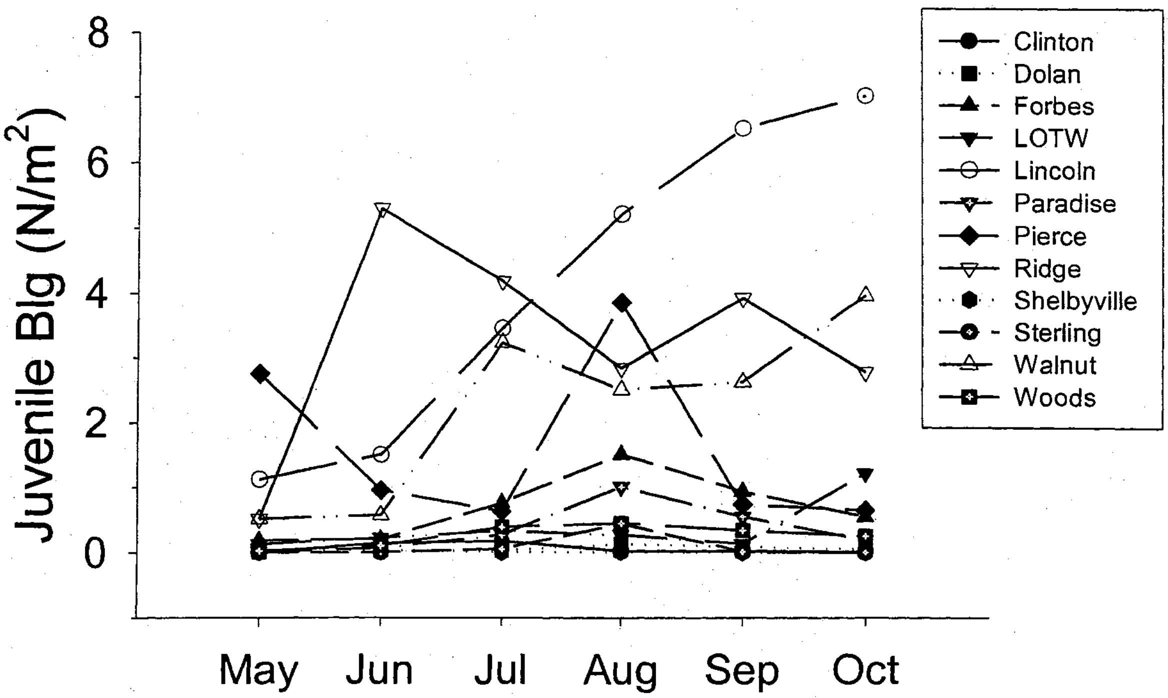

Figure 4-5. Average monthly densities of juvenile bluegill (Blg TL ≤ 60 mm; N/m^2) in 12 study lakes in 2004. Bluegill were collected with a 9.2-m bag seine pulled at four fixed stations in each lake. The lakes represented by open symbols do not contain gizzard shad.

