ILLINOIS NATURAL HISTORY SURVEY

UNIVERSITY OF ILLINOIS

ANNUAL REPORT

July 1, 2012 through June 30, 2013

Surveys and investigations for sportfish management in lakes and rivers in Illinois

M.J. Diana, M.A. Nannini, J.P. Gring, J.A. Garavaglia and D.H. Wahl

Submitted to
Division of Fisheries
Illinois Department of Natural Resources
Federal Aid Project F-185

August 2013

INHS Technical Report 2013 (35)

ANNUAL PROGRESS REPORT

Surveys and investigations for sportfish management in lakes and rivers in Illinois
F-185

Illinois Natural History Survey
University of Illinois

Submitted to
Division of Fisheries
Illinois Department of Natural Resources
Federal Aid Project F-185-R-1
July 1, 2012 through June 30, 2013

David H. Wahl
Principle Investigator

Brian D. Anderson,
Director
Illinois Natural History Survey

Matthew J. Diana
Co-investigator

Acknowledgments:

The authors would like to thank the staff at the Kaskaskia, Ridge, and Sam Parr Biological Stations for laboratory and field help. We would also like to thank the regional and district biologists from the Division of Fisheries, Illinois Department of Natural Resources (IDNR) who provided additional lake survey data, especially M. Mounce, M. Hooe, J. Pontnak, and M. Garthaus. S. Pallo, J. Ferencak, J. Mick and D. Bruce helped coordinate activities with the Division of Fisheries, IDNR. Funds for the Lake Paradise vegetation planting were provided by the National Fish and Wildlife Foundation and the City of Mattoon.

Disclaimer:
This study is conducted under a memorandum of understanding between the Illinois Department of Natural Resources and the Board of Trustees of the University of Illinois. The actual research is performed by the Illinois Natural History Survey, Institute of Natural Resource Sustainability at the University of Illinois. The project is supported through Federal Aid in Sport Fish Restoration by the U.S. Fish and Wildlife Service, the Illinois Department of Natural Resources, and the Illinois Natural History Survey. The form, content, and data interpretation are the responsibility of the University of Illinois and the Illinois Natural History Survey, and not the Illinois Department of Natural Resources.

TABLE OF CONTENTS

EXECUTIVE SUMMARY:

Sportfishing in Illinois is a major recreational activity and source of revenue and proper management of fish populations is paramount to maintaining the quality of the resource. Many different management strategies can be implemented in an attempt to improve the fishery, often without adequate evaluation. Management decisions utilize techniques that may improve the fishery in a particular system. Management techniques often are implemented without being evaluated using scientific methods and instead are based on anecdotal evidence. It is important to evaluate management practices in order to further understand if they are producing the desired fishery and if the current management action addresses the factors that may be limiting to a fishery. Therefore there is a need for more intensive scientific evaluation of management techniques in order to provide managers with evidence that these techniques can be used to produce the desired benefits.

Stocking is a common tool utilized in Illinois to increase largemouth bass populations. However survival of stocked fish has been documented to be low when stocked on top of natural populations. There are a number of techniques that need to be evaluated to determine if stocking survival can be increased. We continued evaluating stocking techniques to improve survival of stocked largemouth bass. Three lakes were stocked with largemouth bass, with half the fish stocked at the boat ramp and half dispersed throughout the lake and into woody or vegetated habitat. Very few stocked fish have been recaptured from any stockings conducted thus far regardless of method. No one stocking method experienced greater growth or survival and the increased handling may contribute to the low survival. CPUE of stocked fish in this experiment has been lower than observed in stockings conducted in previous studies we have conducted and we hope to observe greater survival in future segments in order to evaluate the success of these two stocking strategies.

Muskellunge are commonly stocked in Illinois as there is no documented successful reproduction. It is unclear what stock of muskellunge is best suited to maximize growth and survival in Illinois waters. We conducted final sampling during this segment and in this report present final summary of growth and survival comparisons among the three stocks from Mingo, Pierce, and Sam Dale Lakes. 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 these three Illinois lakes. Populations were sampled by electrofishing and modified fyke net surveys during spring. Data was compiled from all years to describe long-term trends in growth and survival of muskellunge stocks in Illinois. Across years and lakes, the Ohio River drainage stock and the Illinois population generally appear to have similar growth rates through adulthood. Few Upper Mississippi River drainage stock were available for growth comparisons. Analysis of body morphology indicates that fish from the Upper Mississippi River drainage are consistently leaner than those of the other stocks. Results from lake introductions suggest that after the first summer following stocking, the Ohio River drainage stock and Illinois population typically have similar rates of survival, both of which are higher than the Upper Mississippi River drainage stock. This pattern led to consistently lower survival of Upper Mississippi River drainage stock year classes to adulthood as well. The Ohio River drainage stock and Illinois population show similar survival both to adulthood and annually through adult age classes. The specific mechanism responsible for differences in survival rate among stocks is still unknown. Information on growth and survival of muskellunge stocks at varying latitudes will aid in source selection and optimization of limited hatchery resources. Based on these results, we recommend stocking Ohio River drainage or Spring Lake progeny in Illinois lakes. Mississippi River drainage fish will have lower growth and survival in Illinois than these two populations.

In addition to largemouth bass and muskellunge, crappie are commonly stocked to enhance populations. Blacknose crappie have recently been used in stocking efforts because of their distinct mark and their ability to survive handling and hatchery truck transport. Blacknose are a type of black crappie that was originally stocked because the distinct mark and the low occurrence in the wild made it easy to identify stocked fish to evaluate stocking success. There has been some suggestion that blacknose crappie have potential growth and fitness advantages over black crappie, but this has been untested in the field. In addition, little is known about the interbreeding of blacknose crappie with native black crappie or the white crappie species. In this segment, we collected black, white and blacknose crappie from source populations in Illinois and established brood ponds at the Sam Parr Biological Station. In addition blacknose crappie were obtained from Tennessee to compare to the Illinois naturalized fish. In the next segment, we will stock and evaluate the relative growth of age-0 white, black, and blacknose crappie in experimental ponds. When rearing ponds are drained in the next segment, we will estimate abundance and growth of white, black, blacknose, and black x blacknose hybrid crappie as well as the prevalence of the black stripe in the blacknose and black x blacknose hybrid ponds. In addition, we aided in blacknose crappie brood stock collection for the Jake Wolf Memorial Fish Hatchery to establish rearing ponds. Fish reared at the hatchery will be used to stock the Illinois River in the Starved Rock Pool (RM 240) near Ottawa, IL. We will also evaluate the success of this stocking in the next segment.

