Illinois Natural History Survey

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

Annual Progress Report

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David H. Wahl
Principal Investigator

David P. Philipp
Co-investigator

John Epifanio, Director
Center for Aquatic Ecology

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EXECUTIVE SUMMARY: Our overall goal is to develop management strategies that maximize growth, recruitment, and harvest of largemouth bass in Illinois impoundments. Largemouth bass are stocked in Illinois impoundments to compensate for variable recruitment. Even so, the long-term contribution of stocked fish to recruitment and harvest of bass populations is unknown. Because stocking is only one of several management options for this species, it is critical to learn additional information on factors limiting recruitment processes. In addition, information on the importance of rearing technique, size of stocked fish, forage base, cover, resident predators, physical-chemical conditions, and stocking stress in determining largemouth bass stocking success is needed to optimize use of hatchery produced fish.

In job 101.1 we attempt to determine the most reliable and cost-effective method for mass-marking fingerling largemouth bass. We have evaluated the use of fin clips, fin clips followed by freeze cauterization, freeze branding, oxytetracycline (OTC), and photonic dye. In previous reports, we concluded that OTC and fin clips had the best short-term (9 months) retention rates and most efficient application times for 50-mm largemouth bass. OTC was considered to be the most effective marking technique for 50-mm bass, but required sacrificing each fish to check for marks. When sacrificing fish is undesirable, using fin clips is recommended because its short-term retention times are similar to OTC. Fin clips, fin clip cauterization, and freeze branding were examined for long-term retention on 100-mm largemouth bass. During the observation period covering 1999-2002, fin clip cauterization has had the longest retention time, followed by fin clipping and then freeze branding. Identification of fin clips and fin clips cauterized has been complicated by fin regrowth. Freeze branding did not have the problem of fin regrowth, but seasonal variation in appearance on the fish led to difficulty in identifying freeze brands in the fall, when bass have darker external coloration. At this point, we have found no differences in growth rates between fish with these three different marks. Future work will entail further evaluation of seasonal variability in mark retention and extension of the long-term study.

In job 101.2, we evaluated initial contribution of stocked largemouth bass fingerlings in 15 lakes across Illinois. Survival of stocked largemouth bass fingerlings varied considerably across lakes, ranging from 0 to 12 stocked fish per hour of electrofishing during the fall of 2001. Initial stocking mortality was low and was not an important factor in determining overall survival. Although predation rates on stocked fish were high in some lakes, suggesting that losses of stocked largemouth bass to predators can be an important source of mortality, there was no relationship between predator abundance and survival of stocked bass. Abundance of appropriately sized bluegill prey was positively correlated with survival in 1999 and 2000, but not in 2001. Natural recruitment of largemouth bass also varied across lakes but was not correlated with stocking success. Based on our results, the usefulness of supplemental stocking as a management strategy will vary across individual lakes. Additional research regarding the importance of predator and prey populations are needed to determine lake characteristics most favorable for stocking largemouth bass.

All sizes of stocked fish had low initial mortality. Fall CPUE showed that larger sizes of stocked fish had the highest survival and growth. Cost analysis will be conducted in subsequent segments to make recommendations on which size of fish should be stocked in Illinois impoundments. Although, the relative survival of intensively and extensively reared largemouth bass also varied among lakes, few fish were recaptured, and as a result, larger efforts must be put into resampling to accurately assess which rearing strategy yields the highest survival and growth.

Although it is assumed that subsequent increases in standing stock are the direct result of stocking efforts, few data exist to either refute or support that assumption. 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-B1 and MDH-B2 alleles in the natural largemouth bass population of each study lake and verified that our experimental bass were fixed for the MDH-B2B2 genotype. If stocked largemouth bass successfully reproduce in our study lakes, we should find an increase in the frequency of the MDH-B2 allele. Because 10% of the fingerlings stocked into Lake Shelbyville in 2001 contained the MDH-B1B2 genotype, a correction factor will need to be calculated for future analysis of Shelbyville samples. Another complication is that background frequencies of the MDH-B2 allele were found to be higher than anticipated in Forbes and McLeansboro (33% and 55%, respectively). In Murphysboro, Sam Parr, Shelbyville, and Walton Park, background frequencies of the MDH-B2 allele were suitably low, at less than 20%. Because bass stocked into Shelbyville and Forbes should have reached maturation by 2001, we sampled age-0 largemouth bass in these lakes to determine if stocked fish were contributing to natural production within each lake. In Shelbyville, the frequency of the MDH-B2 allele was 18%, as compared to a background frequency of 15%. We will present the results of our analysis on young of the year from Forbes in 2001 in the next report. Because bass stocked in 1999 into the other study reservoirs should be sexually mature by 2002, we will begin sampling the age-0 fish in these lakes along with continuing our age-0 collections in Forbes and Shelbyville.

The objective of 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 age-0 largemouth bass abundance and growth in 11 lakes from May to October, 2001. In addition, we used electrofishing samples the following spring to assess the number of surviving age-0 fish from 2001 in all 11 lakes and to determine the times of peak bass spawning in a subsample of five lakes. Age-0 largemouth bass densities were highly variable among lakes, with rapid declines in density by mid-July. Large inter-lake variability in abundance in the 2001 year class was also observed the following spring. May and June abundances of age-0 bass were positively correlated, but the earliest correlation with subsequent age-0 bass densities was July abundance. July densities of age-0 bass were significantly correlated with recruitment of the 2001 year class from August to the following spring. As an early index of recruitment, the July relationship differs from previous year classes, in which June densities were the best predictors of August abundance. Furthermore, unlike the previous year class (2000), summer abundance of age-0 bass was significantly correlated with recruitment to the following spring. The most consistent correlation between recruitment and prey availability was with juvenile bluegill (15-60 mm TL) abundance. May densities of crustacean zooplankton were positively correlated with juvenile bluegill abundance in August and September, with subsequent positive correlations between late summer abundances of juvenile bluegill and largemouth bass densities in August, September, and the following spring. Age-0 bass abundance was not significantly correlated with bluegill density until mean total lengths of bluegill in littoral habitats were less than 50% of age-0 bass total length. This pattern suggests that size structure of predator and prey can be critical in determining the relative importance of prey abundance to predator recruitment. Size structure of age-0 largemouth bass was variable among study reservoirs, but we did not find any significant correlations between age-0 bass total length and either chlorophyll *a* concentrations or prey abundance. In 2002, we have begun to use electrofishing to assess the times of peak spawning activity of largemouth bass in five of our study lakes. We will combine this information with otolith-derived hatch times to determine the relative survival rates of age-0 bass from different spawning bouts. In future reports, we will have analyzed the effects of total phosphorus concentrations, water level fluctuations, and relative vegetation abundance on largemouth bass recruitment. We will continue to test the utility of early summer age-0 largemouth bass abundance as a predictor of year class strength, because this measurement may be useful to fisheries managers as an early index of bass recruitment. Furthermore, we will combine data from multiple years to assess among year variability in bass recruitment and to test correlations with year class strength.

When male largemouth bass are nesting in the spring, they may be especially vulnerable to angling, which could have detrimental effects on largemouth bass recruitment. In job 101.5, the objective is to assess the level of angling for nesting bass in Illinois and to determine its impact on reproductive success and annual recruitment. To test the strength of the relationship between reproductive success and recruitment, we established six spawning populations of largemouth bass in one-acre ponds, and measured the range of reproductive success and the number of age-0 bass recruiting to the fall. In 2001, we found a significant positive correlation between total reproductive success, in terms of egg abundance, and fall numbers of age-0 bass. This relationship between reproductive success and fall age-0 bass implies that largemouth bass nesting success can be critical to year class strength. We plan on determining the paternity of a subsample of fall recruits from each pond to determine variation in individual contribution to recruitment. Snorkel surveys at Lincoln Trail Lake were used to measure male bass nest site selection and to evaluate the effects of angling and electrofishing on nest success. We used two types of angling treatments, catch-and-release (bass released after two minutes of air exposure) and simulated tournament (bass held for two hours and released at the boat ramp). Although, high turbidity prevented us from effectively surveying for most of the spring, in previous years, male largemouth bass were observed to preferentially select nesting sites containing woody debris, perhaps due to lower brood predator abundance. Mean rates of nest abandonment were 30% from electrofishing, 30% from catch-and-release, 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. Tournament catches were biased towards reproductively active male bass, except in Lake Shelbyville where more females than males were captured. We also evaluated sublethal effects of angling and methods to minimize stress on tournament-angled bass. We found that all angling types elicit a stress response, with degree of exhaustion, water temperature, and amount of air exposure important influencing factors. Repeated handling of fish and high fish density in live wells were both important forms of stress to tournament-angled bass. We will continue to measure the effects of angling and environmental factors (e.g., habitat, predation) on bass nesting success, as well as expand our data on the vulnerability of bass of reproductive age caught in 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 have begun calibrating the model with data derived from our angling manipulations in Lincoln Trail. We are refining the model with our data on natural variation in nest success and size structure of nesting males. Our next step is to incorporate our data on the influence of reproductive success on recruitment, fishing intensity, and characteristics of bass vulnerable to capture by angling. 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 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. Fish growth, differences in mark retention rates and percent regrowth among marking techniques have been measured and assessed every six months starting May 1999 through March 2002.

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%).

In the long-term pond experiments (4" fingerlings), fin cauterization was the longest lasting mark followed by fin clip and freeze brand marks (Figure 1). 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 2). Less fin regrowth in fin cauterized marks made them more obvious than fin clips and required less handling time to identify marks. Freeze brand marks were the most distinguishable and required the least amount of handling time to identify. Freeze brand marks (100%) were clearly visible during the spring of 1999, 2000, 2001, 2002 whereas only 82%, 99%, 99% of freeze brands were distinguishable in the fall of 1999, 2000, 2001 because of darker external coloration (Figure 3). 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 ($\bar{x}$ = 238 mm, TL; March 2002). 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 1999 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 single pelvic fin (e.g., fin clip) or both pelvic fins (e.g., fin cauterized) does not appear to impact foraging success or energy allocation during the four years of growth.

RECOMMENDATIONS: The short-term marking experiments suggest that OTC-marks are preferable over fin clips, fin cauterization, freeze brand, and photonic dye. 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 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. 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 wish to curtail mortality, fin clip marks should be employed due to retention rates comparable to OTC marked 2" largemouth bass. In addition, fin clips take a relatively shorter time to mark fish than freeze brands, fin cauterization, and photonic dye, while simultaneously proving to be less methodologically problematic.

Long-term marking results thus far suggest that freeze brand marks are more distinguishable and take less handling time to identify than fin clips and fin cauterized marks. This in conjunction with better growth rates during the first year as well as the speed and low cost that freeze brands afford suggest that this is the best method for long-term marking of 4" largemouth bass. The seasonal variability of mark visibility for freeze branded fish is potentially problematic and will need to be assessed in subsequent years. We will continue to sample these marked fish at 6-month intervals and 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 water body (e.g. muskellunge Esox masquinongy, Szendrey and Wahl 1996; walleye Stizostedion vitreum, Santucci and Wahl 1993). Largemouth bass, however, reproduce naturally in most Midwestern reservoirs, and therefore stocking occurs in addition to an existing population. The number of natural fish produced during the year of stocking may influence stocking success through competitive interactions for food and habitat. Because native largemouth bass may out compete stocked largemouth bass, a large natural yearclass may decrease stocking success in an individual lake. Conversely, stocked largemouth bass may do well in years with high natural recruitment because they are potentially influenced by the same variables.

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

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

PROCEDURES:

Contribution of Four Inch Fingerlings

We stocked 15 lakes in Illinois with advanced fingerling largemouth bass during August of 1999 - 2001. Lakes varied in size from 11 to 250 ha and were located throughout Illinois, ranging from the Wisconsin to the Kentucky border (Figure 4). Largemouth bass, bluegill Lepomis machrochirus, crappie Pomoxis spp., and channel catfish Ictalurus punctatus were abundant in all study lakes. Gizzard shad Dorosoma cepedianum were present in 11 of the lakes. In addition, we chose lakes with varying levels of available prey and natural largemouth bass recruitment to examine their effects on stocking success.

Bass fingerlings were produced either intensively or extensively at three hatcheries in Illinois (Jake Wolf, Topeka; Little Grassy, Makanda; LaSalle, Marseilles). Intensively reared fish were held inside the hatchery in 265 L concrete tanks and fed commercially produced pellets until stocked. Extensively reared fish were held in ponds and fed on minnows until stocked. Before leaving the hatchery, each fish was given a left pelvic fin clip for future identification. Fish were transported from the hatchery in oxygenated hauling tanks to the recipient lakes. Hauling time ranged between 0.5 to 3 hours. Fifty largemouth bass were measured (nearest mm) and weighed (nearest g) before stocking on each date. Fish were released nearshore at a single location at each lake. Attempts were made to stock largemouth bass at a rate of 60 fish per hectare, however rates varied by individual lake due to varying success of rearing ponds and hatchery production.

We estimated initial stocking mortality on a subset of four lakes by placing 30 fish into each of three floating mesh cages. Largemouth bass were taken directly from the hatchery truck and placed immediately into the cages. Cages were 3 m deep and 1 m in diameter and were placed in at least 3 m of water. The cages were removed after 24 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, 2000 and 2001. 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 from 1999 - 2001. 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 - 2001 data to assess the relationship between survival of stocked bass and natural recruitment, adult largemouth bass abundance, 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 2001 (Mingo and Woods). 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 3). 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 2001. 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:

Similar to results from previous years, survival of stocked largemouth bass was highly variable across lakes in 2001. Catch per unit effort ranged from 0 to 12 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 - 2001 ranged from 0 to 62 %. Survival of stocked fingerlings was highly variable but stocked fish were recaptured in all lakes except Spring Lake South. Fall CPUE of stocked bass was not influenced by the abundance of natural age-0 largemouth bass (r = 0.26; P = 0.30; Figure 5).

Differences in size existed between stocked and natural largemouth bass at the time of stocking in most lakes. There was a significant difference in size between stocked fish and natural largemouth bass found in a lake (paired t-test; t=1.75; P < 0.0001).Because stocked fish were larger than those naturally occurring in the lakes they may have had a competitive advantage over naturally produced fish.

Initial stocking stress did not affect the survival of stocked largemouth bass. Stocking mortality was low across all four lakes from 1999 - 2001 with a mean of 0.58% (± 1.3 SD; Table 3). Stocking mortality was not significantly correlated with temperature at stocking in 2001 (r = 0.33; P = 0.43) and it is concluded that temperature at stocking is not a major factor influencing mortality of stocked largemouth bass.

We examined a total of 1104 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. Similar low predation occured in Woods Lake in 2001 with only nine stocked bass found in predator diets. In contrast, a high proportion of predators (21-26%) sampled in Lake Mingo had stocked largemouth bass in their stomachs in 1999 and 2000. A lower proportion was found in Mingo for 2001 (5.5-10.4%) compaired to other years, but levels were still higher than Woods lake. Despite the wide range in observed predation on stocked largemouth bass across these four lakes, we did not find a correlation with survival (r = -0.04; P = 0.93). Because largemouth bass preyed on stocked fish more than any other potential predator species, we also correlated stocked fish survival and adult largemouth bass (> 200mm) density for all 15 lakes. Density of adult largemouth bass in 2001 did not affect survival of stocked fingerlings (Figure 6; r = 0.27; P = 0.30). Similar lack of relationships were observed for both 1999 (r = -0.34; P = 0.24) and 2000 (r = -0.005; P = 0.99).

Bluegill abundance was important in determining survival of stocked largemouth bass. Survival of largemouth bass was significantly correlated with bluegill densities lakes across all years (Figure 7; r = 0.37; P = 0.01). This suggests that prey abundance may be a limiting factor on survival of stocked largemouth bass.

Stocking Size

Large fingerlings (6") had the highest contribution to the stocked bass population in 2001 and were found in the highest abundance in the fall (Table 4). Unlike the previous two years, advanced fingerlings (8") were stocked the following spring rather than the fall. Advanced fingerlings were the most abundance in spring electroshocking samples in Lake Mingo but few stocked fish of any size and no advanced fingerlings were found in the spring in Woods Lake.

The differential size at stocking was still evident in the fall (Table 4). Fall size of stocked bass was significantly different from natural bass in a lake (paired t-test; $t = 1.75$; $P = 0.0001$). This is similar to previous years, because 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. Advanced fingerling and large fingerlings had larger fall sizes than small and medium fingerlings. The higher growth rate could be attributed to the longer time spent in hatchery conditions or higher growth rates once stocked into a lake.

