ANNUAL PROGRESS REPORT

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 five, 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 two Illinois lakes. Muskellunge fingerlings from two sources were introduced into Pierce Lake, Lake Mingo, and Sam Dale Lake at rates ranging from 0.3 – 5.0 fish per hectare during fall 2006. Availability of additional populations and stocks was limited due to both production and concerns regarding the recent identification and spread of the viral hemorrhagic septicemia (VHS), a viral disease of fish caused by an aquatic rhabdovirus previously unknown in the Midwest. During this segment, electrofishing was conducted during fall 2006 and spring 2007, and combined with modified fyke net surveys from spring 2007 in both reservoirs. Across years and reservoirs, the Ohio River drainage stock and the Illinois population appear to have similar growth rates; both consistently higher than the Upper Mississippi River drainage stock. Results from reservoir introductions suggest that after the first summer, the Ohio River drainage stock and Illinois population typically have similar survival and both are higher than the Upper Mississippi River

drainage stock. These, and future introductions will need to be monitored over additional years to further assess growth and survival differences among stocks.

A pond experiment, consisting of three trials (2002-2004) was initiated at the Sam Parr Biological Station, Marion County, Illinois. For each trial, three 0.4-ha ponds were used to evaluate growth and survival differences among muskellunge stocks. Pooling data from all three trials suggests the Ohio River drainage stock has a growth advantage over the Illinois population and the Upper Mississippi Rive drainage stock one year after stocking. The Illinois population and the Upper Mississippi River drainage stock had similar growth rates over this same time period. The pond trials 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 following 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 five years will be combined with those from future years to identify the long-term growth and survival differences among genetic stocks of muskellunge. Results will be used to develop guidelines for future muskellunge stockings that maximize growth, survival, and angler satisfaction in reservoirs throughout Illinois. As the management of muskellunge fisheries improves due to increased understanding of intraspecific variation, the effects of these highly predacious fisheries on the existing aquatic community also needs to be considered. Beginning in segment six, Job 101.3 will be added to this study aimed at describing the food habits of introduced muskellunge and examining the effects of muskellunge fisheries on existing and native communities. This information, combined with an increased understanding of appropriate stocks, will contribute to a more informed and holistic approach to muskellunge management in Illinois and the lower Midwest.

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 strategies. 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 populations and stocks, 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, Forbes Lake, Marion County, and Sam Dale Lake, Wayne County (Figure 1, Table 2). These reservoirs represent the climatic variation associated with latitude that exists throughout Illinois. Introductions were again made into study lakes in fall 2006 (Table 3); however, stockings were limited due to both limited availability of stocks and recent concerns regarding the effects and dispersal of the viral hemorrhagic septicemia virus (VHSv, Elsayed et al. 2006; Gagne et al. 2007). Research laboratories and state natural resource agencies are continuing to examine the ecology, dispersion, and threat of VHSv and future segments of this project will include additional muskellunge introductions contingent on these findings.

The Cave Run Lake population obtained from the Kentucky Department of Fish and Wildlife represented muskellunge from the Ohio River drainage stock introduced into Lake Mingo in fall 2006. The mixed-stock Illinois population, F1 progeny from North Spring Lake, was obtained from the Jake Wolf Memorial Fish Hatchery, Illinois Department of Natural Resources in 2006 and introduced into three study reservoirs (Table 3). 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 0.3 – 5.0 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 in fall 2004, we also freeze branded all stocked fish in an effort to better enable age determination (in combination with scale aging) in future years. The 2006 brand was a right-anterior vertical brand. The brand will be applied differentially by year, with 2007 fish receiving a left-posterior vertical brand, and so forth (Table 4).

To determine growth rates, nighttime pulse DC boat-electrofishing sampling was performed from October through November 2006 and from March through April 2007 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 – 2006 year classes). Upon capture, muskellunge from the 2002 – 2005 year classes in Lake Mingo and the 2003 – 2005 year classes in Pierce Lake were implanted with a Passive Integrated Transponder (PIT) tag prior to release to aid in future identification (Wagner et al. 2007). 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. Data were used to determine mean daily growth rates (g/d) and mean relative growth rates (standardizing by initial weight, g/g/d) among the stocks of muskellunge in the study reservoirs. Growth rates were analyzed using analysis of variance (ANOVA) models and, as sample sizes allowed, size-at-age data were used to estimate von Bertalanffy growth functions (Beverton 1954; Beverton and Holt 1957; VONBIT© 2005).

Data from electrofishing were combined with modified fyke net surveys conducted April 2 – April 6, 2007 on Mingo Lake and April 16 – April 19, 2007 on Pierce Lake. Modified fyke nets (N = 15) were set in Lake Mingo and run for 4 nights, resulting in 58 net-nights of effort (2 net-nights were discarded due to poor sets, Figure 2). Six modified fyke nets were set in Pierce Lake for 3 nights yielding 18 net-nights of effort (Figure 3). 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 7.0 – 11.0 °C during the sampling weeks.

In addition to the evaluation of growth among muskellunge stocks in reservoirs, we conducted multiple trials of a pond experiment 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. Each year, three 0.4-ha experimental ponds at the Sam Parr Biological Station, Kinmundy, Illinois (Figure 1), were used for these trials. As outlined in prior segments, muskellunge from the Upper Mississippi River drainage stock, the Ohio River drainage stock, and the Illinois population were stocked into the experimental ponds in the falls of 2002, 2003, and 2004; herein referred to as the 2002 – 2004 trials. Thirty-three individuals from each population were stocked into each of the three ponds (total N = 99 fish/pond). Immediately prior to stocking, fish were anesthetized and intraperitoneally implanted with a passive integrated transponder (PIT) tag (Wagner et al. 2007). Following the tagging, each fish was measured in length (nearest mm) and weight (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 each spring and fall following initiation for two years. 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 environments.

FINDINGS:

Modified Fyke Net Surveys – Lake Mingo and Pierce Lake

In Lake Mingo, a total of 98 muskellunge were netted during the 4 nights in April 2007 resulting in an average of 1.7 fish per net-night. Nightly average capture rates (catch-per-unit-effort, CPUE) ranged from 0.40 to 4.21 fish per net-night, with CPUE steadily decreasing each consecutive night of sampling. Of the 98 muskellunge captured, 48 were Ohio River drainage stock, 48 were Illinois population, one was Upper Mississippi River drainage stock, and one was unidentifiable and excluded from subsequent analyses (Table 5). The smallest muskellunge captured was 362 mm and the largest was 1035 mm; weights ranged from 231 g to 9163 g. One muskellunge was age-1, seventeen were age-2, thirty-nine were age-3, twenty-three were age-4, and seventeen were age-5 (Table 5). Sex was not able to be determined for all muskellunge; however, of those identifiable, 28% were female and 72% were male. In future segments, data will be analyzed by gender as sample size permits.

Twenty-four muskellunge were captured during the 3 nights of modified fyke net sampling in Pierce Lake during April 2007, yielding an average of 1.3 fish per net-night. Nightly average capture rates ranged from 0.50 to 1.50 fish per net-night. Of the 24 muskellunge sampled, 6 were Ohio River drainage stock, 18 were Illinois population, and 0 were Upper Mississippi River drainage stock (Table 6). The smallest muskellunge captured was 680 mm and the largest was 881 mm; weights ranged from 2120 g to 5440 g. No age-1 or age-2 muskellunge were captured; however, nine age-3 and thirteen age-4 fish were sampled (Table 6). Males represented 83% of the sampled muskellunge and females the other 17%. Data obtained from the modified fyke net surveys was integrated with electrofishing data for calculations of growth and survival.

2002 Year Class

Two populations, Cave Run Lake (Ohio River drainage stock) and Illinois, stocked into Lake Mingo during fall 2002 (Table 2) were monitored during fall 2006 and spring 2007 (Table 7). 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). One year after stocking, the Ohio River drainage stock exhibited higher mean relative daily growth rate compared to the Illinois population (Figure 4, Table 8). Four and a half years following stocking (spring 2007), the Illinois population and Ohio River drainage stock are of similar length (P = 0.35) and weight (P = 0.77, Table 7).

2003 Year Class

In fall 2003, three populations were introduced in Pierce Lake (Table 2) and were sampled during fall 2006 and spring 2007 (Table 9). 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 no differences in mean daily growth and mean relative daily growth rates between the Illinois population and the Ohio River drainage stock (Figure 5, Table 10) one year after stocking. No Upper Mississippi River drainage stock fish were collected during fall 2004 sampling. Three and a half years following stocking (spring 2007), the Upper Mississippi River drainage stock muskellunge were longer (P = 0.03) than the Ohio River drainage stock fish (Table 9). Illinois muskellunge were intermediate and not different than either conspecific (P > 0.07). Weights were not different among stocks during spring 2007 sampling (P > 0.34, Table 9).

Three populations of muskellunge were introduced in Lake Mingo in fall 2003 (Table 2) and were sampled during fall 2006 and spring 2007 (Table 11). 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 (~ 26.7° C) 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 revealed no differences in mean daily growth rates or mean relative daily growth rates between the Ohio River drainage stock and the Illinois population one year after stocking (Figure 6, Table 12). No Upper Mississippi River drainage stock muskellunge were sampled after spring 2004 (Table 11). Three and a half years following stocking (spring 2007), the Illinois population is significantly longer (P = 0.03), but not heavier (P = 0.33) than the Ohio River drainage stock muskellunge (Table 11).

2004 Year Class

Three populations were introduced in Pierce Lake during fall 2004 (Table 2) and were sampled in fall 2006 and spring 2007 (Table 13). 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). One year after stocking, only two Illinois population and five Ohio River drainage stock muskellunge were sampled during fall 2005. Consequently, statistical comparisons of growth rates are limited; however, of the fish collected in fall 2005 (Table 13), the Illinois muskellunge are larger than the Ohio River drainage stock, suggesting higher growth rates one year following stocking. No muskellunge from the Upper Mississippi River drainage stock were sampled after spring 2005 (Table 13). Two and a half years following stocking (spring 2007), the Illinois population and Ohio River drainage stock are of similar length (P = 0.80) and weight (P = 0.42).