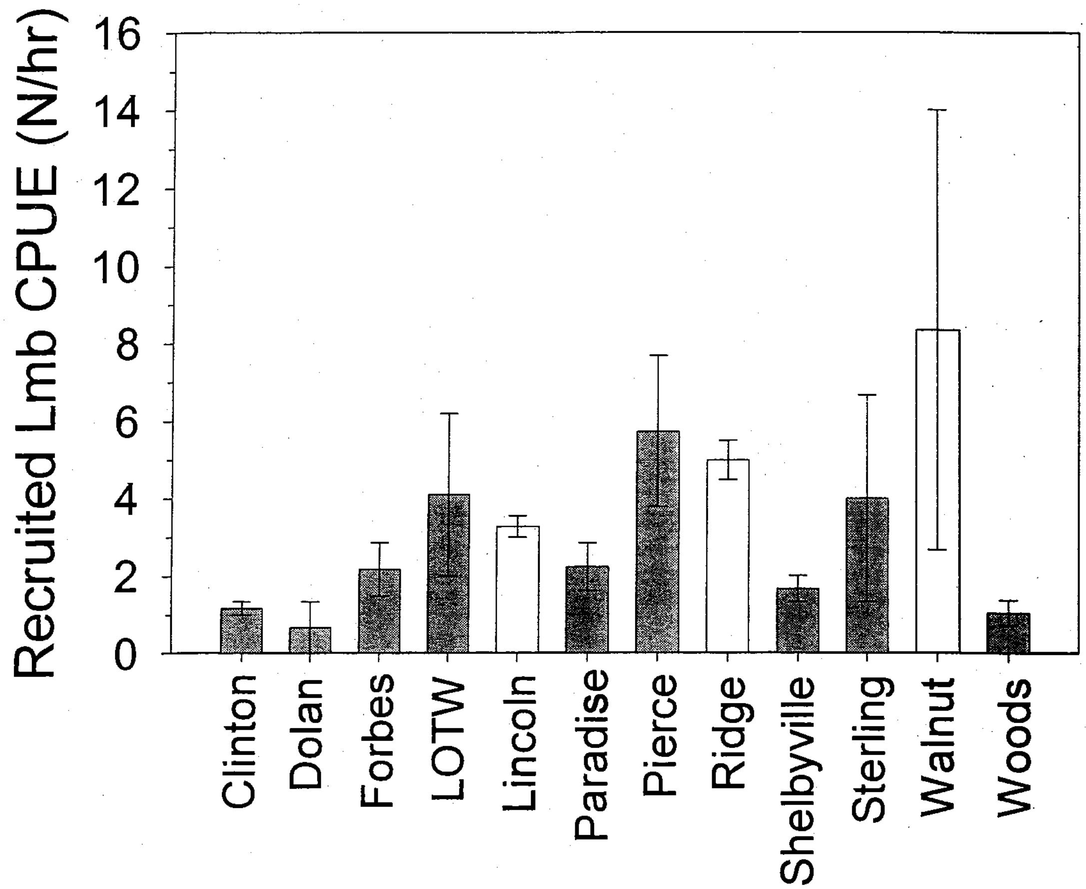

Figure 4-6. Average catch per unit effort (CPUE; N/hr ± 1 SE) of largemouth bass recruited to age-1 for 12 study lakes in spring of 2005. Fish were collected in the spring by using A.C. electrofishing along three shoreline transects for a 0.5 hour each. Open bars represent the lakes without gizzard shad.