Initial stocking mortality was low across all size classes and lakes (Table 4). Medium fingerlings was the only size that experienced mortality in the first day after stocking at both Mingo and Woods Lakes (1.1; 3.5 respectively). All other size classes had no individuals die in the mortality cages. Although water temperatures varied considerably across stocking dates, it did not effect initial mortality. Because of such low stocking mortality, we believe that the initial survival among size classes are not important in determining subsequent contribution to year class strength. Prey and predator abundance are probably more important factors influencing the growth and survival of stocked bass.

Rearing techniques:

Survival of intensively versus extensively reared largemouth bass differed across lakes. In Jacksonville, extensively reared fish had a higher CPUE than intensively reared largemouth bass in fall electrofishing samples (Table 5). Only extensive fish were stocked into Shelbyville and few were recaptured in the fall. No intensive or extensively reared fish were recaptured in Walton Park in 2001 but intensively reared largemouth bass survived better in Walton Park in 2000.

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 have identified thus far is 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 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.

Stocking size

Similar to previous years, advanced and large fingerling largemouth bass had higher survival rates than small and medium fingerlings. 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 2002. Attempts will also be made to supplement shocking in order to increase sample size and recapture a larger number of stocked bass to better represent survival of the two rearing techniques.

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

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

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

Both largemouth and smallmouth bass likely home back to natal areas to spawn (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, 2000, and 2001.

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

Background frequencies of LMB from four of the six study lakes have revealed that less than 20% of the individuals have the MDH B2B2 genotype with the exception of Forbes and McCleansboro (Table 6). The higher frequency of the MDH B2 allele from Forbes and McCleansboro is potentially problematic and may make these lakes difficult to use in determining the contribution of stocked fish to recruitment.

Largemouth bass stocked into Forbes and Lake Shelbyville in the summer of 1998 should be mature and, therefore reproducing. We have collected YOY from both Forbes and Lake Shelbyville to determine if the frequency of the MDH B allele has changed as a result of the stocked fish spawning and passing on the MDH B2 allele. To date, only young of the year from Lake Shelbyville have been analyzed (Table 7).

RECOMMENDATIONS: The preliminary analysis of YOY from Lake Shelbyville does not provide enough evidence to make any recommendations. YOY will need to be collected from all six study lakes for multiple years to determine if the stocked fish are contributing to the overall reproductive success within each lake. The prediction is if the stocked fish are contributing we should see an increase in the MDH B2 allele as more stocked fish are maturing and contributing to the reproductive success.

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

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

INTRODUCTION: Largemouth bass 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.

Similar to most species of fish, relative year class strength of largemouth bass is thought to be set by mortality during the first year of life (Eipper 1975; Timmons et al. 1981; Raibley et al. 1997; Buynak and Mitchell 1998). However, the source and timing of the most important factors of mortality still need to be determined. Some species of fish exhibit critical periods, wherein variation in mortality rate during a particular life stage has a disproportionately large effect on recruitment (Hjort 1914; May 1974; Houde 1994). Based on a literature review of largemouth bass studies in the period 1960-2000, episodic mortality of bass embryos during the nesting stage or daily variation in factors affecting juvenile young of the year survival during the summer and winter are the two most likely forms of critical periods in largemouth bass recruitment (Parkos and Wahl in press). Episodic mortality at the nesting stage was prevalent in systems that experienced large fluctuations in abiotic factors during bass nesting (e.g., water level and temperature), whereas survival through the first summer and winter appears to be the result of complex relationships between young of the year size and prey availability, predation, and winter severity (Parkos and Wahl in press).

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 press). 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 11 lakes in 2001 to assess the influence of various factors on largemouth bass recruitment. Seven lakes were sampled every two weeks, while the remaining four lakes were sampled monthly from May to October. Due to construction on the dam, we did not sample Lake of the Woods in 2001 until September. The lakes chosen for this study varied in surface area, latitude, and trophic state. In addition, we chose lakes with poor, medium, and good largemouth bass recruitment.

Largemouth bass recruitment was assessed by shoreline seining and electrofishing. Seining was conducted using a 9.2-m bag seine pulled along the shoreline at fixed transects. All fish were counted and up to 50 fish were measured for each species. In five lakes, we saved thirty young of year (YOY) largemouth bass from each sampling date for diet and age analyses. Electrofishing was used to collect YOY largemouth bass in the fall after they were no longer vulnerable to the seine. Otolith microstructures were used to estimate the TL cut-off 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 assumption allowed us to estimate the number of YOY surviving their first winter and recruiting to age-1. In the spring of 2002, we used weekly electrofishing to determine the abundance of spawning largemouth bass in order to estimate the timing of peak spawning activity in four lakes (Lincoln Trail, Paradise, Ridge, and Woods). Forbes Lake was also sampled biweekly to determine the timing of bass spawning. Each captured fish was sexed and checked for reproductive condition (immature, running, spent).

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

Physical and chemical variables important to largemouth bass recruitment were sampled in each of the study lakes. Aquatic vegetation was identified and mapped in each lake to estimate percent vegetative cover in June and August. Water level was monitored throughout the spring and summer. Water temperature and dissolved oxygen was measured at 1-m intervals using a YSI oxygen meter. In addition, thermographs were placed into four lakes and recorded water temperature at 2 hour intervals throughout the year. Water samples for chlorophyll-*a* and phosphorous were collected using an integrated tube sampler lowered to twice the secchi depth. Chlorophyll was measured using a flourometer, while total phosphorous was measured with a spectrophotometer.

FINDINGS:

Young-of-the-year (YOY) largemouth bass densities were highly variable across study lakes during 2001 (Figure 8). YOY largemouth bass recruited to the seines in May (Forbes, Lincoln Trail, Paradise, Ridge, Walnut Point) and June in most lakes (Clinton, Dolan, Pierce, Shelbyville, Woods), but not until July in Sterling Lake. YOY largemouth bass densities ranged from 1 to 188 fish per meter shoreline in May and from 1 to 22 fish per meter of shoreline in August. YOY largemouth bass abundances declined over time, with the largest declines occurring by mid-July. June YOY bass abundance was positively correlated with May YOY density ($r = +0.81$; $P = 0.003$), but subsequent YOY bass densities were correlated with neither May nor June abundances. Instead, July YOY bass abundance was a better measure of relative year class strength, with positive correlations between July abundance and YOY numbers in August ($r = +0.67$; $P = 0.02$), September ($r = +0.71$; $P = 0.02$), and October ($r = +0.71$; $P = 0.01$). Variability in abundance was also apparent the following spring (2002), with catch per unit effort (CPUE) of bass from 2001 cohorts ranging from 1 to 33 fish per hour (Figure 9). July YOY largemouth bass abundance was also significantly correlated with electrofishing catch per unit effort of the 2001 cohort in spring of 2002 ($r = +0.67$; $P = 0.03$), suggesting that year class strength was set by July (Figure 10). This relationship between July YOY largemouth bass abundance and YOY bass in August and September, differs from the relationship observed in previous years, where summer and fall YOY bass abundance was correlated with June YOY numbers. Unlike bass in the 2000 cohort, where year class strength did not appear to be established until after winter, summer abundances of YOY largemouth bass of the 2001 cohort were useful in providing an early index of recruitment.

Recruitment of largemouth bass from the 2001 cohort to the following spring was correlated with abundant crustacean zooplankton translating into increased availability of juvenile bluegill as prey. Inshore abundance of crustacean zooplankton in May, when larval largemouth bass are abundant and most dependent on zooplankton prey in littoral habitats, varied from 31-427 individuals per liter (Figure 11). However, abundance of YOY bass from May to July was not positively correlated with May and June zooplankton densities. Instead, YOY largemouth bass abundance in August and September were positively correlated with May densities of crustacean zooplankton ($r = +0.98$; $P < 0.0001$ and $r = +0.95$; $P = 0.0004$, respectively). However, abundance the following spring was not significantly correlated with May crustacean zooplankton density ($r = +0.58$; $P = 0.13$). Juvenile bluegill abundance (TL 15-60 mm) also varied considerably among study lakes, with August densities ranging from 4 to 583 fish per meter of shoreline (Figure 12). Densities of juvenile bluegill in August and September were both positively correlated with May zooplankton abundance ($r = +0.79$; $P = 0.02$ and $r = +0.86$; $P = 0.006$, respectively). Abundances of largemouth bass in September and the following spring were both positively correlated with August densities of juvenile bluegill ($r = +0.66$; $P = 0.03$ and $r = +0.81$; $P = 0.003$). By August, most bluegill in the littoral habitat of our study lakes were in size classes vulnerable to YOY largemouth bass predators (Figure 13; see Lawrence 1954). Abundance of YOY bass the following spring was also positively correlated with overall mean density of juvenile bluegill for 2001 ($r = +0.82$; $P = 0.002$; Figure 14).

Recruitment of largemouth bass from the 2001 cohort was not significantly correlated to chlorophyll *a*, larval fish abundance, or benthic macroinvertebrate densities. Primary productivity varied considerably among the study lakes, with some lakes varying within the year and others being consistently high or low (Figure 15). Overall chlorophyll *a* concentrations among lakes varied from a low of 5.3 μg/L to a high of 55.1 μg/L. YOY largemouth bass abundance was not significantly correlated with either mean chlorophyll *a* concentrations or concentrations in May, June, July, August, or September. However, larval fish abundance was positively correlated with mean chlorophyll *a* concentrations ($r = +0.65$; $P = 0.03$). Mean larval fish density ranged from < 1 to 179 fish/m^3 with multiple peaks throughout the summer (Figure 16). Mean density of larval fish was not significantly correlated with May-October YOY bass abundances or to the number of YOY bass surviving to the following spring. Summer means of benthic macroinvertebrates ranged from 1566/m^2 to 5594/m^2 (Figure 17). Summer abundance of YOY largemouth bass and number of bass recruiting to the following spring were both not significantly related to mean benthic macroinvertebrate density. Number of recruits to the following spring were also not significantly related to annelid biomass (P = 0.41), chironomid larvae and pupae density (P = 0.32), and amphipod and isopod abundance (P = 0.41).

Growth of largemouth bass was variable across lakes (Figure 18). Similar to previous years, peak density of YOY bass had only a marginal negative relationship to average YOY largemouth bass total length (TL) in September (r = -0.62; P = 0.08). September TL of YOY bass was not significantly correlated with overall chlorophyll *a* concentrations (P = 0.28), zooplankton (P = 0.25), benthic macroinvertebrate (P = 0.11), larval fish (0.91), and juvenile bluegill abundances (P = 0.46). The only significant correlation between fall TL of YOY largemouth bass and prey resources was a negative correlation with mean chironmid larvae and pupae abundance (r = -0.63; P = 0.04).

Largemouth bass spawning in 2002 occurred over a 60 day period, beginning in April and ending in June (Figure 19). In Lincoln Trail, Paradise, and Woods, two distinct peaks in spawning activity occurred, one in late April and another in early June. One peak in spawning activity was observed in Ridge Lake in mid-May.

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, and prey availability 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 July was positively correlated with the density of YOY bass in August and September, as well as to the number of age-1 largemouth bass the next spring. This result differs from 2000 wherein overwinter mortality appeared to be an important recruitment bottleneck. Increasing the sample size of yearling largemouth bass collected in the spring helped to reduce the variability in our estimates of overwinter survival of YOY bass. We will continue our spring assessments in order more to 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. We will continue monitoring spawning activity by electrofishing in the four lakes examined in 2002. This data will be compared to records of bass nesting provided by snorkeling transects in Lincoln Trail (see Job 101.5). 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. Furthermore, we will use our spring electrofishing surveys to determine times of peak inshore abundance of sexually mature fish in spawning condition. In early and mid July, we plan on using a combination of electrofishing and seining to collect enough YOY bass to determine the survival of fish from different hatch times. Hatch time can be determined through counts of daily growth rings laid down on the otoliths of YOY fish. Estimates of peak spawning times combined with estimates of hatch times should help us to determine the approximate time of peak nesting behavior. We can then explore potential correlations between environmental factors during nesting and relative year class strength.

Variation in the abundance of potentially important prey items may be crucial to understanding largemouth bass recruitment. In 1998 and 2001, 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, the positive relationship between larval fish density and YOY largemouth bass abundance in 2000 only existed through July, and the correlation between YOY bass and juvenile bluegill abundance in 2001 was not present until August. The timing of the relationship between YOY largemouth bass and prey fish abundance 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. Combining diet information with hatch times will help us to determine the influence of relative timing of spawning on YOY largemouth bass diets. 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. More detailed diet information will enable us to focus our analysis into the importance of invertebrate prey abundance.

Several variables collected but not yet analyzed will be included in future reports. For example, water column nutrient concentrations, temperature, submerged vegetation, and water level still need to be analyzed for effects on largemouth bass recruitment and growth. 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 year 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.

Research programs directed towards elucidating the biological effects of black bass catch-and-release angling mirror the increase in concern for the live release of fish by the public and fisheries managers. By identifying and understanding the factors associated with hooking injury and mortality (Muoneke and Childress 1994; Wilde 1998), fisheries managers, outdoor media, competitive angling groups and conservation organizations have been able to alter angling practices to increase fish survival following catch-and-release. Unfortunately, the use of mortality as the sole endpoint to assess the effectiveness of catch-and-release strategies is inadequate; we need to consider sublethal impacts, as well (Cooke et al. In Press). Although some information exists on how angling related stress may induce mortality (Wood et al. 1983), few studies have focused on what sublethal stress means to the organism, especially in relation to long-term individual fitness (Cooke et al. In Press).

PROCEDURES: To examine the relationship between reproductive success and recruitment in largemouth bass, we stocked seven one-acre ponds with 22 adult bass, ten males and twelve females, in April 2001. All brood fish within each pond were given a unique Floy tag mark for identification of individual bass during snorkel surveys as well as a PIT tag for future identification. Additionally, clips were taken from the caudal fins of all adult bass for future genetic identification. Water temperatures 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 larvae it contained, with scores ranging from one (lowest) to five (highest). Nest indexes were calculated by summing nest scores for each pond. Bass larvae 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 mixed locations in each pond. In October 2001, 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 have been monitored each spring from 1999 to 2002. We gave each nest a tag and recorded egg score (1-5), water depth of the nest location, and the life stage of the eggs or fry. Habitat within a 4m x 4m area around the nest was mapped, making note of substrate, cover, and potential nest predators. We made visual estimates of the total length of the males guarding the nests and noted the presence of any hook wounds. We also chased 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 three of the sites, electrofished through the transect, gave each captured male a caudal clip, and then snorkel surveyed each site the following day to see if the captured males abandoned their nests. Three other transects 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 nests at three of the sites in 2000 and recorded the nests from which we were able to remove the males. Males were released after two minutes of air exposure to simulate a catch and release angling event. The next day, we swam the angled sites and recorded whether or not the nest was abandoned. In 2001, 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 sites 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.

In addition, we summarize how catch-and-release angling affects largemouth bass by synthesizing existing literature and presenting new data from our laboratory. We conducted a series of experiments to assess the real-time physiological and behavioral responses of largemouth bass to different angling related stressors and then monitored their recovery. Techniques used range from simple hooking mortality studies to more complex assessements of physiological and energetic responses using cardiac output (Schreer et al. 2002) and locomotory activity telemetry (Cooke et al. 2000). Methodological details on each of these techniques are reported elsewhere.

FINDINGS: Bass began spawning on 4-15-01, with two distinct peaks in activity at 4-16-01 and 4-23-01 (Figure 20). Both peaks in spawning took place as water temperatures declined. Ponds varied in total nest score (10-25) and total number of nests (3-10). Abundance of fall recruits was positively correlated with nest index ($r = +0.87$; $P = 0.01$; Figure 21). This relationship between reproductive output in the spring and YOY abundance in the fall implies that largemouth bass nesting success has the potential to be critical to eventual year class strength. Similar to previous years, summer estimates of YOY bass abundance failed to significantly correlate with fall recruit numbers.

Timing of spawning was summarized for each of the previous years in Lincoln Trail (Figure 22). In 1999, the spawn appeared to be bimodal, while fish spawning in 2000 and 2001 were unimodal. Spawning duration was similar across years, but timing varied among years. Timing of spawn will be compared to fall survival using otoliths to determine relative contribution of each group to recruitment. Bass began spawning in Lincoln Trail on approximately 4-30-02. A total of 8 nests was found in the six surveyed sections. At this time, heavy rains caused increased turbidity in the lake, making it impossible to accurately assess spawning with snorkel surveys.

Capture rates of nesting males with electrofishing gear ranged from 17 to 67% in the three transects with a mean of 41% (Table 8). The rate of nest abandonment from electrofishing (30%) that removed male largemouth from their nests was about tree times the abandonment rates found on control transects (10%; Table 9).

