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July 1, 2005 through June 30, 2006

EVALUATION OF GROWTH AND SURVIVAL OF DIFFERENT GENETIC STOCKS OF MUSKELLUNGE: IMPLICATIONS FOR STOCKING PROGRAMS IN ILLINOIS AND THE MIDWEST

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EXECUTIVE SUMMARY: Muskellunge *Esox masquinongy* are an important sportsfish that are commonly stocked throughout Illinois and much of the Midwestern United States. In Illinois, as in many other states, the demand for these fishes far exceeds the supply. Stocking has become the primary management tool for establishing and maintaining muskellunge populations. The high costs associated with producing these fishes create the need for efficient management practices. Previous research efforts have determined the size of fish and timing of stocking to maximize growth and survival. However, additional information on muskellunge stocking strategies is needed. Specifically, more biological data on different genetic stocks of muskellunge is needed to determine the best population to stock in a particular body of water to maximize growth and survival.

Morphological and geographic characteristics have suggested multiple distinct groups of muskellunge. More recently, genetic analysis identified several different genetic stocks of muskellunge (Ohio River drainage, Upper Mississippi River drainage, and the Great Lakes drainage stocks), each with multiple populations. Previous work with young-of-year from these populations found differences in growth and food consumption as a function of temperature. As a trophy species, anglers and managers are interested in utilizing populations of fish that grow the fastest, live longest, and obtain a largest maximum size. Because muskellunge populations are either not naturally found or have been eliminated in many Illinois lakes and reservoirs, it is not clear which population to use in stocking efforts. The muskellunge population currently used as brood stock for the stocking program in Illinois is of an unknown origin and may be made up of several different populations. Muskellunge stocks from various populations may perform differently in Illinois waters in terms of growth and survival. Additional information is needed on differences in growth and survival among stocks in waters at varying latitudes in Illinois before management recommendations can be made on which stock is most appropriate. Determining which stock has the highest levels of growth and survival under the various conditions found in Illinois waters will increase stocking success and angler satisfaction. This study examines differences in growth and survival among different stocks of muskellunge in order to make recommendations regarding stocking in Illinois.

During segment four, all activities outlined in the annual work plan were accomplished and were completed within the specified budget. During this segment, two jobs related to muskellunge stock evaluation were completed. Those jobs are (1) evaluation of growth and (2) evaluation of survival among stocks of muskellunge. In this segment of the study, we compare growth and survival of muskellunge from the Upper Mississippi River drainage stock, the Ohio River drainage stock, and the Illinois North Spring Lake progeny in three lakes throughout Illinois. Muskellunge fingerlings from each of the stocks were introduced into Pierce Lake, Lake Mingo, and Sam Dale Lake at rates ranging from 1.6 – 4.9 fish per hectare during fall 2005. Initial mortality due to transport and stocking was assessed using three 3-m deep predator-free cages for 48-h. Mortality from stocking stress was variable, ranging from 0 – 97%. Across years and reservoirs, the Ohio River drainage stock and the Illinois population appear to have similar mean daily growth and mean relative growth rates; both consistently higher than the Upper Mississippi River drainage stock. Initial results from reservoir introductions suggest that the Upper Mississippi River drainage stock generally has an overwinter survival advantage over the Ohio River drainage stock and the Illinois population. However, after the first summer, the Ohio River drainage stock and Illinois population typically have similar survival and both are much higher than the Upper Mississippi River drainage stock. These, and future introductions

will need to be monitored over several years to further assess growth and survival differences among stocks.

Pond experiments were initiated in fall 2002, 2003, and 2004 at the Sam Parr Biological Station, Marion County, Illinois. Three 0.4-ha ponds were used to evaluate growth and survival differences among muskellunge stocks. Pooling data from all three experiments suggests the Ohio River drainage stock has a growth advantage one-year post-stocking over the Illinois population and the Upper Mississippi Rive drainage stock, one-year post-stocking. The Illinois population and the Upper Mississippi River drainage stock had similar growth rates over this same time period. The pond experiments indicate a significantly higher survival rate for the Ohio River drainage stock and the Illinois population than for the Upper Mississippi River drainage stock one-year post-stocking.

These same, as well as additional, populations of muskellunge will be evaluated for growth and survival differences in future years of the study. The results obtained from these first years will be combined with those from future years to identify the long-term growth and survival differences among genetic stocks of muskellunge. These results will be used to develop guidelines for future muskellunge stockings that maximize growth, survival, and angler satisfaction in reservoirs throughout Illinois.

Job 101.1. Evaluating growth of different stocks of muskellunge.

OBJECTIVE: To determine differences in growth among various stocks and populations of muskellunge in Illinois waters.

INTRODUCTION: The taxonomy of the muskellunge has undergone substantial revision over the last century (Crossman 1978; Crossman 1986). During the late 1800's and early 1900's, apparent correlations between markings and location led to the establishment of three separate species for a short time (Crossman 1978). As interpretation of the color and marking distinctions progressed, the idea of subspecies was introduced (Hubbs and Lagler 1958; McClane 1974; Smith 1979). By the late 1970's the idea that all variations were indeed one single species, without enough evidence to warrant subspecies classifications, had been established (Crossman 1978). More recent genetic analysis of various populations revealed three distinct clusters that were found to be related to major river drainage origins, suggesting the existence of divergent stocks (Koppelman and Philipp 1986). Existing information indicates muskellunge persisted through the Wisconsin glacier period in the Mississippi refugium and upon glacial recession, moved north up the Mississippi valley and established its current range via the Mississippi and Ohio River systems, as well as precursors to tributaries of the Great Lakes (Crossman 1978; Crossman 1986). Muskellunge were isolated by major river drainages and experienced different environmental conditions and thermal histories. As these isolated groups diverged through recolonization, genetic processes, such as natural selection, resulted in stocks of muskellunge that are genetically dissimilar, and likely physiologically and behaviorally different from one another (Altukhov 1981; MacLean and Evans 1981; Ihssen et al. 1981; Clapp and Wahl 1996; Begg et al. 1999). The currently identified genetically distinct muskellunge stocks are the Upper Mississippi River drainage stock, the Great Lakes/St. Lawrence River drainage stock, and the Ohio River drainage stock (Koppelman and Philipp 1986; Clapp and Wahl 1996).

Stocks and populations of muskellunge have evolved under different ecological conditions, and as a result, have likely developed physiological differences through selection processes and genetic drift. Such differences could affect performance characteristics, such as growth rates at various temperatures, as has been demonstrated with other freshwater fishes. Luey and Adelman (1984) found significant differences in growth among groups of rainbow smelt *Osmerus mordax* sampled from three zones in Lake Michigan. These findings were consistent with previous genetic evidence suggesting three distinct stocks of rainbow smelt. Studies directed towards evaluating adaptability and differences between northern largemouth bass *Micropterus salmoides salmoides* and Florida largemouth bass *M. s. floridanus* (at the time considered sub-species) in central Illinois found significant growth differences, both overwinter and during the first growing season (Isely et al. 1987; Philipp and Whitt 1991). Growth differences were even observed between two stocks from different river drainages within Illinois (Philipp and Claussen 1995). In addition, a study of life history and electrophoretic characteristics of five allopatric stocks of lake whitefish *Coregonus clupeaformis* found differences in growth rate, as well as other traits, among stocks (Ihssen et al. 1981). As demonstrated by these studies, considerable physiological and/or behavioral differences can be observed among stocks of fish perceived to be very similar and it is important to incorporate this knowledge of stocks into management plans. Differences in growth among genetically distinct muskellunge stocks and populations may prove to be a critical factor in management decisions, such as determining the appropriateness of a population for developing various Illinois fisheries.

Evolutionary theory predicts that organisms adapt, over generations, to the conditions experienced in their specific environment. However, the actual mechanisms and response clines of this adaptation are poorly understood for ectotherms, specifically freshwater fishes. Arguably, the most influential source of environmental variation is the latitudinal gradient and corresponding thermal regime conditions experienced by many temperate fishes. Currently, two competing models exist to explain the nature in which intraspecific growth rates vary across a latitudinal gradient (i.e. among stocks). Thermal adaptation, also termed local adaptation, predicts that growth rates are adapted to the local thermal regime (Levinton 1983; Yamahira and Conover 2002). Physiological rates are expected to operate most efficiently (e.g. highest growth rates) at the temperatures most commonly experienced in the native environment (Levinton 1983; Levinton and Monahan 1983; Lonsdale and Levinton 1985). Studies of marine invertebrates (Levinton 1983; Levinton and Monahan 1983), crustaceans (Lonsdale and Levinton 1985), and fish (Galarowicz and Wahl 2003; Belk et al. 2005) have supported the idea of thermal adaptation.

The second model, countergradient variation, focuses on differences in length of the growing season across latitudes (Conover and Present 1990; Yamahira and Conover 2002). There exists a latitudinal gradient with regards to length of the growing season, with lower latitudes having longer growing seasons than higher latitudes. Countergradient variation predicts relatively high growth rates for individuals experiencing environments that impose relatively strong detrimental effects on growth, such as high latitudes (Conover and Schultz 1995; Belk et al. 2005). The mechanism proposed to direct species towards a countergradient variation response is selective pressure in relation to overwinter survival. In regions with growing seasons of short duration and long winters, it is hypothesized that individuals must be large enough to have the energy reserves necessary to survive winter as well as to decrease predation risk. Over time, the selection via survival towards phenotypes with a propensity for faster growth rates would structure a population, and species group, to display countergradient variation in growth rates. A growing body of literature for several fishes supports the concept of countergradient variation in physiological rates, specifically growth rates (Conover and Present 1990; Nicieza et al. 1994; Schultz et al. 1996; Conover et al. 1997; DiMichele and Westerman 1997; Jonassen et al. 2000).

A commonly used and straight-forward method to explore growth responses across a latitudinal gradient, or among stocks and populations, is a common garden (or common environment) experiment. One such experiment compared food consumption, metabolism, and growth among populations of muskellunge (Clapp and Wahl 1996). These laboratory studies evaluated six populations of young-of-year (YOY) muskellunge (Kentucky's Cave Run Lake, Minnesota's Leech Lake, New York's Lake Chautauqua, Ohio's Clear Fork Lake, St. Lawrence River, and Wisconsin's Minocqua Chain) at varying temperatures (5 – 27.5°C). The populations investigated represented muskellunge from each of the three identified muskellunge stocks, the Ohio River drainage stock, the Upper Mississippi River drainage stock, and the Great Lakes drainage stock (Table 1). Differences in growth and food consumption of YOY among populations were observed at higher temperatures (15 – 27.5°C). However, no significant differences in metabolism were observed at any temperature. Although results of these laboratory experiments showed bioenergetic differences among populations of muskellunge, they could not be explained solely in terms of thermal adaptation or countergradient variation among the established genetic groupings.

Based on the model of thermal adaptation, it would be expected that muskellunge from higher latitudes (Minnesota's Leech Lake and Wisconsin's Minocqua populations) would exhibit higher food consumption, greater conversion efficiency, and faster growth at lower temperatures than muskellunge from lower latitudes (Kentucky's Cave Run Lake population, for example) and conversely, muskellunge from lower latitudes were expected to exhibit greater rates and efficiency at higher temperatures. These relationships, although observed in a few instances, were not consistent in previous work with muskellunge (Clapp and Wahl 1996). If countergradient variation explained growth rate variation, it would be expected that across all temperatures comprising the growing season, muskellunge from the northern populations would exhibit higher food consumption, greater conversion efficiency, and faster growth than muskellunge from lower latitudes. Although not statistically significant, muskellunge from the Upper Mississippi River drainage stock had slightly higher consumption, growth, and metabolic rates from 15 – 25 C than muskellunge from the Ohio River drainage stock (Clapp and Wahl 1996). This pattern, although not significant, warrants further investigation.

In this study, we investigate population differentiation of muskellunge in the field from the YOY stage to adults. Long-term growth of muskellunge will be evaluated in pond and lake experiments. Identifying growth differences among muskellunge populations at these scales is important in defining these populations and in determining the most appropriate populations for specific management applications. Populations may vary in long-term growth, age-at-maturity, and maximum size. In this job, we assessed variation in growth among newly stocked YOY muskellunge from different populations and continued assessment of growth differences among previously introduced populations of muskellunge.

PROCEDURES: As described in previous annual reports, we began by comparing growth between different stocks and populations of muskellunge in Lake Mingo, Vermillion County, Illinois, as well as in Pierce Lake, Winnebago County, and Forbes Lake, Marion County (Figure 1, Table 2). These reservoirs represent the climatic variation associated with latitude that exists throughout Illinois. In 2005, introductions were again made into Lake Mingo and Pierce Lake (Table 3). Due to poor initial survival and/or low catchability of fingerling muskellunge introduced into Forbes Lake during 2003 and 2004, this lake was dropped from the study. Instead, YOY muskellunge were stocked into Sam Dale Lake, Wayne County, Illinois in fall 2005 (Figure 1, Table 3). Choice of stocks was dependent on availability of fish from each of the populations. Future segments of the project will include these same as well as additional stocks and populations.

Muskellunge from the Upper Mississippi River drainage stock were represented by the Leech Lake population obtained from the Minnesota Department of Natural Resources. Hatchery production prohibited obtaining muskellunge from the Wisconsin Department of Natural Resources in fall 2005. Muskellunge from the Ohio River drainage stock included the Lake Chautauqua population obtained from the New York State Department of Environmental Conservation, the Clear Fork Lake population obtained from the Ohio Department of Natural Resources, and the Cave Run Lake population obtained from the Kentucky Department of Fish and Wildlife. The mixed-stock Illinois population is the F1 progeny from North Spring Lake and was obtained from the Jake Wolf Memorial Fish Hatchery, Illinois Department of Natural Resources. Attempts were made to stock as similar of sizes and condition of fish as possible in each lake. Subsamples of each stock were held in three 3-m deep predator-free cages (N=15/cage) for 48-hrs to monitor mortality associated with transport and stocking stress (Clapp et al. 1997; Hoxmeier et al. 1999). Muskellunge from each population were stocked at rates between 1.6 – 4.9 fish per hectare and a subsample of each population was measured in length (nearest mm) and weighed (nearest g) prior to each stocking (Table 3). Each fish was given an identifying complete pelvic fin clip (individual or in combination, Table 4) and freeze cauterization of the wound for later identification of the stock (Boxrucker 1982). Beginning with last segment, we also freeze branded all stocked fish in an effort to better enable age determination (in combination with scale aging) in future years. The 2005 brand was a left-front vertical brand. The brand will be applied differentially by year, with 2006 fish receiving a right-front vertical brand, and so on (Table 4).

To determine growth rates, nighttime pulse DC boat-electrofishing sampling was performed from October through November 2005 and from March through April 2006 on all study reservoirs. Length (nearest mm) and weight (nearest g) measurements were taken on sampled muskellunge. The pelvic fin clip was used to identify the stock and population and a caudal fin clip was used to conduct a Schnabel population estimate within each sampling season (Ricker 1975). Scales were taken from all sampled muskellunge older than YOY in order to determine age class (herein described as 2002 Year Class, 2003 Year Class, 2004 Year Class, and 2005 Year Class). Upon capture, muskellunge from the 2002, 2003, and 2004 Year Classes in Lake Mingo and the 2003 and 2004 Year Classes in Pierce Lake were implanted with a Passive Integrated Transponder (PIT) tag prior to release to aid in future identification. Daily temperatures were recorded using a thermograph placed at 1-m depth to assess the role of temperature in influencing growth rates of different stocks and populations. These data were used to determine mean daily growth rates (g/d) and mean relative growth rates (standardizing by starting weight, g/g/d) among the stocks of muskellunge in the study reservoirs. Growth rates were analyzed using analysis of variance (ANOVA) models.

A trap net survey was conducted April 3 – April 7, 2006 on Mingo Lake and a preliminary netting survey was conducted April 6, 2006 on Pierce Lake. During the first week of April 2006, 11 frame nets were set in Lake Mingo and run for 4 nights, resulting in 44 net-nights of effort (Figure 2). Nets were 3.8 cm bar mesh (1.5 in) and frames were 1.2 X 1.8 m with six 0.75 m hoops. Nets were checked between 0800 and 1200 hr each day. Surface water temperatures were 15.2-15.6 °C during the sampling week. During the first week of April 2006, a preliminary frame netting survey was conducted by Illinois Department of Natural Resources, Division of Fisheries. Six frame nets (3.8 cm mesh, 1.2 X 1.8 m frame, 0.75 m hoops) were set for one night, for a total of 6 net-nights.

In addition to the evaluation of growth among muskellunge stocks in reservoirs, we conducted multiple pond experiments to evaluate growth among stocks in a more controlled environment. Advantages of this approach include greater precision via increased sample sizes, individual fish growth measurements, and replication by means of using several ponds. Three 0.4-ha experimental ponds at the Sam Parr Biological Station, Kinmundy, Illinois, were used for these experiments. Muskellunge from the Upper Mississippi River drainage stock, the Ohio River drainage stock, and the Illinois population were stocked into the experimental ponds in fall 2002 and drained in spring and fall of each subsequent year including 2004. This experiment will herein be referred to as the 2002 Pond Experiment. The pond experiment was repeated with similar muskellunge stocks and populations introduced into experimental ponds during fall 2003 and will herein be referred to as the 2003 Pond Experiment. The 2003 Pond Experiment was drained in spring 2004, fall 2004, spring 2005, and fall 2005 (Table 5). In fall 2004, the pond experiment was again repeated with muskellunge from the Upper Mississippi River drainage stock (Minocqua Chain population), the Ohio River drainage stock (Chautauqua Lake population), and the Illinois population (Table 6) and will be referred to as the 2004 Pond Experiment. Thirty-three individuals from all populations were stocked into each of the three ponds (total N = 99 fish/pond). Immediately prior to stocking, each fish was anesthetized and implanted with a passive integrated transponder (PIT) tag in a similar manner as described by Harvey and Campbell (1989). Following the tagging, each fish was measured in length (nearest mm) and weighed (nearest g) and allowed to recover prior to being stocked into one of the ponds. Hourly temperature readings were recorded using thermographs placed at 1-m depth and on the bottom.

Experimental ponds were drained in October 2005 and March 2006. Muskellunge were collected and identified by the PIT tag. All fish were measured in length (nearest mm) and weight (nearest g) and placed back into one of three 1-acre (0.4-ha) experimental ponds for future evaluations. These data were used to determine mean daily growth rates and mean relative growth rates among the stocks of muskellunge in experimental ponds. Mean daily growth rates were analyzed with an analysis of covariance (ANCOVA) with initial weight as the covariate and mean relative growth rates were analyzed using an ANOVA model. Results of the reservoir and pond evaluations will provide insight as to the fastest growing population in Illinois.

FINDINGS:

Trap Net Surveys – Mingo and Pierce Lakes

In Lake Mingo, a total of 52 muskellunge were netted during the 4 nights resulting in an average of 1.2 fish per net-night. Nightly average capture rates ranged from 0.64 to 2.09 fish per net-night. Of the 52 muskellunge captured, 33 were Ohio River drainage stock, 19 were Illinois population, and 0 were Upper Mississippi River drainage stock (Table 7). The smallest muskellunge captured was 385 mm and the largest was 951 mm; weights ranged from 290 g to 6920 g. One muskellunge was age-1, eleven were age-2, eighteen were age-3, and twenty-two were age-4 (Table 7). Not all muskellunge were able to be assigned a gender; however, of those identifiable, 17% were female and 83% were male. This ratio is not surprising because male muskellunge typically mature at smaller sizes than females (Scott and Crossman 1998). This ratio should become more balanced in future segments as both sexes mature and exhibit spawning characteristics. In future segments, data will be analyzed by gender as sample size permits. Data obtained from the netting survey was integrated with electrofishing data for calculations of growth and survival. In Pierce Lake, one muskellunge was captured resulting in 0.17 fish per net-night. The 892 mm, age-3 muskellunge was from the Illinois population stocked in fall 2003.

2002 Year Class

<u>Mingo Lake</u>

Two populations, Cave Run Lake (Ohio River drainage stock) and Illinois, stocked into Lake Mingo during fall 2002 (Table 2) were monitored during fall 2005 and spring 2006 (Table 8). Unequal numbers were stocked due to limited availability of Cave Run Lake muskellunge.

Mean initial lengths of the two populations were similar, but mean initial weights were higher for the Illinois population than the Cave Run Lake population (Table 2). Sampling in fall 2003 showed that the Ohio River drainage stock muskellunge had a significantly higher mean relative growth rate than the Illinois population one-year post-stocking (Figure 3, Table 9). In fall 2004 and 2005, and spring 2006, too few (1-3) Illinois muskellunge were sampled to make meaningful statistical comparisons of growth rates. Three and a half years after stocking, the Illinois and Ohio River drainage muskellunge appear to have similar length and weight (Figure 4).