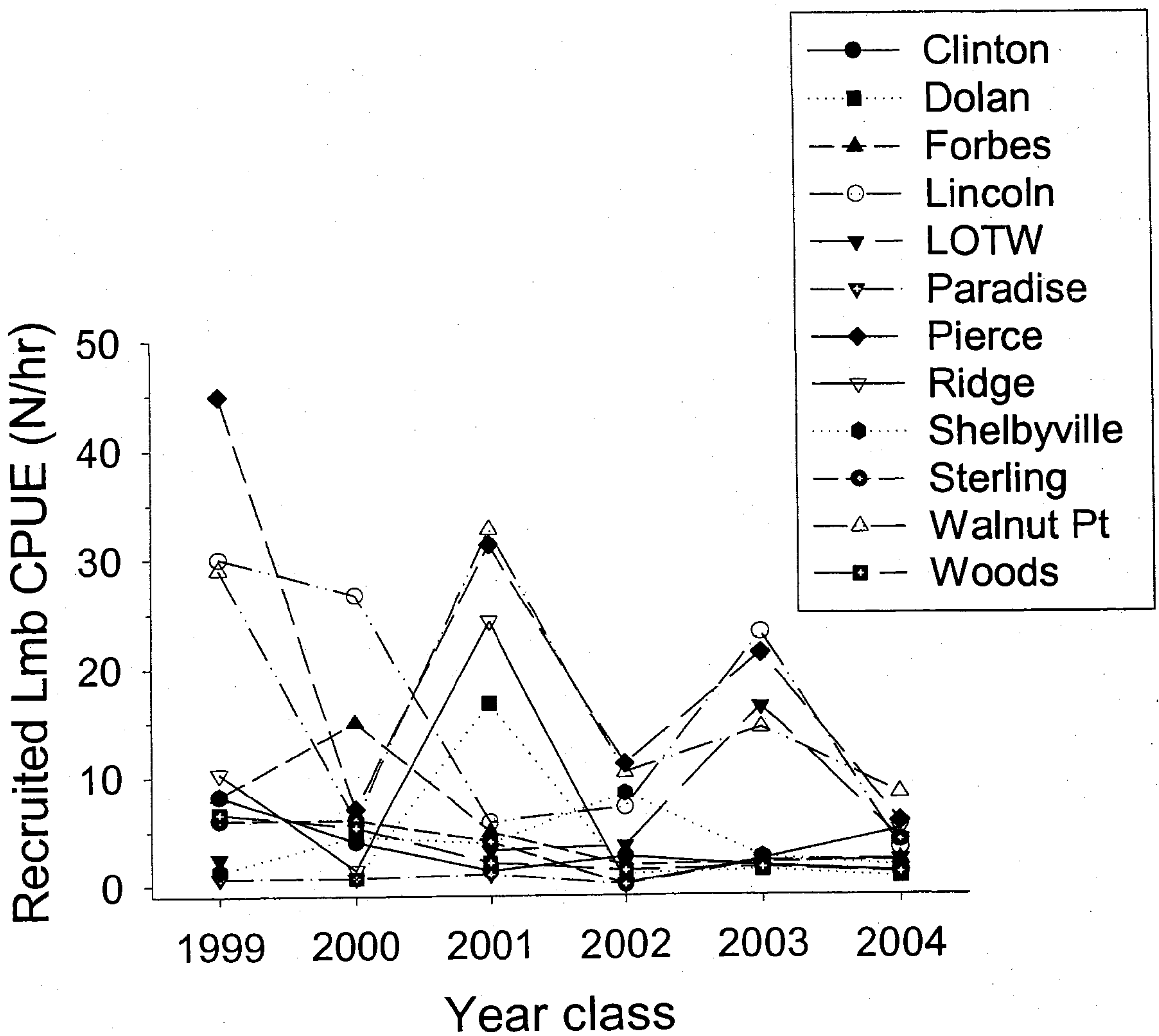

Figure 4-7. Average catch per unit effort (CPUE; N/hr) of largemouth bass recruited to age-1 for 12 study lakes and six year classes. Fish were collected in the spring by using A.C. electrofishing along three shoreline transects for a 0.5 hour each. Open symbols represent lakes without gizzard shad.

