Illinois Natural History Survey

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

Annual Progress Report

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Todd Kassler, David Philipp, and David Wahl

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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. The ultimate goal is to develop management strategies that maximize growth, recruitment, and harvest of largemouth bass in Illinois impoundments.

The ability to reliably identify stocked fish is an essential component to successful population assessment. In job 101.1 we are attempting to determine the most reliable and cost-effective method for mass-marking fingerling largemouth bass. We evaluated fin clips, fin clips followed by freeze cauterization, freeze branding, oxytetracycline (OTC), and photonic dye. After evaluation of short-term (9 months) retention rates of all five marks placed on 50-mm largemouth bass, we concluded that OTC, fin clips, and freeze brands were the most effective marking techniques, especially OTC. OTC was considered to be the most effective marking technique for 50-mm bass, based on high retention of the mark combined with ease of application. Fin clips, fin clip-cauterization, and freeze branding were examined for long-term retention on 100-mm largemouth bass. The longest lasting mark thus far (22 months) has been fin cauterization, followed by fin clipping and freeze branding. Freeze brands involved less handling time for identification than the other two marks, due to fin regrowth with fin clips and fin cauterization. However, ease of freeze brand identification varied seasonally, due to darker fish coloration in the fall, while fin clips and fin cauterization were distinguishable regardless of season. Growth rates were similar amongst fish with all three mark types. Future work will entail further evaluation of seasonal variability in mark retention and extension of the long-term study.

Stocking of largemouth bass is often used to compensate for poor recruitment in an already existing bass population. Surprisingly, few studies have looked at the effectiveness of different largemouth bass stocking strategies. In job 101.2 we examined the contribution of 100-mm fingerlings, compared size specific survival and growth among different sizes of stocked largemouth bass and compared intensive and extensive rearing techniques. Survival of stocked 100-mm largemouth bass varied considerably across lakes, ranging from 0 to 23 stocked fish per hour of electrofishing during the first fall. Initial stocking mortality was low and not an important factor in determining overall survival. Predation rates were high in some lakes, suggesting that losses of stocked bass to predators can be an important source of mortality. However, survival of stocked largemouth bass was not correlated with predator abundance. Natural recruitment of largemouth bass varied by lake, but also did not affect stocking success. In contrast, abundance of appropriately sized bluegill prey was positively correlated with stocked bass survival. Comparison of largemouth bass stocked as small fingerlings (50 mm) in July, medium fingerlings (100 mm) in August, large fingerlings (150 mm) in September, and advanced fingerlings (200 mm) in October showed advanced fingerlings to have the highest survival. Bass stocked as 150-mm fish in September also had high survival. Slower growth of

bass in lakes compared to fish in hatcheries resulted in initial size differences at stocking that persist through fall. Initial stocking mortality was very low, therefore, we feel that factors such as predator and prey abundance are more important determinants of stocking success. We have not found consistent differences in survival between extensive and intensive rearing techniques. We will continue to monitor the long-term survival of stocked bass in our study lakes, examine lake-specific characteristics that influence stocking success, and compare the performance of extensively and intensively reared largemouth bass.

Many species of fish, including largemouth 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. 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. To track the potential contribution of stocked largemouth bass to an existing bass population, we stocked largemouth bass bred at the Little Grassy Hatchery specifically to be fixed for the MDH-B2B2 genotype. Prior to stocking, we evaluated the background frequency of the MDH-B locus in the natural largemouth bass population of each study lake and verified that our experimental bass contained the MDH-B2B2 genotype. Walton Park, Mcleansboro, Murphysboro, Sam Parr, Forbes, and Shelbyville were stocked in 2000. The MDH-B2B2 genotype was found in less than 20% of individuals present in the resident bass population of each lake, and all individuals produced at the Little Grassy Hatchery were confirmed to contain the MDH-B2B2 genotype. A higher background frequency of the MDH-B2B2 genotype than was expected was observed in Forbes and Mcleansboro, therefore, we will expand our sampling of the natural bass population in these lakes to verify the background frequency for the MDH-B locus. If stocked largemouth bass successfully reproduce in our study lakes, we should find an increase in the frequency of the MDH-B2B2 genotype. Bass stocked into Shelbyville and Forbes should reach maturation by 2001, therefore, we will sample young-of-the-year largemouth bass in these lakes to determine if stocked fish are contributing to natural production within each lake.

Largemouth bass recruitment depends on a variety of both biotic and abiotic factors such as prey availability, predator abundance, population structure, vegetation, water level, temperature, and spawning habitat. Our objective in job 101.4 is to determine important mechanisms affecting largemouth bass recruitment in Illinois impoundments and develop recruitment indices for management. We sampled lake physicochemical characteristics, prey availability, and young-of-the-year (YOY) largemouth bass abundance and growth in 13 lakes, eight biweekly and 5 monthly, from May to October. Largemouth bass recruitment was highly variable across study lakes, but among lake variation in abundance declined over the summer as YOY bass numbers dropped in lakes with high initial densities. June abundance of YOY largemouth bass was an accurate index of bass densities throughout the first growing season, but not of yearling largemouth bass densities the following spring. However, size-selective overwinter mortality was not detected in our study lakes. Zooplankton, benthic macroinvertebrates, larval fish, and juvenile bluegill varied across our study lakes, but only larval fish abundance was positively related to largemouth bass recruitment. Larval fish abundance was not significantly correlated with YOY bass abundance until July, which may reflect the timing of a YOY bass diet shift to piscivory. YOY largemouth bass growth also differed between lakes, and became more divergent through time. TL's of YOY bass did not differ between shad and non-shad lakes, but were lower in lakes with higher densities of YOY largemouth bass. Comparison of YOY largemouth bass TL captured by seines and electrofishing gear showed a size bias towards larger bass with electrofishing collections. Samples from both gears will be needed to accurately assess changes in size of age-0 bass over time. We will continue to test our ability to use June YOY largemouth bass abundance to predict year class strength, as this early measurement may be useful to fisheries managers as an index of bass recruitment. Examination of YOY largemouth bass diets will clarify which prey types are important determinants of bass recruitment.

Removal of spawning males by angling in the spring could have detrimental effects on largemouth bass recruitment. 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 and annual recruitment. We tested the relationship between reproductive success and recruitment by establishing six one-acre ponds, representing a range of reproductive success. In 1999, we found that a nest index based on number of nests and embryos could predict fall abundance of YOY largemouth bass, but that fry abundance was not as good a predictor of fall age-0 bass abundance. In 2000, we only had an opportunity to measure fry abundance, and once again, a fry index did not accurately predict fall YOY largemouth bass abundance. Snorkel surveys at Lincoln Trail Lake were used to measure male bass nest site selection and evaluate the effects of angling and electrofishing on nest success. Catch-and-release and tournament type angling treatments were applied to nesting male largemouth bass. Catch-and-release bass were released after two minutes of air exposure and tournament treatment bass were held for two hours and released at the boat ramp. Male largemouth bass were observed to preferentially select nesting sites containing woody debris, perhaps due to lower brood predator abundance. Nest abandonment rates were 14% from electrofishing, 30% from catch-and-release angling, and 100% from simulated tournament angling. 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. We found that 54% of tournament-captured bass in the spring were spawning males. The sex ratio of tournament-angled bass tended to be male-biased. Future work will be to combine paternity analysis of fall YOY bass collected from our one-acre ponds with observations of male bass parental care behavior, experiments designed to determine the factors influencing parental male nest abandonment, evaluate sublethal effects of angling and methods to minimize stress on tournament-angled bass, and continue to monitor the sex ratio and reproductive condition of largemouth bass captured during bass tournaments.

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. 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.

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). Development of recent mass-marking technologies, such as oxytetracycline (OTC), and photonic dyes (New West Technologies) may also prove to be effective, long-term marks for centrarchid fish, although limited information exists on retention time of these marks.

PROCEDURES: We evaluated the retention rate associated with six different mass marking techniques for 2 and 4" largemouth bass. Marking techniques included (1) fin clipping, (2) fin cauterization, (3) freeze branding, (4) oxytetracycline (OTC), and (5) photonic dye. 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. Oxytetracycline (OTC) marks were applied by immersion of fish in an OTC solution for ½ h. Photonic dyes were injected into the anal fin rays of anesthetized fingerling largemouth bass using the PEN-Ject system developed by New West Technologies. Individual fish were marked with 0.2 ml of red photonic dye.

Short-term retention rates were evaluated using a series of indoor tank experiments, 2" largemouth bass were marked with one of five marks (fin clip, freeze brand, fin cauterization, OTC, or photonic dye) and stocked into 300 gallon, recirculating tanks. Each tank was stocked with 75 to 100 fish and each treatment (i.e., mark) was replicated twice for a total of 10 tanks.

Fish were fed a daily ration of Biodiet formulated feed and were reared from September 1998 to June 1999 and were evaluated for mark retention.

To evaluate long-term retention rate on larger fingerlings, we marked 4" fish using fin clips, fin cauterization, or freeze branding. 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). 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). Fingerling bass were stocked into ponds on December 14, 1998 and sampled on May 27, 1999, October 26, 1999, March 20, 2000, November 2, 2000, and March 15, 2001 to assess differences in mark retention rates and percent regrowth among marking techniques.

FINDINGS: Average retention rates for 2" largemouth bass were greatest for fish marked with OTC (99%), followed by fin clips (89%), freeze brands (68%), fin cauterization (63%), and photonic dyes (0%; Figure 1). The higher retention rate coupled with ability to mark large numbers of small fish with OTC suggests that this is the most suitable method for marking 2" largemouth bass. Cauterization of single clipped fins proved difficult on 2" fingerlings since unclipped fins often stuck to the branding iron while cauterizing the removed fin. As a result, both pelvic fins were removed and the entire wound was cauterized by freeze branding. Photonic dyes also performed poorly for 2" largemouth bass. Although easily visible once injected, the photonic dye dissipated within 1-2 months after injection. After 4-5 months, photonic marks were difficult to detect in fingerling bass and were completely absent by nine months after marking. Because of the increased handling time and poor retention rate, photonic marks and fin cauterization appeared to be a poor choice for long-term marks in 2" fingerling largemouth bass.

In the long-term pond experiments (4" fingerlings), fin cauterization was the longest lasting mark followed by fin clip and freeze brand marks (Figure 2). 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 3). 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 (100%) were clearly visible during the spring of 1999, 2000, and 2001 whereas only 82% and 99% of freeze brands were distinguishable in the fall of 1999 and 2000 because of darker external coloration (Figure 4). Conversely, fin clips and fin cauterized marks 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) and was similar among all three marking techniques (mean = 224 mm, TL; March 2001). Freeze brand marked fish had the greatest growth rate followed by fin cauterized and fin clip marked fish from 27 May 1999 to 26 October 2000 but was lowest the following year (i.e., 20 March 2000 to 2 November 2000). Growth of fin cauterized fish was much lower in spring, 2000 than for the other two techniques, but was greatest during 2000. The removal of a pelvic (e.g., fin clip) or both pelvic fins (e.g., fin cauterized) may impact foraging success or energy allocation during the first years growth.

RECOMMENDATIONS: The short-term marking experiments 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 related endeavors that need to not sacrifice fish, fin clip marks should be employed since they had comparable retention rates for OTC marked 2" largemouth bass. In addition, fin clips take a relatively shorter time to mark than freeze branded, fin cauterized, and photonic dye marked fish while simultaneously proving to be less methodologically problematic (see 1999 report).

Preliminary results from long-term marking 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, suggest that freeze brands may be the best method for long-term marking of 4" largemouth bass. However, the seasonal variability to mark visibility for freeze branded fish is potentially problematic and will need to be assessed in subsequent years. We will sample these marked fish at 6-month intervals and continue to 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 waterbody (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 outcompete 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 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 has 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 and 2000. Lakes varied in size from 11 to 250 ha and were located throughout Illinois ranging from the Wisconsin to the Kentucky border (Figure 5). 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. Mean length of extensively reared fish (mean TL = 125 mm ± 2.68 SE) was larger than intensively reared largemouth bass (99 mm ± 0.51). 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 h 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.

To assess the importance of prey availability to stocking success we estimated benthic macroinvertebrate and age 0 bluegill densities. We chose to examine these prey based on previous examination of stocked largemouth bass diets and on existing literature that suggests these groups are important prey for age 0 largemouth bass (Olsen 1996; Garvey and Stein 1998). Estimates of fish prey abundance were obtained on all 15 lakes during the fall of 1999 and 2000. Age 0 bluegill were collected by AC electrofishing concurrently with collection of stocked largemouth bass. We used CPUE of bluegill under 35 mm TL to estimate availability of fish prey based on the maximum size of bluegill that can be consumed by largemouth bass (33% of body length; Timmons et al. 1980). In addition to fish prey, benthic macroinvertebrates were collected on eight lakes during 1999. Macroinvertebrates were collected at six sites in each lake near the time of stocking with a modified stovepipe sampler (20 cm diameter). Samples were washed through a 250-µm sieve bucket and preserved in ETOH and rose bengal. In the laboratory, invertebrates were sorted and identified to order.

We used correlational analysis using 1999 and 2000 data to assess the relationship between survival of stocked bass and natural recruitment, adult largemouth bass abundance, macroinvertebrate density, and bluegill abundance. We examined correlations within and across years. We considered each individual stocking as an experimental unit because of the high variability within a lake in independent variables between years. Significance was determined at $\underline{P} = 0.05$.

Stocking Size

We evaluated the success of four size groups of stocked largemouth bass in two lakes in 2000 (Homer and Charleston). Largemouth bass were stocked as small fingerlings (63 mm) in July, medium fingerlings (100 mm) in August, large fingerlings (156 mm) in September and advanced fingerlings (198 mm) in October (Table 4). 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 and Walton Park during fall 2000. Jacksonville was stocked in August with 5,000 hatchery produced bass and in October with 4,285 pond reared bass. Walton Park was 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 2000. Catch per unit effort ranged from 0 to 13 stocked fish per hour of electrofishing in the fall (Table 2). Contribution of stocked fish to the total number of age 0 largemouth bass in the first fall in 1999 and 2000 ranged from 0 to 62 %. Survival was similar within lakes between years ($\underline{r} = 0.53$; $\underline{P} = 0.05$) but the relationship was primarily influenced by Pierce Lake that had the highest CPUE in both years. When Pierce Lake was removed from the analysis, there was no relationship between CPUE of stocked fish between years ($r = 0.06$; $P = 0.85$), indicating variability in CPUE across years within lakes. Survival of stocked fingerlings was not influenced by the abundance of natural age-0 largemouth bass ($r = 0.19$; $P = 0.30$; Figure 6).

Differences in size existed between stocked and natural largemouth bass at the time of stocking in most lakes. Stocked largemouth bass were larger than natural age 0 largemouth bass at time of stocking in 19 of the evaluations, but smaller than natural largemouth bass in 7 instances. We separated lakes into these two groups and compared relative survival. Survival of stocked largemouth bass (CPUE = 6.5 ± 1.2) was higher in lakes where they had a size advantage over natural largemouth bass than in those lakes where they did not (CPUE = 2.0 ± 0.9; ANOVA; $F = 4.64$; $P = 0.04$). Although there was an initial size difference between extensively and intensively reared largemouth bass, there was no significant difference in their survival (ANOVA; $F = 1.25$; $P = 0.27$).

Initial stocking stress did not effect the survival of stocked largemouth bass. Stocking mortality was low across all four lakes in both years with a mean of 2.6% (± 1.3 SE; Table 3). Lake water temperatures at the time of stocking averaged 27.3 °C (± 0.43 SE) and did not differ between lakes with stocking mortality and those without (ANOVA; $F = 0.31$; $P = 0.60$), suggesting factors other than lake temperature are influencing initial mortality.

We examined a total of 687 stomachs from several potential predator species including largemouth bass, channel catfish, crappie spp., and hybrid striped bass Morone chrysops x M. saxatilis. Adult largemouth bass were the only predators found to feed on stocked fingerlings. The number of stocked fish recovered from largemouth bass stomachs ranged from 0 to 39 fish across lakes (Table 3). In addition, the proportion of largemouth bass with stocked fish in their diets was high, averaging 10% across all stockings (Table 3). Predation varied across the four lakes in which diet analyses were completed (Table 3). We did not find any stocked largemouth bass in predator diets on Woods Lake in 1999 and only one in 2000. In contrast, a high proportion of predators (21-26%) sampled in Lake Mingo had stocked largemouth bass in their stomachs. Despite the wide range in observed predation on stocked largemouth bass across these four lakes, we did not find a correlation with survival ($r = 0.30$; $P = 0.46$). Because largemouth bass preyed on stocked fish more than any other species, we also correlated stocked fish survival and adult largemouth bass (> 200mm) density for all 15 lakes. Density of adult largemouth bass did not affect survival of stocked fingerlings (Figure 7; $r = -0.16$; $P = 0.41$). Similar lack of relationships were observed for both 1999 ($r = -0.34$; $P = 0.24$) and 2000 ($r = -0.005$; $P = 0.99$).

