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CENTER FOR AQUATIC ECOLOGY AND CONSERVATION

ANNUAL PROGRESS REPORT

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

Matt J. Diana, Joseph J. Parkos III,
Julie E. Claussen, David P. Philipp, and David H. Wahl

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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.

There was no new activity in Job 101.1 as final recommendations were presented in previous reports.

In job 101.2 we are assessing stocking strategies for largemouth bass. Supplemental stocking is a widely used management tool for increasing the standing stock of an existing population. Survival of stocked largemouth bass fingerlings to adult size was relatively low and ranged from 0 to 1.3 stocked fish per hour of electrofishing during the spring of 2006. We continue to find large (300 to 550 mm) stocked bass in the adult population and will continue to monitor these fish for growth and survival differences. Six and eight inch bass were stocked at larger sizes than natural and other stocked bass in the lake. These stocked fish however, experience low growth rates after stocking and are similar in size to other bass in the lake shortly after stocking. In this segment, we analyzed diets of large and advanced fingerlings and natural bass in a lake. Stocked bass were raised on pellets to 4 inches and finished on minnows. We found that a slightly higher proportion of stocked bass had empty stomachs and that they were initially feeding on a higher proportion of benthic invertebrates whereas natural bass were feeding on mostly fish and also had some crayfish in the diets.

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 varied on stocked fish and were high 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 were found in similar relative abundances and at similar mean size from the first summer after stocking throughout the following seasons. Cost analysis showed that growing bass to six or eight inches increased the overall cost of producing and stocking largemouth bass. Our recommendation is to stock four inch bass because small fingerlings do not survive well and we find no differences in long-term survival between medium, large, and advanced fingerlings.

The relative survival of intensively and extensively reared largemouth bass varied between lakes. Extensively reared fish experienced higher survival rates in Jacksonville Lake initially, but not in subsequent stockings. Thus far, no differences in survival have been observed between intensively and extensively reared fish in any of the three study

reservoirs. 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, habitat, and abiotic factors 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 fish to a population, fingerlings were produced at the Little Grassy Fish Hatchery with the MDH B2B2 allele as a genetic tag. These genetically tagged fingerlings were then stocked into six study lakes. Once these fish reach 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 2005 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, five 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 2005 year-class and associated environmental conditions in the 12 study lakes. Recruitment to age-1 was not measured in Dolan Lake as it was drawn down (i.e. removed from the study) in 2006. Differences among study lakes in young of the year (YOY) largemouth bass abundance corresponded to differences in total larval fish production, potentially reflecting among-lake differences in reproductive conditions for all fish. Among lakes, survival of YOY largemouth bass to the end of the growing season was positively related to density of juvenile bluegill. Abundance of YOY largemouth bass was the only variable to significantly explain among lake differences in YOY bass growth, indicating the potential importance of intraspecific competition to YOY bass size structure. The relationships between juvenile bluegill density and YOY largemouth bass survival and between YOY bass density and first year growth have been consistently important throughout this study. Similar to the 2002 and 2003 year classes, differences among lakes in recruitment to age-1 were not related to early abundance of YOY bass. A multiple linear regression model for the 2005 year-class found a significant relationship between recruitment to age-1 and secchi depth. Gizzard shad may play an important role in among-lake variation in largemouth bass recruitment, as there was a negative relationship between the abundance of adult shad and secchi depth, juvenile bluegill density, and largemouth bass recruitment. In previous segments, survival of YOY largemouth bass to the fall has also been negatively correlated with gizzard shad abundance.

In Job 101.5, we snorkeled bass nests in order to assess survival of various cohorts, as well as map nesting habitat and behavior. Bass spawning in Lincoln Trail Lake was observed between 4/19/2006 and 5/18/2006. Largemouth bass were found spawning over a variety of substrates and did not show strong preference for any one type. Bass exhibited varying levels of aggressiveness, but we did not observe high levels of nest predation by crayfish, bluegill and other sunfish. We will continue to monitor nests for substrate preferences and factors influencing nest predation and aggressiveness of guarding male bass.

There is potential for angling to have a large influence on largemouth bass populations. In particular, competitive tournament fishing for black bass has grown rapidly in the United States over the past several years. Previous work has shown high levels of mortality associated with these tournaments in other parts of the United States. Paper tournaments have potential for eliminating a majority of handling associated with bass tournaments and could greatly reduce mortality. In this segment we conducted a paper tournament simultaneously with a typical style tournament (weigh in at the boat ramp) to evaluate how the results will differ. We also evaluated alternative ways of determining the best angler (largest bass or total number of fish caught). Paper tournament results were statistically similar to weigh in results (i.e. rank order of anglers). The ranking changed more dramatically when all fish caught were used in the tournament results. We will combine this data with those collected from 3 other tournaments to assess the potential of paper tournaments as an alternative to weigh-ins.

In Job 101.6 a portion of Clinton Lake that was closed to fishing was sampled to determine the effects of the refuge on largemouth bass populations. Electrofishing samples yielded a higher abundance of adult largemouth bass in the refuge than in the main lake. Seine samples however showed higher abundance of young-of-year largemouth bass and other species of fish in the main lake in the fall of 2005 and spring of 2006. Some increase in the number of largemouth bass has also been observed throughout the lake. Sampling will continue at Clinton Lake to monitor largemouth bass populations for changes relative to 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.

RECOMMENDATIONS: No activity in this segment. Final recommendations were provided in previous reports.

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 largemouth bass populations. Supplemental stocking efforts are directed at either increasing harvest rates and reproductive potential, or restoring a fish community's predator/prey balance. However, for these positive benefits to occur, stocked fish must contribute to the natural population. Numerous studies have examined either the 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 the introductions of largemouth bass into ponds (Dillard and Novinger 1975; Modde 1980; Stone and Modde 1982). Surprisingly, few studies have examined the factors thought to influence of supplemental stocking of largemouth bass. The few studies that have examined the contribution of stocked largemouth bass to a natural population, examined only one (Lawson and Davies 1979; Buynak and Mitchell 1999) or two lakes (Boxrucker 1986; Ryan et al. 1996). Given that lakes are highly variable, examining stocking evaluations in only one or two lakes limits our ability to make generalizations.

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

Previous stocking evaluations conducted in the Midwest have often examined species that do not naturally reproduce in the recipient water body (e.g. muskellunge Esox masquinongy, Szendrey and Wahl 1996; walleye Stizostedion vitreum, Santucci and Wahl 1993). Largemouth bass, however, reproduce naturally in most Midwestern impoundments, and therefore supplemental stocking programs are directed at enhancingexisting populations. 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 where the population exhibits high natural recruitment because they are potentially influenced by the same variables.

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

Differences in rearing method (e.g., intensive raceway versus extensive ponds) of the largemouth bass fingerlings may also influence growth and survival. Largemouth bass raised on commercial food pellets have been shown to grow better when stocked into rearing ponds than those fed a diet of fathead minnows (Hearn 1977). A number of Illinois reservoirs and impoundments are stocked with largemouth bass raised extensively in nursery ponds. These and other lakes can also be stocked using largemouth bass raised at state hatcheries. The relative merits of these two rearing techniques have not yet been assessed.

PROCEDURES:

<u>Size Specific Stocking</u>

We evaluated the success of four size groups of stocked largemouth bass in four lakes (Charleston, Homer, Mingo, and Woods; Figure 2-1). Largemouth bass were stocked as small fingerlings (50 mm) in July, medium fingerlings (100 mm) in August, large fingerlings (150 mm) in September and advanced fingerlings (200 mm) in October (Table 2-1) for 3 years in Mingo and Woods and 4 years in Charleston and Homer. 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 growth and survival of the different size groups of stocked largemouth bass. We estimated initial stocking mortality by placing 30 fish into each of three floating mesh cages. Largemouth bass were taken directly from the hatchery truck and placed immediately into the cages. Cages were 3 m deep and 1 m in diameter and were placed in at least 3 m of water. The cages were 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 collected using a tubing method (Van Den Avyle 1979) and the number of stocked bass as well as size and type of prey were recorded. Predator diets were examined daily the first week and weekly thereafter until they were found to contain no stocked bass on two consecutive sample dates.

Diets were also collected on large and advanced fingerlings, as well as natural fish after stocking to evaluate differences in feeding following stocking. Stocked and natural largemouth bass were collected by AC electrofishing 3 shoreline transects (½ hour each) at set intervals following stocking (two weeks, one month, and two months). Both stocked and natural largemouth bass diets were examined by tubing unless the fish was too small, in which case it was collected and dissected in the laboratory.

In this segment, sampling efforts were made to collect age 1+ fish from previous stockings in the four study lakes. Each lake was sampled twice in the spring of 2005, and twice in the fall of 2005. Three transects were AC electrofished for 30 minutes each on all study lakes each sampling date. All largemouth bass were collected, measured for total length, and examined for clips. Catch per unit effort was calculated for each size of stocked bass and natural bass and used to compare survival of the different stocks. Mean total length was calculated for each stock and used to compare growth differences. The growth and survival data from 2005 and 2006 were combined with data from previous segments to evaluate overall differences in growth and survival. Differences in survival and growth among the various sizes of stocked fish were examined using 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 2005 and 2006. 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 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.

In this segment, we examined growth and survival of age 1+ fish stocked in previous segments. 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 continued to examined growth, survival and mortality of adults of different sizes of largemouth bass stocked in previous segments. Unmarked largemouth bass were collected to examine for OTC marks for evidence of small fingerlings surviving to adulthood. However, no OTC marks were observed in any study reservoir on adult bass otoliths. The lack of OTC marks in adult bass supports the estimates of low survival in the first year after stocking and the conclusion that small fingerlings are not surviving past the first year following stocking.

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 stockings and lakes that were stocked with different sizes of bass. Six-inch bass were stocked at a significantly larger size than the 2 and 4-inch bass as well as natural bass in the lakes and were larger than other stocked 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 very little difference in size between all of the size groups stocked and natural bass. Similarly, eight-inch bass stocked in the spring (May) were significantly larger than their cohorts but by the summer all were similar in size. All sizes of stocked bass as well as the natural bass were of similar length going into the second winter and no long-term growth differences were evident. Although there are initial size differences at stocking for large and advanced fingerlings, lags in growth occur shortly after, perhaps as a result of the transition the bass go from foraging in hatchery conditions to the wild.

In this segment we examined diets of large and advanced fingerlings and compared them to natural largemouth bass in our study reservoirs in order to identify potential causes of the lag in growth we observed. Both large and advanced fingerlings had a slightly larger proportion of empty stomachs when compared to the natural bass of similar size (Figure 2-3). We also observed that both large and advanced fingerlings were feeding on higher proportions of invertebrates initially following stocking compared to the natural bass that were feeding on a larger proportion of fish (Figure 2-4). Natural bass also had crayfish in their diets whereas neither large nor advanced stocked fingerlings were observed preying on crayfish. This suggests that stocked bass may not be feeding as much and may be utilizing different prey resources than natural fish. These differences may adversely affect growth rates and cause the observed growth lag.

In this segment, we examined survival of the different sizes of stocked fingerlings that were stocked in previous segments and are now adults. We found medium, large, and advanced fingerlings surviving to adulthood in all study lakes. The contribution of these stocked fish to the adult bass population varied among lakes, but in general was a relatively low proportion of the total bass population (Table 2-2). Charleston had the lowest catch per unit effort of natural largemouth bass and also appeared to have the highest survival of stocked bass. We also found evidence of stocked bass in Homer Lake in spring 2006. Woods and Mingo lakes did not have any stocked bass sampled in spring 2006. These lakes were last stocked in 2003 and may not have any stocked bass surviving to age 3 whereas some of the fish stocked in Homer and Charleston in 2004 have survived to age 2.

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 2-5), probably because little time had passed since they were stocked. As a result, 6-inch bass abundance was higher going into the first winter than 2 and 4-inch size groups, whereas, over winter survival was extremely low for 6-inch bass. Eight-inch fish were stocked in the spring and as a result spring electrofishing samples yielded higher numbers than other sizes of stocked fish. However, a short time after stocking, CPUE during the summer months for 8-inch bass had declined to similar levels as 4 and 6-inch bass. Overall survival was low for all stocking sizes and as the majority of fish in electrofishing samples of older age groups were naturally produced fish. This pattern is consistent over the following 2-3 years and CPUE for the 4, 6, and 8-inch fish remained low at around 2 to 3 bass per hour of electrofishing compared to the wild fish CPUE of 28 fish per hour. In the future, population estimates will be calculated to determine the total number of stocked bass of each size that we observe in the adult population.

Cost of producing fish increased with the size of the fish being produced (Table 2-3). Small fingerlings were the cheapest to produce, even though they were stocked in the largest quantity. Advanced fingerlings were the most expensive to produce due to overwintering them in the hatchery ponds. Rearing techniques were changed in 2003 resulting in a reduction in the cost of production of medium, large, and advanced fingerlings. These fish were fed prepared pellets for a longer duration than before 2003 and were finished on minnows for a reduced period of time.. Fingerlings produced prior to 2003 were similar to fish produced after the rearing techniques were changed. Repeated measures ANOVA showed no differences in post stocking growth ($P = 0.55$) or survival ($P = 0.39$) existed between rearing techniques for any sizes of largemouth bass in the spring and fall electrofishing transects. Because of this, we focused on the stocking size and assumed that the rearing techniques did not influence growth or survival of the different sizes of stocked fingerlings. Because of the lack of differences in growth and survival between the pre 2003 and post 2003 stockings, we used cost estimates from post 2003 because they better represent the cost of rearing these fish with current hatchery production capabilities and methods. Medium fingerlings were the most cost effective size to stock based on better survival when compared to small fingerlings and similar survival and low cost when compared to large and advanced fingerlings.