Abandonment rates from simulated tournaments were substantially higher than from catch and release angling (Table Table 10). In addition, tournament anglers in the spring appear to target spawning bass. The percentage of bass that were reproductively active ranged from 34.2% to 78.0% of all fish captured (Table 11). Tournament anglers tended to capture more males than females, which may indicate that anglers are targeting males that are either on nests or actively guarding offspring. Sex ratios (males : females) ranged from 1.1:1 to 3.3:1 across lakes Mattoon, Mill Creek, and Forbes during the spawn. Captured males were smaller than females during the spawning period and had total lengths that ranged from 357 mm to 409 mm. Shelbyville had different results with a sex ratio (male:female) of 1:4.5. Captured males in Shelbyville were also larger than the females during the spawn, but were smaller during the postspawn observation period. Mill Creek and Shelbyville produced sex ratios for the postspawn period of 1:1.4 and 1:1, respectively. Lake Mattoon and Forbes had sex ratios of 1.4:1 and 1.8:1, respectively.

Our physiological data suggest that all angling elicits a stress response, however, the magnitude of this response is determined by the degree of exhaustion and varies with water temperature. Our results also suggest that air exposure, especially following exhaustive exercise, places an additional stress on fish that increases the time needed for recovery and likely the probability of death. Indeed, when angled, heart rates increase rapidly, however, during air exposure, heart rates drop drastically, indicating bradycardia (Figure 23). When returned to the water, heart rates accelerate, indicating tachycardia. Simulated tournament conditions revealed that metabolic rates of captured fish increase with live-well densities greater than one individual, placing a greater demand on live-well oxygen conditions (Figure 24).

RECOMMENDATIONS: In future reports, we will investigate potential links between parental male traits (e.g., age, size, behavior) and survival of offspring. Genetic analysis of fall YOY nest origins will be used to test 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 addition, we will continue to monitor bass nesting in the experimental ponds in order to measure the influence of variation in nesting success on fall recruitment.

In future segments, we will examine potential factors influencing largemouth bass spawning time in Lincoln Trail Lake. In addition, we will examine the consequences of those differences in spawning time through fall recruitment for young-of-year bass. Examination of nest site habitat and nest predator densities will again take place next year to increase sample sizes. Relationships among habitat type and predator abundance, male aggression level, and ultimately nest success will be closely examined. Our data from Lincoln Trail shows a higher 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 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 three of the four 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.

The repeated handling of fish during tournament angling, including culling, the addition of fish or other live-well disturbances, and the final tournament weigh-in, which adds an additional several minutes of air exposure, further adds to already heightened stress levels. When these cumulative stressors do not result in death, the resultant energetic disruptions clearly have negative impacts not only on the short term health and condition of the fish, but also most likely on its biological fitness, i.e., its lifetime reproductive success. Using data from in situ cardiac monitoring of fish in livewells, we have estimated livewell oxygen demands for black bass across a range of water temperatures, fish densities, and livewell sizes. This information is essential for ensuring adequate livewell management to facilitate reduced mortality and enhanced recovery. We also show that following angling, nest-guarding male bass face a reduction in their locomotory activity that may reduce their ability to successfully defend the nest. Although most concerns about catch-and-release angling occur at the population and community level, our assessment of various angling, handling and retention practices identifies ways to minimize the effects of angling upon individual fish, and to ensure that these effects do not manifest themselves as problems at the population level.

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 25). Under a tournament angling scenario, our model would predict a strong decrease in nest success as fishing pressure increased. In Lincoln Trail Lake, from 1999-2001, the number of bass nests has ranged from 6-12 nests/100 m of shoreline, with natural abandonment rates from 9-27% (Table 12). Average total length of male largemouth bass guarding nests ranged from 292-325 mm. These and future data will be used to parameterize the model of effects of angling on bass populations.

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

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, 15 March 2001, 18 October 2001, and 12 March 2002. Genotypes for each mark are given.

			Growth Rate (g/d)						
Physical Mark	Genotype	Stocking density (No./pond)	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	3/15/01 to 10/18/01	10/18/01 to 3/12/02
FC	1:1	75	0.10	0.19	0.05	0.38	0.08	0.04	0.18
FB	1:2	100	0.09	0.23	0.05	0.30	0.08	0.05	0.18
FCFB	2:2	75	0.10	0.22	0.03	0.41	0.10	0.06	0.18

Table 2. Advanced fingerling largemouth bass stocked into 15 Illinois reservoirs in August 2001. 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			Fall			
	Stocking Date	Stocking Size (mm)	#/ha	Stocked CPUE (#/hr)	Stocked TL (mm)	Natural CPUE (#/hr)	Natural TL
Bloomington (250)	8/14/01	101	64	10.7	166	234.7	140
Charleston (113)	8/14/01	102	62	12.0	143	10.3	103
Forbes (212)	7/18/01	111	31	3	183	28.7	141
Homer (32)	8/14/01	102	63	2	188	27.3	125
Jacksonville (198)	8/15/02	101	25	16	216	42.3	143
Kakusha (21)	8/9/01	103	69	1.5	136	21.9	149
Le Aqua Na (16)	8/8/01	~100	67	0.7	144	19.7	90
McLeansboro (30)	8/1/01	~100	61	1.7	147	34.0	141
Mingo (69)	7/10/01	57	123	4.7	108	32.0	115
Mingo (69)	8/15/01	98	62	8.6	151	32.0	115
Mingo (69)	11/6/01	156	37	11.6	152	32.0	115
Mingo (69)	5/9/02	220	23	Not Stocked until Spring		32.0	115
Murphysboro (58)	7/18/01	111	62	0.7	191	12.0	119
Pierce (66)	8/8/01	102	62	2.7	180	154.7	128
Sam Parr (73)	7/18/01	111	62	12.7	196	67.3	181
Shelbyville (4451)	7/20/01	~100	2	10.3	219	47.3	110
Spring N (194.1)	8/15/01	102	74	1.3	149	51.3	148
Spring South (277)	8/15/01	102	62	0	--	28.7	104
Walton Park (12)	8/1/01	97	104	3.3	234	27.3	117
Woods (11)	7/10/01	60	127	2.4	107	20.9	115
Woods (11)	8/15/01	102	64	0.1	116	20.9	115
Woods (11)	11/6/01	150	25	2.9	154	20.9	115
Woods (11)	6/26/02	201	14	Not Stocked until Spring		20.9	115

Table 3. Mean (± 1 SE) initial stocking mortality and number of fingerling largemouth bass recovered from predator stomachs following stocking into two Illinois lakes during 2001. 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 diets for three days after stocking.

					Predator Diets		
Lake	Stocking Date	Size stocked (inches)	Stocking Mortality	Lake Temp C	Stomachs Examined	Number of Stocked Bass	Percent of Predators
Mingo	7/10/01	2	0	28.4	193	10	5.2
	8/15/01	4	1.1	27.2	240	25	10.4
	11/6/01	6	0	11.9	248	4	1.6
	5/9/02	8	0	18.6	84	0	0
Woods	7/10/01	2	0	28.9	176	7	4
	8/15/01	4	3.5	27.2	74	2	2.7
	11/6/01	6	0	11.9	53	0	0
	6/26/02	8	0	27	36	0	0

Table 4. Comparison of stocking success of four sizes of largemouth bass in lakes Mingo and Woods. 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 holding cages and counting the number dead after 24 hours.

	Stocking					Fall 2001			Spring 2002		
Lake	Date	Total Length	SD	Number Stocked	Stocking mortality	CPUE	Total Length	SD	CPUE	TL (mm)	SD
Mingo	7/10/01	57	4.8	8500	0	4.7	108	12.9	Not Worked up		
Mingo	8/15/01	98	8.7	4250	1.12	8.6	151	26.4	0	--	--
Mingo	11/6/01	156	8.3	2550	0	11.6	152	11.2	3	156	9.1
Mingo	5/9/02	220	25.4	1600	0	Not Stocked			14.7	207.8	25.1
Woods	7/10/01	60	5.0	1400	0	2.4	107	17.0	Not Worked up		
Woods	8/15/01	102	11.7	700	3.53	0.1	116	0	0	--	--
Woods	11/6/01	150	8.6	280	0	2.9	154	9.0	2.3	155.2	10.5
Woods	6/26/02	201	9.4	150	0	Not Stocked			0	--	--

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	Number	Total length at	Fall CPUE	Natural Fall CPUE
Jacksonville	8/15/01	Intensive	5000	101	0.7	24.7
Jacksonville	8/15/01	Extensive	11000	~100	6.3	--
Shelbyville	7/20/01	Extensive	22311	109	0.8	--
Walton Park	8/1/01	Intensive	625	97	0	18.7
Walton Park	8/1/01	Extensive	625	~100	0	--

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 (N = 40) Fall 00	1/1 = 21	1/2 = 11	2/2 = 8	
Forbes (Total N = 158)	1/1 = 81	1/2 = 49	2/2 = 28	1 = 0.668 2 = 0.332
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 (N = 16) Fall 00	1/1 = 3	1/2 = 6	2/2 = 7	
McCleansboro (N = 11) Summer 01	1/1 = 2	1/2 = 6	2/2 = 3	
McCleansboro (N = 28) Fall 01	1/1 = 13	1/2 = 9	2/2 = 6	
McCleansboro (Total N = 89)	1/1 = 23	1/2 = 34	2/2 = 32	1 = 0.449 2 = 0.551
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 (N = 14) Fall 00	1/1 = 10	1/2 = 3	2/2 = 1	
Murphysboro (N = 5) Summer 01	1/1 = 5	1/2 = 0	2/2 = 0	
Murphysboro (Total N = 98)	1/1 = 80	1/2 = 12	2/2 = 6	1 = 0.878 2 = 0.122
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 (N = 25) Fall 00	1/1 = 22	1/2 = 0	2/2 = 3	
Sam Parr (Total N = 101)	1/1 = 75	1/2 = 16	2/2 = 10	1 = 0.822 2 = 0.178
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 N = 211)	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 (N = 35) Summer 01	1/1 = 28	1/2 = 4	2/2 = 3	
Walton Park (Total N = 85)	1/1 = 66	1/2 = 11	2/2 = 8	1 = 0.841 2 = 0.159

Table 7. Frequencies of MDH B2B2 from young of the year in Lake Shelbyville.

	Genotypes			Allele Frequencies	
Shelbyville (N = 23) Summer 01	1/1 = 15	1/2 = 6	2/2 = 2		
Shelbyville (N = 64) Fall 01	1/1 = 47	1/2 = 13	2/2 = 4		
Shelbyville (Total N = 87)	1/1 = 62	1/2 = 19	2/2 = 6	1 = 0.822	2 = 0.178

Table 8. Number of bass nests on electrofished transects and percent of these nests the following day that had nest-guarding males previously captured by electrofishing. All males captured by electrofishing were given a fin clip and released at the end of the transect. Snorkel surveys were used to determine number of nests on the transect and the number of clipped males the following day.

		Electrofishing	
Date	Transect	# Nests Found	% Clipped fish on nest
5/17/00	1	6	67
4/30/01	1	5	40
4/30/01	2	6	17
		Mean Capture Rate	**41**

Table 9. Percent abandonment of unmanipulated nests and nests where the parental male was captured by electrofishing. Transects were 440 meters long and abandonment was determined by snorkel surveys the days following experimental manipulations.

		Electrofish		**Control**	
Date	Transect	# Nests Found	% Abandonment	# Nests Found	% Abandonment
5/17/00	1	6	17	16	19
4/30/01	1	5	40	8	13
4/30/01	2	6	33	6	0
	Mean Abandonment Rates (%)		**30**		**10**

Table 10. Abandonment rate of male largemouth bass collected from nests with either catch and release or tournament angling.

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

Table 11. Number of fish examined, sex ratios, average TL (mm), and percent ripe/running bass from tournaments at Mill Creek, Mattoon, Stephen Forbes, and Shelbyville Lakes during spawn and post-spawn 1999, 2000, 2001, and 2002. Percent running bass are given for males, percent ripe bass for females, and all fish that are reproductively active are combined for a total.

Lake	N	Sex Ratio (males:females)	Mean TL(mm) Males	Females	Percent Ripe/running Males	Females	Total
Forbes							
Spawn	70	1.41:1	408.6	455.3	39.0	65.5	50.0
Post-spawn	39	1.81:1	439.2	398.9			
Mattoon							
Spawn	72	1.12:1	405.4	438.2	34.2	70.5	51.4
Post-spawn	25	1.44:1	384.0	392.6			
Mill Creek							
Spawn	130	3.3:1	357.4	425.7	36.4	40.0	37.2
Post-spawn	44	1:1.39	398.2	404.6			
Shelbyville							
Spawn	22	1:4.5	465.5	420.0	50.0	78.0	62.2
Post-spawn	202	1:1	411.6	430.5			

Table 12. Number of largemouth bass nests, percent abandonment rate, and average total length (TL) of nesting males from 1999-2001 in Lincoln Trail. All numbers are from snorkel surveys conducted every other day of three 440-m transects for the duration of the spawning period.

Year	# nests/ 100 m shoreline	Abandonment rate (%)	Nesting male TL (mm)
1999	6	27	305
2000	11	9	325
2001	12	20	292

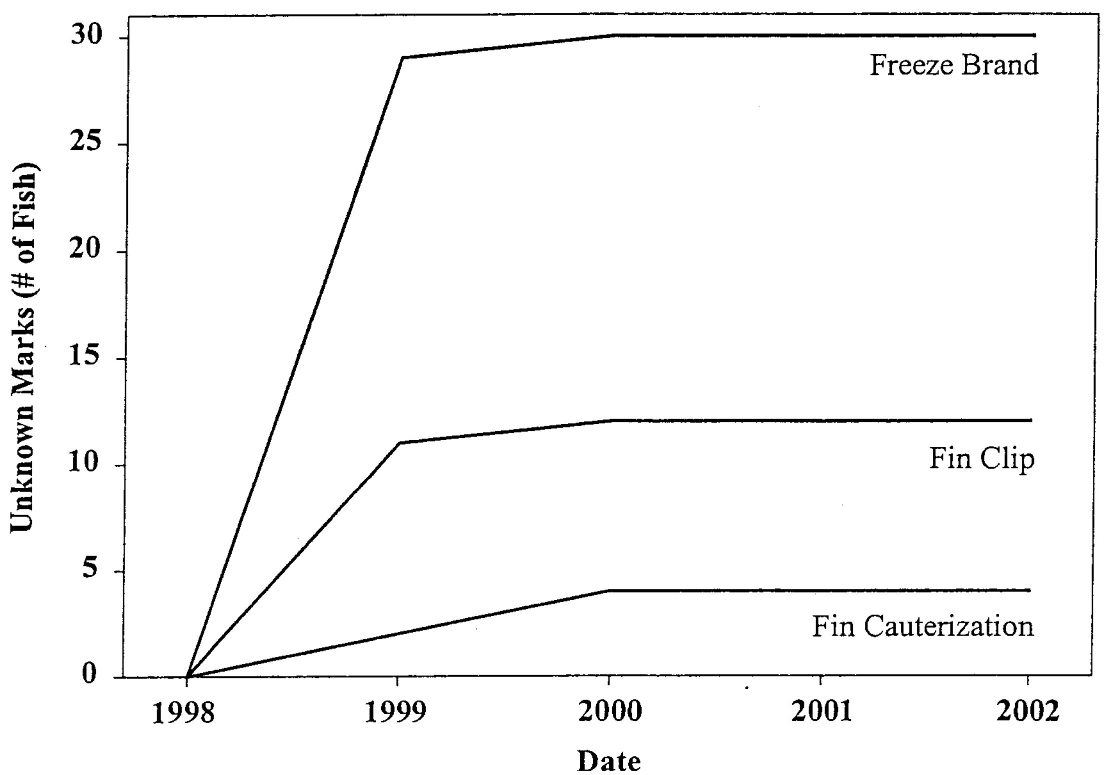

Figure 1. Cummulative number of 4" largemouth bass with unrecognizable marks sacrificed and identified by 1:1 (Fin Clip), 1:2 (Freeze Brand), or 2:2 (Fin Cauterization) MDH-B genotype for each date sampled.