Prey abundance was important in determining survival of stocked largemouth bass, but importance varied with type of prey. Survival of stocked largemouth bass was not related to densities of either total benthic macroinvertebrates ($r = -0.25$; $P = 0.59$) or chironomids ($r = 0.09$; $P = 0.82$); however, there was a positive relationship between stocked largemouth bass CPUE and age 0 bluegill abundance across both years (Figure 8; $r = 0.56$; $P = 0.002$). The effect of bluegill prey abundance on survival was also strong within years (1999; $r = 0.81$; $P < 0.001$; 2000; $r = 0.66$; $P = 0.007$).

Stocking Size

Advanced fingerlings had the highest survival across both study lakes (Table 4). However, the high numbers of advanced fingerlings collected might be a reflection of the short time period between the time they were stocked and subsequently sampled. Large fingerlings also survived well in both lakes. Small and medium fingerlings had similar survival to the first fall. Unlike previous stocking assessments, small fingerlings were abundant during the fall. In Lake Charleston, small fingerlings were five times more abundant then medium fingerlings in the fall. This may be the result of stocking slightly larger small fingerlings in 2000 as compared to previous years.

The differential size at stocking was still evident in the fall (Table 4). Similar to previous years, largemouth bass grew faster under hatchery conditions than in lake conditions. This differs from the results found for stocked walleye in Illinois where fish grew faster in the lakes (Hoxmeier et al. 1999). Walleye stocked as fry and 50-mm fingerlings were often larger when the 100-mm walleye were stocked from the hatchery. In contrast, naturally spawned bass were always smaller than stocked bass and therefore stocked fish may have had a competitive advantage.

Initial stocking mortality was low across all size classes and lakes (Table 4). Although water temperatures varied considerably across stocking dates, it did not effect initial mortality. Because of such low stocking mortality, we believe that the differences found in survival of different size classes are not a result of stocking stress. Again, prey and predator abundance are probably important factors influencing the growth and survival of stocked bass.

Rearing techniques:

Results of intensive versus extensive stocked largemouth bass differed across lakes. In Jacksonville, extensively reared fish had a higher CPUE than intensively reared largemouth bass (Table 5). Conversely, intensively reared largemouth bass survived better in Walton Park. Size differences between intensive and extensive largemouth bass were greater in Jacksonville than in Walton Park, which may explain the larger difference in CPUE.

RECOMMENDATIONS:

Contribution of stocked largemouth bass appears to be lake dependent. Therefore, determining whether supplemental stocking is a useful management strategy will depend on characteristics of the recipient waterbody. The most important variable for largemouth bass stocking success that we identified was the availability of appropriate prey; however, losses to predation were probably also important. Conversely, natural recruitment levels and abiotic factors did not appear to affect stocked largemouth bass survival. Consideration of lake-specific characteristics will allow development of optimal stocking strategies for largemouth bass.

Because largemouth bass populations are often naturally reproducing, decisions about when and where to supplementally stock must be made carefully. Mixing of non-native stocks can have deleterious effects on future survival and reproductive success (Philipp and Whitt 1991). Once a decision to stock has been made, our results suggest important guidelines for maximizing survival. We found natural recruitment levels do not influence survival of stocked largemouth bass. As a result, natural recruitment levels should be used in determining whether or not a lake should be stocked and not as an indicator of stocked largemouth bass survival. To improve survival, our results suggest that supplemental stocking of large fingerlings should be conducted in lakes with high age 0 bluegill abundance. Predator abundance and size structure may also influence stocking success but we found no evidence of stocking mortality for the sizes of fish we examined. Determining lake characteristics that are best suited for largemouth bass stocking at various sizes and rearing techniques will help optimize use of hatchery resources.

Advanced and large fingerling largemouth bass had higher survival rates than small and medium fingerlings. However, small fingerlings had higher survival rates through fall than previous years. Cost associated with producing different sizes of bass need to be calculated in order to determine the best size to stock in terms of cost/benefit. During the next several years we will monitor the long-term survival of stocked fish in these lakes to determine which size contributes most to the adult largemouth bass population.

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 2001. Attempts will be made to stock bass from both techniques at similar sizes to determine if mechanisms other than size cause differences in survival between intensively and extensively reared fish.

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 (Kassler, Philipp, Svec, and Suski, unpublished data 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 during 1998, Walton Park, Murphysboro, Mcleansboro, Sam Parr, Forbes, and Shelbyville in 1999 and 2000.

Prior to actual stocking, samples of fish from the hatchery rearing ponds were sampled, and protein electrophoretic analysis (Philipp et al., 1979) was used to determine if those fish had the MDH B2B2 genotype. Also prior to stocking, a sample of naturally produced largemouth bass were collected from each study lake and analyzed to determine the inherent background frequency of the MDH-B locus. In 2001, YOY from Forbes Lake and Lake Shelbyville will be sampled to determine if the frequency of the MDH B2 allele has increased through reproduction of the stocked fish. The fish stocked into Forbes Lake and Lake Shelbyville should have reached maturation and will begin spawning. The other four lakes will be sampled in the summer of 2002 for YOY to assess if the frequency of the MDH-B2 allele has changed.

FINDINGS: Analysis of LMB fingerlings from the Little Grassy Fish Hatchery confirmed they all had the MDH-B2B2 genotype (Forbes Lake N=92 and Lake Shelbyville N=115). Background frequencies of LMB from four of the six study lakes have revealed that less than 20% of the individuals have the MDH B2B2 genotype (Table 6). The higher frequency of the MDH B2 allele from Forbes and McCleansboro is unclear. Larger fish older than three years will be sampled from Forbes and McCleansboro to assess the background frequency of older naturally reproduced fish. If the frequency of the MDH-B2 allele in the older fish is high then that lake will not be used for this experiment.

RECOMMENDATIONS: The contribution of stocked largemouth bass to the reproductive success of a given lake will be determined by calculating the frequency of the MDH B2 allele before and after stocking. Random size distributions of largemouth bass were sampled from each lake to determine the pre-stock frequency of the MDH B2 allele prior to stocking. Once the stocked fish reach maturation, the frequency of the MDH B2 allele will be calculated to determine a post stock frequency in each lake. An increase in the MDH B2 allele from each lake will provide evidence that stocked fish contributed to the reproductive success of a lake.

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 recruitment depends on a variety of both biotic factors (e.g., prey availability, predator abundance, population structure, vegetation, etc.) and physical factors (e.g., spring water levels and temperature, spawning habitat, human disturbance such as angling) (Kramer and Smith 1962; Carline et al. 1984; Gutreuter and Anderson 1985; DeVries and Stein 1990). Many of these factors can be altered through management actions. As a result, the need to identify which of these factors influence year-class strength and to be able to predict recruitment of largemouth bass has been highlighted as an essential component to successful management of the species. Most previous studies have focused on a single factor or lake (Kramer and Smith 1962) with no comparison across lakes of which factors are most important in determining recruitment.

Determining the critical period(s) and the factors influencing recruitment of largemouth bass populations would enable biologists to better predict management needs, such as stocking and vegetation control. Understanding the underlying biological mechanisms important to largemouth bass recruitment would provide biologists a means to evaluate and potentially improve recruitment. Size of spawning females, for example, has been positively correlated to survival of YOY largemouth bass (Miranda and Muncy 1987). Hence, management actions that protect large females or increase growth rates for adult fish may have a positive influence on recruitment. Moreover, our studies on bass in Canada indicate that year class strength is positively correlated to reproductive success; thus, human actions and biotic conditions that increase spawning opportunities/success or decrease spawning disturbance/failure will affect recruitment. Brood predation, for example, may be linked to removal of males from their nests and, therefore, could be affected through alternative management action. A better understanding of the timing of critical periods in the recruitment dynamics of largemouth bass will allow development of new indices that can help guide management decisions.

Other important biotic factors such as food availability (Olson 1996; Garvey et al. 1998), predation (Ludsin and DeVries 1997), and cover (Davies et al. 1982; Durocher et al. 1984) have been linked to growth and survival of young largemouth bass. Abundance of invertebrate prey, for example, can have important implications for growth of YOY largemouth bass which in turn can affect timing of ontogenetic diet shifts (e.g. to piscivory) and survival of YOY bass (Olson 1996). Similarly, fish prey composition can affect growth of young largemouth bass. In Ohio reservoirs, for example, YOY largemouth bass exhibited greater growth variability in shad *Dorosoma spp.* dominated systems than in bluegill *Lepomis macrochirus* dominated systems, implying that recruitment dynamics may be linked to assemblage structure of available prey species (Garvey and Stein 1998). Similarly, vegetation type and percent cover play an important role in providing invertebrate prey and shelter for juvenile largemouth bass and have been positively linked to year-class strength in bass populations (Durocher et al. 1984). Other biotic factors, such as size of spawning females, have also been positively correlated to survival of YOY largemouth bass (Gutreuter and Andersen 1985; Miranda and Muncy 1987). Earlier spawning by larger females results in a size advantage to young largemouth bass that has been correlated to overwinter survival and first-year recruitment (Ludsin and DeVries 1997; Keast and Eadie 1985). Work in northern Illinois found overwinter mortality to be unrelated to size of fish entering winter, but rather to events occurring earlier in life (Fuhr et al. in review). Whether these relationships occur over a wider geographic range and and types of reservoirs is unclear.

Physical factors such as water temperature (Olson 1996), water level (Miranda et al. 1984) and wind and wave action (Kramer and Smith 1962) have also been correlated to recruitment dynamics in largemouth bass. In Lake Shelbyville, Illinois, for example, spring water level fluctuations (increasing and decreasing) have been negatively linked to year class strength in largemouth bass (Kohler et al. 1993). As a result, timing of water level manipulations in flood control reservoirs might be altered to improve spawning conditions and recruitment for largemouth bass (Miranda et al. 1984). To date, most evaluations of recruitment dynamics in largemouth bass have been carried out on limited spatial scales (e.g. single lakes or reservoirs). Studying effects of physical and biotic factors across a gradient of lake types (e.g. reservoirs, state impoundments, cooling reservoirs, etc) will identify mechanisms important in Illinois aquatic habitats. Large-scale, comparative studies will increase our understanding of factors important to growth and survival of young-of-year largemouth bass and help provide management alternatives that improve year-class strength in bass populations.

PROCEDURES: We sampled 13 lakes to assess the influence of various factors on largemouth bass recruitment. Eight lakes were sampled every two weeks, while the remaining five lakes 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. Thirty young of year (YOY) largemouth bass were retained 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. TL's of YOY largemouth bass collected in September were compared between seines and electrofishing to test for gear size selectivity. Otolith microstructures were used to estimate the difference in TL between age-1 and YOY largemouth bass. 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 allowed us to estimate the number of YOY surviving their first winter and recruiting to age-1.

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 2.5 minutes along the shoreline and an additional 2.5 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 three lakes and recorded water temperature at 2 hour intervals through out 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:

Largemouth bass recruitment was highly variable across study lakes (Figure 9). Young- of-year (YOY) largemouth bass densities ranged from 0.01 to 15.73 per meter shoreline in June. Largemouth bass recruitment was not significantly different between shad and non-shad lakes ($t = 1.33$; $P = 0.28$). Summer variation in YOY largemouth bass abundance declined as densities decreased across lakes in August and September, with the largest declines in lakes with the highest YOY bass densities. Similar to 1998 and 1999, there was a positive relationship between June and August YOY largemouth bass densities ($r = 0.95$; $P < 0.001$). Furthermore, June and September YOY largemouth bass densities were also positively related ($r = 0.77$; $P = 0.04$; Figure 10). However, June YOY largemouth bass density (N/m) was not significantly related to age-1 largemouth bass abundance (N/hour) the following spring ($r = 0.44$; $P = 0.31$). Fall CPUE (N/hour) of YOY bass was also not significantly related to CPUE of age-1 fish the following spring ($r = 0.38$; $P = 0.40$). The relationship between June YOY largemouth bass abundance and densities of YOY bass in August and September could be useful in providing an early index of recruitment. However, if there is no relationship between fall YOY bass densities and age-1 bass abundance the following spring, largemouth bass year class strength may not be established until after the first winter.

Growth of largemouth bass differed across lakes and became more pronounced through fall (Figure 11). Peak density of YOY bass had a marginal negative relationship to average YOY largemouth bass TL in September ($r = -0.73$; $P = 0.06$; Figure 12). YOY largemouth bass TL was not significantly different between shad and non-shad lakes ($t = -0.91$; $P = 0.43$). Bass were collected by seines from June to October and by electrofishing in October. Size biases associated with each collection method can complicate comparisons of apparent growth between lakes. Comparison of mean TL of YOY bass collected in October by electrofishing and seining showed that larger fish are captured more often by electrofishing ($t = 3.56$; $P = 0.02$; Figure 13). Across 4 lakes, mean TL in fall electrofishing samples were not significantly different from age-1 TL's the following spring ($t = -1.57$; $P = 0.22$). If the first winter is an important recruitment bottleneck, the pattern of mortality may not be size-specific.

Invertebrate prey resources varied in abundance across study lakes and across seasons. Crustacean zooplankton abundance varied from 1.71-189.6/L inshore and 2.09-92.22/L offshore Figure 14). Inshore zooplankton abundance in May, when largemouth bass are in a larval stage and most dependent on zooplankton prey in littoral habitats, did not have a significant positive relationship with July YOY bass density ($r = -0.27$; $P = 0.61$). Mean overall crustacean zooplankton density also did not have a significant positive affect on July YOY bass abundance ($r = -0.07$; $P = 0.89$). Summer mean benthic macroinvertebrate density in 1998 ranged from 1054.53/m^2 to 21003.09/m^2 (Figure 15). In1998, total benthic macroinvertebrate density was positively related to YOY bass abundance in July ($r = 0.89$; $P = 0.02$), but not in June, August, and September ($P \geq 0.39$). Mean YOY bass TL in September was also not positively related to mean benthic macroinvertebrate density ($r = 0.45$; $P = 0.37$). Across 7 study lakes in 2000, mean benthic macroinvertebrate densities ranged from less than 2600/m^2 to greater than 11000/m^2. However, there was no relationship between total benthic macroinvertebrate density and YOY bass abundance ($P \geq 0.12$). Furthermore, mean September YOY largemouth bass TL was negatively related to benthic macroinvertebrate density ($r = -0.93$; $P = 0.003$). Either conditions associated with higher macroinvertebrate abundance represent poor environmental conditions for YOY bass, or lumping taxa of invertebrates that are unavailable to YOY largemouth bass with benthic invertebrates more commonly found in bass diets may obscure positive relationships between YOY bass and macroinvertebrate prey abundance. Isolating specific macroinvertebrate taxa that are more available to YOY bass may yield more biologically and statistically significant relationships. For example, August YOY bass density was positively related to annelid biomass in 2000 ($r = 0.77$; $P = 0.04$).

Fish prey varied in both abundance and importance across seasons. Mean larval fish density ranged from < 1 to 81.4 fish/m^3 with multiple peaks throughout the summer (Figure 16). Ridge Lake and Walnut Point had summer larval densities much higher than other study lakes. June, July, and August YOY largemouth bass densities were not positively related to the number of larval fish present in May or June ($P \geq 0.22$). However, July and August densities of YOY bass were positively related to July larval fish density ($r = 0.82$ and 0.80, respectively; $P = 0.03$), and August YOY bass density was also positively related to August larval fish abundance ($r = 0.75$; $P = 0.05$). Abundance the following spring, of age-1 largemouth bass, was positively related to mean overall larval fish abundance in 2000 ($r = 0.82$; $P = 0.03$) and July 2000 larval fish density ($r = 0.76$; $P = 0.05$). This suggests that largemouth bass recruitment may be positively related to the abundance of larval fish prey at specific times during first summer. Alternatively, conditions favorable for the production of larval fish may also have had a positive effect on bass recruitment. Juvenile bluegill (15-60 mm TL) density is typically used as a measure of available fish prey for YOY largemouth bass. Similar to the previous year, bluegill densities were extremely high in Ridge Lake compared to other study lakes (Figure 17). However, juvenile bluegill density was not positively related to mean September TL of YOY largemouth bass ($r = -0.07$; $P = 0.88$), to densities of YOY bass in August or to age-1 bass the following spring ($P \geq 0.39$). Similar to benthic macroinvertebrate prey, comparing sizes of bluegill available to YOY largemouth bass may provide a more accurate assessment of the actual abundance of bluegill available as prey.