2003 Year Class

Pierce Lake

In fall 2003, three populations were introduced in Pierce Lake (Table 2). Unequal numbers were stocked due to limited availability of the populations. Some differences in stocking sizes existed with the Upper Mississippi River drainage stock having the lowest mean initial lengths and weights and the Illinois population having the highest mean initial lengths and weights (Table 2). Previous sampling showed significant overwinter differences in mean relative growth rates among populations over the first six-months post-stocking, with the Illinois population and the Ohio River drainage stock having similar mean relative growth rates, but both having significantly higher mean relative growth rates than the Upper Mississippi River drainage stock. Subsequent sampling (Table 10) found low numbers of fish and sample sizes were also very low from the spring 2005 sampling. During fall 2005 sampling only two muskellunge were collected, and both were from Illinois population. The spring 2006 sampling resulted in one muskellunge, an Illinois population fish. Due to small sample sizes, definitive conclusions regarding growth rates cannot be drawn. However, lengths and weights through time using the data from stocking through spring 2005 suggest the Illinois population and Ohio River drainage stock have similar growth rates (Figure 5). No Upper Mississippi River drainage muskellunge have been captured since spring 2004 – the winter following stocking. Trap net surveys will be integrated into the spring sampling regime with the hope that sample sizes will increase in future segments.

Mingo Lake

Three populations of muskellunge were introduced in Lake Mingo in fall 2003. Unequal numbers were stocked due to limited availability of the populations. Stocking sizes were similar, with the Illinois population having only slightly higher mean initial lengths and weights (Table 2). Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. The Upper Mississippi River drainage stock and the Ohio River drainage stock exhibited 0% mortality and the Illinois population exhibited 13% mortality. This mortality was attributed to the warmer water temperatures (~ 80° F) when the Illinois muskellunge were stocked in late August (Mather and Wahl 1989; Wahl 1999). Subsequent analyses of survival will be adjusted to account for this initial mortality. Previous sampling (Table 11) revealed no differences in mean daily growth rates nor mean relative growth rates between the Ohio River drainage stock and the Illinois population one-year post-stocking. Sampling in fall 2005 resulted in only one Ohio River drainage stock and five Illinois population muskellunge captured. However, largely due to the inclusion of trap netting, nine Ohio River drainage stock and ten Illinois population muskellunge were captured in spring 2006 (Table 11). No Upper Mississippi River drainage stock muskellunge have been captured since spring 2004 – the winter following stocking. Examining lengths and weights over time (Figure 6) suggests little or no growth difference between the Ohio River drainage stock and Illinois population muskellunge.

Forbes Lake

Two populations of muskellunge were introduced in Forbes Lake in fall 2003. Unequal numbers were stocked due to limited availability of the populations. Stocking sizes were similar among populations (Table 2). No muskellunge were captured during spring 2004, fall 2004, or spring 2005 sampling seasons, despite 11, 8, and 6 hours of electrofishing effort, respectively. Therefore, no results of growth are reported. Sampling of Forbes Lake was terminated in fall 2005 and as a replacement, Sam Dale Lake was incorporated into the study design.

2004 Year Class

Pierce Lake

Three populations were introduced in Pierce Lake during fall 2004 (Table 2). Unequal numbers were stocked due to limited availability of the populations. Only slight differences in stocking size existed with the Upper Mississippi River drainage stock marginally longer and heavier than the Illinois population. In turn, the Illinois population was only slightly larger, an average of 11 mm and 12 g, than the Ohio River drainage stock muskellunge (Table 2). As reported in greater detail in previous segments, significant overwinter differences in mean daily growth rates and mean relative growth rates among populations were observed in spring 2005. Both the Ohio River drainage stock and Illinois population had similar growth rates, with both having significantly higher growth rates than the Upper Mississippi River drainage stock. One year after stocking, only two Illinois population and five Ohio River drainage stock muskellunge were sampled during the fall 2005 sampling season (Table 12). Due to low sample sizes, statistical comparisons of growth rates are not feasible; however, examining the lengths and weights through time suggests that the Illinois population and the Ohio River drainage stock are exhibiting similar growth rates (Figure 7). No muskellunge from the Upper Mississippi River drainage stock were sampled during the fall 2005 season (Table 12, Figure 7). Additionally, no muskellunge were sampling during the spring 2006 sampling season. Trap net surveys will be integrated into the spring sampling regime with the hope that sample sizes will increase in future segments.

Mingo Lake

In fall 2004, three populations of muskellunge were introduced in Lake Mingo (Table 2). Unequal numbers were stocked due to limited availability of the populations. Negligible differences in stocking size existed among populations, with the Leech Lake and Illinois populations not differing in mean initial length or weight and the Leech Lake and Clear Fork Lake populations having similar mean initial weight. The Illinois population had a slightly higher mean initial length and weight than the Clear Fork Lake population that, in turn, had a modestly higher mean initial length than the Leech Lake population (Table 2). Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. Subsequent analyses of survival will be adjusted to account for this initial mortality. Previous sampling (Table 13) showed significant differences in overwinter growth rates six-months post-stocking. The Illinois population exhibited a significantly higher mean daily growth rate than the Ohio River drainage stock, and the Ohio River drainage stock had a significantly higher mean daily growth rate than the Upper Mississippi River drainage stock. After adjusting for differences in initial stocking weight, no differences were observed in mean relative growth rates between the Illinois population and the Ohio River drainage stock; however, both populations had significantly higher mean relative growth rates than the Upper Mississippi River drainage stock. During fall 2005 sampling, one-year post-stocking, three Illinois population and one Upper Mississippi River drainage stock muskellunge were captured, and no Ohio River drainage stock fish were sampled. Small sample sizes prohibited statistical analyses of growth rates. With trap netting efforts, adequate numbers of Illinois population and Ohio River drainage stock muskellunge were captured in spring 2006 (Table 13). However, only one Upper Mississippi River drainage stock fish was sampled. The data suggests that the Upper Mississippi River drainage stock may have substantially reduced growth rates compared to the Illinois population and Ohio River drainage stock muskellunge (Figure 8). In addition, the Illinois population may have a slight growth advantage over the Ohio River drainage stock during the eighteen months at-large (Figure 8).

Forbes Lake

Three populations were introduced in Forbes Lake in fall 2004 (Table 2). Although initial stocking mortality was low to moderate, no muskellunge were captured during fall 2004 or spring 2005 sampling seasons, despite 8 and 6 hours of electrofishing effort, respectively. Sampling of Forbes Lake was terminated in fall 2005 and as a replacement, Sam Dale Lake was incorporated into the study design.

2005 Year Class

Pierce Lake

Three populations were introduced in Pierce Lake during fall 2005 (Table 3). Unequal numbers were stocked (Leech Lake N = 166, Clear Fork Lake N = 302, and Illinois N = 300) due to limited availability of the populations. Minimal differences in stocking size existed between the Ohio River drainage stock and Illinois population muskellunge. The Upper Mississippi River drainage stock was slightly smaller than the other two populations at stocking (Table 3). Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. The Upper Mississippi River drainage stock exhibited 7% mortality and the Ohio River drainage stock 47% mortality. Due to logistical constraints, mortality cages were not used when stocking the Illinois population; however, a stocking event in Lake Mingo, the study reservoir with the most similar climate, the day prior revealed 0% mortality. We assume mortality for the Illinois population to be minimal. Subsequent analyses of survival will be adjusted to account for these initial mortality calculations. Spring 2006 sampling (Table 14) revealed significant overwinter differences in mean daily growth rates

(Table 15, ANOVA, P = 0.001) and mean relative growth rates (Table 15, ANOVA, P = 0.013) among populations, with the Illinois population and Ohio River drainage stock exhibiting similar mean daily growth and mean relative growth rates (Figure 9, Tukey, P = 0.41, P = 0.25, respectively). Both the Illinois population and the Ohio River drainage stock had significantly higher mean daily growth rates compared to the Upper Mississippi River drainage stock (Figure 9, Tukey, P = 0.02, P = 0.004, respectively). However, when initial size is accounted for, only the Ohio River drainage stock had a significantly higher mean relative growth rate than the Upper Mississippi River drainage stock (Figure 9, Tukey, P = 0.01), whereas the Illinois population had a similar mean relative growth rate (Figure 9, Tukey, P = 0.24).

Mingo Lake

Three populations of muskellunge were introduced in Lake Mingo in fall 2005 (Table 3). Unequal numbers were stocked (Leech Lake N = 193, Chautauqua Lake N = 196, and Illinois N = 325) due to limited availability of the populations. Negligible differences in stocking size existed between the Upper Mississippi River drainage stock and the Ohio River drainage stock, and the Illinois population was about 30 mm longer and 30-35 g heavier than the other two populations at stocking (Table 3). Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. Both the Illinois population and the Ohio River drainage stock exhibited 0% mortality and the Upper Mississippi River drainage stock had a 4% mortality rate. Subsequent analyses of survival will be adjusted to account for this initial mortality. Spring 2006 sampling (Table 16) showed significant differences in overwinter growth rates (Table 17). The Illinois population exhibited significantly higher mean daily growth and mean relative growth rates than the Upper Mississippi River drainage stock (Figure 10, Tukey, P = 0.003, P = 0.01, respectively). The Ohio River drainage stock exhibited intermediate growth rates which were, for the most part, statistically similar to both the Illinois population and the Upper Mississippi River drainage stock (Figure 10, Tukey, P = 0.28 – 0.54). However, the difference in mean daily growth rate between the Ohio River drainage stock and the Illinois population was marginally significant (Figure 10, Tukey, P = 0.051).

Sam Dale Lake

Four populations (three stocks) were introduced in Sam Dale Lake in fall 2005 (Table 3). Unequal numbers were stocked (Leech Lake N = 192, Cave Run Lake N = 306, Clear Fork Lake N = 306, and Illinois N = 300) due to limited availability of the populations. Stocking sizes were fairly similar with the largest difference existing between the Kentucky Cave Run Lake population and the Illinois population (Table 3). Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. The Upper Mississippi River drainage stock exhibited a 4% mortality rate and the Illinois population had a 38% mortality rate. The water temperature at the time of the Illinois population stocking was 27.4 °C. Muskellunge from the Kentucky Cave Run Lake population were obtained in mid-August and experienced a 97% mortality rate, likely due to the cumulative stressors of transportation, handling, and stocking at warm (31.0 °C) water temperatures. Because of the failed stocking, Ohio Clear Fork Lake muskellunge were obtained in late September and stocked with a 62% mortality rate, also likely due to warm (29.3 °C)water temperatures in the southern reservoir. Collectively, 125 muskellunge were assumed to survive from the Ohio River drainage stock introductions (Table 3). Subsequent analyses of survival will be adjusted to account for this initial mortality. No muskellunge were captured during fall 2005 or spring 2006 sampling seasons, despite 6 and 12.5 hours of electrofishing effort, respectively. This lake will be stocked again in future segments and sampling will continue.

Pond Experiments

Pond experiments were initiated in fall 2002 and were repeated in fall 2003 and 2004. Results from the fall 2002 pond experiment were presented in previous annual reports. Three populations of muskellunge were stocked in equal numbers into three 0.4-ha experimental ponds at the Sam Parr Biological Station in late October 2003 as described in previous annual reports. The ponds were drained in subsequent springs and falls (Table 5, Figure 11). After one year, the Illinois population and the Upper Mississippi River drainage stock exhibited similar mean daily growth rates, while the Ohio River drainage stock had a significantly higher mean daily growth rate than both the Illinois population and the Upper Mississippi River drainage muskellunge. The Ohio River drainage stock exhibited the highest mean relative growth rate, the Upper Mississippi River drainage stock intermediate, and the Illinois muskellunge had the lowest mean relative growth rate. In spite of these initial differences, no cumulative differences in mean daily growth rates were observed among the populations over the entire experiment through termination in October 2005 (Table 18, Figure 12, ANCOVA, $P = 0.22$). Due to initial differences in starting size yet similar ending size, the Ohio River drainage stock and the Upper Mississippi River drainage stock exhibited significantly higher mean relative growth rates than the Illinois population (Table 18, Figure 12, Tukey, $P < 0.0001$ for both comparisons).

Three populations of muskellunge were also stocked in equal numbers into three 0.4-ha experimental ponds at the Sam Parr Biological Station in late October 2004. The Upper Mississippi River drainage stock is represented by the Minocqua Chain population, the Ohio River drainage stock is represented by the Chautauqua Lake population, and the Illinois population is the progeny of the North Spring Lake. The initial mean lengths and weights were not significantly different between the Illinois muskellunge and the Upper Mississippi River drainage stock fish (Table 6). The initial mean length and weight for the Ohio River drainage stock was slightly lower (Table 6). No short-term mortality was observed and ponds were drained in subsequent springs and falls (Table 6, Figure 13). The Illinois population and Ohio River drainage stock exhibited significantly higher mean daily growth rates than the Upper Mississippi River drainage stock one-year post-stocking (Table 19, Figure 14, Tukey, $P = 0.04$, $P = 0.007$, respectively). However, the Ohio River drainage stock had a higher mean relative growth rate than both the Illinois population (Figure 14, Tukey, $P < 0.0001$) and the Upper Mississippi River drainage stock (Tukey, $P < .00001$).

A mixed-model approach was used to assess the effects of stock on one-year post-stocking growth rates using combined data from the three years of pond experiments. Year and pond nested within year were treated as random block effects and stock was a fixed treatment effect. The mixed-model adjusts for the missing Upper Mississippi River drainage stock in the 2002 pond experiment. Response variables were mean daily growth (g/d) and mean relative growth (g/g/d). Mean daily growth was analyzed using an analysis of covariance (ANCOVA) with initial weight as a covariate and mean relative growth was analyzed with in analysis of variance (ANOVA). Blocking efficiently accounted for variation associated with pond and year and the covariate was significant in the ANCOVA analysis (Table 20). The effect of stock was significant (ANCOVA, ANOVA, $P < 0.0001$) for both the mean daily growth and mean relative growth analyses (Table 20). The Ohio River drainage stock exhibited significantly higher mean daily growth and mean relative growth than both the Illinois population (Tukey, $P < 0.0001$) and the Upper Mississippi River drainage stock (Figure 15, Tukey, $P < 0.0001$). The Illinois population and the Upper Mississippi River drainage had similar mean daily growth rates (Tukey, $P = 0.67$) and mean relative growth rates (Tukey, $P = 0.71$).

RECOMMENDATIONS: Any long-term differences among muskellunge populations we observe in reservoir and pond experiments will have important implications for conservation of native muskellunge populations, as well as for introduction of muskellunge into waters where they do not naturally occur. When muskellunge are introduced in areas where they have not previously occurred, such as Illinois impoundments, knowledge of population differentiation will be useful in planning stocking programs. Growth differences we observed among YOY and juvenile muskellunge during the first four years of this study can influence initial survival; both by loss to predation (Wahl and Stein 1989) and loss due to over-winter mortality (Bevelhimer et al. 1985; Carline et al. 1986). We have found initial growth differences among populations of muskellunge that will need to continue to be monitored as fish mature.

In the reservoir experiment, the Illinois population and Ohio River drainage stock generally exhibit similar growth rates and trajectories. The Upper Mississippi River drainage stock almost always grew slower. However, in the pond experiment, the Ohio River drainage stock had significantly higher growth rates than both the Illinois population and the Upper Mississippi River drainage stock when the three years of experiments were pooled. The Illinois population and the Upper Mississippi River drainage stock exhibited similar growth rates. Thus far in this study, the thermal adaptation concept seems to explain growth of muskellunge stocks more closely than the countergradient variation theory. The climate of the Ohio River drainage is generally more similar to Illinois than is the climate of the Upper Mississippi River drainage. Under the assumptions of the thermal adaptation concept, it would be predicted that the Ohio River drainage stock would exhibit higher growth rates in Illinois than the Upper Mississippi River drainage stock. The North Spring Lake population used for broodstock in Illinois was first established in the early 1980’s and has subsequently been stocked yearly with muskellunge from throughout the native range of the species. The actual progeny of broodstock from any particular year results in an unknown-origin population, or possibly, a mixed-origin population. Future years of data will be needed, with as similar of initial lengths and weights as possible among stocks and populations, to be able to determine if the current trend of faster growth of the Ohio River drainage stock, as compared to the Upper Mississippi River drainage stock, is consistent.

Further fall and spring monitoring of the study reservoirs will be conducted, as well as additional introductions of the various stocks into the reservoirs for the purpose of growth evaluation. Netting will be continued in Pierce and Mingo Lakes in future years and incorporated into the protocol of Sam Dale Lake as year classes mature. The experimental ponds from the 2004 pond experiment will be drained in fall 2006 to evaluate growth of the muskellunge stocks in the experiment. The results obtained from these samples will be combined with data from future years to identify differences among genetic stocks of juvenile and adult muskellunge and to develop guidelines for future stockings that maximize growth in impoundments throughout Illinois.

Job 101.2. Evaluating survival of different stocks of muskellunge.

OBJECTIVE: To determine differences in survival among various stocks and populations of muskellunge in Illinois waters.

INTRODUCTION: In addition to growth, survival differences among genetically distinct muskellunge stocks and populations may be important in determining the most appropriate populations for use in management applications. Survival and other population characteristics is the consequence of life history modes to which stocks have evolved (Begg et al. 1999). Physiological differences among stocks could affect survival rates at various temperatures and will affect the value of a population for stocking in various waters throughout Illinois.

Numerous studies have investigated differences in survival among stocks; however most of this work has been done with salmonids. Significant differences in survival were found between hatchery reared and wild steelhead trout *Salmo gairdneri* in stream and pond evaluations; however outcomes varied between systems (Reisenbichler and McIntyre 1977). Genetic origin has been shown to influence survival among stockings of lake trout *Salvelinus namaycush* in two lakes in Ontario (MacLean et al. 1981). In comparisons of survival of northern largemouth bass *Micropterus salmoides salmoides*, Florida largemouth bass *Micropterus salmoides floridanus,* and their F1 hybrids in central Illinois, the native northern largemouth bass was shown to have the highest survival rates (Philipp and Whitt 1991). Further work suggested significant survival differences between stocks of northern largemouth bass from two different river drainages within Illinois when both were stocked in northern and southern Illinois (Philipp and Claussen 1995). These studies suggest that geographic origin (stock) can have a substantial influence on survival in a given region.

Limited work has been done evaluating survival differences among muskellunge stocks and populations. In Minnesota, performance of four native muskellunge populations of the Mississippi River drainage stock showed similar survival, with the exception of the lower survival of the Shoepack population (Younk and Strand 1992). Performance differences were also evaluated among 5 local populations in Wisconsin and compared to the performance of the Leech Lake, Minnesota population (Margenau and Hanson 1996; Margenau and Hanson 1997). Short-term (<60 d) survival was higher for the Mud/Callahan Lake population compared to the other four Wisconsin populations (Maragenau and Hanson 1996). The remaining four populations all expressed similar short-term survival. Results showed that the Leech Lake population could be introduced into Wisconsin lakes and survive; however, there was no distinct advantage over the Wisconsin lake muskellunge populations (Margenau and Hanson 1997). All of these studies examined survival among populations of muskellunge from one stock, the Upper Mississippi River drainage stock. There exists a need to evaluate the survival differences among the three genetic stocks of muskellunge, the Ohio River drainage stock, the Upper Mississippi River drainage stock, and the Great Lakes drainage stock (Table 1). Many muskellunge fisheries, including those in Illinois, are sustained by stockings of muskellunge into waters where the species has been extirpated or for new introductions. In these scenarios, it would be beneficial to know which stock and populations have the highest survival in the thermal regime of the region to be stocked.

In this job, we are investigating population and stock differentiation in terms of survival for muskellunge in the field. Long-term survival of muskellunge is being evaluated in reservoir and pond experiments. Identifying survival differences among muskellunge populations at these scales is important in defining these populations and in determining the most appropriate populations for specific management applications. In this job, we continued assessment of variation in survival among different YOY and juvenile muskellunge populations. Future work will monitor survival of these populations through adults.

PROCEDURES: Initially, we compared survival among different stocks and populations of muskellunge in Lake Mingo, Vermillion County, Illinois, as well as in Pierce Lake, Winnebago County, and Forbes Lake, Marion County (Table 2, Figure 1). These reservoirs represent the latitudinal climatic variation that exists throughout Illinois. In 2005, introductions were again made into Pierce and Mingo Lakes (Table 3). Forbes Lake was removed from the project due to consistently poor survival and/or catchability rates of stocked muskellunge, and Sam Dale Lake, Wayne County, Illinois was added (Table 3, Figure 1). Choice of stocks was dependent on availability of fish from each of the populations. Future segments of the project will include these same as well as additional stocks and populations.