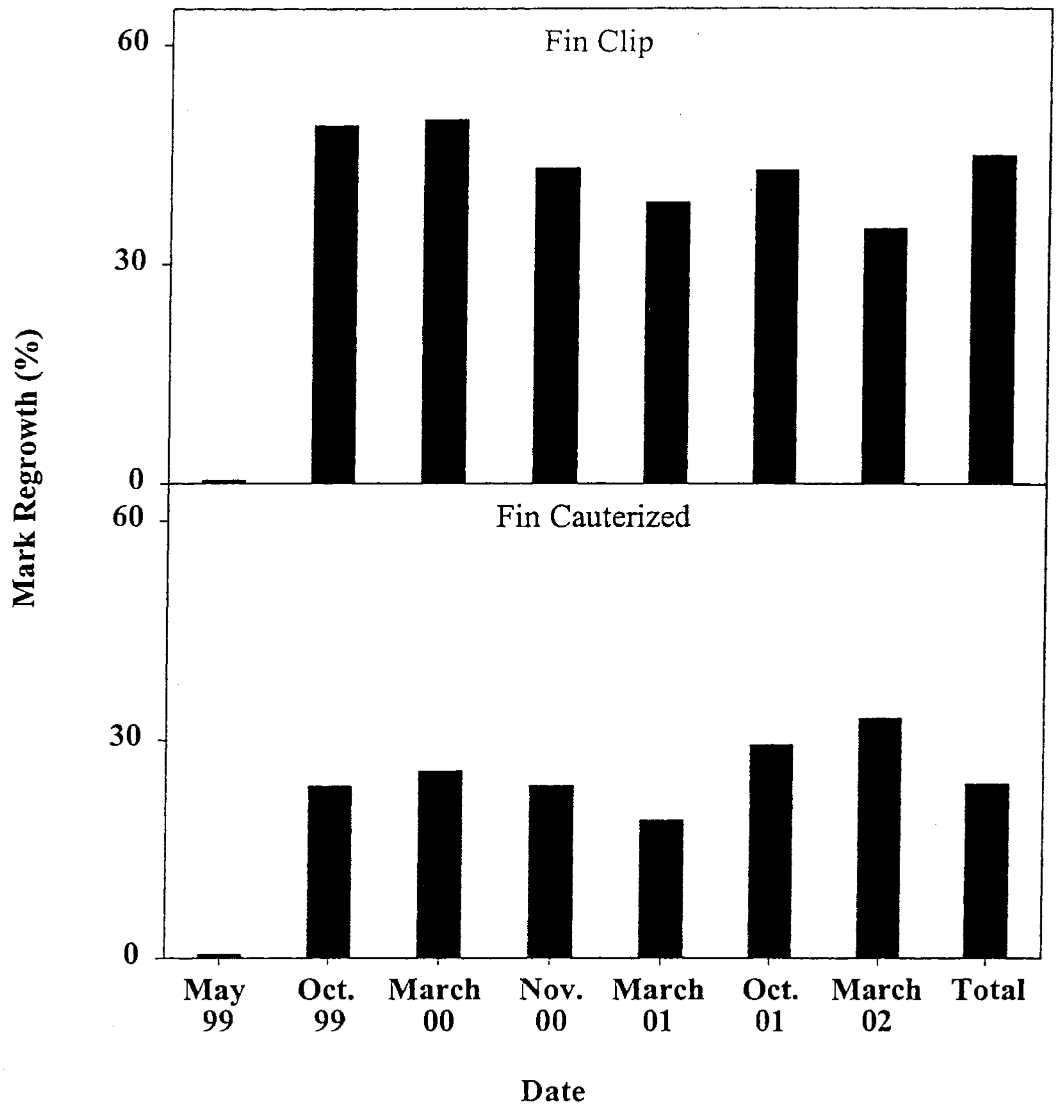

Figure 2. Average mark regrowth (%) for fin clip, fin cauterized, and freeze brand marked 4" largemouth bass through time. Total denotes experiment wise average (%) regrowth for fin clip and fin cauterized marks.

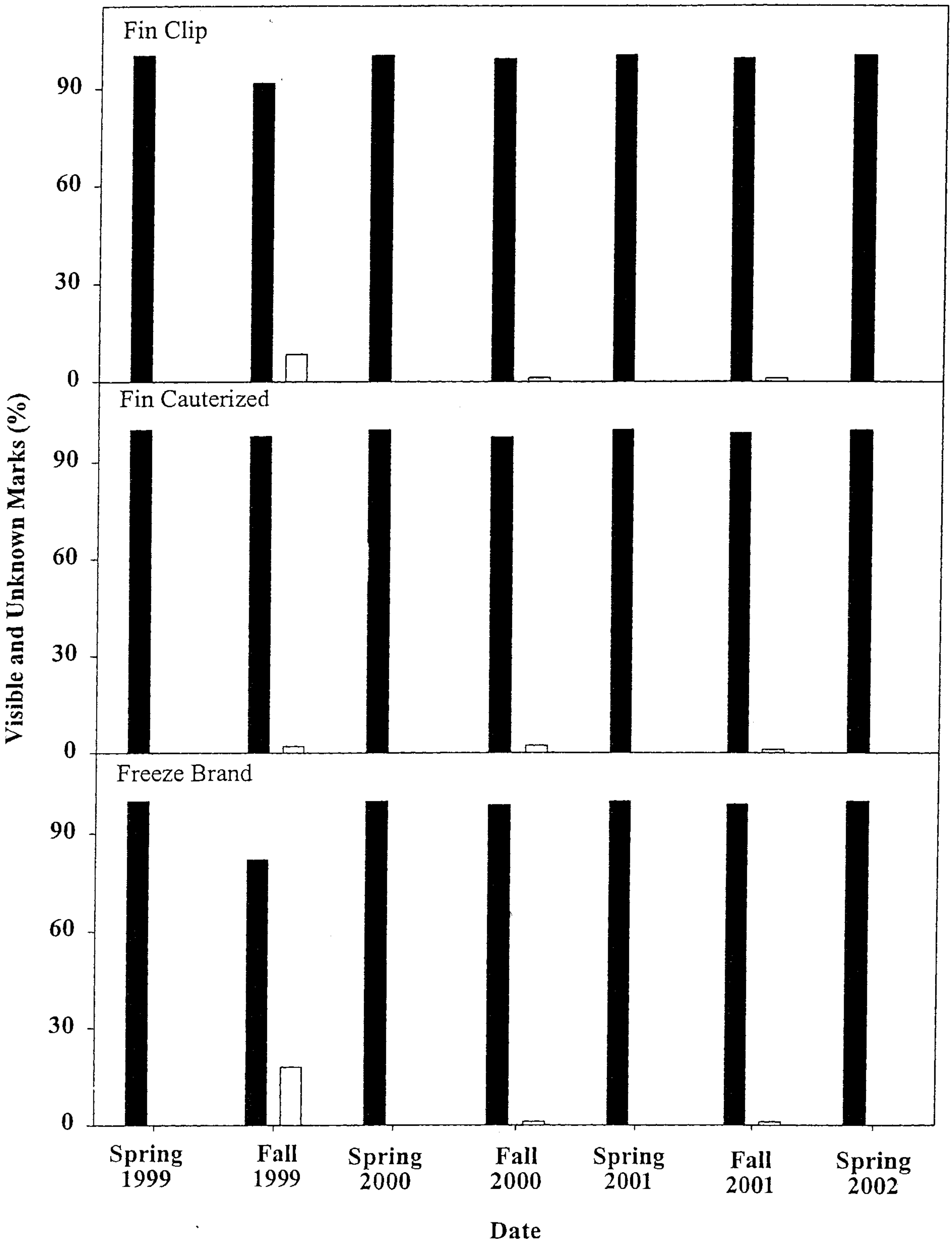

Figure 3. Percent of visible marks (dark bars) and those that were undiscernable (light bars) and identified by gentic markers for fin clip, fin cauterized, and freeze brand marks sampled seasonally.

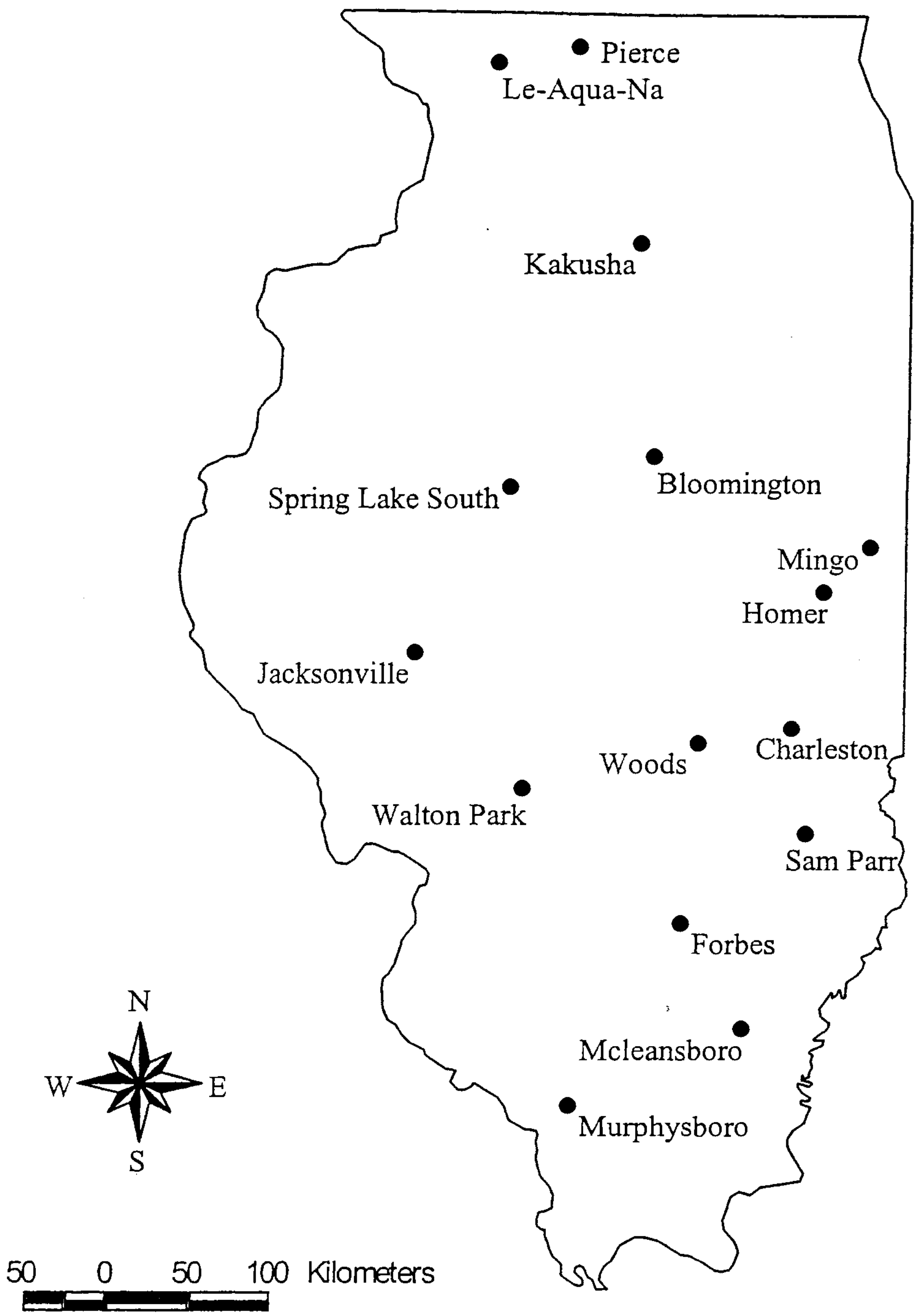

Figure 4. Locations of 15 lakes in Illinois stocked with fingerling largemouth bass in 1999 and 2000.

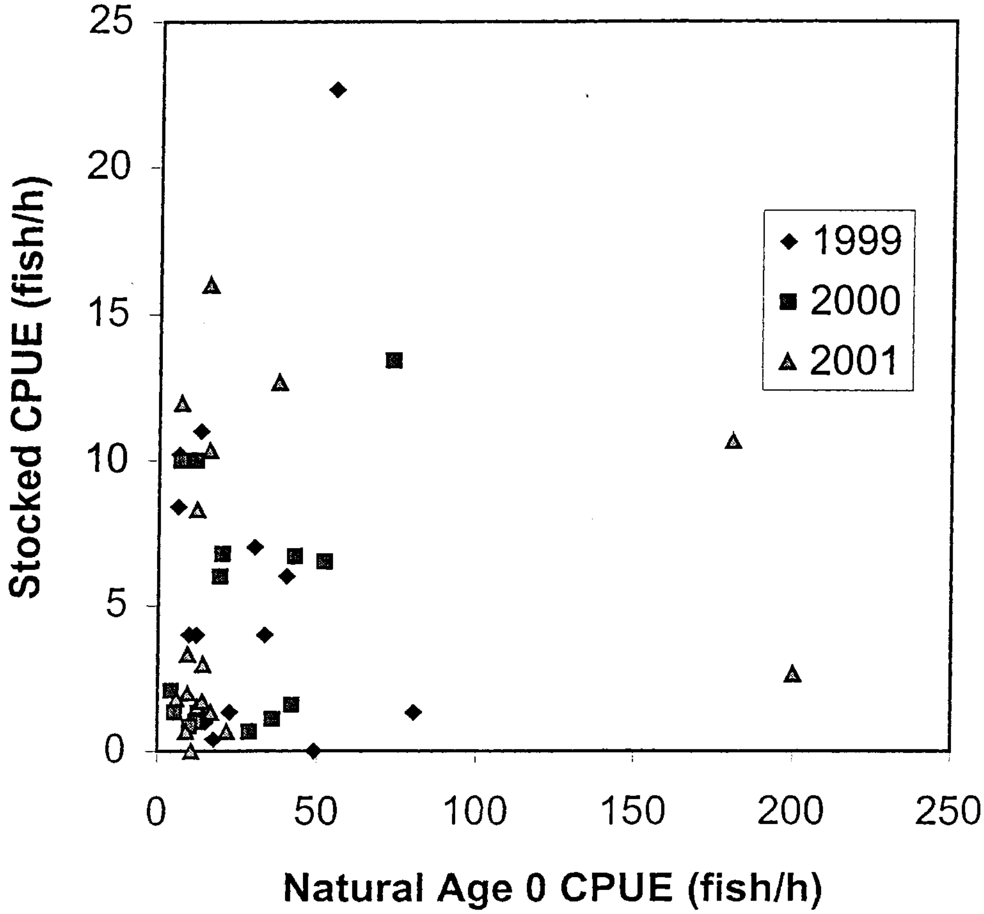

Figure 5. Relationship between stocked and natural age 0 largemouth bass catch per unit effort in Illinois reservoirs. CPUE is based on the number of largemouth bass caught per hour during fall AC electrofishing. Largemouth bass were stocked as advanced fingerlings (96 mm) in summer of 1999 (•), 2000 (○), and 2001 (□).

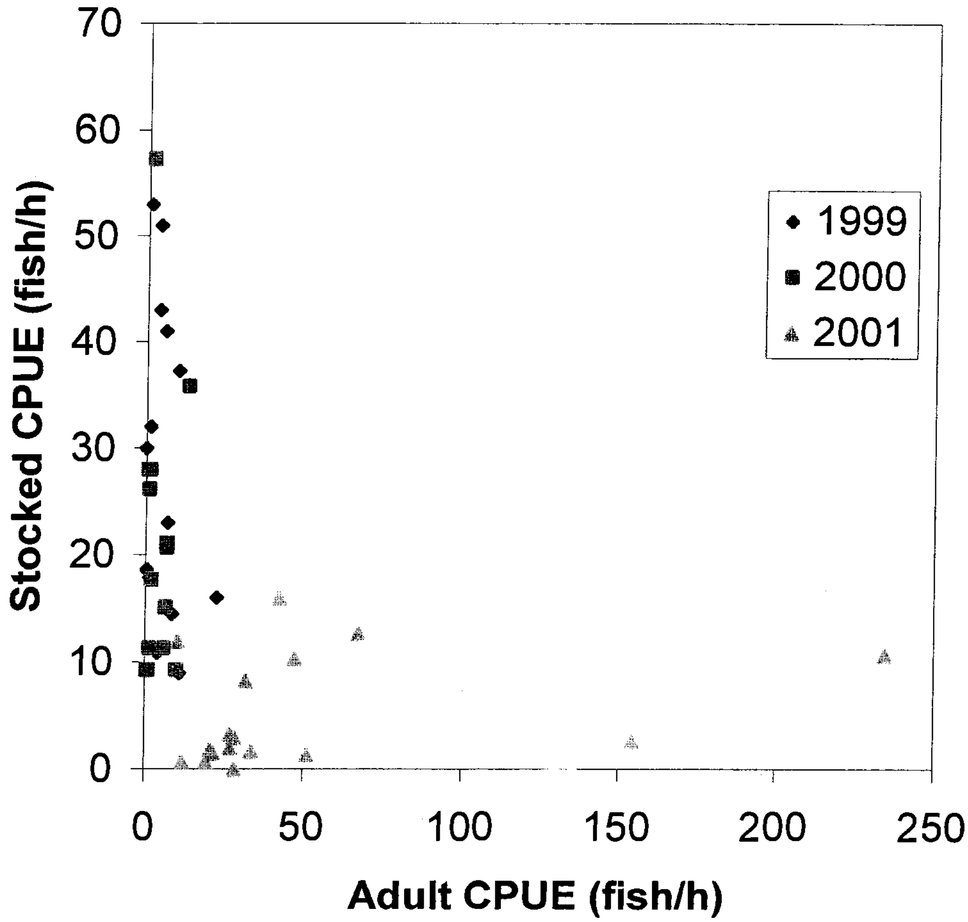

Figure 6. Relationship between stocked largemouth bass survival and predator density for Illinois reservoirs stocked in 1999 (●) and 2000 (○), 2001 (□). Predator density is measured as number of adult largemouth bass (> 200 mm) collected per hour of electrofishing.