RECOMMENDATIONS: Densities of young-of-the-year largemouth bass were different across lakes, suggesting recruitment is related to biotic and abiotic differences among lakes as well as large scale environmental events. The importance of environmental conditions, such as water temperature and rainfall, to recruitment variability can only be assessed through multiple year evaluations. Our preliminary results suggest that spawning success, predation, prey availability, and overwinter mortality may have a large influence on the growth and survival of age-0 largemouth bass. We will continue to monitor prey resources, physicochemical characteristics, and predation pressure to determine how these variables interact to influence largemouth bass recruitment.

Accurately assessing the number of YOY largemouth bass surviving to first annulus formation will be important in determining the timing of establishment of year class strength. Abundance of YOY largemouth bass in June was positively correlated with the density of YOY bass in August and September, but not to number of age-1 largemouth bass the next spring. This result suggests overwinter mortality may be an important recruitment bottleneck. However, the sample size of yearling largemouth bass collected in the spring needs to be increased to reduce the variability in our estimates of overwinter survival of YOY bass. These assessments will enable us to more accurately determine whether or not the first winter experienced by largemouth bass is important in establishing year class strength. Identifying the time of year that establishes largemouth bass year class strength will help us to develop an early index of recruitment that can be used by fisheries managers to make timely stocking decisions.

Dynamics at the nesting and larval stage of bass development may also be important to largemouth bass recruitment variability. Typically, YOY largemouth bass are not captured in our seines until June, when they are approximately 20 mm, and most of our study lakes are too turbid to accurately observe largemouth bass nests. However, we have been able to monitor largemouth bass nests in Lincoln Trail Lake in the springs of 1999-2001. Lincoln Trail Lake is also intensively sampled for juvenile bass, productivity, water quality, and prey availability. We will combine our observations of bass nesting with the results of our other sampling to determine the importance of specific times of the year and developmental stages to largemouth bass recruitment.

Variation in the abundance of potentially important prey items may be crucial to understanding largemouth bass recruitment. In previous years, juvenile bluegill density had a positive relationship with YOY largemouth bass density, but in 2000, this relationship was not evident. Instead, larval fish density was an important positive correlate with YOY largemouth bass abundance. Interestingly, this positive relationship between larval fish density and YOY largemouth bass abundance only existed through July. The timing of this relationship may reflect the ontogeny of largemouth bass piscivory as YOY bass grow large enough to successfully capture and handle fish prey. Further work must be done to quantify the diets of YOY largemouth bass in order to establish the timing of piscivory in YOY bass cohorts and its implications for growth. The lack of significant relationships between YOY bass abundance and benthic macroinvertebrate density may result from combining macroinvertebrates for analysis. Examining YOY largemouth bass diets will identify those benthic invertebrates that are actually selected for by age-0 bass in our study lakes. More detailed diet information will enable us to focus our analysis into the importance of invertebrate prey abundance.

Several variables not yet examined will be included in future reports. For example, primary productivity, water column nutrient concentrations, temperature, submerged vegetation, and water level still need to be analyzed for effects on largemouth bass recruitment and growth. All of the relevant analyses also need to be expanded to include our study lakes from the southern part of the state (e.g., Forbes Reservoir). Additionally, examining variability in largemouth bass recruitment and growth across multiple years in conjunction with yearly variation in important abiotic and biotic factors will provide a strong test of the identity and timing of those factors that explain the most variation in largemouth bass year class strength. Better understanding of the factors that control largemouth bass recruitment variability will enable us to make recommendations for effective management actions to enhance this valuable fishery.

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

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

INTRODUCTION: Removal of spawning males by angling in the spring have 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 recruitment historically has been that there is no relationship between standing adult stock and recruitment. Although much of the data behind that belief was 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 class strength.

Because male largemouth bass and smallmouth bass experience reduced levels of food consumption while providing parental care (Kramer and Smith 1962; Pflieger 1966; Coble 1975), 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 impacts 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 the 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.

PROCEDURES: To examine the relationship between reproductive success and recruitment in largemouth bass, we stocked six one-acre ponds with 22 adult bass, ten males and twelve females, on April 18, 2000. All brood fish within each pond were given a unique Floy tag mark for identification of individual bass during snorkel surveys. Additionally, clips were taken from the caudal fins of all adult bass for future genetic identification. Water temperatures and secchi depths were monitored for the duration of the observation period. Snorkel surveys were conducted by swimming the shoreline of each pond and mapping the locations of bass nests. Each nest was given a tag and assigned a score based on how many eggs or fry it contained, with scores ranging from one (lowest) to five (highest). Bass fry were collected from each nest for later genetic identification. Observations were made for a period of 13 days. Summer abundance of YOY largemouth bass were made monthly by use of a 6.7-m bag seine pulled 12 meters at four fixed locations in each pond. In October 2000, we drained the ponds, censussed young-of-the-year (YOY) bass, and saved a subsample of YOY bass for later genetic determination of paternity.

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 were monitored from 4-23-01 to 5-15-01. 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 4 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 the male 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.

To assess the potential effect of electrofishing on nest guarding by males, we snorkel surveyed nests at six of the sites, electrofished all the males off the nests, gave each male a caudal clip, and then snorkel surveyed each site again to see if the captured males abandoned their nests. The other six sites were used as controls for the experiment. These sites were snorkel surveyed as in the treatments, but were not electrofished. We also assessed the effects of catch-and-release and tournament angling on nest guarding by parental males. We hook and line angled all 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. The next day, we swam the angled sites and recorded whether or not the nest was abandoned. In 2001, we angled nests from two of the sites and simulated tournament conditions by holding the fish for two hours and releasing the fish at the boat ramp. We swam the transects the following day and recorded abandonment by the males.

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.

FINDINGS: Bass began spawning before the snorkel surveys began, therefore, nest scores and counts were based primarily on the locations and numbers of fry balls distributed throughout each pond. Ponds varied in total nest score (3-21) and total number of nests (3-9). Average nest scores were lower than the previous year, potentially due to inaccuracies associated with nest score estimation from fry balls in 2000. Fall abundance of YOY bass had a marginal negative correlation with pond nest score total ($r = -0.80$; $P = 0.06$; Figure 18). If this correlation is not spurious, density-dependent mortality may have been important in ponds with high nest production of YOY bass. However, due to uncertainties associated with our nest scoring in 2000, we need to be cautious in the interpretation of 2000 results. Final YOY largemouth bass biomass was not significantly correlated with monthly summer CPUE from seines ($P \geq 0.45$).

Bass spawned in Lincoln Trail from 4-26-01 to 5-15-01. A total of 154 nests were found in the twelve surveyed sections. As indicated by number of new nests by date (Figure 19), spawning occurred over a three-week period in 2000 and a two-week period in 2001. Spawning also began approximately one week later in 2001. Average total length of the nesting males was 292 mm with a range of 229 to 381 mm. Only six bass were found to have hook wounds. Largemouth bass preferentially selected spawning sites, selecting wood (36%) over open (34%), vegetation (23%), and detritus (7%). More aggressive fish seem to select woody spawning areas possibly because these areas have the lowest number of nest predators, making them preferential nesting sites (Figure 20). We found a low rate of nest abandonment from electrofishing that removed male largemouth from their nests (Table 7). More parental males abandoned their nest after being caught by hook and line angling than by electrofishing (Table 7). Abandonment rates from simulated tournaments were substantially higher than from catch and release angling.

Tournament anglers in the spring appear to target spawning bass. Fifty-four percent of fish captured in spring tournaments were engaged in some stage of spawning. The percentage of bass that were reproductively active ranged from 44.2% to 83.3% of all fish captured (Table 8). Tournament anglers tended to capture more males than females (Table 8), which may indicate that anglers are targeting males that are either on nests or actively guarding offspring. Sex ratios (males : females) ranged from 1:1.5 to 3.3:1 across lakes Mattoon, Mill Creek, and Forbes in 1999, 2000, and 2001. Males were smaller than females during the spawn and had total lengths that ranged from 357.4 mm to 439.2 mm. The higher number of immature bass caught in Mill Creek coupled with smaller average total lengths may be attributable to a 12 to 15 inch slot limit. Conversely, Mattoon and Stephen Forbes have a 14-inch minimum size limit and thus may have a higher percentage of larger and actively spawning bass.

RECOMMENDATIONS: Many of our observations in the one-acre ponds were compromised by missing the beginning of the spawning period. However, during snorkel surveys the previous year, fry production was positively correlated with egg production, therefore, our results from the 2000 snorkel observations may have accurately reflected conditions within the ponds. In that case, if higher nest production was negatively related to final YOY bass production, limited food resources in the ponds may have created conditions wherein cannibalism was prevalent under high YOY bass densities. In future observations, we will follow largemouth bass cohorts within each pond from eggs to independent juveniles. We will continue to save tissue samples from the adults and fry from each nest so that later genetic analysis can reveal if specific nests contribute disproportionate numbers of YOY to the final fall pond population. This paternity analysis, combined with measurements of size, condition, age, and care behavior of each specific parental bass, can help us to identify the traits of parental males and females that have high nest success.

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. Our data from Lincoln Trail shows a low rate of nest abandonment due to electrofishing. These results need to be expanded with larger sample sizes, but suggest that spring sampling with electrofishing equipment may not affect largemouth nesting success. Further work is also needed to increase sample size on the potential effect of angling on nest guarding by parental largemouth, 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 for 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.

In conjunction with our angling experiments, we will continue to monitor bass tournaments in order to assess if large, reproductively active males are being preferentially caught. Data from two of the three lakes examined suggests that this may be the case during spring tournaments. Using this data, we will be able to make predictions about how angling will affect fall recruitment of largemouth bass. In subsequent segments, we will begin to examine sublethal effects of angling on bass, as well as assess methods to reduce stress during tournament angling events.

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.

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.

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 21). Under a tournament angling scenario, our model would predict a strong decrease in nest success as fishing pressure increased. We need additional information on nest abandonment rates at a range of fishing pressures to test predications of the model.

RECOMMENDATIONS: To refine the model, we need to get better data on how the various parameters vary in nature and why they vary. That should involve conducting a variety of field experiments using different populations of largemouth bass, and eventually smallmouth bass. In addition, we need to advance the model from the conceptual stage to the mathematical one so we can acquire better predictive capabilities. Once these models are constructed, we will need to test them with large scale manipulative experiments.

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. Stocking density and growth rates for 4" largemouth bass marked with fin clips (FC), freeze brands (FB), or fin cauterization (FCFB). Fish were stocked into three 0.3-acre ponds on 14 December 1998 and sampled 27 May 1999, 26 October 1999, 20 March 2000, 2 November 2000, and 15 March 2001. Genotypes for each mark are given.

Physical Mark	Genotype	Stocking density (No./pond)	Growth Rate (g/d)				
			12/14/98 to 5/27/99	5/27/99 to 10/26/99	10/26/99 to 3/20/00	3/20/00 to 11/2/00	11/2/00 to 3/15/01
FC	1:1	75	0.10	0.19	0.05	0.38	0.0
FB	1:2	100	0.09	0.23	0.05	0.30	0.08
FCFB	2:2	75	0.10	0.22	0.03	0.41	0.10

Table 2. Advanced fingerling largemouth bass stocked into 15 Illinois reservoirs in August 2000. Catch per unit effort (CPUE) is based on the number of fish collected per hour of AC electrofishing in the first fall after stocking. Total length (TL) is the mean length of stocked largemouth bass collected in the fall.

Lake (ha)	Stocking Date	N/ha	Stocking size (mm)	Fall CPUE	Fall TL (mm)
Bloomington (250)	08/10/00	60	98	1.3	116
Charleston (113)	08/09/00	60	98	0.7	122
Forbes (212)	08/09/00	30	135	6.7	143
Homer (32)	08/10/00	60	102	1.6	125
Jacksonville (198)	08/09/00	47	126	7.8	161
Kakusha (21)	08/24/00	60	104	6.5	116
Leaquana (16)	08/23/00	62	98	4.4	119
Mcleansboro (30)	08/09/00	60	135	10.0	146
Mingo (69)	08/15/00	60	102	6.8	118
Murphysboro (58)	08/09/00	60	135	6.0	154
Pierce (66)	08/17/00	60	98	13.4	116
Sam Parr (73)	08/09/00	60	135	10.0	161
Spring South (247)	08/11/00	60	98	1.1	110
Woods (11)	08/14/00	60	101	1.3	121
Walton Park (12)	08/11/00	107	118	2.1	124

Table 3. Mean (± 1 SE) initial stocking mortality and number of fingerling largemouth bass recovered from predator stomachs following stocking into four Illinois lakes during 1998 to 2000. Initial stocking mortality was estimated by holding stocked fingerlings in floating mesh cages for 24 hours. The total number and percent of stocked fish were those found in largemouth bass (> 200 mm TL) diets for three days after stocking.

				Predator Diets		
Lake	Year	Stocking Mortality	Lake Temperature(°C)	Stomachs Examined	Number of Stocked Bass	Percent of Predators
Charleston	1998	0 (0)	27.8	124	9	4.8
	2000	0 (0)	27.0	79	17	15.2
Homer	1999	0 (0)	26.5	112	4	3.6
	2000	0 (0)	28.6	65	4	6.2
Mingo	1999	6.8 (5.1)	27.1	118	39	26.3
	2000	0 (0)	25.4	42	18	23.8
Woods	1999	7.8 (2.9)	26.6	64	0	0
	2000	5.9 (4.3)	29.0	29	1	3

Table 4. Comparison of stocking success of four sizes of largemouth bass in lakes Charleston and Homer. Catch per unit effort (CPUE) is measured as number of fish per hour of AC electrofishing during the following fall. Each size class was given a distinct mark for future identification. Stocking mortality was estimated by holding stocked bass in 3 mesh holding cages and counting the number dead after 24 hours.

Lake	Date	TL at Stocking (mean ± SD)	Number Stocked	Stocking Mortality	CPUE Fall	Total Length (mm) Fall
Charleston	07/19/00	62 ± 4.5	15,000	0	4.9	99
	08/09/00	98 ± 7.2	7,000	0	0.9	122
	09/07/00	155 ± 15.2	3,000	8.0	13.2	156
	10/12/00	197 ± 14.9	1,079	0	43.3	200
Homer	07/19/00	63 ± 5.1	4,000	1.1	1.9	100
	08/10/00	102 ± 6.3	2,000	0	2.1	127
	09/07/00	156 ± 13.4	800	7.8	14.2	162
	10/12/00	199 ± 17.7	400	0	25.7	206

Table 5. Largemouth bass stocking summaries for lakes Jacksonville and Walton Park. Intensively reared bass were raised in raceways while extensively reared bass were raised in ponds. Catch per unit effort (CPUE) is based on the number of fish collected per hour of day electrofishing during October-November.

Lake	Date	Rearing Technique	Number Stocked	Total Length at Stocking	Fall CPUE
Jacksonville	08/09/00	Intensive	5,000	98	0.3
Jacksonville	10/07/00	Extensive	4,285	155	7.8
Walton Park	08/11/00	Intensive	625	98	1.6
Walton Park	08/09/00	Extensive	625	135	0.5

Table 6. Frequencies of MDH B2B2 from six study lakes in Illinois prior to stocking.

	Genotypes			Allele Frequencies	
Forbes (N = 41) Fall 98	1/1 = 16	1/2 = 20	2/2 = 5		
Forbes (N = 47) Summer 99	1/1 = 32	1/2 = 10	2/2 = 5		
Forbes (N = 30) Summer 00	1/1 = 12	1/2 = 8	2/2 = 10		
Forbes (Total)	1/1 = 60	1/2 = 38	2/2 = 20	1 = 0.669	2 = 0.331
McCleansboro (N = 19) Summer 99	1/1 = 4	1/2 = 5	2/2 = 10		
McCleansboro (N = 15) Summer 00	1/1 = 1	1/2 = 8	2/2 = 6		
McCleansboro (Total)	1/1 = 5	1/2 = 13	2/2 = 16	1 = 0.338	2 = 0.662
Murphysboro (N = 58) Summer 99	1/1 = 48	1/2 = 6	2/2 = 4		
Murphysboro (N = 21) Summer 00	1/1 = 17	1/2 = 3	2/2 = 1		
Murphysboro (Total)	1/1 = 65	1/2 = 9	2/2 = 5	1 = 0.880	2 = 0.120
Sam Parr (N = 8) Fall 98	1/1 = 4	1/2 = 3	2/2 = 1		
Sam Parr (N = 53) Summer 99	1/1 = 40	1/2 = 11	2/2 = 2		
Sam Parr (N = 15) Summer 00	1/1 = 9	1/2 = 2	2/2 = 4		
Sam Parr (Total)	1/1 = 53	1/2 = 16	2/2 = 7	1 = 0.803	2 = 0.197
Shelbyville (N = 60) Summer 98	1/1 = 43	1/2 = 16	2/2 = 1		
Shelbyville (N = 103) Summer 99	1/1 = 77	1/2 = 20	2/2 = 6		
Shelbyville (N = 48) Summer 00	1/1 = 38	1/2 = 9	2/2 = 1		
Shelbyville (Total)	1/1 = 158	1/2 = 45	2/2 = 8	1 = 0.855	2 = 0.145
Walton Park (N = 17) Summer 99	1/1 = 12	1/2 = 5	2/2 = 0		
Walton Park (N = 33) Summer 00	1/1 = 26	1/2 = 2	2/2 = 5		
Walton Park (Total)	1/1 = 38	1/2 = 7	2/2 = 5	1 = 0.830	2 = 0.170

Table 7. Abandonment rate of male largemouth bass collected from nests with either electrofishing gear or hook and line angling.