Rearing techniques:

In this segment, fish from previous stockings were sampled to compare long-term differences in growth and survival. We observed a high level of variability in survival of intensively and extensively reared bass. No consistent pattern in survival was observed and which rearing technique yielded the highest survival varied by year and lake (Figure 2-6). Due to the variability between lakes and years, and the low level of survival for both intensively and extensively stocked bass, it is difficult to determine which rearing strategy performs the best.

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 differences were evident between the different sizes of stocked fish. In particular, a lag in growth occurred for the 6 and 8-inch fish after stocking and despite being larger initially, they were soon similar in size to the natural population. This may be due to an acclimation period where hatchery bass adjust to feeding on natural prey resources. The study lakes primarily have bluegill forage and it may take some time for minnow fed hatchery bass to become efficient at feeding on different prey fish. Laboratory feeding experiments will be continued in 2006. We also need to continue analysis of diets from large and advanced fingerlings to better understand differences from natural fish. In future segments we will use bioenergetics models to estimate if the differences in diet can account for the growth lag observed in stocked fish. These analyses combined with the feeding experiments will help us understand how stocked bass feed and if these mechanisms account for the observed growth and survival differences from natural 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. We have continued to observe adult stocked bass in the lake populations and plan to continue to monitor these fish. We will also continue analyses to examine the effects of predation on the different sizes of stocked bass. We will complete population estimates for each lake and use the diet data from the weeks following stocking to estimate the total proportion of each stocking that is lost to predation. We feel predation is a major factor influencing survival of stocked bass and predation estimates are crucial to understanding the success of each stocking.

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. In future segments, we will continue to follow the fish stocked in previous years to observe any differences in long-term survival and growth. Attempts will also be made to supplement electrofishing sampling efforts to increase sample size and recapture a larger numbers of stocked bass to better represent growth 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.

As part of previous segments of this study and another Federal Aid in Sports Fish Restoration Project F-128-R "Quality Management of Bluegill: Factors Affecting Population Size Structure" we have found highly variable survival of four inch stocked largemouth bass among lakes (N=17). Some lakes in these studies have had very low survival of stocked fish, whereas others have had reasonably good survival. To develop management recommendations on optimal stocking strategies for largemouth bass, we need additional information on factors influencing success of largemouth bass stockings. The need for this information was highlighted at a recent Largemouth Bass Stocking Symposium in Missouri that brought together researchers and managers from throughout the Midwest. As a result, we will expand the activities in this job and begin to address these questions by analyzing our existing data to examine relationships between a number of environmental variables and largemouth bass stocking success. Variables to examine will include, among others, a number of lake productivity and habitat components, as well as metrics related to prey and predator populations. These analyses will help guide future work on this important fisheries management question.

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 premise. 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. 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 long-term costs and benefits of the bass stocking program.

PROCEDURES: Largemouth bass stocked in each study lake were produced at the Little Grassy Hatchery bred specifically to be fixed for the MDH-B2B2 genotype as a genetic tag. These fish were either stocked directly into a target lake (Forbes, McLeansboro, Murpphysboro, Sam Parr, and Walton Park), or first introduced into rearing ponds near the target lake before being stocked (Sheblyville). 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 and continued through 2005.

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. In this segment, young-of-year from the six lakes were sampled by boat electrofishing to determine if the frequency of the MDH B2 allele has increased through reproduction of the stocked fish. These sampling 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 each 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.

Sampling of largemouth bass began in 2003, when the earliest stocked fish should have begun reaching maturity. All lakes were sampled for YOY in 2003, 2004, and 2005 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 three of the six lakes the MDH B2 allele frequencies have increased (18% to 43%). In future segments we will evaluate differences among lakes that may contribute to this variability. In the other 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 are not 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 and may be why the change is so small compared to the other lakes.

RECOMMENDATIONS: Genetic frequencies from YOY spawned from largemouth bass stocked with the MDH B2 allele have increased in three of the six study lakes. Values have not increased dramatically in Forbes, McCleansboro, and Lake Shelbyville. It is too early to evaluate the affects of stocking in McCleansboro Lake and Lake Shelbyville. McCleansboro Lake had a higher frequency MDH B2 allele from the pre-stocking sample, and therefore the effects of stocking are not clear. We will continue to monitor this lake to determine if changes can be observed in spite of these background levels. Sampling should continue in each of the study lakes for several years during the post-spawning months. Lakes will also need to be monitored for several more years in order to allow fish from the later stockings to mature and contribute to the potential spawning population in the lakes. 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, 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). In addition, none of the sizes of stocked fish exhibit any growth advantage over time that influences or enhances year class strength.

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 (Miller et al. 1988; Goodgame and Miranda 1993; Olson 1996). With fish species that are primarily piscivorous as adults, such as largemouth bass, a successful transition from invertebrate to fish prey during the first year of life could be critical for future survival and success (Mittelbach and Persson 1998). The availability of both invertebrate prey during the earliest life stages and vulnerable fish prey are likely to be important for the consistent and timely development of piscivory (Olson 1996). The growth advantage gained by a switch to piscivory should be important to recruitment due to the size-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 addresses this critical gap in knowledge by monitoring multiple largemouth bass populations and their associated aquatic communities across multiple years. By monitoring over several years, our study encompasses variable environmental conditions and recruitment levels. Identification of important mechanisms and indexes of largemouth bass recruitment will guide management of sustainable largemouth bass populations and aid in prioritization of stocking efforts for lakes less likely to produce strong year classes.

PROCEDURES: We sampled 12 reservoirs in 2005 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). Electrofishing was used to collect YOY largemouth bass in the fall after they were too large to be effectively sampled by seining. Electrofishing the following spring was used to estimate recruitment to age-1. Based on otolith-derived ages, all largemouth bass from fall to the following spring that were less than or equal to 150 mm total length were considered to belong to the same year class.

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. 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. In June and August, aquatic vegetation was identified and mapped in each lake to estimate the amount of vegetation cover. Water samples for chlorophyll-*a* and total phosphorus were collected during regular sampling dates, 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. All variables were transformed with a natural logarithm, except total length, benthos density, and chlorophyll *a* concentration. 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 2005, 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 $0.02/m^2$ to $2.81/m^2$. The highest densities of YOY largemouth bass were found in Lake of the Woods, Pierce, Walnut Point, and Woods while the lowest abundances of YOY were in Dolan, Paradise, and Shelbyville (Figure 4-1). Despite high initial densities of YOY, reservoirs such as Lake of the Woods exhibited high mortality of YOY largemouth bass, with low relative abundance by the end of the growing season (Figure 4-3A). Peak abundance of YOY largemouth bass was positively correlated with total larval fish density (Spearman; $r = +0.61$; $P = 0.05$). Recruitment to the end of the growing season was variable among lakes (Figure 4-3A) and not significantly correlated with peak density of YOY largemouth bass (Spearman; $r = +0.33$; $P = 0.29$). YOY largemouth bass growth was larger in lakes with longer growing seasons (Dolan, Forbes; Figure 4-2). YOY largemouth bass total length at the end of the growing season varied from 80 mm (Ridge) to 132 mm (Forbes; Figure 4-3B) and was negatively correlated with year class strength ($r = -0.64$; $P = 0.04$). Number of YOY largemouth bass surviving to the end of the growing season was positively correlated with density of juvenile bluegill ($r = +0.59$; $P = 0.04$) and negatively correlated with benthos density ($r = -0.53$; $P = 0.08$) and relative abundance of adult gizzard shad ($r = -0.51$; $P = 0.09$). After stepwise selection procedure, only juvenile bluegill abundance was found to significantly explain among-lake variation in recruitment of YOY largemouth bass to the end of the growing season (adj. $R^2 = 0.28$; $P = 0.04$). Seine CPUE of YOY largemouth bass as late as September was positively correlated with June and peak densities of YOY ($P \leq 0.01$), however, recruitment of YOY largemouth bass to the fall (electrofishing CPUE) was not significantly correlated with any earlier YOY densities ($P > 0.05$).

Water quality, habitat structure (Table 4-1), and biotic variables (Table 4-2) potentially important to YOY largemouth bass growth and survival varied among lakes and time of year. Secchi depth transparency varied from 0.45-2.43 meters (Table 4-1) and was negatively related to concentrations of chlorophyll *a* (r = -0.75; P = 0.009) and total phosphorus (r = -0.61; P = 0.05). Proportion of lake area that was vegetated varied from 0-30% among 8 study lakes and amount of vegetation increased only slightly from spring to summer (Table 4-1). Types of emergent and submersed vegetation varied among reservoirs and changed in composition between spring and summer samples (Table 4-3). Inshore density of crustacean zooplankton in the spring was highly variable among lakes, with average densities ranging from 17 individuals/L to 132/L (Table 4-2). Benthos density was lowest in Forbes and highest in Lake of the Woods (Table 4-2). Larval fish abundance also varied among lakes, with average values ranging from $0.06/m^3$ to $20.5/m^3$ (Table 4-2). *Lepomis* and *Dorosoma* species were the dominant larval fish collected in the 12 study lakes (93-100% all larval fish collected; mean = 98%). Timing of peak larval abundance differed between shad and sunfish, with *Lepomis* larvae peaking in abundance in July and shad larvae peaking earlier in May and June (Figure 4-4). Larval *Lepomis* were present throughout the growing season in most of the study lakes, with some lakes exhibiting multiple peaks in larval *Lepomis* abundance (e.g., Woods). Abundances of all larval fish combined were positively correlated with chlorophyll *a* concentration (r = +0.81; P = 0.002). 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 14.3/hr to 1005/hr (Table 4-2). Average water clarity decreased with increasing gizzard shad abundance (r = -0.58; P = 0.06). Among lakes, average density of juvenile bluegill ranged from $0.005/m^2$ to $3.18/m^2$ (Table 4-2). Over time, juvenile bluegill abundance was highly variable, sometimes exhibiting multiple peaks in abundance (Figure 4-5). In general, juvenile bluegills were more abundant in reservoirs without gizzard shad (Figure 4-5) and post-spring density of juvenile bluegill was negatively correlated with gizzard shad catch per unit effort (Spearman; r = -0.87; P = 0.0006).

Relative abundance of largemouth bass recruited to age-1 did not exceed 6/hr in any reservoir except Ridge Lake (Figure 4-6). Recruitment strength was not significantly correlated with either YOY largemouth bass densities throughout the previous growing season ($P \geq 0.11$) or with fall abundance of YOY largemouth bass (Spearman; r = +0.22; P = 0.52). For the 2005 year-class, recruitment was correlated with post-spring density of juvenile bluegill (r = +0.56; P = 0.07), chlorophyll *a* concentration (r = -0.60; P = 0.05), total phosphorus concentration (r = -0.54; P = 0.09), secchi depth (r = +0.62; P = 0.04), and abundance of adult gizzard shad (r = -0.53; P = 0.10). All variables except secchi depth were not significant ($\alpha = 0.15$) in the stepwise selection procedure; therefore the linear regression model related recruitment of the 2005 year-class to secchi depth (adj. R^2 = 0.31; P = 0.04).

RECOMMENDATIONS: Similar to the 2002 and 2003 cohorts, there were no reliable indicators of bass recruitment strength. These results differ from those of three previous year classes where July densities of YOY largemouth bass were an early indication of recruitment strength. In 2005, differences among lakes in YOY largemouth bass densities appeared to be mirrored by total larval fish production (primarily *Lepomis* and gizzard shad), perhaps indicating where lake conditions were generally favorable for successful reproduction. Density of juvenile bluegill continues to be an important variable indicating high survival of YOY largemouth bass. For the 2005 year-class, an environmental variable, secchi depth, also proved to be dependable as an early indicator of largemouth bass recruitment strength. Where gizzard shad reach high densities, they may indirectly depress YOY largemouth bass survival. For example, gizzard shad abundance was negatively related to both the density of juvenile bluegill, an important prey species, and to secchi depth, an indicator of largemouth bass recruitment. Similar to previous years, YOY largemouth bass sizes were lower in lakes where the density of YOY was high, pointing to the potential for intraspecific competition as an important factor regulating first-year growth of largemouth bass.

The significant influence of multiple variables on largemouth bass recruitment points out the relatively complex mechanisms responsible for recruitment variation of largemouth bass populations. 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. Each year of the study provides 12 data points for analyzing factors responsible for among-lake differences in largemouth bass recruitment. However, each year only provides one data point for analyzing factors influencing within-lake, among-year sources of recruitment variation. Environmental factors such as vegetation that are typically thought of as having an effect on YOY fish growth and survival have yet to be shown to have a significant effect on bass recruitment in this study. However, the range of vegetation abundance in the 12 study lakes is narrow and to properly study the effects of vegetation a wider range of abundance is needed. Previously, we have been estimating vegetation abundance at the whole lake scale. As an expansion of our vegetation sampling, we will increase effort in several lakes that we are currently studying by concurrently sampling fish and vegetation communities at a number of sites. With these data, we can examine relationships between vegetation composition, density and largemouth bass density and size structure. In future segments, we will use these data on factors that control largemouth bass recruitment to build predictive models of annual recruitment that can be used to make recommendations for stocking and other management actions.