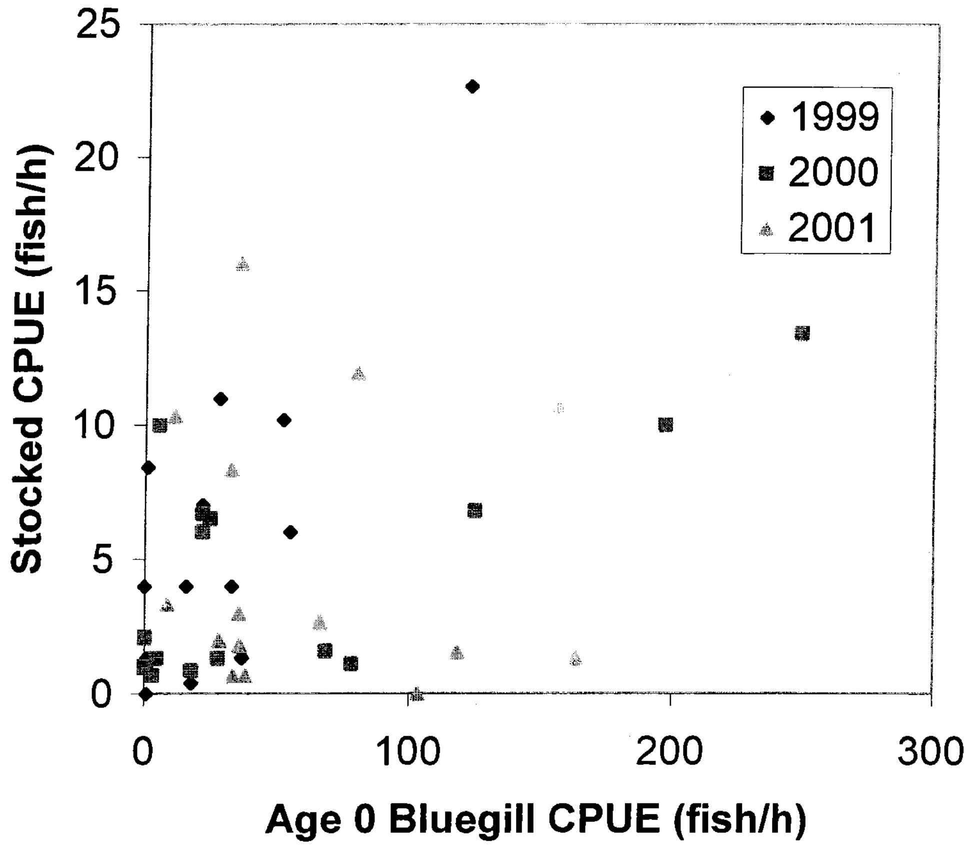

Figure 7. Relationship between stocked largemouth bass survival and age 0 bluegill abundance for Illinois reservoirs stocked in 1999 (●), 2000 (○)and 2001 (□). Age 0 bluegill abundance was measured as the number of bluegill under 35 mm TL collected per hour of electrofishing.

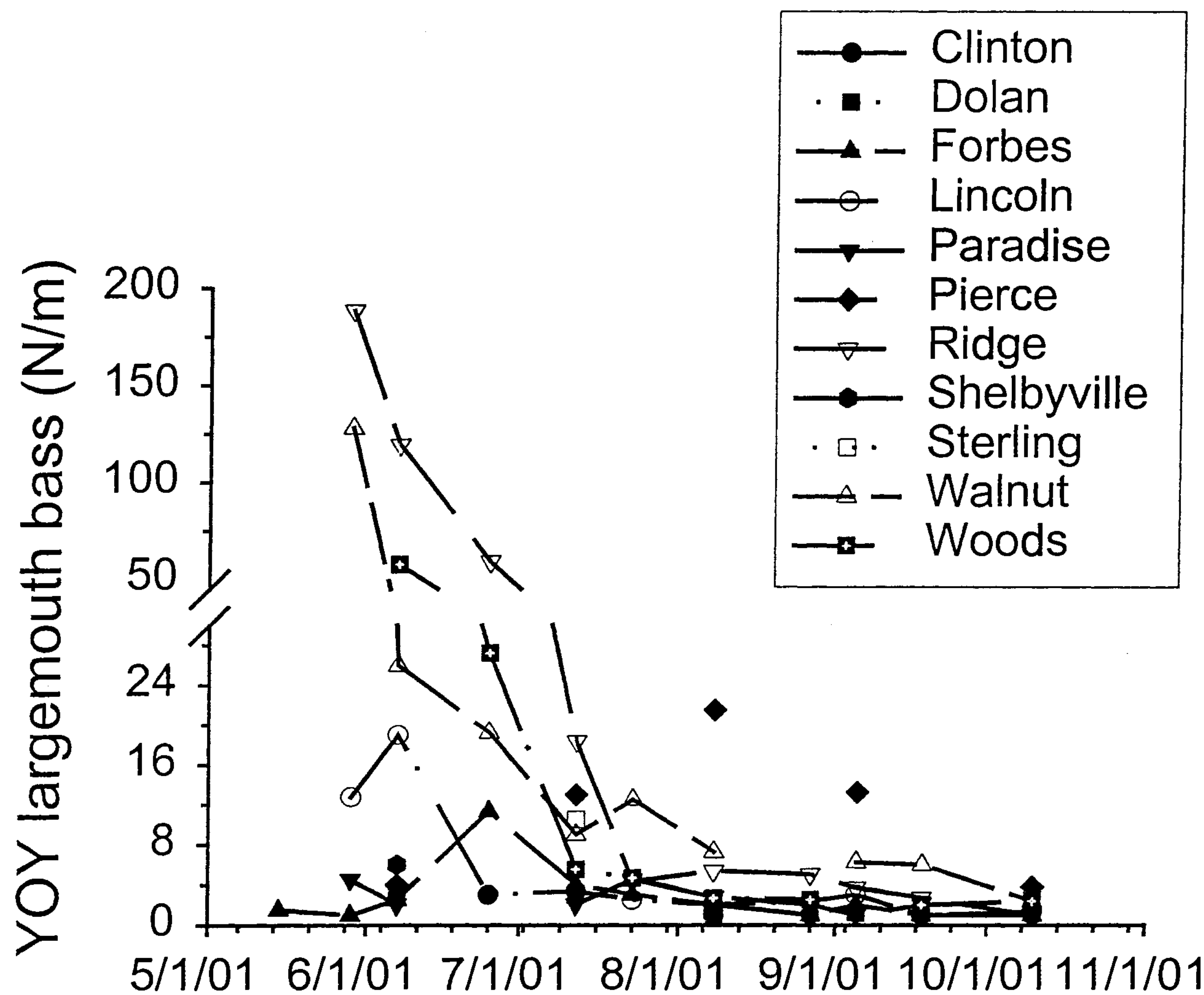

Figure 8. Average monthly young of the year (YOY) largemouth bass densities (N/m shoreline) for 11 study lakes. Largemouth bass were collected with a 9.2-m bag seine from 4 stations in each lake. Closed symbols represent lakes with gizzard shad, whereas, open symbols represent lakes without shad.

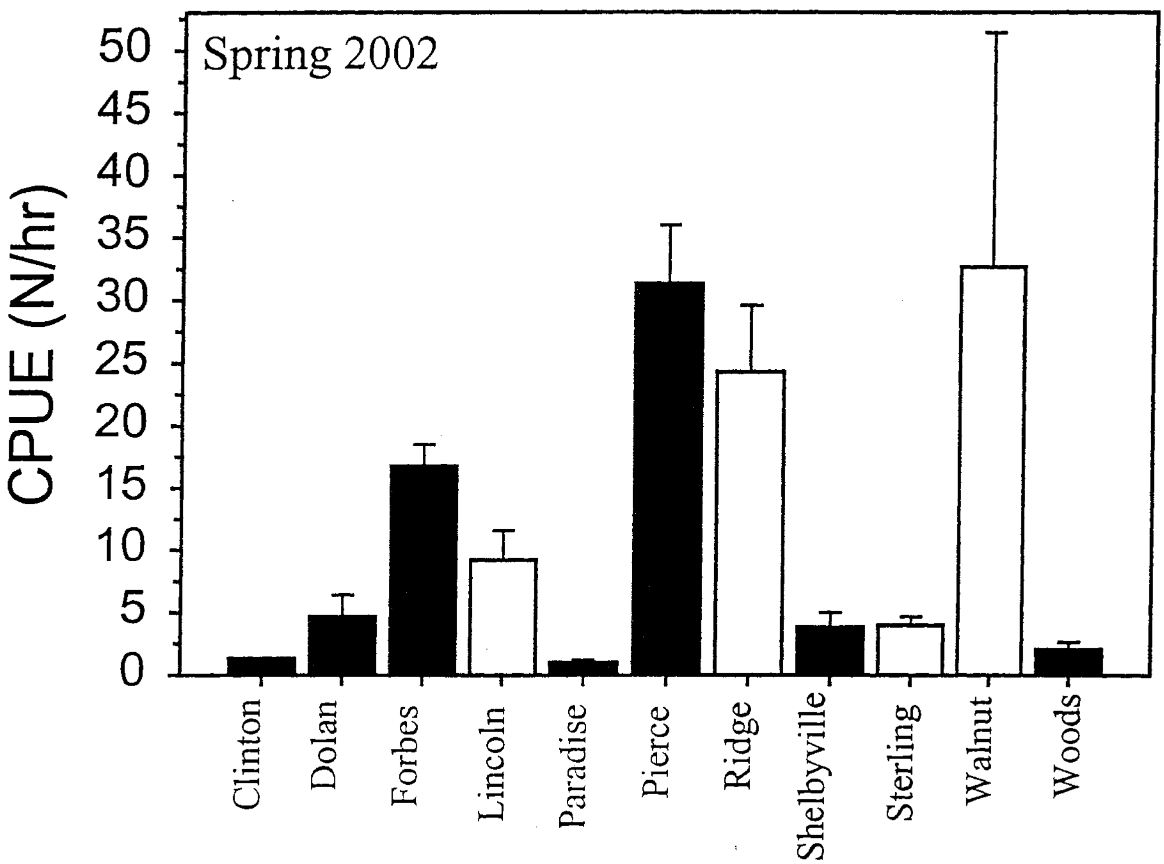

Figure 9. Average catch per unit effort (CPUE; N/hour) of YOY largemouth bass from the 2001 cohort collected the following spring in 11 study lakes. Based on annual otolith rings, bass ≤ 150 mm TL were considered to be YOY. Closed bars represent lakes with gizzard shad, whereas, open bars represent lakes without shad.

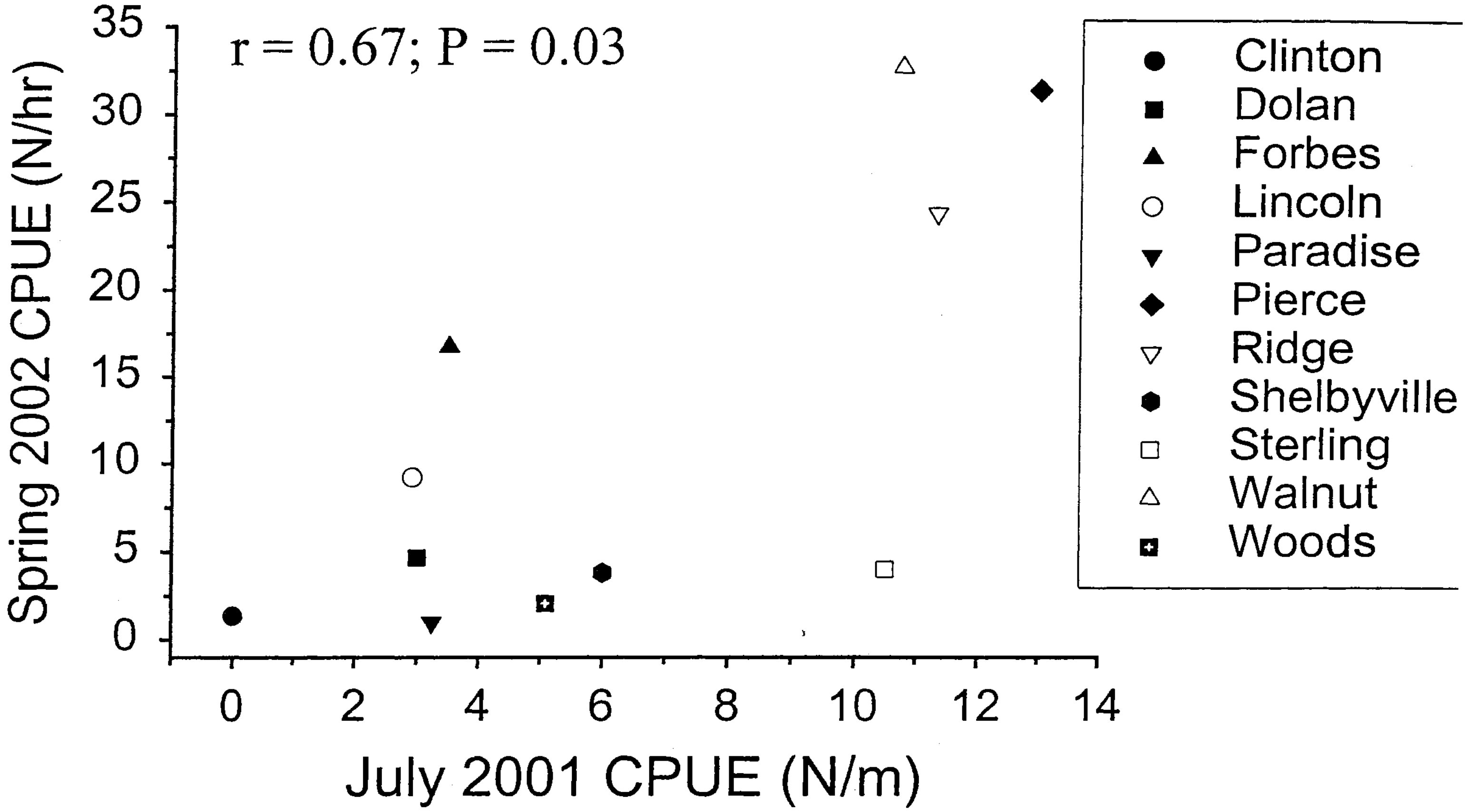

Figure 10. Relationship between July abundance of young of the year (YOY) largemouth bass (N/m; seine) and abundance of bass from the 2001 year class the following spring (N/hour; AC electrofishing) in 11 study lakes. Based on annual otolith rings, bass < 150 mm TL were considered to be YOY from 2001.