Harvest regulations are commonly employed by fisheries managers to protect overharvest of fish populations or manage size structure. There are a large variety of regulations used in Illinois with varying management goals. In this study, we continued to assess largemouth bass populations in lakes with varying harvest regulations. The default largemouth bass regulation in Illinois is no length limit with a 6 fish bag. This was by far the most common regulation, followed by a standard 14 inch 6 fish bag. We observed some evidence that lakes with slot limits had a greater number of memorable fish, but no significant differences in abundance in any size class of largemouth bass was detected. Lakes with restrictive regulations showed similar largemouth bass size structure and abundance as lakes allowing all harvest. Low harvest rates or poor compliance to regulations may result in no differences and will be evaluated in future segments.

We also began to examine crappie regulations in Illinois lakes and how they relate to crappie populations. We determined regulations for lakes with DNR data available in the FAS database resulting in 327 lakes (46 white crappie only, 137 black crappie only, and 144 with both. Most lakes had unregulated crappie populations. The most common regulation types were bag limits and length/bag limits. Bag limits ranged from 5 -30 fish per day and length limits were either 9 or 10 inches. We found that lakes with length/bag regulations have significantly higher CPUEs than lakes with bag limits or lakes with no regulations. CPUE of crappie from lakes with bag limits was not different than unregulated lakes. Length and bag regulations may be appropriate to utilize to increase the number of crappie in a lake. We will continue to examine crappie regulations and include information on size structure in future reports.

Angling tournaments are becoming increasingly popular. Although most tournaments practice live release, there can be high delayed mortality or a variety of sub-lethal impacts of competitive angling tournaments on the individual fish. Previous research has focused on measuring and reducing the stress of individual fish caught in tournaments, but little work has focused on the effect of these practices on the entire fish population. In this study, we continued to assess tournament activity and make comparisons with largemouth bass populations in a number of lakes in Illinois. We contacted lake managers and tournament directors to obtain competitive bass fishing tournament results to quantify the level of tournament activity on a lake and relate it to largemouth bass populations. Information from tournaments conducted on 12 lakes was used to evaluate varying tournament pressure in addition to 4 lakes with no tournaments activity. Tournament pressure (angler hours per acre) varied from 0 to 21.8 hours/acre and the mean number of tournaments a year was 19 (range 0 – 57). Larger lakes tended to have larger tournaments with a higher number of participants, but lake size was not related to total tournament pressure or the number of tournaments. The CPUE of memorable sized fish in electrofishing samples was the only fish population variable that was related to tournament pressure. Lakes with higher tournament pressure had fewer memorable sized fish in electrofishing samples. We did not detect any changes in abundance or size structure of largemouth bass vulnerable to tournament angling (> 355 mm) or production of young-of-year fish related to tournament pressure. We will continue to collect tournament and largemouth bass population data on these lakes and add additional lakes to this analysis as part of future segments to further understand the influence of tournaments on largemouth bass populations.

In addition we have conducted experimental tournament angling on Ridge Lake in order to determine how tournaments can effect reproduction, abundance, and growth of largemouth bass. In this segment, we conducted spring largemouth bass tournaments while fish were on the nest and compared the changes in the fish population to previous years with tournaments and years with no tournaments. We observed no consistent changes in young-of-year production or adult abundance for largemouth bass that was related to tournament activity in the spring. We will continue to alternate tournament and no tournament years to further evaluate the potential effects of tournaments on lake wide recruitment.

In addition to stocking and regulations, habitat restoration is critical to managing sportfish populations. The lack of suitable habitat for sportfish spawning, feeding and cover from predators can greatly limit a population. Understanding the importance of habitat and how to manage habitat conditions is important to managers. We have continued to conduct habitat manipulations in a number of lakes in an attempt to enhance largemouth bass populations. We continue to evaluate vegetation plantings at Lake Paradise, drawdown and rotenone efforts at Dolan and Woods Lakes, and vegetation removal through chemical treatments at Airport and Stillwater Lakes. We have observed little change in largemouth bass populations at Lake Paradise due to difficulties in establishing vegetation. Woods Lake is currently drawn down and will be rotenone treated to remove gizzard shad and carp this winter. We will begin evaluating fish populations when it is allowed to refill. Dolan Lake was drawn down to encourage vegetation establishment and rotenone treated to remove gizzard shad and carp. Despite a rebound in the gizzard shad densities, carp have not reestablished in the lake and the vegetation cover has significantly increased coinciding with an increase in largemouth bass densities in this lake. Vegetation removal treatments at Airport Lake have not been entirely successful. We have not been able to document a decrease in vegetation density and therefore no changes in largemouth bass populations were observed. Stillwater Lake was successfully treated for vegetation and the lake has remained at a lower vegetation density following initial treatment.

We have also been measuring vegetation density and cover in 11 lakes and evaluate how largemouth bass populations vary among different vegetation types, cover, and fluctuations. We observed few differences in catch rates for young-of-year or adult largemouth bass associated with vegetation cover or shoreline vegetation in 2012. Vegetation has traditionally been related to prey resources (benthic invertebrates, zooplankton, prey fish) however it was not significantly related in 2012. We will continue to evaluate trends in fish populations related to vegetation density in future segments.

It is important to quantify habitat in a system in order to fully understand factors that may be limiting a fishery. In mid-sized rivers there is not a standardized method for evaluating habitat in Illinois. Research is needed to create a habitat evaluation method for mid-sized rivers and relate these habitat measures to fish populations. We initiated a project in this segment to address sampling needs for non wadable river habitat and relate habitat to fish communities. We have begun to develop and implement a technique using side scan sonar to map river habitat. We will be able to use this technique to quantify habitat types along with more tradition sampling methods. We will sample fish associated with each habitat type and evaluate relationships between them initially in the Kaskaskia River and expanding to other rivers in future segments.

Reproduction and the survival of fish to adulthood can be influenced by a multitude of factors. Understanding variables related to recruitment of fish populations can aid in developing management strategies or identifying limiting factors in a system. Many management practices are focused on enhancing natural recruitment by reducing mortality through practices such as fishing refuges or escapement barriers. Fishing refuges can limit disturbance of fish populations during spawning and protect juvenile and adult fish from fishing mortality and may increase natural recruitment, but have not been well evaluated. We continued to assess two fishing refuges in Otter Lake to determine the potential benefits to spawning and survival of largemouth bass. We observed no differences in CPUE or seine catch of young-of-year or adult largemouth bass in closed refuge sites and sites open to fishing. The refuge has only been in place for 3 years and it may take more time to benefit the fish population. Previous research at Clinton Lake showed increases in largemouth bass numbers in refuge locations, but the results were not evident until after a few years. We will continue to follow changes in the largemouth bass population in Otter Lake to determine how they are influenced by closed fishing refuges.