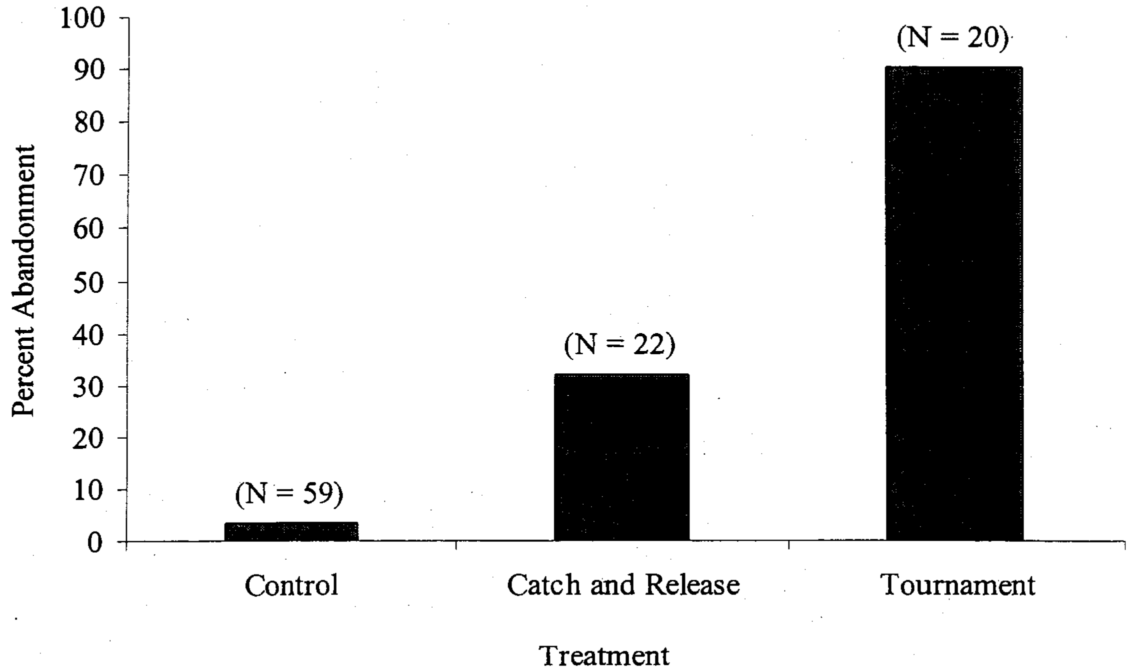

Figure 5-1. Abandonment rates of male largemouth bass from controls with no angling, catch-and-release and a simulated tournament.