As described in Job 101.1, we stocked muskellunge from the Upper Mississippi River drainage stock, the Ohio River drainage stock, and the Illinois population into three study reservoirs in fall 2005 (Table 3). Muskellunge were stocked at a large fingerling size to increase initial survival across all populations as determined in previous studies (Carline et al. 1986; Szendrey and Wahl 1996; McKeown et al. 1999). Stocked fish were also reared under as similar conditions and feeding regimes as possible so as to eliminate any indirect biases on either survival or vulnerability to predation (Szendrey and Wahl 1995). Subsamples of each stock were held in three 3-m deep predator-free cages (N = 15/cage) for 48-hrs to monitor mortality associated with transport and stocking stress (Clapp et al. 1997; Hoxmeier et al. 1999). Muskellunge from each population were stocked at rates between 1.6 – 4.9 fish per hectare (Table 3). Each fish was given an identifying complete pelvic fin clip (individual or in combination) and freeze cauterization of the wound for later identification of the stock (Table 4). Previous work has suggested that removal of any single paired fin is equally detrimental to short-term survival (3-mos) and the loss of a pelvic fin is less detrimental than loss of a pectoral fin over the long term (McNeil and Crossman 1979). Beginning with this segment, we freeze branded all stocked fish to be used in combination with scale aging to better determine age in future years. The 2005 brand was a left-front vertical brand. The brand will be applied differentially by year, such that each stocking year will have a different freeze brand location (Table 4). The freeze brand, in conjunction with the pelvic fin clip, will allow accurate identification of both the major river drainage stock as well as the specific population under examination. To determine survival, nighttime pulse DC boat-electrofishing sampling was conducted from October through November 2005 and from March through April 2006 on all study reservoirs. A trap netting survey was also conducted on Mingo Lake April 3 – April 7, 2006. As appropriate, electrofishing catch-per-unit-effort (CPUE), fish-per-net-night, relative survival (adjusted for initial mortality), and Schnabel population estimates (Ricker 1975) were used to assess survival differences among stocks.

In addition to the evaluation of survival differences among muskellunge stocks in reservoirs, we conducted multiple pond experiments to evaluate survival among stocks in a more controlled environment. Advantages of this approach include the ability to obtain a direct measurement of relative survival via pond draining. Three 0.4-ha experimental ponds at the Sam Parr Biological Station, Kinmundy, Illinois, were used for this experiment. As described in previous annual reports, muskellunge from the Upper Mississippi River drainage stock, the Ohio

River drainage stock, and the Illinois population were stocked into the experimental ponds in fall 2002 and repeated in fall 2003 and 2004. Every year, thirty-three YOY from each population were stocked into each of the three ponds (total N = 99 fish/pond).

Experimental ponds were subsequently drained every spring and fall at approximately 6 mo intervals. Muskellunge were collected and population identified by PIT tags. All surviving fish were returned into one of three 0.4-ha experimental ponds for future evaluations. These data were used to determine survival among the stocks of muskellunge in experimental ponds using a logistic analysis of variance model (Proc Genmod, SAS). Results of the reservoir and pond evaluations will provide insight as to the best surviving population in Illinois.

FINDINGS:

2002 Year Class

<u>Mingo Lake</u>

Two populations, Cave Run Lake (Ohio River drainage stock) and Illinois (Table 1), stocked into Lake Mingo during fall 2002 (Table 2) were monitored during fall 2005 and spring 2006. Unequal numbers were stocked due to limited availability of Cave Run Lake muskellunge. One-year post-stocking survival was similar for the Ohio River drainage muskellunge and the Illinois population. Survival one-year post-stocking was 28% for the Ohio River drainage stock and 24% for the Illinois population. Adjusted CPUE was calculated to account for unequal stocking numbers between stocks and populations and again showed no differences between populations one-year post-stocking (Table 21). Recapture numbers of both populations were too low during the fall 2004 sampling season to draw accurate survival conclusions. In fall 2005, three-years post-stocking, few fish were again captured (Illinois population, N = 3; Ohio River drainage stock, N = 7). However, adjusted CPUE suggests a relative survival rate over five times greater for the Ohio River drainage stock as compared to the Illinois population (Table 21, RS = 5.5). Spring 2006 trap-netting supports this conclusion with only two of the twenty-two muskellunge from the 2002 Year Class originating from the Illinois population (Table 7).

2003 Year Class

<u>Pierce Lake</u>

In fall 2003, three populations were introduced in Pierce Lake (Table 2). As reported in previous annual reports, overwinter survival was evaluated via sampling during spring 2004 with Schnabel population estimates. Survival over the 6-mo interval from stocking through spring 2004 was estimated to be 25% for the Ohio River drainage stock and 1% for the Illinois population. Too few recaptures of Illinois and Ohio River drainage stock muskellunge during fall 2004 sampling prevented Schnabel population estimate analysis of survival for the one-year post-stocking period for the populations; however, CPUE indicates higher survival for the Illinois population (Table 22). Only two muskellunge from the 2003 Year Class were captured in fall 2005, both Illinois population muskellunge. Similarly, only one Illinois muskellunge was captured in the spring 2006 trap net sampling. These results suggest very low survival for all stocked muskellunge from the 2003 Year Class.

Mingo Lake

Three populations of muskellunge were introduced in Lake Mingo in fall 2003 (Table 2). No difference in adjusted CPUE was observed between the Ohio River drainage muskellunge and the Illinois fish during the fall 2004 sampling season (ANOVA, P = 0.34), indicating no one-year post-stocking survival differences between the two populations (Table 22). However, relative survival analysis suggests a two-fold survival advantage of the Ohio River drainage stock over the Illinois population (RS = 2.4). In fall 2005, two-years post-stocking, five out of six captured 2003 Year Class muskellunge were from the Illinois population. Spring 2006 trap netting provided a larger sample size and relative survival analyses suggested a 30% higher survival from the time of stocking for the Ohio River drainage stock over the Illinois population (Table 7). No Upper Mississippi River drainage stock muskellunge were sampled after 6-mo post-stocking.

Forbes Lake

Two populations of muskellunge were introduced in Forbes Lake in fall 2003 (Table 2). No muskellunge were captured during the spring 2004, fall 2004, or spring 2005 sampling seasons despite 11, 8, and 6 hours of electrofishing effort, respectively. Sampling of Forbes Lake was terminated in fall 2005 and as a replacement, Sam Dale Lake was incorporated into the study design.

2004 Year Class

Pierce Lake

In fall 2004, three populations of muskellunge were introduced in Pierce Lake (Table 2). Overwinter survival was assessed during spring 2005 sampling by means of adjusted CPUE analysis, as low numbers of within season recaptures prevented calculation of Schnabel population estimates (Table 23). Analysis of variance test of the effect of stock on adjusted CPUE revealed no distinct survival differences among stocks (Figure 16; P = 0.69). Relative survival suggested approximately a three-fold survival advantage for the Ohio River drainage stock compared to the Illinois population (Table 23, RS = 3.1) one-year post-stocking. No Upper Mississippi River drainage stock muskellunge were sampled in fall 2005. Additionally, no muskellunge were captured in spring 2006 efforts.

Mingo Lake

Three populations were introduced in Lake Mingo in fall 2004 (Table 2). A sub-sample of stocked muskellunge were held in predator-free cages and analyses of survival are adjusted to account for the measured initial mortality. Spring 2005 sampling suggested differential survival among stocks of muskellunge. Schnabel population estimates indicate that the Upper Mississippi River drainage stock had the highest survival (100%), followed by the Ohio River drainage stock (55%) and the Illinois population (19%). However, few recaptures limit the precision of the Schnabel estimates. Adjusted CPUE differed significantly among stocks (ANOVA, P = 0.04), with the Upper Mississippi River drainage muskellunge exhibiting significantly higher survival than the Illinois population (Table 23, Figure 17, Tukey, P = 0.04). The Upper Mississippi River drainage stock had a similar mean adjusted CPUE as the Ohio River drainage stock (Figure 17, Tukey, P = 0.11), and in turn, the Ohio River drainage stock had a similar mean adjusted CPUE as the Illinois population (Tukey, P = 0.89). In combination, the survival analyses suggest that the Upper Mississippi River drainage muskellunge exhibited significantly higher overwinter survival compared to the Ohio River drainage stock and the Illinois population. Sampling in fall 2005, one-year post-stocking, indicated overall low survival with only three Illinois population and one Upper Mississippi River drainage stock muskellunge captured. Again, electrofishing sampling in spring 2006 resulted in low sample sizes with only one Upper Mississippi River drainage stock and one Ohio River drainage stock muskellunge captured (Table 23). However, trap net sampling in spring 2006 provided a larger sample size. Lack of within-season recaptures limited our ability to calculate Schnabel population estimates, but relative survival calculations suggest a slight survival advantage of the Ohio River drainage stock over the Illinois population from the time of stocking until spring 2006 (Table 7, RS = 1.4).

<u>Forbes Lake</u>

Three populations of muskellunge were introduced in Forbes Lake in fall 2004 (Table 2). No muskellunge were captured during the fall 2004 or spring 2005 sampling seasons, despite 8 and 6 hours of electrofishing effort, respectively. Sampling of Forbes Lake was terminated in fall 2005 and as a replacement, Sam Dale Lake was incorporated into the study design.

2005 Year Class

<u>Pierce Lake</u>

Three populations of muskellunge were introduced in Pierce Lake in fall 2005 (Table 3). Unequal numbers were stocked (Leech Lake N = 166, Clear Fork Lake N = 302, and Illinois N = 300) due to limited availability of the populations. Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. The Upper Mississippi River drainage stock exhibited a 7% initial mortality rate and the Ohio River drainage stock had a 47% initial mortality rate. Due to logistical constraints, mortality cages were not used during the Illinois stocking. However, based on 100% survival the day prior in Lake Mingo (Table 3), we feel that initial mortality was minimal for the Illinois stocking in Pierce Lake. Subsequent analyses of survival will be adjusted to account for initial mortalities as assessed by the mortality cages. Zero mark-recaptures during the spring 2006 sampling prohibited the calculation of Schnabel population estimates for the Ohio River drainage stock. However, adequate recaptures allowed for Schnabel population estimates to be calculated for the Upper Mississippi River drainage stock and Illinois population muskellunge. The Upper Mississippi River drainage stock exhibited the highest survival with an estimated 32% survival from the time of stocking (Table 24). The Illinois population had a much lower survival estimate of 3%. Based on relative survival calculations, the Ohio River drainage stock only had slightly lower survival than the Illinois population (RS = 0.8). Adjusted CPUE differed significantly among stocks (Table 24, ANOVA, P = 0.008), with the Upper Mississippi River drainage stock having significantly higher adjusted CPUE than the Ohio River drainage stock (Figure 18, Tukey, P = 0.01) and the Illinois population (Figure 18, Tukey, P = 0.02). Adjusted CPUE did not differ between the Ohio River drainage stock and the Illinois population muskellunge (Figure 18, Tukey, P = 0.99). Combined, the survival analyses suggest significantly higher overwinter survival for the Upper Mississippi River drainage stock than for the Ohio River drainage stock or the Illinois population.

Mingo Lake

In fall 2005, three populations of muskellunge were introduced in Lake Mingo (Table 3). Unequal numbers were stocked (Leech Lake N = 193, Chautauqua Lake N = 196, and Illinois population N = 325) due to limited availability of the populations. Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. The Upper Mississippi River drainage stock exhibited a 4% initial mortality rate and both the Ohio River drainage stock and the Illinois population had 0% initial mortality (Table 3). Subsequent analyses of survival will be adjusted to account for the initial mortality experienced by the Upper Mississippi River drainage stock. Despite fourteen muskies being sampled in spring 2006, few recaptures prohibited calculation of Schnabel population estimates. Relative survival analyses indicate generally similar overwinter survival among stocks. The Upper Mississippi River drainage stock had slightly higher survival than the Ohio River drainage stock and Illinois population (Table 24, RS = 1.8, 1.5, respectively). The Illinois population exhibited about 20% higher relative survival than the Ohio River drainage stock (Table 24, RS = 1.2). Analysis of adjusted CPUE from spring 2006 electrofishing indicates no significant differences among stocks (Table 24, ANOVA, P = 0.87), in general agreement with the conclusions drawn from the relative survival calculations.

Sam Dale Lake

Three populations of muskellunge were introduced into Sam Dale Lake in fall 2005 (Table 3). Unequal numbers were stocked (Leech Lake N = 192, Cave Run Lake N = 306, Clear Fork Lake N = 306, and Illinois N = 300) due to limited availability of the populations. Three 3-m deep predator-free mortality cages were monitored for 48-hrs post-stocking to evaluate stocking mortality of each population. The Upper Mississippi River drainage stock exhibited a 4% mortality rate and the Illinois population had a 38% mortality rate. Muskellunge from the Kentucky Cave Run Lake population were obtained in mid-August and experienced a 97% mortality rate, likely due to the cumulative stressors of transportation, handling, and stocking at warm (31.0 °C) water temperatures. Because of the failed stocking, Ohio Clear Fork Lake muskellunge were obtained in late September and stocked with a 62% mortality rate, also likely due to warm (29.3 °C) water temperatures in the southern reservoir. Collectively, 125 muskellunge were assumed to survive from the Ohio River drainage stock introductions (Table 3). Subsequent analyses of survival will be adjusted to account for this initial mortality. No muskellunge were captured during fall 2005 or spring 2006 sampling seasons, despite 6 and 12.5 hours of electrofishing effort, respectively. Sampling of Sam Dale Lake will continue and will be reported in subsequent segments.

Pond Experiments

Three populations of muskellunge were stocked in equal numbers into three 0.4-ha experimental ponds at the Sam Parr Biological Station in late October 2003 as described in previous annual reports. The ponds were drained in subsequent springs and falls (Table 5). No overwinter survival differences were observed among stocks following the first 6-mos post-stocking (X^2, P = 0.19); however, significant differences were observed thereafter (Figure 19). One-year post-stocking, the Ohio River drainage stock exhibited significantly higher survival than the Illinois (X^2, P = 0.0006) and the Upper Mississippi River drainage stock (Figure 19, X^2, P < 0.0001). The Illinois population, in turn, exhibited higher survival than the Upper Mississippi drainage stock. This pattern held constant through the spring and fall 2005 drainings (Figure 19).

Three populations of muskellunge were also stocked in equal numbers into three 0.4-ha experimental ponds in October 2004. Ponds were visually monitored for 48-hrs post-stocking and no short-term mortality was observed. Ponds were drained in subsequent springs and falls (Table 6). No significant overwinter survival differences were observed among stocks 6-mos post-stocking (Figure 20, X^2, P = 0.12). All three muskellunge stocks had survival rates ranging from 40 – 55%. One-year post-stocking survival differed marginally among stocks (X^2, P = 0.10), with the Upper Mississippi River drainage stock exhibiting significantly higher survival than the Ohio River drainage stock (Figure 20, X^2, P = 0.03). No survival differences were observed among stocks 18-mos post-stocking (Figure 20, X^2, P = 0.12).

A logistic analysis of variance (Proc Genmod, SAS) was used to assess survival differences one-year post-stocking among genetically distinct stocks of muskellunge fingerlings. Data from the 2002, 2002, and 2004 experiment were incorporated into the model, blocking by pond nested within year. Both the pond and stock effect significantly contributed to the variation observed in survival rates (X^2, P < 0.0001). The Illinois population and the Ohio River drainage stock had similar survival rates one-year post-stocking (X^2, P = 0.46), and both exhibited significantly higher survival rates than the Upper Mississippi River drainage stock (Figure 21, X^2, P < 0.0001).

RECOMMENDATIONS: Any long-term differences in survival among muskellunge populations will have important implications for conservation and stocking of muskellunge. Survival differences we observed among YOY and juvenile muskellunge during the initial segments of this study can influence the success and cost-effectiveness of a muskellunge stocking program (Margenau 1992). We have found initial survival differences among populations of muskellunge that will need to continue to be monitored as fish grow into adults.

Preliminary reservoir results suggest that the Upper Mississippi River drainage stock typically has on overwinter survival advantage over the Ohio River drainage stock and Illinois population; however, after the first summer, the Ohio River drainage stock and Illinois population consistently exhibit higher one-year post-stocking survival than the Upper Mississippi River drainage stock. The first summer at Illinois latitudes appears to negatively affect the survival of muskellunge from the Upper Mississippi River drainage stock. In subsequent monitoring of year classes, it appears that the Ohio River drainage stock achieves a higher survival rate than the Illinois population. The pond experiments support these general conclusions. Typically, no differences in overwinter survival were observed; however, in two of the three years of the study, the Ohio River drainage stock and Illinois population exhibited significantly higher one-year post-stocking survival than the Upper Mississippi River drainage stock. The pooled analysis of the three pond experiments suggests that the Ohio River drainage stock and Illinois population have similar one-year post-stocking survival, and collectively these muskellunge have significantly higher survival than fish from the Upper Mississippi River drainage.

Further fall and spring monitoring of the study reservoirs will be conducted, as well as additional introductions of the various stocks into the three reservoirs for the purpose of evaluating survival differences among stocks. In particular, additional stockings in Sam Dale Lake are needed given the apparent low survival of the initial stocking. The three 0.4-ha experimental ponds will be drained in fall 2006 to evaluate survival of the muskellunge stocks. The results obtained from these past and future years will be used to identify long-term differences in survival and longevity among genetic stocks of muskellunge.

Job 101.3. Analysis and reporting.

OBJECTIVE: To prepare annual and final reports summarizing information and develop guidelines for proper selection of muskellunge populations for stocking in Illinois impoundments.

PROCEDURES and FINDINGS: Data collected in Jobs 101.1 – 101.2 were analyzed to begin developing guidelines regarding appropriate muskellunge populations for stocking throughout Illinois. In future segments, recommendations will be made that will allow hatchery and management biologists to make decisions that will maximize benefits for the muskellunge program in Illinois.

BUDGET TABLE:

Project Segment 4

Job	Proposed Cost	Actual Cost
Job 101.1	$22,075	$22,075
Job 101.2	$22,600	$22,600
Job 101.3	$7,884	$7,884

LITERATURE CITED

Altukhov, Y.P. 1981. The stock concept from the viewpoint of population genetics. Canadian Journal of Fisheries and Aquatic Sciences 38: 1523-1538.

Begg, G.A., K.D. Friedland, and J.B. Pearce. 1999. Stock identification and its role in stock assessment and fisheries management: an overview. Fisheries Research 43: 1-8.

Belk, M.C., J.B. Johnson, K.W. Wilson, M.E. Smith, and D.D. Houston. 2005. Variation in intrinsic individual growth rate among populations of leatherside chub (*Snyderichthys copei* Jordan & Gilbert): adaptation to temperature or length of growing season? Ecology of Freshwater Fish 14: 177-184.

Bevelhimer, M.R., R.A. Stein, and R.F. Carline. 1985. Assessing significance of physiological differences among three esocids with a bioenergetics model. Canadian Journal of Fisheries and Aquatic Sciences 42: 57-69.

Boxrucker, J.C. 1982. Mass marking of fingerling largemouth bass by fin-clipping followed by freeze-cauterization of the wound. North American Journal of Fisheries Management 2: 94-96.

Carline, R.F., R.A. Stein, and L.M. Riley. 1986. Effects of size at stocking, season, largemouth bass predation, and forage abundance on survival of tiger muskellunge, Pages 151-167 *in* G. E. Hall, editor. Managing Muskies. American Fisheries Society, Special Publication 15, Bethesda, Maryland, USA.

Clapp, D.F., Y. Bhagwat, and D.H. Wahl. 1997. The effect of thermal stress on walleye fry and fingerling mortality. North American Journal of Fisheries Management 17: 429-437.

Clapp, D.F. and D.H. Wahl. 1996. Comparison of food consumption, growth, and metabolism among muskellunge – an investigation of population differentiation. Transactions of the American Fisheries Society 125: 402-410.

Conover, D.O. and T.M.C. Present. 1990. Countergradient variation in growth rate: compensation for length of the growing season among Atlantic silversides from different latitudes. Oecologia 83: 316-324.

Conover, D.O., and E.T. Schultz. 1995. Phenotypic similarity and the evolutionary significance of countergradient variation. Trends in Ecology & Evolution 10: 248-252.

Conover, D.O., J.J. Brown, and A. Ehtisham. 1997. Countergradient variation in growth of young striped bass (*Morone saxatilis*) from different latitudes. Canadian Journal of Fisheries and Aquatic Sciences 54: 2401-2409.

Crossman, E.J. 1978. Taxonomy and distribution of North American esocids. Pages 13-26 *in* R.L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Special Publication 11, Washington, D.C., USA.

Crossman, E.J. 1986. The noble muskellunge: a review. Pages 1-13 *in* G.E. Hall, editor. Managing Muskies. American Fisheries Society, Special Publication 15, Bethesda, Maryland, USA.