Emigration or “escapement” of sportfish from reservoirs over the impounding barrier is commonly viewed as a major limitation in the successful development of high density populations. Reports and anecdotal evidence suggest that this problem is particularly ubiquitous for muskellunge in the Midwest. However, little documented information exists on the patterns and magnitude of escapement, particularly for fish that occur in low densities such as muskellunge. In this segment, we continued to monitor muskellunge escapement in Lakes Mingo and Sam Dale. Both lakes have a PIT tag array installed on the spillway that will monitor the passage of any tagged fish. Muskellunge were captured in the spring during four weeks of fyke netting. We determined population estimates using mark recapture techniques and PIT tagged all muskellunge upon release. Despite observing high levels of spillway escapement in 2011 at Sam Dale, escapement was not observed in either lake in 2012. In 2012, there was little flow over the dams due to a dry summer season and we did not observe any escapement of muskellunge. Spring rain in 2013 has provided the potential of spillway escapement. We will download data from the receivers and report our observations in the next segment.

In this segment, we began to evaluate crappie recruitment in a number of lakes. We initiated spring and fall electrofishing and fyke netting to assess white, black, and blacknose crappie populations. We collected fish for dissection and otolith reading to determine age, growth, and maturity status. We also collected samples to assess prey resources and predator abundance in each study lake. We collected monthly water quality, zooplankton, larval fish and seasonal benthic invertebrate samples. Vegetation was surveyed in June and August and water level was recorded. In future segments we will use this data to determine what factors are related to crappie recruitment and make recommendations for managing crappie populations.

In order to assess sportfish populations and compare populations across Illinois, it is critical to use standardized gears that are efficient in collecting the targeted fish species. Standardized practices for population assessments in Illinois have traditionally been AC shoreline electrofishing. Alternative electrofishing gears using direct current have become more popular recently due to perceived greater efficiency for certain species of fish. There is a need to evaluate how catch rates vary between the AC and DC electrofishing in order to compare historic data if gear changes are made. We conducted AC and DC electrofishing runs on four lakes in both spring and fall. Catch rates for largemouth bass, crappie, and bluegill were similar for both small and large fish between gears. We did observe greater catch rates for gizzard shad and common carp when using DC gear. We will continue to conduct AC and DC sampling and future analyses will focus on more species and the size of fish that is captured.

Study 101: Sportfish Enhancement

Job 101.1: The effects of dispersed versus point stocking on largemouth bass survival and growth.

<u>Objectives</u>: To compare various stocking strategies for largemouth bass.

<u>Introduction:</u>

Fish stocking is common throughout North America for a number of species. Fish may be stocked to introduce a species to a new system (Dauwalter and Jackson 2005), sustain a population in areas where the fish do not reproduce naturally (Santucci et al. 1994), supplement wild populations that have been reduced due to anthropogenic influences (i.e. fishing, habitat degradation; Wingate 1986) or to alter the genetics of a population (Maceina et al. 1988; Buckmeier et al. 2003). The initial success of a stocking program depends on the survival of introduced fish. Much research examining the success of stocking programs has focused on initial survival (Boxrucker 1986; Buckmeier and Betsill 2002; Hoffman and Bettoli 2005), though more recent work has focused on survival to adulthood (Diana and Wahl 2008; Buynak and Mitchell 1999; Wahl and Stein 1993).

Supplemental stocking of largemouth bass *Micropterus salmoides* is a commonly used management tool to enhance populations. Supplemental stocking efforts are directed at either increasing harvest rates and reproductive potential, or restoring predator/prey balance in a fish community. However, for these positive benefits to occur, stocked fish must contribute to the natural population. Numerous studies have examined either the introductions of different genetic stocks of largemouth bass (Rieger and Summerfelt 1978; Maceina et al. 1988; Mitchell et al. 1991; Gilliland 1992; Terre et al. 1993) or the introductions of largemouth bass into ponds (Dillard and Novinger 1975; Modde 1980; Stone and Modde 1982). Surprisingly, few studies have examined the factors thought to influence supplemental stocking of largemouth bass. The few studies that have examined the contribution of stocked largemouth bass to a natural population, examined only one (Lawson and Davies 1979; Buynak and Mitchell 1999) or two lakes (Boxrucker 1986; Ryan et al. 1996). Given that lakes are highly variable, examining stocking evaluations from only one or two lakes limits our ability to make generalizations.

In previous studies, we have evaluated various aspects of largemouth bass stocking success with the goal of increasing survival and growth. We examined the potential benefits of stocking larger fish by comparing the stocking success of four sizes of largemouth bass (Diana et al. 2009), but found no differences in survival and growth of 4, 6, and 8 inch fish. We recommended stocking four inch fish based on cost benefit analyses and the lack of survival of larger fish. We also evaluated different rearing techniques by comparing growth and survival of largemouth bass produced in raceways to those produced in rearing ponds (Diana et al. 2011). Although initial survival and growth of extensively reared fish was significantly higher, long-term survival was low and no differences in rearing technique were observed. Despite low long-term survival of stocked fish, using genetically marked fish we were able to verify that stocked fish are successfully spawning and contributing to young-of-year production (Diana et al. 2011). There is a continued need to attempt to increase survival of stocked largemouth bass by identifying the factors limiting their long-term survival. Largemouth bass are typically stocked at the boat ramp in a point stocking style. We hypothesize that by distributing fish throughout the lake, there is potential for increased dispersion of fish and better survival when stocked into cover such as vegetation or wood. In previous studies, we began comparing point versus dispersed stocking of largemouth bass but low initial survival of stocked fish has limited our ability to draw strong conclusions. In this project, we are conducting additional years of stockings to evaluate their success.

Procedures:

This job continues research initiated as part of previous studies F-135-R evaluating the influence of stocking location on survival of stocked largemouth bass. Otter Lake, Homer Lake, Lake Mingo, and Lake Charleston (n=4) were stocked with 100mm largemouth bass fingerlings using two stocking techniques. In this segment, half of the fish at each lake will be stocked at the boat ramp, directly from the hatchery truck, while the other half will be loaded into aerated hauling tanks in boats and distributed throughout the lake. Distributed stockings will target placing fingerlings into wood and vegetated habitat dispersed throughout the lake. Fish were marked with a pelvic fin clip two weeks prior to stocking at the Jake Wolf Memorial Fish Hatchery. Fish stocked at the boat ramp were given a left pelvic fin clip and fish to be dispersed were given a right pelvic fin clip. Lakes were sampled two times in the fall and two times in the spring using DC or AC 3-phase electrofishing. Three 30 minute electrofishing transects were performed on each sampling date and all largemouth bass were collected, measured for total length, examined for clips, and scales were collected from all clipped fish for age determination. CPUE was calculated for stocked and wild fish and contribution of stocked fish to the total bass population was calculated. The CPUE from this segment was combined with the data from previous stockings in the same lakes. Catch rates and mean size were calculated for each year class and compared between the two rearing techniques. CPUE from electrofishing was calculated and differences between stockings were examined using repeated measures ANOVA and Tukey-Kramer (T-K) adjusted P value were used to determine significance in post hoc tests.