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; Cooke et al. 2002). While male bass are providing parental care for their broods, they are extremely aggressive (Ridgway 1988; Cooke et al. 2002) 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). We are assessing the relationship between nesting success and recruitment in Lincoln Trail Lake. In addition we are determining which cohort (based on spawning date) contributed the most to largemouth bass recruitment. The strategy of maximizing reproductive success by protecting successful spawning bass from angling assumes that there is a positive relationship between reproductive success and recruitment. One of our objectives 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; Cooke et al. 2002). 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, substantial catch-and-release angling for nesting bass could 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, including 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. All these practices could contribute to increased abandonment by nesting males. 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. We have also performed nest observations in order to quantify varying levels of nest predation as well as mapped largemouth bass nests in order to better understand habitat suitable for nesting.

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 and subjected to a rather involved weigh-in procedure. The weigh-in process, using the best current techniques, usually involves extended air exposure of a bass that has been shown to contribute to mortality associated with tournaments. The delayed mortality of bass involved in tournaments can be substantial and may be as high as 30 – 70 percent (Allen et al 2004, Edwards et al 2004, Schram et al 1987, Weathers et al 1987, and Wilde et al 1998). We are continuing to examine ways to reduce this mortality of bass during tournaments. One method of reducing this mortality may be paper tournaments where anglers record data on captured fish and release them at the time of capture. This would eliminate stress associated with both holding the bass in a livewell and the weigh-in. During this segment, we conducted a paper tournament along with a regular weigh-in to examine the similarities and differences as well as assess alternative measures of fishing success.

PROCEDURES:

Nest observations: Snorkeling surveys were used to assess bass spawning activity, nest site selection by males, aggressiveness of males guarding a nest, and the level of nest predation in Lincoln Trail Lake. Snorkeling began on April 19, 2006 and continued through May 18, 2006. Six transects have been monitored each of several years. 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. Young-of-year largemouth bass were collected in the fall by AC electrofishing (three transects on two dates). Otoliths were removed from these bass, mounted on microscope slides and sanded to increase the clarity of the growth rings. Two readers examined each otolith and the daily growth rings were counted. The number of rings was then used to back calculate spawn date for each fish collected. The relative number of young of year spawned from each week was compared to the frequency of new nests observed for that week in order to determine differences in survival.

Paper tournaments: We contacted tournament organizers and conducted a paper tournament in conjunction with a regular bass tournament on Lake Shelbyville during the summer of 2005. Each angler was given a data sheet and a pencil and asked to record each fish caught to the nearest ¼ inch. Forms were collected at the conclusion of the tournament. Bass caught by participating anglers were measured for total length and weighed. The fish were then released back into Lake Shelbyville via a release boat along with the remaining tournament fish. Data from the weigh-in was provided by the tournament director and included the number of bass caught, total weight and big bass weight for each angler. Length and weight data collected at the weigh-in was used to produce a length to weight regression that could estimate the weight of each fish based on the length recorded by each angler in the paper tournament. The weight of each fish was summed for each angler to get estimated total weight. The paper tournament data was compared to that of the weigh-in to examine differences in results and assess different measures of fishing success. All anglers were ranked by total estimated weight from the paper data. This ranking was then compared to the tournament results to examine differences between weigh-in and paper tournament results. We also compared rankings when bass of all sizes were included in the paper tournament as well as using total paper length rather than estimated weight. Mean rank change was calculated as the average number of places an angler changed from the weigh-in results. Differences in rankings for each tournament were examined using Wilcoxon signed rank tests..

FINDINGS:

Nest Observations:

A total of 48 nests were observed between 4/19/2006 and 5/18/2006 in Lincoln Trail Lake. The appearance of new nests was related to the water temperature on the date of sampling (Figure 5-1). When water temperatures were increasing, we saw a greater number of new bass nests. Bass spawned on a variety of substrates and did not seem to prefer any particular nesting habitat. The greatest proportion of bass spawned on sandy areas (29%) followed by detritus, gravel, and wood (Figure 5-2). All substrate types were represented in relatively equal proportions. Few bass nests were in heavy vegetation (4%), but the total proportion of vegetation surrounding the nest was also generally low (10%).

We did not observe high levels of egg predation when the bass were chased away from the nest. Only two bass nests had predators feeding on eggs during the five-minute interval. These two bass with nest predation had similar aggressiveness (mean times chased off the nest = 4) when compared to other males guarding nests (mean times chased off nest = 3.7). Only 5 of the 49 nests had potential egg predators surrounding the nest at the time of observation. Our sample size of nests with predators will need to be increased in the future.

Paper tournaments:

A total of 65 boats fished in the tournament of which 34 participated in the paper tournament. The length to weight calculation used was

$$\text{Wt (lbs)} = 0.0002\ \text{L (inches)}^{3.3267}$$

This regression had an R^2 of 0.93 and was used to calculate weight from length for each fish caught in the paper tournament (Figure 5-3). The mean rank change was calculated as the average difference between the tournament rank and paper rank for each angler (0 would indicate perfect agreement). Paper tournament results were similar to weigh in results (mean rank change 1.3; Z = -0.512, P = 0.609) although some anglers were ranked in different order in the paper tournament (Table 5-1). We also evaluated alternative ways of determining the best angler. First, we compared total length of fish caught with total weight and found that total length was closely related and ranked the angler groups similarly (mean rank change = 1.4). Second, we varied the fish that were included in the paper tournament (total weight of all sizes of fish caught). The ranking changed more dramatically when all fish caught (all sizes) were used in the tournament results (mean rank change 6.0). This data will be combined with data collected from 3 other tournaments to make conclusions on the success of paper tournaments as an alternative to weigh-ins.

RECOMMENDATIONS:

Monitoring largemouth bass spawning activity in Lincoln Trail has allowed us to determine the duration of the spawn as well as the relative number of nests formed each week. In future segments we will continue to monitor nesting activity and collect otoliths from young of year bass in the fall. The otoliths from previous years will be removed and the daily rings will be read (as time permits) in order to back calculate spawning date. The relative number of bass collected in the fall from each spawning date will be compared to the number of new bass nests to determine differences in survival. A number of factors related to spawning date could influence survival. Earlier spawned fish may have a size and growth advantage over later spawned fish. The timing of nesting and hatch and the presence of nest and other predators may also influence survival differently throughout the spawning period. We will continue to evaluate these factors in future segments.

Monitoring largemouth bass nesting in Lincoln Trail has also allowed us to determine where nesting is occurring and the types of habitat bass prefer for spawning. Continuing to evaluate preferences in spawning habitat and available habitat for bass spawning is important in order to understand what factors may influence nesting success. Management strategies such as improving nesting habitat may be important in lakes where spawning success is low due to lack of appropriate habitat. We have also observed varying levels of nest predation and aggressiveness of bass guarding the nest. In future segments, we will incorporate additional nest mapping data. This data will continue to be utilized to evaluate spawning substrate and habitat preferences and to examine factors that may influence the aggressiveness and success of nesting bass. In addition, habitat adjacent to the nest may be important for YOY bass for feeding and avoiding predation.

Preliminary results suggest that paper tournaments offer potential as an effective means of evaluating angling success. Paper tournaments could be used to reduce abandonment of nests during the spawning period as well as reduce mortality at times of high temperature (late summer). Catch and release practices also affect reproductive success (Philipp et al. 1997), but not to the extent of competitively angled fish subjected to livewell and weigh-in conditions. Some other advantages of paper tournaments are the lack of need for regulation exemptions to include smaller bass or more bass than the existing creel limits. The drawbacks with paper tournaments are the lack of a trophy to show off at the weigh in and the possibility for cheating on recording sizes and numbers of fish caught. Paper tournaments may be especially useful for smaller club tournaments that have a less competitive nature where these issues are less of a factor. Other approaches such as photo documentation may be useful at larger events. Some changes in ranking occur with paper tournaments and one potential cause may be the accuracy of measurement as anglers used ¼ inch gradation on measuring boards. We will evaluate the effect of this variation by using measurements taken to the nearest millimeter during the weigh in. Providing anglers with measuring boards with a finer gradation may provide for more accurate paper tournament results. Another alternative would be for anglers to use scales so weight measurements can be taken on each boat.

In future segments, we will continue to monitor bass tournaments in order to assess if reproductively active males are being preferentially caught. Logistical issues prevented us from expanding these data in the current segment. Data from three of the four lakes examined thus far suggests that this may be the case during both spring 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 is not skewing sex ratio estimates. However, sample sizes are very small thus far for these surveys and future segments will focus on increasing the sample number of angler surveys to batter assess the effects of culling. Additional research to determine the implications of angling bass from the nest on the overall bass population and stock structure are needed. These data would allow predictions about how angling may affect recruitment of largemouth bass. 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 handling stress during springtime tournaments would be helpful. Previous work has suggested the weigh-in process 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, paper tournaments or other similar approaches.

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

OBJECTIVE: To evaluate the effects of fish refuges on Illinois bass recruitment and size structure.

INTRODUCTION: Largemouth bass can be vulnerable to anglers while spawning and reproductive success may depend on the level of angling stress the fish undergoes during this period. This has sparked a recent controversy in anglers as to 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 nests can cause nest abandonment, 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 permanently 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 are using 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 post refuge. Samples collected during 1999 – 2001 represent pre-refuge. In this segment, post refuge electrofishing transects and seines hauls were performed in the spring and fall of 2005 and the spring of 2006. 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 the establishment of the refuge. Sampling at sites inside the refuge in 2003 through 2006 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 from previous segments have shown some increases in the catch of young of year largemouth bass throughout the lake and refuge after the refuge was established. In the spring of 2005 through the spring of 2006, 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 outside of the refuge. With the increased number of adult bass in the refuge, we would expect to see an increase in young of year production inside the refuge, however this is not being observed consistently in our seine and electrofishing samples. Continued assessment of young-of-year bass is required in order to assess if the refuge is enhancing 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. However, these results are also based on a low sample size and must be supplemented in future segments in order to fully assess the potential lake-wide effects the refuge may have as a tool for managing bass populations.

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. areas of this report, thesample sizes are low due to limited access to the refuge after it was established. As a result, in future segments, we will continue to sample the refuge in the spring and fall of each year and analyze electrofishing and seine CPUE data for young of year bass production in order to determine if the refuge is affecting natural reproduction and recruitment. In future segments, we would also like to expand these assessments to include one or more additional lakes in order to thoroughly evaluate the benefits of fishing refuges on largemouth bass recruitment and survival. We will continue to work with biologists in Illinois to identify potential study lakes to establish experimental refuges.

There are many potential harvest regulations that can be used to manage bass populations, including size and creel limits, closed seasons, and spawning refuges. Each of them, either singly or collectively, can have a different impact on the population, either by affecting size structure and/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 continue to 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 plan to 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 (e.g. vegetation manipulation) to manage bass population recruitment and size structure.

Job 101.7. Analysis and reporting.

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

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

Segment 8

Job	Proposed Cost	Actual Cost
Job 1	$0	$0
Job 2	$62,370	$62,370
Job 3	$47,520	$47,520
Job 4	$65,340	$65,340
Job 5	$53,460	$53,460
Job 6	$38,610	$38,610
Job 7	$29,700	$29,700

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Table 2-1. Mean size and stocking density of different stages of stocked largemouth bass.

Size	Mean Total Stocking Length (mm)	St Err	Mean Stocking Density (# / ha)	St Err
Small Fingerlings	57.3	0.82	116.9	3.36
Medium Fingerlings	102.3	1.93	58.7	1.05
Large Fingerlings	151.6	2.77	25.9	1.05
Advanced Fingerlings	201.3	3.45	13.8	1.30

Table 2-2. Mean catch per unit effort of adult stocked and natural largemouth bass in the four stocked reservoirs.

Lake	Size	2005 Spring		2005 Fall	
		CPUE	Std Err	CPUE	Std Err
CHARLESTON	Natural	3.50	0.17	6.00	3.00
	Two	0.00		0.00	
	Four	0.33	0.33	0.00	0.00
	Six	2.33	1.67	2.50	2.50
	Eight	9.50	9.17	0.00	0.00
HOMER	Natural	26.34	0.32	11.00	0.33
	Two	0.00		0.00	
	Four	0.00	0.00	0.33	0.33
	Six	1.00	0.33	0.33	0.33
	Eight	1.67	1.67	0.33	0.33
MINGO	Natural	27.27	4.73	5.17	1.83
	Two	0.00		0.00	
	Four	0.33	0.33	0.00	0.00
	Six	1.55	0.21	0.33	0.33
	Eight	2.74	0.08	0.33	0.33
WOODS	Natural	15.48	3.65	10.33	0.33
	Two	0.00		0.00	
	Four	0.20	0.20	0.00	0.00
	Six	0.77	0.57	0.00	0.00
	Eight	0.34	0.20	0.00	0.00

Table 2-3. Cost of producing different sizes of stocked fish. Mean total is the mean cost of stocking the four lakes used in this study. Rearing strategies were altered in 2003 to reduce hatchery costs.

Size	Cost per Fish	Mean Cost per hectare
Small Fingerlings	$0.03	$3.51
Medium Fingerlings (Pre 2003)	$0.60	$35.23
Medium Fingerlings (Post 2003)	$0.15	$8.81
Large Fingerlings (Pre 2003)	$1.95	$50.52
Large Fingerlings (Post 2003)	$0.72	$18.65
Advanced Fingerlings (Pre 2003)	$5.38	$74.28
Advanced Fingerlings (Post 2003)	$4.05	$55.91

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). Fish were stocked into each of the lakes for 6 to 8 years ending in 2005. Post-stocking collections are the number of individuals taken from each of the six lakes in Illinois during 2003 through 2005. Post Stocking allele frequencies are calculated for the MDH B2 allele for each of the six lakes from 2003 to 2005 (Table 3.1b).