Sample Date	Treatment	Number Nests	Number Abandoned	% Abandoned
5/11, 16/00	Electrofishing	51	3	6
5/11,16/00	C & R Angling	10	3	30
5/3/01	Electrofishing	28	4	14
5/8/01	Tourn. Angling	4	4	100

Table 8. Sex ratios, average TL (mm), and percent spawning bass from tournaments at Mill Creek, Mattoon, Stephen Forbes, and Shelbyville Lakes during spawn and post spawn 1999, 2000, and 2001. Percent spawning bass are given for males, females, and all fish combined.

Lake	N	Sex Ratio (males:females)	Mean TL (mm) Males	Mean TL (mm) Females	Percent Spawning Males	Percent Spawning Females	Percent Spawning Total
Forbes							
Spawn	10	1.46:1	408.6	458.4	43.9	67.9	53.6
Post-spawn	6	1.67:1	439.2	398.9			
Mattoon							
Spawn	6	1:1.08	406.1	441.4	76.9	89.2	83.3
Post-spawn	1	1:1.5	386.5	373.3			
Mill Creek							
Spawn	3	3.3:1	357.4	425.7	43.9	45.0	44.2
Shelbyville							
Post-spawn	3	1:1	411.6	430.5			

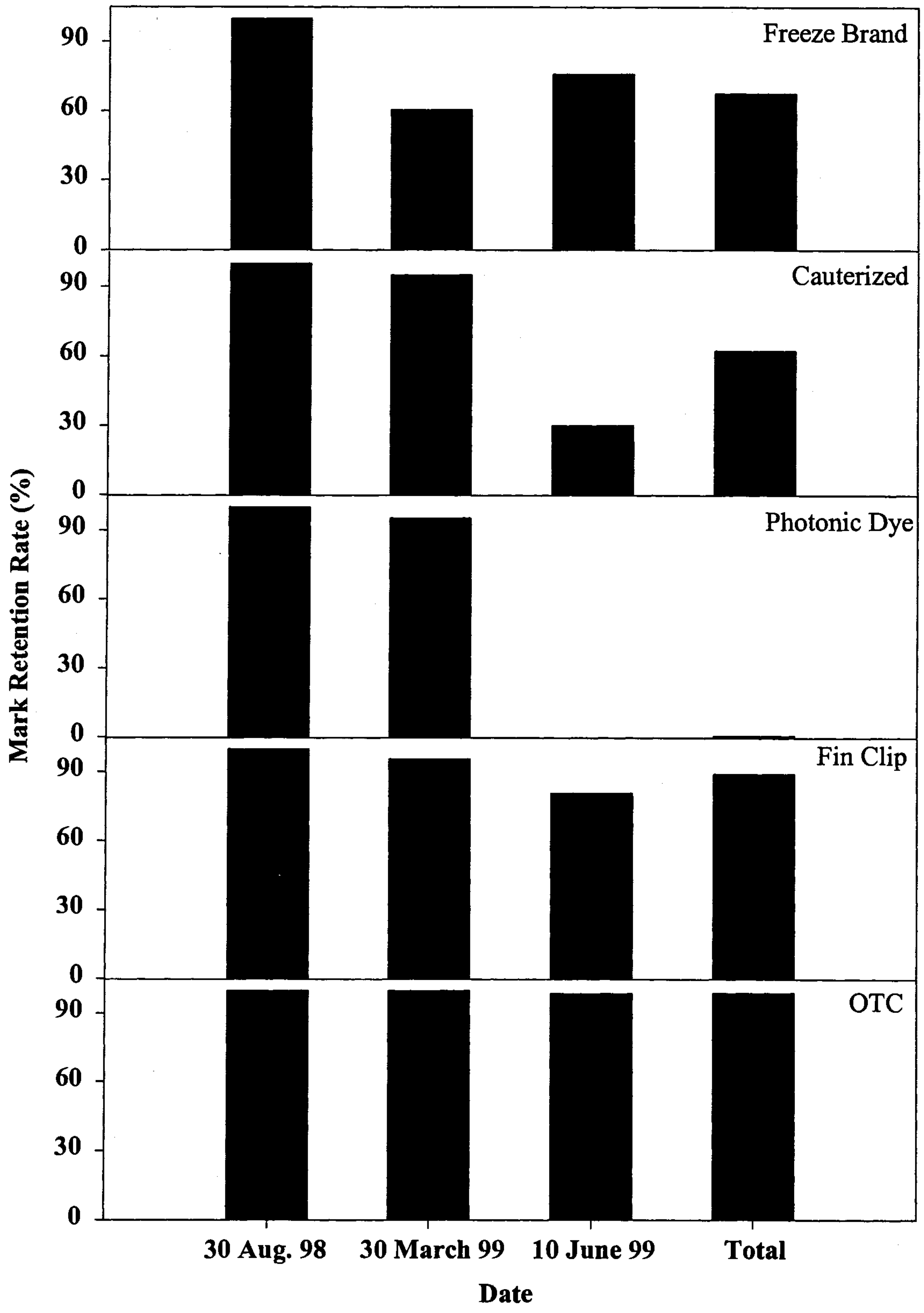

Figure 1. Retention rates for freeze brands, fin cauterizations, photonic dye, fin clips, and oxytetracycline (OTC) marks applied to 2" fingerling largemouth bass. Total represents the cumulative percent of visible marks for all dates combined.

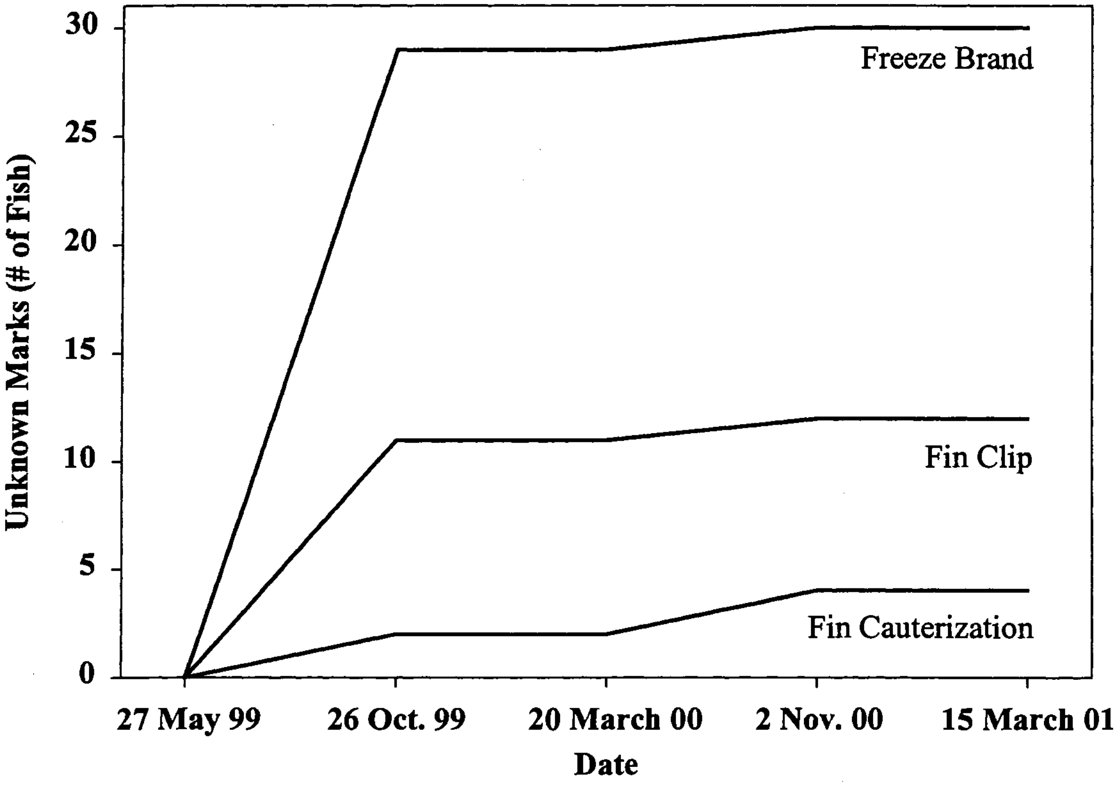

Figure 2. Cummulative number of 4" largemouth bass with unrecognizable marks sacrificed and identified by 1:1 (Fin Clip), 1:2 (Freeze Brand), or 2:2 (Fin Cauterization) MDH-B genotype for each date sampled.

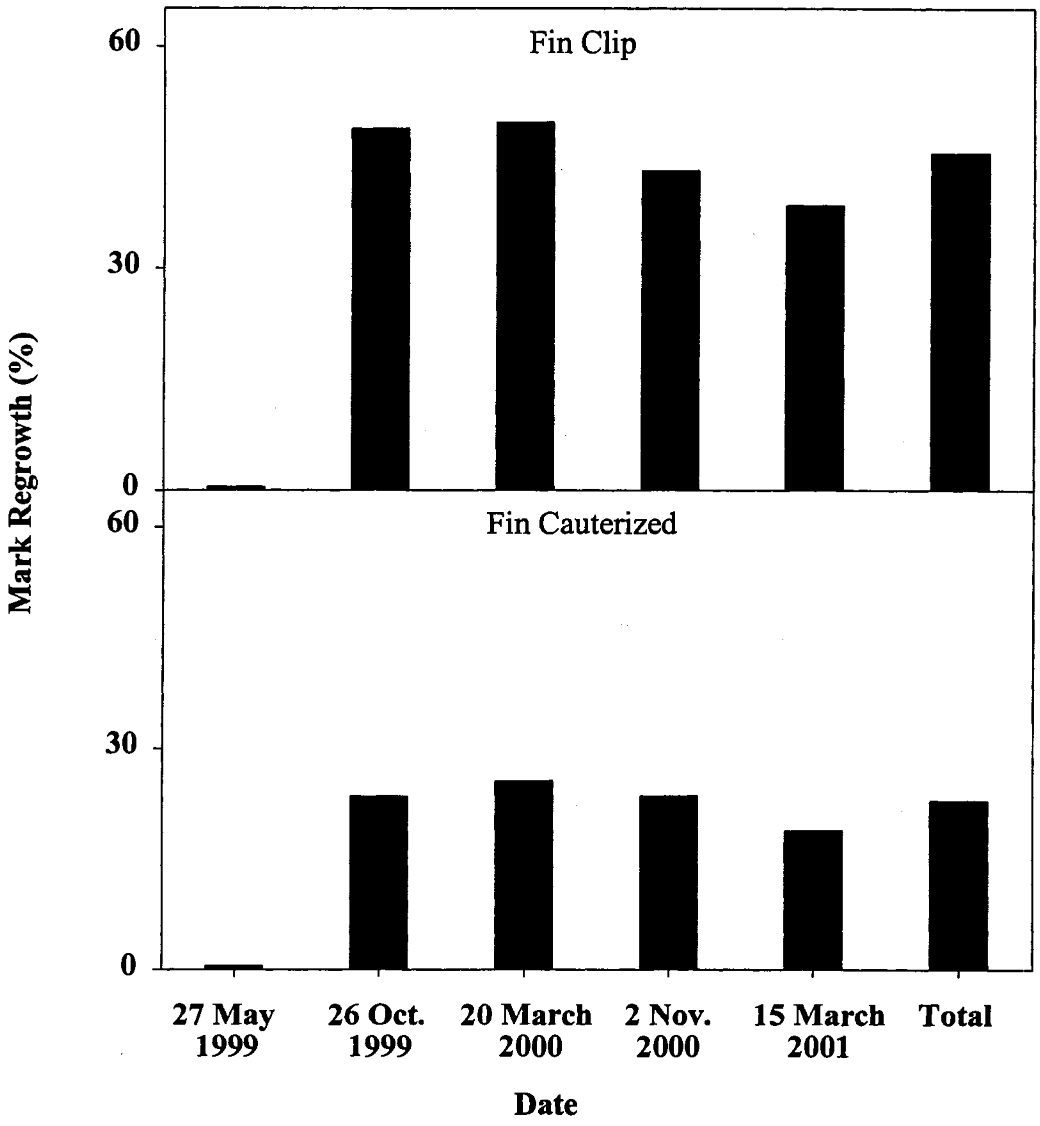

Figure 3. Average mark regrowth (%) for fin clip, fin cauterized, and freeze brand marked 4" largemouth bass through time. Total denotes experiment wise average (%) regrowth for fin clip and fin cauterized marks.

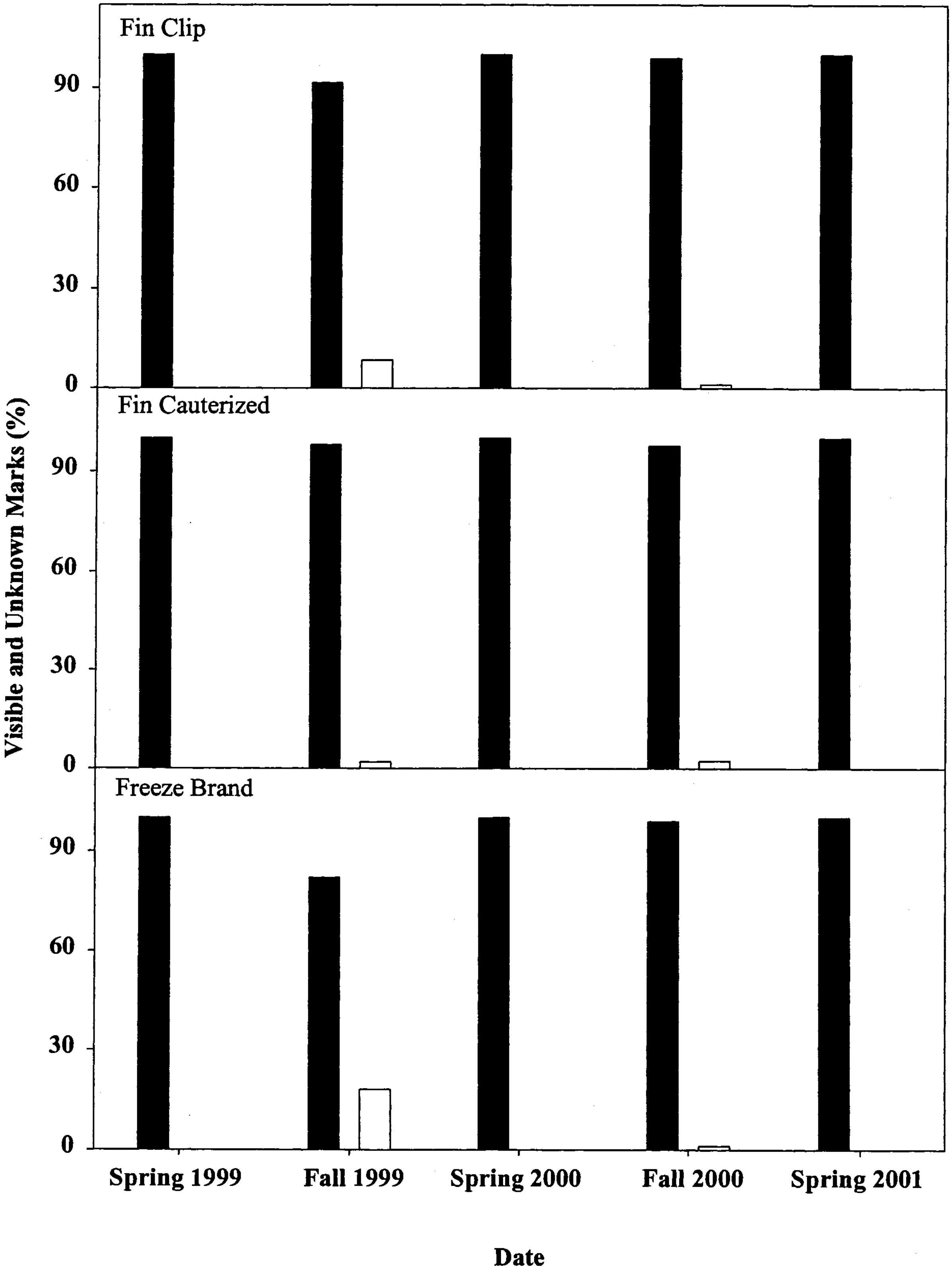

Figure 4. Percent of visible marks (dark bars) and those that were undiscernable (light bars) and identified by gentic markers for fin clip, fin cauterized, and freeze brand marks sampled seasonally.