DiMichele, L. and M.E. Westerman. 1997. Geographic variation in development rate between populations of the teleost *Fundulus heteroclitus*. Marine Biology 128: 1-7.

Galarowicz, T.L. and D.H. Wahl. 2003. Differences in growth, consumption, and metabolism among walleyes from different latitudes. Transactions of the American Fisheries Society 132: 425-437.

Harvey, W.D. and D.L. Campbell. 1989. Retention of passive integrated transponder tags in largemouth bass brood fish. The Progressive Fish Culturist 51: 164-166.

Hubbs, C.L. and K.F. Lagler. 1958. Fishes of the Great Lakes region. Cranbrook Institute of Science Bulletin 26.

Ihssen, P.E., D.O. Evans, W.J. Christie, J.A. Reckahn, and R.L. DesJardine. 1981. Life history, morphology, and electrophoretic characteristics of five allopatric stocks of lake whitefish *Coregonus clupeaformis* in the Great Lakes region. Canadian Journal of Fisheries and Aquatic Sciences 38: 1790-1807.

Isely, J.J., R.L. Noble, J.B. Koppelman, and D.P. Philipp. 1987. Spawning period and first-year growth of northern, Florida, and intergrade stocks of largemouth bass. Transactions of the American Fisheries Society 116: 757-762.

Jonassen, T.M., A.K. Imsland, R. Fitzgerald, S.W. Bonga, E.V. Ham, G. Naevdal, M.O. Stefansson, and S.O. Stefansson. 2000. Geographic variation in growth and food consumption efficiency of juvenile Atlantic halibut related to latitude. Journal of Fish Biology 56: 279-294.

Koppelman, J.B. and D.P. Philipp. 1986. Genetic applications in muskellunge management. Pages 111-121 *in* G.E. Hall, editor. Managing Muskies. American Fisheries Society, Special Publication 15, Bethesda, Maryland, USA.

Levinton, J.S. 1983. The latitudinal compensation hypothesis: growth data and a model of latitudinal growth differentiation based upon energy budgets. I. interspecific comparison of *Ophryotrocha* (Polychaeta: Dorvilleidae). Biological Bulletin (Woods Hole) 165: 686-698.

Levinton, J.S. and R.K. Monahan. 1983. The latitudinal compensation hypothesis: growth data and a model of latitudinal growth differentiation based upon energy budgets. II. intraspecific comparisons between subspecies of *Ophryotrocha puerilis* (Polychaeta: Dorvilleidae). Biological Bulletin (Woods Hole) 165: 699-707.

Lonsdale, D.J. and J.S. Levinton. 1985. Latitudinal differentiation in copepod growth: an adaptation to temperature. Ecology 66: 1397-1407.

Luey, J.E. and I.R. Adelman. 1984. Stock structure of rainbow smelt in western Lake Superior: population characteristics. Transactions of the American Fisheries Society 113: 709-715.

MacLean, J.A. and D.O. Evans. 1981. The stock concept, discreteness of fish stocks, and fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 38: 1889-1898.

MacLean, J.A., D.O. Evans, N.V. Martin, and R.L. DesJardine. 1981. Survival, growth, spawning distribution, and movements of introduced and native lake trout *Salvelinus namaycush* in two inland Ontario Lakes. Canadian Journal of Fisheries and Aquatic Sciences 38: 1685-1700.

Margenau, T.L. 1992. Survival and cost-effectiveness of stocked fall fingerling and spring yearling muskellunge in Wisconsin. North American Journal of Fisheries Management 12: 484-493.

Margenau, T.L. and D.A. Hanson. 1997. Performance of Leech Lake, Minnesota, muskellunge in a Wisconsin Lake. Wisconsin Department of Natural Resources Research Report 175 175: 1-11.

Margenau, T.L. and D.A. Hanson. 1996. Survival and growth of stocked muskellunge: effects of genetic and environmental factors. Wisconsin Department of Natural Resources Research Report 172 172: 1-11.

Mather, M.E., and D.H. Wahl. 1989. Comparative mortality of three esocids due to stocking stressors. Canadian Journal of Fisheries and Aquatic Sciences 46: 214-217.

McClane, A.J. 1974. McClane's field guide to freshwater fishes of North America. Holt, Rinehart, and Winston, New York, NY, USA.

McKeown, P.E., J.L. Forney, and S.R. Mooradian. 1999. Effects of stocking size and rearing method on muskellunge survival in Chautauqua Lake, New York. North American Journal of Fisheries Management 19: 249-257.

McNeil, F.I. and E.J. Crossman. 1979. Fin clips in the evaluation of stocking programs for muskellunge *Esox masquinongy*. Transactions of the American Fisheries Society 108: 335-343.

Midwest Regional Climate Center (MRCC). 2004. http://mcc.sws.uiuc.edu/

National Oceanic and Atmospheric Administration (NOAA). 2004. http://www.noaa.gov/

New York State Climate Office (NYSCO). 2004. http://nysc.eas.cornell.edu/

Nicieza, A.G., F.G. Reyes-Gavilan, and F. Brana. 1994. Differentiation in juvenile growth and bimodality patterns between northern and southern populations of Atlantic salmon (*Salmo salar* L.). Canadian Journal of Zoology 72: 1603-1610.

Pennsylvania State Climatologist (PSC). 2004. http://pasc.met.psu.edu/PA_Climatologist/index.php

Philipp, D.P. and G.S. Whitt. 1991. Survival and growth of northern, Florida, and reciprocal F1 hybrid largemouth bass in Central Illinois. Transaction of the American Fisheries Society 120: 58-64.

Philipp, D.P. and J.E. Claussen. 1995. Fitness and performance differences between two stocks of largemouth bass from different river drainages within Illinois. American Fisheries Society Symposium 15: 236-243.

Reisenbichler, R.R., and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout *Salmo gairdneri*. Journal of the Fisheries Research Board of Canada 34: 123-128.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191. 382 pp.

Schultz, E.T., K.E. Reynolds, and D.O. Conover. 1996. Countergradient variation in growth among newly hatched *Fundulus heteroclitus*: geographic differences revealed by common-environment experiments. Functional Ecology 10: 366-374.

Scott, W.B. and E.J. Crossman. 1998. Freshwater fishes of Canada, 2nd Edition. Oakville, Ontario, Canada.

Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana, Illinois, USA.

Szendrey, T.A. and D.H. Wahl. 1995. Effect of feeding experience on growth, vulnerability to predation, and survival of esocids. North American Journal of Fisheries Management 15: 610-620.

Szendrey, T.A. and D.H. Wahl. 1996. Size-specific survival and growth of stocked muskellunge: effects of predation and prey availability. North American Journal of Fisheries Management 16: 395-402.

Wahl, D.H. and R.A. Stein. 1989. Comparative vulnerability of three esocids to largemouth bass *Micropterus salmoides* predation. Canadian Journal of Fisheries and Aquatic Sciences 46: 2095-2103.

Wahl, D.H. 1999. An ecological context for evaluating the factors influencing muskellunge stocking success. North American Journal of Fisheries Management 19: 238-248.

Weatherbase. 2004. http://www.weatherbase.com/

Yamahira, K. and D.O. Conover. 2002. Intra- vs. interspecific latitudinal variation in growth: adaptation to temperature or seasonality? Ecology 83: 1252-1262.

Younk, J.A. and R.F. Strand. 1992. Performance evaluation of four muskellunge *Esox masquinongy* strains in two Minnesota lakes. Minnesota Department of Natural Resources Section of Fisheries Investigational Report No. 418. pp 22.

Table 1. Sources of young-of-year muskellunge stocks used for evaluation of growth and survival. Kentucky, Ohio, Pennsylvania, and New York populations are from the Ohio River drainage (Ohio stock); Minnesota and Wisconsin populations are from the Upper Mississippi River drainage (Mississippi stock); St. Lawrence River muskellunge are from the Great Lakes drainage (Great Lakes stock). Cooling (CDD) and heating (HDD) degree days are calculated using a base temperature of 65° F, with 1961 - 1990 data from the National Oceanic and Atmospheric Administration, Midwest Climate Center, Pennsylvania State Climatologist, and the New York State Climate Office.

Population (abbreviation)	Source Water	Drainage (stock)	Latitude (north)	Cooling Degree Days (CDD)	Heating Degree Days (HDD)	Mean Annual Temp. (F)
Kentucky (KY)	Cave Run Lake	Ohio River	37° 35′	1154	4713	55.2
Ohio (OH)	Clear Fork Lake	Ohio River	39° 30′	703	6300	49.6
Pennsylvania (PA)	Pymatuning Reservoir	Ohio River	41° 30′	322	6934	47.4
New York (NY)	Lake Chautauqua	Ohio River	42° 07′	350	6279	49.4
St. Lawrence (SL)	St. Lawrence River	Great Lakes	42° 25′	551	6785	45.4
Wisconsin (WI)	Minocqua Chain	Mississippi River	45° 30′	215	9550	39.3
Minnesota (MN)	Leech Lake	Mississippi River	46° 35′	347	9495	39.9
Illinois (IL)	North Spring Lake	*	40° 40′	998	6097	50.8

Table 2. Stocking summary of muskellunge populations from the Upper Mississippi River drainage (MISS), Ohio River drainage (OH) and North Spring Lake, IL progeny (IL) introduced in Pierce Lake, Lake Mingo, and Forbes Lake during falls 2002 - 2004. Adjusted number of fish and number per hectare account for initial mortality as determined by mortality cage estimates. Total length (nearest mm) and weight (nearest g) were measured prior to stocking. Values in parentheses represent 95% confidence intervals.

Lake	Stock	Population	Stocking Date	Number of Fish		Number per Hectare		Mean Length (mm)	Mean Weight (g)
				Stocked	Adjusted	Stocked	Adjusted		
			2002						
Mingo	OH	Cave Run Lake, KY	October 30, 2002	171	171	2.4	2.4	315 (±7.5)	155 (±8.2)
	IL	North Spring Lake, IL	October 24, 2002	400	400	5.6	5.6	336 (±5.6)	200 (±11.7)
			2003						
Pierce	MISS	Leech Lake, MN	November 7, 2003	100	100[†]	1.6	1.6	197 (±5.0)	28 (±2.5)
	OH	Lake Chautauqua, NY	September 19, 2003	234	234[†]	3.8	3.8	225 (±2.6)	44 (±1.7)
	IL	North Spring Lake, IL	August 29, 2003	500	500[†]	8.2	8.2	258 (±3.3)	77 (±2.9)
Mingo	MISS	Leech Lake, MN	October 31, 2003	285	285	4.0	4.0	237 (±9.0)	60 (±7.7)
	OH	Clear Fork Lake, OH	September 4, 2003	288	288	4.0	4.0	227 (±2.5)	56 (±2.2)
	IL	North Spring Lake, IL	August 29, 2003	500	433	7.0	6.0	258 (±3.3)	77 (±2.9)
Forbes	MISS	Minocqua Chain, WI	September 9, 2003	217	158	1.0	0.7	248 (±4.8)	87 (±4.7)
	IL	North Spring Lake, IL	August 29, 2003	500	400	2.2	1.8	258 (±3.3)	77 (±2.9)

Table 2. Continued.

Lake	Stock	Population	Stocking Date	Number of Fish: Stocked	Number of Fish: Adjusted	Number per Hectare: Stocked	Number per Hectare: Adjusted	Mean Length (mm)	Mean Weight (g)
			2004						
Pierce	MISS	Leech Lake, MN	October 29, 2004	200	200†	3.3	3.3	287 (±7.9)	96 (±9.7)
	OH	Cave Run Lake, KY	September 14, 2004	242	242†	4.0	4.0	261 (±5.0)	76 (±5.1)
	IL	North Spring Lake, IL	August 26, 2004	300	300†	4.9	4.9	272 (±4.7)	88 (±5.1)
Mingo	MISS	Leech Lake, MN	October 30, 2004	193	193	2.7	2.7	280 (±8.2)	85 (±9.1)
	OH	Clear Fork Lake, OH	September 14, 2004	245	147	3.4	2.1	261 (±5.6)	74 (±5.3)
	IL	North Spring Lake, IL	August 27, 2004	300	293	4.2	4.1	273 (±4.6)	88 (±5.3)
Forbes	MISS	Minocqua Chain, WI	October 6, 2004	57	53	0.3	0.2	303 (±6.5)	135 (±9.9)
	OH	Chautauqua Lake, NY*	October 5, 2004	101	94	0.4	0.4	233 (±2.8)	50 (±1.9)
	OH	Pymatuning Lake, PA*	October 5, 2004	238	238	1.1	1.1	187 (±3.3)	27 (±1.5)
	IL	North Spring Lake, IL	August 26, 2004	500	333	2.2	1.5	270 (±4.6)	89 (±5.4)

†Mortality cages not utilized due to logistical constraints

* Populations differentially marked with vertical vs. horizontal back-right freeze brand on side of body

Table 3. Stocking summary of muskellunge populations from the Upper Mississippi River drainage (MISS), Ohio River drainage (OH) and North Spring Lake, IL progeny (IL) introduced in Pierce Lake, Lake Mingo, and Sam Dale Lake during fall 2005. Adjusted number of fish and number per hectare account for initial mortality as determined by mortality cage estimates. Total length (nearest mm) and weight (nearest g) were measured prior to stocking. Values in parentheses represent 95% confidence intervals.

Lake	Stock	Population	Stocking Date	Number of Fish		Number per Hectare		Mean Length (mm)	Mean Weight (g)
				Stocked	Adjusted	Stocked	Adjusted		
Pierce	MISS	Leech Lake, MN	October 10, 2005	166	154	2.7	2.5	235 (±5.1)	50 (±3.7)
	OH	Clear Fork Lake, OH	September 24, 2005	302	161	4.9	2.6	261 (±4.1)	75 (±3.8)
	IL	North Spring Lake, IL	August 31, 2005	300	300[†]	4.9	4.9	270 (±4.6)	87 (±5.1)
Mingo	MISS	Leech Lake, MN	October 11, 2005	193	186	2.7	2.6	233 (±5.5)	48 (±3.8)
	OH	Chautauqua Lake, NY	September 28, 2005	196	196	2.7	2.7	234 (±3.7)	45 (±2.3)
	IL	North Spring Lake, IL	August 30, 2005	325	325	4.5	4.5	267 (±4.8)	79 (±5.8)
Sam Dale	MISS	Leech Lake, MN	November 16, 2005	192	185	2.4	2.4	255 (±5.9)	57 (±4.9)
	OH	Cave Run Lake, KY	August 19, 2005	306	10[‡]	3.9	0.1	232 (±5.0)	56 (±3.5)
	OH	Clear Fork Lake, OH	September 23, 2005	306	115[‡]	3.9	1.5	261 (±4.1)	75 (±3.8)
	IL	North Spring Lake, IL	August 31, 2005	300	186	3.8	2.4	273 (±4.1)	88 (±5.2)

[†]Mortality cages not utilized due to logistical constraints

[‡]Stocking events combined for subsequent analyses due low initial survival

Table 4. Summary of age-identifying freeze brands given to all stocked muskelluge by year. Freeze brands, in conjunction with scale samples, will allow for greater aging accuracy. Prior to introduction, muskellunge from the Upper Mississippi River drainage (MISS), the Ohio River drainage (OH), and the North Spring Lake, IL progeny (IL) are given a unique and consistent complete pelvic fin clip followed by cauterization of the wound.

Stocking Year	Age-Identifying Freeze Brand
Fall 2004	Right-back vertical
Fall 2005	Left-front vertical
Fall 2006	Right-front vertical
Fall 2007	Left-back vertical

Stock	Stock-Identifying Complete Fin Clip
MISS	Both pelvic
OH	Left pelvic
IL	Right pelvic

Table 5. Summary of initial and subsequent lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2003. Ponds were drained in spring and fall of each subsequent year. The Ohio River drainage stock is represented by the Kentucky Cave Run Lake population and the Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population. Values in parentheses represent 95% confidence intervales.

Season	Ohio River Drainage	Mississippi River Drainage	Illinois
		Length (mm)	
Fall 2003	292 (± 4.5)	283 (± 7.2)	353 (± 3.9)
Spring 2004	338 (± 3.9)	323 (± 6.5)	386 (± 4.7)
Fall 2004	407 (± 5.5)	391 (± 8.1)	426 (± 6.7)
Spring 2005	422 (± 6.8)	411 (± 9.4)	439 (± 6.8)
Fall 2005	478 (± 7.8)	476 (± 77.0)	483 (± 7.5)
		Weight (g)	
Fall 2003	96 (± 4.3)	98 (± 8.3)	190 (± 7.4)
Spring 2004	181 (± 7.4)	146 (± 9.6)	278 (± 11.1)
Fall 2004	302 (± 13.3)	251 (± 19.8)	334 (± 17.9)
Spring 2005	320 (± 18.1)	265 (± 30.5)	336 (± 15.9)
Fall 2005	518 (± 28.6)	485 (± 384.4)	511 (± 25.5)

Table 6. Summary of initial and subsequent lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2004 and drained in March 2006. The Ohio River drainage stock is represented by the New York Lake Chautauqua population and the Upper Mississippi River drainage stock is represented by the Wisconsin Minocqua Chain population. Values in parentheses represent 95% confidence intervals.

Season	Ohio River Drainage	Mississippi River Drainage	Illinois
		Length (mm)	
Fall 2004	234 (± 1.9)	304 (± 2.5)	308 (± 3.5)
Spring 2005	289 (± 2.9)	336 (± 3.9)	340 (± 5.0)
Fall 2005	419 (± 16.8)	436 (± 9.3)	440 (± 11.7)
Spring 2006	430 (± 17.4)	456 (± 9.4)	454 (± 15.7)
		Weight (g)	
Fall 2004	51 (± 1.5)	137 (± 4.0)	128 (± 5.8)
Spring 2005	120 (± 5.3)	198 (± 7.4)	196 (± 9.6)
Fall 2005	343 (± 49.8)	380 (± 32.0)	381 (± 37.3)
Spring 2006	383 (± 53.2)	462 (± 33.0)	463 (± 53.0)

Table 7. Summary of muskellunge captured in trap nets April 3-7, 2006 in Mingo Lake. Catch-per-unit-effort (CPUE) is expressed as muskellunge per net-night adjusted to account for different initial stocking numbers. Age classes correspond to year of stocking: IV = 2002, III = 2003, II = 2004, and I = 2005.

	Age-Classes							
	I		II		III		IV	
Stock	N	CPUE	N	CPUE	N	CPUE	N	CPUE
MISS	0	0.00	0	0.00	0	0.00	N/A	N/A
OH	0	0.00	4	0.62	9	0.71	20	2.66
IL	1	0.07	7	0.54	9	0.47	2	0.11

Table 8. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of two stocks of muskellunge introduced in Lake Mingo during fall 2002. Spring and fall sampling periods are comprised of multiple sampling events per season. The Ohio River drainage stock is represented by the Kentucky Cave Run Lake population and the Illinois muskellunge are North Spring Lake, IL progeny. Values in parentheses represent 95% confidence intervals.

Season	Ohio River Drainage	Illinois
	Length (mm)	
Fall 2002	315 (±7.5)	336 (±5.6)
Fall 2003	623 (±16.3)	650 (±11.6)
Fall 2004	818 (±35.4)	843 (±0.0)
Fall 2005	897 (±41.6)	849 (±78.2)
Spring 2006	874 (±24.1)	877 (±438.4)
	Weight (g)	
Fall 2002	155 (±8.2)	200 (±11.7)
Fall 2003	1457 (±106.4)	1735 (±118.3)
Fall 2004	3983 (±592.2)	4639 (±0.0)
Fall 2005	5701 (±1250.0)	4233 (±1839.2)
Spring 2006	5220 (±387.7)	5050 (±15501.6)

Table 9. Analysis of variance tests of the effect of stock on mean daily growth rates (g/d) and mean relative growth rates (g/g/d) of muskellunge populations from the Ohio River drainage and North Spring Lake, IL introduced in Lake Mingo during fall 2002. Growth is for the 1-yr interval from stocking through the following fall (October through December 2003). Sum of squares are Type III (SAS Institute V8).

Source of Variation	Degrees of Freedom	Sum of Squares	F	Pr > F
		Mean daily growth rate (g/d)		
Stock	1	2.470	6.26	0.02
Error	38	14.990		
		Mean relative growth rate (g/g/d)		
Stock	1	0.0000575	5.09	0.03
Error	38	0.000429		

Table 10. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced in Pierce Lake during fall 2003. Spring and fall sampling seasons were comprised of multiple sampling events per season. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the New York Lake Chautauqua population, and the Illinois muskellunge are North Spring Lake, IL progeny. Values in parentheses represent 95% confidence intervals.