Table 3.1a

Lake	N			Allele Frequency	
	1:1	1:2	2:2	1	2
Forbes	81	49	28	0.67	0.33
McClean	23	34	32	0.45	0.55
Murphy	80	12	6	0.88	0.12
Sam Parr	75	16	10	0.82	0.18
Shelby	158	45	8	0.86	0.14
Walton	66	11	8	0.84	0.16

Table 3.1b

Lake	2003			2004			2005		
	N	1	2	*N*	1	2	*N*	1	2
Forbes	94	0.59	0.41	125	0.58	0.42	85	0.61	0.39
McClean	87	0.53	0.47	100	0.49	0.51	100	0.44	0.56
Murphy	112	0.73	0.27	87	0.80	0.20	66	0.70	0.30
Sam Parr	100	0.77	0.23	101	0.63	0.37	67	0.53	0.47
Shelby	66	0.73	0.27	209	0.86	0.14	153	0.82	0.18
Walton	101	0.8	0.2	31	0.58	0.42	52	0.41	0.59

Table 4-1. Average values of total phosphorus (TP; μg/L), secchi depth (m), and aquatic vegetation cover in spring and summer (% of lake area) in 12 study lakes in Illinois during 2005. Dashes refer to data not available when this report was written.

Lake	TP	Secchi	Spring Veg.	Summer Veg.
Clinton	126	0.85	-	-
Dolan	110	0.48	-	-
Forbes	30.4	0.62	-	-
Lake of t. Woods	8.9	0.64	< 1%	2%
Lincoln Trail	3.7	2.43	25%	26%
Paradise	200	0.45	6%	6%
Pierce	13.7	0.79	14%	30%
Ridge	22.8	1.39	29%	13%
Shelbyville	87.4	1.11	-	-
Sterling	< 1	1.41	13%	15%
Walnut	48.8	0.83	7%	8%
Woods	94.2	0.47	0%	0%

Table 4-2. Average values of chlorophyll *a* (μg/L), spring density of crustacean zooplankton (N/L), benthos (N/m^2), total larval fish density (N/m^3), juvenile bluegill density (N/m^2), and fall abundance of adult gizzard shad (N/hr) in 12 study lakes in Illinois during 2005.

Lake	Chlorophyll	Zooplankton	Benthos	Larval	Juv Bluegill	Gizzard shad
Clinton	68.9	n/a	17541	1.26	0.04	101.3
Dolan	73.1	95	2428	1.77	0.24	16
Forbes	68.3	79	1343	4.22	0.92	37
Lake of t. Woods	71.7	95	55335	11.4	0.3	87
Lincoln Trail	44.2	42	11780	2.3	3.18	0
Paradise	65.7	20	9877	4.77	0.33	215
Pierce	59.4	20	12439	5.8	0.7	95
Ridge	44.9	n/a	34166	0.11	3.04	0
Shelbyville	49.7	41	2830	0.67	0.005	1005
Sterling	27.1	17	15042	0.06	0.09	14.3
Walnut	82.3	132	34190	20.5	1.52	0
Woods	78.9	52	25150	4.77	0.13	86

Table 4-3. Taxa of aquatic vegetation present in eight study lakes in spring and summer 2005. The presence of aquatic vegetation was determined during whole-lake vegetation-mapping surveys in June and August. Vegetation taxa codes are AMP (American pondweed), BRS (bulrush), CAT (cattail), CHR (chara species), COO (coontail), CYL (curlyleaf), ELO (elodea), LPW (leafy pondweed), LYL (water lily), MFL (milfoil), SDK (spatterdock), SGO (sago pondweed), SNA (southern naiad), STF (sweetflag), SWD (smartweed), WWW (water willow).

Lake	Spring	Summer
Lake of t. Woods	CAT	CAT
Lincoln Trail	AMP, CYL, COO, ELO, SGO	AMP, BRS, COO, ELO, NAIAD spp
Paradise	CAT, SDK, STF, WWW	SDK, WWW
Pierce	CAT, COO, LPW, MFL	COO, ELO, MFL, SGO
Ridge	CHR, CYL, SGO	COO, MFL, SGO, SNA
Sterling	AMP, CHR, CYL, ELO, SGO	CAT, COO, MFL, SGO, SWD
Walnut	AMP, COO, LPW	COO, LYL, SGO, WWW
Woods	none	none

Table 5-1. Results of tournament weigh-in and paper tournaments. Angler rank refers to the place they would have finished in a tournament based on the described conditions.

Angler Group	Tournament (14 inch Min)			Paper Tornament (14 inch Min)			Paper Tournament (No Size Limit)			Paper Tournament (Total Length)		
	# of LMB	Total Weight (lbs)	Rank	# of LMB	Total Weight (lbs)	Rank	# of LMB	Total Weight (lbs)	Rank	# of LMB	Total Length (in)	Rank
1	5	13	1	5	11.58	2	15	18.32	6	5	82	1
2	5	12.55	2	5	12.34	1	14	20.21	4	5	82	2
3	5	11.61	3	5	11.22	3	13	18.63	5	5	82	3
4	5	10.58	4	5	8.57	5	24	25.30	1	5	76	4
5	4	9.8	5	4	6.38	14	14	15.82	7	4	59	10
6	3	9.66	6	3	8.77	4	5	10.81	15	3	51	11
7	5	9.42	7	5	7.65	9	20	20.86	3	5	74	7
8	5	9.38	8	5	7.56	10	11	11.41	14	5	73	8
9	5	8.93	9	5	8.43	6	9	11.56	12	5	76	5
10	5	8.48	10	5	7.96	7	25	23.84	2	5	74	6
11	2	8.25	11	2	7.83	8	2	7.83	21	2	39	16
12	4	7.99	12	4	7.31	11	14	14.38	9	4	62	9
13	3	7.72	13	3	7.09	12	11	14.77	8	3	50	12
14	3	7.32	14	3	6.74	13	6	9.79	18	3	49	13
15	2	6.64	15	2	6.16	15	6	9.36	19	2	36	17
16	3	6.22	16	3	5.46	16	3	5.46	28	3	46	14
17	2	5.46	17	2	4.51	18	4	5.76	27	2	33	18
18	3	5.28	18	3	4.57	17	11	9.82	17	3	44	15
19	2	3.62	20	2	3.28	19	12	11.46	13	2	30	19
20	2	3.61	21	2	3.01	23	2	3.01	32	2	29	23
21	2	3.55	22	2	3.10	20	6	6.57	22	2	30	20
22	2	3.47	23	2	3.10	20	2	3.10	31	2	30	20
23	2	3.37	24	2	2.93	24	10	5.92	25	2	29	24
24	2	3.19	25	2	2.93	24	8	8.24	20	2	29	24
25	2	3.16	26	2	3.10	20	5	6.44	23	2	30	20
26	2	3.14	27	2	2.56	26	5	3.89	30	2	28	26
27	1	2.87	28	1	2.25	27	10	13.17	10	1	17	27
28	1	2.59	29	1	2.25	27	11	12.53	11	1	17	27
29	1	2.03	30	1	1.82	29	6	4.97	29	1	16	29
30	1	1.98	31	1	1.82	29	1	1.82	35	1	16	29
31	1	1.67	32	1	1.46	31	4	2.73	33	1	15	31
32	1	1.39	33	1	1.46	31	1	1.46	36	1	15	31
33	0	0	34	0	0.00	33	11	6.42	24	0	0	33
34	0	0	34	0	0.00	33	3	1.85	34	0	0	33
35	0	0	34	0	0.00	33	16	10.81	15	0	0	33
36	0	0	34	0	0.00	33	8	5.78	26	0	0	33

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			
2003	21.5	23.8	-	87.5
2004	20.7	28.3	42.0	146.0
2005	27.5	18.3	33.0	25.0
2006	14.1	-	24.0	-

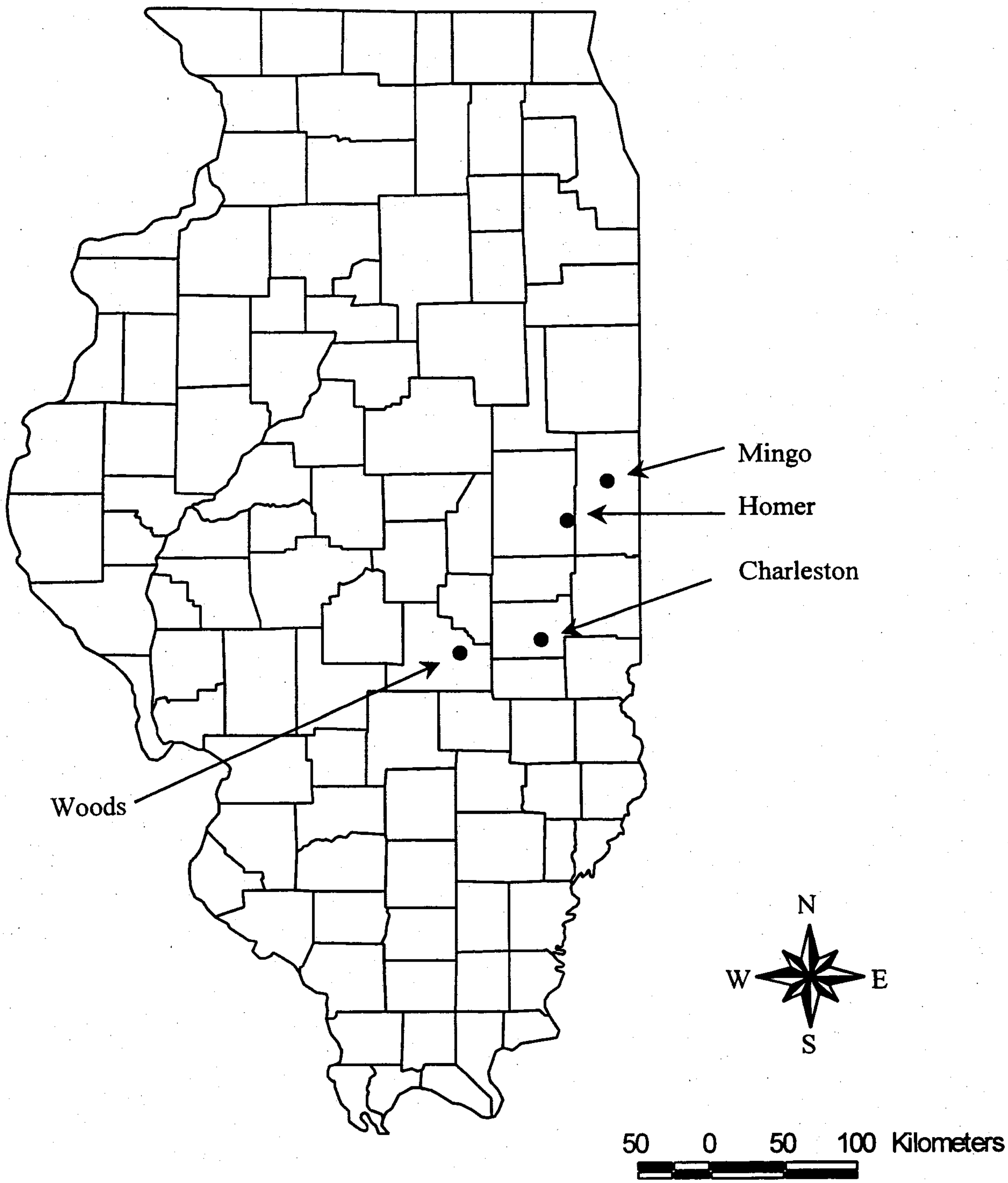

Figure 2-1. Location of 4 lakes in Illinois stocked with four sizes of fingerling largemouth bass in 1999 – 2005.