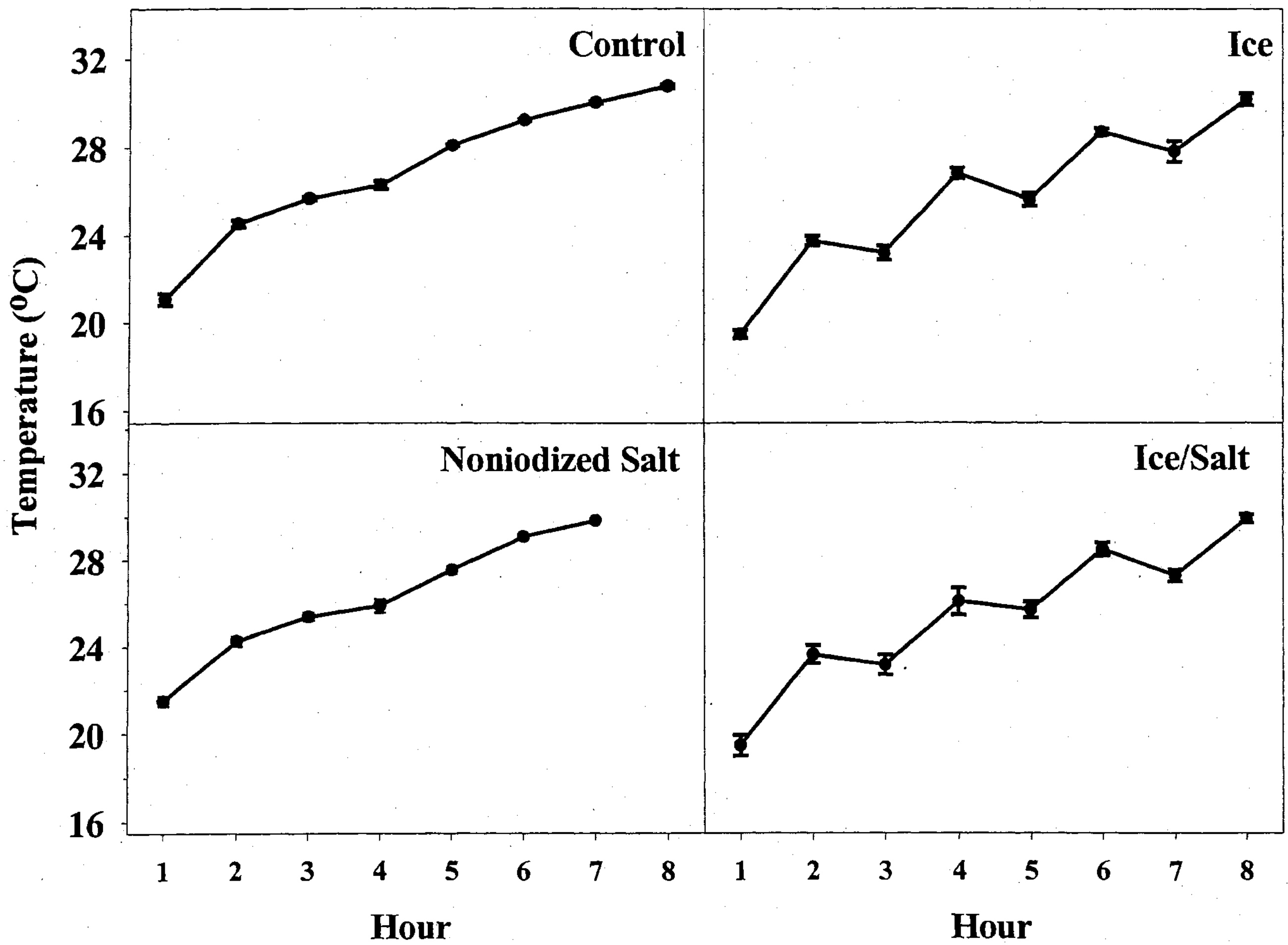

Figure 5-2. Mean (± 1 S.E.) hourly temperatures (°C) for live wells that contained either recirculated lake water (control), ice, noniodized salt, or a combination of noniodized salt and ice.

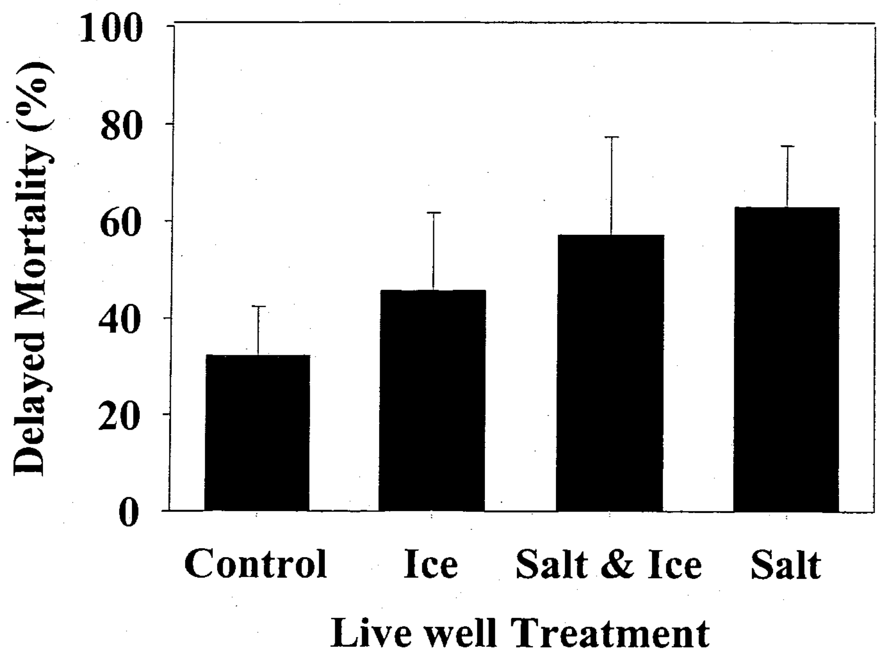

Figure 5-3. Delayed mortality (%) of largemouth bass held for five days within net pens floated within the lake of capture. Bars represent the average mortality (± 1 S.E.) combined for to tournaments conducted during July and August for largemouth bass confined to live wells that contained either recirculated lake water (control), ice, noniodized salt, or a combination of noniodized salt and ice.