In fall 2004, three populations of muskellunge were introduced in Lake Mingo (Table 2) and sampled in fall 2006 and spring 2007 (Table 14). 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. During fall 2005 sampling, one year after 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. Two and a half years following stocking (spring 2007), the Illinois population and Ohio River drainage stocks are of similar length (P = 0.94) and weight (P = 0.85). Although only one Upper Mississippi River drainage stock fish was captured during spring 2007, this fish is of similar size compared to same-age conspecifics.

2005 Year Class

Three populations were introduced in Pierce Lake during fall 2005 (Table 2) and sampled in fall 2006 and spring 2007 (Table 15). 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 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 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. One year after stocking, only one Upper Mississippi River drainage stock muskellunge and two Ohio River drainage fish were collected (Table 15), limiting the relevancy of statistical comparisons. Based on the limited sample, the Illinois population appears to be exhibiting higher growth rates than conspecifics (Table 15). Further, no muskellunge from the 2005 year class were collected during spring 2007 electrofishing and modified fyke net sampling.

Three populations of muskellunge were introduced in Lake Mingo in fall 2005 (Table 2) and sampled during fall 2006 and spring 2007 (Table 16). 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 2). 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. Only Illinois population muskellunge were collected during fall 2006 sampling (Table 16). Consequently, no statistical comparisons are possible for growth rates one year after stocking. No Upper Mississippi River drainage stock fish were collected after spring 2006 (Table 16). One and a half years after stocking (spring 2007), the Illinois population is significantly longer (P = 0.0013) and heavier (P = 0.0011) than the Ohio River drainage stock (Table 16).

Because of low survival or catchability, sampling of Forbes Lake was terminated in fall 2005 and, as a replacement; Sam Dale Lake was incorporated into the study design beginning in 2005. Four populations (three stocks) were introduced in Sam Dale Lake in fall 2005 (Table 2) and sampled in spring 2007. Stocking sizes were fairly similar with the largest difference existing between the Kentucky Cave Run Lake population and the Illinois 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. 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 estimated to survive from the Ohio River drainage stock introductions (Table 2). Subsequent analyses of survival will be adjusted to account for this initial mortality. No muskellunge were captured during fall 2005, spring 2006, fall 2006, or spring 2007 despite significant electrofishing effort. This lake will be stocked again in future segments and sampling will continue.

2006 Year Class

Only one population of muskellunge, the Illinois North Spring Lake progeny, was introduced into Pierce Lake during fall 2006 (Table 3) due to limited availability of additional populations and in- and out-of-state concerns regarding VHSv. This lake will be stocked in future segments to establish additional year classes of multiple populations and stocks. Sampling will continue on this lake in future segments.

Two populations of muskellunge were introduced in Lake Mingo in fall 2006 (Table 3) and sampled in spring 2007 (Table 17). Unequal numbers were stocked (Cave Run Lake N = 332 and Illinois N = 302) due to limited availability of the populations. Fish from the Upper Mississippi River drainage stock were not obtained due to concerns regarding VHSv. Muskellunge from the Illinois population were about 15% longer than fish from the Ohio River drainage stock (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 Illinois population exhibited a 7% mortality rate and the Cave Run Lake population experienced a 42% mortality rate. The water temperature at the time of the Cave Run Lake population stocking was 28.2 °C. Subsequent analyses of survival will be adjusted to account for this initial mortality. Twenty-five Illinois muskellunge were sampled during spring 2007 (Table 17); however, only two fish were captured from the Ohio River drainage stock, limiting the validity of statistical analyses of growth rates. This lake will be stocked in future segments to establish additional year classes of multiple populations and stocks. Sampling will continue on this lake in future segments.

Only one population of muskellunge, the Illinois North Spring Lake progeny, was introduced into Sam Dale Lake during fall 2006 (Table 3) due to limited availability of additional populations and in- and out-of-state concerns regarding VHSv. This lake will be stocked in future segments to establish additional year classes of multiple populations and stocks. Sampling will continue on this lake in future segments.

Pooled Year Classes

To compare growth of stocks across year classes, data from spring sampling periods in Pierce Lake were pooled and used to construct size-at-age von Bertalanffy growth functions. Mean total length and age frequencies at ages 1 through 4 were incorporated into VONBIT© version B/2005. Overall, the growth trajectories of the Illinois population and the Ohio River drainage stock were similar; with the exception of a slightly lower size-at-age of the Ohio River drainage stock at ages 1-3 (Figure 7). Currently available data was insufficient to construct a growth function for the Upper Mississippi River drainage stock. Data collected in future segments will be incorporated with current data to provide more precise growth functions and to extend growth functions to older ages.

Stock-specific growth was also summarized across year classes using pooled data from spring sampling periods in Lake Mingo. Mean total length and age frequencies at ages 1 through 5 were incorporated into VONBIT© version B/2005. Growth trajectories were very similar between the Illinois population and the Ohio River drainage stock (Figure 8). Available data was insufficient to construct a growth function for the Upper Mississippi River drainage stock; however, growth rates from previous segments were generally lower for the Upper Mississippi River drainage stock compared to conspecifics. Data collected in future segments will be incorporated with current data to provide more precise growth functions and to extend growth functions to older ages.

Pond Experiment

Trials were initiated in fall 2002, 2003, and 2004. Results from the fall 2002 and 2003 trials were presented in previous annual reports. 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 (Table 18) and sampled through fall 2006. 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 18). The initial mean length and weight for the Ohio River drainage stock was slightly lower. No short-term mortality was observed and ponds were drained each subsequent spring and fall (Table 18, Figure 9). As presented in previous annual reports, the Illinois population and Ohio River drainage stock exhibited significantly higher mean daily growth rates than the Upper Mississippi River drainage stock one year after stocking. However, the Ohio River drainage stock had a higher mean relative daily growth rate than both the Illinois population and the Upper Mississippi River drainage stock during this same period.

A mixed-model ANOVA was used to assess the effects of stock on growth rates one year after stocking using combined data from the three trials. 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 trial. Response variables were mean daily growth (g/d) and mean relative daily growth rate (g/g/d). Mean daily growth was analyzed using an analysis of covariance (ANCOVA) with initial weight as a covariate and mean relative daily growth was analyzed with an analysis of variance (ANOVA). Blocking efficiently accounted for variation associated with pond and year and the covariate was significant in the ANCOVA analysis (Table 19). The effect of stock was significant (ANCOVA, ANOVA, $P < 0.0001$) for both the mean daily growth and mean relative growth analyses (Table 19). The Ohio River drainage stock exhibited significantly higher mean daily growth and mean relative daily growth than both the Illinois population (Tukey, $P < 0.0001$) and the Upper Mississippi River drainage stock (Figure 10, 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 introductions 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 juvenile muskellunge during the first five 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 has typically grown 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 trials 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 appears 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 are 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 evaluations. Modified fyke netting will be continued in Pierce and Mingo Lakes in future segments and incorporated into the protocol of Sam Dale Lake as year classes mature. The pond experiment is complete and findings will continue to be compared to reservoir samples in future segments of the study. The results contained in this report will be combined with data from future segments 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 of 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 muskellunge populations. Future work will monitor survival of these populations through adults.

PROCEDURES: As described in prior segments, survival among different stocks and populations of muskellunge is being compared in Pierce Lake, Winnebago County, Lake Mingo, Vermillion County, and Sam Dale Lake, Wayne County (Table 2, Figure 1). These reservoirs represent the latitudinal climatic variation that exists throughout Illinois. In 2006, limited introductions were again made into Pierce Lake, Lake Mingo, and Sam Dale Lake (Table 3). Asides from the Illinois population, only one additional population was obtained and introduced into a study reservoir due to availability and concerns regarding VHSv (Elsayed et al. 2006; Gagne et al. 2007). Future segments of the project will include additional stockings, depending on VHSv research findings and regulatory policies.

As described in Job 101.1, we stocked muskellunge from the Illinois population and the Ohio River drainage stock into three study reservoirs in fall 2006 (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). Size-specific effects from predation (Wahl and Stein 1989), prey availability (Szendrey and Wahl 1996), and thermal stress (Wahl 1999) have been shown to be negligible with muskellunge ≥ 200 mm total length. 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 0.3 – 5.0 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). Additionally, foraging behaviors and growth of age-0 muskellunge were not affected by fin-clipping any of the paired fins (individual or in combination) in controlled trials (Scimone et al., in review). Beginning in fall 2004, we freeze branded all stocked fish to be used in combination with scale aging to better determine age in future years. The 2006 brand was a right-anterior 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 2006 and from March through April 2007 on all study reservoirs. Modified fyke net surveys were also conducted on Lake Mingo April 2 – April 6, 2007 and on Pierce Lake April 16 – April 19, 2007. As appropriate, electrofishing and modified fyke net catch-per-unit-effort (CPUE, fish per hour or fish per net-night) 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 trials of a pond experiment 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 falls 2002 – 2004. Each trial was initiated by introducing thirty-three YOY from each population 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 (Wagner et al. 2007). 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 two-factor logistic analysis of variance model (Proc Genmod, SAS) with stock and pond as factors. Results of the reservoir and pond evaluations will provide insight as to the best surviving population in Illinois.

FINDINGS:

2002 Year Class

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 2006 and spring 2007. As reported in previous annual reports, survival one year after stocking was similar for the Ohio River drainage muskellunge (28%) and the Illinois population (24%) as determined from Schnabel population estimates. Adjusted CPUE was calculated to account for unequal stocking numbers between stocks and populations and again showed no differences between populations one year after stocking (Table 20). Adjusted CPUE was similar ($P = 0.17$) between the Ohio River drainage stock and the Illinois population during the spring 2007 modified fyke net survey, suggesting similar survival of the two populations four and a half years after stocking. Schnabel population estimates were not computed due to inadequate within-season recapture numbers during spring 2007.