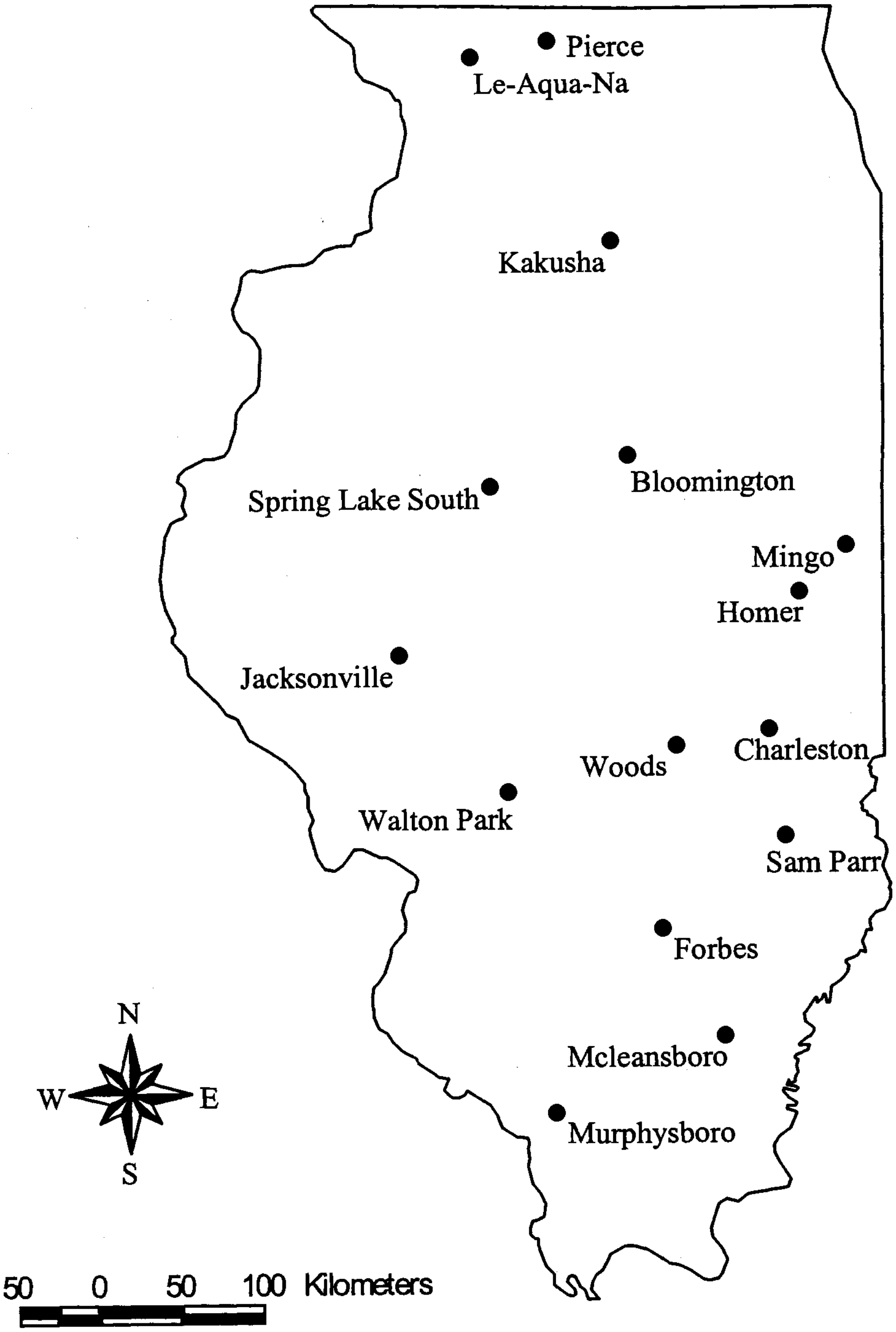

Figure 5. Locations of 15 lakes in Illinois stocked with fingerling largemouth bass in 1999 and 2000.

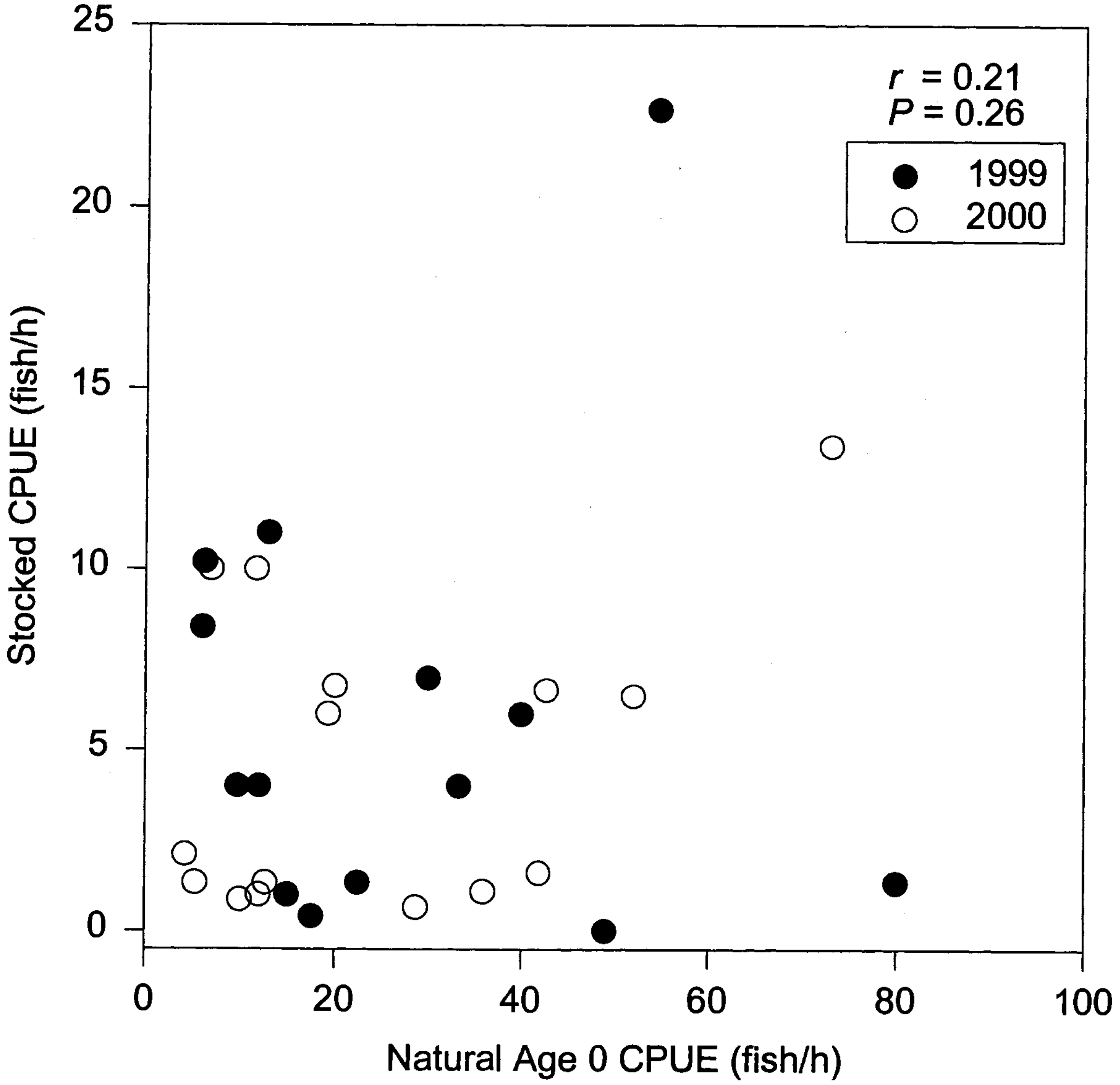

Figure 6. Relationship between stocked and natural age 0 largemouth bass catch per unit effort in Illinois reservoirs. CPUE is based on the number of largemouth bass caught per hour during fall AC electrofishing.

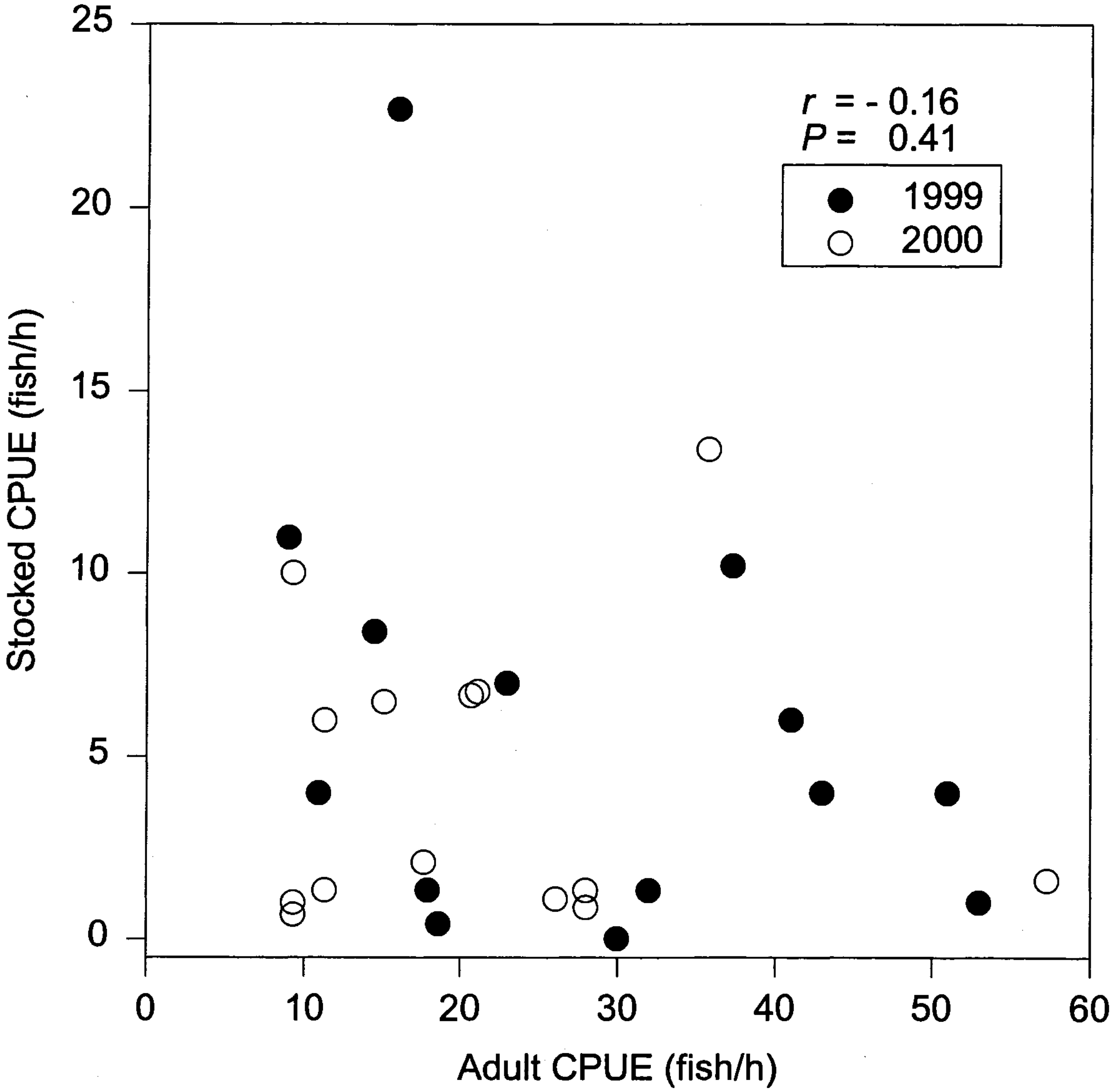

Figure 7. Relationship between stocked largemouth bass survival and predator density for Illinois reservoirs stocked in 1999 and 2000. Predator density is the number of adult largemouth bass (>200 mm) collected per hour of electrofishing.

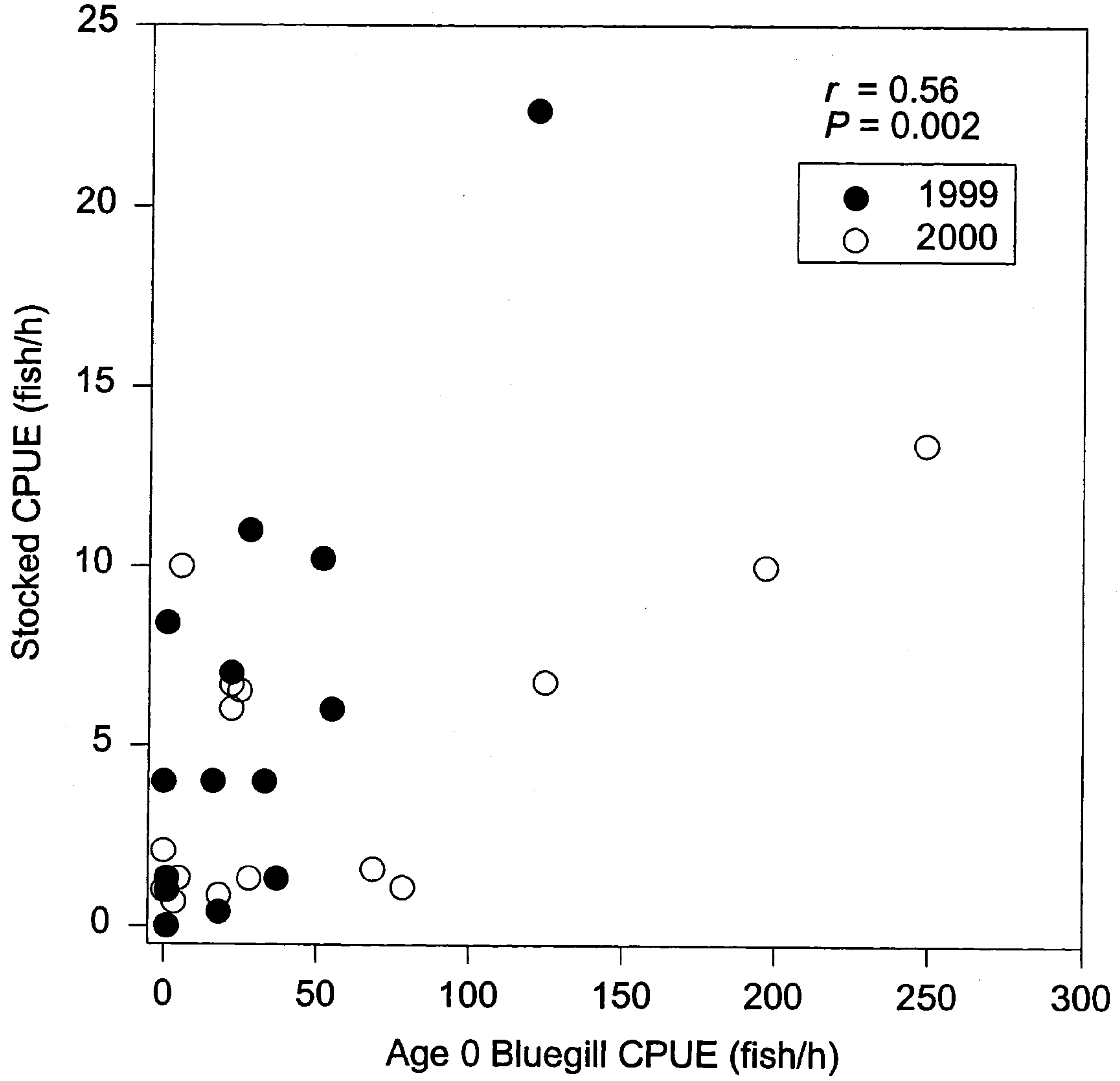

Figure 8. Relationship between stocked largemouth bass survival and age 0 bluegill abundance for Illinois reservoirs stocked in 1999 and 2000. Age 0 bluegill abundance is the number of bluegill under 35 mm TL collected per hour of electrofishing.