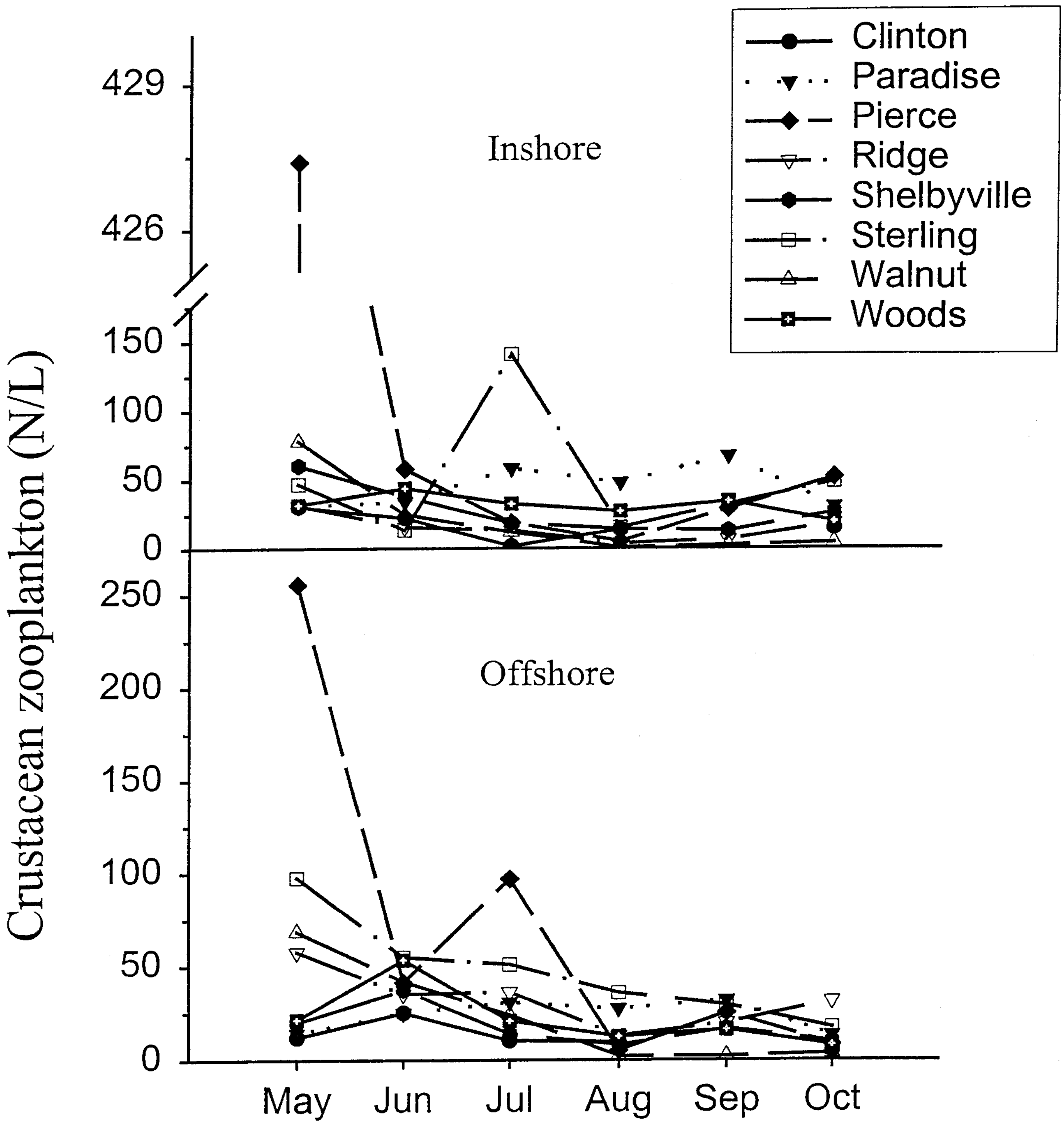

Figure 11. Average monthly crustacean zooplankton (excluding nauplii and rotifers) densities (N/L) in inshore and offshore habitat of 8 study lakes. Closed symbols represent lakes with gizzard shad and open symbols represent lakes without shad.

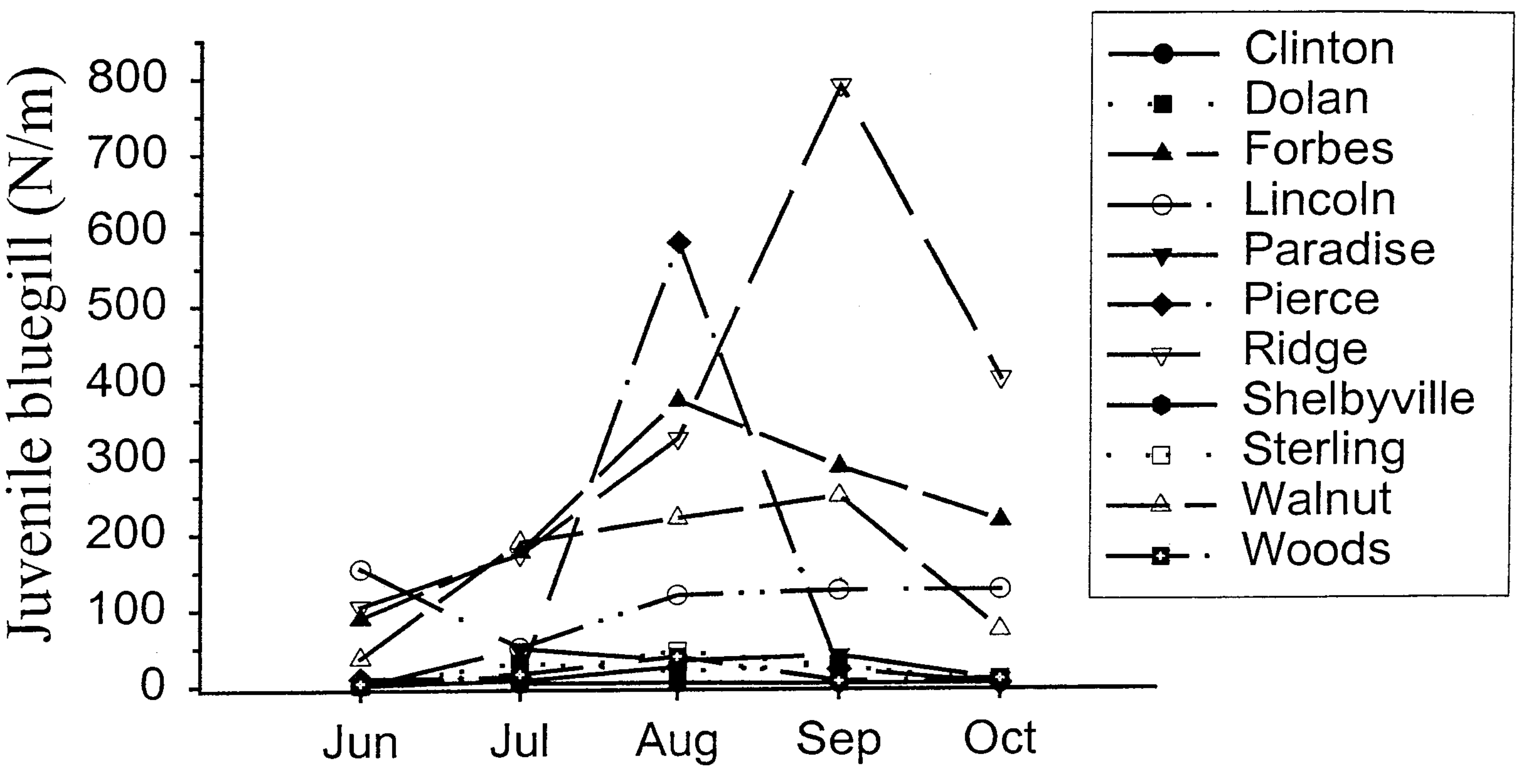

Figure 12. Mean juvenile bluegill (15-60 mm TL) densities (N/m shoreline) for 11 study lakes. Bluegill were collected at 4 stations with a 9.2-m bag seine. Closed symbols represnt lakes with gizzard shad, whereas, open symbols are lakes without shad.

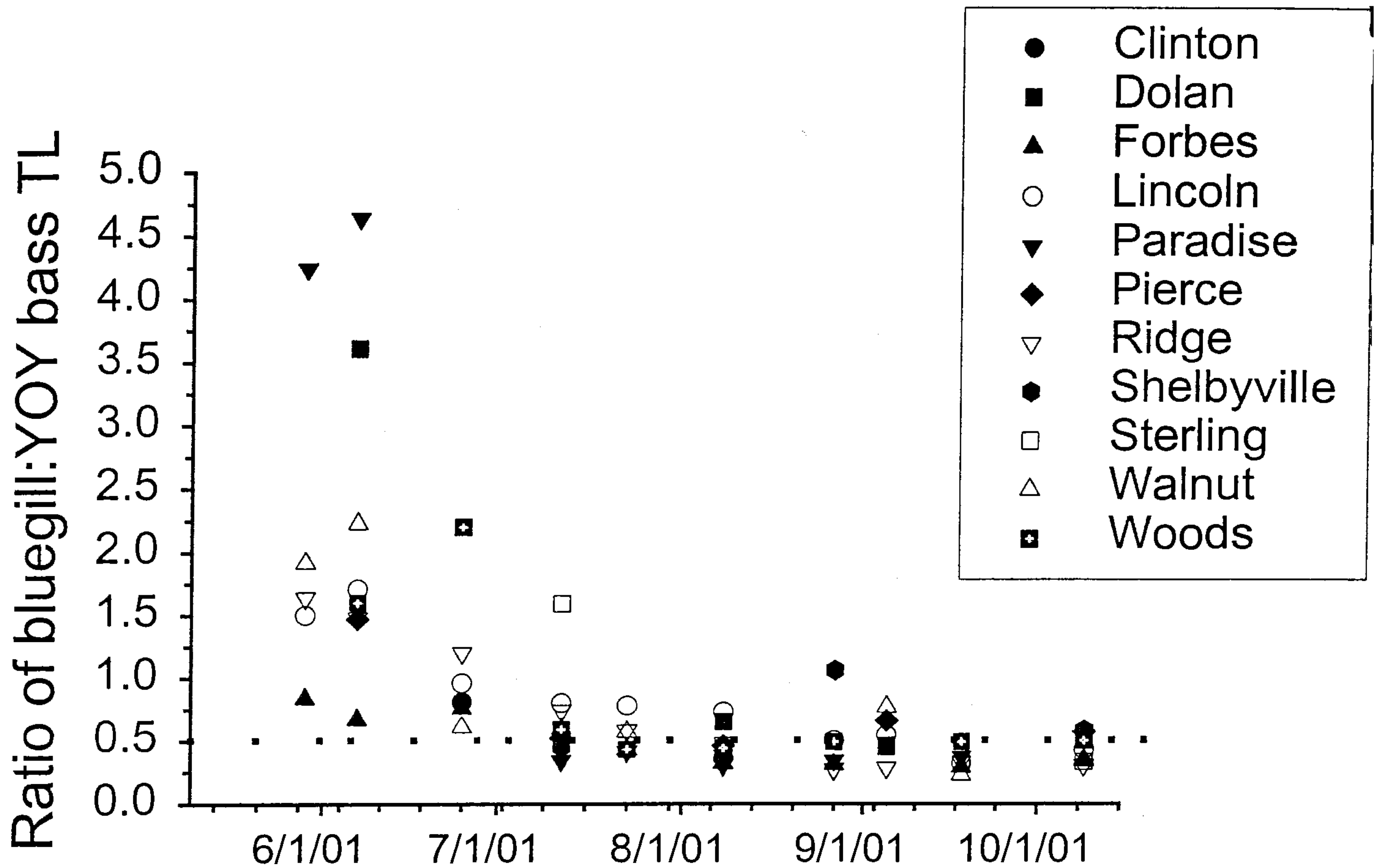

Figure 13. Ratio of bluegill total length (TL) to YOY largemouth bass TL through time in eleven study lakes. Points at or below the dotted line represent average bluegill lengths that were less than or equal to half of predator body length and were considered vulnerable to predation. Closed symbols represent lakes with gizzard shad and open symbols represent lakes without shad.

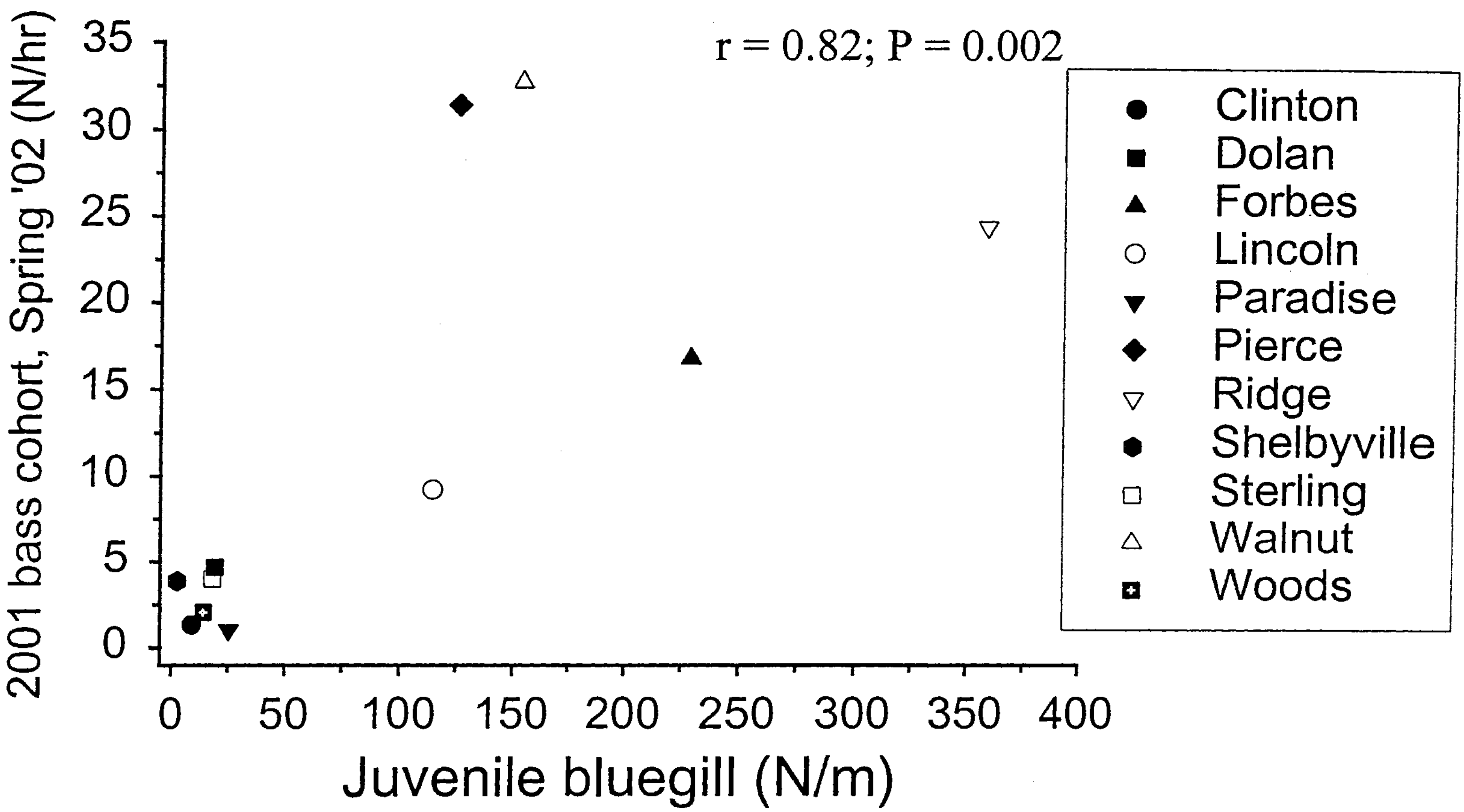

Figure 14. Relationship between mean juvenile bluegill (15-60 mm TL) density (N/m shoreline) and abundance of largemouth bass from the 2001 cohort captured by electrofishing the following spring (N/hour) in eleven study lakes. Closed symbols represent lakes with gizzard shad, whereas, open symbols represent lakes without shad.