Season	Mississippi River Drainage	Ohio River Drainage	Illinois
		Length (mm)	
Fall 2003	197 (±5.0)	225 (±2.6)	258 (±3.3)
Spring 2004	202 (±46.2)	284 (±9.4)	347 (±11.4)
Fall 2004	-	471 (±324.0)	552 (±34.0)
Spring 2005	-	511 (±457.4)	580 (±163.2)
		Weight (g)	
Fall 2003	28 (±2.5)	44 (±1.7)	77 (±2.9)
Spring 2004	28 (±21.7)	102 (±11.6)	191 (±30.8)
Fall 2004	-	532 (±813.2)	931 (±251.4)
Spring 2005	-	839 (±3621.3)	1319 (±1572.3)

Table 11. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced in Lake Mingo during fall 2003. Spring and fall sampling seasons were comprised of multiple sampling events per season. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Ohio Clear Fork Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Values in parentheses represent 95% confidence intervals.

Season	Mississippi River Drainage	Ohio River Drainage	Illinois
		Length (mm)	
Fall 2003	237 (±9.0)	227 (±2.5)	258 (±3.3)
Spring 2004	301 (±18.0)	306 (±9.7)	349 (±9.3)
Fall 2004	-	541 (±34.1)	565 (±52.5)
Spring 2005	-	577 (±58.6)	611 (±972.0)
Fall 2005	-	811 (±0.0)	747 (±26.8)
Spring 2006	-	744 (±22.5)	745 (±34.6)
		Weight (g)	
Fall 2003	60 (±7.7)	56 (±2.2)	77 (±2.9)
Spring 2004	105 (±22.2)	128 (±17.1)	191 (±18.8)
Fall 2004	-	1011 (±287.5)	1128 (±425.8)
Spring 2005	-	1461 (±605.3)	1836 (±11486.4)
Fall 2005	-	3830 (±0.0)	2625 (±417.3)
Spring 2006	-	3133 (±388.8)	2867 (±378.0)

Table 12. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced in Pierce Lake during fall 2004. Spring and fall sampling seasons were comprised of multiple sampling events per season. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Kentucky Cave Run Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. No fish from the 2004 Year Class were captured in the spring 2006 sampling. Values in parentheses represent 95% confidence intervals.

Season	Mississippi River Drainage	Ohio River Drainage	Illinois
		Length (mm)	
Fall 2004	287 (±7.9)	261 (±5.0)	272 (±4.7)
Spring 2005	292 (±14.4)	331 (±19.5)	360 (±18.5)
Fall 2005	-	518 (±47.4)	551 (±393.9)
Spring 2006	-	-	-
		Weight (g)	
Fall 2004	96 (±9.7)	76 (±5.1)	88 (±5.1)
Spring 2005	98 (±21.0)	188 (±63.9)	236 (±48.4)
Fall 2005	-	721 (±207.6)	992 (±3195.6)
Spring 2006	-	-	-

Table 13. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced in Lake Mingo during fall 2004. Spring and fall sampling seasons were comprised of multiple sampling events per season. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Ohio Clear Fork Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Values in parentheses represent 95% confidence intervals.

Season	Mississippi River Drainage	Ohio River Drainage	Illinois
		Length (mm)	
Fall 2004	280 (±8.2)	261 (±5.6)	273 (±4.6)
Spring 2005	297 (±9.2)	334 (±8.4)	371 (±9.9)
Fall 2005	468 (±0.0)	-	586 (±79.6)
Spring 2006	449 (±0.0)	563 (±33.8)	602 (±21.9)
		Weight (g)	
Fall 2004	85 (±9.1)	74 (±5.3)	88 (±5.3)
Spring 2005	104 (±10.6)	179 (±16.7)	250 (±25.6)
Fall 2005	468 (±0.0)	-	1238 (±685.3)
Spring 2006	480 (±0.0)	1216 (±258.9)	1440 (±204.4)

Table 14. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced in Pierce Lake during fall 2005. Spring sampling was conducted from March 20 through April 24, 2006. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Ohio Clear Fork Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Values in parentheses represent 95% confidence intervals.

Season	Mississippi River Drainage	Ohio River Drainage	Illinois
		Length (mm)	
Fall 2005	235 (±5.1)	261 (±4.1)	270 (±4.6)
Spring 2006	255 (±7.4)	317 (±34.0)	307 (±35.1)
		Weight (g)	
Fall 2005	50 (±3.7)	75 (±3.8)	87 (±5.1)
Spring 2006	63 (±6.3)	142 (±59.3)	140 (±39.5)

Table 15. Analysis of variance tests of the effect of stock on mean daily growth rates (g/d) and mean relative growth rates (g/g/d) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Pierce Lake during fall 2005. Growth is for the 6-mo interval from stocking through the following spring (March through April 2006). Sum of squares are Type III (SAS Institute V8).

Source of Variation	Degrees of Freedom	Sum of Squares	F	Pr > F
		Mean daily growth rate (g/d)		
Stock	2	0.400	8.54	0.001
Error	31	0.726		
		Mean relative growth rate (g/g/d)		
Stock	2	0.0000437	5.01	0.013
Error	31	0.000135		

Table 16. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced in Lake Mingo during fall 2005. Spring sampling was conducted from March 29 through April 27, 2006. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the New York Chautauqua Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Values in parentheses represent 95% confidence intervals.

Season	Mississippi River Drainage	Ohio River Drainage	Illinois
		Length (mm)	
Fall 2005	233 (±5.5)	234 (±3.7)	267 (±4.8)
Spring 2006	250 (±38.3)	283 (±81.0)	366 (±38.4)
		Weight (g)	
Fall 2005	48 (±3.8)	45 (±2.3)	79 (±5.8)
Spring 2006	61 (±32.7)	98 (±88.5)	247 (±82.1)

Table 17. Analysis of variance tests of the effect of stock on mean daily growth rates (g/d) and mean relative growth rates (g/g/d) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Lake Mingo during fall 2005. Growth is for the 6-mo interval from stocking through the following spring (March through April 2006). Sum of squares are Type III (SAS Institute V8).

Source of Variation	Degrees of Freedom	Sum of Squares	F	Pr > F
		Mean daily growth rate (g/d)		
Stock	2	1.367	10.46	0.003
Error	11	0.719		
		Mean relative growth rate (g/g/d)		
Stock	2	0.00018	5.94	0.018
Error	11	0.00017		

Table 18. Analysis of variance tests of the effects of stock, initial weight, and pond on mean daily growth rates (g/d) and mean relative growth rates (g/g/d) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2003 and drained during October 2005. Sum of squares are Type III (SAS Institute V8).

Source of Variation	Degrees of Freedom	Sum of Squares	F	Pr > F
		Mean daily growth rate (g/d)		
Stock	2	0.0324	1.58	0.216
Initial Weight	1	0.0028	0.27	0.603
Pond	2	0.0662	3.22	0.048
Error	52	0.5342		
		Mean relative growth rate (g/g/d)		
Stock	2	0.0002	39.39	<0.0001
Pond	2	0.000003	0.75	0.475
Error	53	0.0001		

Table 19. Analysis of variance tests of the effects of stock, initial weight, and pond on mean daily growth rates (g/d) and mean relative growth rates (g/g/d) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2004 and drained during October 2005. Sum of squares are Type III (SAS Institute V8).

Source of Variation	Degrees of Freedom	Sum of Squares	F	Pr > F
		Mean daily growth rate (g/d)		
Stock	2	0.2208	5.71	0.005
Initial Weight	1	0.1122	5.81	0.018
Pond	2	4.6522	120.31	<0.0001
Error	85	1.6433		
		Mean relative growth rate (g/g/d)		
Stock	2	0.0017	148.80	<0.0001
Pond	2	0.0007	62.22	<0.0001
Error	86	0.0005		

Table 20. Analysis of variance tests of the effects of stock, initial weight, year, and pond nested within year on one-year post-stocking mean daily growth rates (g/d) and mean relative growth rates (g/g/d) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2002, 2003, and 2004. Sum of squares are Type III (SAS Institute V8).

Source of Variation	Degrees of Freedom	Sum of Squares	F	Pr > F
		Mean daily growth rate (g/d)		
Stock	2	1.0417	22.52	<0.0001
Initial Weight	1	0.1515	6.55	0.011
Year	2	2.4001	1.53	0.289
Pond (Year)	6	6.2055	44.72	<0.0001
Error	284	6.5681		
		Mean relative growth rate (g/g/d)		
Stock	2	0.0023	223.21	<0.0001
Year	2	0.0010	4.13	0.073
Pond (Year)	6	0.0009	29.24	<0.0001
Error	285	0.0015		

Table 21. Adjusted catch-per-unit-effort of electrofishing (fish/hr) through time of three stocks of muskellunge introduced in Mingo Lake in fall 2002.

Sampling Season	Effort (hr)	Adjusted CPUE	
		OH	IL
Spring 2003	26.4	8.97	5.30
Fall 2003	16.0	6.40	4.40
Spring 2004	21.0	7.57	0.97
Fall 2004	22.6	1.16	0.10
Spring 2005	28.4	1.34	0.76
Fall 2005	17.7	1.86	0.34
Spring 2006	11.1	0.00	0.23

Table 22. Adjusted catch-per-unit-effort of electrofishing (fish/hr) through time of three stocks of muskellunge introduced in Pierce and Mingo Lakes in fall 2003.

Sampling Season	Effort (hr)	Adjusted CPUE		
		MISS	OH	IL
			Pierce Lake	
Spring 2004	16.5	2.92	3.33	0.74
Fall 2004	17.6	0.00	0.55	0.98
Spring 2005	26.0	0.00	0.31	0.23
Fall 2005	18.1	0.00	0.00	0.24
Spring 2006	15.6	0.00	0.00	0.00
			Lake Mingo	
Spring 2004	21.0	2.28	3.83	3.53
Fall 2004	22.6	0.00	1.26	0.74
Spring 2005	28.4	0.00	0.73	0.15
Fall 2005	17.7	0.00	0.17	0.51
Spring 2006	11.1	0.00	0.00	0.21

Table 23. Adjusted catch-per-unit-effort of electrofishing (fish/hr) through time of three stocks of muskellunge introduced in Pierce and Mingo Lakes in fall 2004.

Sampling Season	Effort (hr)	Adjusted CPUE		
		MISS	OH	IL
			Pierce Lake	
Spring 2005	26.0	1.77	1.08	1.10
Fall 2005	18.1	0.00	1.20	0.37
Spring 2006	15.6	0.00	0.00	0.00
			Lake Mingo	
Spring 2005	28.4	6.30	3.11	2.43
Fall 2005	17.7	0.23	0.00	0.50
Spring 2006	11.1	0.48	0.63	0.00

Table 24. Adjusted catch-per-unit-effort of electrofishing (fish/hr) through time of three stocks of muskellunge introduced in Pierce and Mingo Lakes in fall 2005.

Sampling Season	Effort (hr)	Adjusted CPUE MISS	OH	IL
			Pierce Lake	
Spring 2006	15.6	8.53	1.55	1.86
			Lake Mingo	
Spring 2006	11.1	2.45	1.35	1.43

Figure 1. Illinois reservoirs stocked for evaluation of growth and survival among muskellunge stocks.

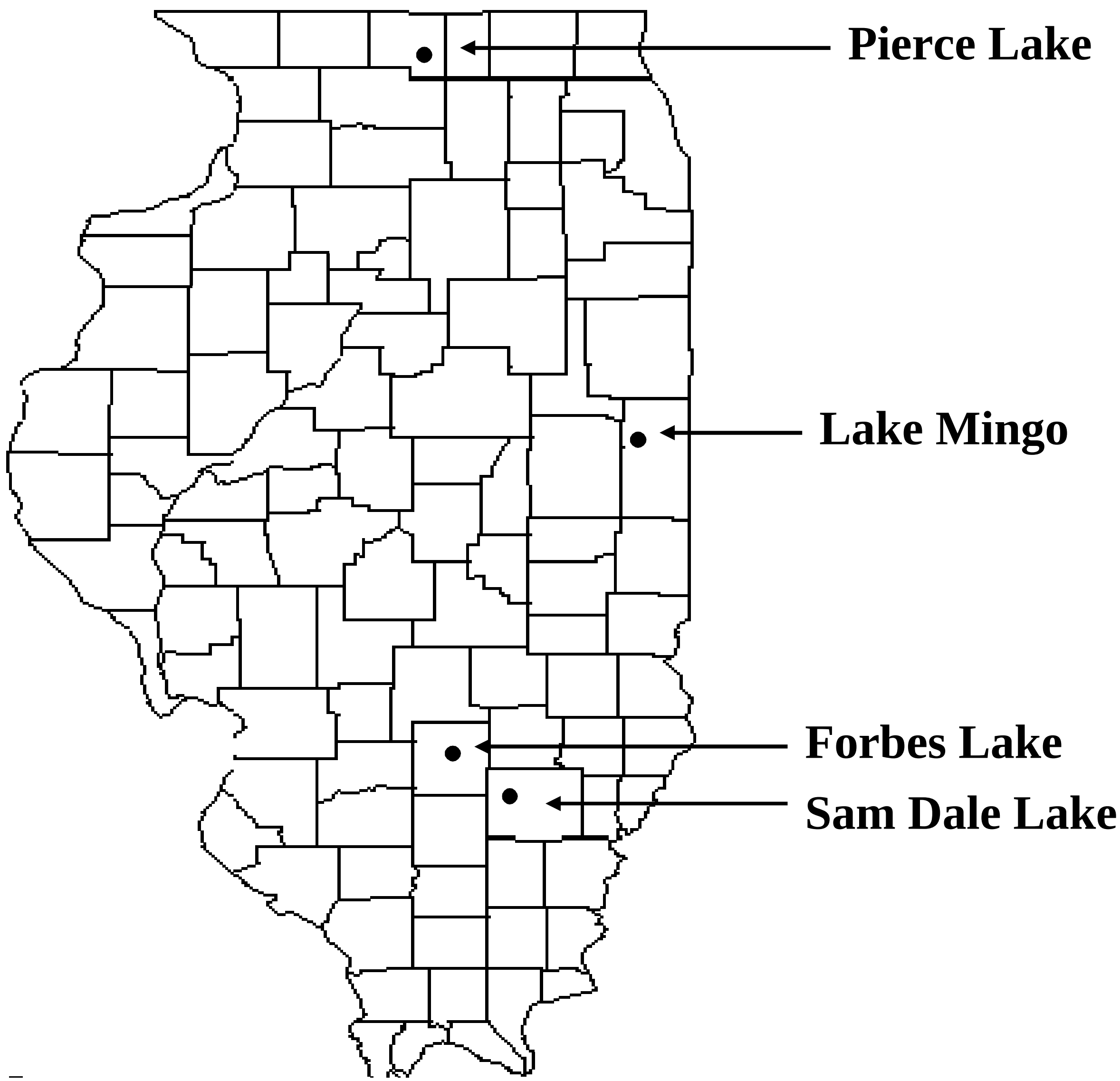

Figure 2. Locations of the 11 trap nets set in Lake Mingo on April 3 and removed on April 7, 2006. Total effort was 44 net-nights.

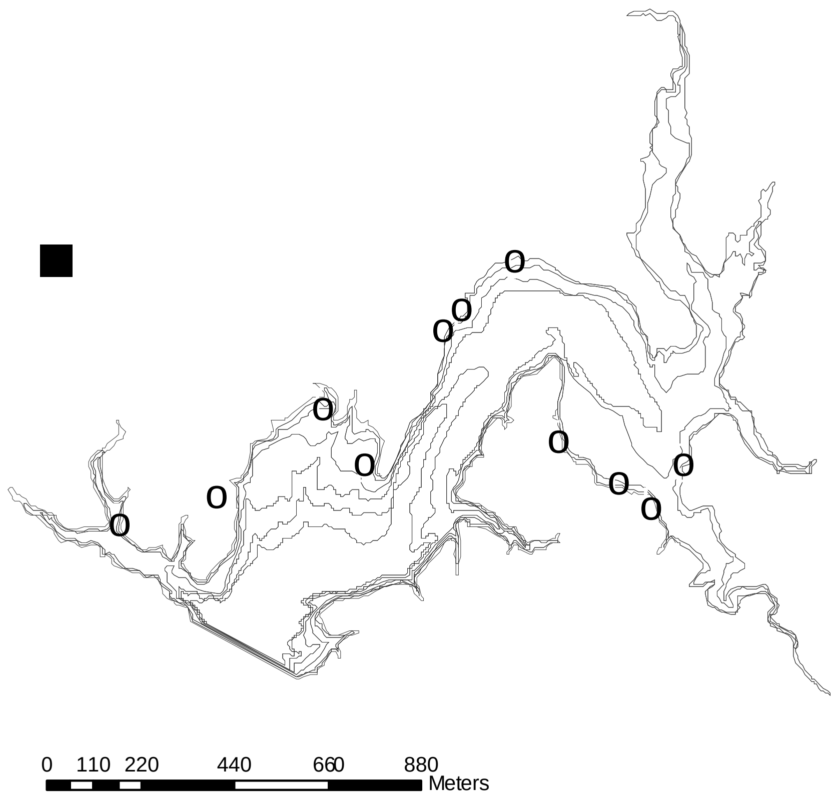

Figure 3. Mean daily growth rates (g/d, solid bars) and mean relative growth rates (g/g/d X 100, open bars) of muskellunge populations from the Ohio River drainage and North Spring Lake, IL introduced in Lake Mingo during fall 2002. Growth is from the time of stocking through the first fall (October through December 2003). The Ohio River drainage stock is represented by the Kentucky Cave Run Lake population and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

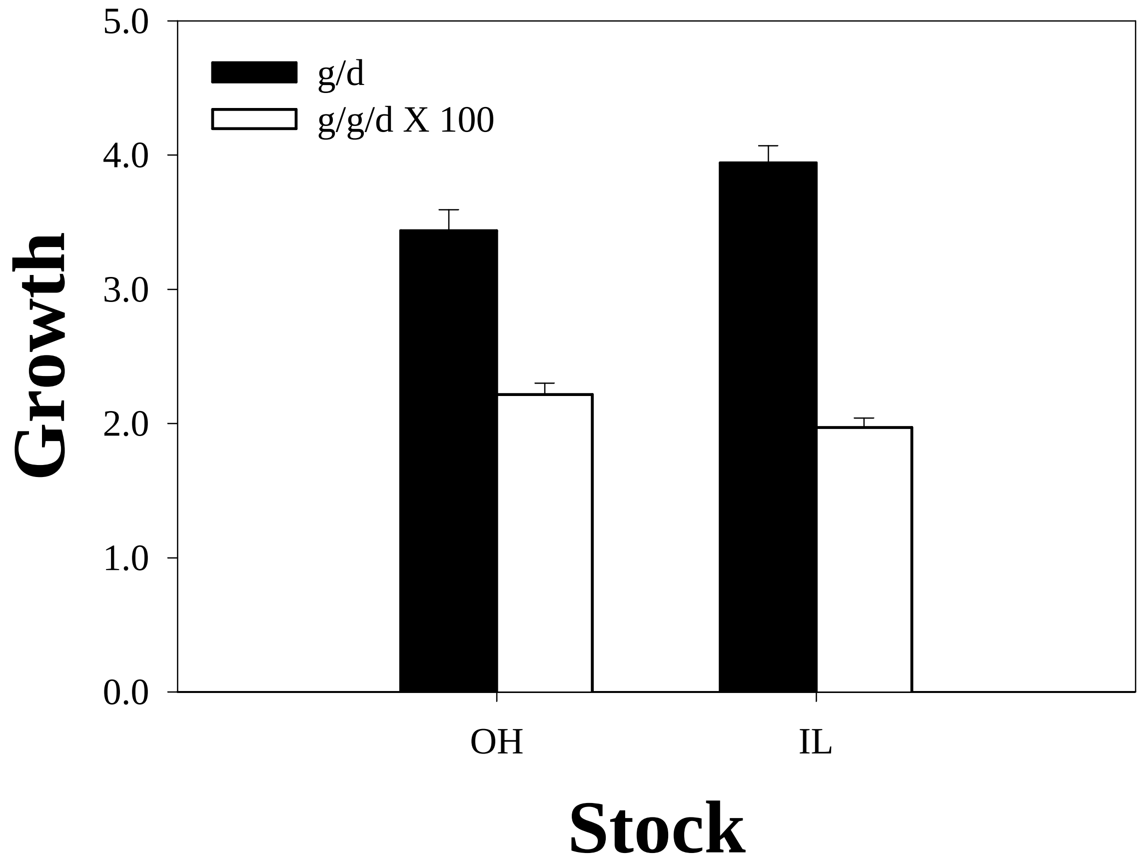

Figure 4. Stocking and subsequent sample mean lengths (nearest mm) and weights (nearest g) of muskellunge populations from the Ohio River drainage and North Spring Lake, IL introduced in Lake Mingo during fall 2002. The Ohio River drainage stock is represented by the Kentucky Cave Run Lake population and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