Findings:

Four lakes were stocked with four inch largemouth bass in 2012 for comparison of boat ramp and dispersed stocking. All lakes continued to have very low survival of both boat ramp and dispersed stocked fish to the first fall following stocking (Table 101.1). Continued low survival of the stocked fish from both stocking methods has made it difficult to evaluate these methods. At this point there is no difference in mean CPUE of boat ramp or dispersed stocked fish in the first fall following stocking and catch rates the following spring are very low. We have continued to recapture some fish from previous stockings in our electrofishing samples, but the CPUE is very low and there is no consistent difference between stocking method (Figure 101.1). The poor survival of all stocked fish may be contributed to by the warm water temperatures on the date of stocking which occurs in early August. High mortality of dispersed fish could be affected by the increased handling time associated with loading the fish onto a boat and dispersing them throughout the lake. We did not however observe good survival of fish stocked at the boat ramp where this handling did not occur. Additional years of stocking are required to evaluate differences in these stocking techniques. We will continue to stock four lakes each year as part of future studies using these strategies in order to make management recommendations regarding stocking locations to maximize survival.

Recommendations:

We will continue evaluating stocking location as part of the next segment to assess the potential to increase survival of stocked largemouth bass. At this point, we have observed very low survival of largemouth bass stocked both at the boat ramp and dispersed throughout the lake. Survival of fish in this study has been lower than survival observed from previous stockings we have evaluated. Survival may have been limited due to the high temperatures on the dates of stocking or the increased handling time due to the stocking techniques. We will continue to attempt to stock the fish during the lowest possible temperatures to facilitate survival. We will continue to compare survival of point stocking versus dispersed stocking at multiple locations of optimal habitat throughout the study lakes. In the next segment we will stock Lake Charleston, Homer Lake, Lake Mingo, and Otter Lake using these two methods for one additional year. We will evaluate growth and survival by conducting spring and fall electrofishing. Ultimately we hope to evaluate if increased survival of stocked largemouth bass can be achieved through these techniques and provide management recommendations on best stocking method.

Our results continue to suggest the need to evaluate long-term survival of largemouth bass to fully evaluate stocking success. Although stocked fish may exhibit similar survival to wild fish in a lake initially following stocking, significant mortality can occur through adulthood. Stocking success could be evaluated incorrectly if long-term survival is not considered. We have found that recruitment of largemouth bass is not determined in the first year after stocking. Many previous evaluations of stocking success for other species have not examined stocking success beyond the first spring. These studies may omit a critical period for determining survival of stocked fish. For largemouth bass, success of stocked fish in the first year is often not reflected in future creel data providing further evidence for variable survival following the first year after stocking (Boxrucker 1986; Neal et al. 2002). Managers should consider survival to age-1 and adult fish when managing a lake or reservoir by stocking. Considering the availability of appropriate prey and habitat for larger stocked fish may reduce mortality and increase recruitment to the fishery. We will continue to evaluate different stocking methods which may increase long term survival of stocked largemouth bass. At this point, we have not been able to find benefits of stocking extensively reared fish or larger fish. In future studies we will examine other lake specific factors that may influence stocking success such as prey abundance and availability, available habitat, thermal regimes, and fishing pressure. We will examine variation among lakes in order to further explore what factors may play a role in determining growth and survival of stocked fish. Evaluating largemouth bass rearing and stocking techniques will have direct effects on the stocking program in Illinois. Distributing fish throughout a lake rather than stocking at a single location will allow us to determine if point stocking results in reduced survival of stocked fish. Results from these studies will be used to adjust stocking methods to increase contribution of stocked fish to the natural population and improve largemouth bass fisheries in Illinois.

Job 101.2: Assessment of growth and survival of different genetic stocks of adult muskellunge in Illinois lakes.

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

Introduction:

Genetically distinct stocks are becoming the operational unit in fisheries management to optimize performance on a regional scale. Understanding stock differentiation becomes increasingly important with a trophy species like muskellunge where 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 extirpated in many Illinois lakes and reservoirs, it is not clear which population to use in stocking efforts. Additional information is needed on differences in growth and survival among stocks in waters at varying latitudes within Illinois before management recommendations can be made on which stock is most appropriate.

Genetic analysis of muskellunge populations revealed three distinct clusters suggesting the existence of divergent stocks in the Upper Mississippi, Ohio, and St. Lawrence River drainages (Koppelman and Philipp 1986). Evolutionarily derived differences in physiology, morphology, and behavior between stocks of muskellunge have been suggested by previous research and similar differences have been documented in a number of other fish species. Such differences have been shown to affect performance characteristics, measured in terms of growth rate, survival, and maximum body sizes. Past research comparing source populations of muskellunge in Minnesota found differences in growth rate and maximum size between two genetically divergent populations native to Shoepack Lake and Leech Lake Minnesota (Younk and Strand 1992; Wingate and Younk 2007). As a result of these findings the Minnesota Department of Natural Resources switched its hatchery brood source from Shoepack to Leech Lake muskellunge greatly increasing performance (Wingate and Younk 2007). A similar study focused on two populations of muskellunge from within Wisconsin found a difference in growth performance attributable to both environmental and genetic components (Margenau and Hanson 1996). Research conducted by the Illinois Natural History Survey compared food consumption, metabolism and growth among populations of YOY muskellunge from each of the major stocks and found differences in growth and food consumption at temperatures from 15-27.5˚C (Clapp and Wahl 1996). The study of which this is a continuation found similar growth among fish from the Ohio River drainage stock, Upper Mississippi river drainage stock, and progeny of the Illinois hatchery system in Pierce Lake in northern Illinois and Lake Mingo in central Illinois (Wolter et al. 2011). We also found that Upper Mississippi River drainage fish showed poor survival in comparison to other stocks. The findings of this study have important management implications, however comparisons of growth and determination of the ecological mechanisms driving growth rates in muskellunge are incomplete due to poor survival of Upper Mississippi River drainage fish and limited sample sizes. In addition, the southern lake in the study, Lake Sam Dale, did not begin receiving annual stockings of muskellunge from the Upper Mississippi River drainage and Ohio River drainage stocks until 2005 due to concerns about VHS. Initial assessments suggest that survival of Upper Mississippi River drainage fish in Lake Sam Dale is higher than in other study lakes, but these data are based on juveniles and not adult fish. Two additional years of sampling in Lake Sam Dale in the current study will provide an opportunity to characterize growth rate of Upper Mississippi River drainage fish in Illinois through older ages and allow comparison among stocks in a more southerly reservoir. In addition to growth rate, maximum body size is a characteristic of interest when managing trophy fish like muskellunge. Bergmann's rule dictates that intraspecific variation in body size should show increased maximum body size in higher latitude populations and is supported by numerous taxa (Blackburn et al. 1999). The mechanism for this cline in body size may be nonadaptive, such as a physical restriction on cell size or cell differentiation rates, or it may be adaptive, related to timing of maturation or energy allocation (Angilletta et al. 2004). At this time it is not clear if differences in maximum body size exist among stocks of muskellunge. As the year classes of muskellunge included in this study reach older ages we will be able to monitor these differences.