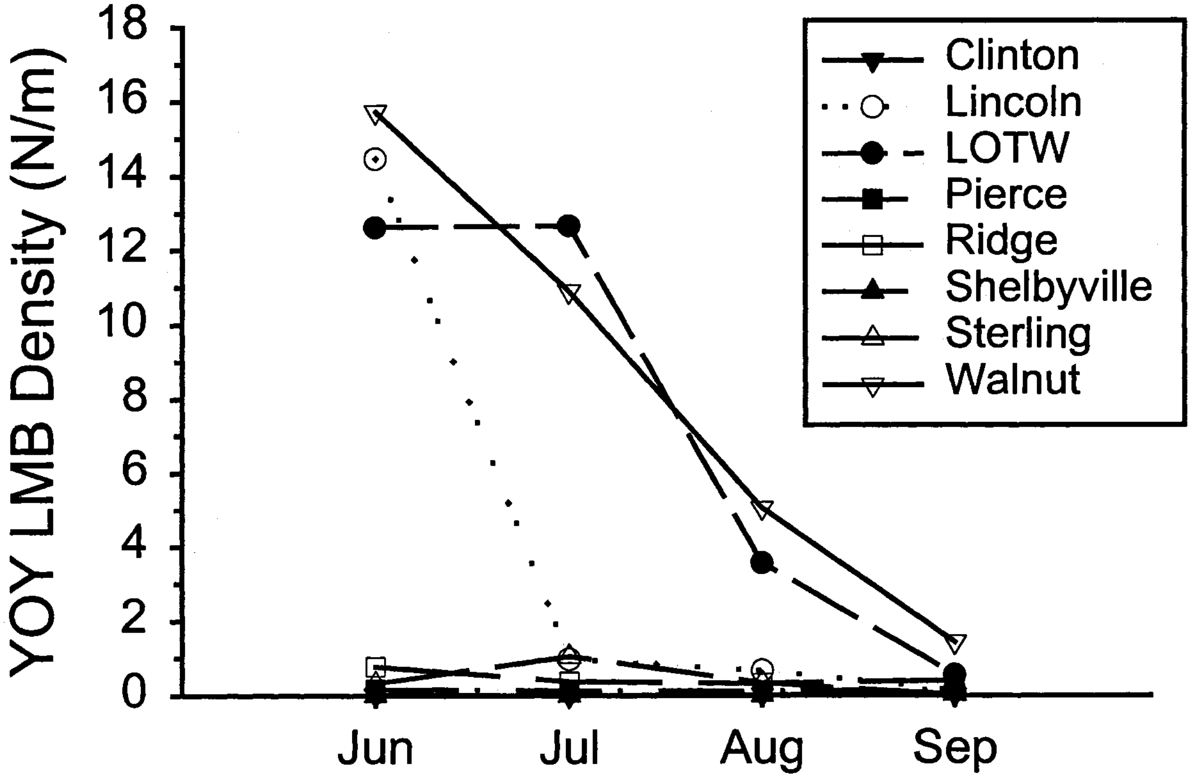

Figure 9. Average monthly young-of-the-year (YOY) largemouth bass densities (N/m shoreline) for 8 study lakes. Largemouth bass were collected from 4 sites in each lake with a 6.7-m bag seine. Closed symbols represent lakes with shad, whereas, open symbols represent lakes without shad.

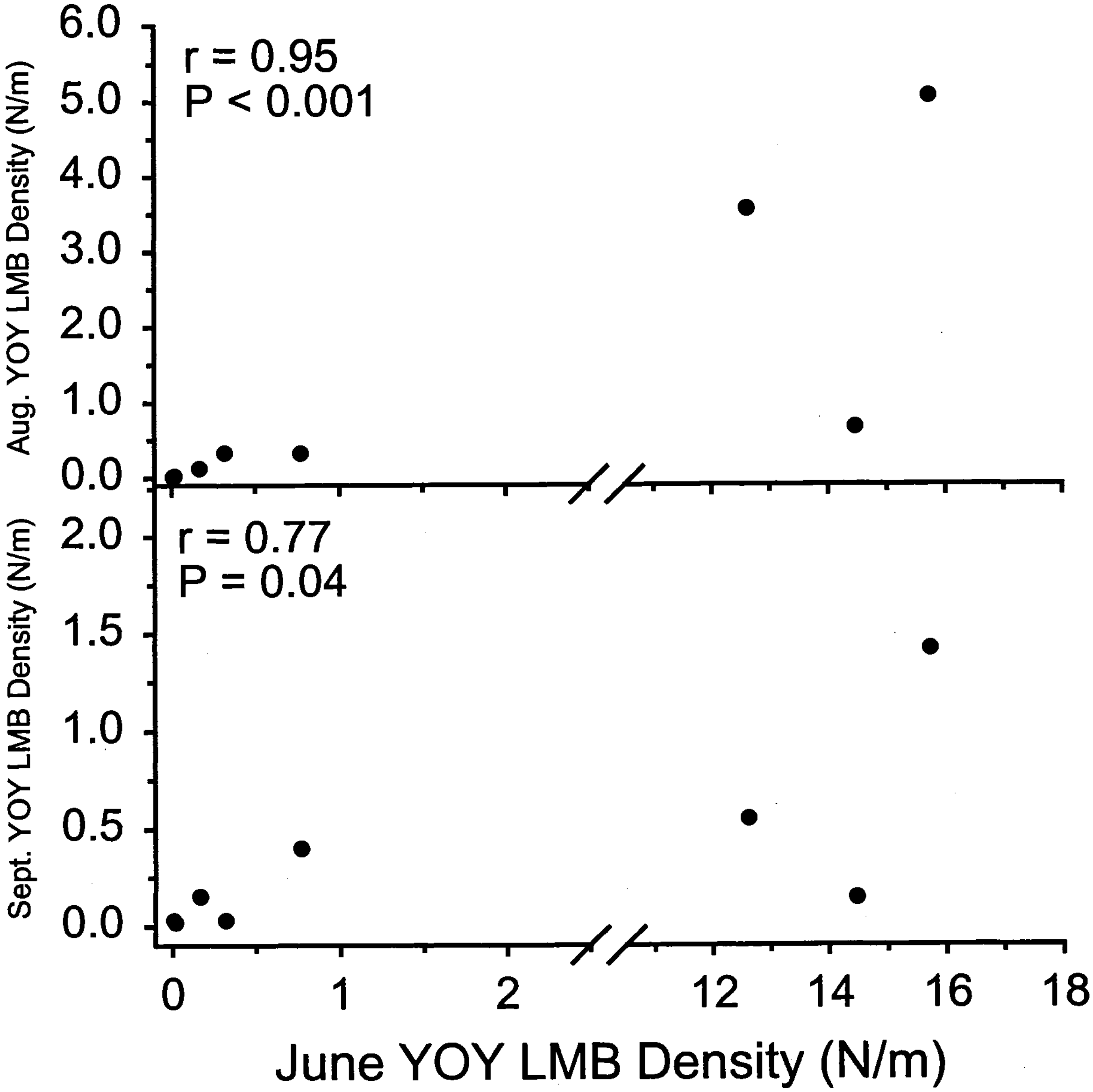

Figure 10. Relationship between June density (N/m shoreline) of young-of-the-year (YOY) largemouth bass and YOY largemouth bass densities in August and September in 8 study lakes. Largemouth bass were collected from 4 sites in each lake with a 6.7-m bag seine.

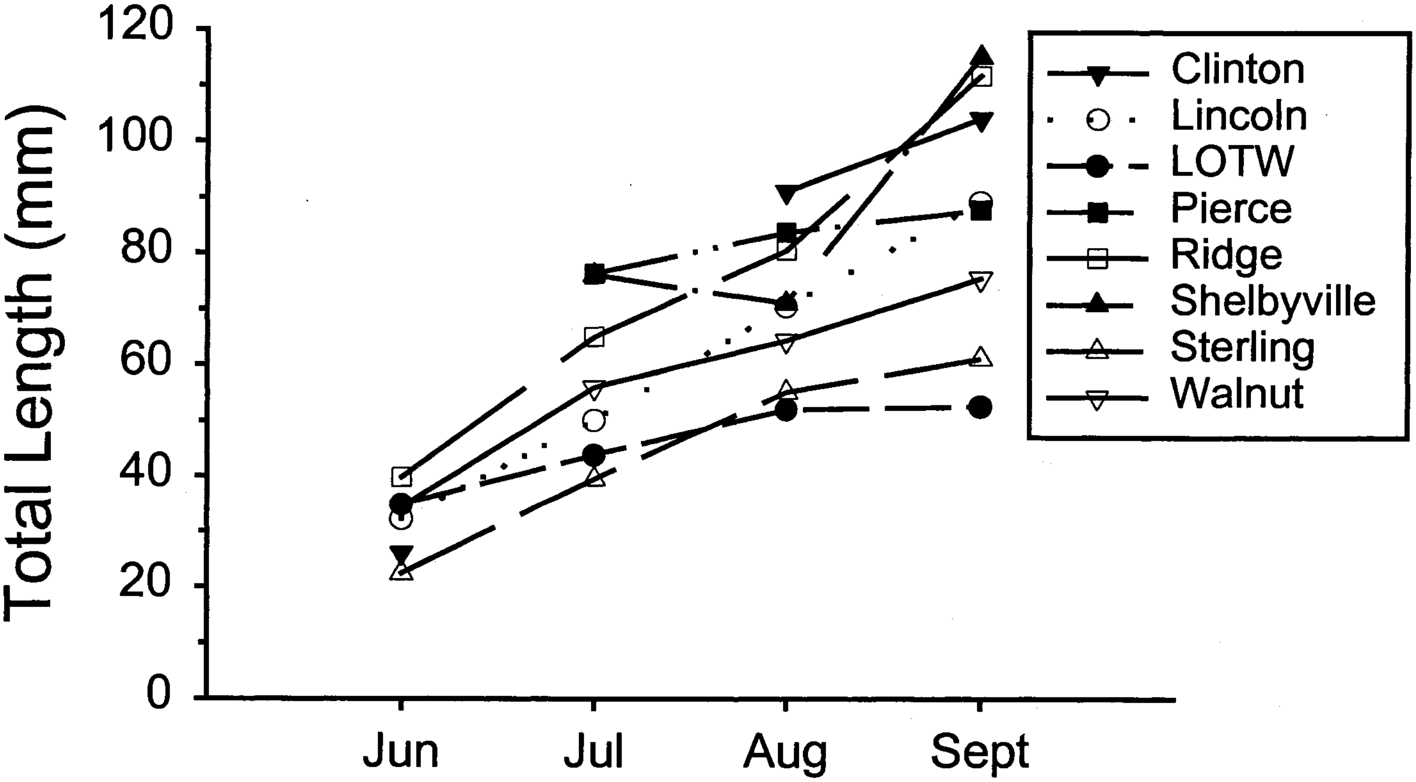

Figure 11. Average total length of young-of-the-year largemouth bass collected from 8 study lakes. Largemouth bass were collected from 4 sites in each lake with a 6.7-m bag seine. Closed symbols represent lakes with shad, whereas, open symbols represent lakes without shad.

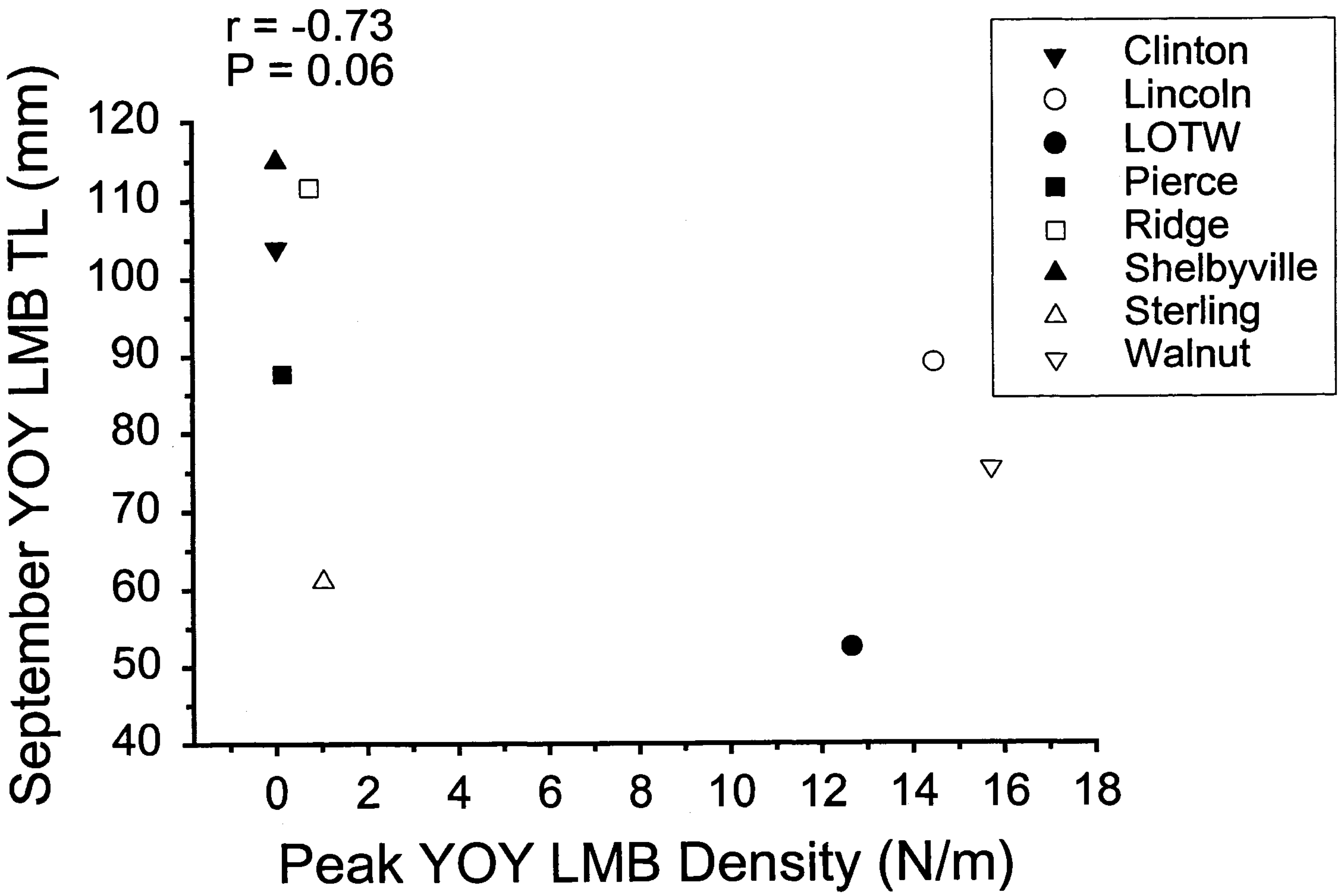

Figure 12. Relationship between peak young-of-the-year (YOY) largemouth bass density (N/m shoreline) and average YOY largemouth bass TL (mm) in September for 8 study lakes. Fish were collected using a 6.7-m bag seine.

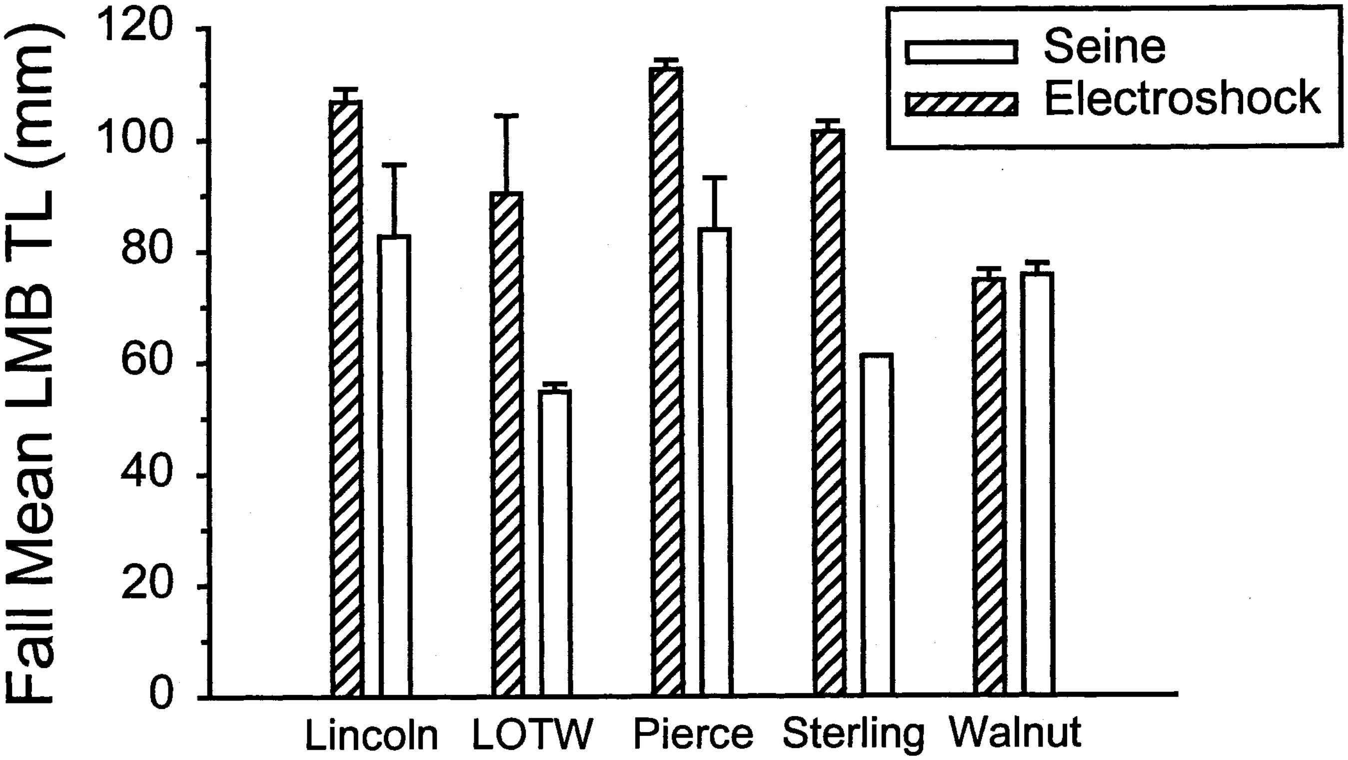

Figure 13. Difference in mean fall TL (mm ± SE) of young-of-the-year largemouth bass sampled with a 6.7-m bag seine and day AC electrofishing in 5 study lakes.