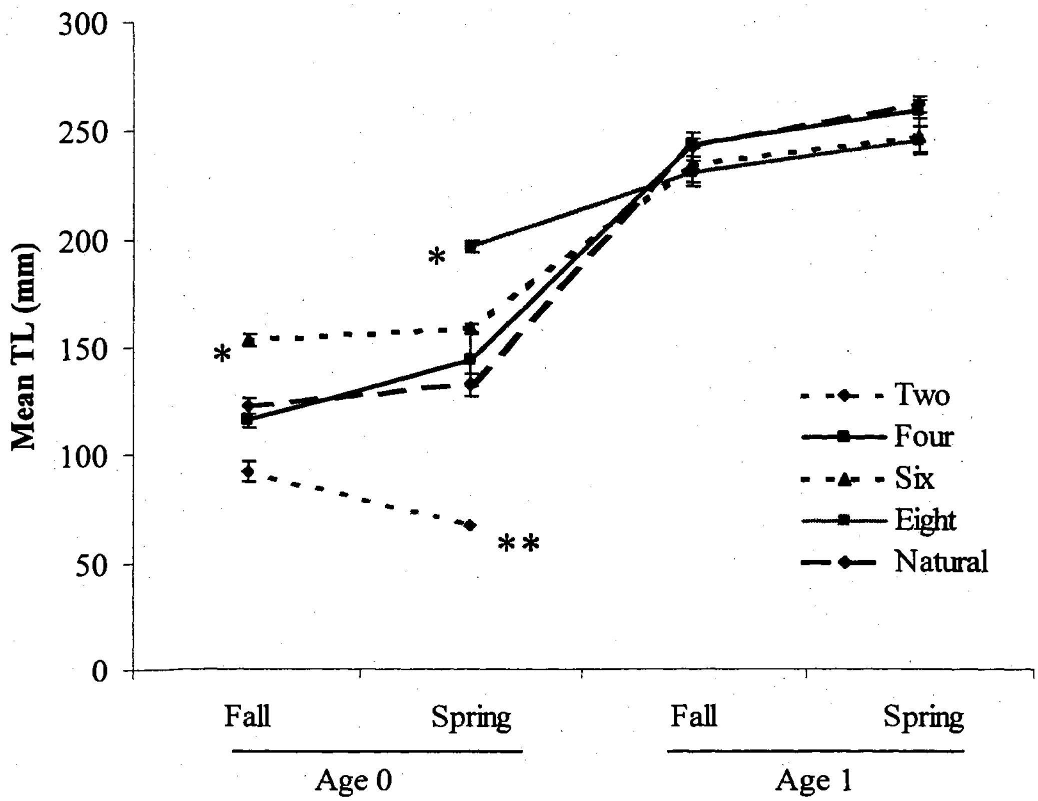

Figure 2-2. Mean total length of four sizes of stocked largemouth bass over the first two years of growth after stocking in 4 reservoirs during 1998-2006. Values are mean total length (mm) +/- 1SE in each season following stocking. Bass were collected by 3 phase AC electrofishing transects in the spring and fall. The asterisks represent a mean that is significantly different than the other means within a season.

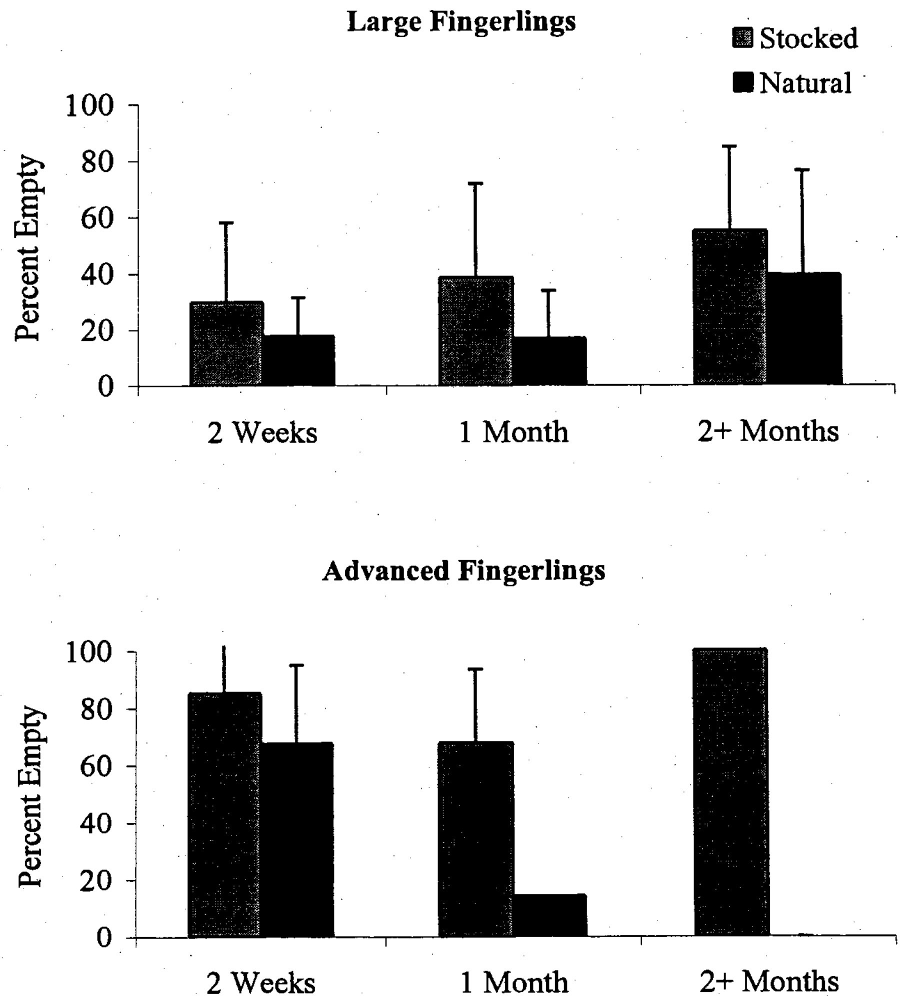

Figure 2-3. Percent of empty stomachs of examined stocked and natural largemouth bass. Bass were collected by AC electrofishing two weeks, one month and two months following stocking.

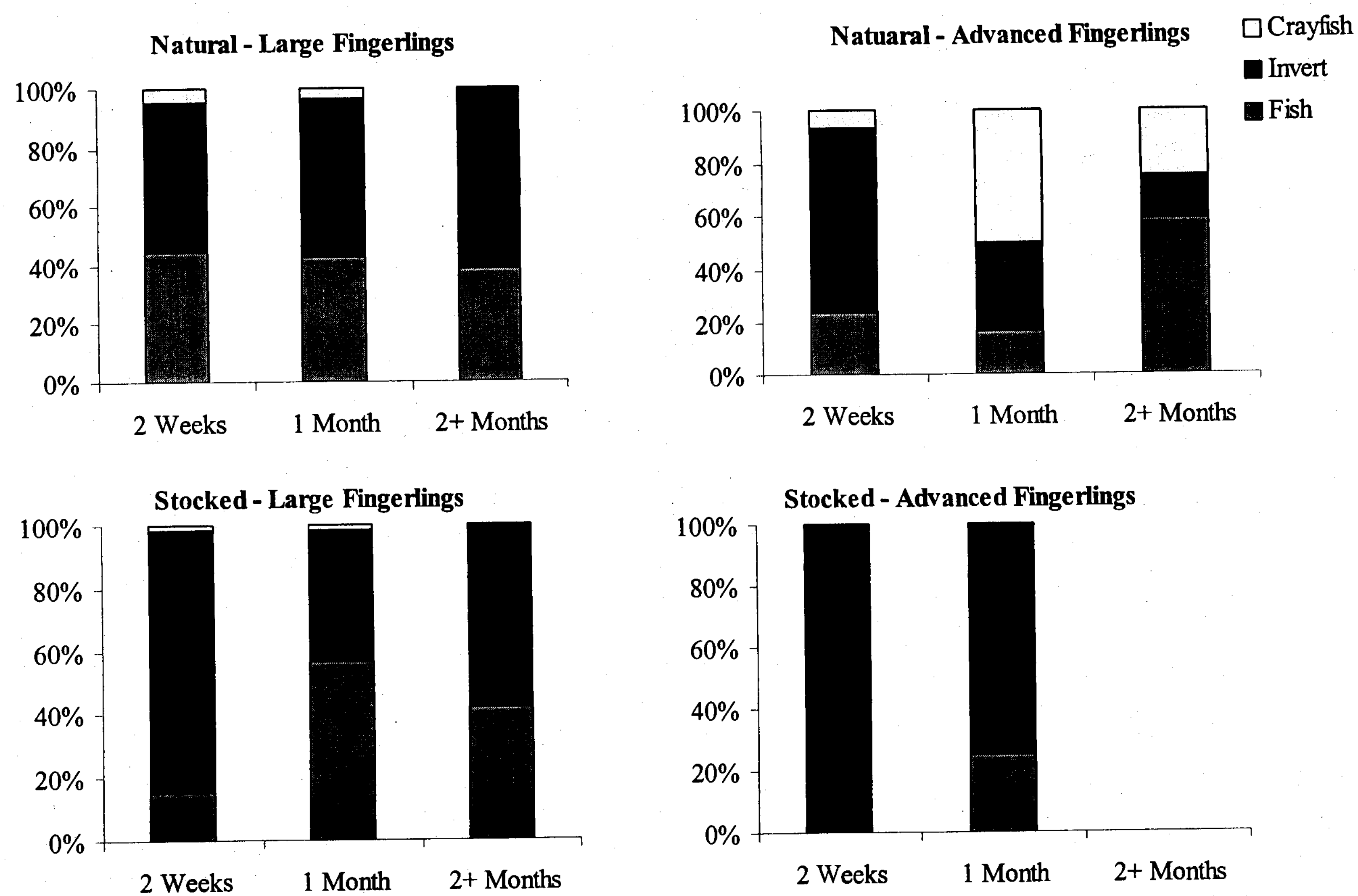

Figure 2-4. Proportion of diet composed of crayfish, benthic macroinvertebrate, and fish for natural, large and advanced fingerlings at two weeks, one month and two months following stocking.

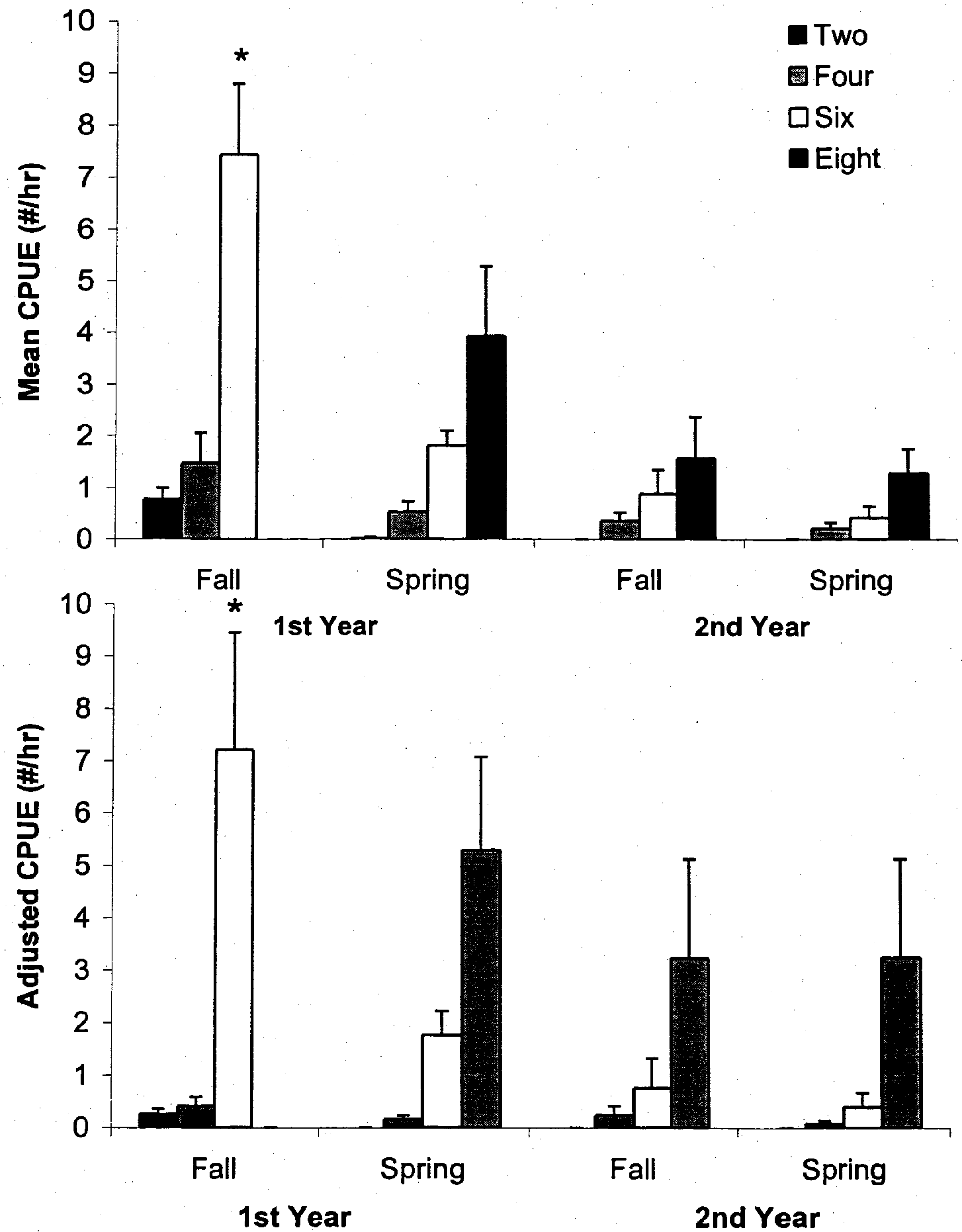

Figure 2-5. Mean catch per unit effort for lakes stocked with four sizes of largemouth bass in 1998-2006. Adjusted CPUE is calculated as the CPUE from electrofishing divided by the total number stocked multiplied by 1000. Error bars represent standard error. An Asterisk represents a significant difference within a season.