Procedures:

We evaluated stocking success of three different stocks of muskellunge in three Illinois Lakes. Lakes in this study included Lake Mingo (Vermillion County), Pierce Lake (Winnebago County), and Sam Dale Lake (Wayne County). These reservoirs represent the climatic variation associated with latitude that exists throughout Illinois. The three stocks that were evaluated were from the Upper Mississippi River Drainage, the Ohio River Drainage, and from an Illinois source of mixed origins. Stockings from various source populations representing each stock were introduced into Lake Mingo since Fall of 2002, Pierce Lake since Fall of 2003 and Sam Dale Lake since 2005 (Table 101.2). At each stocking, all three stocks were introduced into each lake and attempts were made to stock as similar of sizes and condition of fish as possible. Subsamples of each source population 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). Muskellunge from each population were stocked at rates between 3.3-4.9 fish per hectare and a subsample of each population was measured in length (nearest mm) and weighed (nearest g) prior to each stocking. Each fish was given an identifying complete pelvic fin clip and freeze cauterization of the wound for later identification of the stock (Boxrucker 1982). In the fall 2004 we began freeze branding all stocked fish in an effort to improve age determination (in combination with scale ageing). The brand location differs by year.

To determine growth rates of juvenile fish (ages 0-2) we conducted nighttime pulsed DC boat-electrofishing from October through November and March through April annually from 2002-2012. Beginning in spring 2006 we began sampling adult muskellunge (ages 2+) with modified fyke net surveys in Lakes Mingo and Pierce, and in 2010 we began modified fyke netting surveys on Sam Dale Lake. Nets in Lake Mingo (N=11), in Pierce Lake (N=10), and in Sam Dale (N=10), were 3.8 cm bar mesh (1.5 in) and frames were 1.2 X 1.8 m with six 0.75 m hoops. During a two to four week period each spring on each lake nets were checked between 0800 and 1200 hour each day over surface temperatures from 7.0 – 11.0 ˚C. Upon capture the pelvic fin clip was used to identify the stock and population and caudal fin clips were used to conduct Schnabel population estimates within each sampling season (Ricker 1975). Scales were taken from all sampled muskellunge older than YOY (age-0) to determine age class. Muskellunge older than YOY were implanted with a Passive Integrated Transponder (PIT) tags prior to release to aid in future identification (Wagner 2007). Data were used to determine mean daily growth rates (g/d) and mean relative daily growth rates standardized by weight (g/g/d) among the stocks through age-1. Growth rates were analyzed using analysis of variance (ANOVA) models. General patterns in size-at-age (length and weight) and growth trajectory between stocks were compared using ANOVA models including terms for stock and year class at each age and von Bertalanffy growth functions (Beverton and Holt 1957). Where sample sizes allowed all analyses of adult growth were stratified by lake and gender. All analyses were performed with the SAS® System and P-values less than 0.05 were considered significant.

We compared survival rates among stocks by individual year class using adjusted catch-per-unit effort (CPUE) data (adjusted for stocking mortality) from electrofishing (juveniles to age-1) and spring modified fyke net surveys (adults ages 2+). ANOVA was used to compare survival among stocks stratified by year class and lake. Comparisons of survival to adulthood and annual survival between stocks are presented in this report. To estimate survival and evaluate potential differences between stocks we utilized CPUE data from spring fyke net samples collected during 2007-2011 (Lake Mingo), 2008-2012 (Pierce Lake) and 2010-2013 (Sam Dale). Catch rates were used to compare both survival to adulthood between stocks and annual survival of adult fish after age 3 between stocks and across years. To compare survival of each stock to adulthood an adjusted CPUE for each age class was calculated and compared among stocks within each lake using a blocked one way ANOVA (blocked by year class). Annual survival estimates for adult fish were calculated by the ratio of CPUE estimates in successive years for each age class (Ricker 1975). Analysis was restricted to adult muskellunge year classes (ages 3-7) because these were the year classes fully recruited to the gear (Ricker 1975). Mean annual survival rates of adult fish were then compared between stocks using paired t-tests on pooled survival estimates from ages 3-7 in each lake. Significance for all analyses was determined at $P \leq 0.05$.

Findings:

A total of 215 muskellunge were captured during 312 net-nights of modified fyke net sampling in Lake Sam Dale between 2010 and 2013 yielding an average of 0.69 fish per net-night. No study fish were captured in 2013 spring fyke netting efforts. Of the 215 muskellunge sampled over this period 106 were Ohio stock, 99 were Illinois stock, and six were Upper Mississippi stock. The largest muskellunge sampled during this period was 975 mm. Males represented 51% of the sampled muskellunge and females the other 49%. A total of 472 muskellunge were captured during 216 net-nights of modified fyke net sampling in Pierce Lake between 2007 and 2012, yielding an average of 2.19 fish per net-night. Of the 472 muskellunge sampled, 110 were Ohio drainage stock, 355 were Illinois stock and 8 were Upper Mississippi River drainage stock. The largest muskellunge captured over this period was 1023 mm. Males represented 70% of the sampled muskellunge and females the other 30%. A total of 419 muskellunge were captured during 532 net-nights of modified fyke net sampling in Lake Mingo between 2006 and 2011 (netting could not be completed on Lake Mingo in 2012 due to an unexpected overwinter drawdown followed by an extended period of low precipitation) yielding an average of 0.79 fish per net-night. Of the 419 muskellunge sampled over this period 146 were Ohio stock, 268 were Illinois stock, and four were Upper Mississippi stock. The largest muskellunge sampled during this period was 1069 mm. Males represented 51% of the sampled muskellunge and females the other 49%. Data from modified fyke net surveys was integrated with electrofishing data for calculations of growth and survival.