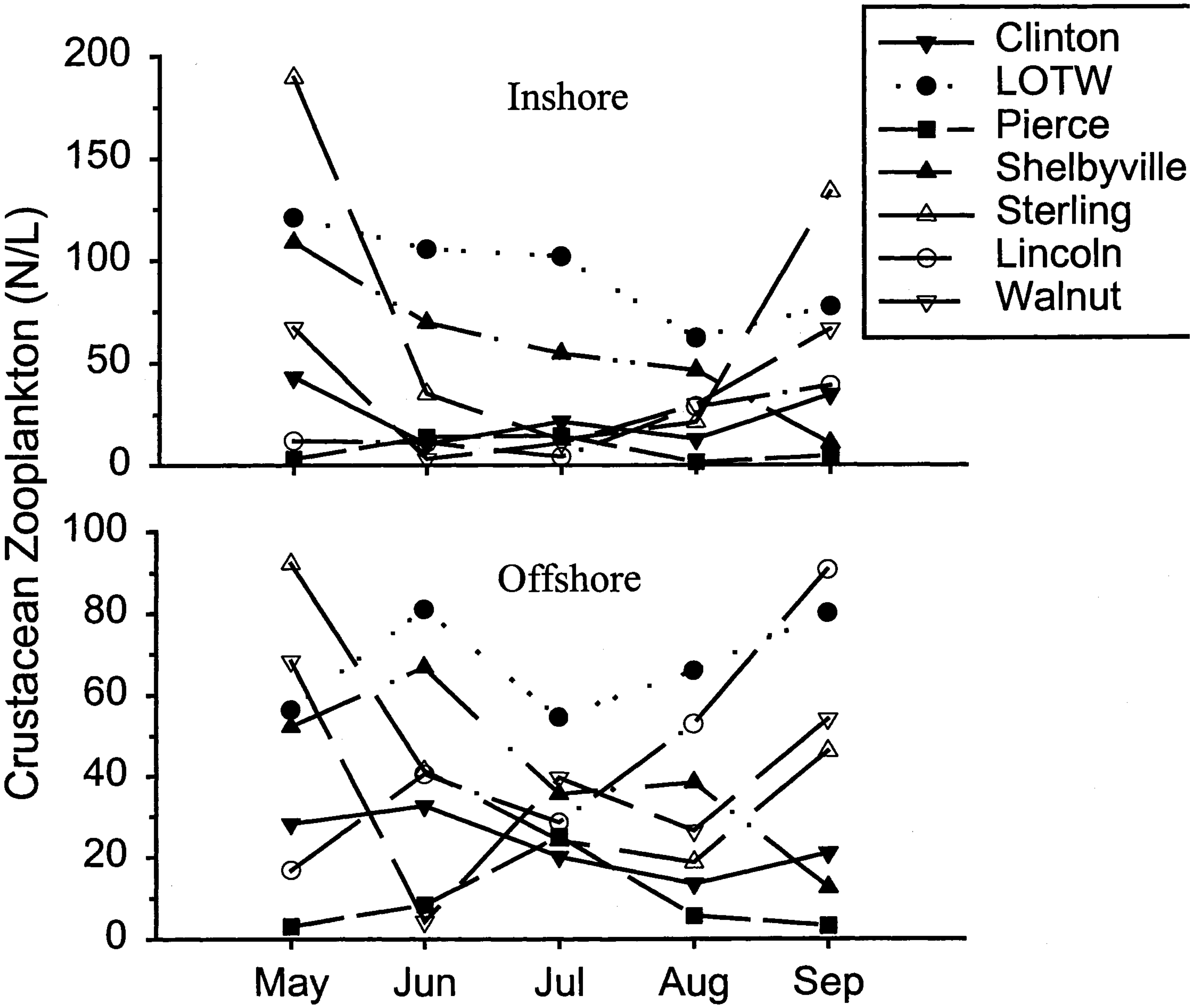

Figure 14. Average monthly crustacean zooplankton (excluding nauplii and rotifers) densities (N/L) in inshore and offshore habitat of 7 bass study lakes. Closed symbols represent lakes with shad, whereas open symbols represent lakes without shad.

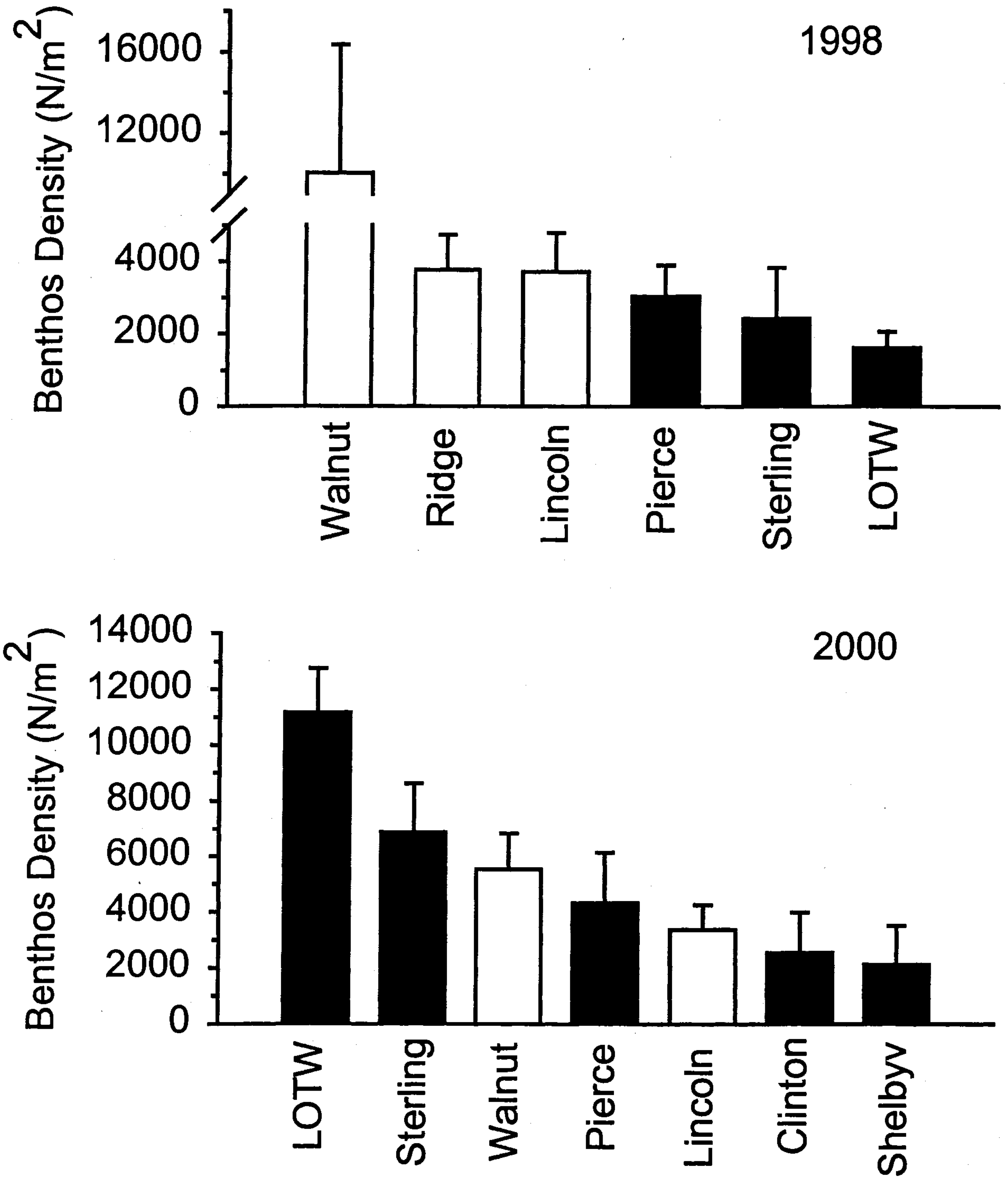

Figure 15. Average June density (N/m^2 ± SE) of benthic macroinvertebrates (excluding Gastropods and Pelycopods) for 6 study lakes in 1998 and 2000. Benthic macroinvertebrates were collected from 6 sites in each lake with a 20-cm diameter stovepipe sampler. Closed bars represent lakes with shad, whereas open bars represent lakes without shad.

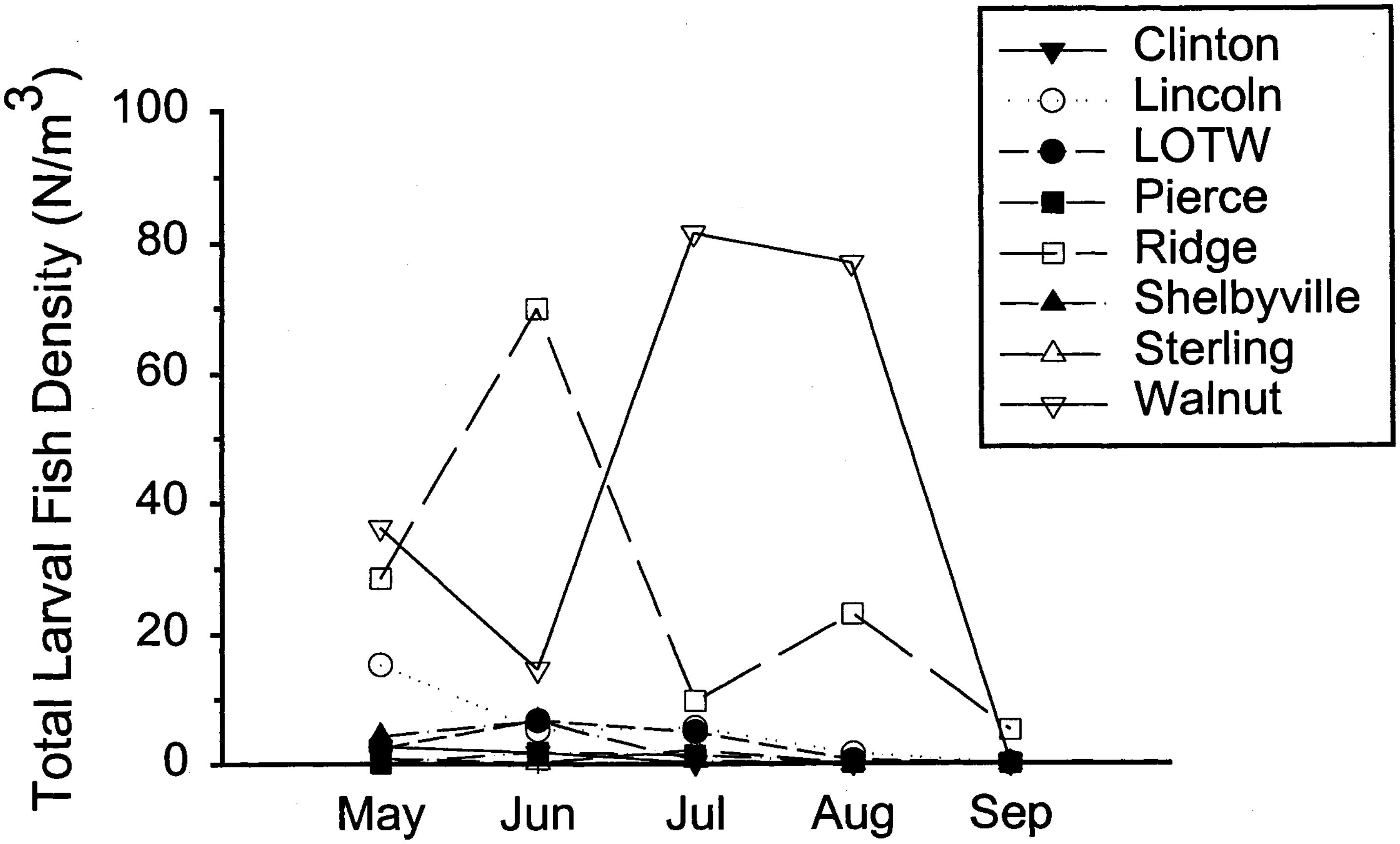

Figure 16. Mean larval fish density (N/m^3) in 8 study lakes. Larval fish were collected using 0.5-m diameter push net with 500-um mesh at 6 sites within each lake. Closed symbols represent lakes with shad and open symbols represent lakes without shad.

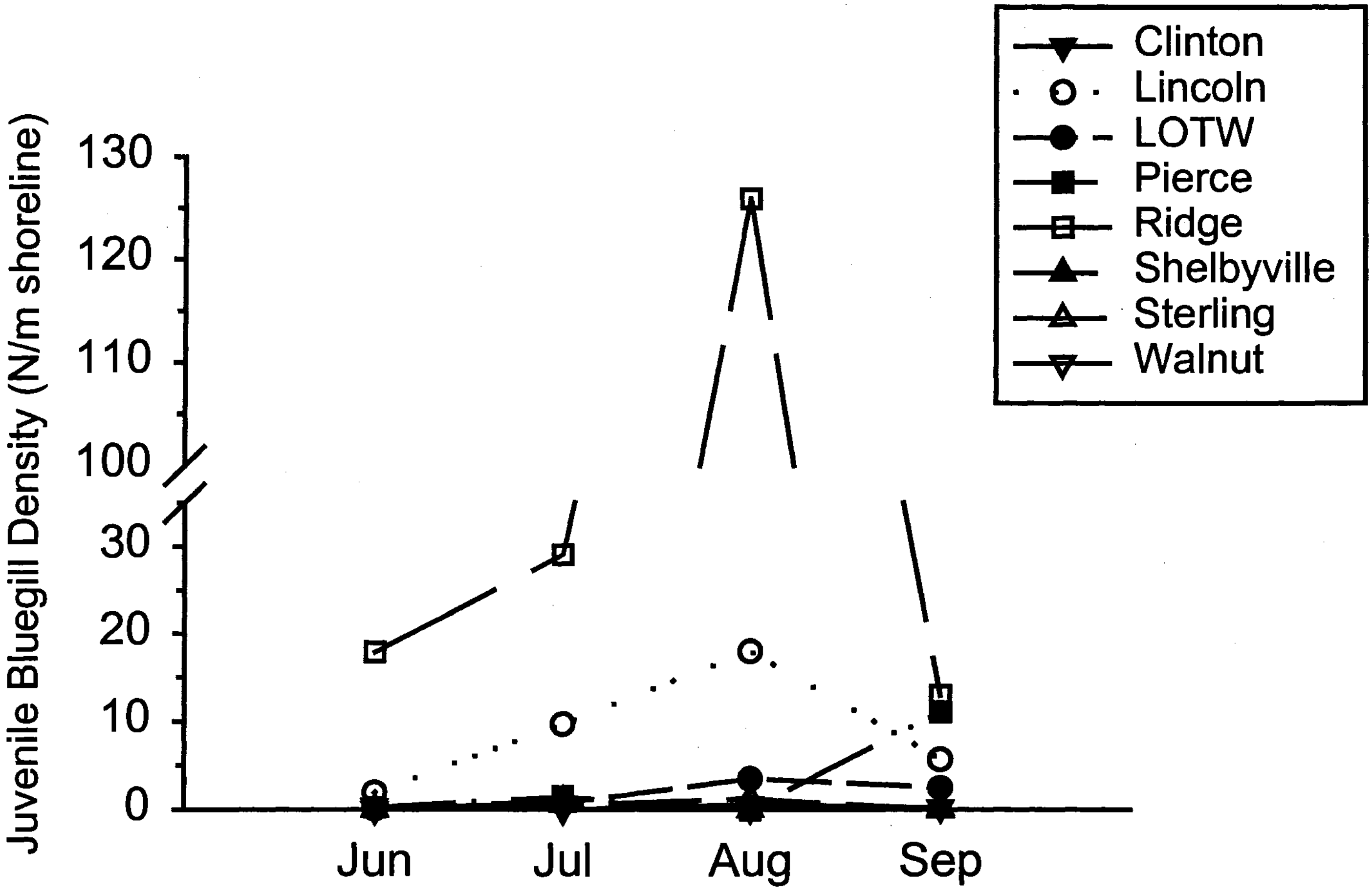

Figure 17. Mean juvenile (15-60 mm TL) bluegill densities(N/m shoreline) for 8 study lakes. Bluegill were collected from 4 sites in each lake with a 6.7-m bag seine. Closed symbols represent lakes with shad, whereas open symbols represent lakes without shad.