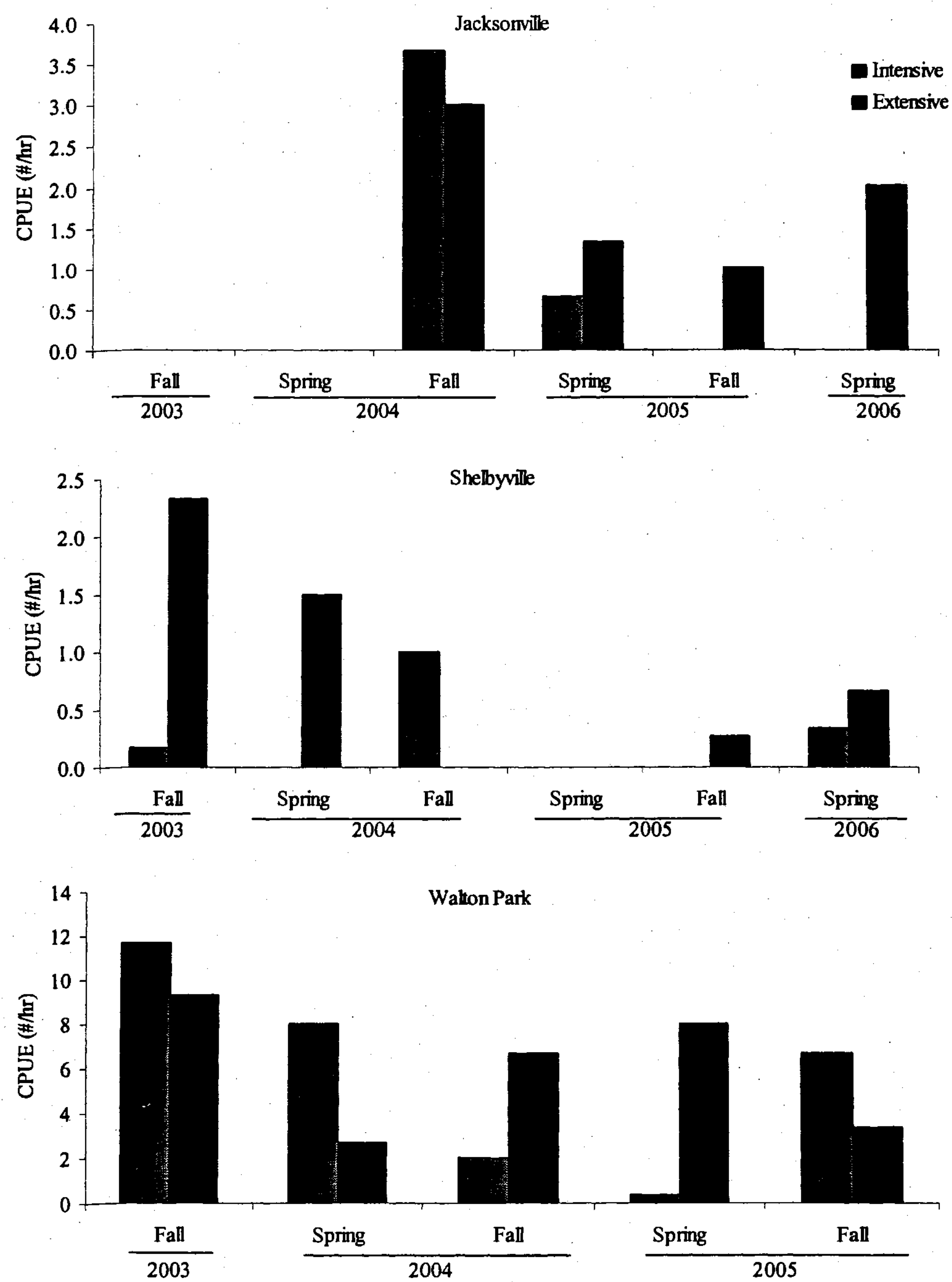

Figure 2-6. Catch per unit effort (CPUE) through time for adult stocked largemouth bass reared either intensively or extensively and recaptured in spring and fall. Catch per unit effort is the number of fish per hour of AC electrofishing.

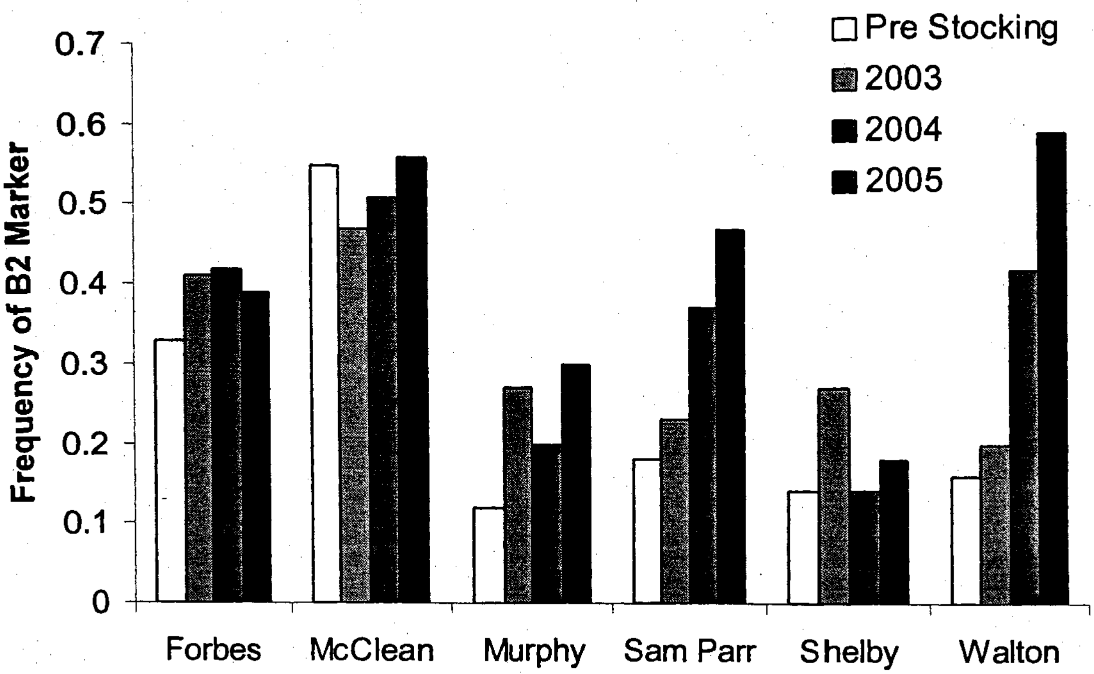

Figure 3-1. Frequency of the B2 allele in the six study lakes previous to stocking and in 2003-2005 during which stocked bass were expected to begin reaching reproductive age.

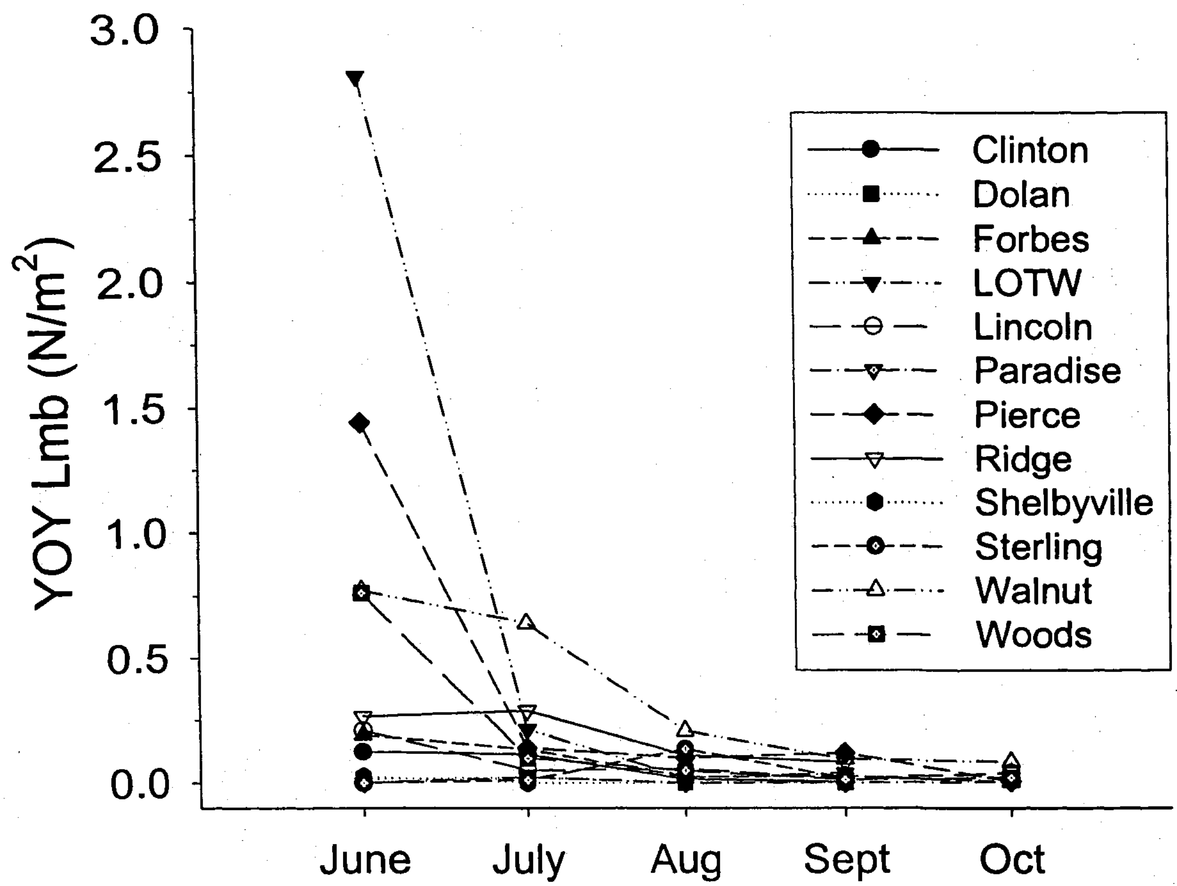

Figure 4-1. Average monthly young of the year (YOY) largemouth bass densities (N/m2) for 12 study lakes in 2005. YOY largemouth bass were collected with a 9.2-m bag seine at 4 fixed stations in each reservoir. Closed symbols represent reservoirs with gizzard shad, whereas, open symbols represent reservoirs without gizzard shad.

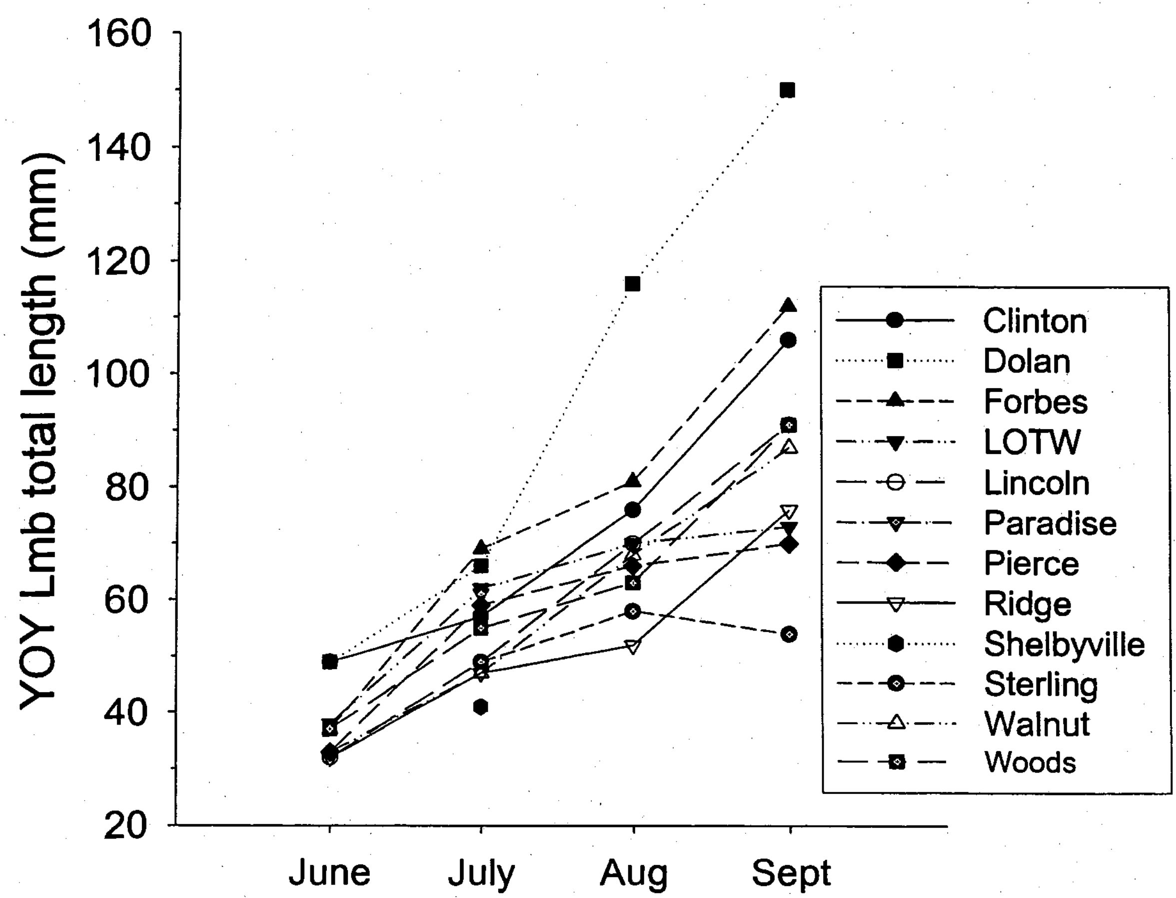

Figure 4-2. Monthly averages of YOY largemouth bass total lengths (mm) in 12 reservoirs in 2005. Fish were collected with a 9.2-m bag seine from 4 fixed stations in each lake. Open symbols represent systems without gizzard shad.