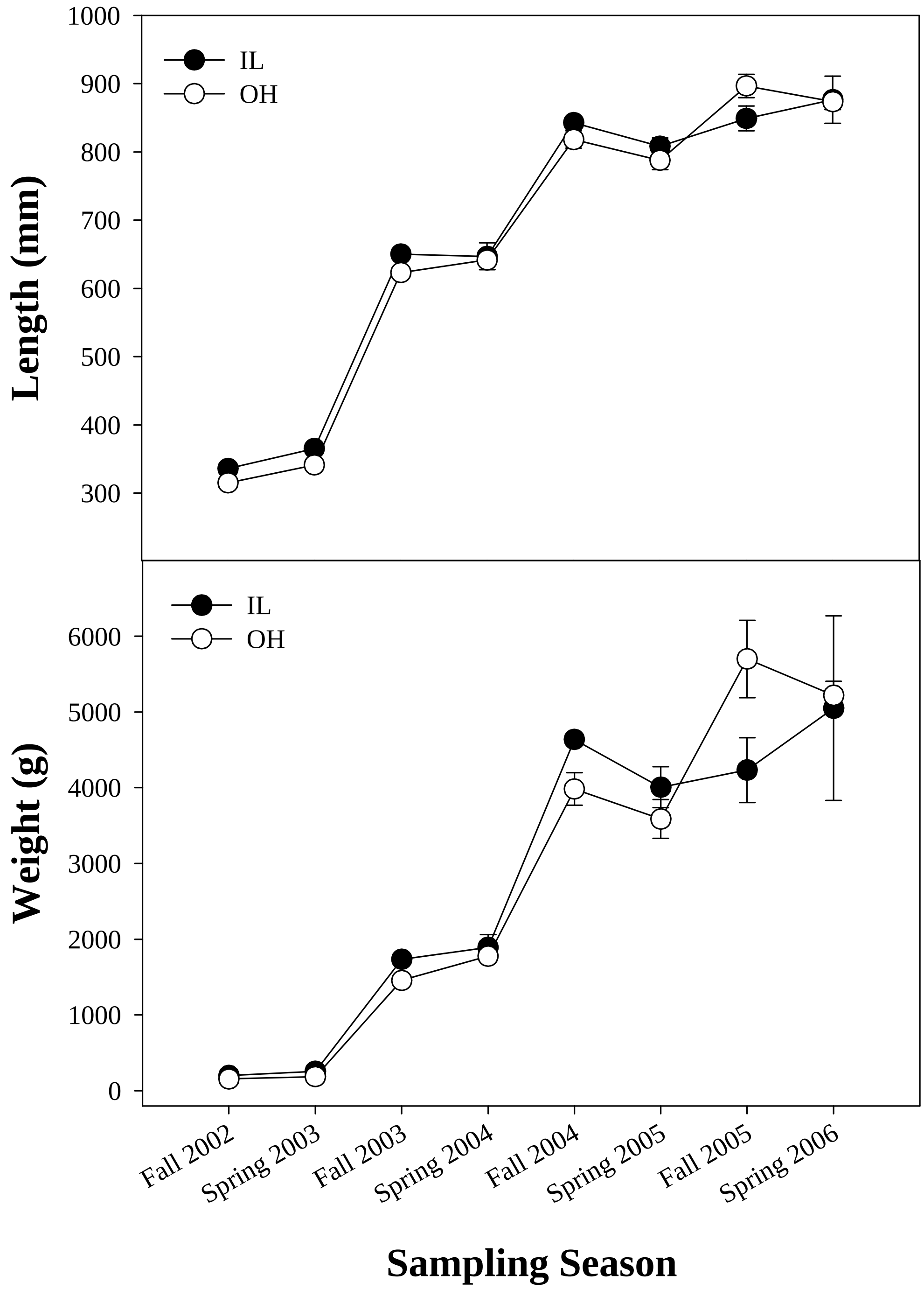

Figure 5. Stocking and subsequent sample mean lengths (nearest mm) and weights (nearest g) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Pierce Lake during fall 2003. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the New York Lake Chautauqua population, and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

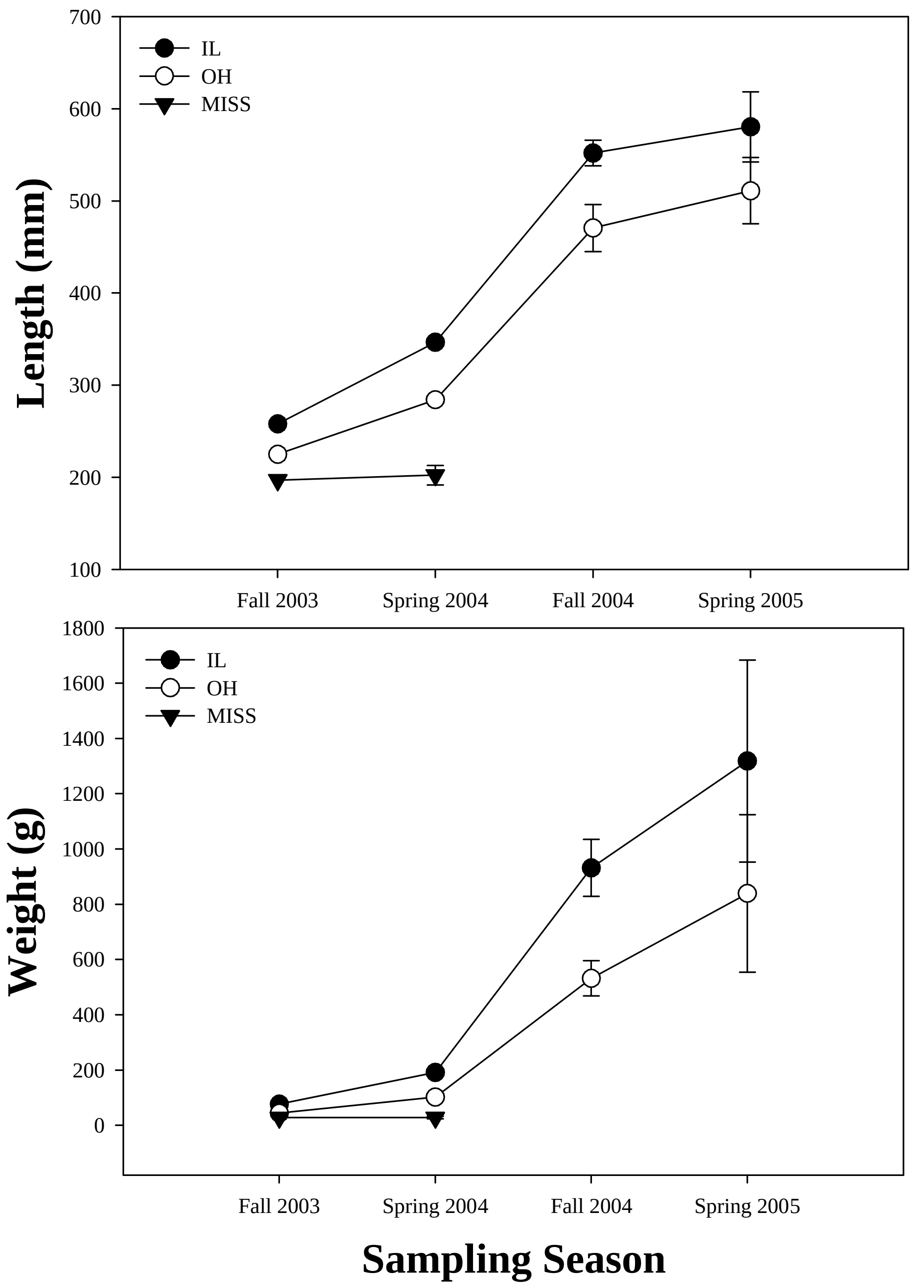

Figure 6. Stocking and subsequent sample mean lengths (nearest mm) and weights (nearest g) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Lake Mingo during fall 2003. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Ohio Clear Fork Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

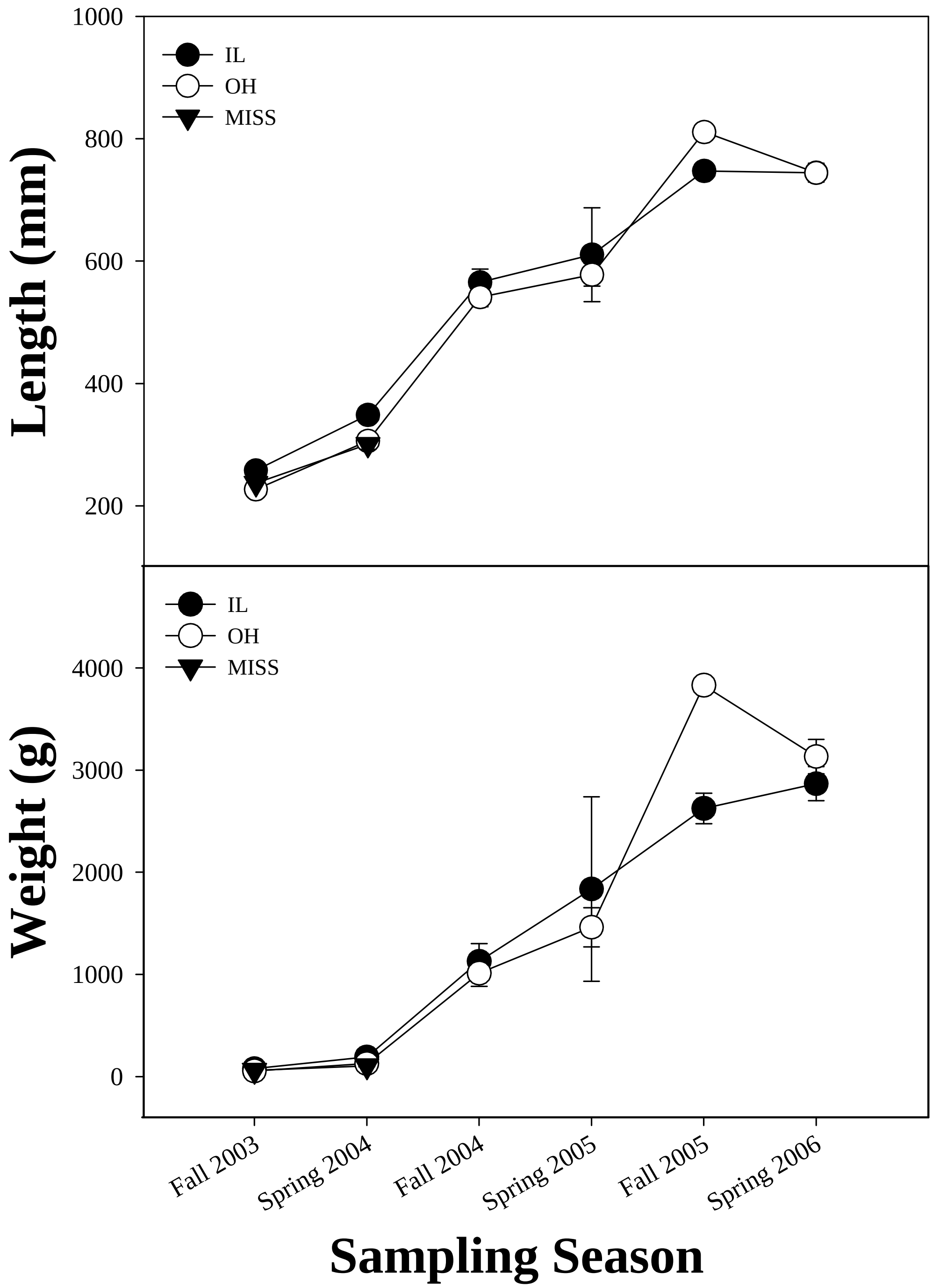

Figure 7. Stocking and subsequent sample mean lengths (nearest mm) and weights (nearest g) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Pierce Lake during fall 2004. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Kentucky Cave Run Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

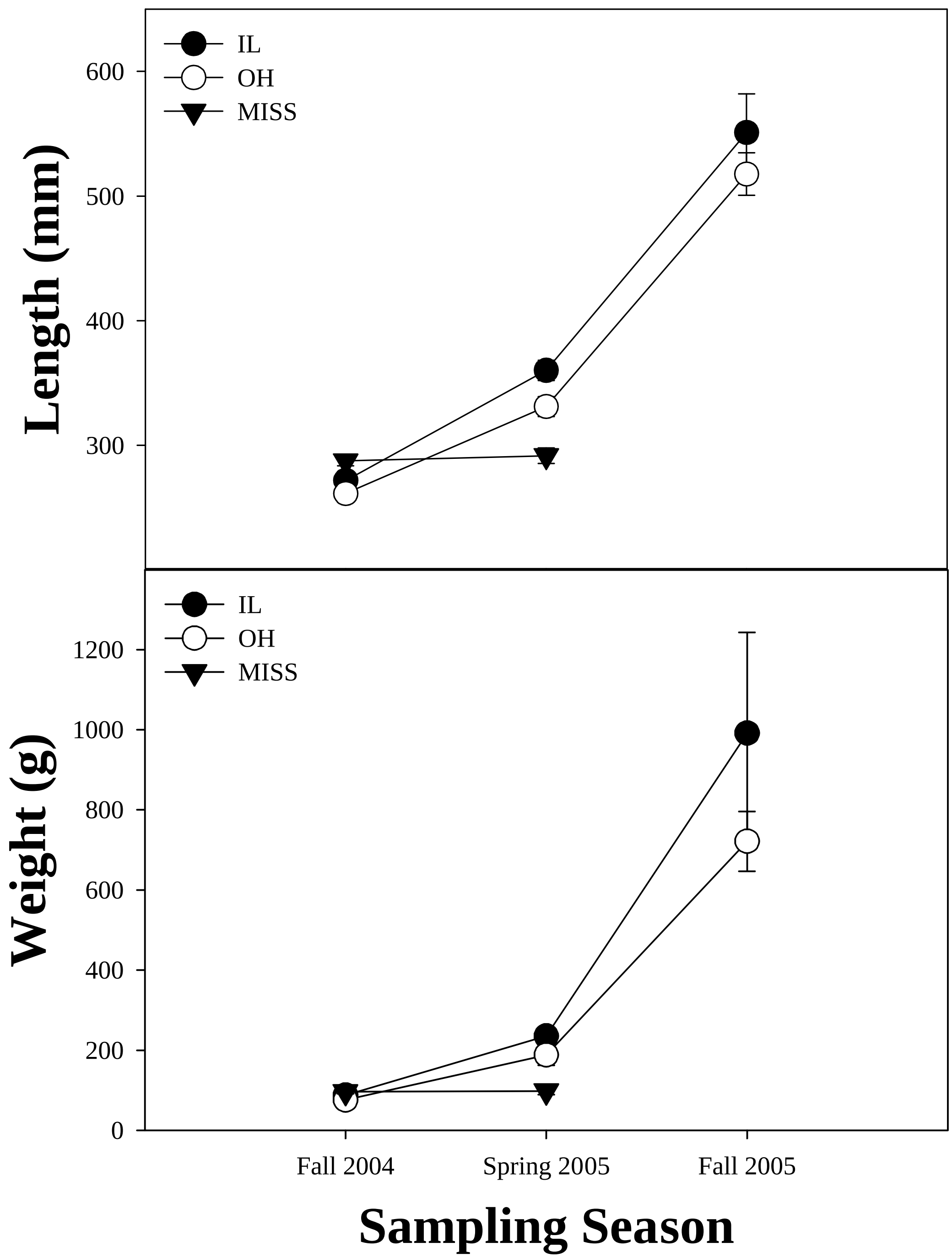

Figure 8. Stocking and subsequent sample mean lengths (nearest mm) and weights (nearest g) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Lake Mingo during fall 2004. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Ohio Clear Fork Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

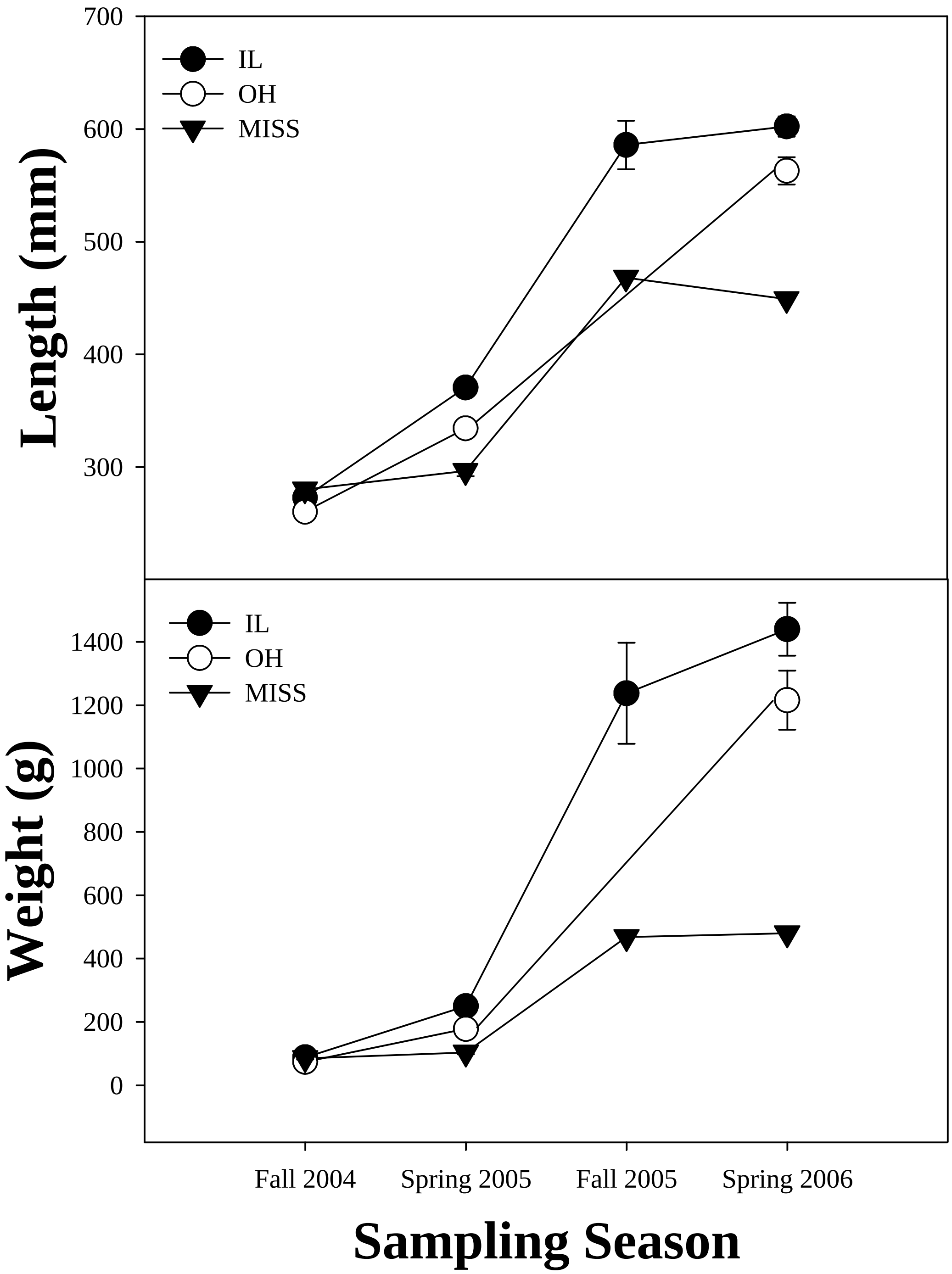

Figure 9. Mean daily growth rates (g/d, solid bars) and mean relative growth rates (g/g/d X 100, open bars) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Pierce Lake during fall 2005. Growth is from the time of stocking through spring (March through April 2006). The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the Ohio Clear Fork Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

