Illinois Natural History Survey

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

Annual Progress Report

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Submitted to

Division of Fisheries
Illinois Department of Natural Resources

Illinois Natural History Survey
Center for Aquatic Ecology
607 East Peabody Drive
Champaign, Illinois 61820

August 2003

Aquatic Ecology Technical Report 03/10

ANNUAL PROGRESS REPORT

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Submitted to
Division of Fisheries
Illinois Department of Natural Resources
Federal Aid Project F-135-R
July 1, 2002 to June 30, 2003

August 2003

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Acknowledgments:

The authors would like to thank the staff at the Kaskaskia, Ridge, and Sam Parr Biological Stations for laboratory and field help. Especially M. Anderson, M. Baldock, B. Bauer, L. Csoboth, T. Edison, E. Effert, L. Einfalt, A. Larson, K. Mann, K. Schnake, N. Siepker, B. Sims, A. Smith, and M. Tomassi. We would also like to thank the regional and district biologists from the Division of Fisheries, IDNR who provided additional lake survey data. S. Pallo and L. Dunham helped coordinate activities with the Division of Fisheries.

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EXECUTIVE SUMMARY: 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. Because stocking is only one of several management options for this species, it is critical that additional information on factors limiting recruitment processes be identified. In addition, information on the importance of rearing technique, size of stocked fish, forage base, cover, resident predators, physical-chemical conditions, and stocking stress in determining largemouth bass stocking success is needed to optimize use of hatchery produced fish.

In Job 101.1 we are attempting to determine the most reliable and cost-effective method for mass-marking fingerling largemouth bass. We evaluated the long-term retention rates of fin clips, fin clips followed by freeze cauterization, and freeze branding. Amongst all three marking types, freeze-branding marks exhibited the least amount of fin regrowth and were the easiest marks to distinguish, except in the spring when bass coloration darkens. Over the four-year period of this study, fin-cauterized marks have been the longest lasting and none of the mark types have significantly influenced bass growth. We will continue this long-term study by periodically monitoring mark retention and growth.

Supplemental stocking is a widely used management tool for increasing the standing stock of an existing population. Survival of stocked largemouth bass fingerlings varied considerably across lakes, ranging from 0 to 21.7 stocked fish per hour of electrofishing during the fall of 2002. Initial stocking mortality was low among different sizes of stocked bass. Stocking mortality was related to temperature at the time of stocking, therefore, stocking during cooler times of year should reduce mortality. Predation rates on stocked fish was low among all sizes of stocked fish. Four inch fish experienced the highest level of predation and may be more susceptible to bass predation than other sizes of stocked largemouth bass. Despite initial differences in size and catch per unit effort (CPUE), all stocked bass except 2-inch fish were found in similar relative abundances and at similar mean size from the first summer after stocking throughout the following seasons. The exception was 2-inch bass which did not occur in samples after the first spring following stocking. Cost analysis will be conducted in subsequent segments in order to make recommendations on which size of fish should be stocked in Illinois impoundments.

The relative survival of intensively and extensively reared largemouth bass varied between lakes. However, few fish were recaptured and larger efforts must be put into sampling in order to accurately assess which rearing strategy yields the highest survival and growth. Based on our results thus far, the usefulness of supplemental stocking as a management strategy will vary by individual lakes. Additional research regarding the importance of predator and prey populations are needed to determine lake characteristics most favorable for stocking largemouth bass.

In Job 101.3 our objective is to evaluate the long-term contribution of stocked largemouth bass to the numbers of harvestable and reproducing adults. The contribution of stocked largemouth bass to an existing bass population will be tracked by stocking largemouth bass specifically fixed for the MDH-B2B2 genotype. Prior to stocking, we evaluated the background frequency of the MDH-B1 and MDH-B2 alleles in the natural largemouth bass population of each study lake and verified that our experimental bass contained the MDH-B2B2 genotype. In

2001, five out of fifty fingerlings stocked into Lake Shelbyville contained the MDH B1B2 genotype, therefore, a correction factor will be used to analyze future samples from this lake. Background frequencies of the MDH-B2 allele were typically less than 20%, except in Forbes (33%) and McLeansboro (55%). The high background frequency of the MDH-B2 allele in McLeansboro will potentially complicate any estimate of contribution made by stocked bass in this lake. If stocked largemouth bass successfully reproduce in our study lakes, we should find an increase in the frequency of the MDH-B2 allele.

The goal of Job 101.4 is to determine the mechanisms responsible for variation in largemouth bass recruitment in Illinois lakes. Total phosphorus and important components of the reservoir food web were monitored in 12 study lakes from May to October. Abundance and size structure of YOY largemouth bass was extremely variable across all 12 reservoirs. Peak abundance of YOY largemouth bass was positively related to the size of vegetated area within a reservoir. The earliest significant indicators of YOY largemouth bass density at the end of the 2002 growing season was July and August abundances. YOY largemouth bass densities at these times were negatively related to total phosphorus concentrations and positively correlated with the abundances of macroinvertebrates and juvenile bluegill. Overall, density of juvenile bluegill was the most consistent correlate of YOY largemouth bass abundance. Number of YOY largemouth bass surviving to age-1 was significantly correlated with fall abundance of YOY, therefore, recruitment strength of the 2002 year class was set by YOY mortality during the first summer. Similar to YOY abundance, the strongest correlation with year class strength was density of juvenile bluegill. YOY largemouth bass size structure at the end of the growing season was larger and positively correlated with primary productivity in reservoir communities containing gizzard shad than in those without gizzard shad. However, fall size structure of YOY largemouth bass did not significantly affect recruitment strength. Across years, recruitment patterns have varied a great deal among the 12 study reservoirs, with recruitment either consistently low, declining, increasing, or varying from year to year. We will continue to monitor these populations in order to understand the causes of these recruitment patterns.

Removal of spawning males by angling in the spring could have detrimental effects on largemouth bass recruitment and size structure. In Job 101.5, our objective was to assess the level of angling for nesting bass in Illinois and to determine its impact on reproductive success, recruitment, and size strucutre. Snorkel surveys at Lincoln Trail Lake were used to measure male bass nest site selection and to test the effects of angling and electrofishing on nest success. Manipulations included catch-and-release (bass were released after two minutes of air exposure), tournament (bass were held for two hours and released at the boat ramp), and electrofishing (bass were captured with an AC electrofishing boat, measured for total length, given a fin clip, held for 30 minutes, and released 100 meters from their nests). Nest abandonment rates were 12% for control bass (unmanipulated), 39% for electrofishing, 30% for catch-and-release, and 100% for tournament treatments. Bass tournaments were monitored at Mill Creek Lake, Mattoon Lake, Forbes Reservoir, and Lake Shelbyville during the spawning and post-spawning period to determine the extent to which nesting male largemouth bass are at risk from tournament angling relative to non-nesting males and females. Many reproductively active bass (47%; N = 4 lakes) were captured by anglers during spring tournaments. More males than females were caught by tournament anglers during the spawning season (2:1; male:female) and this difference disappeared after the spawn (1:1; male:female). Based on a pond experiment wherein 4 ponds were stocked with mature bass subjected to typical tournament stressors (exhaustive exercise, air exposure, culling, live-well retention, and weigh-in) and 4 ponds were stocked with control bass, tournament-stressed populations produced similar numbers of recruits but smaller offspring than the control populations. Based on a series of experiments, we found that live-well retention causes stress responses in largemouth bass but creation of the appropriate live-well conditions can ameliorate these effects.

There are a number of potential options that can be used to help manage bass populations in Illinois, including a variety of different harvest regulations such as size and bag limits, closed seasons, and spawning sanctuaries. In Job 101.6, we are working on a model to evaluate the effects of various angling scenarios and pressures on Illinois bass recruitment and size structure. As a starting point, we have constructed a conceptual model based on a population of bass in a hypothetical lake to describe how reproductive success is impacted by fishing. We are currently calibrating the model with data derived from our angling manipulations in Lincoln Trail Lake. Field experiments on different bass populations will be used to refine the parameters used in the model. When the model has been advanced to a mathematical stage, we will test it with large scale manipulative experiments. In addition, largemouth bass abundance and size structure has been collected from Clinton Lake prior to the closing of a fishing refuge. Data from within the refuge will be collected in future sampling seasons and compared to values from before the closure. With this series of experiments, we are working towards the ultimate goal of developing management strategies that maximize growth, recruitment, and harvest of largemouth bass in Illinois impoundments.

Job 101.1 Evaluating marking techniques for fingerling largemouth bass

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

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

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

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

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

Long-term growth appears to be unhampered by fin clips, fin cauterization, or freeze brand marks (Table 1-1). Fish have grown to a similar length over the 4-year period (291 mm, TL; March 2003) regardless of the three marking techniques. The removal of a pelvic (fin clip; 289 mm, TL), or both pelvic fins (fin cauterized; 295 mm, TL) compared to freeze branding (288 mm, TL) does not appear to impact foraging success or energy allocation.

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

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

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

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

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

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

Previous stocking evaluations conducted in the Midwest have often examined species that do not naturally reproduce in the recipient water body (e.g. muskellunge *Esox masquinongy*, Szendrey and Wahl 1996; walleye *Stizostedion vitreum*, Santucci and Wahl 1993). Largemouth bass, however, reproduce naturally in most Midwestern reservoirs, and therefore stocking occurs in addition to an existing population. 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 yearclass may decrease stocking success in an individual lake. Conversely, stocked largemouth bass may do well in years with high natural recruitment because they are potentially influenced by the same variables.

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

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

PROCEDURES:

Contribution of Four Inch Fingerlings

We stocked 15 lakes in Illinois with advanced fingerling largemouth bass during August of 1999 - 2002. Lakes varied in size from 11 to 250 ha and were located throughout Illinois, ranging from the Wisconsin to the Kentucky border (Figure 2-1). Largemouth bass, bluegill *Lepomis machrochirus*, crappie *Pomoxis* spp., and channel catfish *Ictalurus punctatus* were abundant in all study lakes. Gizzard shad *Dorosoma cepedianum* were present in 11 of the lakes. In addition, we chose lakes with varying levels of available prey and natural largemouth bass recruitment to examine their effects on stocking success.

Bass fingerlings were produced either intensively or extensively at three hatcheries in Illinois (Jake Wolf, Topeka; Little Grassy, Makanda; LaSalle, Marseilles). Intensively reared fish were held inside the hatchery in 265 L concrete tanks and fed commercially produced pellets until stocked. Extensively reared fish were held in ponds and fed on minnows until stocked. Before leaving the hatchery, each fish was given a left pelvic fin clip for future identification. 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 nearshore 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.

We estimated initial stocking mortality on a subset of four lakes by placing 30 fish into each of three floating mesh cages. Largemouth bass were taken directly from the hatchery truck and placed immediately into the cages. Cages were 3 m deep and 1 m in diameter and were placed in at least 3 m of water. The cages were removed after 24 or 48 hours and the number of live and dead fish were counted.

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

Stocking Size

We evaluated the success of four size groups of stocked largemouth bass in two lakes in 2002 (Homer and Charleston). 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 spring 2003 (Table 2-1). Each size group was given a distinctive mark for identification during subsequent sampling. Small fingerlings were immersed in oxytetracycline (OTC), while larger fingerlings were marked with distinctive fin clips. Following stocking, we evaluated the importance of stocking stress, physicochemical properties, predation, and prey availability, on the growth and survival of the different size groups of stocked largemouth bass.

The effects of rearing techniques on growth and survival of stocked largemouth bass were evaluated in lakes Jacksonville, Shelbyville and Walton Park during fall 2002. Study lakes were stocked both by Little Grassy Fish Hatchery (pond production) and Jake Wolf Fish Hatchery (raceway production). Different clips were given at each hatchery for future identification. Electrofishing was conducted during fall and spring to assess the contribution of largemouth bass from rearing ponds and raceways. All bass were examined for clips, weighed, and measured.

FINDINGS:

Survival of stocked largemouth bass was highly variable across lakes in 2002. Catch per unit effort ranged from 0 to 21.7 stocked fish per hour of electrofishing in the fall. Many factors could influence survival of stocked largemouth bass. We attempted to examine some of these factors by examining size specific stocking success.

We examined growth, survival and mortality of different sizes of largemouth bass. Two inch bass were stocked at a smaller size than natural bass in the study lakes and remained smaller for the duration of the time they remained in electrofishing samples (Figure 2-2). Four inch bass were stocked at a similar size as unclipped (natural) bass and continued to grow at a similar rate. Six inch bass were stocked at a larger size than attained by both the 2 and 4 inch bass as well as natural bass in the lakes (Figure 2-2). There were also size differences going into the first winter, with 6-inch stocked fish larger than those stocked as 4-inch fish, followed by the 2-inch size of stocked fish. This suggests there is a potential for size specific mortality over winter. The following spring however, size differences no longer existed between all of the size groups and natural bass. Eight inch bass were stocked in the spring at a larger size than all other bass at that time but by the summer the size difference no longer existed. All sizes of stocked bass as well as the natural bass were of similar length going into the second winter. Although there are initial size differences at stocking, lags in growth occur shortly after, perhaps as the bass go from foraging in hatchery conditions to the wild. There were little differences in growth after the first year so we must examine other factors that may influence stocking success.

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

Predation on stocked bass could reduce overall survival if levels are high. Smaller bass may be more vulnerable to predation and may have a higher potential mortality. Predation on stocked largemouth bass was primarily by adult largemouth bass populations present in the study lakes. Northern pike, channel catfish, and white crappie also preyed on stocked largemouth bass, but in very limited amounts due to the low abundance of these fish in the study lakes. As a result, largemouth bass were examined as the main predators of stocked bass. Four inch advanced fingerlings experienced the highest level of bass predation (8.8% of potential bass predators with stocked bass in their diet) of all sizes of stocked bass. Predation was generally low, however, across all sizes of stocked bass (Figure 2-4). Because low levels of mortality due to predation were observed, other factors were examined to explain the low overall survival of stocked bass. Lake temperature at the time of stocking may play a role in determining observed stocking mortality. All mortality observed in mortality cages took place at temperatures over 23° C. (Figure 2-5). No stocking mortality was observed for 8 inch bass throughout the duration of the study. All 8 inch bass stockings took place in the spring when water temperatures were cooler and had not yet reached 23° C. Stocking mortality was generally low for all sizes of stocked bass and was never observed to be higher than 10%.

Rearing techniques:

Survival of intensively versus extensively reared largemouth bass differed across lakes. In Jacksonville, intensively reared fish had a higher CPUE than extensively reared largemouth bass in fall and spring electrofishing samples (Table 2-3). Walton Park also had a greater CPUE of intensively reared bass in the fall but no intensive or extensive bass were recaptured in the spring electrofishing samples. Lake Shelbyville, however, had higher CPUE of extensively reared bass in the spring and fall.

RECOMMENDATIONS:

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

Results from comparisons between intensive and extensive stocked fish were not consistent across lakes, suggesting the need for further exploration of the effectiveness of the two techniques. Comparisons of these two techniques will be conducted again in Walton Park, Shelbyville, and Jacksonville in 2003. Attempts will also be made to supplement shocking efforts in order to increase sample size and recapture a larger number of stocked bass to better represent survival of fish from the two rearing techniques.

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

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

INTRODUCTION: Many species of fish, including both largemouth and smallmouth bass, are cultured in hatcheries for release into lakes and streams in an effort to establish new or supplement existing populations. Although it is assumed that subsequent increases in the standing stock are the direct result of those stocking efforts, little data exist to either refute or support that idea. Furthermore, if the stocking effort does indeed increase the standing stock of adult bass, it remains unclear how that increase could or would impact the level of reproduction and recruitment in subsequent generations.

Both largemouth and smallmouth bass likely home back to natal areas to spawn (Philipp, and Ridgway, personal communication), therefore it is possible that introduced bass may not compete successfully with resident bass for optimal spawning sites or may simply make poor choices in selecting nesting sites on their own. Under either of these scenarios, the level of reproductive success of stocked bass would be lower than that of resident bass. Preliminary results of largemouth bass stocked into Clinton Lake during 1984 (Philipp and Pallo, unpublished results) indicated that survival of the stocked fish to at least age 4 was good (approximately 8-10% of that year class), however those individuals made no discernable contribution to any later year classes. To justify continued stocking efforts for largemouth bass in Illinois, it is important to determine the actual contribution that stocked fish make to bass populations. The objective of this job is to compare the survival and reproductive success of stocked bass to resident bass. In this way, we can assess the costs and benefits of the bass stocking program in a long-term timeframe.