2003 Year Class

In fall 2003, three populations were introduced in Pierce Lake (Table 2). Too few within-season recaptures of muskellunge during fall 2004 prevented the calculation of Schnabel population estimates. Adjusted CPUE indicates no differences between the Ohio River drainage stock and the Illinois population (Tukey, $P = 0.45$). No Upper Mississippi River drainage stock fish were captured during fall 2002, one year following stocking. Three and a half years following stocking, the Ohio River drainage stock and the Illinois population exhibited similar adjusted CPUE (Tukey, $P = 0.94$) during the spring 2007 modified fyke net survey, indicating similar survival. No Upper Mississippi River drainage stock muskellunge from the 2003 year class were sampled in the spring 2007 modified fyke nets (Table 6).

Three populations of muskellunge were introduced in Lake Mingo in fall 2003 (Table 2). As presented in earlier annual reports, no difference in adjusted CPUE was observed between the Ohio River drainage muskellunge and the Illinois fish during the fall 2004 sampling season (Table 21), indicating no survival differences one year after stocking. No Upper Mississippi

River drainage stock muskellunge were sampled after spring 2004. Three and a half years following stocking, the Ohio River drainage stock and the Illinois population exhibited similar adjusted CPUE (Tukey, P = 0.99) during the spring 2007 modified fyke net survey, indicating similar survival. No Upper Mississippi River drainage stock muskellunge from the 2003 year class were sampled in the spring 2007 modified fyke nets (Table 5). For both Pierce and Mingo Lakes, Schnabel population estimates could not be obtained for the spring 2007 sampling period due to low or no within-season recaptures.

2004 Year Class

In fall 2004, three populations of muskellunge were introduced in Pierce Lake (Table 2). One year following stocking, no differences in adjusted CPUE were detected between the Ohio River drainage stock and the Illinois population (Tukey, P = 0.24). No fish from the Upper Mississippi River drainage were sampled during fall 2005 (Table 22). Further, no muskellunge from the Upper Mississippi River drainage stock or Illinois population were sampled during electrofishing sampling from spring 2006 – spring 2007 (Table 22). Two and a half years following stocking (spring 2007), no differences in modified fyke net CPUE existed between the Ohio River drainage stock and the Illinois population (Tukey, P = 0.33). No Upper Mississippi River drainage fish from the 2004 year class were captured in spring 2007 nets (Table 6). Too few within-season recaptures for the Ohio River drainage stock and the Illinois population limited our ability to calculate Schnabel population estimates during spring 2007.

Three populations were introduced in Lake Mingo in fall 2004 (Table 2). Although survival during the first winter was high for the Upper Mississippi River drainage stock, catch rates have declined and were lowest for this stock at older ages. No differences (Tukey, P = 0.99) in adjusted CPUE were observed one year following stocking between the Upper Mississippi River drainage stock and the Illinois population (Table 22). No fish from the Ohio River drainage stock 2004 year class were collected during fall 2005 sampling (Table 22). Two and a half years after stocking, no differences in modified fyke net CPUE were observed among stocks (P = 0.38, Table 5) during the spring 2007 survey. Specifically, the Ohio River drainage stock and the Illinois population exhibited very similar catch rates (Tukey, P = 0.94). Lack of sufficient within-season recaptures in spring 2007 prohibited the computation of Schnabel population estimates.

2005 Year Class

Three populations of muskellunge were introduced in Pierce Lake in fall 2005 (Table 2). No differences in adjusted CPUE were detected among stocks one year after stocking (Table 23). Further, no muskellunge from the 2005 year class were collected during the spring 2007 modified fyke net survey (Table 6), limiting our ability to address survival to date.

In fall 2005, three populations of muskellunge were introduced in Lake Mingo (Table 3). Fish from the Illinois population were captured during fall 2006 sampling; however, no muskellunge from the Upper Mississippi River drainage and Ohio River drainage stock were captured one year after stocking (Table 23). One and a half years after stocking, no 2005 year class muskellunge from the Upper Mississippi River drainage stock were collected in modified fyke net sampling (Table 5); however, fish from the Ohio River drainage stock and Illinois population were collected at similar rates (Tukey, P = 0.97, Table 5).

Three populations of muskellunge were introduced into Sam Dale Lake in fall 2005 (Table 2). No muskellunge were captured during fall 2006 or spring 2007 sampling seasons, despite adequate effort. Sampling of Sam Dale Lake will continue and any captures of this year class will be reported in subsequent segments.

2006 Year Class

During fall 2006, only Illinois population muskellunge were introduced into Pierce Lake (Table 3) due to limited availability and concerns regarding VHSv. Because of a lack of conspecific comparisons, survival within this year class will not be compared during this or future segments.

In fall 2006, two populations of muskellunge were introduced in Lake Mingo (Table 3). Unequal numbers were stocked (Cave Run Lake N = 332 and Illinois population N = 302) 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 Ohio River drainage stock exhibited a 42% initial mortality rate and the Illinois population had a 7% initial mortality rate (Table 3). Subsequent analyses of survival will be adjusted to account for the initial mortality experienced by both populations. Lack of within-season recaptures prohibited the calculation of Schnabel population estimates for the 2006 year class muskellunge during spring 2007 sampling. The Illinois population exhibited significantly higher adjusted CPUE (Table 24) compared to the Ohio River drainage stock, suggesting higher overwinter survival.

Only the Illinois population was introduced into Sam Dale Lake (Table 3) during fall 2006 due to limited availability of other stocks and VHSv concerns. Despite adequate effort, no muskellunge were collected during spring 2007 sampling. As a result, survival will not be compared during this or future segments for the 2006 year class in Sam Dale Lake.

Pond Experiments

As discussed in greater detail in Job 101.1 and previous annual reports, three pond trials (2002-2004) were conducted at the Sam Parr Biological Station. Each trial consisted of three ponds (0.4-ha) that were stocked with equal numbers of each of three stocks during the fall and drained in subsequent springs and falls. During this segment, the 2004 trial was terminated by draining ponds in fall 2006. Two years after stocking, significant differences (X^2, P = 0.035) in survival existed among stocks for the 2004 trial. The Upper Mississippi River drainage stock exhibited the highest survival rate (24%), marginally higher than the Illinois population (14%, X^2, P = 0.069). The Ohio River drainage stock had the poorest survival (11%) and was similar to the Illinois population (X^2, P = 0.57) but less than the Upper Mississippi River drainage stock (X^2, P = 0.018).

A logistic analysis of variance (Proc Genmod, SAS) was used to assess survival differences one year after stocking among genetically distinct stocks of muskellunge fingerlings. Data from all three trials 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 one year survival rates (X^2, P = 0.46), and both exhibited significantly higher survival rates than the Upper Mississippi River drainage stock (Figure 11, X^2, P < 0.0001).

RECOMMENDATIONS: Any long-term differences in survival among muskellunge populations will have important implications for the conservation of native muskellunge populations, as well as for introductions of muskellunge into waters where they do not naturally occur. Survival differences we observed among 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 mature.

Preliminary reservoir results suggest that the prevailing trend in survival one year after stocking is equal survival between the Ohio River drainage stock and Illinois population, with the Upper Mississippi River drainage typically exhibiting poor survival. The first summer at Illinois latitudes appears to negatively affect the survival of muskellunge from the Upper Mississippi River drainage stock. During spring netting surveys, the Ohio River drainage stock and Illinois population consistently were represented similarly in catches. The Upper Mississippi River drainage stock is typically captured at lower rates than conspecifics, suggesting that the trends observed in survival one year after stocking remain as cohorts age. The pond experiment supports these general conclusions. The pooled analysis of the three pond trials suggest that the Ohio River drainage stock and Illinois population have similar survival one year after stocking, 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 stockings. In future segments, sampling effort will be shifted to include less fall electrofishing sampling and will include greater effort during spring modified fyke net surveys. Capturing more muskellunge during these net surveys will provide greater precision for von Bertalanffy growth functions and will result in more within-season recaptures, enabling calculation of Schnabel population estimates. 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.

Muskellunge introductions in Pierce and Mingo Lakes are generally successful and an increasing high density muskellunge fishery is being maintained or developed in study reservoirs. The establishment or enhancement of muskellunge fisheries requires not only an understanding of the appropriate source stock, but also the potential effects on the recipient aquatic community. Specifically, the rate that muskellunge populations feed on other ecologically and recreationally important fishes should be considered. In addition, an introduced top predator such as muskellunge may have important indirect effects, such as competition for a common prey resource, that can cascade though and alter the aquatic community. A limited number of studies have examined diet composition of adult muskellunge and even fewer have considered potential interactions between muskellunge and other piscivorous top predators. Results from previous studies have been inconclusive about the effects of introduced muskellunge on the existing fish community. These uncertainties have allowed angler groups targeting species other than muskellunge to develop antagonistic opinions and attitudes towards muskellunge populations that may be unwarranted. Although muskellunge can provide new and exciting fisheries in Illinois waters, it is essential to consider their potential effects on other recreationally and ecologically important sportsfish populations; most notably largemouth bass populations.