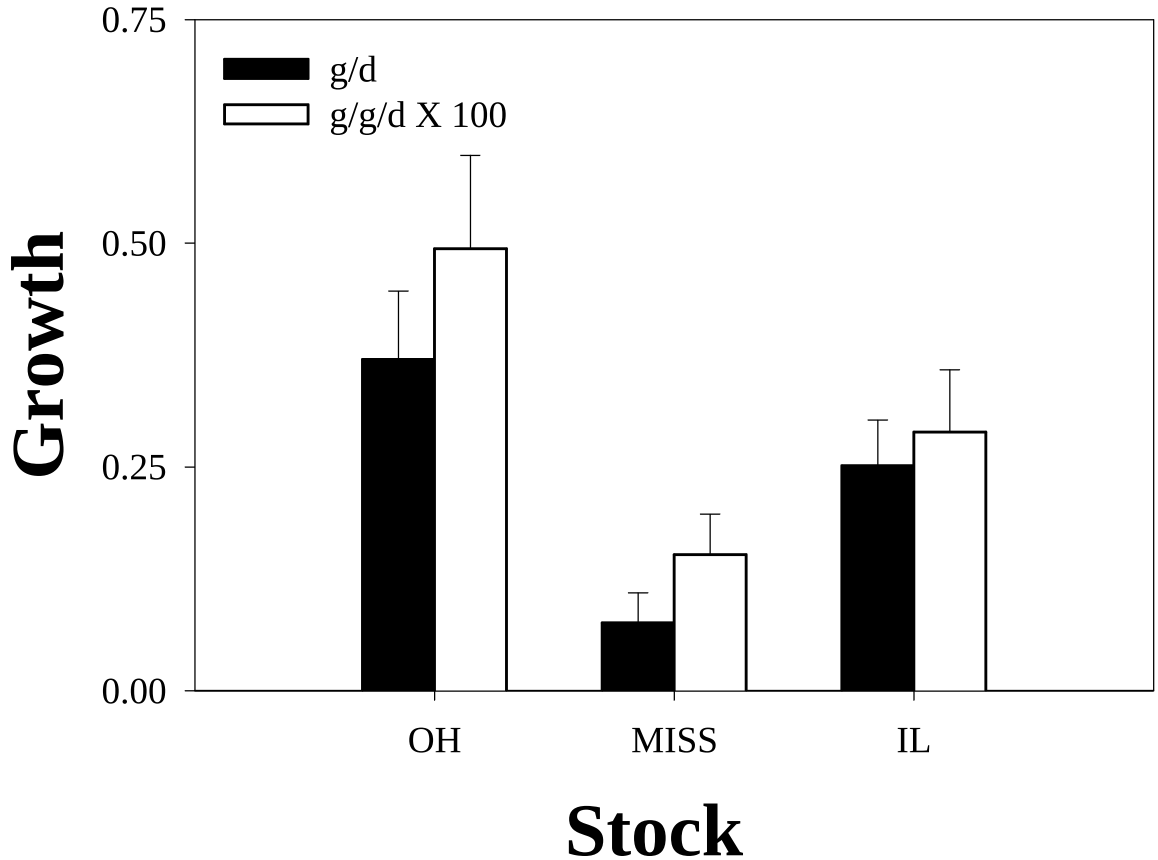

Figure 10. Mean daily growth rates (g/d, solid bars) and mean relative growth rates (g/g/d X 100, open bars) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Lake Mingo during fall 2005. Growth is from the time of stocking through spring (March through April 2006). The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population, the Ohio River drainage stock is represented by the New York Chautauqua Lake population, and the Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

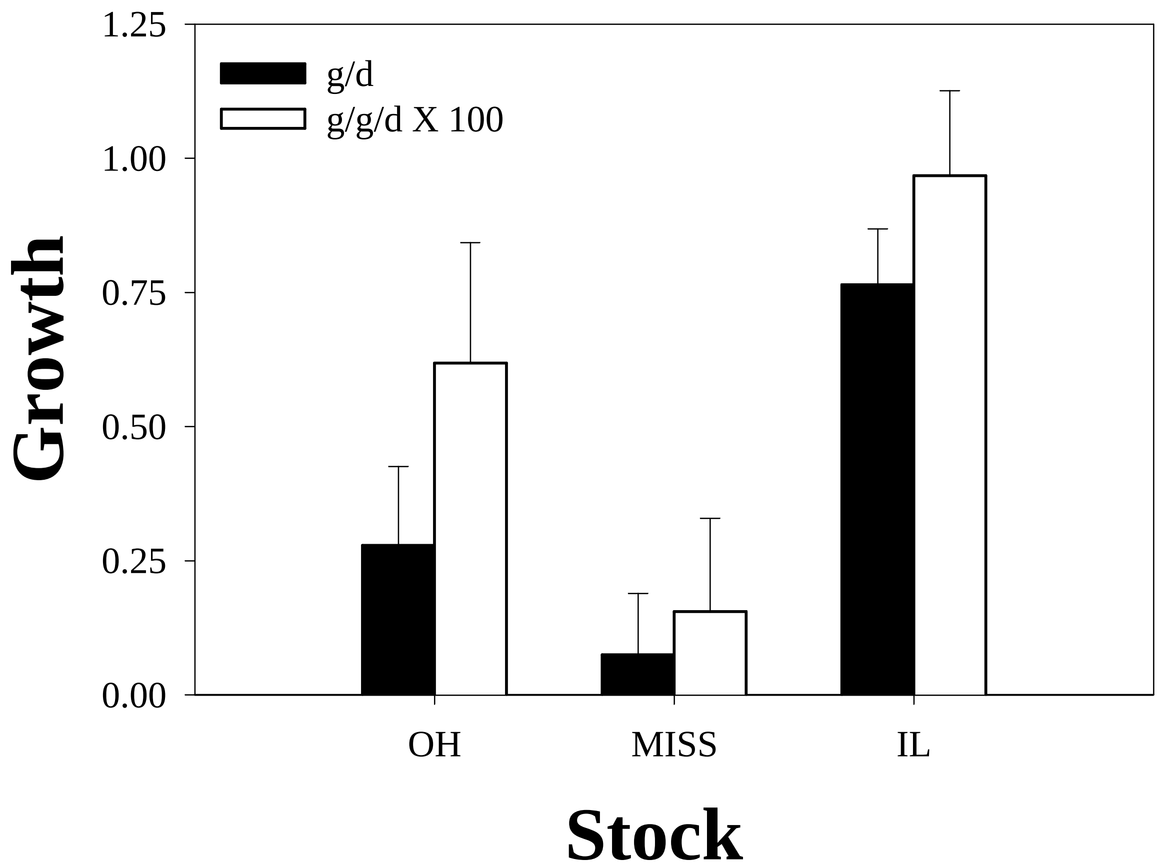

Figure 11. Stocking and subsequent sample mean weights (nearest g) of muskellunge populations introduced into 3, 0.4-ha ponds in October 2003 and drained during April 2004, October 2004, April 2005, and October 2005. Vertical lines represent ±1 standard error.

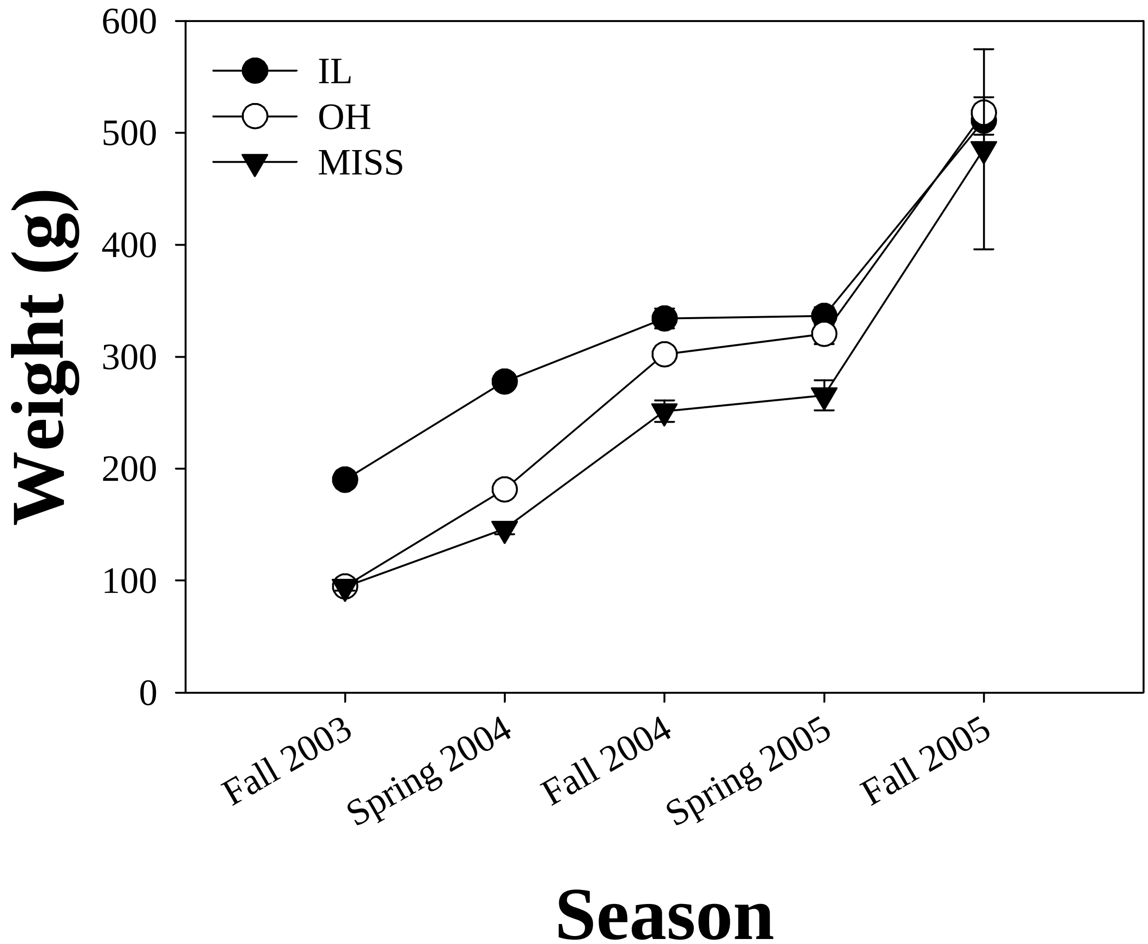

Figure 12. Mean daily growth rates (g/d, solid bars) and mean relative growth rates (g/g/d X 100, open bars) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2003 and drained during October 2005. Vertical lines represent ±1 standard error.

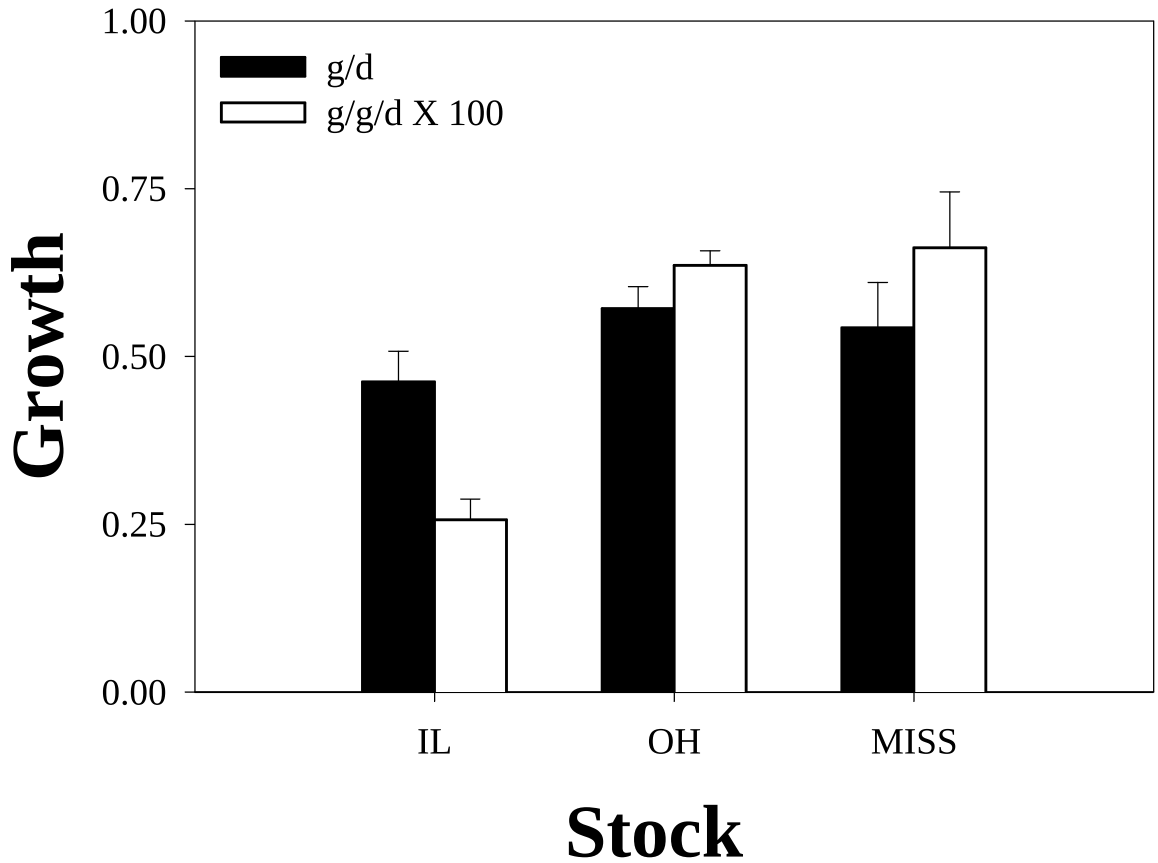

Figure 13. Stocking and subsequent sample mean weights (nearest g) of muskellunge populations introduced into 3, 0.4-ha ponds in October 2004 and drained during April 2005, October 2005, and March 2006. Vertical lines represent ±1 standard error.

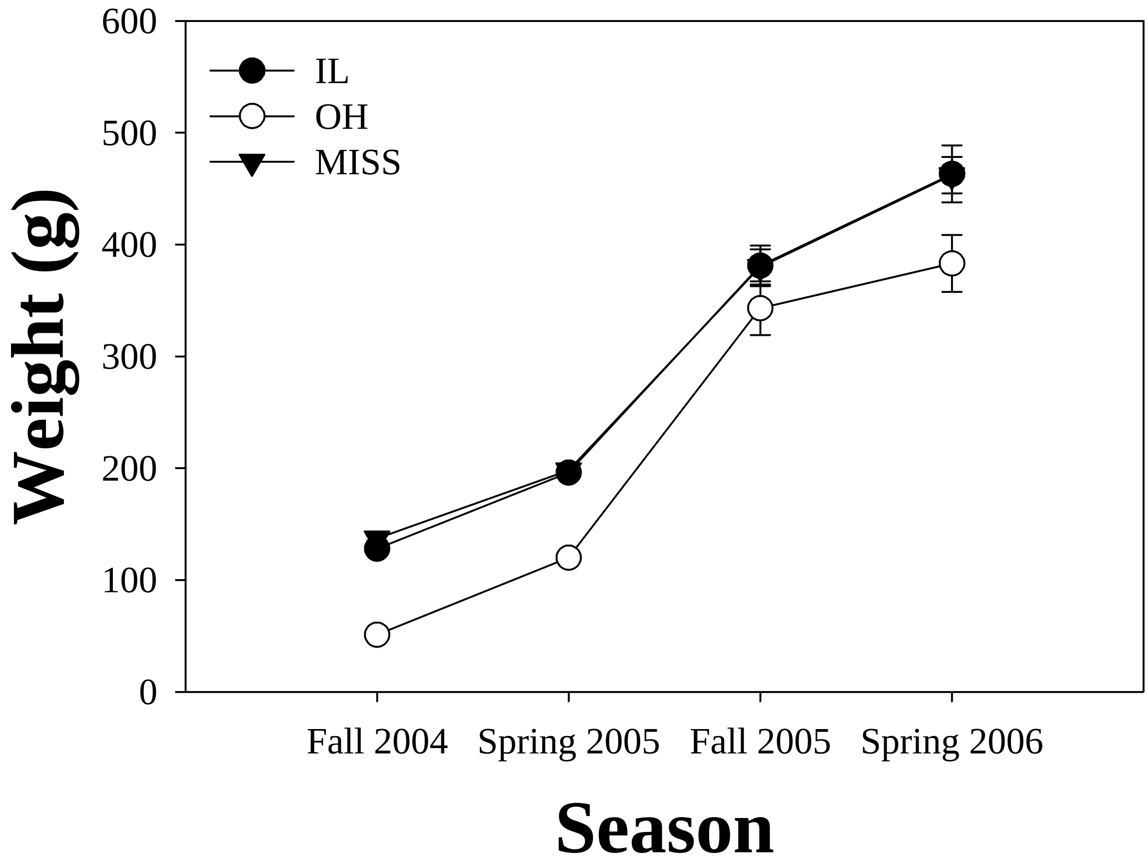

Figure 14. Mean daily growth rates (g/d, solid bars) and mean relative growth rates (g/g/d X 100, open bars) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2004 and drained during October 2005. One-year growth is from the time of stocking through the following October. Vertical lines represent ±1 standard error.

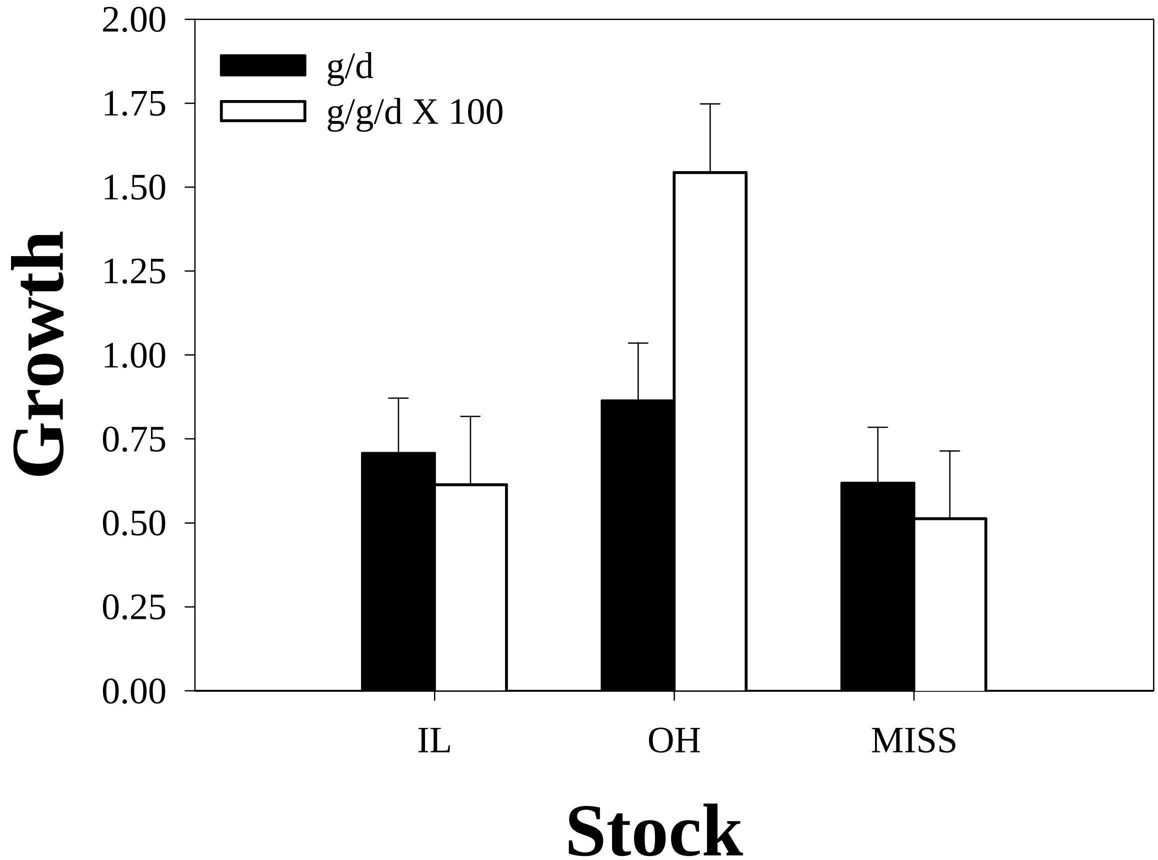

Figure 15. Mean daily growth rates (g/d, solid bars) and mean relative growth rates (g/g/d X 100, open bars) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2002, 2003, and 2004. Growth is shown for one-year post-stocking. Vertical lines represent ±1 standard error.