PROCEDURES: Largemouth bass to be stocked in each selected study lake were those produced at the Little Grassy Hatchery bred specifically to be fixed for the MDH-B2B2 genotype as a genetic tag. These fish were stocked directly into a target lake, while others were first introduced into rearing ponds near the target lake before being stocked. Six study lakes were stocked and sampled; Lake Shelbyville and Forbes Lake beginning in 1998, and these in addition to Walton Park, Murphysboro, Mcleansboro, and Sam Parr in 1999-2002.

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. Beginning in 2001 and 2002, YOY from the six lakes were sampled to determine if the frequency of the MDH B2 allele has increased through reproduction of the stocked fish. The fish stocked into these lakes should be beginning to become sexually mature and should begin to reproduce.

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

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

Largemouth bass stocked into Forbes and Lake Shelbyville in the summer of 1998 and Mcleansboro, Murphysboro, Sam Parr, and Walton Park in 1999 should be sexually mature and reproducing. We have collected YOY from these lakes to determine if the frequency of the MDH B allele has changed as a result of the stocked fish spawning and passing on the MDH B2 allele (Table 3-1). To date, only young of the year from Lake Shelbyville have been analyzed and are not adequate to make recommendations.

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

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

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

INTRODUCTION: Largemouth bass *Micropterus salmoides* recruitment in Illinois reservoirs is variable among systems and years (Parkos et al. 2002). Despite a large number of studies on the population dynamics of largemouth bass, the mechanisms responsible for largemouth bass recruitment variability are still largely unknown (Jackson and Noble 2000). The current lack of consensus on general mechanisms is likely to be a result of extensive region- and system-specific variation in the factors influencing largemouth bass recruitment (Garvey et al. 2002). Most studies of largemouth bass dynamics have been performed on single systems in lower latitude regions, therefore, there is a current need for studies of recruitment mechanisms across multiple systems in other portions of the largemouth bass range (Parkos and Wahl 2002). Our current research addresses these needs by simultaneously evaluating the importance of a range of environmental factors over multiple years to largemouth bass recruitment in reservoir systems that vary in important abiotic and biotic components (see Table 4-1).

Fish recruitment in general is driven by variation in either reproductive output (Ricker 1954) or mortality rates during the earliest life stages (Houde 1987). Appropriate habitat and the composition and size of the adult spawning stock are usually considered to be the key factors influencing reproductive output (Rutherford 2002). For nesting fishes, environmental fluctuations and high nest predation rates can also potentially limit reproductive output (Parkos and Wahl 2002). Mortality rate of young of the year (YOY) fishes is typically size-dependent, therefore, variables affecting growth are also important to variation in survival and, ultimately, recruitment (Miller et al. 1988). For piscivorous species, the timing of the behavioral switch from preying on invertebrates to a diet of primarily fish is crucial for rapid growth during the juvenile life stages (Mittelbach and Persson 1998). Important causes of YOY mortality are predation, starvation, and extreme abiotic conditions. Recruitment variation can be the result of either episodic mortality at sensitive life stages or small changes in daily mortality rates (Houde 1989). Different sources of mortality will be important during different life stages, therefore, determining the critical time frame for YOY survival will help to focus management on those mechanisms most influential to recruitment.

Largemouth bass dynamics appear to be driven by either events during nesting or juvenile mortality during the first summer and winter (Parkos and Wahl 2002). Potential factors influencing nest success are fluctuating abiotic conditions (e.g., water level and temperature) and nest predation. Juvenile mortality is typically the result of either predation during the first growing season or predation and starvation during the first winter. Vulnerability to predators is often ameliorated by rapid growth and the availability of cover (Miranda and Hubbard 1994). Furthermore, cannibalism is an important form of predation pressure on largemouth bass, therefore, any early growth advantage can be crucial for individual survival (Post et al. 1998; Parkos and Wahl 2002). An early switch to piscivory by largemouth bass YOY is often linked to increased growth and condition, potentially resulting in increased foraging efficiency, lower vulnerability to predators, and increased chance of overwinter survival (Olson 1996; Ludsin and

DeVries 1997). The availability of appropriately sized prey is likely to be critical for early piscivory, growth, and survival through the first summer and winter. Two of the most important species of fish prey for largemouth bass are bluegill *Lepomis macrochirus* and gizzard shad *Dorosoma cepedianum*, and the vulnerability of these two species is likely to be contingent upon the temporal range of the protracted spawning events of bluegill and factors influencing gizzard shad growth rates (Garvey et al. 2002). Overwinter survival appears to be strongly size-dependent for largemouth bass YOY and influenced by factors such as food availability, predation, and individual condition (Ludsin and DeVries 1997; Fullerton et al. 2000). However, there is currently no evidence that overwinter mortality is important to largemouth bass recruitment in Illinois (Fuhr et al. 2002).

Identification of the mechanisms causing variation in largemouth bass recruitment will help to prioritize management options for the maintenance and enhancement of Illinois largemouth bass populations. Management actions, such as protection of nesting adults or regulation of water level, could potentially enhance reproductive output (Miranda et al. 1984; Suski et al. 2002), while juvenile survival may be enhanced by increasing the availability of cover and prey (Durocher et al. 1984). Furthermore, identification of reservoirs with consistently high or low recruitment and determination of reliable recruitment indices will help to prioritize largemouth bass stocking. Largemouth bass are both an important game species and component of reservoir food webs, therefore, many benefits can be gained by an understanding of largemouth bass recruitment mechanisms. Our current project will greatly aid in this goal by providing a long-term, multiple system data set on bass population dynamics and relevant ecological factors.

PROCEDURES: We sampled 12 reservoirs in 2002 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.

Largemouth bass recruitment was assessed by shoreline seining and 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. In five lakes, we saved thirty young of year (YOY) largemouth bass from each sampling date for diet and age analyses. Electrofishing was used to collect YOY largemouth bass in the fall after they were no longer vulnerable to the seine. Based on otolith-derived ages, all largemouth bass from fall to the following spring that were less than 150 mm were considered to belong to the same year class. This assumption allowed us to estimate the number of YOY surviving their first winter and recruiting to age-1. In the spring of 2002, we used weekly electrofishing to determine the abundance of spawning largemouth bass in order to estimate the timing of peak spawning activity in four lakes (Lincoln Trail, Paradise, Ridge, and Woods). Forbes Lake was also sampled biweekly to determine the timing of bass spawning. Each captured fish was sexed and checked for reproductive condition (immature, running, spent).

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 taken either from the thermocline or from the bottom (if the lake was not stratified) to the surface. Zooplankton samples were preserved in a 4% Lugols solution and returned to the lab for processing. Zooplankton subsamples were counted until 200 organisms from two taxonomic groups were counted. Measurements were taken on 30 individuals of each species from two of the inshore and two of the offshore sites. Larval fish were sampled at six sites on each lake using an 0.5-m diameter larval 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 the YOY largemouth bass.

Physical and chemical variables important to largemouth bass recruitment were sampled in each of the study lakes. Aquatic vegetation was identified and mapped in each lake to estimate percent vegetative cover in June and August. 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 and recorded water temperature at 2 hour intervals throughout the year. Water samples for chlorophyll-*a* and phosphorous were collected using an integrated tube sampler lowered to twice the secchi depth. Chlorophyll was measured using a flourometer, while total phosphorous was measured with a spectrophotometer.

FINDINGS: Young of the year (YOY) largemouth bass densities were highly variable across study reservoirs during 2002 (Figure 4-1). YOY largemouth bass recruited to the seines in May (Lake of the Woods, Lincoln Trail, Walnut Point; avg TL = 13 mm), June (Clinton, Dolan, Forbes, Ridge; avg TL = 28 mm), and July (Paradise, Pierce, Sterling; avg TL = 46 mm). Peak YOY largemouth bass densities ranged from 0.006 to 3.74 fish per square meter. Differences in abundance were smaller over time.due to larger declines from July to August in reservoirs with higher YOY densities. July abundance was the earliest density of YOY largemouth bass significantly correlated with fall YOY captured by seines (Spearman; $r_s = 0.67$; $P = 0.02$). When fall YOY estimates were based on electrofishing catch per unit effort, the highest correlation with fall abundance was August density (Spearman; $r_s = 0.58$; $P = 0.08$). Based on analysis of five study lakes (Lake of the Woods, Lincoln Trail, Sterling, Walnut, Woods) that ranged from 0-5357 square feet of vegetated area in the spring, peak abundance of YOY largemouth bass was positively correlated with spring aquatic vegetation (Pearson; $r = 0.82$; $P = 0.09$). Abundance of largemouth bass YOY surviving their first winter was also highly variable across reservoirs (Figure 4-2). Abundance of YOY recruited to age-1 was significantly correlated with the electrofishing estimate of fall abundance of YOY (Spearman; $r_s = 0.81$; $P = 0.005$). The largest correlation between largemouth bass recruited to age-1 and any spring or summer abundance was June YOY density (Pearson; $r = 0.57$; $P = 0.07$). Based on the above patterns, year class strength of the 2002 cohorts of largemouth bass did not appear to be set until fall (late September to early October).

Densities of YOY largemouth bass were primarily related to total phosphorus and the abundance of important prey resources. Nutrient concentrations and important components of the aquatic community varied in abundance among the study reservoirs (Table 4-1; Figure 4-3).

August YOY were negatively related to concentrations of total phosphorus (Spearman; r_s = -0.65; P = 0.02) and positively correlated with benthic macroinvertebrate density (Spearman; r_s = 0.77; P = 0.01). Total phosphorus concentrations varied from 43 to 477 µg/L and were higher in reservoirs with abundant gizzard shad (lakes with vs. without gizzard shad; t = -2.37; P = 0.04). YOY largemouth bass densities throughout the growing season were most consistently correlated with juvenile bluegill (15-60 mm TL) abundance (Table 4-2). Juvenile bluegill densities were positively correlated with the abundance of zooplankton (Spearman; r_s = 0.64; P = 0.05) and benthic macroinvertebrates (Spearman; r_s = 0.79; P = 0.006). The abundance of YOY recruited to age-1 was not significantly correlated with the abundance of any prey types, but the strongest correlation was with density of juvenile bluegill in August (Spearman; r_s = 0.54; P = 0.09).

The 12 study reservoirs varied in YOY largemouth bass size structure (Figure 4-4). YOY largemouth bass total lengths at the end of the growing season ranged from 60 to 113 mm (Figure 4-5). August total length of YOY largemouth bass was positively correlated with chlorophyll *a* concentrations in June (Pearson; r = 0.71; P = 0.02) and July (Pearson; r = 0.68; P = 0.03), however, fall size structure was more weakly correlated with chlorophyll *a* (Spearman; r_s = 0.61; P = 0.06). Fall size structure of YOY was not significantly correlated with recruitment of YOY to age-1 (Spearman; r_s = 0.32; P = 0.36). Average total length in fall seine samples from combined 2001 and 2002 year classes was larger in reservoirs with gizzard shad than in those without (t = -2.55; P = 0.02); however, the effect of gizzard shad presence was marginally insignificant on fall of 2002 size structure as estimated by electrofishing (t = -1.95; P = 0.09).

Across years, recruitment to age-1 has varied both within and among reservoirs (Table 4-3). For some reservoirs, relatively strong year classes are followed by low recruitment from the next year class (Dolan, Pierce, Ridge, Walnut Point). In Pierce Lake, some of the variation in recruitment may be correlated with spring water temperatures (Pearson; r = 0.84; P = 0.16) and discharge (Pearson; r = -0.87; P = 0.32). Alternatively, high abundance of yearling largemouth bass may represent higher than usual predation pressure on YOY. Other lakes have exhibited a decline in recruitment from 1999 to 2002 year classes (Clinton, Forbes, Lincoln Trail, Woods), with only Lake Shelbyville showing an increase in recruitment. Survival to age-1 has been consistently low in the remaining study lakes (Lake of the Woods, Paradise, Sterling).

In spring of 2003, peak proportions of largemouth bass in reproductive condition were found from late April to early May (Figure 4-6). Lincoln Trail had the earliest peak at April 23rd, while Paradise and Woods exhibited the latest peak at May 9th. Similar to previous years, Lincoln Trail appeared to have two peaks in inshore abundance of reproductive adults.

RECOMMENDATIONS: The timing of the establishment of largemouth bass year class strength has been very variable across the 2000-2002 year classes. The 2002 year class did not appear to be established until fall, the 2001 year class was set by July, and recruitment strength of the 2000 cohort may not have been set until spring of 2001. Various factors affecting reproductive output, first summer survival, and overwinter mortality may be responsible for this variation in timing. Factors potentially influencing reproductive output include vegetation abundance, water level, and water temperature. Future reports shall expand the testing of the importance of these factors by increasing sample size to include more lakes and years. Furthermore, additional data on peak abundance of reproductive adults will enable us to focus our correlations relative to reproductive output to the days when largemouth bass are most likely nesting. Recruitment strength of the 2002 year class appeared to be set by first summer mortality and to be strongly correlated to prey abundance, especially juvenile bluegill. Currently, we are quantifying YOY largemouth bass diets to test the hypothesis that an earlier and more persistent switch to piscivory is correlated with higher recruitment. Furthermore, we shall use the results of previous feeding experiments to aid in identifying the abundance of those fish that can be considered vulnerable to YOY largemouth bass predation in order to test if variation in the availability of vulnerable fish prey is correlated to largemouth bass year class strength. Many previous studies have considered mortality during the first winter to be primarily responsible for setting year class strength of largemouth bass. We have found little evidence of year class strength being set by size-specific mortality over the first winter, but at least one cohort may in fact have followed this pattern (2000 year class). To test the influence of first winter mortality on recruitment, we will examine the effect of winter severity, fall YOY size structure, and fall prey availability on overwinter survival.

The twelve study reservoirs have exhibited highly variable recruitment with patterns of either consistently low, declining, rising, or variable recruitment from the 1999-2002 year classes. Factors such as poor conditions for reproduction or low food availability may be responsible for consistently small year class strength. In lakes where each strong year class is followed by low recruitment, a high abundance of yearling largemouth bass may depress recruitment through intense predation on YOY largemouth bass. In lakes, such as Lake of the Woods, where YOY are extremely abundant, but recruitment is generally low, intraspecific competition or high predation pressure may limit recruitment. Future reports shall explore the potential effect of predator abundance and cannibalism on year class strength.

In many of our study lakes, gizzard shad represent the dominant biomass of the fish community, and therefore, this species may have a strong influence on largemouth bass recruitment. In 2002, gizzard shad were associated with higher total phosphorus concentrations and lower abundance of YOY largemouth bass. However, YOY largemouth bass in gizzard shad lakes were also generally larger and could have positive effects on recruitment. To this point, we have not found any differences in recruitment between lakes with or without gizzard shad, but the differences in YOY size structure may nonetheless be quite important. We will detail whether or not gizzard shad are an important component of YOY largemouth bass diets or if gizzard shad increase largemouth bass sizes through a more indirect mechanism.

The significant influence of multiple variables on largemouth bass recruitment points out the relatively complex mechanisms responsible for recruitment variation in these fish. Future reports shall incorporate multivariate statistical tests in order to aid in separating out the important components of largemouth bass recruitment. Furthermore, as values from 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. Further analysis on the correlation among reservoirs in year class strength will help us to identify those reservoirs in which relative year class strength varies simultaneously, perhaps due to similar mechanisms governing recruitment variation. Better understanding of the factors that control largemouth bass recruitment will enable us to make recommendations for effective management actions to enhance this valuable fishery.

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

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

INTRODUCTION: Identifying the effects of capture and handling stress on largemouth bass reproduction is important given the continued growth in popularity of angling, including the common practice of catch and release (Quinn 1996) and competitive angling events (Gustaveson et al., 1991; Schramm et al. 1991a,b; Wilde et al. 1998). However, the ultimate consequences of angling stress in terms of overall reproductive success in largemouth bass have received little attention. Removal of spawning males by angling in the spring has unknown effects on largemouth bass recruitment. In the spring, male largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*) build solitary, highly visible 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 males alone remain to provide all parental care for the developing offspring, a period that may last four or more weeks (Ridgway 1988). While male bass are providing parental care for their broods, they are extremely aggressive (Ridgway 1988) and, therefore, highly vulnerable to many angling tactics (Neves 1975; Kieffer et al. 1995). Even though this vulnerability has never been assessed accurately, many fisheries management agencies have invoked closed fishing periods, catch-and-release regulations, and various length and harvest limits in different combinations in an attempt to limit harvest of male bass during the spawning season (see Schramm et al. 1995). This strategy of maximizing reproductive success by protecting the successful spawners from angling harvest and even disturbance operates under the assumption that there is some positive relationship between reproductive success and recruitment. The standard dogma in fisheries has been that there is no relationship between standing adult stock and recruitment. Although much of the data for those conclusions has been collected for marine species, that belief has been generalized to freshwater species as well, even those species for which there is extended parental care (e.g., largemouth and smallmouth bass). The error in logic has been compounded further by extending the dogma to include the "lack of relationship" to recruitment and reproductive success. That extension clearly makes little sense for species, such as the basses, which have been shown to have high levels of variability in the percentage of adults that choose to spawn in any given year. In addition, because there is also a substantial and variable level of natural brood abandonment, the numbers of successful broods would not at all be expected to be related to the numbers of adults. One objective of this job is to assess how well reproductive success correlates with recruitment, at least through the establishment of YOY year class strength.