In future segments, we will examine food habits of muskellunge populations located throughout Illinois in multiple lakes (3 – 5) across a range of latitudes in Illinois, including the three previously stocked as part of this study, Pierce, Mingo, and Sam Dale Lakes. Additional lakes will include Lake Shelbyville, Ridge Lake, and others to be determined with input from IDNR District Fisheries Biologists, based on forage base and existing fish communities. Muskellunge will be collected during the spring, summer, and fall of each study year by modified fyke netting and electrofishing and stomach contents will be extracted using modified gastric lavage techniques. In addition, prey communities will be assessed through relative abundance of prey fish species collected by seining, electrofishing, and hydroacoustics. Food habits of potential sympatric competitors, primarily largemouth bass, will also be examined. Diets will be described using a variety of indices, including the percent index of relative importance. Data collected will allow for the description of muskellunge diet characteristics and those of other top predators. This information, collected as part of a new Job 101.3, when combined with ongoing studies of growth and survival, will provide much needed information concerning the establishment and management of muskellunge fisheries in Illinois and the lower Midwest.

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 5

Job	Proposed Cost	Actual Cost
Job 101.1	$22,292	$22,292
Job 101.2	$22,822	$22,822
Job 101.3	$7,961	$7,961

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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, Forbes Lake, and Sam Dale Lake during falls 2002 - 2005. Unequal numbers were stocked due to limited availability of the populations. 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 interval.

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)

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)

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)
			2005						
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

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

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

Table 3. Stocking summary of muskellunge populations from the Ohio River drainage (OH) and North Spring Lake, IL progeny (IL) introduced in Pierce Lake, Lake Mingo, and Sam Dale Lake during fall 2006. 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.

				Number of Fish		Number per Hectare			
Lake	Stock	Population	Stocking Date	Stocked	Adjusted	Stocked	Adjusted	Mean Length (mm)	Mean Weight (g)
Pierce	IL	North Spring Lake, IL	August 23, 2006	303	303†	5.0	5.0	286 (±6.3)	116 (±8.8)
Mingo	OH	Cave Run Lake, KY	August 16, 2006	332	192	4.6	2.7	244 (±5.3)	66 (±5.9)
	IL	North Spring Lake, IL	August 23, 2006	302	282	4.2	3.9	281 (±7.6)	112 (±10.1)
Sam Dale	IL	North Spring Lake, IL	August 23, 2006	303	20	3.9	0.3	278 (±7.2)	106 (±10.0)

†Mortality cages not utilized due to logistical constraints

Table 4. Summary of age-identifying freeze brands given to all stocked muskellunge 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-Posterior Vertical
Fall 2005	Left-Anterior Vertical
Fall 2006	Right-Anterior Vertical
Fall 2007	Left-Posterior Vertical

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

Table 5. Summary of muskellunge captured in modified fyke nets April 2-6, 2007 in Lake Mingo. 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: V = 2002, IV = 2003, III = 2004, II = 2005, and I = 2006.

	Ohio River Drainage		Mississippi River Draiange		Illinois	
Age	N	CPUE	N	CPUE	N	CPUE
I	0	0.00	N/A	N/A	1	0.06
II	7	0.62	0	0.00	10	0.53
III	20	2.35	1	0.09	18	1.06
IV	9	0.54	0	0.00	14	0.56
V	12	1.21	N/A	N/A	5	0.22

Table 6. Summary of muskellunge captured in modified fyke nets April 16-19, 2007 in Pierce 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 = 2003, III = 2004, II = 2005, and I = 2006.

	Ohio River Drainage		Mississippi River Draiange		Illinois	
Age	N	CPUE	N	CPUE	N	CPUE
I	N/A	N/A	N/A	N/A	0	0.00
II	0	0.00	0	0.00	0	0.00
III	3	0.69	0	0.00	6	1.11
IV	3	0.71	0	0.00	10	1.11

Table 7. 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)
Fall 2006	935 (±0.0)	-
Spring 2007	944 (±30.2)	967 (±49.5)
	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	5355 (±1141.9)	4233 (±1839.2)
Spring 2006	5220 (±387.7)	5050 (±15501.6)
Fall 2006	5920 (±0.0)	-
Spring 2007	6627 (±705.5)	6823 (±1705.7)

Table 8. Analysis of variance tests of the effect of stock on mean daily growth rates (g/d) and mean relative daily 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 daily growth rate (g/g/d)		
Stock	1	0.0000575	5.09	0.03
Error	38	0.000429		

Table 9. 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)
Fall 2005	-	-	666 (±870.4)
Spring 2006	-	-	892 (±0.0)
Fall 2006	-	-	-
Spring 2007	903 (±95.3)	819 (±73.5)	843 (±21.6)
		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)
Fall 2005	-	-	1460 (±6099.0)
Spring 2006	-	-	6096 (±0.0)
Fall 2006	-	-	-
Spring 2007	5070 (±3049.5)	3980 (±1775.3)	4318 (±555.5)

Table 10. Analysis of variance tests of the effect of stock on mean daily growth rates (g/d) and mean relative daily 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 2003. Growth is for the 1-yr interval from stocking through the following fall. 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	0.921	3.18	0.12
Error	7	2.029		
		Mean relative daily growth rate (g/g/d)		
Stock	1	0.000003363	0.07	0.80
Error	7	0.000353		

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)	352 (±11.7)
Fall 2004	-	541 (±34.1)	562 (±44.6)
Spring 2005	-	578 (±58.6)	611 (±972.0)
Fall 2005	-	811 (±0.0)	747 (±26.8)
Spring 2006	-	744 (±22.5)	745 (±34.6)
Fall 2006	-	-	835 (±0.0)
Spring 2007	-	856 (±22.3)	885 (±15.0)
		Weight (g)	
Fall 2003	60 (±7.7)	56 (±2.2)	77 (±2.9)
Spring 2004	105 (±22.2)	128 (±17.1)	202 (±29.0)
Fall 2004	-	1011 (±287.5)	1112 (±358.3)
Spring 2005	-	1461 (±605.3)	1836 (±11486.4)
Fall 2005	-	3830 (±0.0)	2625 (±417.3)
Spring 2006	-	3133 (±388.8)	2867 (±378.0)
Fall 2006	-	-	4750 (±0.0)
Spring 2007	-	5226 (±613.6)	5500 (±308.7)

Table 12. Analysis of variance tests of the effect of stock on mean daily growth rates (g/d) and mean relative daily 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 2003. Growth is for the 1-yr interval from stocking through the following fall. 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	0.200	0.22	0.65
Error	16	14.486		
		Mean relative daily growth rate (g/g/d)		
Stock	1	0.000245	1.05	0.32
Error	16	0.003725		

Table 13. 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	-	-	-
Fall 2006	-	775 (±0.0)	-
Spring 2007	-	741 (±77.5)	749 (±51.3)
		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	-	-	-
Fall 2006	-	3250 (±0.0)	-
Spring 2007	-	3090 (±996.4)	2822 (±392.5)

Table 14. 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	540 (±914.8)	-	573 (±285.9)
Spring 2006	449 (±0.0)	563 (±33.8)	602 (±21.9)
Fall 2006	740 (±0.0)	-	753 (±38.8)
Spring 2007	780 (±0.0)	772 (±17.1)	771 (±18.0)
		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	966 (±6321.3)	-	1125 (±2477.7)
Spring 2006	480 (±0.0)	1216 (±258.9)	1440 (±204.4)
Fall 2006	2080 (±0.0)	-	2973 (±518.5)
Spring 2007	3610 (±0.0)	3421 (±237.6)	3388 (±282.6)

Table 15. 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 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 2005	235 (±5.1)	261 (±4.1)	270 (±4.6)
Spring 2006	255 (±7.4)	317 (±34.0)	307 (±35.1)
Fall 2006	443 (±0.0)	430 (±1124.5)	503 (±51.0)
Spring 2007	-	-	-
		Weight (g)	
Fall 2005	50 (±3.7)	75 (±3.8)	87 (±5.1)
Spring 2006	63 (±6.3)	142 (±59.3)	140 (±39.5)
Fall 2006	362 (±0.0)	498 (±2515.0)	693 (±316.7)
Spring 2007	-	-	-

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 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 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)
Fall 2006	-	-	594 (±67.0)
Spring 2007	-	562 (±29.0)	638 (±29.9)
		Weight (g)	
Fall 2005	48 (±3.8)	45 (±2.3)	79 (±5.8)
Spring 2006	61 (±32.7)	98 (±88.5)	247 (±82.1)
Fall 2006	-	-	1346 (±869.2)
Spring 2007	-	1225 (±236.9)	1712 (±169.7)

Table 17. Summary of stocking and subsequent mean lengths (nearest mm) and weights (nearest g) of three stocks of muskellunge introduced in Lake Mingo during fall 2006. Spring sampling was conducted from March 15 through May 4, 2007. 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 Upper Mississippi River Drainage muskellunge were introduced. Values in parentheses represent 95% confidence intervals.

Season	Ohio River Drainage	Illinois
	Length (mm)	
Fall 2006	244 (±5.3)	281 (±7.6)
Spring 2007	359 (±343.1)	375 (±13.1)
	Weight (g)	
Fall 2006	66 (±5.9)	112 (±10.1)
Spring 2007	223 (±711.5)	270 (±37.2)

Table 18. 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. Ponds were drained in spring and fall of each subsequent year. 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)
Fall 2006	460 (± 18.5)	498 (± 9.4)	502 (± 19.6)
		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)
Fall 2006	450 (± 52.5)	575 (± 34.0)	591 (± 78.1)

Table 19. Analysis of variance tests of the effects of stock, initial weight, year, and pond nested within year on mean daily growth rates (g/d) and mean relative daily growth rates (g/g/d) one year after stocking 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 daily 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 20. Adjusted catch-per-unit-effort (CPUE) of electrofishing (fish/hr) through time of two stocks of muskellunge introduced into Lake Mingo in fall 2002. Adjusted CPUE is subject to a natural logarithmic transformation and analyzed using an analysis of variance.