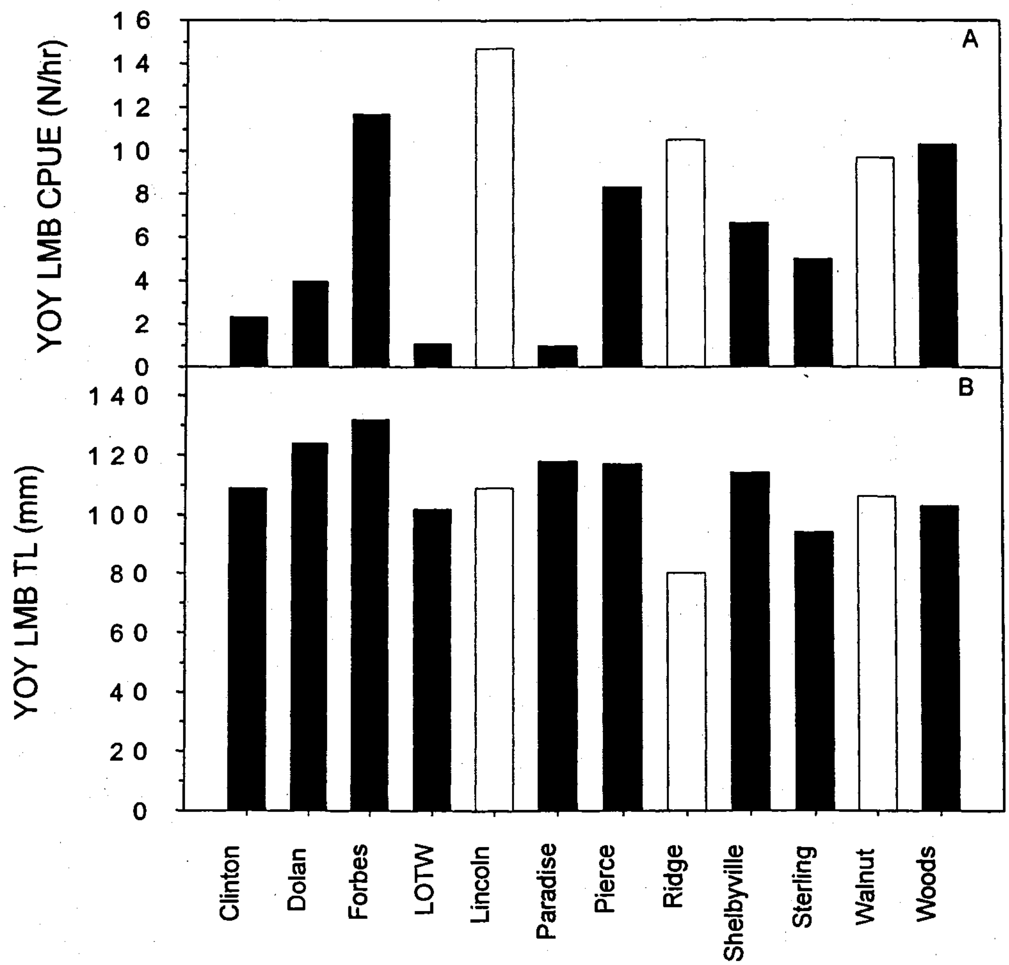

Figure 4-3. (A) Catch per unit effort (N/hr) and (B) total length (mm) of YOY largemouth bass at the end of the growing season in 12 reservoirs. Fish were collected by use of A.C. electrofishing along three shoreline transects. Open bars are lakes without gizzard shad.

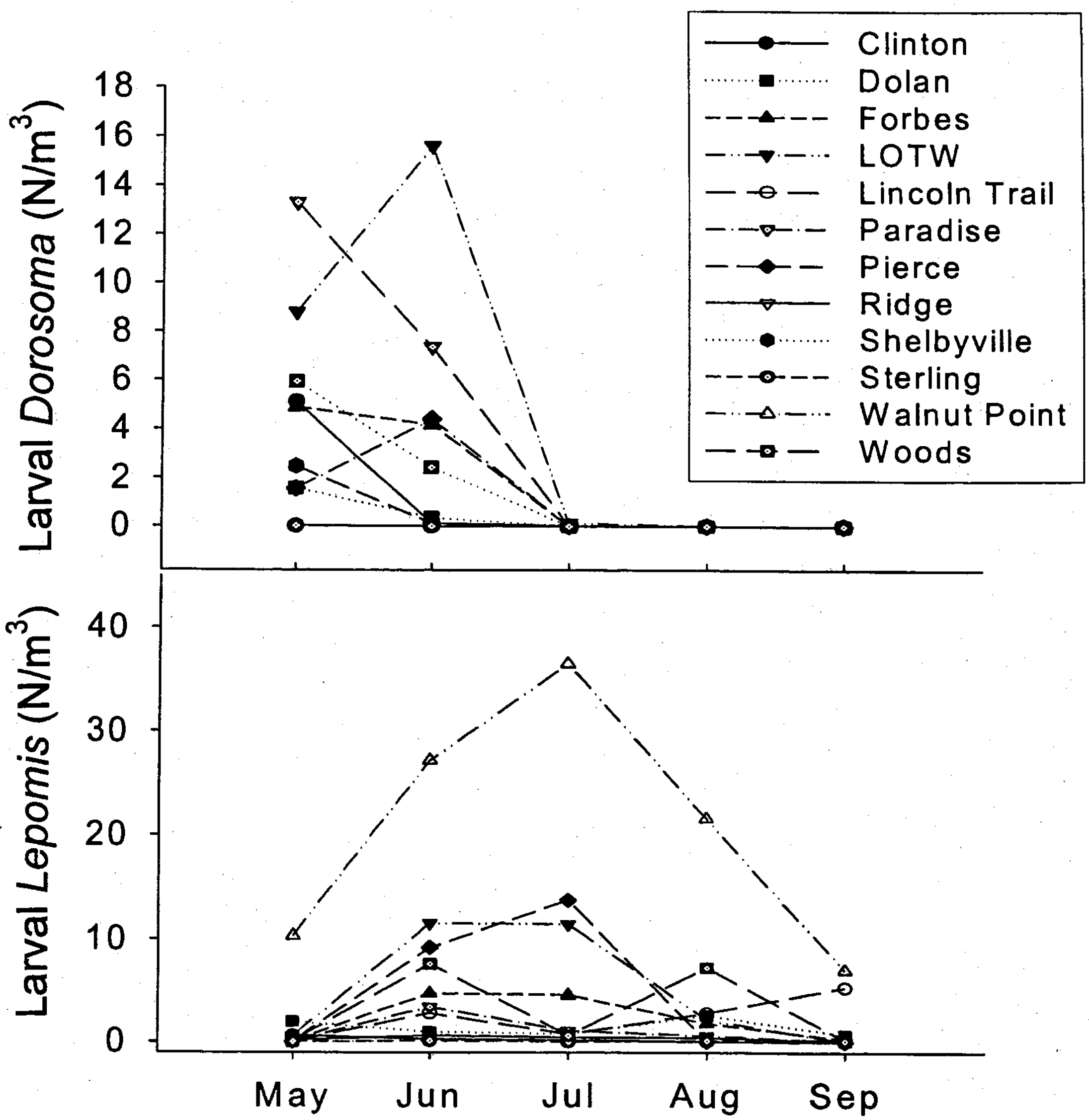

Figure 4-4. Average monthly densities of larval Dorosoma and Lepomis (N/m3) in 12 reservoirs in 2005. Larval fish were collected with a 0.5-m diameter push nest with 500-mm mesh at six fixed stations. Open symbols are lakes with no shad.

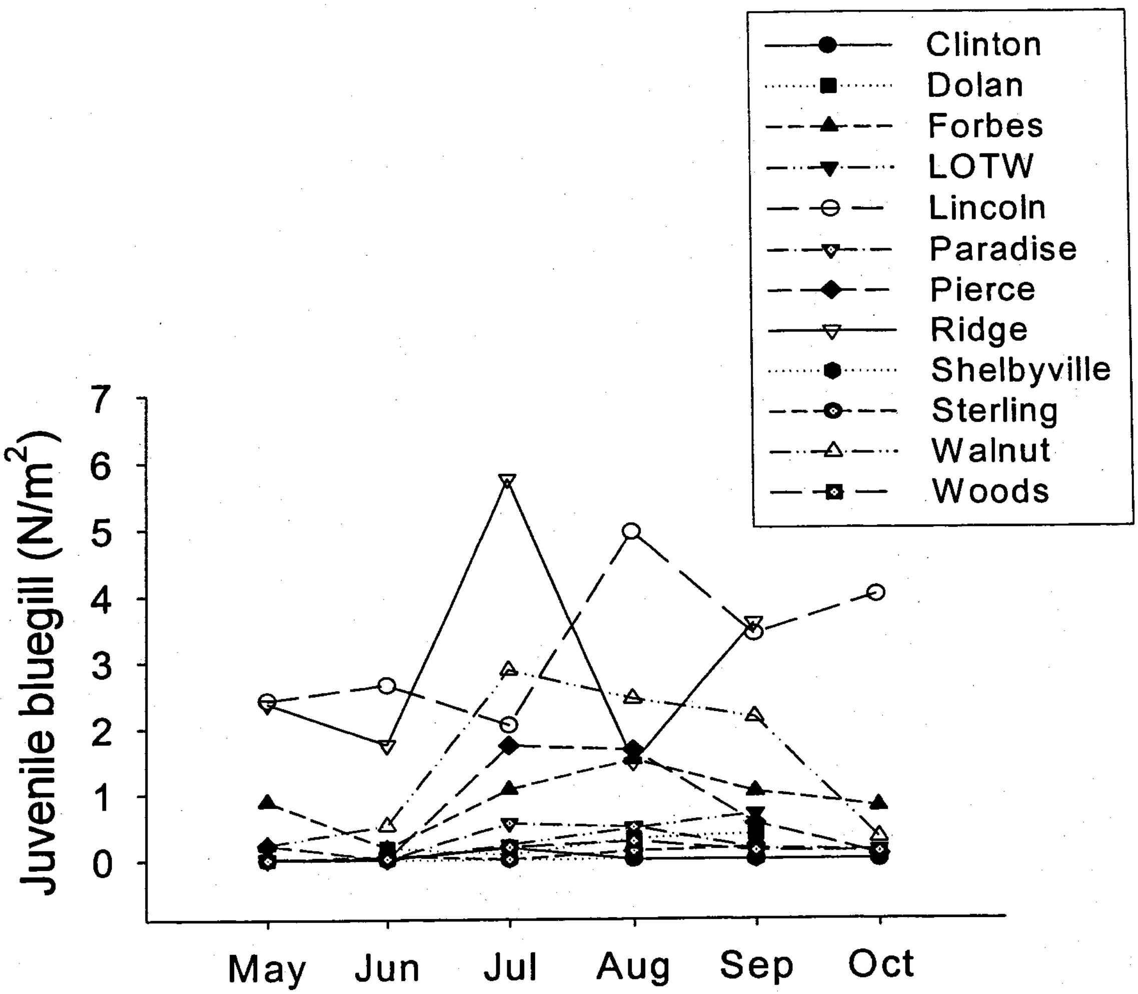

Figure 4-5. Average monthly densities of juvenile bluegill (TL < 60 mm; N/m2) in 12 reservoirs in 2005. Fish were collected with a 9.2-m bag seine pulled at four fixed stations in each lake. Reservoirs with open symbols do not contain gizzard shad.

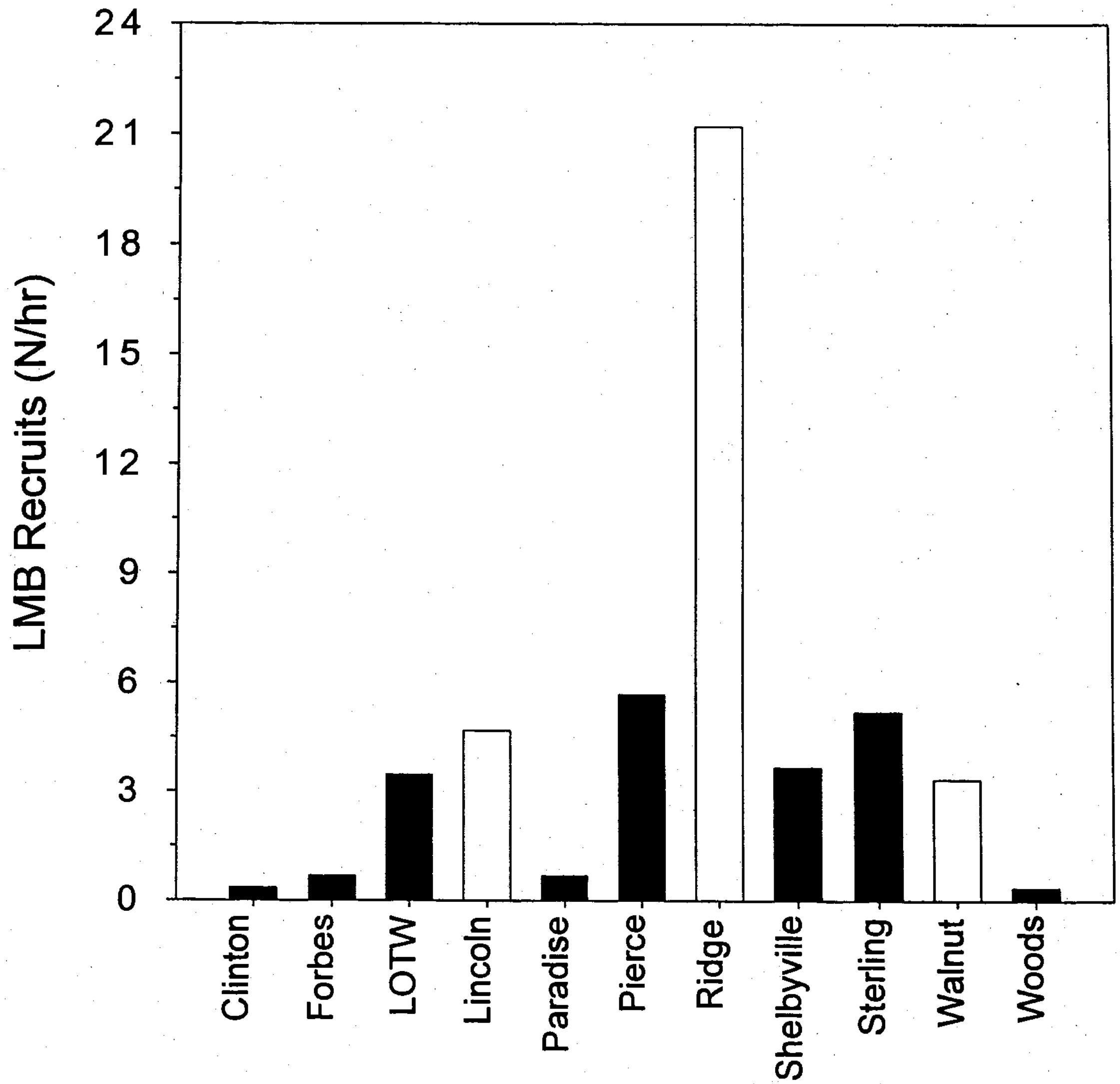

Figure 4-6. Catch per unit effort (N/hr) of largemouth bass recruited to age-1 in 12 reservoirs in spring of 2006. Fish were collected by A.C. electrofishing along three shoreline transects for a 0.5-hr each. Open bars are lakes with no gizzard shad.