Male largemouth bass and smallmouth bass experience reduced levels of food consumption while providing parental care (Kramer and Smith 1962; Pflieger 1966; Coble 1975), therefore, this period in the reproductive cycle is characterized by a continual decrease in energy storage and somatic growth. The quality of post swim-up parental care provided is influenced by the energy reserves of the nesting male (Ridgway and Friesen 1992). As a result, any energetically costly activity, such as the type of exhaustive exercise experienced during angling, could result in a decreased ability or willingness of that male to provide continued parental care (Kieffer et al. 1995) and thus, negatively impact offspring survival. In fact, Philipp et al. (1997) have confirmed that preseason angling of nesting bass, even on a catch-and-release basis, results in increased brood predation and male abandonment rates. It is likely, therefore, that substantial levels of catch-and-release, much less catch-and-harvest, angling for nesting bass would have negative effects on the production of black bass fry at the population level. Moreover, because female black bass choose to spawn preferentially with the largest males (Wiegmann et al. 1992), the largest males have the largest broods. Furthermore, because parental investment decision rules dictate that those males with the largest broods will defend those broods most aggressively, we would expect that the individual nesting males that are most at risk in a catch-and-release (even full harvest) scenario are the largest ones, i.e., those that have enjoyed the most mating success. This is indeed what we have observed; angling efforts disproportionately target that portion of the male population that is most productive and, therefore, most important with respect to reproductive success.

Despite the increase in prevalence of catch-and-release angling tournaments in North America, there is still very little research on the effects of catch-and-release angling tournaments on fish. By identifying and understanding the factors associated with hooking and handling injury and mortality (Mouneke and Childress 1994; Wilde 1998), fisheries managers, outdoor media, competitive angling groups, and conservation organizations have been able to increase fish survival following catch-and-release. One component of fishing tournaments that has been identified as a possible opportunity for improvement is during the period of live-well retention (Cooke et al. 2002). In this segment, we document the behavioral and physiological responses of fish to live-well retention to develop strategies that facilitate recovery.

PROCEDURES: Snorkel surveys were used to assess the extent of bass spawning activity, nesting site selection by spawning males, and the effects of angling and electrofishing on nesting success in Lincoln Trail Lake. Twelve sites are monitored each spring. We gave each nest a tag and recorded egg score (1-5), water depth of the nest location, and the life stage of the eggs or fry. Habitat within a 4m x 4m area around the nest was mapped, making note of substrate, cover, and potential nest predators. We made visual estimates of the total length of the males guarding the nests and noted the presence of any hook wounds. We also chased a subset of males off the nest for a 5-minute period to observe nest predation while the male was absent. Number of predators, their size and time spent feeding in the nest was recorded. The number of times the male had to be chased from the nest in the five-minute observation period was recorded as a measure of aggressiveness.

We assessed the effects of catch-and-release and tournament angling on nest guarding by parental males. We hook and line angled nests at three of the sites in 2000 and recorded the nests from which we were able to remove the males. Males were released after two minutes of air exposure to simulate a catch-and-release angling event. The next day, we swam the angled sites and recorded whether or not the nest was abandoned. In 2001 and 2003, we angled nests and simulated tournament conditions by holding the fish for two hours and releasing the fish at the boat ramp. We swam the sites the following day and recorded nest abandonment by the males. In 2003, we also assessed the potential effects of electrofishing on nesting success by nest-guarding male largemouth bass. We snorkel surveyed nests In Lincoln Trail Lake before assigning each nest either a control or electrofishing treatment. Control nests were not manipulated while electrofished nests were approached perpendicular to the bank with the AC electrofishing boat, stunned, and removed from the nest. Total lengths were taken, upper caudal clips given, and fish were held for 30 minutes before being released 100 meters from the nest site. We then snorkel surveyed each nest site the following day to note abandonment rates.

Throughout the spawn and post-spawn period, we monitored bass tournaments at Mill Creek, Mattoon, Forbes, and Shelbyville Lakes to determine if nesting males were more at risk from anglers than either non-nesting males or females. The total length, sex, and reproductive condition of each fish brought to weigh-in was recorded. In 2003 we began interviewing anglers at weigh-ins to determine if anglers were culling fish and influencing sex ratios observed at the conclusion of the tournaments. From our data, we noted that females were larger on average than males; therefore, sex ratios may be skewed towards larger females as anglers culled out smaller males. If this were true, male capture rates may have been substantially more than that of females.

We examined the effects of simulated tournaments (i.e., exhaustive exercise, air exposure, culling, live-well conditions, and weigh-in-procedures) on largemouth bass reproductive processes prior to spawning. Adult largemouth bass were held for two months prior to spawning. Fish were sorted into a control and simulated tournament group (treatment) based upon weight, total length (TL), and gender. Fish were acclimated prior to being subjected to a suite of stressors (i.e., exhaustive exercise, air exposure, culling, live-well conditions and weigh-in procedures) designed to simulate tournament-angling practices. Fish were first chased manually for 90 s., exposed to air for 60 s, and introduced to live-wells and held at a density of five fish per live-well for 6 h. At the termination of live-well retention, fish were held in a water-filled bag for 120 s to simulate the movement of fish from the boat to the weigh-in site. The contents of the bag were then emptied into a laundry basket, to simulate weigh-in, prior to being introduced into eight 0.04 ha ponds (N = 5 males, N = 5 females per pond). Four of the eight ponds were stocked with stressed largemouth bass randomly selected from those fish that had experienced stress; the remaining four ponds were stocked with non-stressed control fish and allowed to spawn. Ponds were drained and all adult and age-0 largemouth bass were removed, enumerated, weighed and measured. Otoliths from age-0 largemouth bass produced from adults in stressed (N = 20 per pond) and non-stressed (N = 20 per pond) treatments were prepared and the number of daily growth rings was counted. We compared the number, length, weight, and age of offspring produced from stressed adults with those produced from controls.

We conducted a series of experiments to assess the real-time physiological and behavioral responses of largemouth bass to live-well retention. Techniques used in this study incorporated assessments of physiological and energetic responses using cardiac output, blood biochemistry, and behavioral responses using videography. Methodological details on each of these techniques are reported elsewhere and blood analyses were conducted in collaboration with Dr. Bruce Tufts and Cory Suski from Queen's University.

FINDINGS: Timing of spawning was summarized for each year in Lincoln Trail (Figure 5-1). In 1999 the spawn appeared to be bimodal, while fish spawning in 2000, 2001, and 2003 was unimodal. Spawning duration is similar across years, but appears different because of limited sampling trips in some years. Initiation of spawning was similar across years, except for 2003 when early warm weather likely caused spawning to commence earlier than previous years. Bass began spawning in Lincoln Trail on approximately April 22. A total of 44 nests were found in the six surveyed sections. These numbers dropped on subsequent sampling dates (Figure 5-1). Snorkel surveys were delayed from May 1 to May 22 due to heavy rainfall and increased turbidity levels in the lake.

Abandonment rates from simulated tournaments were substantially higher than from catch and release angling (Table 5-1). Abandonment rates of control and electrofished bass is summarized in Table 5-2. A total of 91 nests were used to evaluate the impacts of electrofishing during largemouth bass spawning. Average abandonment rates of electrofished bass (39%) was over three times that of control fish (12%).

Tournament anglers in the spring appear to target spawning bass. The percentage of bass that were reproductively active ranged from 37.0% to 51.4% of all fish captured (Table 5-3). Tournament anglers tended to capture more males than females, which may indicate that anglers are targeting males that are either on nests or actively guarding offspring. Sex ratios (males : females) ranged from 1.1:1 to 2.3:1 across lakes Mattoon, Mill Creek, and Forbes during the spawn. Average total length of captured males (357 mm to 409 mm) was smaller than female average size (426 mm to 455 mm) during the spawning period. Shelbyville had different results with a sex ratio (male:female) of 1:1.2. Average size of captured males in Shelbyville (393 mm) were also smaller than the females (419 mm) during the spawn. Mill Creek and Shelbyville produced sex ratios for the postspawn period of 1:1.4 and 1:1, respectively while Lake Mattoon and Stephen Forbes had sex ratios of 1:1.5 and 1.8:1, respectively.

In the first year of angler interviews, we have thus far only surveyed 5 anglers to determine if they were culling smaller male fish from their creel to increase their weights with larger female fish during the spawn. Of the five anglers surveyed, only one had captured a limit of fish. No anglers had culled any fish from their creel. Additionally, we asked how many short fish were captured and released. Several anglers had released short fish.

Age-0 largemouth bass produced from parents subjected to simulated tournaments were smaller and weighed less than controls (Table 5-4). Length and weight differences at the time of draining appear small ($\bar{x} = 4.0$ mm, TL; $\bar{x} = 0.2$ g respectively), but the relative differences were high as a percent of total length (11%) and body weight (26%). Length frequency distributions of age-0 largemouth bass at draining also were variable among individual ponds within a treatment (Figure 5-2). However, when length frequencies were combined across ponds they differed between treatments. Length frequency distributions of the cohort produced from parents that experienced stress was skewed toward smaller size classes compared to controls (Figure 5-2). Numbers of age-0 largemouth bass recruited to each pond were highly variable, resulting in no difference between treatments (Table 5-4). Daily ring counts from age-0 largemouth bass otoliths indicated that individuals subjected to stress had earlier swim-up dates (2 d) compared to largemouth bass that were not stressed (Table 5-4).

When we monitored the physiological response of fish to a variety of tournament-related stressors, live-well retention resulted in less physiological disturbance than the actual angling event or weigh-in. Energy stores were replenished, stress hormones decreased, metabolites were eliminated, and heart rate decreased during live-well retention (Figure 5-3).

Observations using videography revealed that during live-well retention, fish expended significant energy maintaining position to prevent repeated physical collision with the live-well walls, particularly during rough water conditions. Live-well design should thus incorporate elements that minimize sloshing of water and it may be prudent to restrict tournaments on days with rough water conditions. Furthermore, our videographic observations suggest that bass interact aggressively with conspecifics and thus, there may be some merit in minimizing density or using a sedative to calm the fish. Indeed, previous work in our lab using smallmouth bass determined that fish density can also affect recovery of fish in the live-well (Cooke et al. 2002). Metabolic rates of captured fish increase with live-well densities greater than one individual, due to a greater demand on live-well oxygen conditions. The repeated handling of fish during tournament angling, including culling, the addition of fish or other live-well disturbances, and the final tournament weigh-in, which adds an additional several minutes of air exposure, further adds to already heightened stress levels.

This season, we also began experimentation with the anesthetic clove oil (see Keene et al. 1998) as a tool to stabilize and calm largemouth bass during live-well retention. Our preliminary data indicate that low levels of clove oil that reduce sensory activity, but allow fish to maintain equilibrium, results in a general calming effect that reduces conspecific interactions (Figure 5-4). Research by other groups (i.e., Wagner et al. In press) indicates that clove oil is effective at minimizing stress in fish already exposed to the stressor, such as what would be experienced by bass in fishing tournaments. Previous research by our group determined that current commercially available live-well additives actually increase metabolic rate and retard physiological recovery (Cooke et al. 2002). Therefore, clove oil may provide an alternative tool for anglers to calm fish during retention and this should be a focus of future research.

RECOMMENDATIONS: In future segments, we will examine potential factors influencing largemouth bass spawning time in Lincoln Trail Lake. In addition, we will examine the consequences of those differences in spawning time through fall recruitment for young-of-year bass. Examination of nest site habitat and nest predator densities will again take place next year to increase sample sizes. Relationships among habitat type and predator abundance, male aggression level, and ultimately nest success will be closely examined. Further work is also needed to increase sample sizes on the potential effect of angling on nest guarding by parental largemouth bass, but preliminary results show about a 30% abandonment rate due to catch-and-release angling and a 100% abandonment rate due to tournament angling. To understand how to minimize negative impacts of angling, future experiments need to determine which factors are most important in influencing the parental decision to abandon, and to understand when and how these important factors interrelate in natural systems. These experiments should test nest abandonment and male aggression towards nest predators for fish that are experimentally angled and in controls that are not manipulated. Our data from Lincoln Trail shows increased rates of nest abandonment due to electrofishing confirming that spring sampling with electrofishing equipment negatively impacts largemouth bass nesting success.

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

Largemouth bass exposed to simulated tournaments can delay the swim-up date of offspring and negatively affect the size of young produced. The effects of stress on offspring will most likely vary with the severity and duration of the stressor, the gonadal maturation stage of the adults. Delays in swim-up date and smaller progeny resulting from stress could have negative population consequences. Smaller larval and juvenile fishes within a cohort have a number of disadvantages such as an increased risk to starvation and predation leading to lower survival. Size specific mortality can have important consequences for later recruitment when inter and intraspecific competition is strong and resources are limiting. Additional experiments will be required to test if the differences in size we observed remain throughout the first year of life, reduce over winter survival, and effect later recruitment. The single exposure to a sequence of acute stressors in our experiment occurred a few days prior to spawning and thus was probably too late to affect fecundity but may effect egg quality and lower progeny survival (e.g., increased cannibalism within and among broods). If additional work confirms our findings, then protection of potential spawners from stressors or attempts to minimize physiological disturbance prior to spawning would be warranted.

In subsequent segments, we will begin to examine effects of sublethal angling stressors on largemouth bass feeding behavior, growth, and survival. To further investigate the impacts of angling on largemouth bass reproduction and its relation to lake recruitment, we will examine: 1) the influence of sublethal angling stressors prior to spawning on female egg health. 2) the influence of delayed spawning or decreased progeny size on offspring survival due to cannibalism among broods. 3) feeding behavior of largemouth bass following angling, and 4) practical procedures (e.g. livewell conditions, weigh-in and release procedures) that can be implemented by tournament participants and organizers to further reduce initial and delayed largemouth bass mortality.

Our data suggest that live-well retention itself does result in a stress response, but if fish are provided with appropriate conditions, fish will actually recover during this period. Collectively, the results of our research program examining the effects of live-well retention on fish provide direction for fisheries managers, anglers, and tournament organizers to enhance the recovery and survival of fish retained in live-wells. The information we present is essential for ensuring adequate live-well management.

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

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

INTRODUCTION: There are a number of potential options that can be used to help manage bass populations in Illinois, including a variety of different harvest regulations such as size and bag limits, closed seasons, and spawning sanctuaries. Each of these has a different impact on the population, by affecting numbers and/or sizes of adults. Some regulations have the potential for impacting recruitment more than others, but little information is available comparing those impacts. We need to develop a theoretical framework by which we can assess how and why management regulations impact populations. To accomplish that task, we need to develop a conceptual model of how reproductive success is impacted by these various management actions, then develop a set of parental care decision rules that are based on field-developed parameters, and combine those to devise a predictive model that can help evaluate how best to manage bass populations under varying conditions.

The model we are developing is designed to determine how the reproductive success of a population changes under varying levels of fishing pressure, and how various management options affect that change. To establish baseline data, we need to determine a variety of parameters, some of which include density of nesting males along a shoreline (including how much variation exists within and among lakes), size and age of the nesting males, natural levels of brood abandonment (including how much variation exists among lakes and years), fishing pressure during the spawning season, vulnerability of nesting males to fishing (including how much variation exists among lakes as well as among male sizes), etc. The objective of this job is to use a combination of data gathered from studies in Illinois (including the creel and FAS databases), data gathered from our studies in Ontario, and literature studies to build this model.