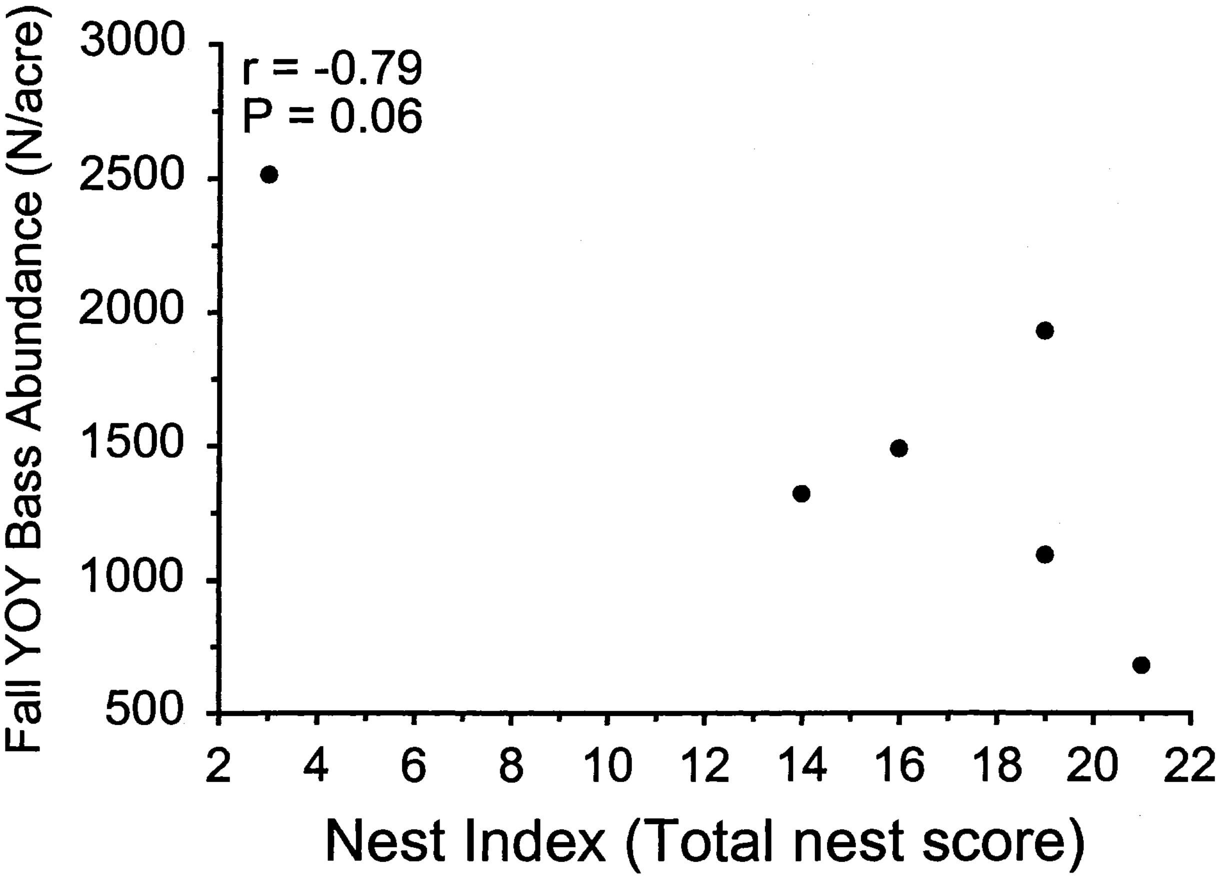

Figure 18. Relationship in ponds between fall biomass of young-of-the-year largemouth bass and nest index score.

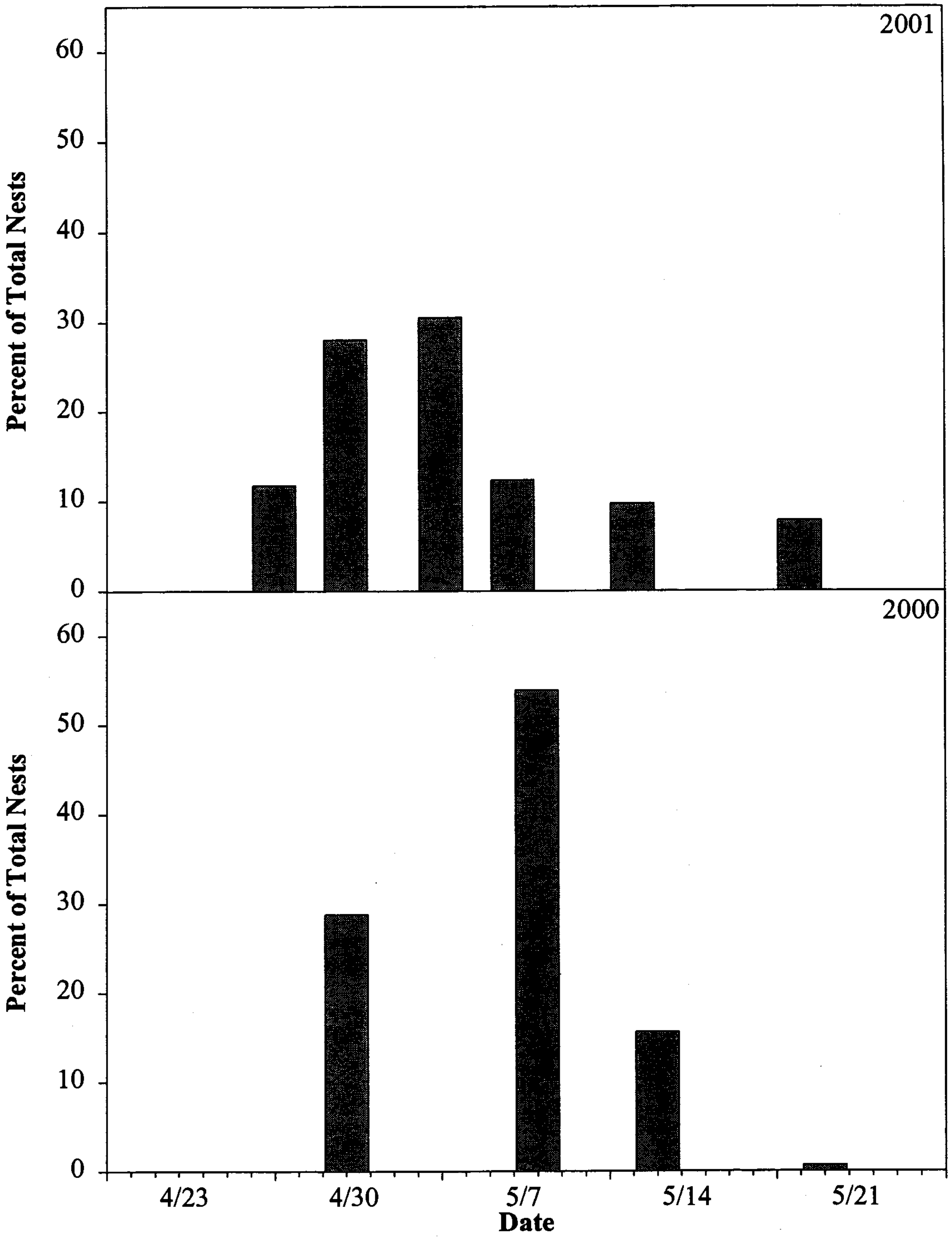

Figure 19. Number of new largemouth bass nests as a percentage of the total number observed by date for 2000 and 2001 on Lincoln Trail Lake.

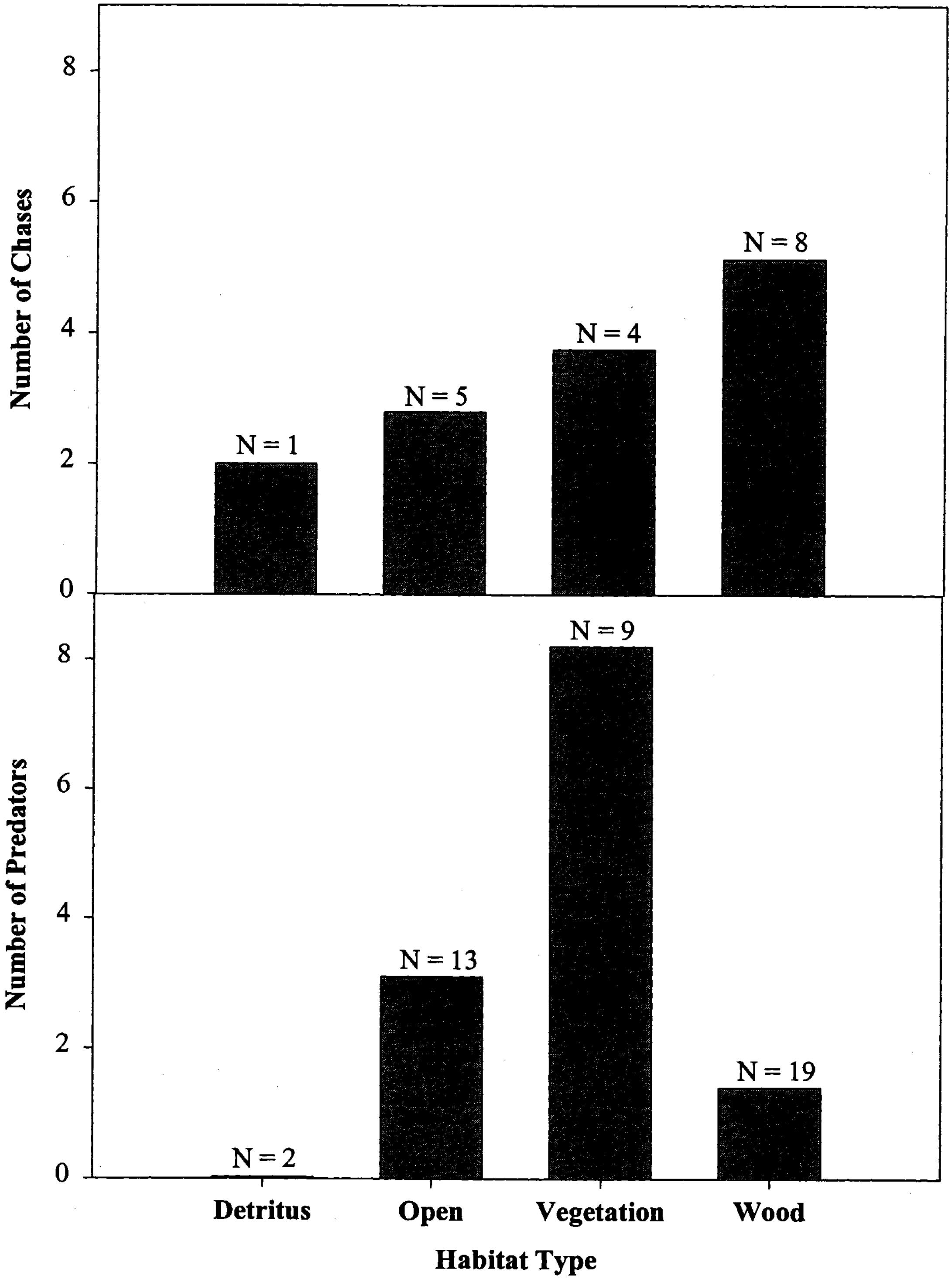

Figure 20. Average male largemouth bass aggression and average number of nest predators observed in habitats classified as detritus, open, vegetation, or wood in Lincoln Trail Lake.

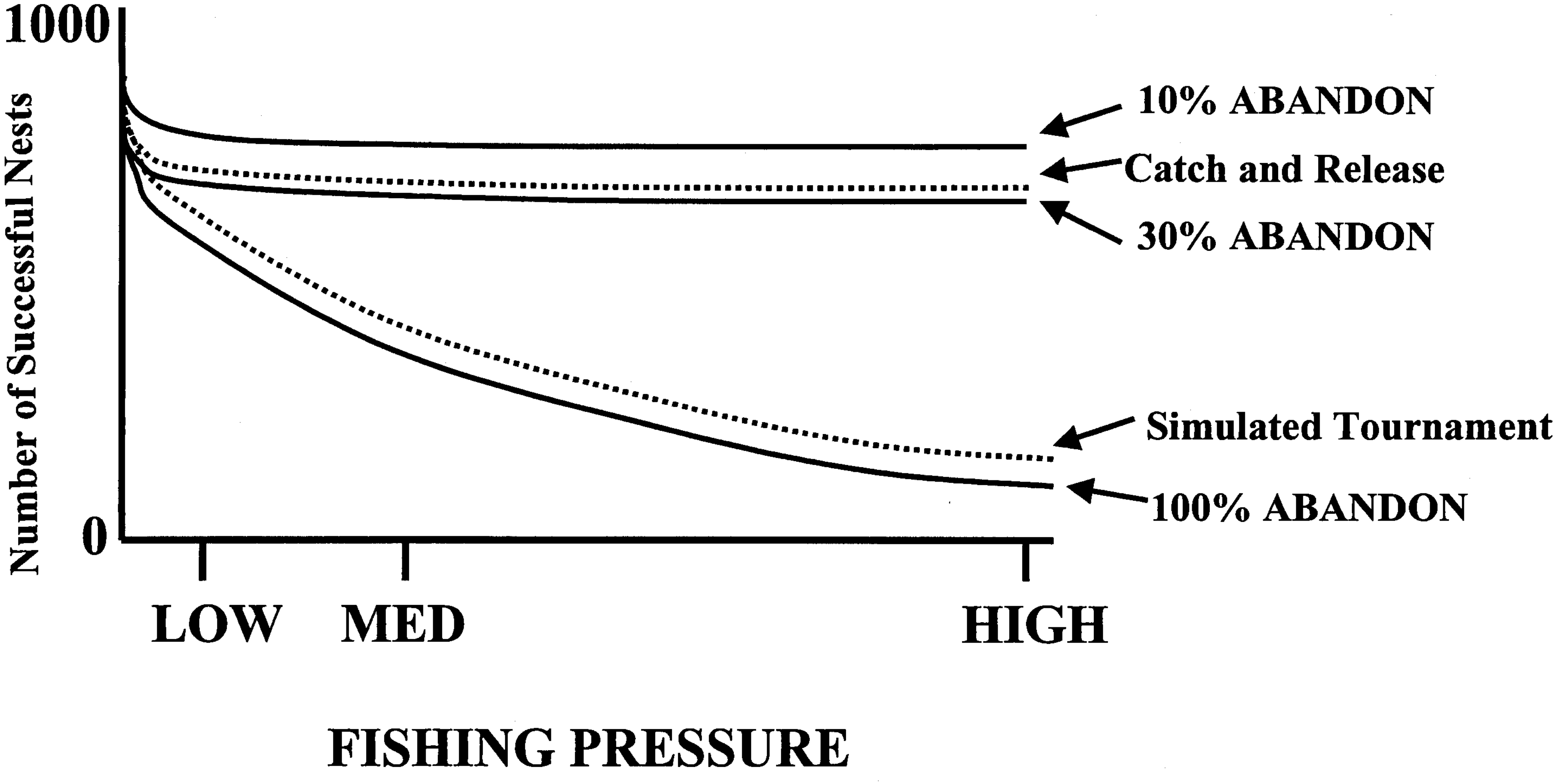

Figure 21. Effect of fishing pressure on the number of successful largemouth bass nests in Lincoln Trail with comparisons of 10 and 100% abandonment rates predicted from the model (solid lines) and abandonment rates from catch-and-release and simulated tournament angling (dotted lines).