In Lake Mingo mean length-at-age was significantly different among stocks (ANOVA, $P < 0.01$). The Illinois stock and the Ohio River drainage stock were longer than the Upper Mississippi River stock at age-2. For male muskellunge there also was a significant difference in mean length at age-5 with the Ohio River drainage stock being significantly longer than the Illinois stock (ANOVA, $P < 0.05$). No differences were found among the stocks for female muskellunge through age-7. Few older fish and few Upper Mississippi River drainage fish limited our ability to make comparisons between stocks. In general all three stocks of muskellunge appear to be growing at similar rates in Lake Mingo. Mean weights of muskellunge in Lake Mingo were also significantly different among stocks at age-2 (ANOVA, $P < 0.01$) with the Illinois and Ohio River Drainage stocks being significantly heavier than the Upper Mississippi River Drainage stock. The three stocks of muskellunge appear to be growing at similar rates measured by their average weights through time. In general, few differences in mean weight-at-age were found among the stocks.

In Pierce Lake, male muskellunge from the Upper Mississippi River drainage stock were significantly longer than that of either of the other two stocks through age-4 (ANOVA $P = 0.02$). However, at ages 5 and 6 there were not statistically significant differences between stocks. Female age-3 Illinois fish were significantly longer than Ohio River drainage fish. No Upper Mississippi River drainage females have been sampled in Pierce Lake, limiting comparisons between all stocks. In general, Ohio River drainage and Illinois fish appear to grow at similar rates in Pierce Lake. No differences in weight were found among stocks in Pierce Lake at age-2. Female muskellunge showed a significant difference in weight at age-3 with the Illinois stock being heavier than the Ohio River drainage stock (ANOVA, $P < 0.05$) but there were no significant differences for older females at ages 4-6. Mean weight-at-age seemed to be similar among stocks in Pierce Lake although inferences on the Upper Mississippi River drainage stock are limited to males due to poor survival.

In Sam Dale Lake, Upper Mississippi River drainage muskellunge were significantly longer than Ohio River drainage muskellunge at age-2 with Illinois muskellunge intermediate (ANOVA, $P < 0.01$). Length-at-age was similar between Ohio and Upper Mississippi River drainage fishes at age-3 for both genders. At age-4 Ohio River drainage males were longer than Illinois males. Upper Mississippi River drainage fish were significantly longer than Illinois females at age-4 with Ohio River drainage females being intermediate. Upper Mississippi muskellunge were significantly heavier than Ohio River muskellunge at age-2 with Illinois muskellunge intermediate (ANOVA, $P < 0.01$). Weight-at-age was similar for age-3 fish across all stocks. At age-4 Ohio River Drainage males were heavier than Illinois males. Age-4 female weight-at-age was similar between all stocks. Comparisons of length and weight differences were not possible for age-5 fish due to limited number of older fish recaptured.

Examination of Von Bertalanffy growth functions fit to length-at-age data for each stock and gender of muskellunge revealed patterns similar to those based on mean length and weight. In Mingo, both male and female muskellunge from the Ohio River Drainage stock have lower lengths at ages 1-3 but then surpass Illinois males at ages 4-7, resulting in a higher asymptotic lengths for Ohio males than Illinois males. Pierce Lake showed male Illinois fish being longer than Ohio fish at younger ages although asymptotic lengths are nearly identical. The growth trajectory of female muskellunge in Pierce Lake was generally also similar among stocks. No differences in asymptotic length or growth coefficients were found between stocks. A growth function was also constructed for Upper Mississippi River drainage fish in each lake, but because of low survival male and female muskellunge were pooled to allow for estimates of growth. The Upper Mississippi River drainage function shows a growth trajectory very similar to the other two stocks with similar asymptotic lengths and growth coefficients. Collectively these analyses show similar growth trajectories for all three different muskellunge stocks in both Mingo and Pierce Lakes (e.g. Figure 101.2). Von Bertalanffy growth curves could not be completed for Sam Dale Lake because few fish survived long enough to complete these estimates.

We compared survival to adulthood (age-3) in Lakes Mingo, Pierce, and Sam Dale among stocks across year classes (Table 101.3). In Lake Mingo, Ohio River Drainage fish had significantly higher survival to adulthood than Upper Mississippi River drainage fish (ANOVA, P = 0.03). Survival of the Illinois population muskellunge was intermediate. There was no significant difference in survival to adulthood in fish stocked into Pierce Lake (ANOVA, P = 0.23). There were also no significant differences in survival to adulthood in fish stocked into Lake Sam Dale (ANOVA, P = 0.16). In general, there were few survival differences through age 3 with the exception of lower survival of Upper Mississippi River drainage fish in Lake Mingo.

Data from spring fyke net surveys conducted on Lakes Mingo, Pierce, and Sam Dale allowed estimation of annual survival rates for adult muskellunge ages 3-6+ in all lakes. In Lakes Mingo and Pierce estimates could be calculated for Illinois and Ohio River drainage stock but not the Upper Mississippi River drainage stock due to low survival. In Lake Sam Dale annual survival of all three stocks could be compared. Average annual survival estimates for adults in Lake Mingo was for the period from 2007-2011. Average annual survival in Lake Mingo was 57% for the Ohio River drainage stock and 54% for the Illinois population. No significant difference in average annual survival of adult muskellunge between the Illinois population and Ohio River drainage stock were found (Paired-t = -0.35; P = 0.37) and the mean annual survival estimates for both populations were very similar. The average annual survival estimate in Pierce Lake was 50% for the Illinois population and the Ohio River drainage stock. Adult Upper Mississippi River drainage fish were captured in low numbers, limiting our ability to describe annual mortality. Paired t-test analysis did not find a significant difference between the Illinois population and the Ohio River drainage stock (Paired t = 0.9; P = 1.0). The average annual survival in Lake Sam Dale was 16% for the Illinois population, 21% for the Ohio stock, and 7% for the Upper Mississippi River stock. These rates of survival were not significantly different from one another (ANOVA, P = 0.68). No differences were observed in survival between Ohio and Illinois stocks in all study lakes. Low survival of the Mississippi stock was observed in all three lakes limiting the ability to calculate survival rates.