Largemouth bass can be vulnerable to anglers while spawning and the success of the spawn may depend on stress the fish undergoes during this period. This has sparked a recent controversy in anglers whether or not bed fishing (angling fish off the nest) is detrimental to bass populations. Our recent research (Job 101.5) suggests that angling largemouth bass off the nest can cause the fish to abandon the nest, which results in the failure of the nest to produce offspring. Many states have implemented closed seasons or spawning refuges, which are closed to fishing in an attempt to alleviate this problem. It is unclear if these management techniques are appropriate for Illinois reservoirs.

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

PROCEDURES: We have constructed a conceptual model based on a population of bass in a hypothetical lake to describe how reproductive success is impacted by fishing. The hypothetical lake has 10 km of shoreline, a surface area of 1500 acres, and an annual spawning population of 1000 adult males (i.e., 1000 males receive eggs in a nest they construct). Factors affecting the number of successful nests in this model include fishing pressure, minimum length limits, abandonment rates, and protected spawning areas. We used abandonment rates determined from our angling manipulations in Lincoln Trail combined with this model to examine the effects of fishing pressure on nesting success.

Population abundance and size structure of largemouth bass were assessed in Clinton Lake using spring and fall electrofishing and seining in 1999-2003. Data collected before 2001 will be compared to samples collected after this time. Three shoreline electrofishing transects were performed on the lake in the fall and in the spring using AC electrofishing gear during the day. One electrofishing transect is located in the current refuge on Clinton Lake while the other two are located 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 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.

FINDINGS: In Lincoln Trail, abandonment rates were 30% for catch and release angling and 100% for simulated tournament angling (see job 101.5). Using this rate in the model, we would predict little change in the number of successful nests with changes in catch-and-release fishing pressure (Figure 6-1). Under a tournament angling scenario, our model would predict a strong decrease in nest success as fishing pressure increased.

Mean CPUE for largemouth bass in Clinton Lake from 1999 through 2003 was 22.6 fish per hour of electrofishing (Table 6-1). 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 refuge.

RECOMMENDATIONS: To refine the model, we will continue to measure natural parameters (i.e, size structure of nesting males, number of nests, and natural abandonment rates), and the effects of angling by experimental catch-and-release and tournament angling manipulations of nesting male bass. We will further develop our model by using creel survey data for fishing pressure and our tournament data for characteristics of bass vulnerable to angling.

We will continue to monitor largemouth bass abundance and size structure in the Clinton Lake refuge through the next several field seasons. Access must be gained to the closed area of the lake in order to perform sampling after the implementation of the refuge. Sampling will also continue at all other sites on the lake in order to determine the local and lake-wide effects of the refuge. In future segments, we will also analyze electrofishing and seine CPUE data for young of year bass production.

Job 101.7. Analysis and reporting.

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

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

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

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

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

Lake	Stocking Date	Size (mm)	Stocking Mortality (%)	Lake Temp	Number of Largemout Bass Stomachs Examined	Empty stomachs	# of stocked fish consumed	% of predators with stocked LMB in stomach
Charleston	7/22/2002	55	2.41	31	83	52	3	3.61
	9/3/2002	104	0.00	30	49	78	3	6.12
	9/16/2002	162	0.00	25	8	97	0	0.00
	5/12/2003	188	0.00	19.3	7	100	0	0.00
Homer	7/22/2002	55	6.02	29.4	96	51	2	2.08
	9/4/2002	105	0.00	28	84	66	2	2.38
	9/16/2002	163	0.00	25.3	18	92	0	0.00
	5/12/2003	188	0.00	17.4	26	100	0	0.00

Table 2-2. Comparison of survival among three sizes of stocked and naturally produced largemouth bass. Catch per unit effort (CPUE) is the mean from electrofishing samples performed in the fall of 2002 and spring of 2003. CPUE is reported as number of fish per hour of AC electrofishing.

Lake	Size	Fall CPUE	Spring CPUE
CHARLESTON	Natural	3.9	1.3
	4	11.2	2.0
	6	4.9	2.4
	8	0.0	16.3
HOMER	Natural	11.9	8.6
	4	3.4	0.0
	6	4.5	1.1
	8	0.0	2.0

Table 2-3. Largemouth bass stocking summaries for lakes Jacksonville, Shelbyville, and Walton Park. Intensively reared bass were raised in raceways while extensively reared bass were raised in ponds. Catch per unit effort (CPUE) is based on the number of fish collected per hour of daytime AC electrofishing in fall and spring months.

Lake	Rearing Technique	Number Stocked	Fall CPUE	Spring CPUE
Jacksonville	Intensive	5000	5.00	5.00
	Extensive	15000	0.00	2.00
Shelbyville	Intensive	8800	0.00	3.64
	Extensive	35000	6.00	10.00
Walton Park	Intensive	1250	21.67	0.00
	Extensive	1250	5.33	0.00

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

Source	Pre-Stocking Genotypes (N)			Pre-Stocking Allele Frequencies		Post-Stocking Collection (N)
				1	2	
Little Grassy Fish Hatchery	1/1 (0)	1/2 (05)	2/2 (262)	0.05	0.95	100
Forbes	1/1 (81)	1/2 (49)	2/2 (28)	0.67	0.33	98
McCleansboro	1/1 (23)	1/2 (34)	2/2 (32)	0.45	0.55	105
Murphysboro	1/1 (80)	1/2 (12)	2/2 (06)	0.88	0.12	108
Sam Parr	1/1 (75)	1/2 (16)	2/2 (10)	0.82	0.18	107
Shelbyville	1/1 (158)	1/2 (45)	2/2 (08)	0.86	0.14	100
Walton Park	1/1 (66)	1/2 (11)	2/2 (08)	0.84	0.16	50

Table 4-1. Average values of total phosphorus (TP; μg/L), chlorophyll *a* (chloro; μg/L), zooplankton (zoop; N/L), benthos (N/m^2), larval fish (larval; N/m^3), juvenile bluegill (blg; N/m^2), and aquatic vegetation (veg; ft^2) in the twelve study reservoirs during 2002. Data that are starred (*) will be presented in future reports.

Lake	TP	chloro	zoop	benthos	larval	blg	veg
Clinton	477	29.6	8.26	1011	1.35	0.06	*
Dolan	152	45.2	34.17	*	2.9	0.24	*
Forbes	82	20.8	35.32	*	7.8	0.56	*
Lake of t. Woods	66	27.4	83.1	11440	21.1	8.58	5357
Lincoln Trail	75	16.6	26.3	6407	409	2.63	2645
Paradise	229	37.8	29.5	2824	16.9	0.07	*
Pierce	80	34.9	43.6	6574	10.8	1.47	*
Ridge	90	12	166	4012	2.02	3.69	*
Shelbyville	100	22.6	24	839	12.6	0.04	*
Sterling	43	4.46	54.9	5013	7.99	0.11	1438
Walnut Point	82	36.1	28.9	6055	*	1.93	163
Woods	182	31	33	2757	6.89	0.46	0

Table 4-2. Spearman correlation coefficients for the relationships between the mean densities of YOY largemouth bass (N/m^2) during 2002 and average values of total phosphorus (TP; µg/L), chlorophyll *a* (chlorophyll; µg/L), zooplankton (N/L), benthos (N/m^2), larval fish (N/m^3), and juvenile bluegill (bluegill; N/m^2). Sample size is 12 for all variables except benthos (N = 10) and larval fish (N = 11). * is $P \leq 0.05$, ** is $P \leq 0.01$, and *** is $P \leq 0.001$.

Lake	TP	Chlorophyll	Zooplankton	Benthos	Larval fish	Bluegill
May	-0.46	0.01	-0.15	0.59	0.67*	0.61*
Jun	-0.29	-0.19	0.22	0.49	-0.3	0.67*
Jul	-0.36	-0.18	0.28	0.6	0.03	0.85***
Aug	-0.65*	-0.3	0.28	0.77**	0.23	0.86***
Sep	-0.53	-0.13	0.45	0.74**	0.12	0.96***
Oct	-0.30	-0.23	0.35	0.43	0.02	0.70**

Table 4-3. Catch per unit effort (N/hr) of largemouth bass recruited to age-1. Abundances are means of largemouth bass captured by AC electrofishing three shoreline transects for 0.5 hour each in the spring. Data that are not available are starred (*).

Lake	1999	2000	2001	2002
Clinton	8.17	4	1.33	2.58
Dolan	*	0.67	16.8	1
Forbes	8.22	15	4.89	1.78
Lake of t. Woods	2.5	*	3.17	3.59
Lincoln	30	26.7	5.78	7.11
Paradise	0.67	0.67	1	0
Pierce	44.9	7	31.3	11.1
Ridge	10.3	1.43	24.3	0.12
Shelbyville	1.34	4.5	3.84	8.39
Sterling	6	6	4	0
Walnut Point	29	6	32.7	10.3
Woods	6.57	5.33	2.06	1.33

Table 5-1. Abandonment rate of male largemouth bass collected from nests with either catch and release or tournament angling.

Sample Date	Treatment	Number Nests	Number Abandoned	% Abandoned
5/11,16/00	C & R Angling	10	3	30
5/8/01, 5/1/03	Tourn. Angling	5	5	100

Table 5-2. Number of nests found by snorkel surveys in Lincoln Trail Lake, number receiving electrofishing and control treatments, and the number of abandoning males. Abandonment rates of nesting males are given for each date, each treatment, and all dates combined by treatment.

			Electrofish		Control	
Date	# Nests Found		# Nests Treated	% Abandonment	# Nests Treated	% Abandonment
4/22/03	44		17	47	22	9
4/29/03	28		8	38	12	17
5/1/03	19		9	33	9	11
Total # Nests	**91**	**Mean Abandonment Rates (%)**		**39**		**12**

Table 5-3. Number of fish surveyed, sex ratios, average TL, and percent spawning bass from tournaments on Mill Creek, Mattoon, Shelbyville, and Steven Forbes during spawn and post-spawn 1999 thru 2003. Percent spawning are given for males, females, and all fish combined.

Lake		N	Sex Ratio (males:females)	Mean TL(mm)		Percent Spawning		
				Males	Females	Males	Females	Total
Forbes								
	Spawn	70	1.41:1	408.6	455.3	39.0	65.5	50.0
	Post-spawn	39	1.81:1	439.2	398.9			
Mattoon								
	Spawn	72	1.12:1	405.4	438.2	34.2	70.5	51.4
	Post-spawn	8	1:1.5	386.5	373.3			
Mill Creek								
	Spawn	149	2.3:1	357.4	425.7	44.0	63.0	50.0
	Post-spawn	44	1:1.39	398.2	404.6			
Shelbyville								
	Spawn	123	1:1.2	393	419	40.0	34.0	37.0
	Post-spawn	202	1:1	411.6	430.5			

Table 5-4. Average total length, weight, number, and age (± 1 SE) of adult and resulting age-0 largemouth bass between ponds stocked with stressed and non-stressed (control) adult largemouth bass. Comparisons for all response variables between treatments were analyzed with mixed model, nested analysis of variance except number that was compared with a one-way analysis of variance.

		Stressed		Control		Contrasts	
		Mean	SE	Mean	SE	F-value (df)	P-value
Adult Largemouth Bass							
Male	Length (mm)	357	± 4	363	± 8	0.11 (1, 6)	0.75
	Weight (g)	597	± 39	641	± 90	0.13 (1, 6)	0.72
Female	Length (mm)	385	± 12	386	± 15	0.01 (1, 6)	0.94
	Weight (g)	866	± 76	944	± 104	0.19 (1, 6)	0.66
Age-0 Largemouth Bass							
	Length (mm)	31	± 0.38	35	± 0.43	40.94 (1, 6)	< 0.01
	Weight (g)	0.59	± 0.03	0.76	± 0.04	10.84 (1, 6)	< 0.01
	Number	214	± 54	444	± 239	0.88 (1, 6)	0.38
	Age (days)	48	± 0.63	50	± 0.58	3.64 (1, 6)	0.05

Table 6-1. Catch per unit effort (CPUE) for control and refuge electrofishing transects performed proir to the closing of the refuge area. CPUE is the number of Largemouth bass collected per hour o AC electrofishing.

Year	Control		Refuge	
	Spring	Fall	Spring	Fall
1999	28.8	33.0	56.0	48.0
2000	32.4	8.0	18.0	2.4
2001	26.0	48.7	10.0	22.0

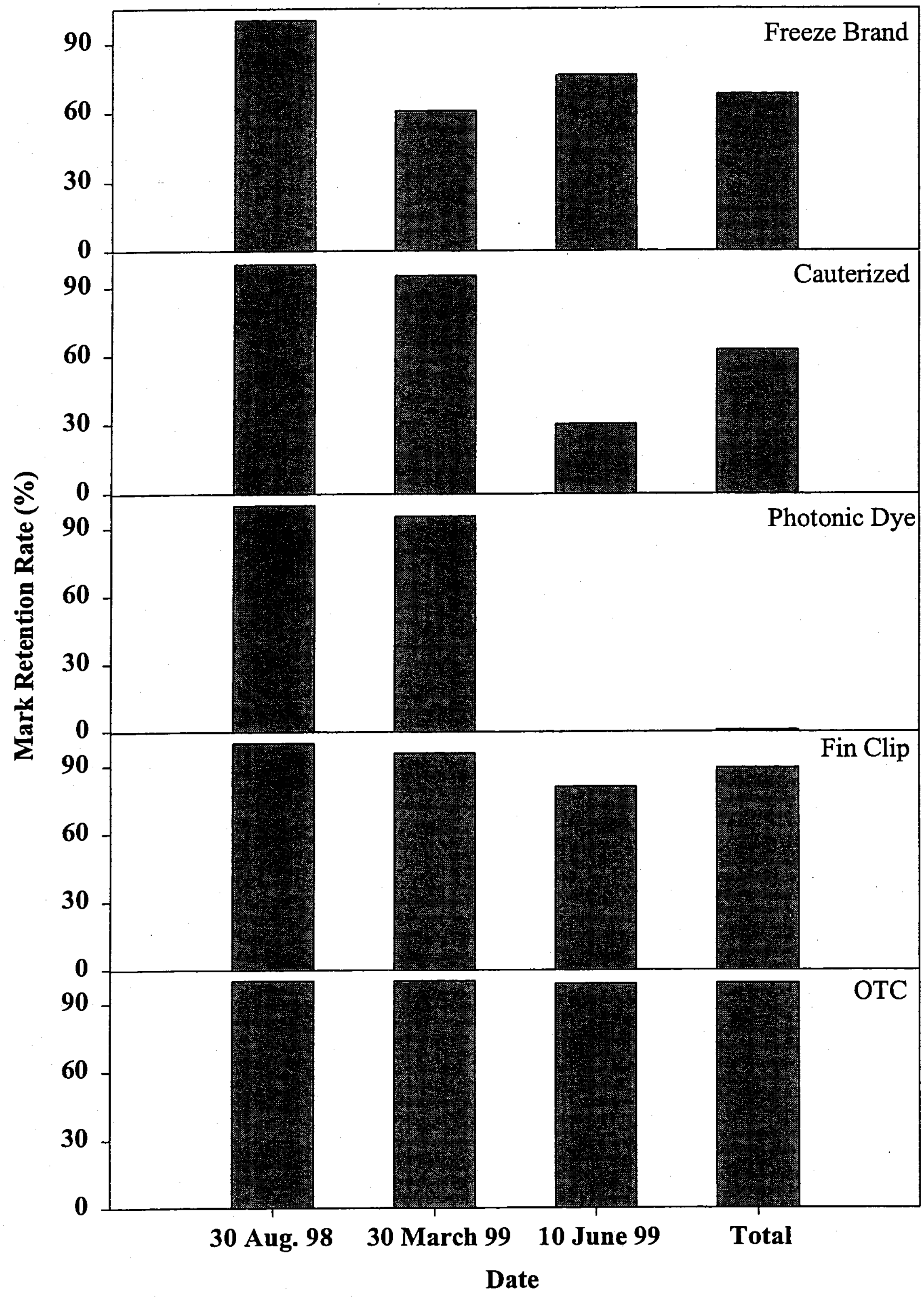

Figure 1-1. Retention rates for freeze brands, fin cauterizations, photonic dye, fin clips, and oxytetracycline (OTC) marks applied to 2" fingerling largemouth bass. Total represents the cumulative percent of visible marks for all dates combined.