Sampling Season	Effort (hr)	Adjusted CPUE		P
		OH	IL	
Spring 2003	26.4	8.97	5.30	0.14
Fall 2003	16.0	6.40	4.40	0.36
Spring 2004	21.0	7.57	0.97	0.031
Fall 2004	22.6	1.16	0.10	0.051
Spring 2005	28.4	1.34	0.76	0.53
Fall 2005	17.7	1.86	0.34	0.034
Spring 2006	11.1	0.00	0.23	0.36
Fall 2006	15.7	0.40	0.00	0.35
Spring 2007	15.8	0.00	0.14	0.34

Table 21. Adjusted catch-per-unit-effort (CPUE) of electrofishing (fish/hr) through time of three stocks of muskellunge introduced into Pierce and Mingo Lakes in fall 2003. Adjusted CPUE is subject to a natural logarithmic transformation and analyzed using an analysis of variance. Lower case letters denote statistical differences following Tukey's means separation.

Sampling Season	Effort (hr)	Adjusted CPUE			P
		MISS	OH	IL	
		Pierce Lake			
Spring 2004	16.5	2.92	3.33	0.74	0.22
Fall 2004	17.6	0.00	0.55	0.98	0.053
Spring 2005	26.0	0.00	0.31	0.23	0.43
Fall 2005	18.1	0.00	0.00	0.24	0.12
Spring 2006	15.6	0.00	0.00	0.00	-
Fall 2006	13.8	0.00	0.00	0.00	-
Spring 2007	11.3	1.54	0.00	0.31	0.52
		Lake Mingo			
Spring 2004	21.0	2.28	3.83	3.53	0.47
Fall 2004	22.6	0.00[b]	1.26[a]	0.74[ab]	0.014
Spring 2005	28.4	0.00[b]	0.73[a]	0.15[ab]	0.049
Fall 2005	17.7	0.00	0.17	0.51	0.17
Spring 2006	11.1	0.00	0.00	0.21	0.41
Fall 2006	15.7	0.00	0.00	0.15	0.40
Spring 2007	15.8	0.00	0.00	0.50	0.16

Table 22. Adjusted catch-per-unit-effort (CPUE) of electrofishing (fish/hr) through time of three stocks of muskellunge introduced into Pierce and Mingo Lakes in fall 2004. Adjusted CPUE is subject to a natural logarithmic transformation and analyzed using an analysis of variance. Lower case letters denote statistical differences following Tukey's means separation.

Sampling Season	Effort (hr)	Adjusted CPUE			
		MISS	OH	IL	P
			Pierce Lake		
Spring 2005	26.0	1.77	1.08	1.10	0.79
Fall 2005	18.1	0.00[b]	1.20[a]	0.37[ab]	0.046
Spring 2006	15.6	0.00	0.00	0.00	-
Fall 2006	13.8	0.00	0.26	0.00	0.39
Spring 2007	11.3	0.00	0.32	0.00	0.41
			Lake Mingo		
Spring 2005	28.4	6.30[a]	3.11[ab]	2.43[b]	0.031
Fall 2005	17.7	0.46	0.00	0.34	0.49
Spring 2006	11.1	0.48	0.63	0.00	0.62
Fall 2006	15.7	0.29[a]	0.00[a]	1.29[b]	0.0004
Spring 2007	15.8	0.00	0.35	0.52	0.24

Table 23. Adjusted catch-per-unit-effort (CPUE) of electrofishing (fish/hr) through time of three stocks of muskellunge introduced into Pierce and Mingo Lakes in fall 2005. Adjusted CPUE is subject to a natural logarithmic transformation and analyzed using an analysis of variance.

Sampling Season	Effort (hr)	Adjusted CPUE			P
		MISS	OH	IL	
		Pierce Lake			
Spring 2006	15.6	8.53	1.55	1.86	0.078
Fall 2006	13.8	0.39	0.94	1.72	0.41
Spring 2007	11.3	0.00	0.00	0.00	-
		Lake Mingo			
Spring 2006	11.1	2.45	1.35	1.43	0.99
Fall 2006	15.7	0.00	0.00	0.75	0.16
Spring 2007	15.8	0.00	0.00	0.18	0.39

Table 24. Adjusted catch-per-unit-effort (CPUE) of electrofishing (fish/hr) through time of three stocks of muskellunge introduced into Pierce and Mingo Lakes in fall 2005. Adjusted CPUE is subject to a natural logarithmic transformation and analyzed using an analysis of variance.

Sampling Season	Effort (hr)	Adjusted CPUE			
		MISS	OH	IL	P
			Pierce Lake		
Spring 2007	11.3	N/A	N/A	1.94	-
			Lake Mingo		
Spring 2007	15.8	N/A	0.79	4.67	0.0096

Figure 1. Location of the Sam Parr Biological Station and the Illinois reservoirs stocked for evaluation of growth and survival among muskellunge stocks.

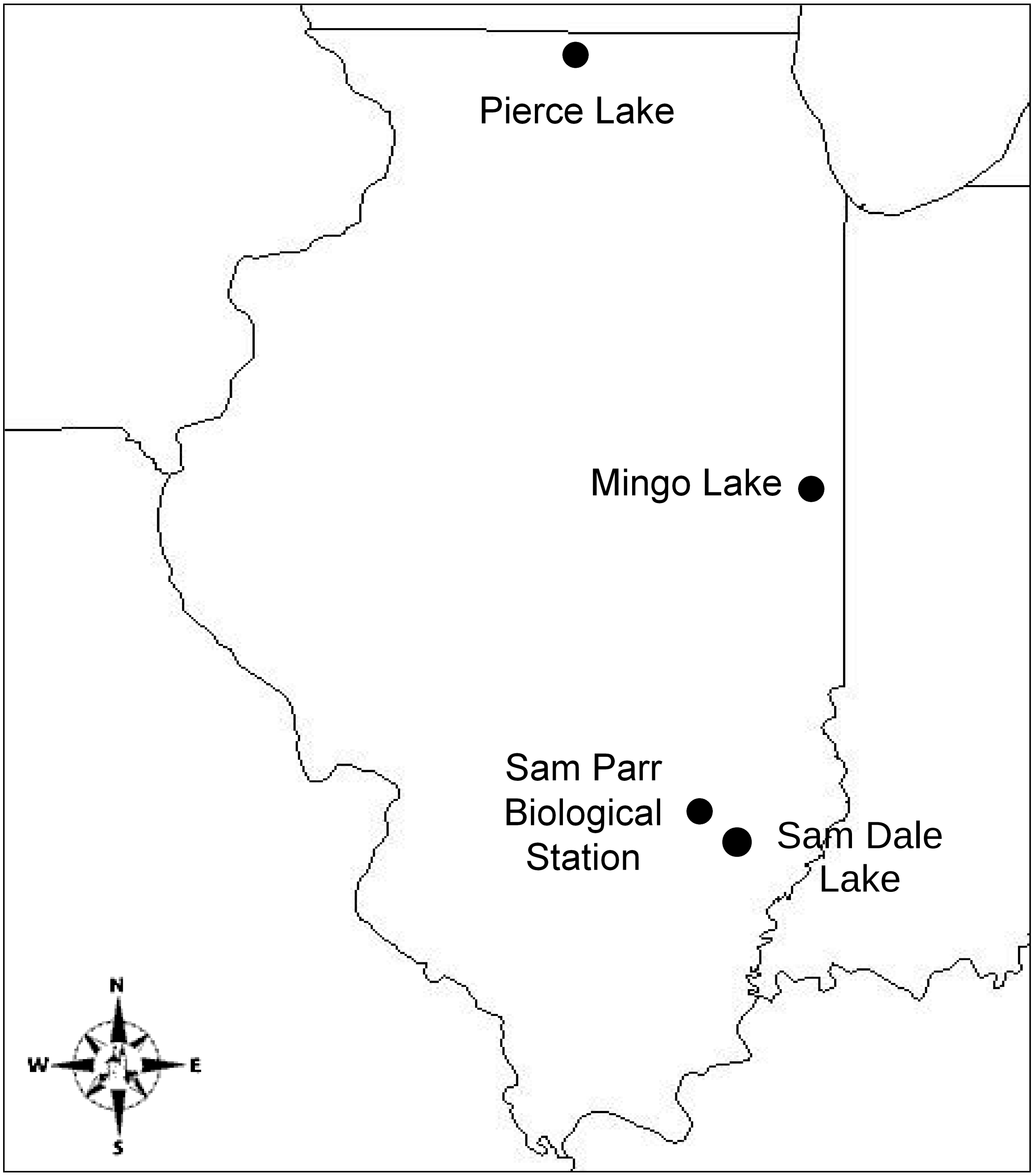

Figure 2. Locations of the 15 modified fyke nets set in Lake Mingo on April 2 and removed on April 6, 2007. Total effort was 58 net-nights.

Figure 3. Locations of the 6 modified fyke nets set in Pierce Lake on April 16 and removed on April 19, 2007. Total effort was 18 net-nights.