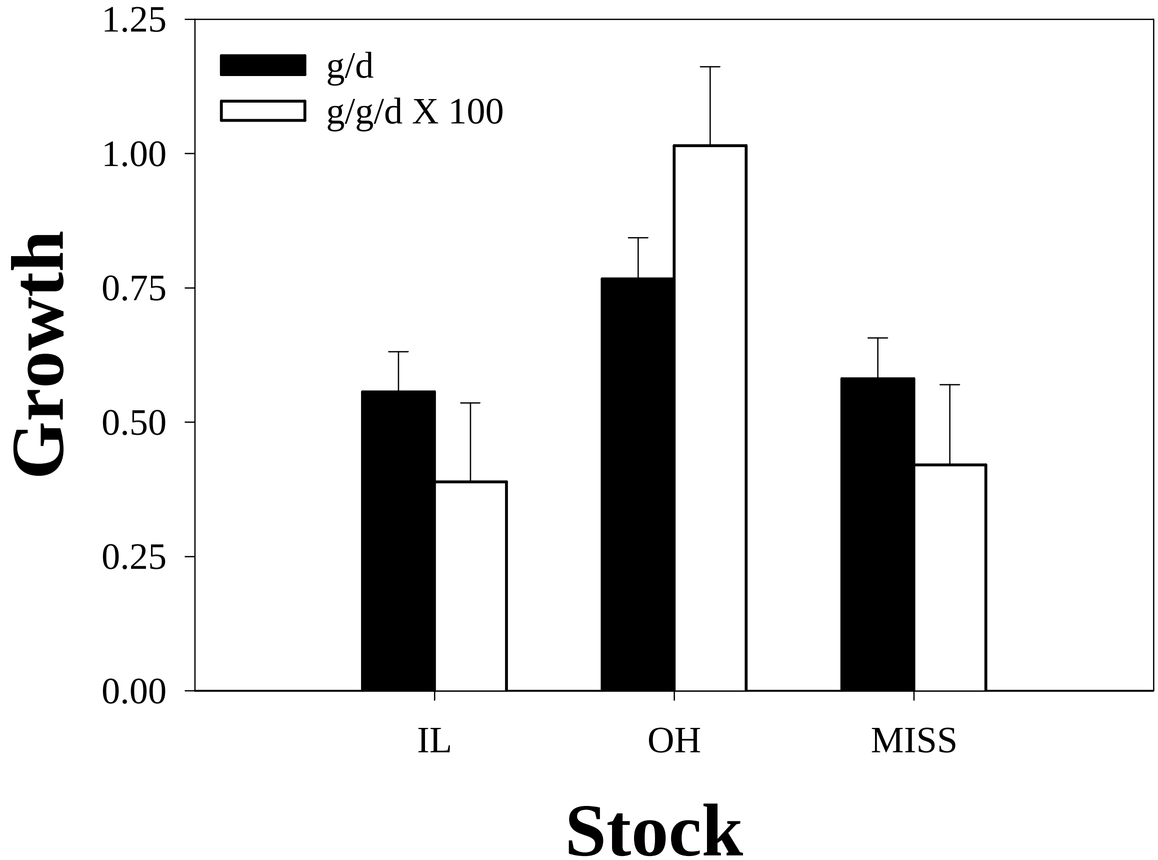

Figure 16. Adjusted catch-per-unit-effort (CPUE) during the spring 2005 sampling season for the Upper Mississippi River drainage stock, the Ohio River drainage stock, and the North Spring Lake, IL progeny introduced in Pierce Lake in fall 2004. Vertical lines represent ±1 standard error.

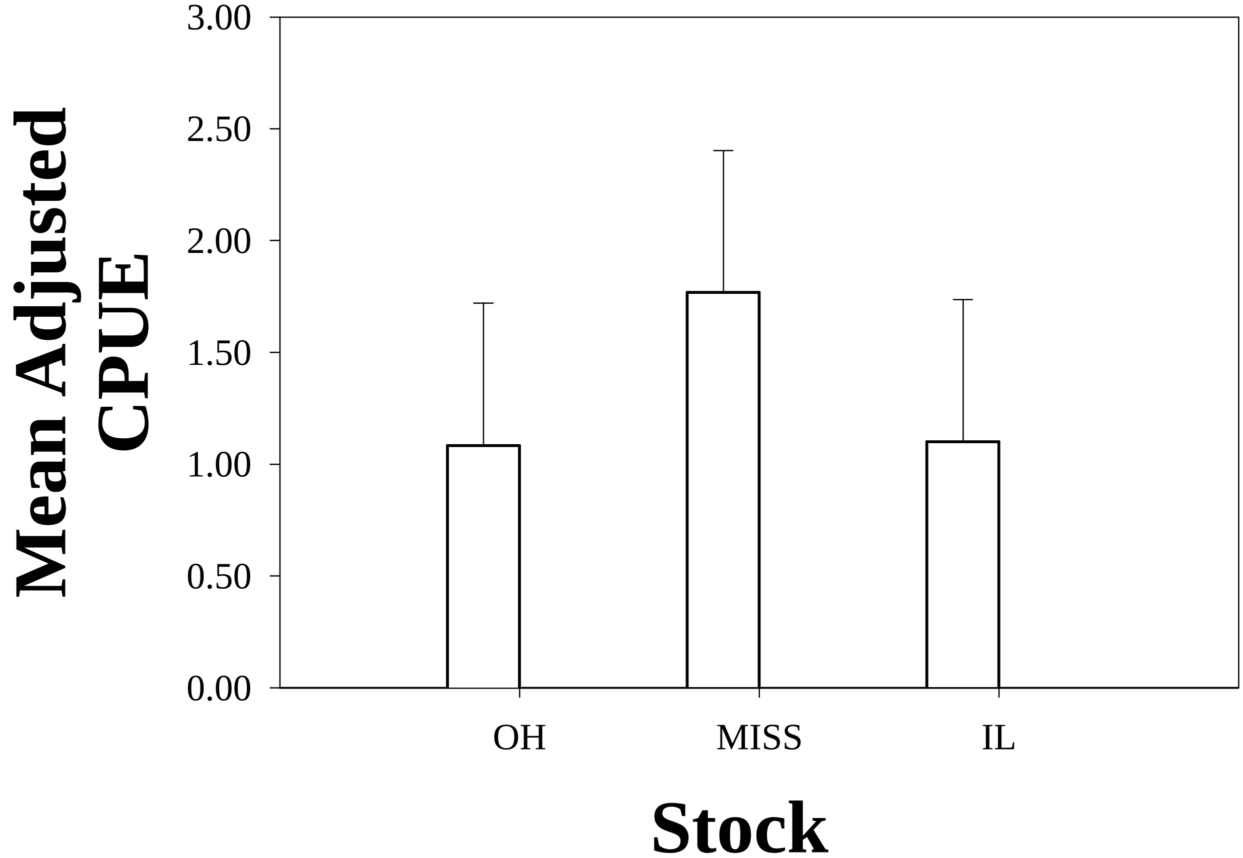

Figure 17. Adjusted catch-per-unit-effort (CPUE) during the spring 2005 sampling season for the Upper Mississippi River drainage stock, the Ohio River drainage stock, and the North Spring Lake, IL progeny introduced in Lake Mingo in fall 2004. Vertical lines represent ±1 standard error.

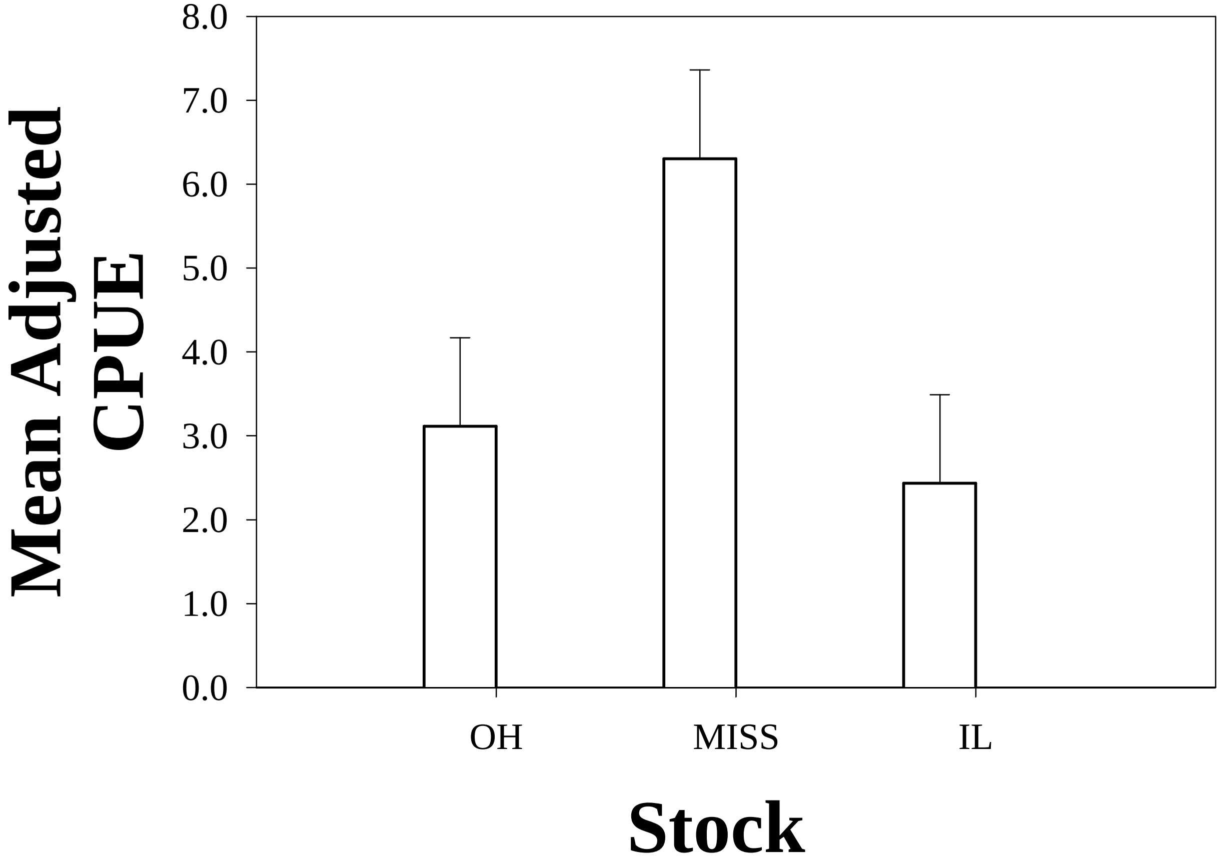

Figure 18. Adjusted catch-per-unit-effort (CPUE) during the spring 2006 sampling season for the Upper Mississippi River drainage stock, the Ohio River drainage stock, and the North Spring Lake, IL progeny introduced in Pierce Lake in fall 2005. Vertical lines represent ±1 standard error.

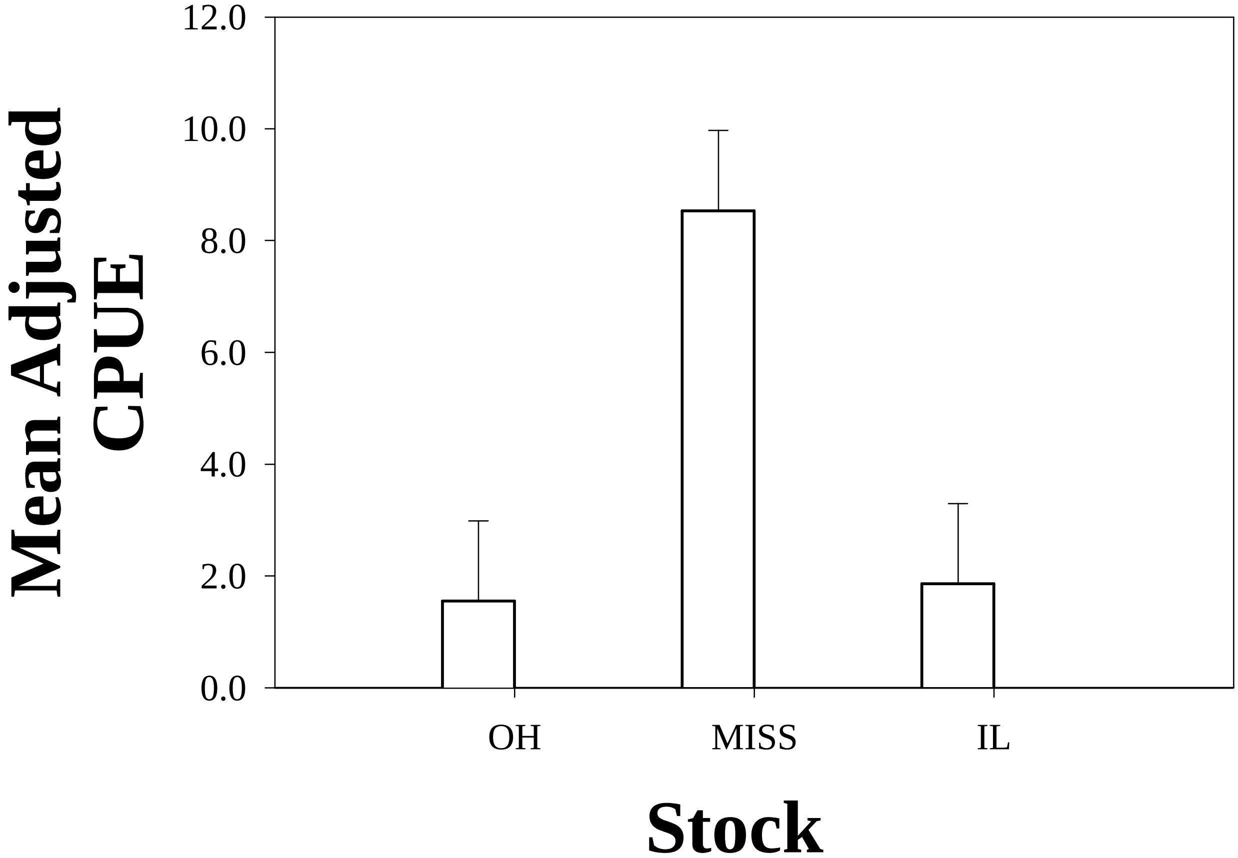

Figure 19. Survival of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2003 and drained during April 2004, October 2004, April 2005, and October 2005. Survival measurements for each season are calculated from the time of stocking. Vertical lines represent 95% confidence limits.

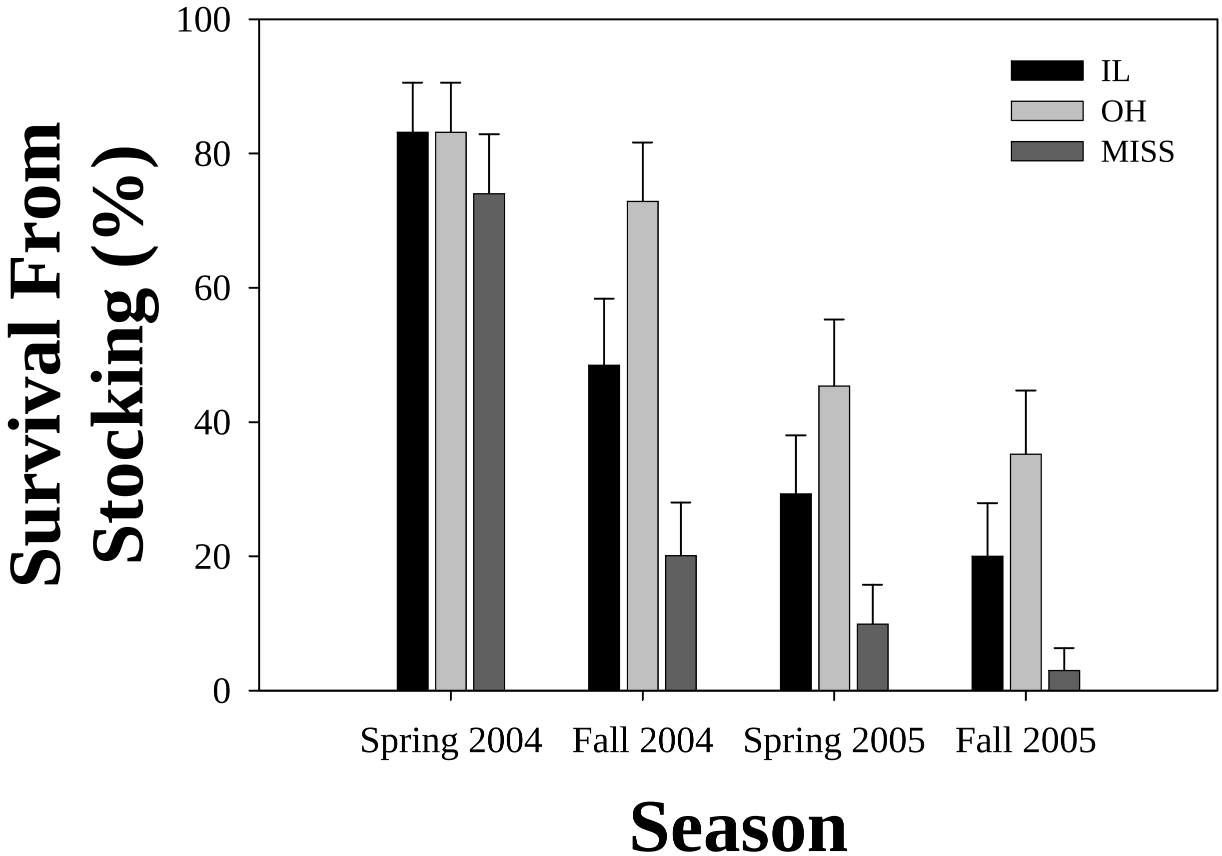

Figure 20. Survival of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2004 and drained during April 2005, October 2005, and March 2006. Survival measurements for each season are calculated from the time of stocking. Vertical lines represent 95% confidence limits.

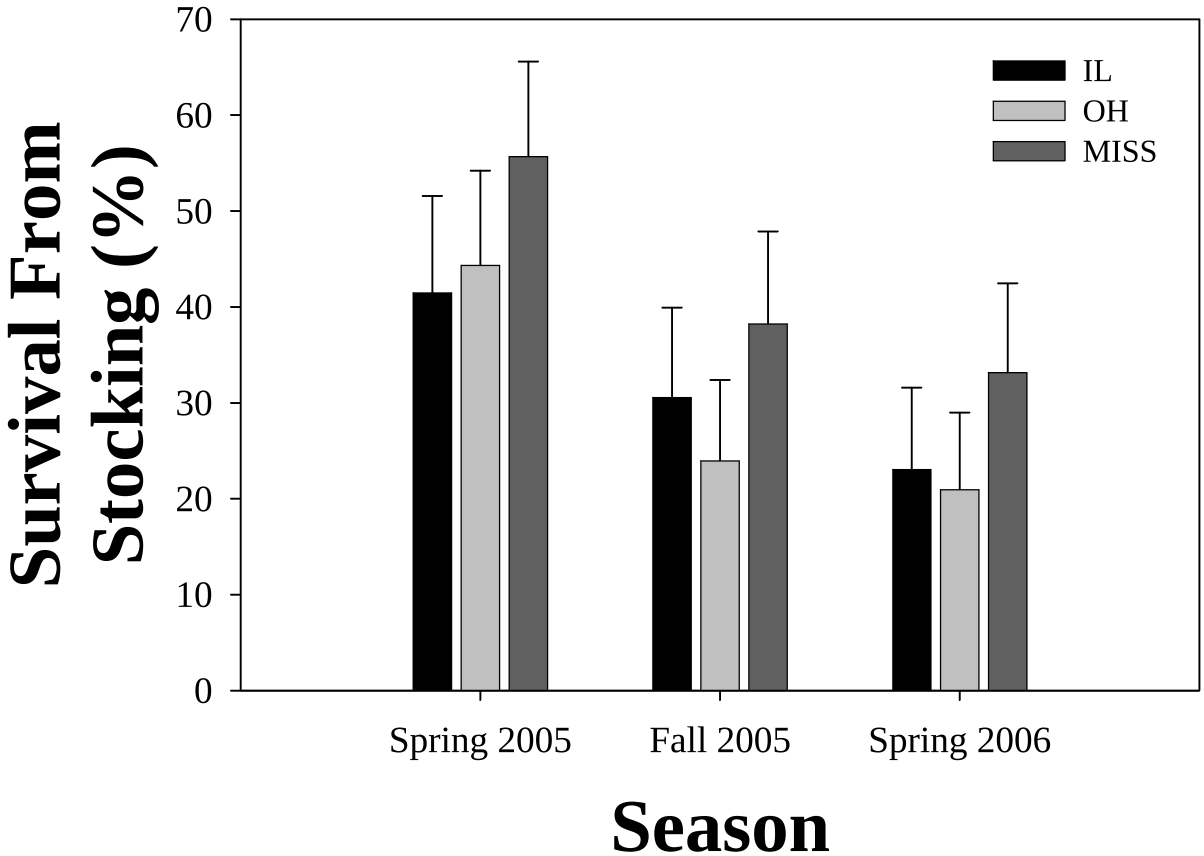

Figure 21. Survival of three stocks of muskellunge introduced into 3, 0.4-ha ponds in Octobers 2002, 2003, and 2004. Data are pooled and analyzed with logistic analysis of variance. One-year post-stocking survival measurements are calculated from the time of stocking. Vertical lines represent 95% confidence limits.