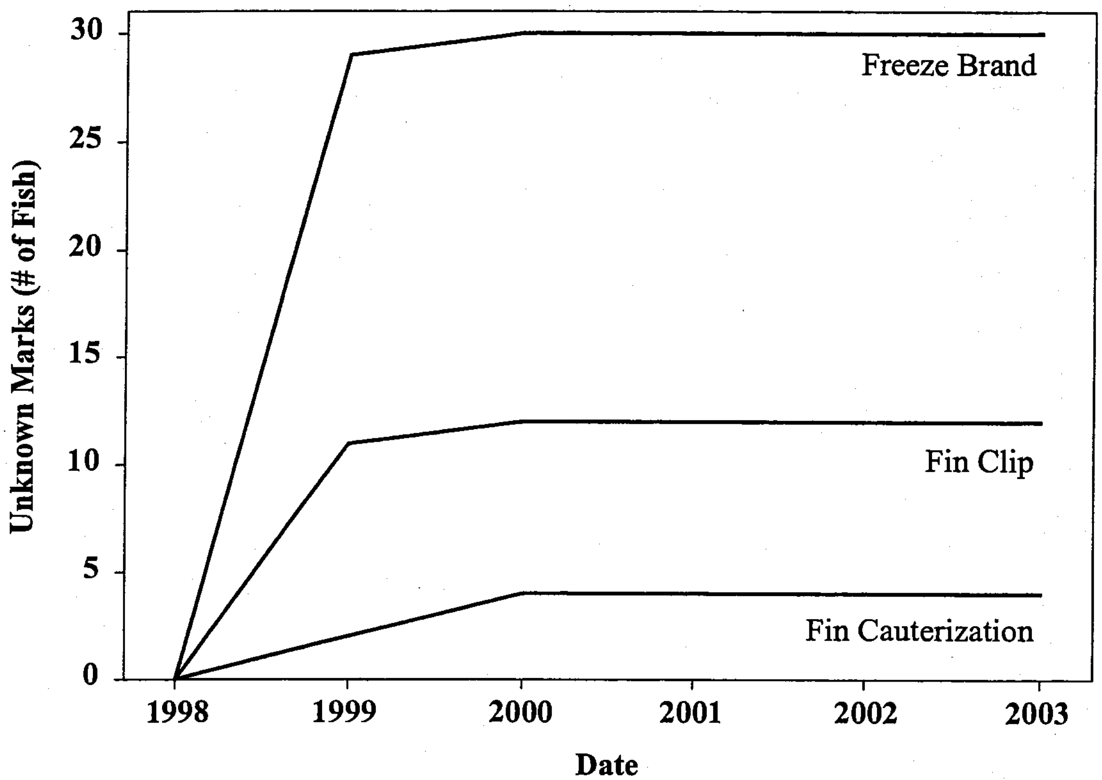

Figure 1-2. Cummulative number of 4" largemouth bass with unrecognizable marks sacrificed and identified by 1:1 (Fin Clip), 1:2 (Freeze Brand), or 2:2 (Fin Cauterization) MDH-B genotype for each date sampled.

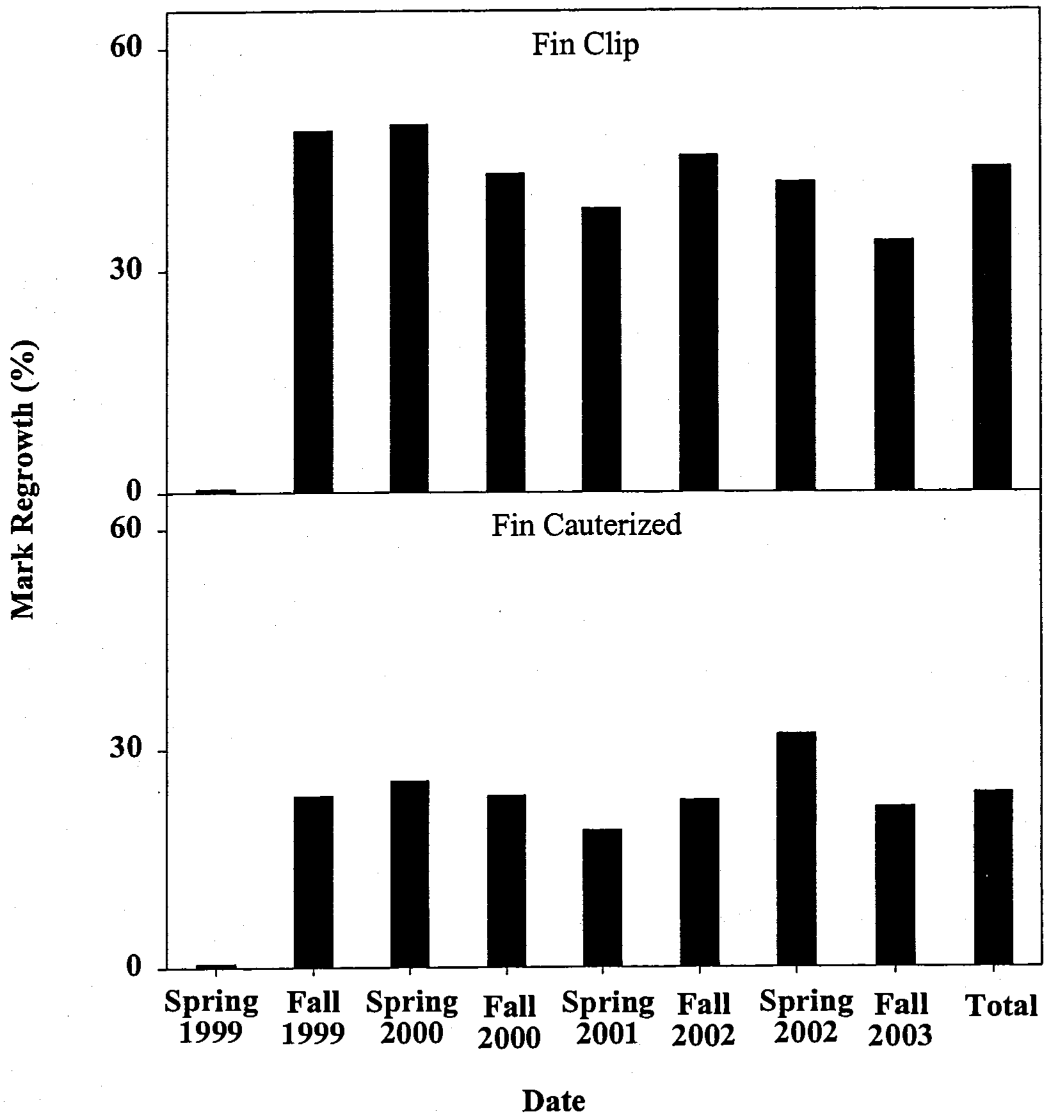

Figure 1-3. Average mark regrowth (%) for fin clip, fin cauterized, and freeze brand marked 4" largemouth bass through time. Total denotes experiment wise average (%) regrowth for fin clip and fin cauterized marks.

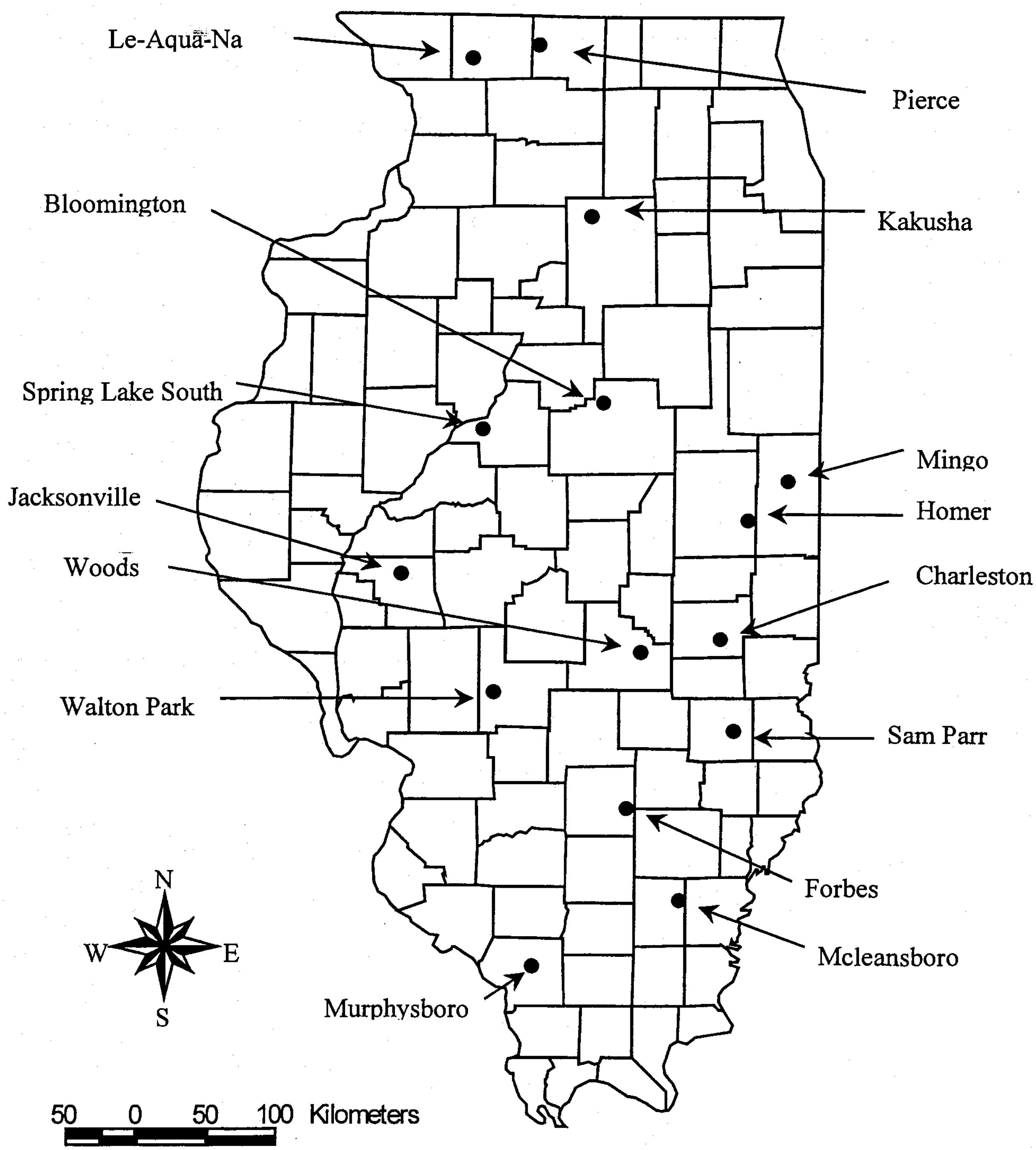

Figure 2-1. Location of 15 lakes in Illinois stocked with fingerling largemouth bass in 1999 – 2003.

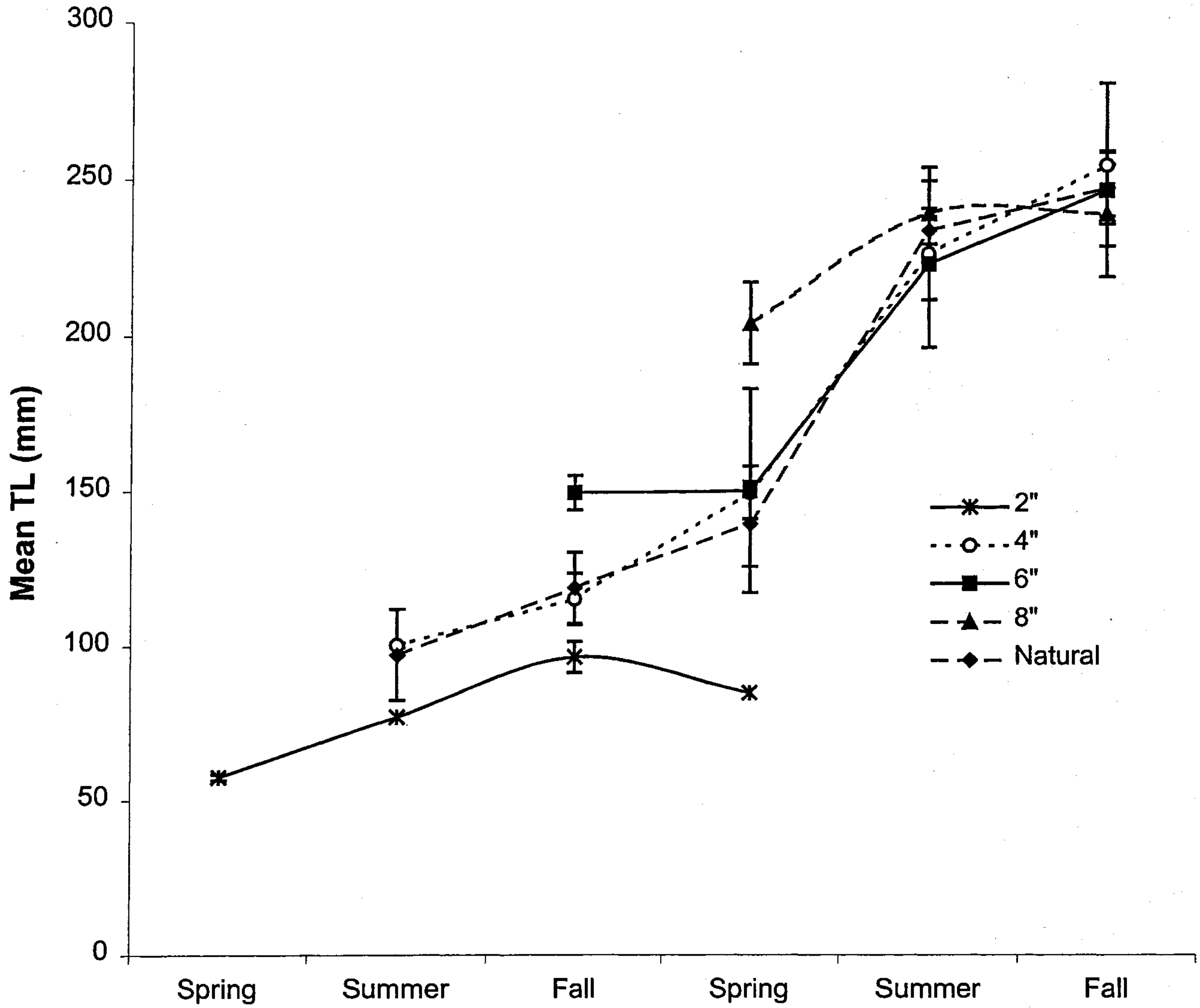

Figure 2-2. Mean growth through time of different sized largemouth bass after stocking in 4 reservoirs in 3 years during 1998-2003. Values are mean total length (mm) +/- 1SE in each season following stocking.