Recommendations:

This segment concludes this job and we have reported final findings. We found a pattern of very similar growth trajectories and few differences in mean length or weight at older ages between all three stocks. There is some evidence that the Upper Mississippi River drainage stock is longer than the other stocks at older ages in Pierce Lake. Coupled with slightly slower growth of Ohio fish, these findings support the hypothesis of thermal adaptation to explain growth patterns in muskellunge. The natal climate of the Ohio River drainage stock is generally more similar to Lake Mingo than Pierce Lake. Under the assumptions of the thermal adaptation concept, it would be predicted that the Ohio River drainage stock would exhibit better performance in Lake Mingo than in Pierce Lake, which agrees with our results. However, results from Sam Dale Lake, the southernmost lake included in the study, also show Upper Mississippi fish growing faster across several age classes. If this pattern continued through older age classes it would provide evidence to support the countergradient variation theory which states that fish from northern latitudes should grow faster across all thermal environments. However, based on current results, the conclusion is no difference in growth among stocks at any latitude within Illinois.

We found similar survival between the Illinois population and Ohio River drainage muskellunge and much lower survival for the Upper Mississippi River drainage stock in all lakes. During spring netting surveys of adult muskellunge, the Illinois population and the Ohio River drainage stock were consistently represented at similar levels in catches. In contrast, few Upper Mississippi River drainage muskellunge were sampled beyond age-1 in all three lakes. The recapture rate of Upper Mississippi River drainage stock muskellunge in most cases was too low to allow quantitative comparisons with the other stocks. Limited recaptures of Upper Mississippi River drainage fish in Lake Sam Dale allowed some comparisons that also indicated lower survival of this stock, but there was low statistical power associated with these tests.

Survival of all stocks in all lakes was typically lower between 2011 and 2013 than in other years. All three study lakes occur on reservoirs meaning that dam escapement is a possible source of fish loss that could explain some reduction in CPUE in these waterbodies. The spring of 2011 and 2013 had above average precipitation leading to sustained periods of water discharge from all three study lakes. We monitored escapement during this time on Mingo and Sam Dale Lakes and results are summarized in Job 104.2. While other factors including warm summer temperatures, predation, or delayed mortality from catch and release angling likely contribute to annual mortality of muskellunge populations in Illinois, dam escapement should also be considered to be a factor influencing populations.

No major differences were evident in growth among the different stocks and all these stocks of fish will reach desirable size for anglers. The Upper Mississippi stock had the lowest survival of the three and large fish were rarely recaptured. Despite angler belief that this stock has the greatest trophy potential, it would not be preferred for establishing a fishery in Illinois. The Mississippi stock fish we did recapture did not have higher growth rates and when we could estimate Von Bertalanffy growth curves, they did not have greater potential for larger maximum length. However, we do not recommend stocking Mississippi stock fish in Illinois based on the experimental evidence from this study. The Illinois stock performed similarly to the Ohio stock in both growth and survival as predicted since the Ohio fish were from a similar latitude and temperature regime as Illinois. The results of this study suggest no reason for a change in stocking practices in Illinois unless there is a desire to use a pure stock rather than the current mixed stock. Most likely the Ohio fish from initial fish acquisitions by the state experienced the greatest survival and the current Illinois stock is comprised of primarily these fish. However, this cannot be verified without additional genetic work.

Job 101.3: Evaluation of crappie stocking success in Illinois lakes and rivers.

Objectives: To determine the survival and growth of stocked crappie.

Introduction:

There has been recent interest in producing crappie in hatcheries in Illinois for stocking and there have been some recent examples of crappie stocking through propagation in lakeside rearing ponds. Little is known about the survival, growth, and contribution of these stocked fish to the adult population and their benefits to the fishery. Blacknose crappie have been used in recently in an attempt to evaluate the success of crappie stockings. Blacknose crappie are a phenotypic variant of black crappie characterized by a dominant predorsal black stripe. Blacknose crappie occur naturally in at least 13 states, but rarely in Illinois (Buchanan and Bryant 1973). When stocked in Illinois waters, the black stripe can be used to differentiate stocked fish from naturally produced individuals. There is some suggestion that blacknose crappie are a more durable fish and therefore more suitable for stocking due to increased survival and growth in hatchery environments, but this has not been directly tested. Black crappie are more common in southern latitudes and may not be appropriate for stocking throughout Illinois. In addition, little is known of the effects of propagated blacknose crappie interbreeding with natural white and black crappie found in Illinois lakes. There is a need for evaluation of crappie stockings as well as the use of blacknose crappie in Illinois stocking efforts. We are addressing these needs in the current job.

Crappie stocking is an increasingly common management practice in Illinois, and has been employed in other states to enhance populations (Racey and Lochmann 2002). Success of crappie stockings can be variable and first year contribution of stocked blacknose crappie has varied from 0 to 93% in several lakes in Tennessee and was lake dependent (Isermann et al. 2002). Contribution of stocked fish to the population was reported to be low for both black crappie in a Florida lake (4.8%; Myers et al. 2000) and white crappie in an Arkansas lake (0 to 3.8%; Racey and Lochmann 2002). Handling mortality during stocking can contribute to low success of stocking and can account for as much as 67% for white crappie (mean 23%) in the first 24 hours after stocking (Racey and Lochmann 2002). Difficulty harvesting fish from ponds was reported as a main source of handling mortality in a number of experiments rearing black crappie (Racey and Lochmann 2002; Smeltzer and Flickinger 1991; Martin 1988). Initial stocking mortality has been reported lower for blacknose crappie (13%; Isermann et al. 2002) and black crappie (7%; Meyers and Rowe 2001). Variable success of crappie stocking may reduce the utility of stocking to enhance crappie populations. In addition, crappie are prolific breeders and production of natural fish may not be a limiting factor to crappie recruitment, reducing the benefit of stocking fish.

Most evaluations of stocking success in crappie use oxytetracycline (OTC) to mark stocked fish for future identification (Conover and Sheehan 1996; Isermann et al. 1999; Isermann et al. 2002; Racey and Lochmann 2002). Retention rate for OTC marks is high (Conover and Sheehan 1996; Isermann et al. 1999; Isermann et al. 2002; Racey and Lochmann 2002), but identification of stocked fish marked with OTC is labor intensive and requires that the fish is killed and the otoliths removed and examined under a scope with an ultraviolet light source. Blacknose crappie are easily distinguished from black crappie via the unique black line running along the dorsal side of the head to the nose (Buchanan and Bryant 1973). Because they can be easily identified, blacknose crappie have been used as a mark in studies evaluating stocking success and OTC mark efficacy (Isermann et al. 1999), but it requires that no blacknose crappie are present in the lake and previously stocked blacknose crappie are not reproducing. In addition not all blacknose crappie produced in ponds retain the mark potentially further confounding their use in stocking (Isermann et al. 2002; Parsons and Meals 1997). There is need to evaluate stocking success of crappie in Illinois as well as the use of blacknose crappie in studies evaluating stocking success.