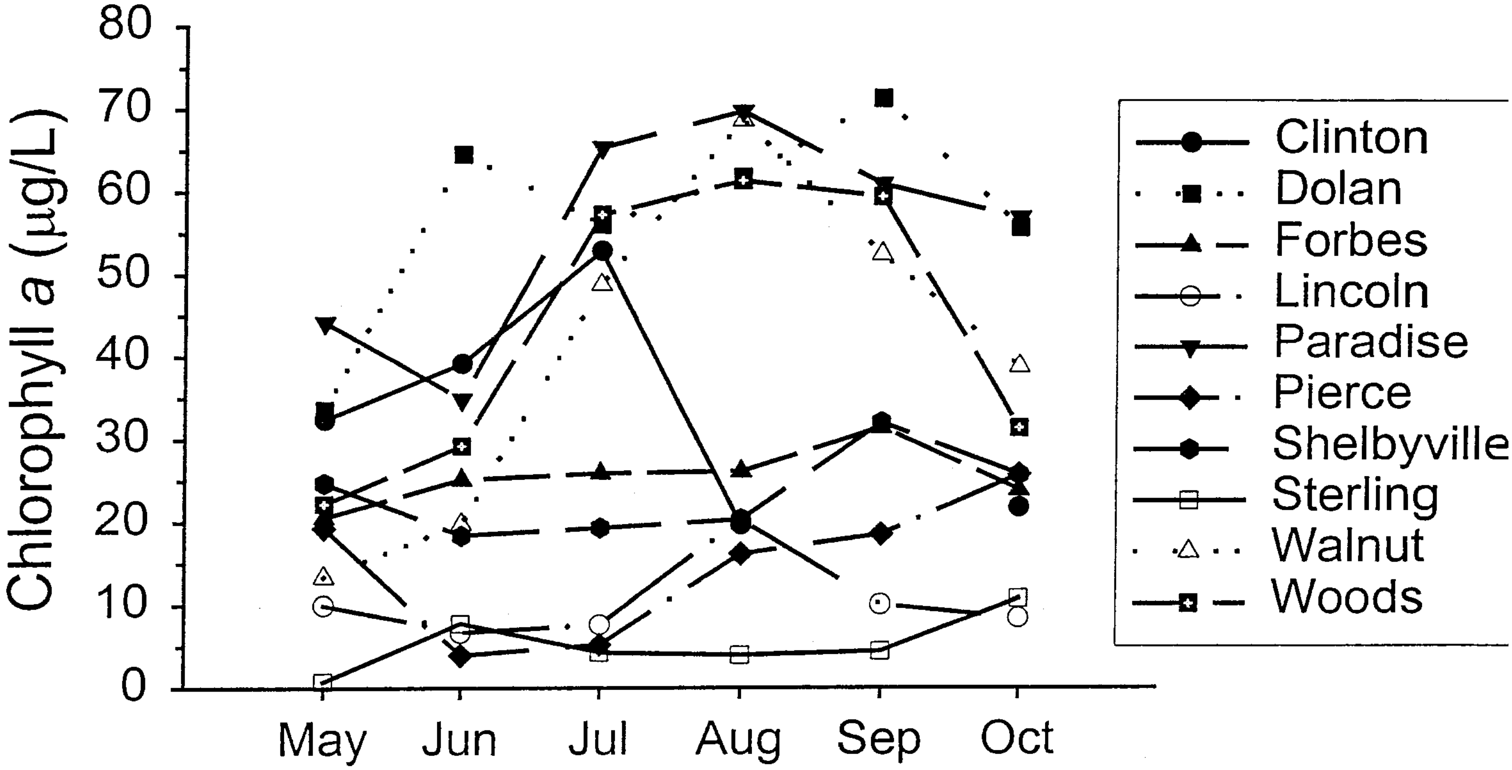

Figure 15. Average monthly concentration of chlorophyll *a* (µg/L) in 10 study lakes. Water samples were collected using an integrated tube sampler lowered to twice the secchi depth. Closed symbols represent lakes with gizzard shad, whereas, open symbols represent lakes without shad.

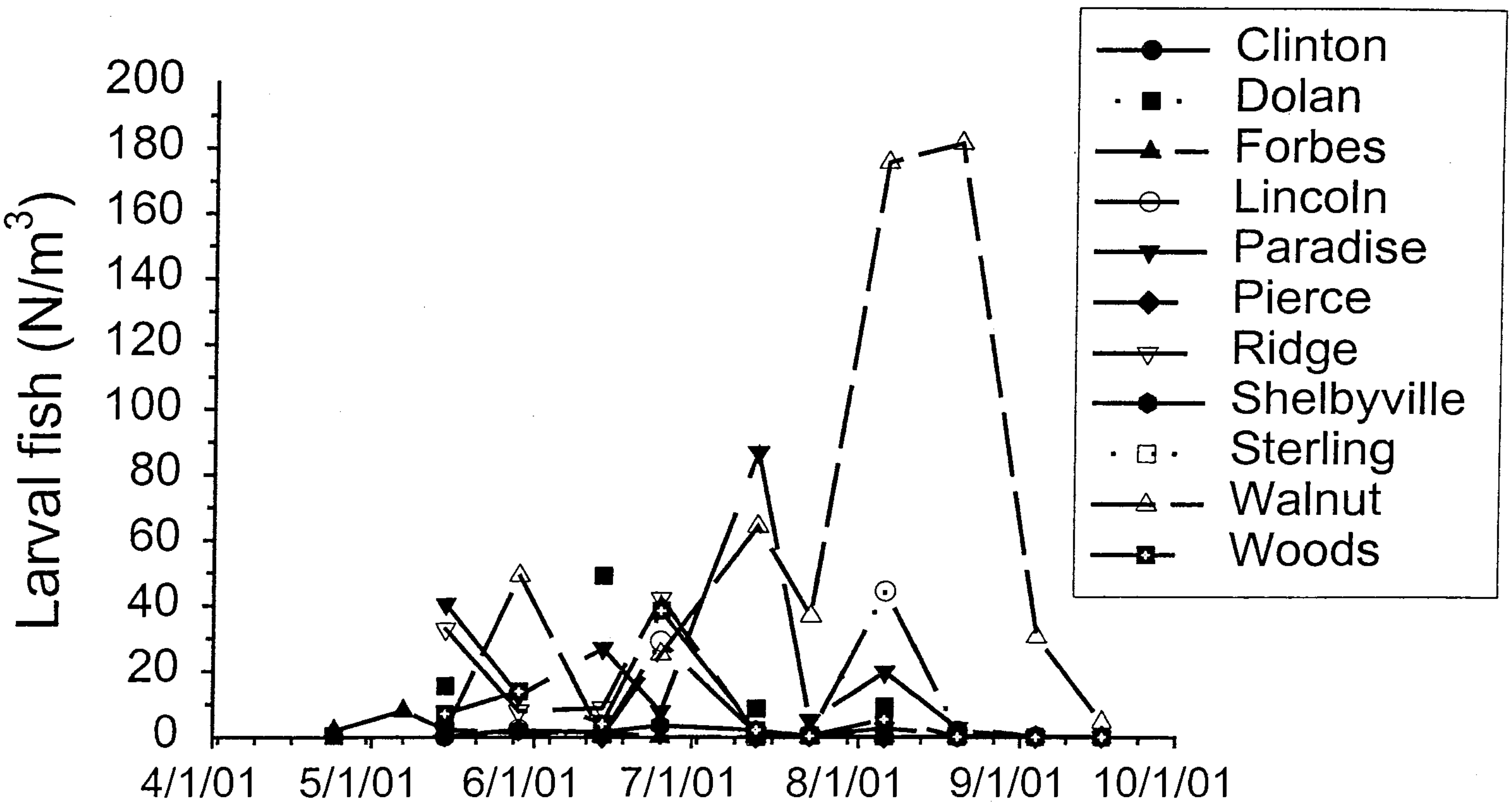

Figure 16. Mean larval fish density (N/m^3) in 11 study lakes. Larval fish were collected using a 0.5-m diameter push net with 500-μm mesh at 6 stations within each lake. Closed symbols represent lakes with gizzard shad, whereas, open symbols represent lakes without shad.

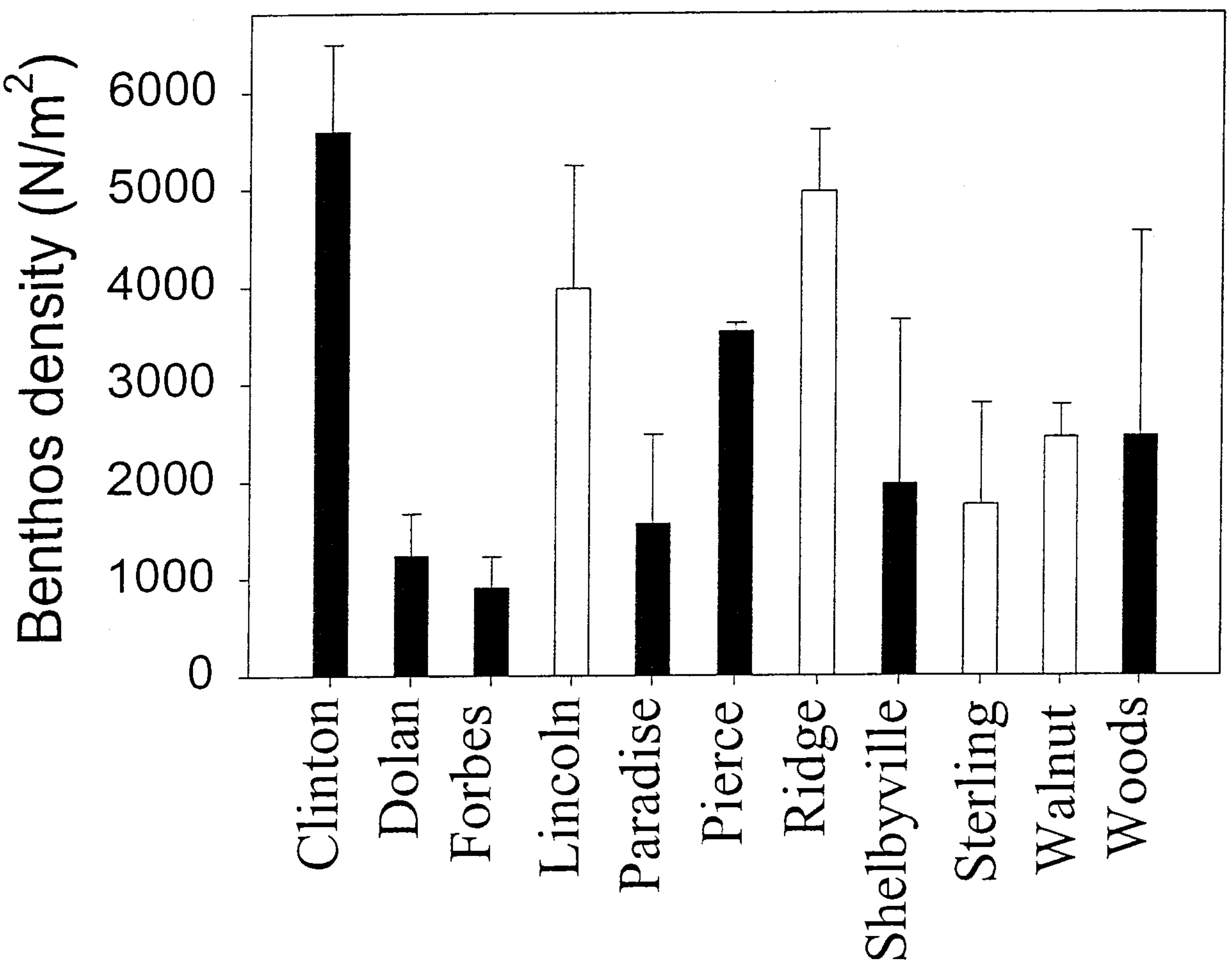

Figure 17. Average summer density ($N/m^2 \pm SE$) of benthic macroinvertebrates for 11 study lakes. Benthic macroinvertebrates were collected with a 20-cm diameter stovepipe sampler from 6 stations in each lake. Closed bars represent lakes with gizzard shad, whereas, open bars are lakes without shad.

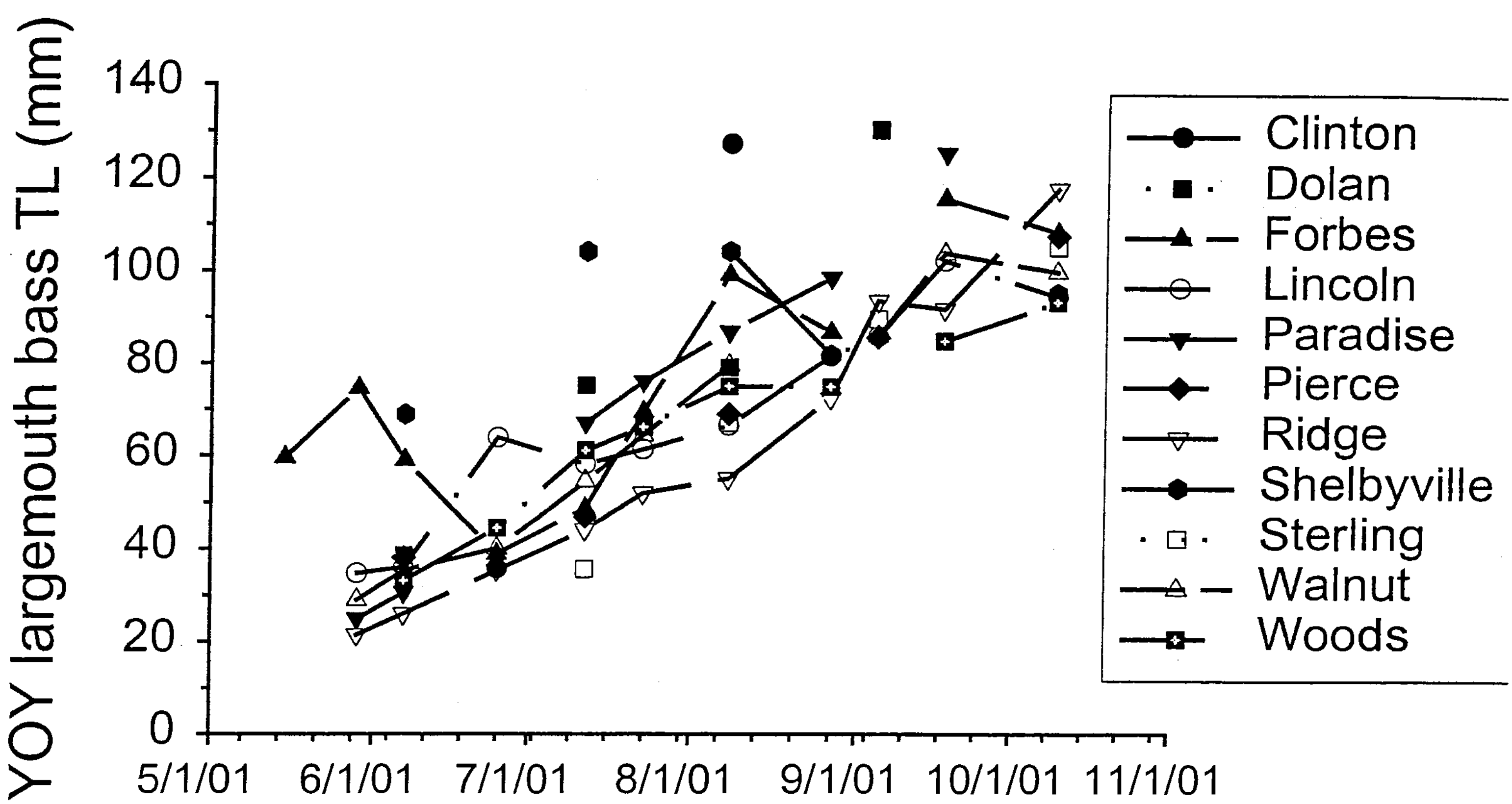

Figure 18. Average total length (mm) of young of the year largemouth bass collected from 11 study lakes. Largemouth bass were collected with a 9.2-m bag seine from 4 stations in each lake. Closed symbols represent lakes with gizzard shad, whereas, open symbols are lakes without shad.