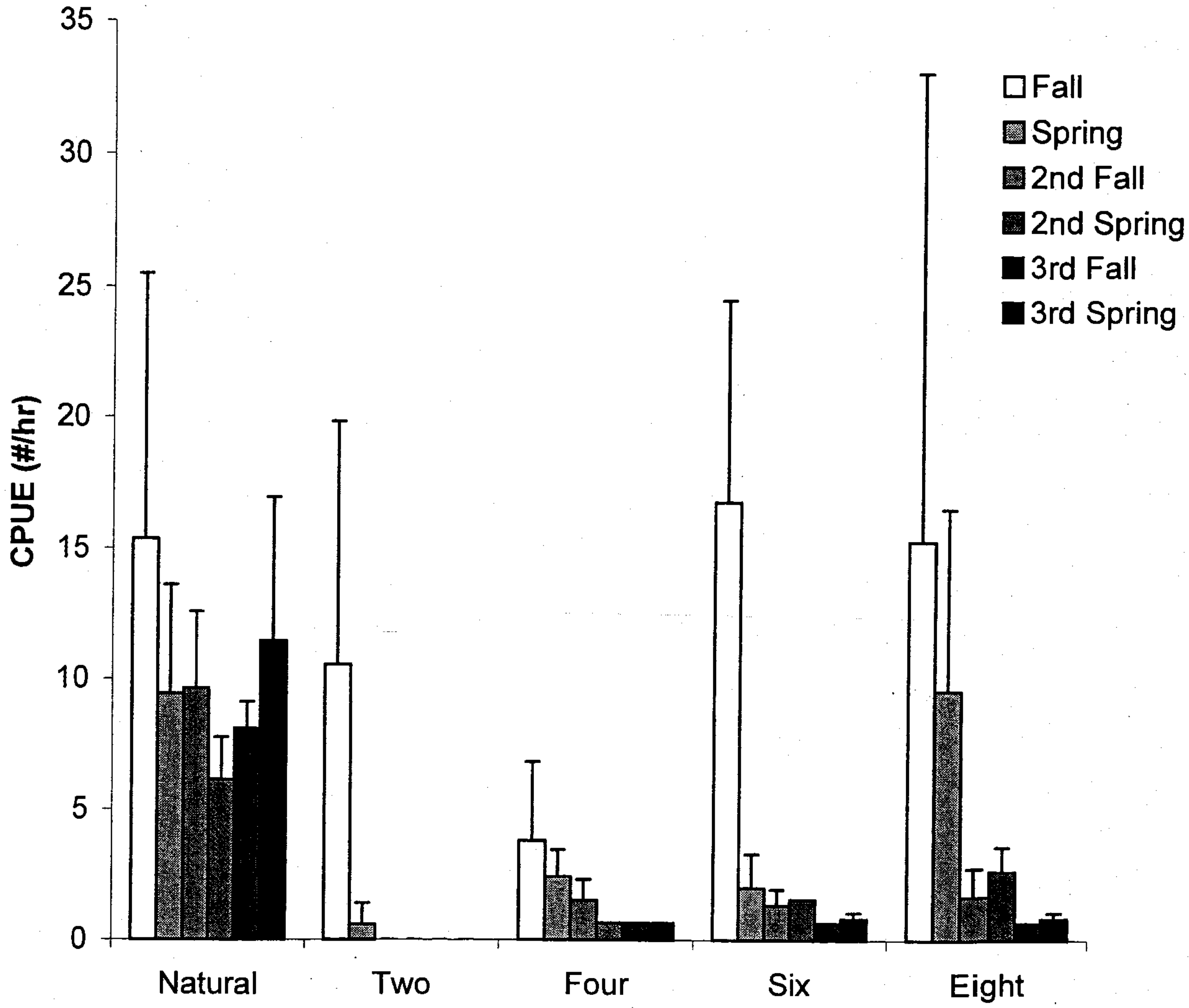

Figure 2-3. Catch per unit effort (CPUE) through time for different sizes of stocked largemouth bass in 4 reservoirs in 3 years during 1998-2003. Catch per unit effort is the number of fish per hour of AC electrofishing.

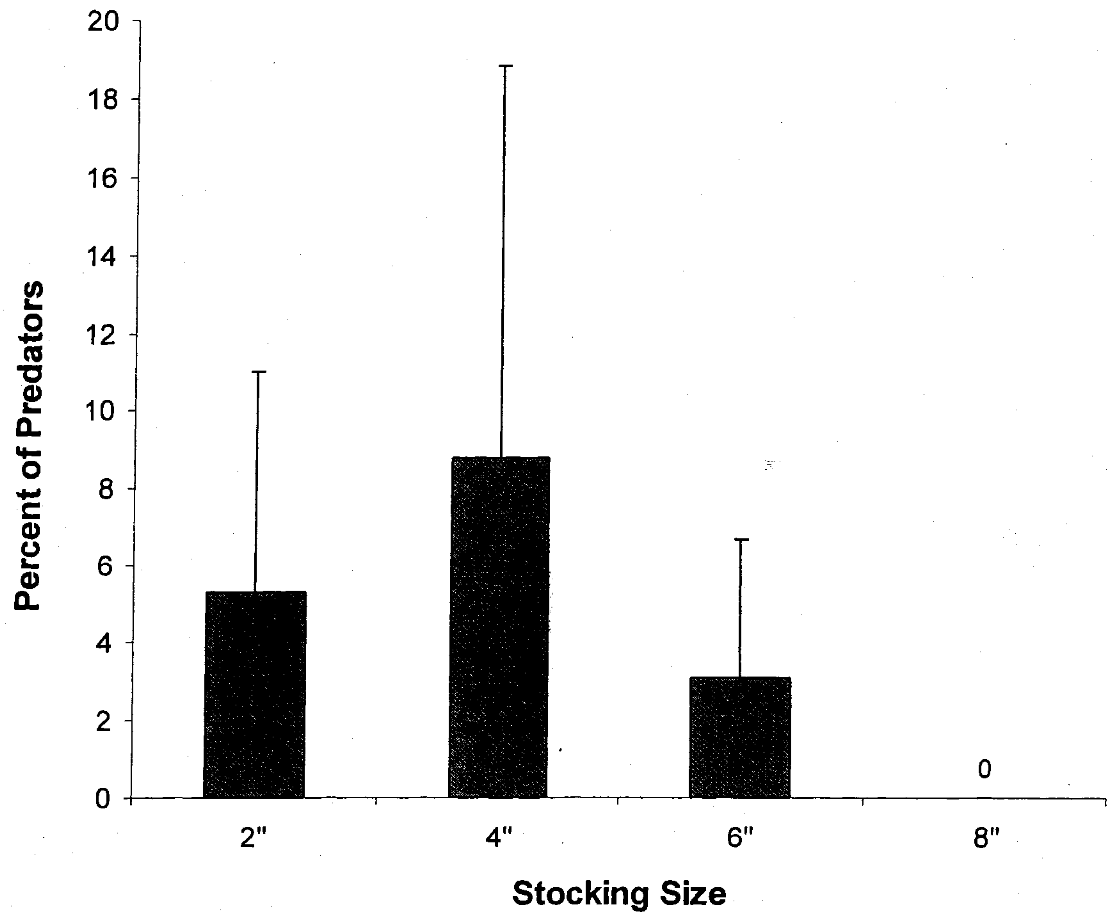

Figure 2-4. Percent of largemouth bass predators with stocked bass in their diet in 4 reservoirs in 3 years during 1998-2003. Values represent the mean percent (+/- 1 SE) of predators with stocked largemouth bass in their diets following stocking. No predation was observed prior to stocking.

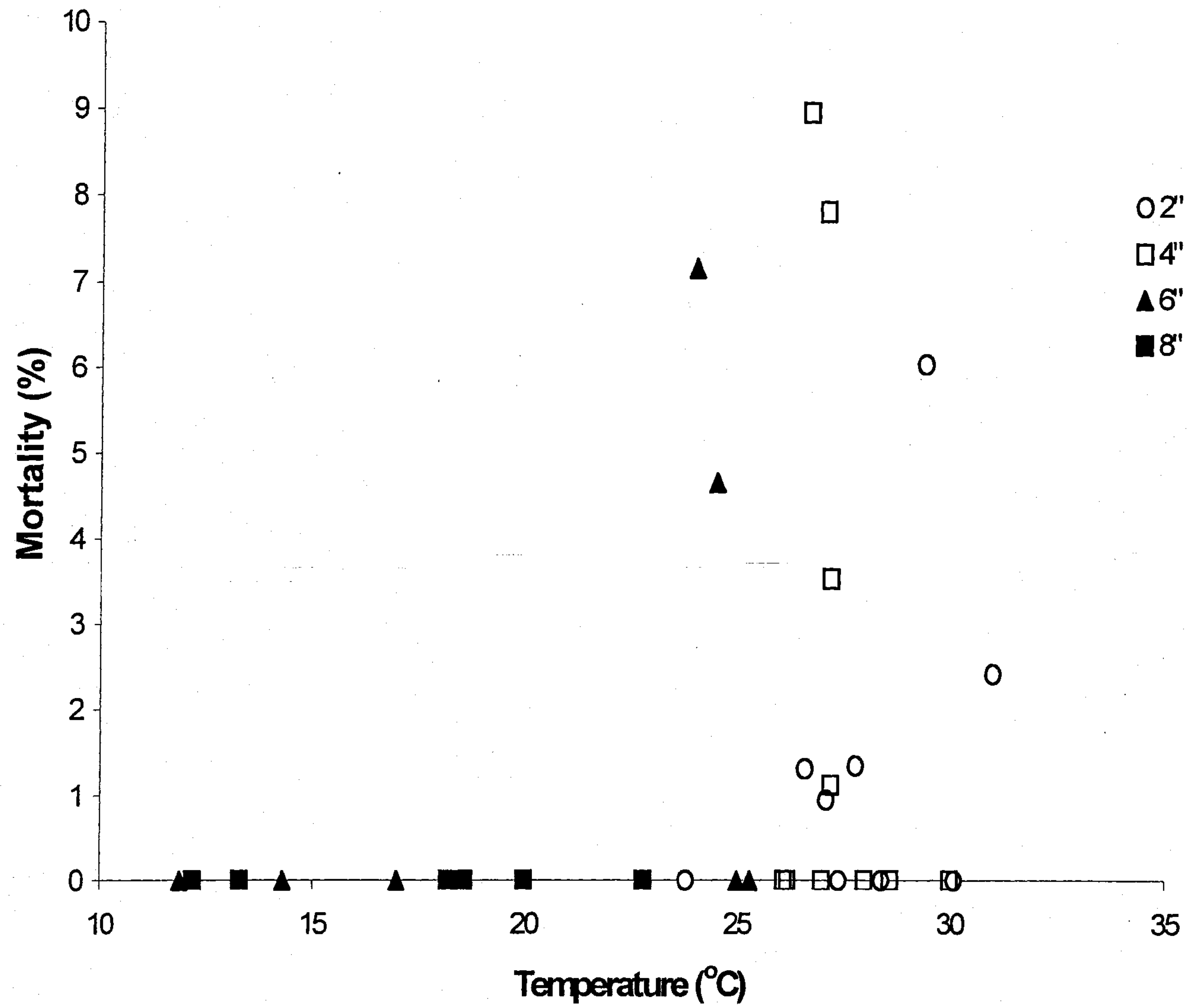

Figure 2-5. Relationship between mortality at stocking and temperature. Stocking mortality was estimated by holding bass in 3 mesh cages and counting the number of dead after 48 hours. Temperature is the lake surface temperature at the time of stocking.

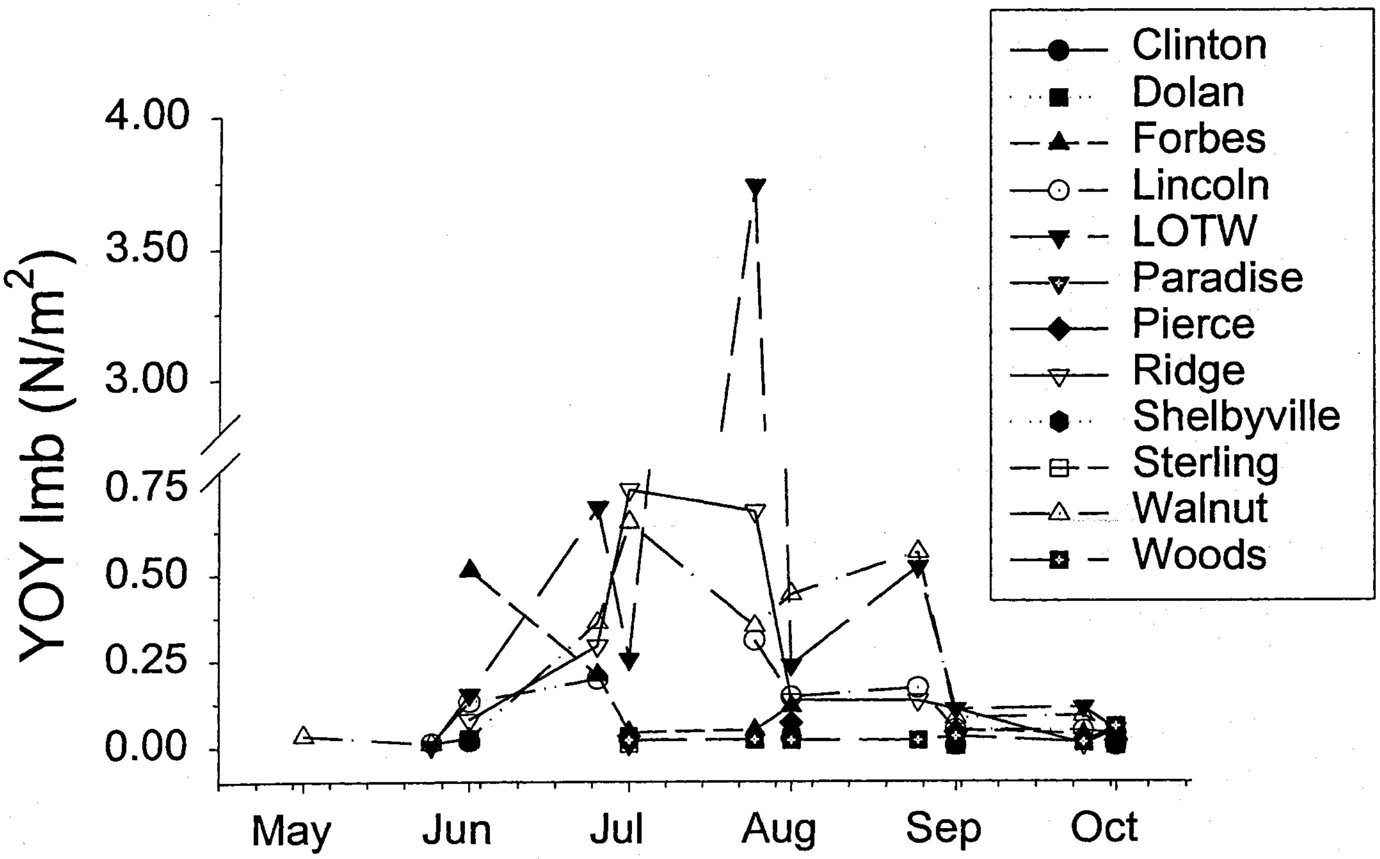

Figure 4-1. Average monthly young of the year (YOY) largemouth bass densities (N/m^2) for 12 study lakes. Largemouth bass were collected with a 9.2-m bag seine from 4 stations in each lake. Closed symbols represent lakes with gizzard shad, whereas, open symbols represent lakes without gizzard shad.

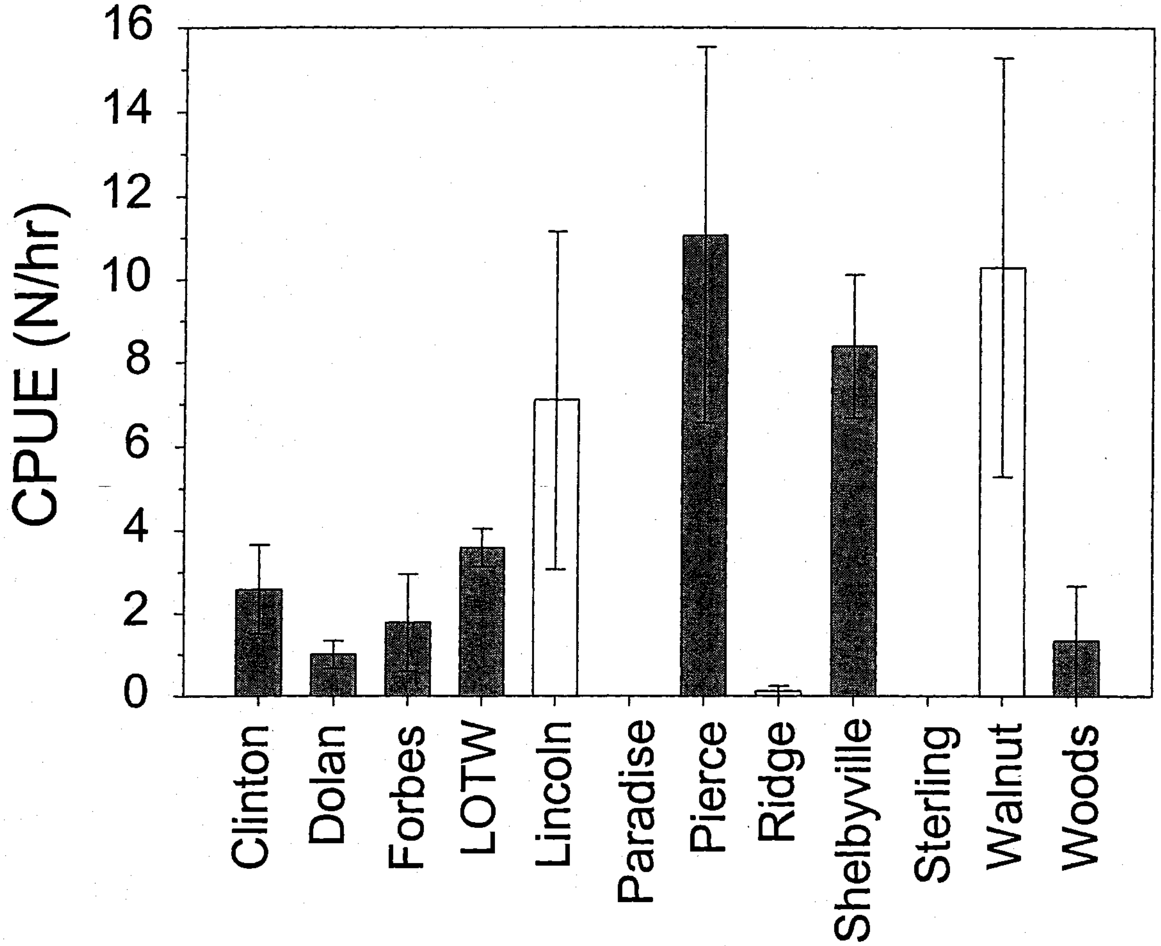

Figure 4-2. Average catch per unit effort (CPUE; N/hr ± 1 SE) of largemouth bass recruiting to age-1. Based on annual otolith rings, largemouth bass < 150 mm TL were considered to be YOY. Shaded bars represent lakes with gizzard shad, whereas open bars represent lakes without gizzard shad.