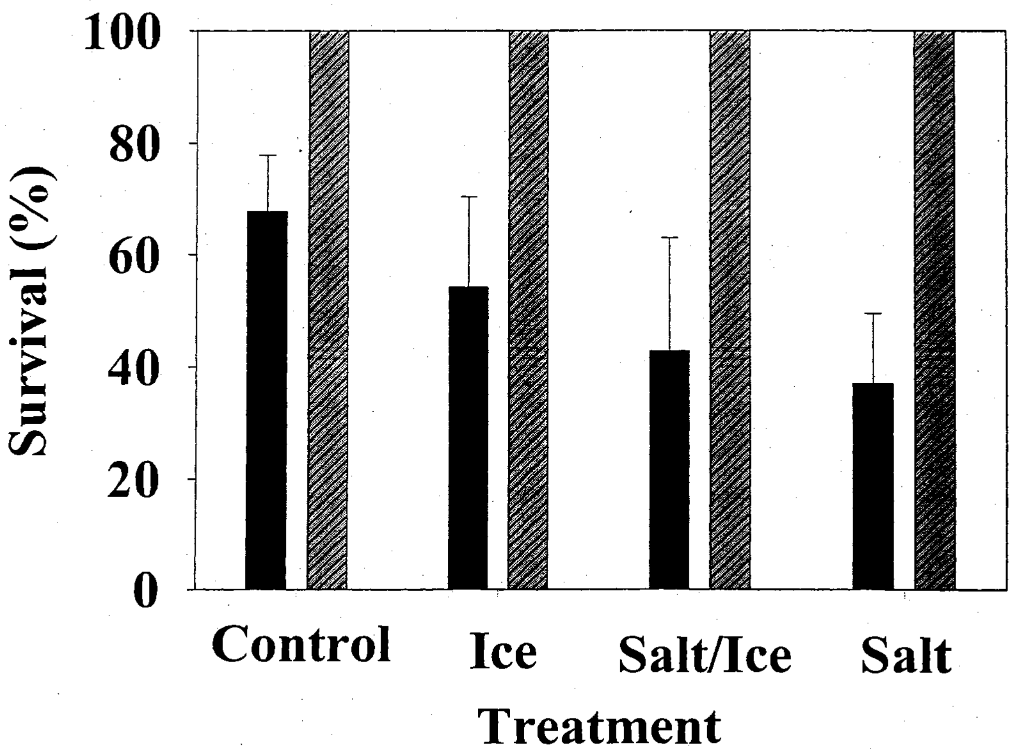

Figure 5-4. Largemouth bass survival five days following confinement in liv wells containing either recirculated lake water (control), ice, noniodized salt, or a combination of noniodized salt and ice during a tournament. Solid bars (± 1 S.E.) represent fish captured in tournaments during July and August and gray bars with slash lines represent those fish used in laboratory experiments.

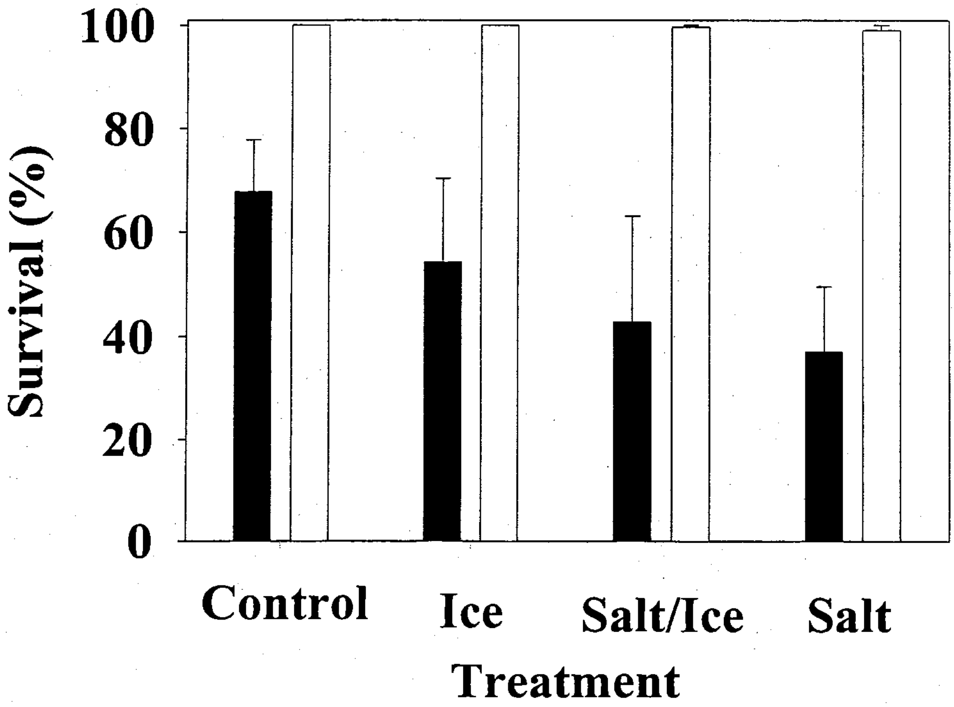

Figure 5-5. Largemouth bass survival five days following confinement in liv wells containing either recirculated lake water (control), ice, noniodized salt, or a combination of noniodized salt and ice during a tournament. Solid bars (± 1 S.E.) represent fish captured in tournaments during July and August and white bars represent those fish used in pond experiments.