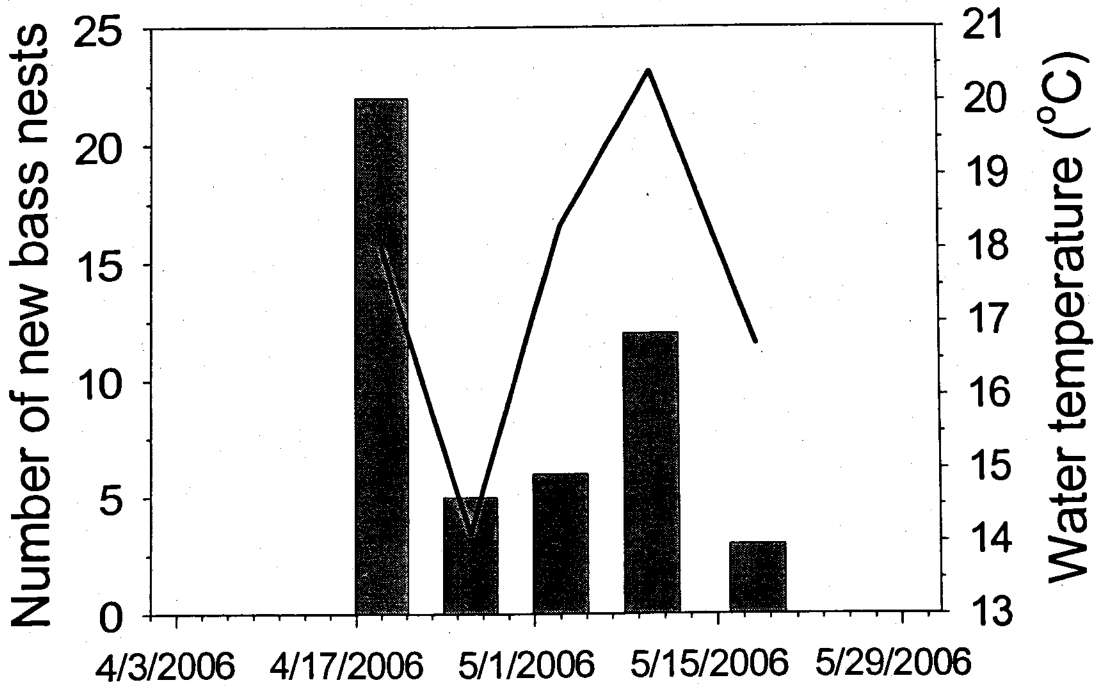

Figure 5-1. Number of new largemouth bass nests and water temperature (oC) over time in Lincoln Trail reservoir during spring 2006.

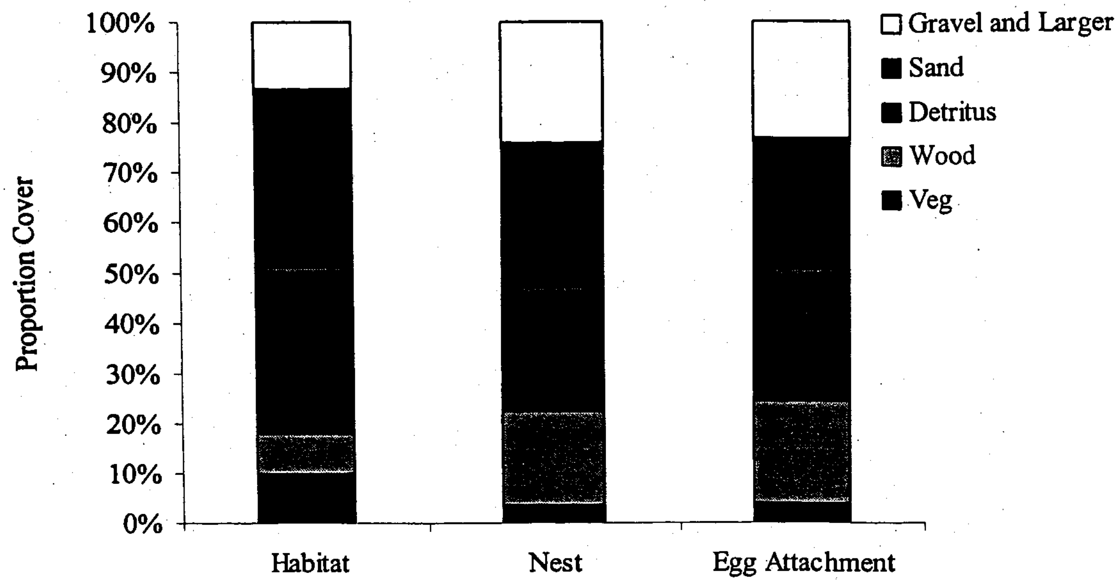

Figure 5-2. Proportion of cover in the 4 by 4 meter area surrounding a nest (Habitat), the nest (Nest), and the substrate the eggs were attached to in a nest (Egg Attachment). Gravel and larger is the sum of gravel, cobble and pebble and Detritus is the sum of leaves, sticks, and detritus.

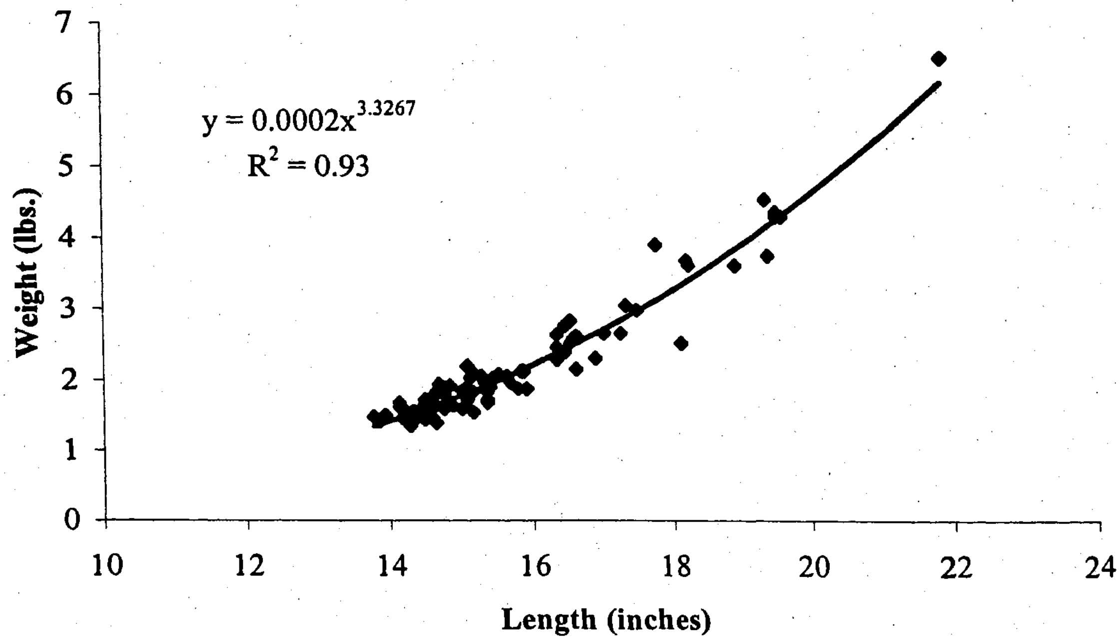

Figure 5-3. Length-weight relationship for largemouth bass measured and weighed by Illinois Natural History Survey staff at the paper tournament weigh-in.

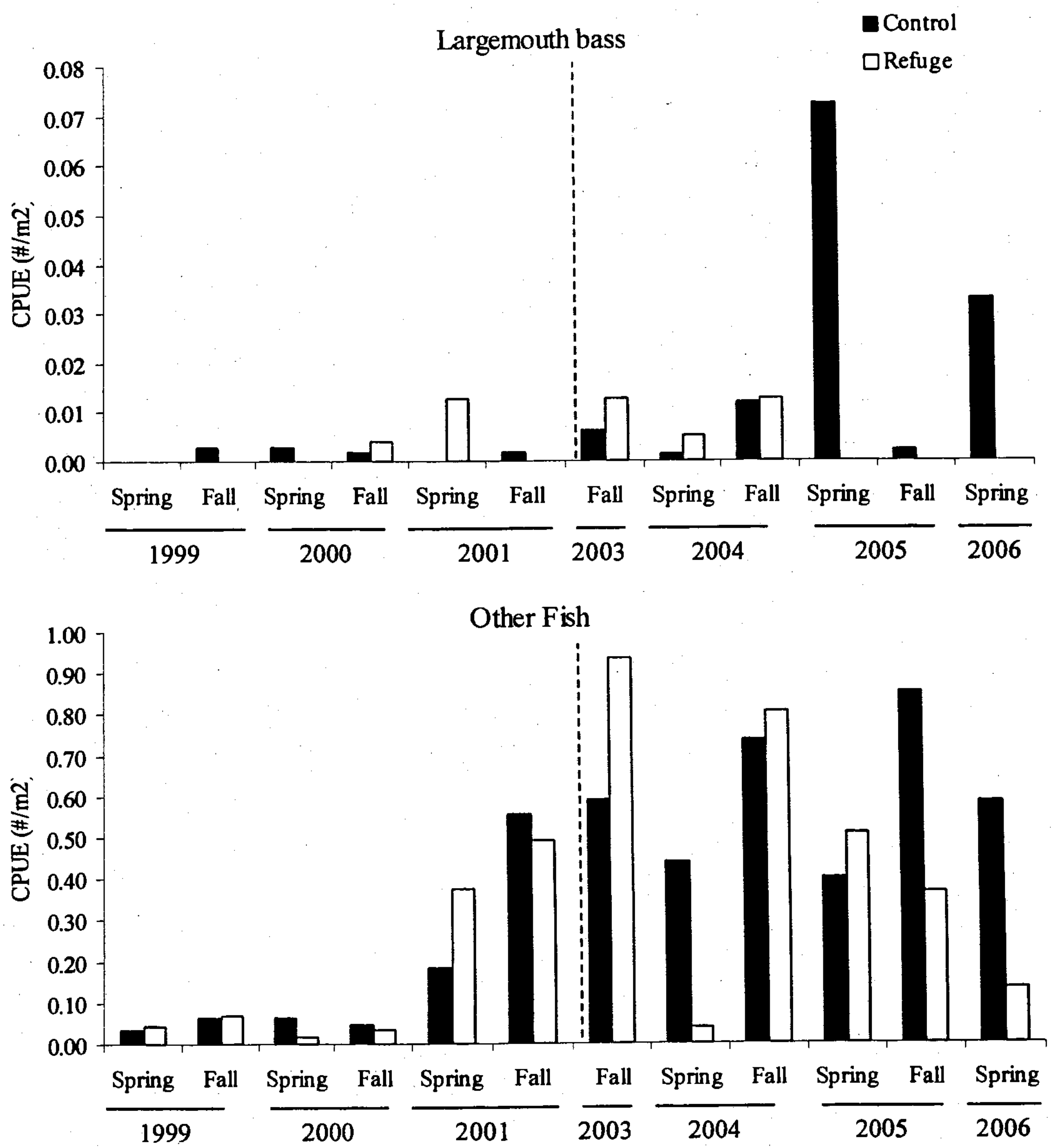

Figure 6-1. Catch per unit effort from seine hauls taken from the main lake and inside the refuge in spring and fall 1999 - 2006. The refuge sites were not sampled in 2002 or spring 2003. CPUE is measured as number of fish per square meter. The dashed line represents when the refuge was closed to the public.