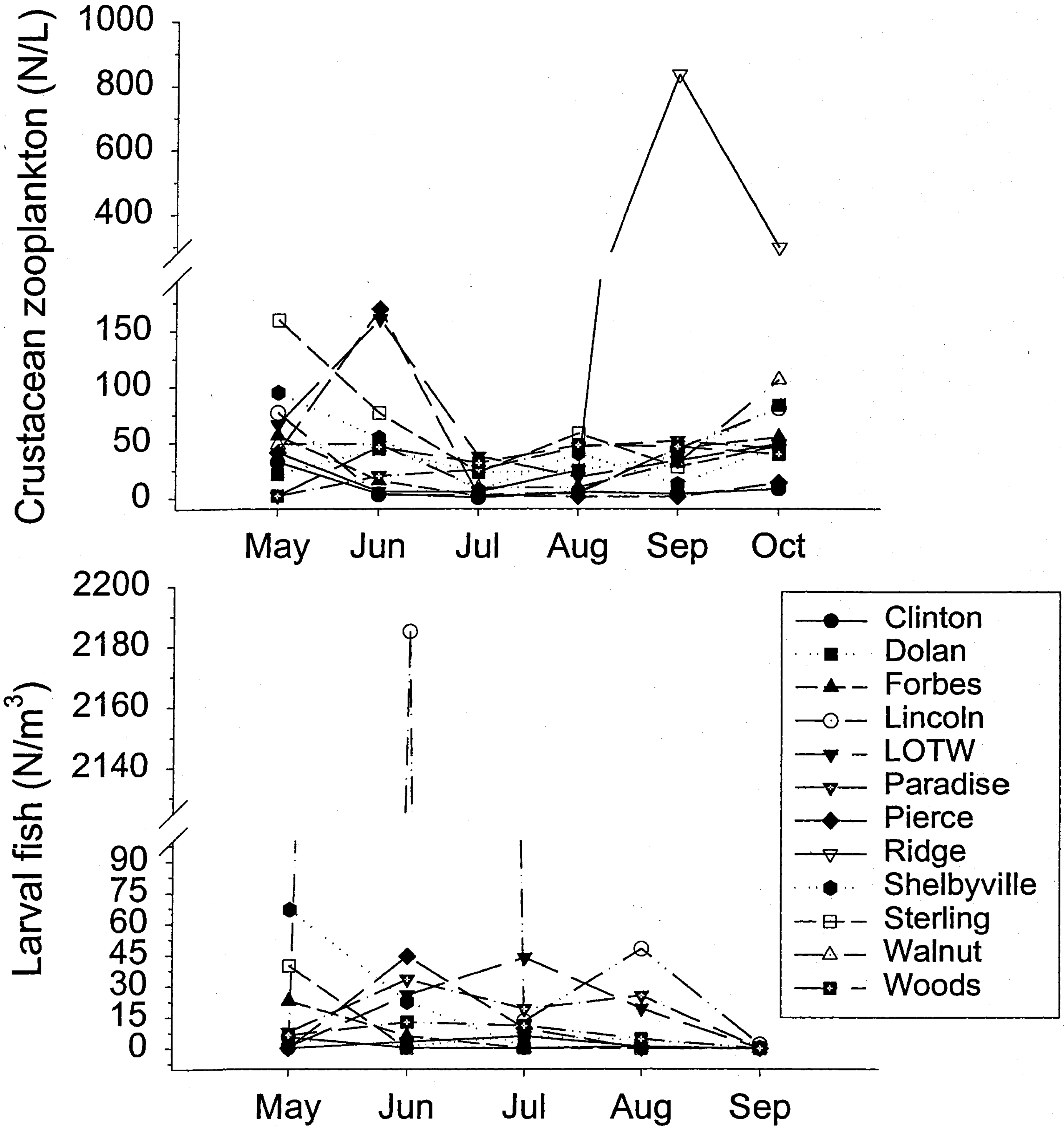

Figure 4-3. Average monthly densities of (a) inshore crustacean zooplankton (N/L) and (b) larval fish (N/m3). Closed symbols represent lakes with gizzard shad and open symbols represent lakes without gizzard shad. Walnut Point is not included in the larval fish graph.

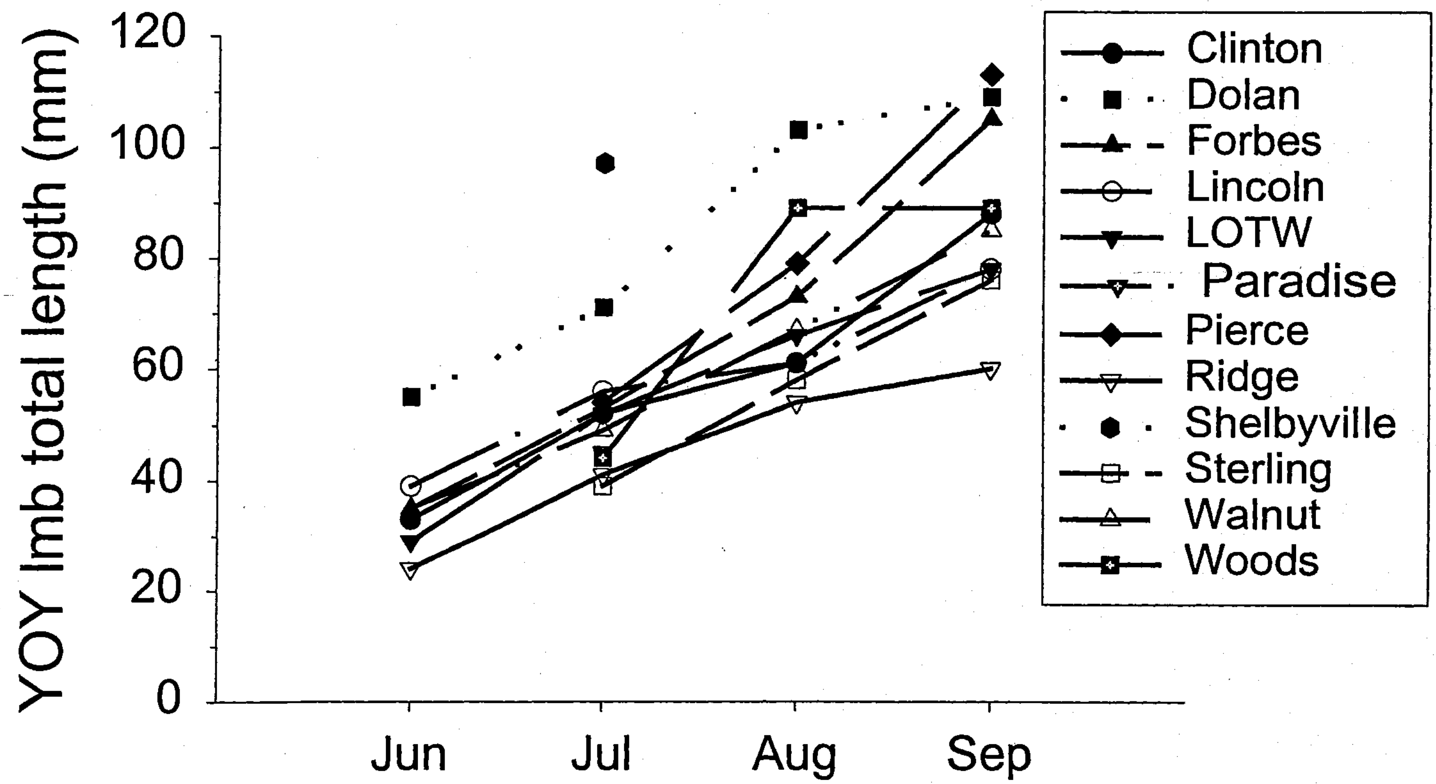

Figure 4-4. Average total length (mm) of young of the year largemouth bass collected from 12 study lakes. Largemouth bass were collected with a 9.2-m bag seine from 4 stations in each lake. Closed symbols represent lakes with gizzard shad, whereas open symbols are lakes without gizzard shad.

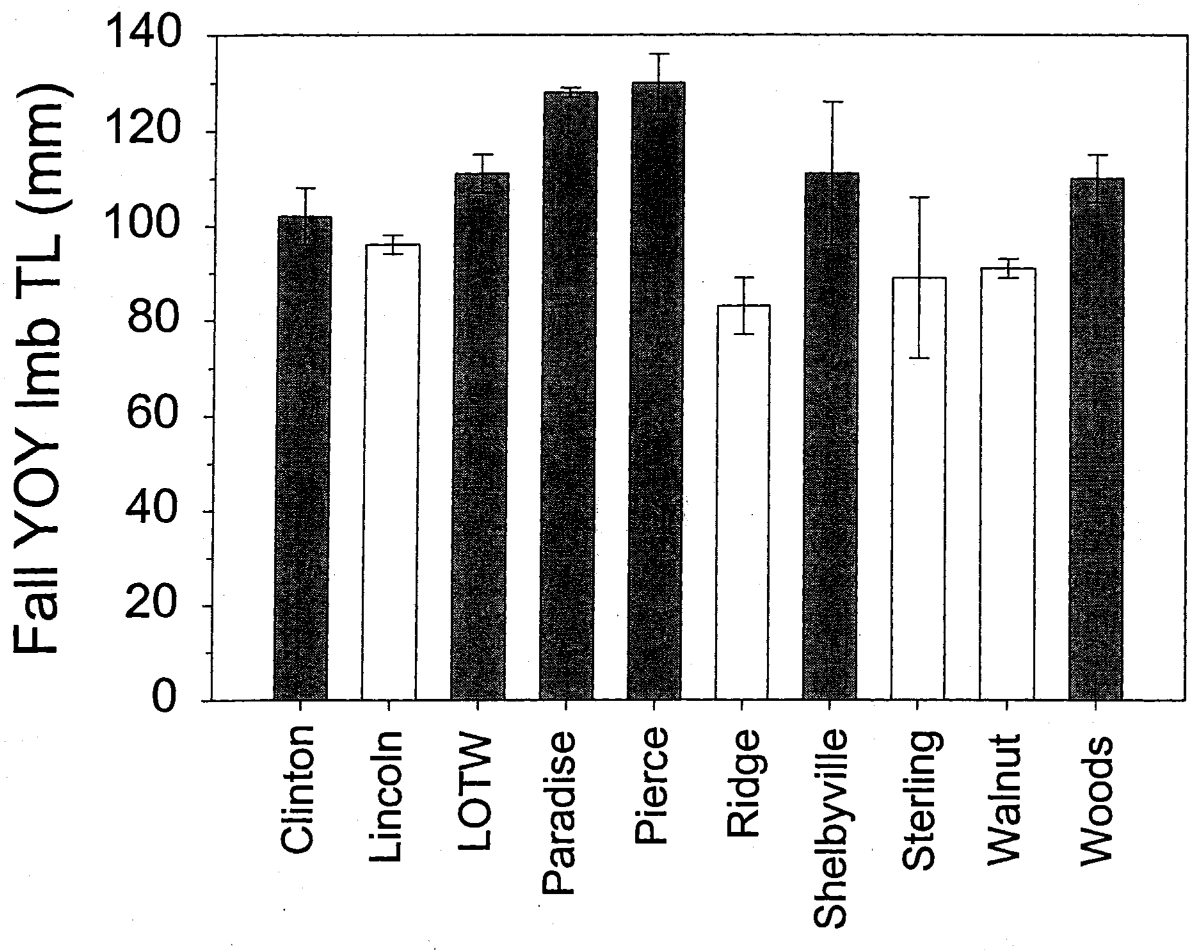

Figure 4-5. Average fall total length (mm ± 1 SE) of young of the year largemouth bass collected from 12 study lakes. Largemouth bass were collected from late September to early October using A.C. electrofishing along 3 shoreline transects for a 0.5 hour each.

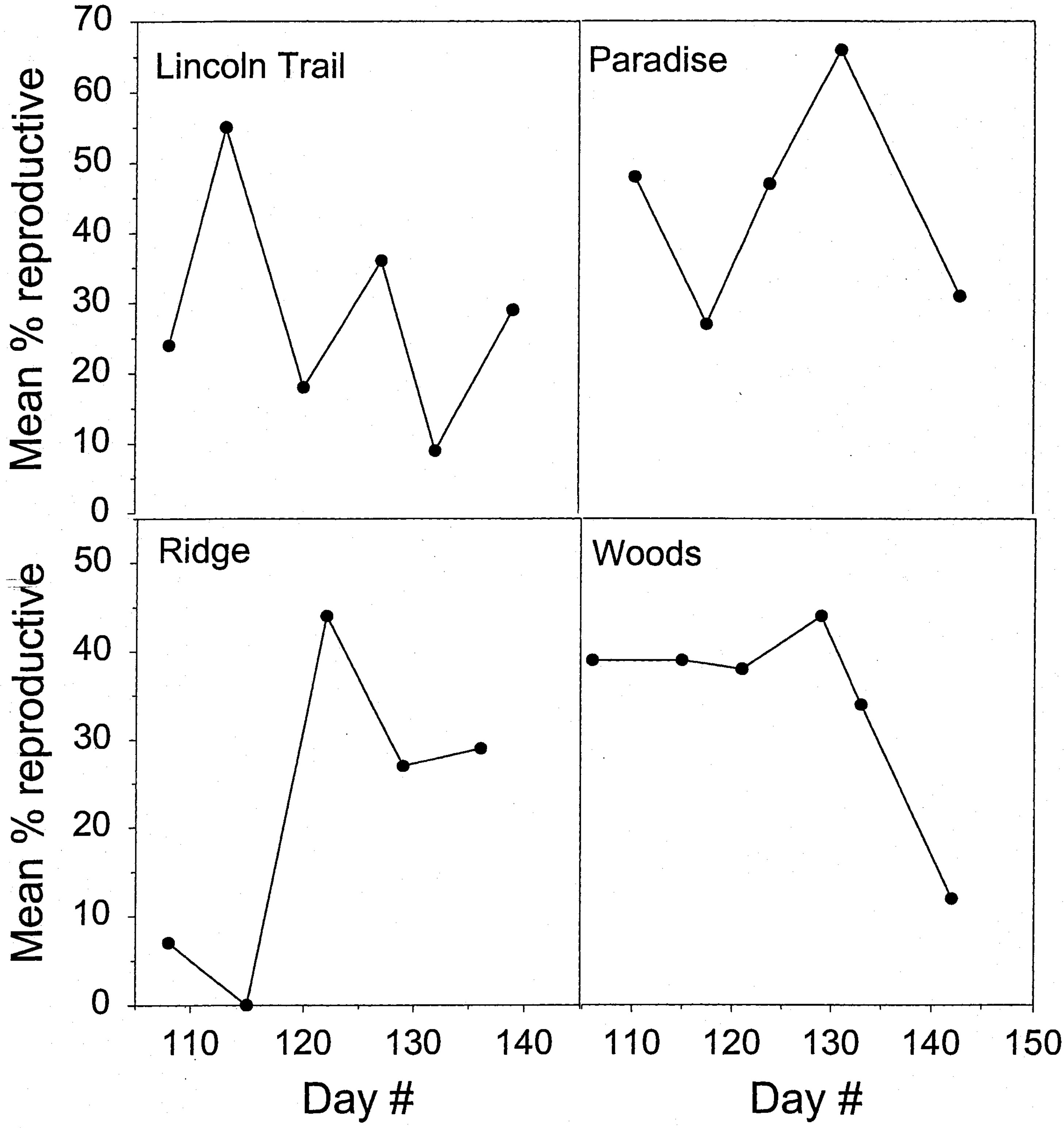

Figure 4-6. Mean percentage over time of total largemouth bass catch that was in reproductive condition during spring 2003. Male largemouth bass were considered reproductive if gametes were freely flowing, and female bass were considered reproductive if they were in ripe condition (e.g., freely flowing gametes or swollen condition). All bass were captured using 0.5 hour of AC electrofishing along three shoreline transects.