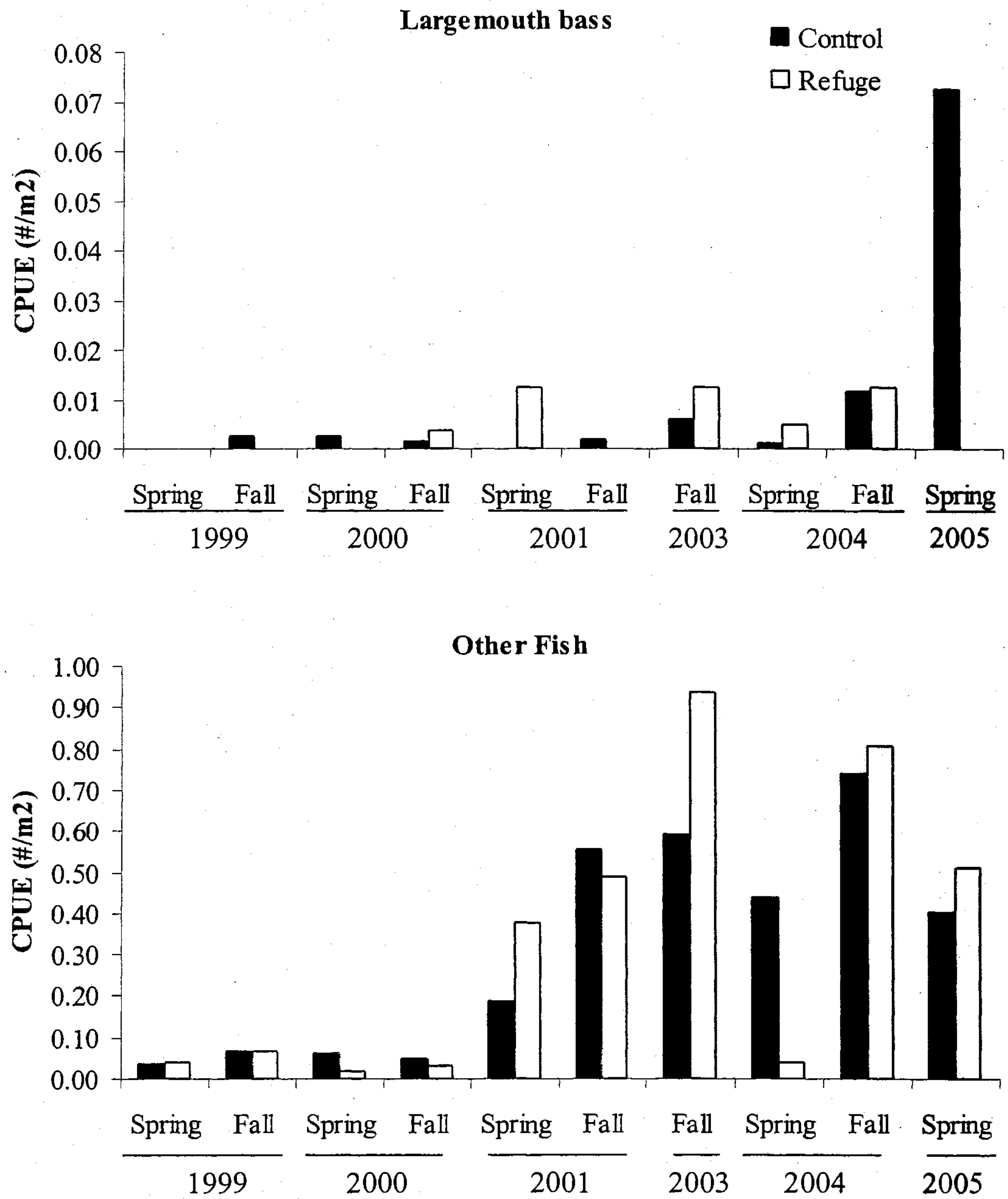

Figure 6-1. Catch per unit effort from seine hauls taken from the main lake and inside the refuge in spring and fall 1999 - 2005. The refuge sites were not sampled in 2002 or spring 2003. CPUE is measured as number of fish per square meter. The dashed line represents when the refuge was closed to the public.