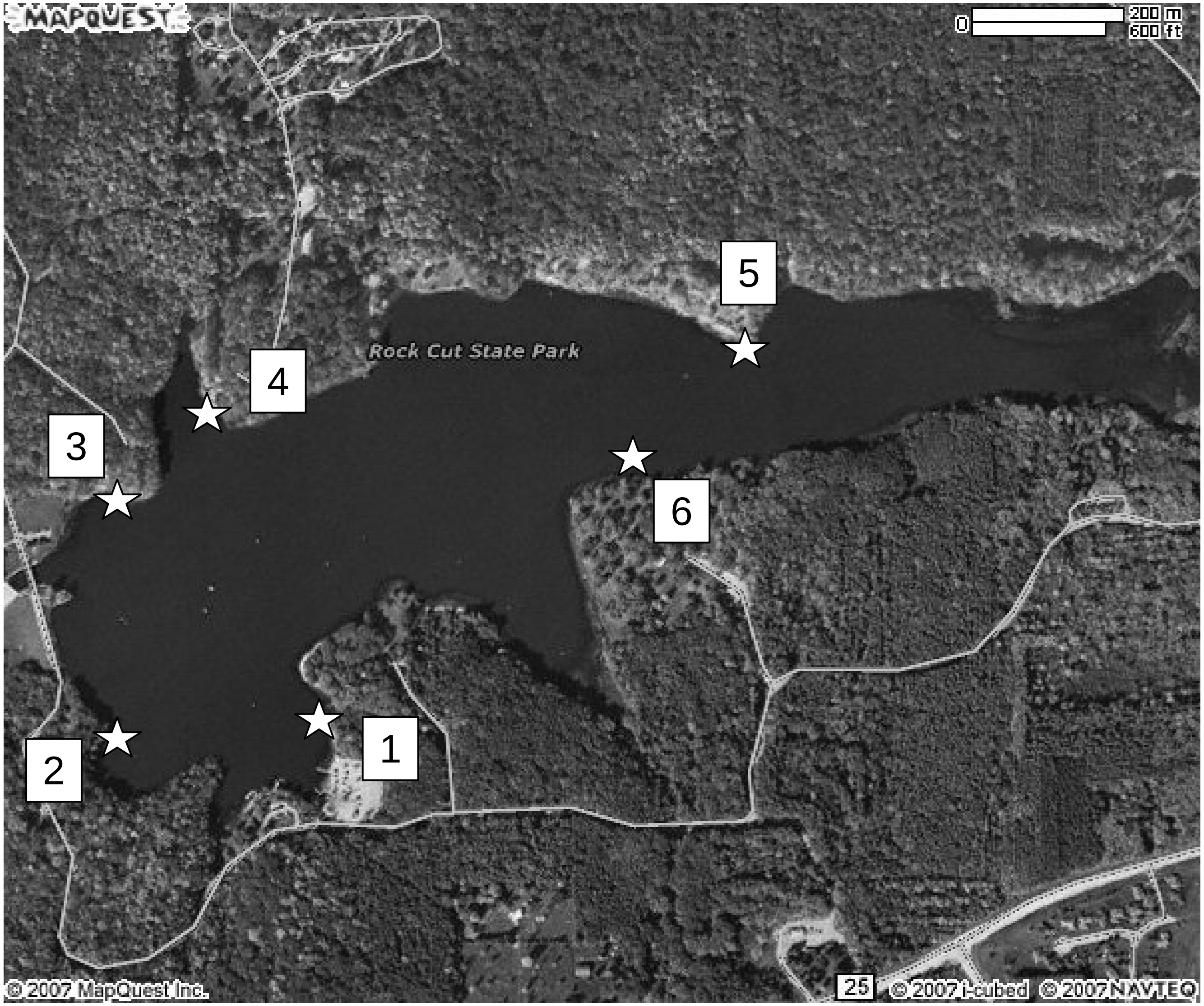

Figure 4. Mean daily growth rates (g/d, solid bars) and mean relative daily growth rates (g/g/d X 100, open bars) of muskellunge populations from the Ohio River drainage and North Spring Lake, IL introduced in Lake Mingo during fall 2002. Growth is from the time of stocking through the first fall (October 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.

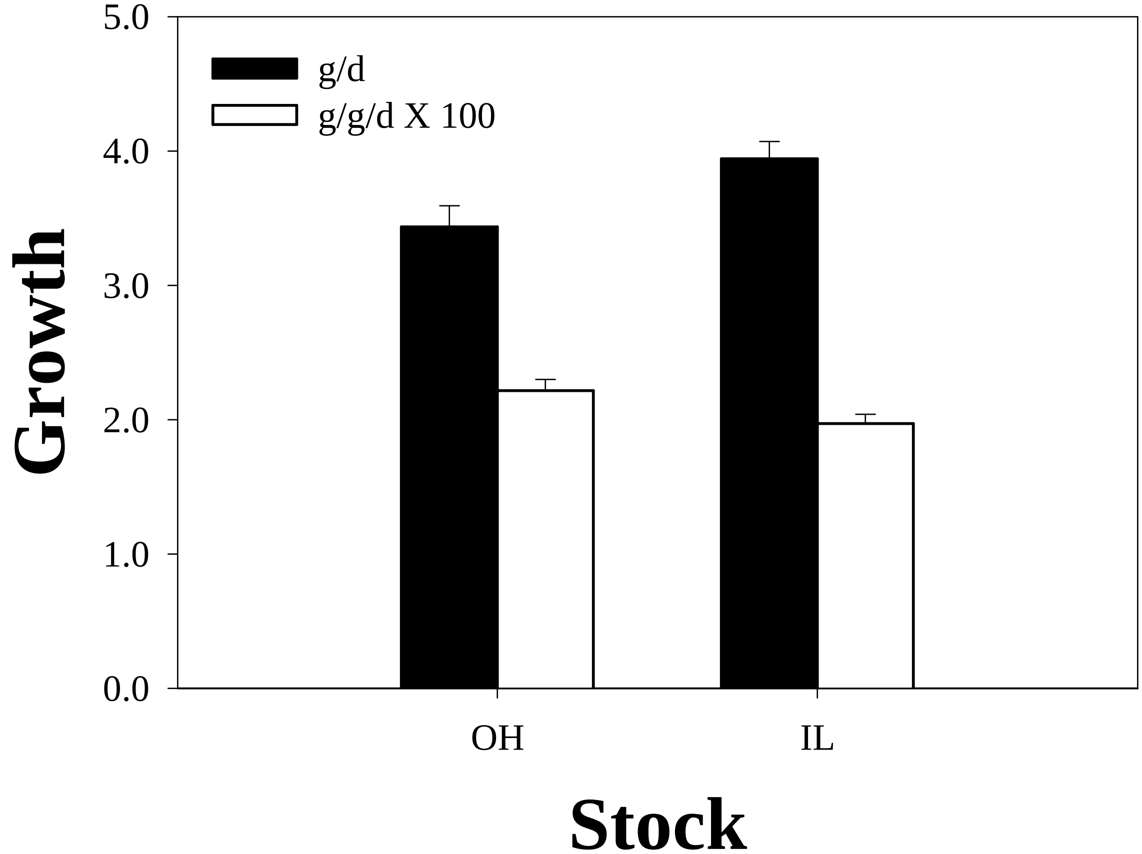

Figure 5. Mean daily growth rates (g/d, solid bars) and mean relative daily growth rates (g/g/d X 100, open bars) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Pierce Lake during fall 2003. Growth is from the time of stocking through the following fall. The Upper Mississippi River drainage stock is represented by the Minnesota Leech Lake population and the Ohio River drainage stock is represented by the New York Chautauqua Lake population. Illinois muskellunge are North Spring Lake, IL progeny. Vertical lines represent ±1 standard error.

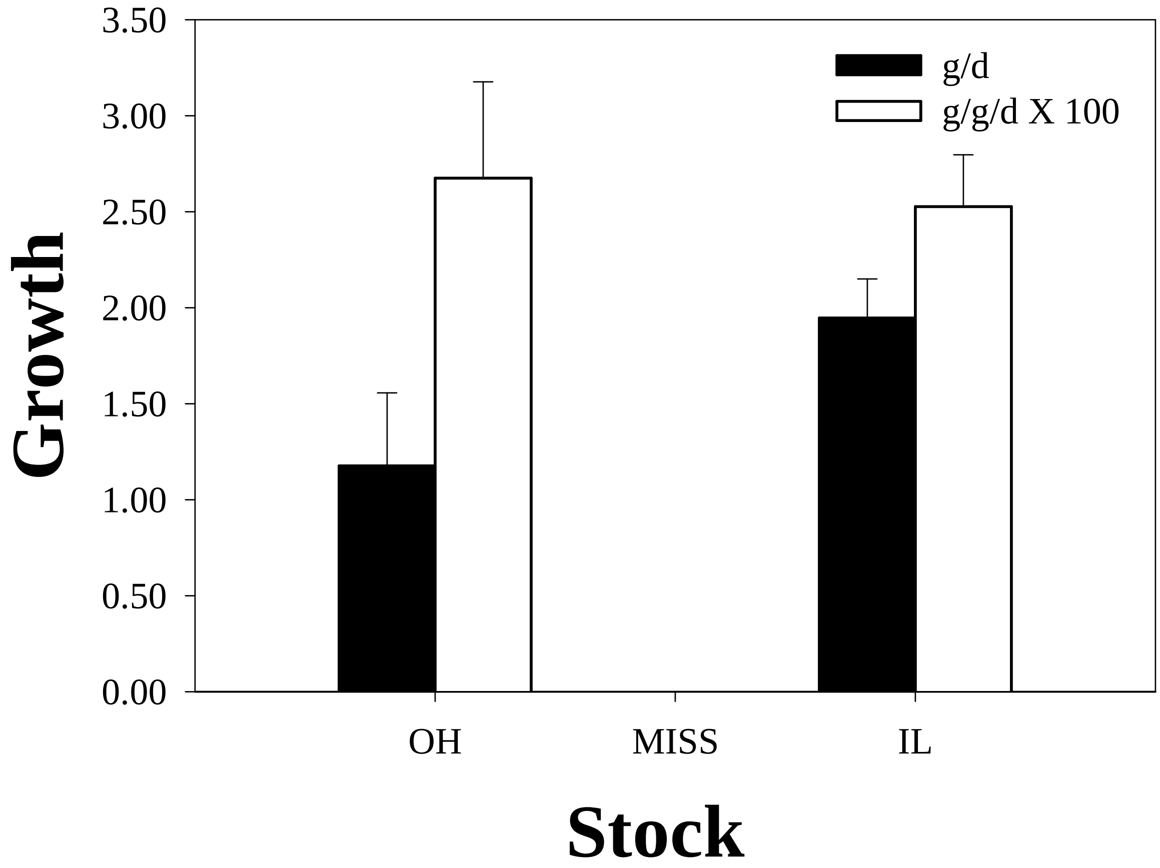

Figure 6. Mean daily growth rates (g/d, solid bars) and mean relative daily growth rates (g/g/d X 100, open bars) of muskellunge populations from the Upper Mississippi River drainage, the Ohio River drainage, and North Spring Lake, IL introduced in Lake Mingo during fall 2003. Growth is from the time of stocking through the following fall. 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.