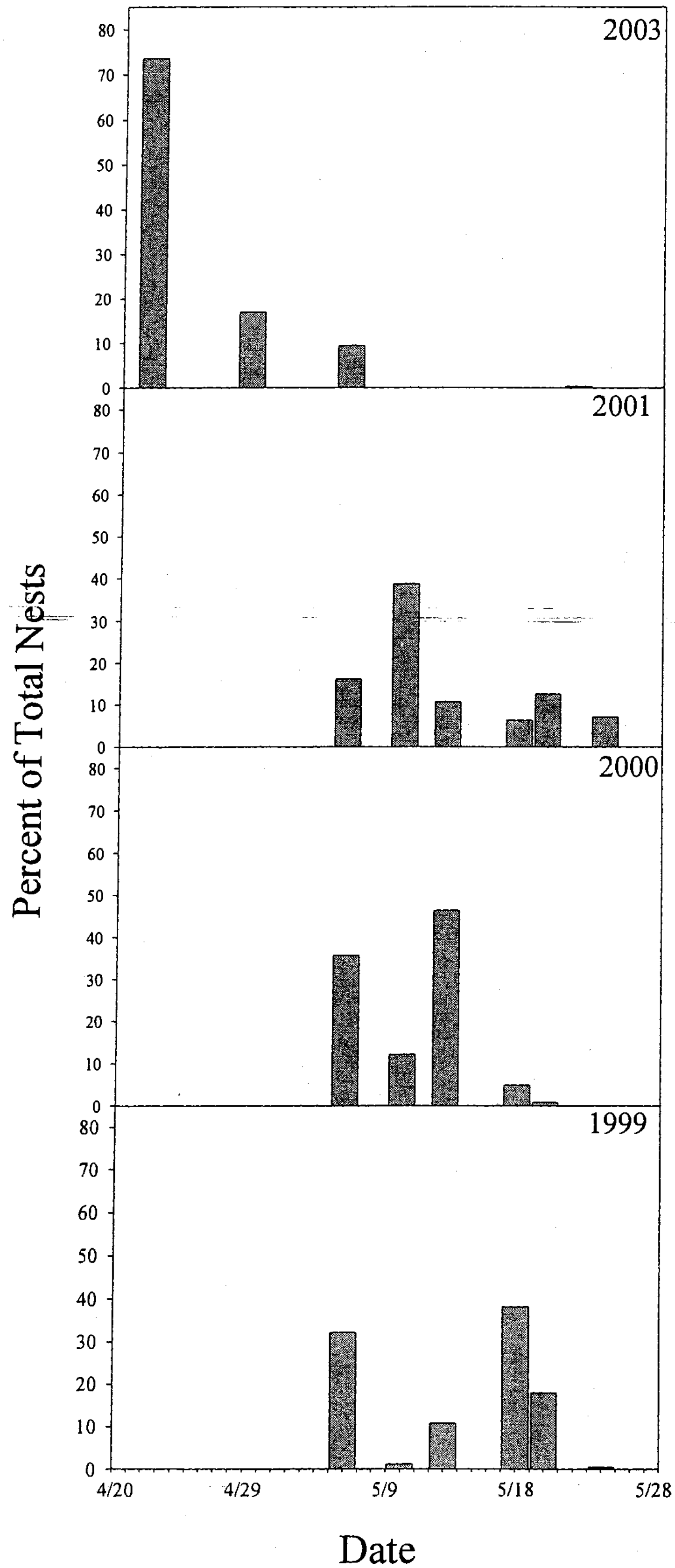

Figure 5-1. Number of new largemouth bass nests as a percentage of the total number observed by date for 1999 through 2003 on Lincoln Trail Lake.

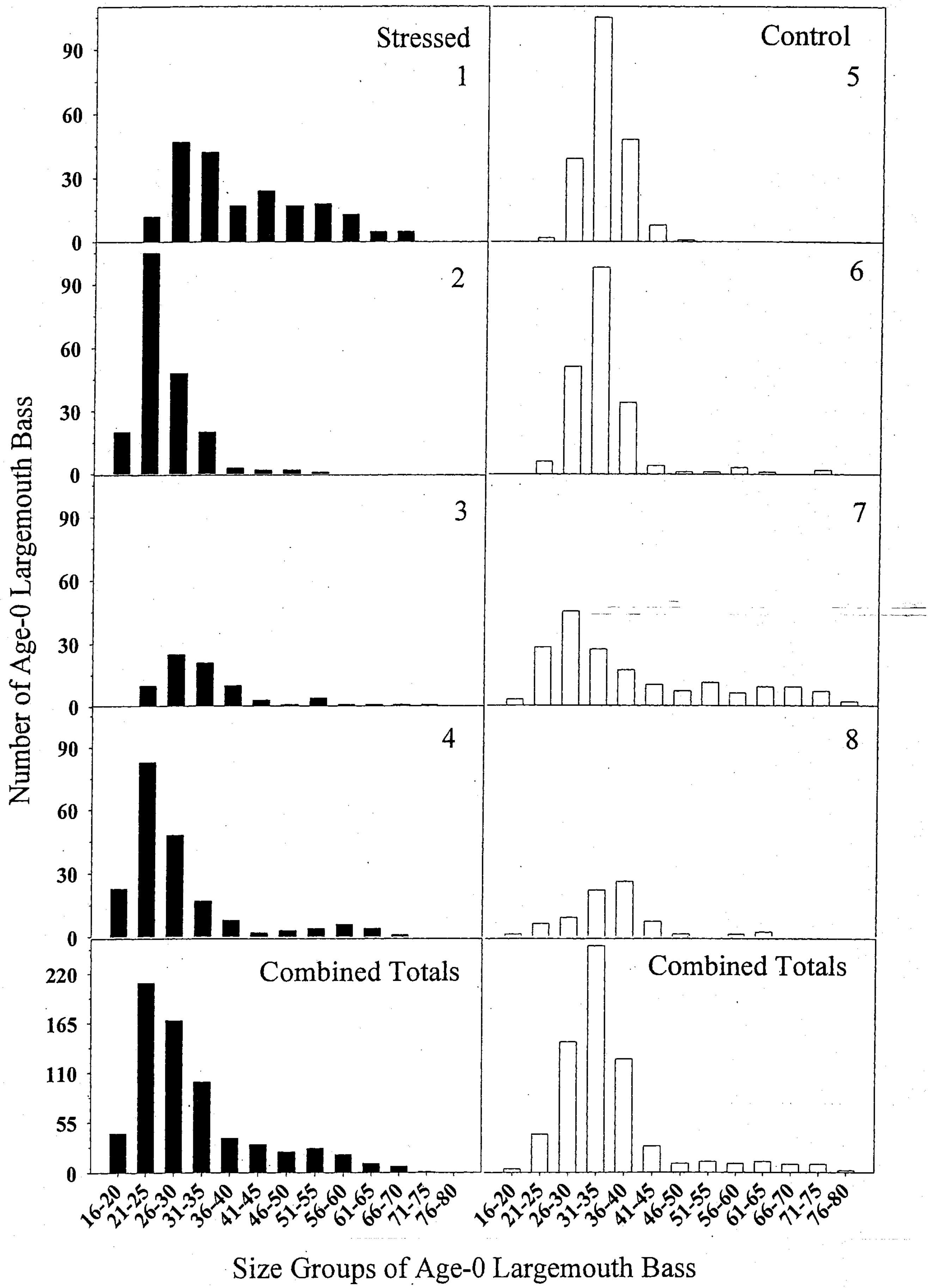

Figure 5-2. Length frequency distribution (%) by 4-mm size increments of age-0 largemouth bass produced by either stressed (panels 1-4) or non-stressed (panels 5-8) adults. Totals in the bottom panels represent fish combined across treatments (N = 4 ponds/treatment).

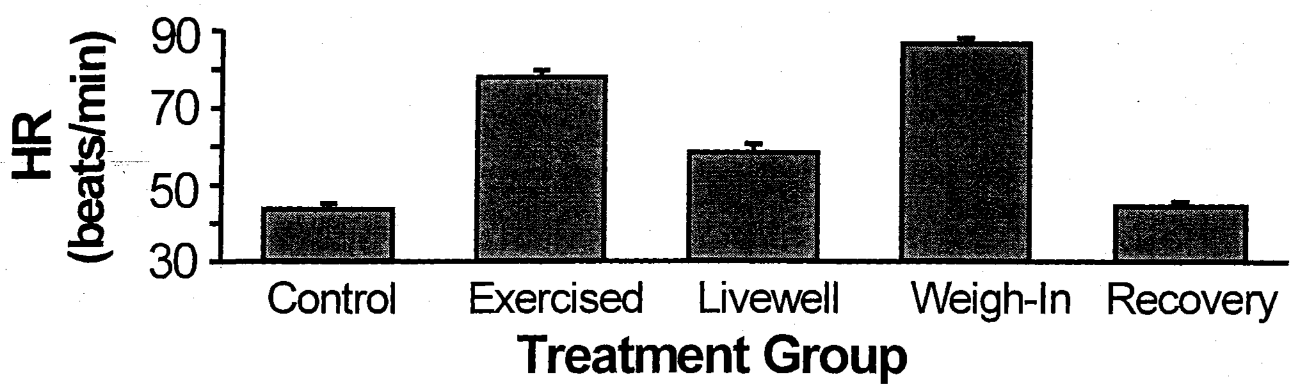

Figure 5-3. Heart rate of largemouth bass during different components of a catch-and-release angling tournament. Note that when provided with appropriate conditions in the livewell, including low density of fish, minimal disturbance, and adequate water quality, fish actually begin recovery, as evidenced by lower heart rates than fish that are just angled (exercised).

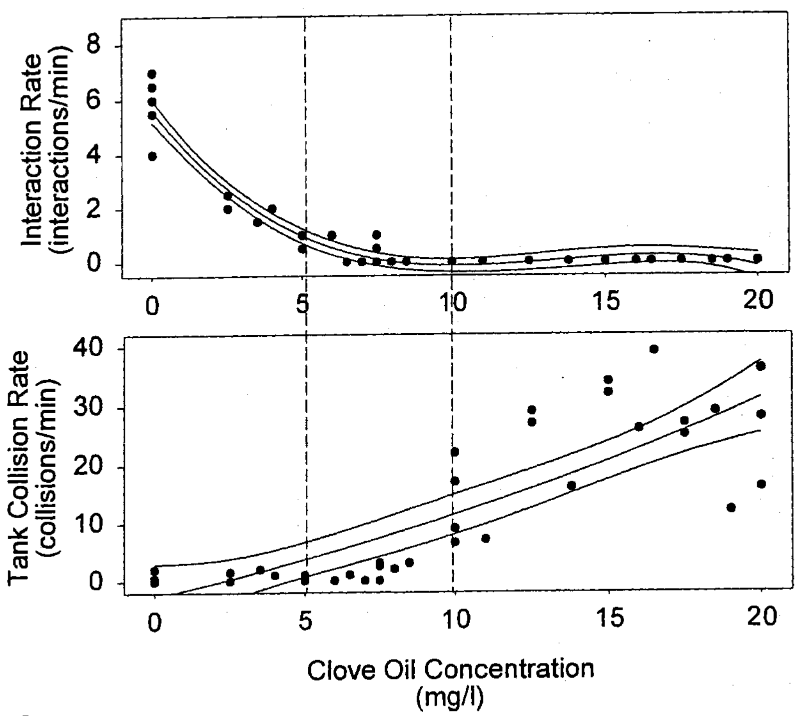

Figure 5-4. Behavior of largemouth bass during exposure to rough conditions intended to simulate conditions during livewell retention. Fish were exposed to clove oil sedative concentrations ranging from 0 to 20 mg/L. Interactions between fish decreased at higher concentrations (top panel), however, collisions with the tank increased as fish became too lethargic and were unable to maintain equilibrium or stop from hitting the wall of the livewell (bottom panel). Taken together, concentrations ranging from ~5 to 10 mg/L seem to be effective for both minimizing interaction between fish while still permitting them to avoid excessive livewell wall collisions. These optimal levels of sedation are indicated between the dashed lines on the figure. Regressions include 95% confidence limits.

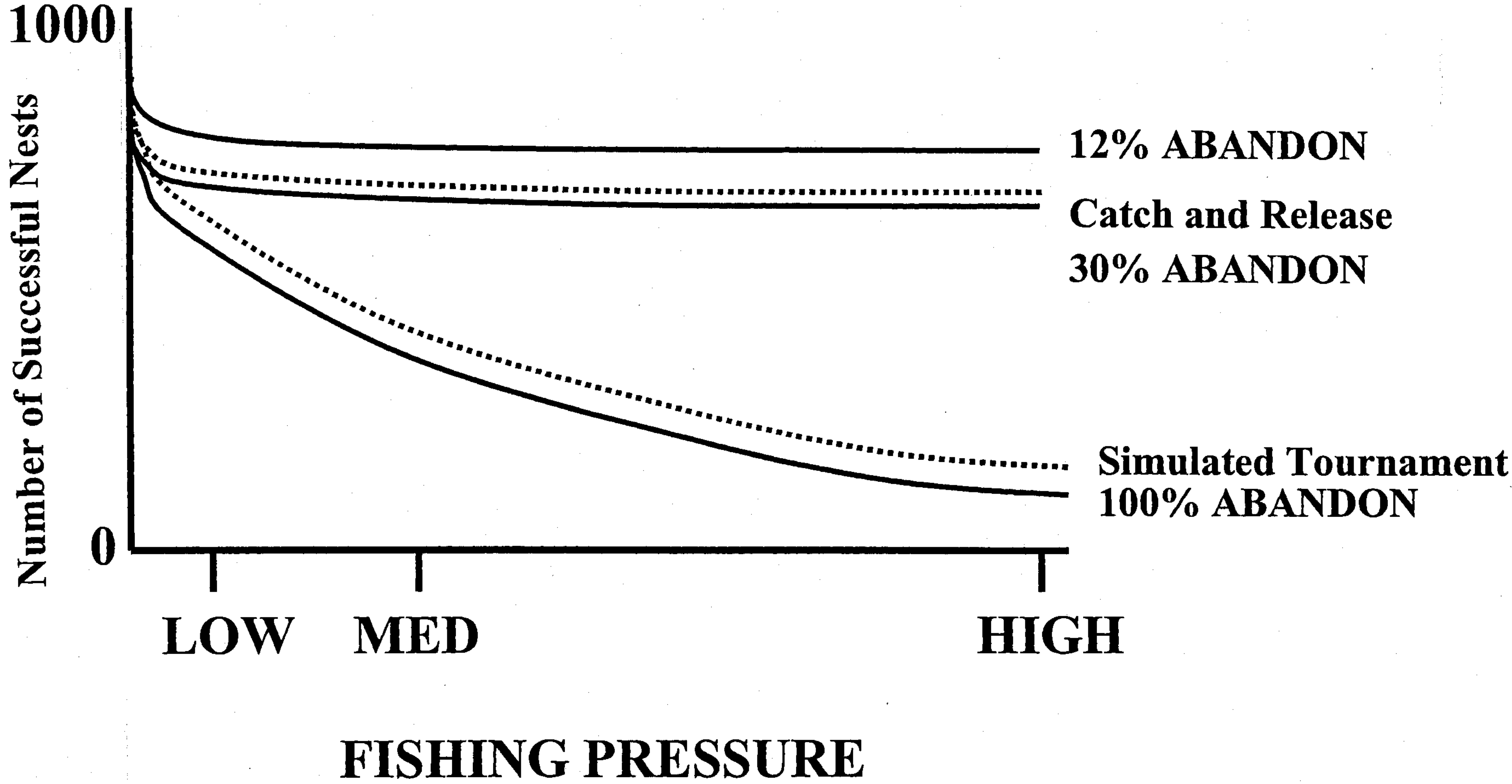

Figure 6-1. Effect of fishing pressure on the number of successful largemouth bass nests in Lincoln Trail with comparisons of 12 and 100% abandonment rates predicted from the model (solid lines) and abandonment rates from catch-and-release and simulated tournament angling (dotted lines).