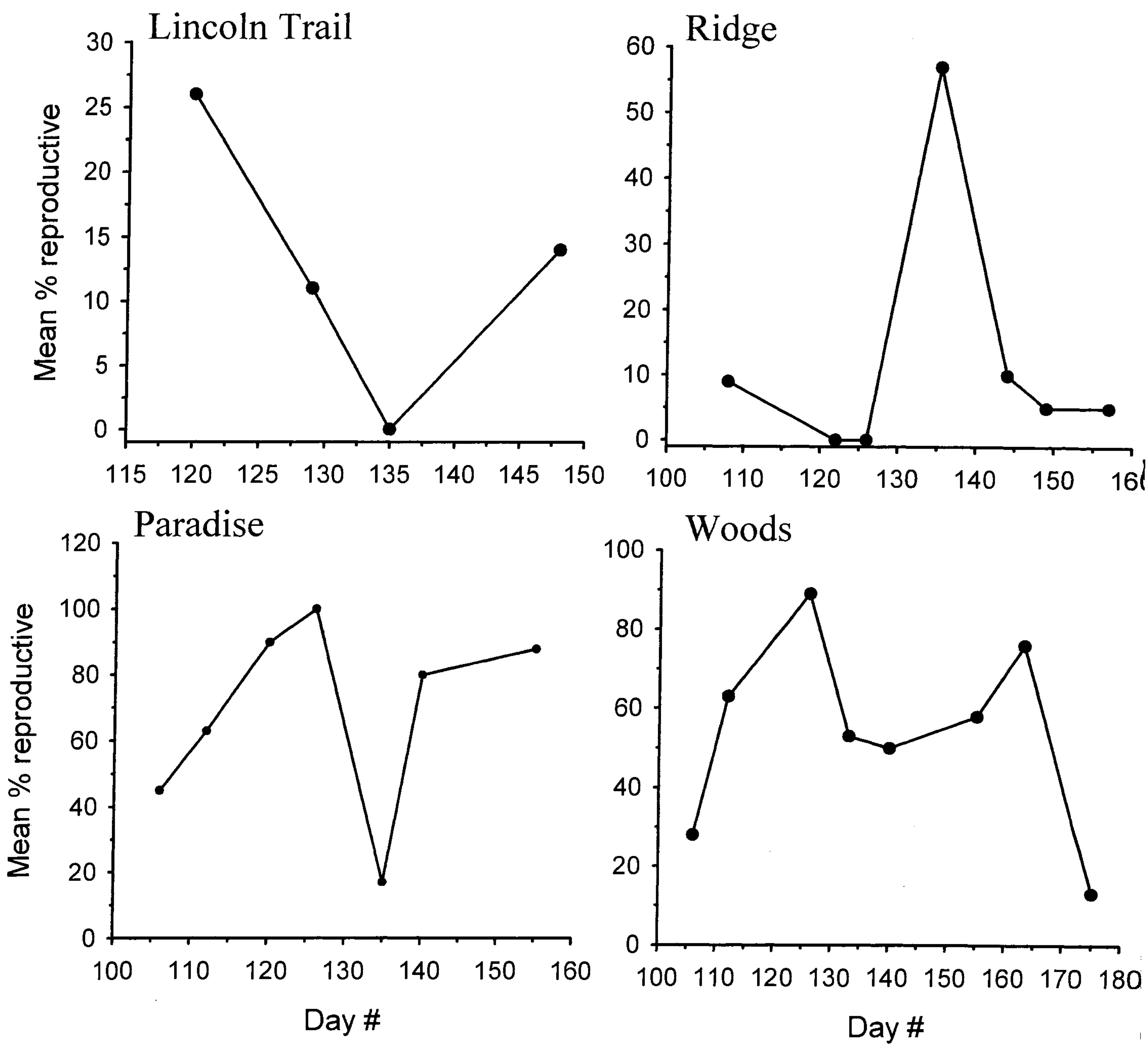

Figure 19. Mean percentage over time of total largemouth bass catch that was in reproductive condition during spring 2002. Male largemouth bass were considered reproductive if gametes were freely flowing, and female bass were considered reproductive if they were in ripe condition (e.g., freely flowing gametes or swollen condition). All bass were captured using AC electrofishing for 30 minutes along three shoreline transects, except in Ridge Lake, where the entire shoreline was sampled.

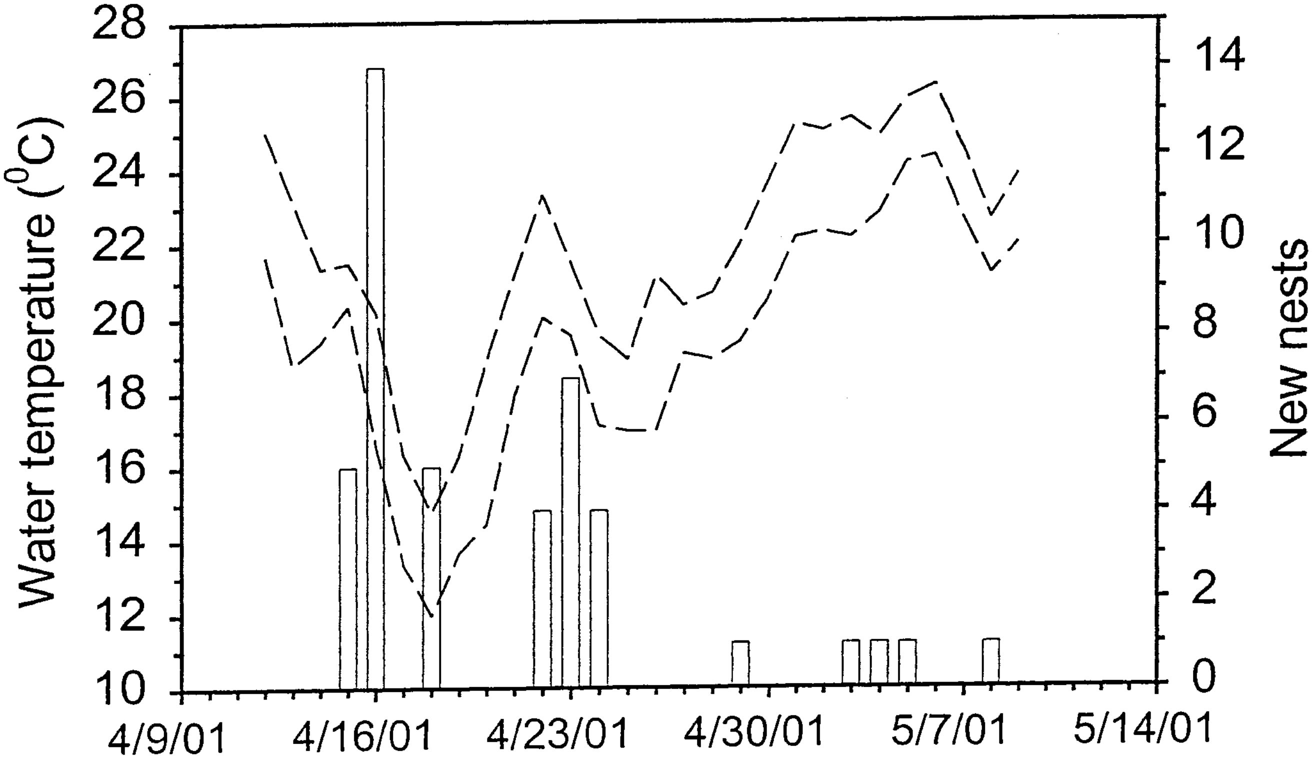

Figure 20. Minimum and maximum water temperatures (dotted lines) and appearance of new largemouth bass nests (bars) over time in 1-acre ponds at Sam Parr biological station.

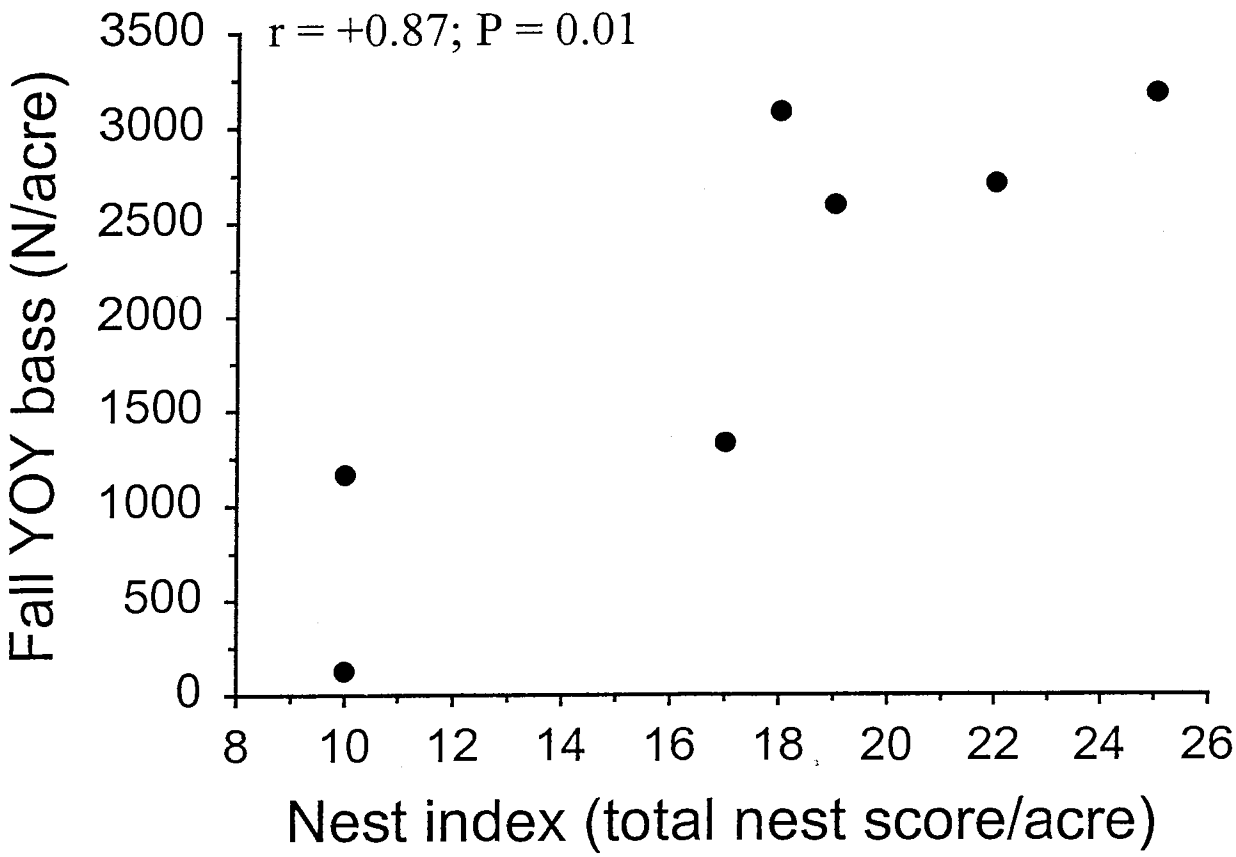

Figure 21. Relationship between fall abundance of young of the year largemouth bass (N/acre) and nest index score (total nest score/acre).

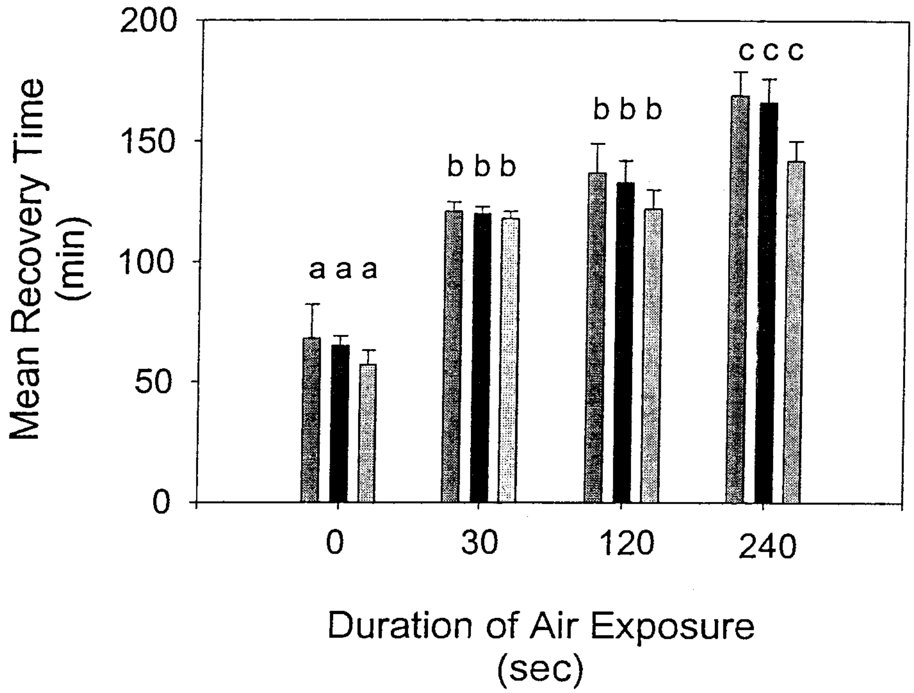

Figure 24 – Air exposure effects on smallmouth bass cardiac recovery. Adult smallmouth bass from Lake Erie were held in 12°C water for two weeks prior to surgery. Doppler flow probes were affixed around the ventral aorta of fish as described by Schreer et al. (2001). After surgery fish were held individually in 100l tanks for 24 h prior to experimentation. Fish were exposed to one of four treatments: 60 sec of chasing (N=4), 60 sec of chasing and 30 sec of air exposure (N=4), 60 sec chasing and 120 sec air exposure (N=4), and 60 sec chasing and 240 sec air exposure (N=4). The time for each of three cardiac parameters (cardiac output (CO), heart rate (HR), and stroke volume (SV)) to return to pre-disturbance levels was plotted to the nearest minute (Schreer et al. 2001). Dissimilar letters indicate statistically significant differences ($P<0.05$). Bars represent means ± 1 SE.

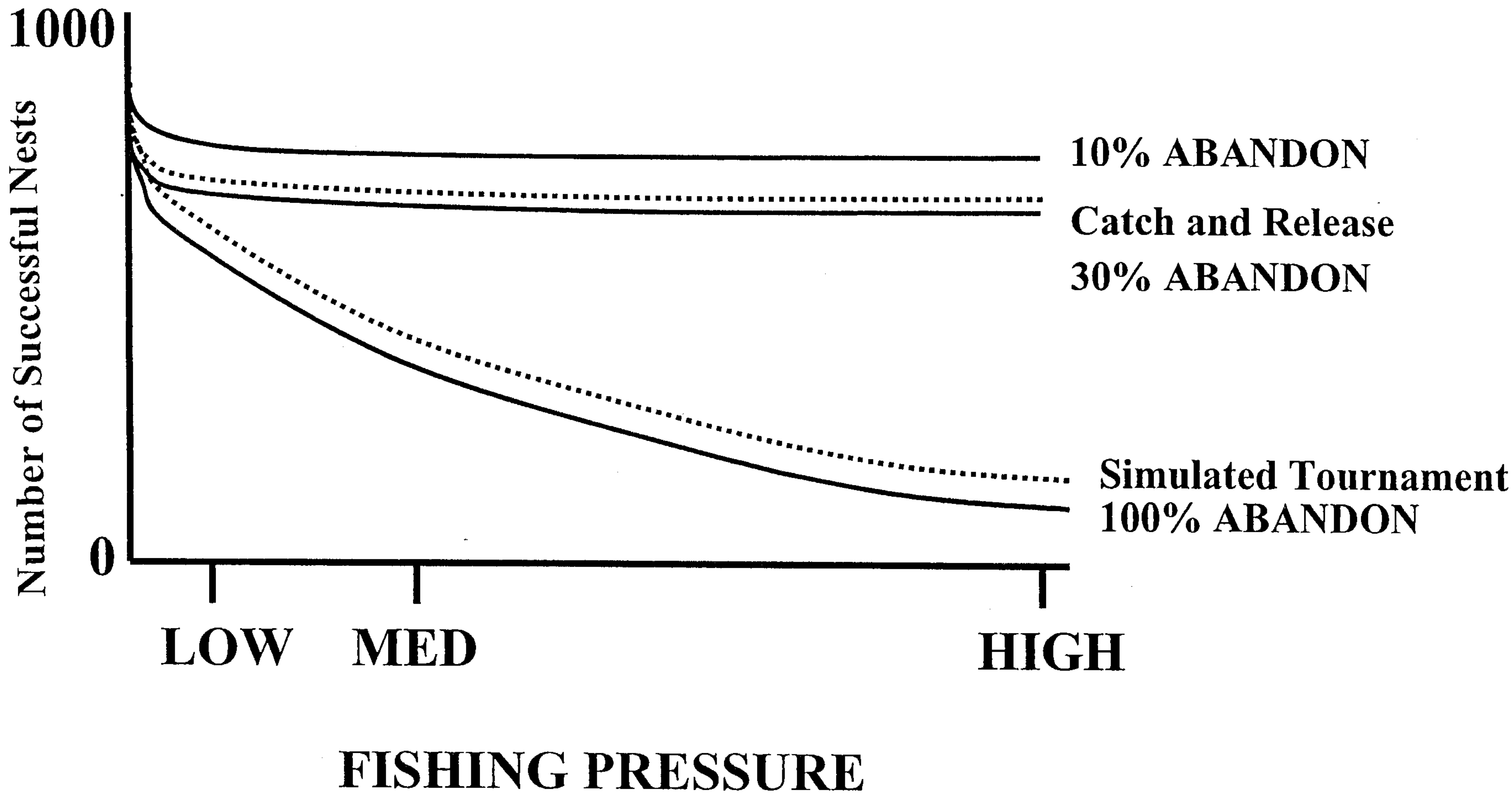

Figure 25. Effect of fishing pressure on the number of successful largemouth bass nests in Lincoln Trail with comparisons of 10 and 100% abandonment rates predicted from the model (solid lines) and abandonment rates from catch-and-release and simulated tournament angling (dotted lines).