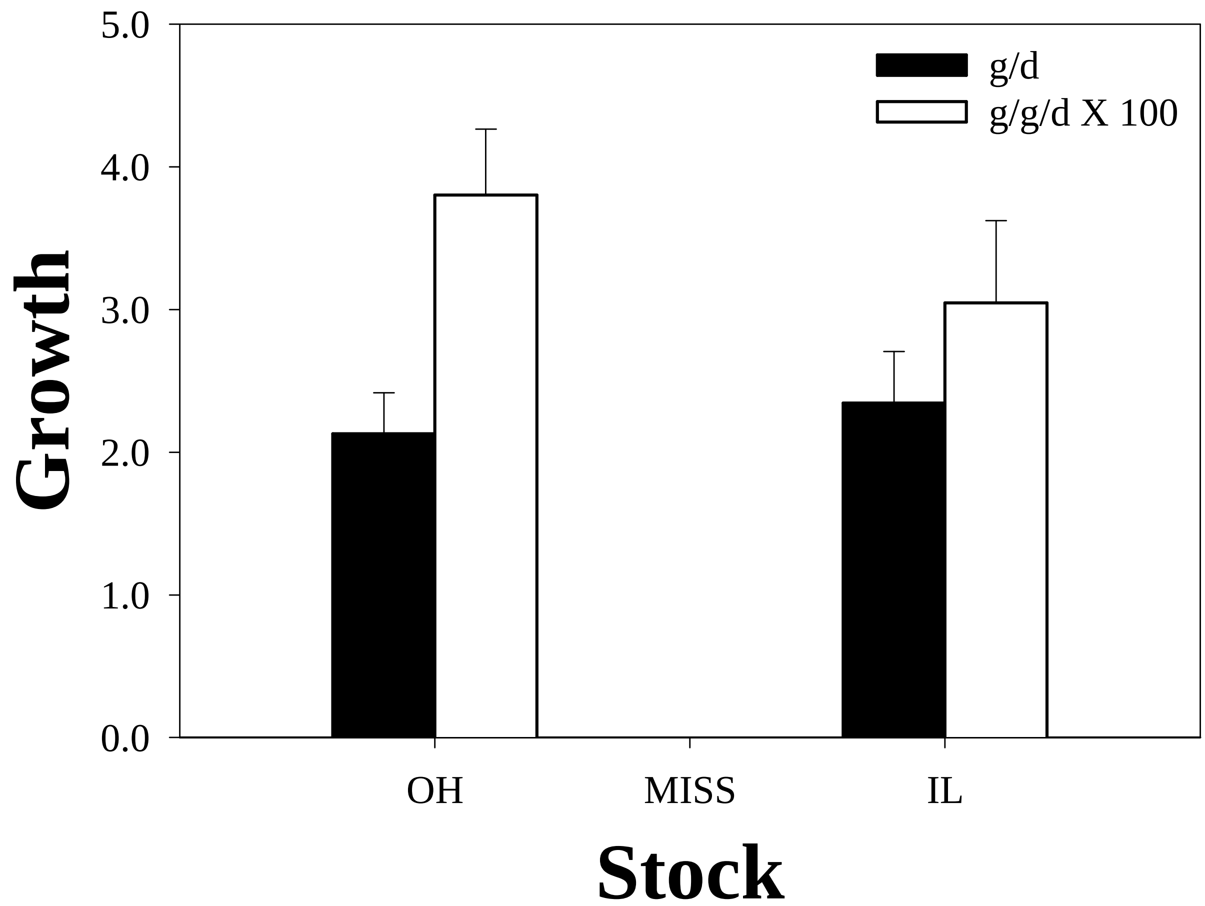

Figure 7. Mean total length (mm) at age and fitted von Bertalanffy growth functions for the Illinois population (solid line) and the Ohio River drainage stock (dashed line) introduced into Pierce Lake from fall 2003 through fall 2005.

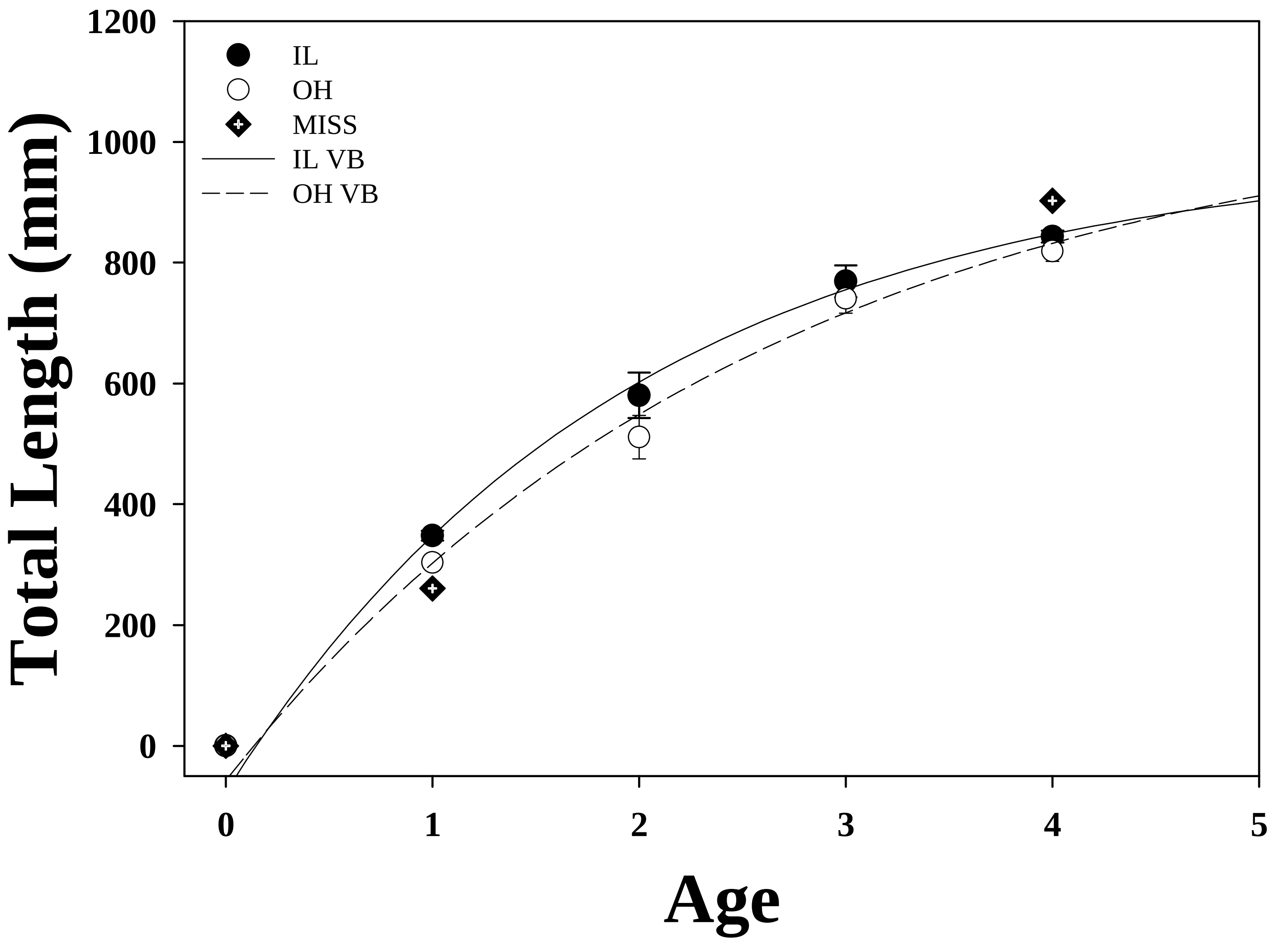

Figure 8. Mean total length (mm) at age and fitted von Bertalanffy growth functions for the Illinois population (solid line) and the Ohio River drainage stock (dashed line) introduced into Lake Mingo from fall 2002 through fall 2005.

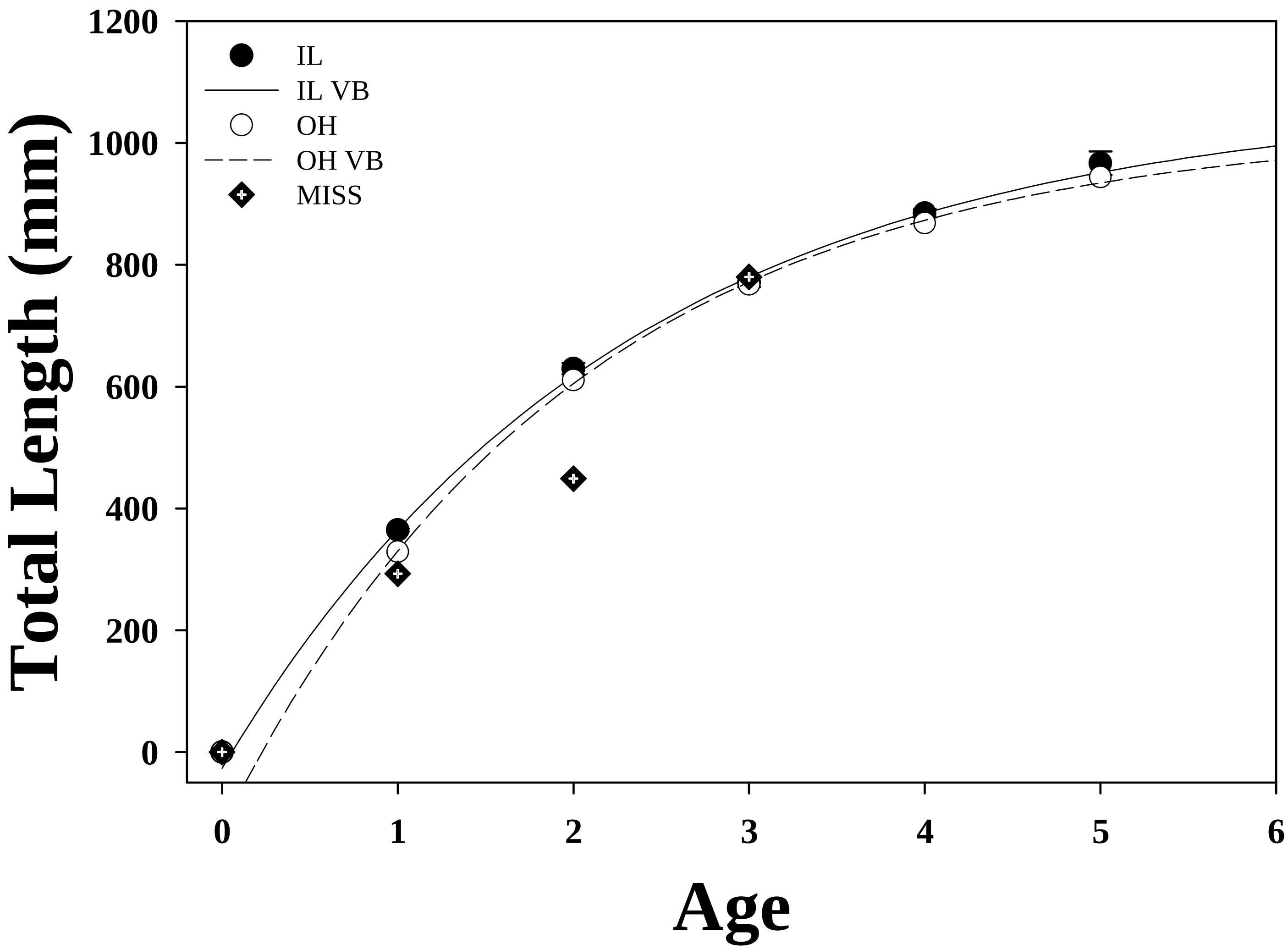

Figure 9. Stocking and subsequent sample mean weights (nearest g) of muskellunge populations introduced into 3, 0.4-ha ponds in October 2004 and drained during April 2005, October 2005, March 2006, and October 2006. Vertical lines represent ±1 standard error.

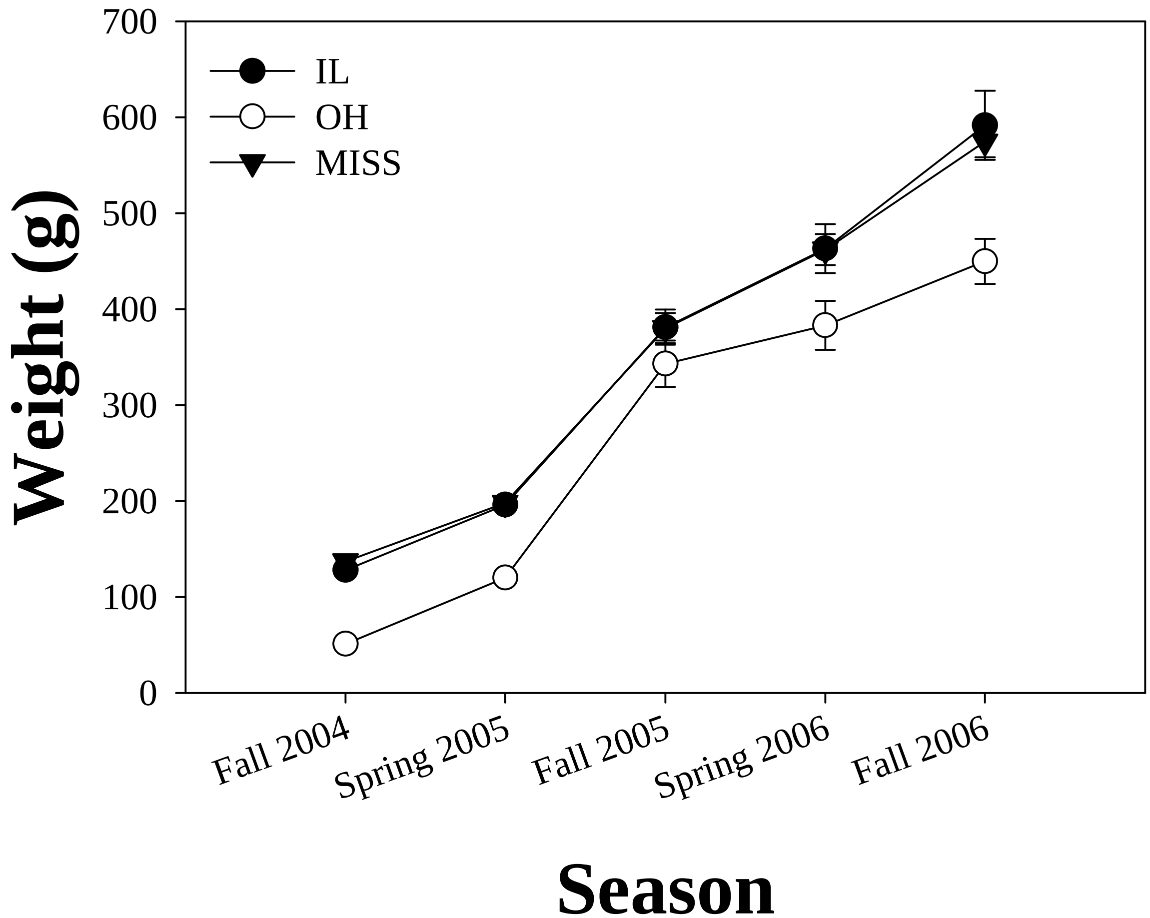

Figure 10. Mean daily growth rates (g/d, solid bars) and mean relative daily growth rates (g/g/d X 100, open bars) of three stocks of muskellunge introduced into 3, 0.4-ha ponds in October 2002, 2003, and 2004. Growth is shown for one year following stocking. Vertical lines represent ±1 standard error.

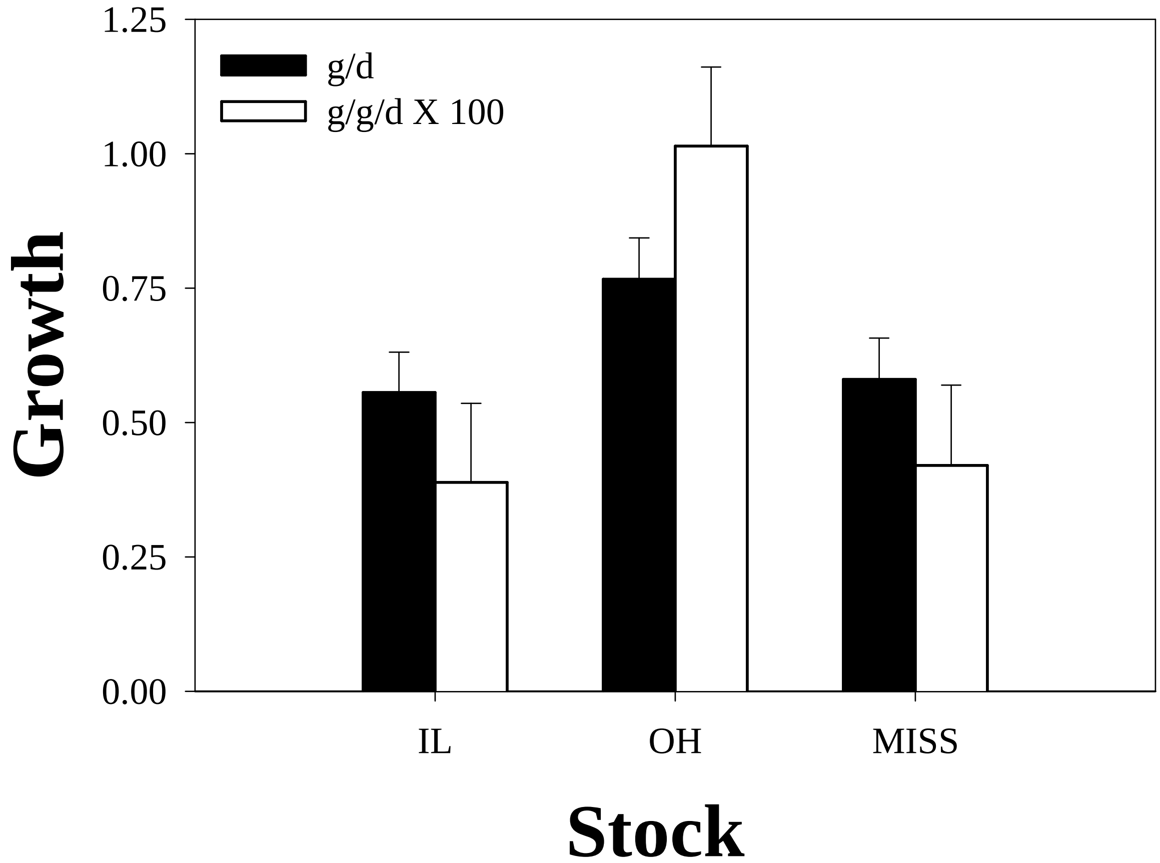

Figure 11. Survival of three stocks of muskellunge introduced into 3, 0.4-ha ponds in Octobers 2002, 2003, and 2004. Data are pooled and analyzed with logistic analysis of variance. Survival estimates are calculated from the time of stocking until one year after stocking. Vertical lines represent 95% confidence limits.