Procedures:

In this segment, we are conducted pond experiments to evaluate differences in growth and survival among juvenile black, white, blacknose, and blacknose "hybrid" (male blacknose x female black) crappie. Ponds (0.4-ha) at the Sam Parr Biological Station were stocked in the spring of 2013 with different species/strains of adult crappie. Ponds were stocked with 32-48 broodfish, in equal numbers of males and females. Ponds were stocked in four treatments, white crappie alone, black crappie alone, blacknose crappie alone, and with a mixture of male blacknose and female black crappie. In the fall, ponds will be drained and fish will be collected for use in pond experiments. At that time we will evaluate the prevalence of the blacknose mark in the blacknose and blacknose hybrid ponds.

Fish from the rearing ponds will be stocked into experimental ponds for assessment of stocking success. We will evaluate differences in growth and survival of juvenile black, white, and blacknose crappie. Ten experimental ponds (0.04-ha) will be stocked with age-0 crappie of each of these three strains produced in rearing ponds. The number of fish and biomass of age-0 fish of each species/strain will be held constant for all ponds (N=120 of each species/strain, 9,000 fish/ha), within the range of natural densities of juvenile crappie (173-10,456 fish/ha; Mitzner 1981). Abundance, length (mm), and weight (g) of age-0 crappie will be recorded at the time of stocking and after a three-month period to determine relative growth and survival among the three strains/species.

Any additional black, white, and blacknose crappie will be stocked into Ridge Lake to assess differences in growth and survival. There are currently no crappie populations in Ridge Lake and we will evaluate growth, survival and reproduction of the three types of crappie. We will conduct spring and fall electrofishing as well as monitor prey resources using the methods outlined in Job 103.1. In future segments, we will attempt to identify additional lakes to use in evaluating success of crappie stockings.

We will assist in evaluation of blacknose crappie stocking in the Starved Rock pool of the Illinois River. In this segment, Jake Wolf Memorial Fish Hatchery began rearing blacknose crappie for stocking in the Illinois River near Ottawa, IL. Brood fish were collected from Clinton Lake and placed in rearing ponds. The number of fish stocked will depend upon the production from the pond. We will conduct electrofishing, mini fyke netting, seining, and gill nets in the river to assess the survival and growth of stocked blacknose crappie in the Illinois River. We will evaluate the potential for these stockings to create a viable fishery.

Findings:

In this segment, we successfully produced juvenile white, black, blacknose, and black x blacknose hybrid crappie in the rearing ponds. In the next segment, we will stock and evaluate the relative growth of age-0 white, black, and blacknose crappie in experimental ponds. Brood stock were also collected for stocking in rearing ponds at the Jake Wolf Memorial Fish Hatchery. Fall sampling will be conducted to evaluate stocking success.

Recommendations:

Research on crappie stocking success will provide information on its utility as a management technique for increasing crappie populations. We will compare juvenile blacknose crappie growth and survival to black and white crappie both in the rearing environment and in lakes to determine if they are a viable option for stocking in Illinois as well as for use in identifying stocked fish. Despite anecdotal claims that blacknose crappie are more adaptable to hatchery conditions and a faster growing strain, no studies have compared blacknose and black crappie growth rates. Pond experiments will allow us to identify issues related to integrating blacknose crappie into the breeding population of white and black crappie and how this could affect management. Ultimately these results will have a direct influence on management of crappie populations in Illinois.

We will attempt to identify lakes for crappie stocking based on need determined by IDNR biologists and interest in continuing research. Lakes will be sampled two times in both spring and fall to determine growth and survival of the stocked fish and their contribution to the native crappie population. We will continue stocking for multiple years in order to replicate measurements of stocking success and examine factors that influence variability in survival and growth. We will provide management recommendations for the use of black and blacknose crappie stocking to enhance crappie populations.

Study 102: Harvest, Regulations, and Tournaments

Job 102.1: Evaluation of effect of largemouth bass harvest regulations on population structure in Illinois lakes.

Objectives: To evaluate the effects of various angling regulations on Illinois bass recruitment and size structure.

Introduction:

Angling is a popular recreational activity where fish are caught and either released, or harvested for food. Unregulated harvest of fish populations can result in overexploitation resulting in undesired density or size of fish. Harvest regulations are one of the more common management tools utilized to maintain or improve sport fisheries. However, changes in fish populations as a result of a regulation are rarely assessed. When regulations are assessed, they are generally in one lake or are not long-term enough to adequately measure changes in size structure and abundance. Regulations must be obeyed and require both angler cooperation and enforcement by conservation police. In addition, these regulations require harvest rates great enough to produce the desired effect. Largemouth bass are commonly released after capture and the general fishery is more catch-and-release oriented.

Angling regulations are a commonly used management tool for sustaining or improving sport fish fisheries. Increasing the quality of angler catch or harvest rates are common rationales for harvest regulations (Paukert et al. 2007). However, compilation of 91 studies using minimum-length limits and slot-length limits concluded that most studies evaluating regulations were conducted over too short a period and did not include creel data to document if a regulation increased angler catch rates (Wilde 1997). Both recruitment variation and the length of the evaluation can influence the ability to detect changes in a fish population due to a regulation (Allen and Pine 2000). Crappie and largemouth bass are commonly managed using minimum length limits (Buynak et al. 1991; Colvin 1991; Webb and Ott 1991; Wilde 1997; Maceina et al. 1998), but a wide variety of other regulations are also being used in Illinois. Potential regulations include bag limits, maximum size limits, minimum size limits, slot limits, bag limits that vary by the size of the fish, and catch-and-release only. Many of these regulation types are even less understood and there is a need for evaluation across a number of lakes and species.

A wide variety of largemouth bass regulations have been utilized to manage their populations. The most commonly used regulations are minimum size and protected slot limits (Wilde 1997; Paukert et al. 2007). The goals of using minimum size and slot limits include increasing abundance and size structure of largemouth bass resulting in an increase of larger fish available for anglers (Anderson 1976; Eder 1984; Dent 1986; Redmond 1986; Richards 1986). Length limits are the most common regulation for largemouth bass and are designed to allow a fish to spawn at least once before being harvested and reduce overall harvest (Redmond 1986). Slot limits have been utilized when largemouth bass populations are extremely slow growing and there is an overabundance of small fish (Anderson 1976; Eder 1984). Slot limits allow the harvest of small fish while protecting fish that have grown out of the crowded size class, yet still allowing anglers to harvest larger fish. Both of these regulations have associated bag limits where the total number of fish harvested is limited to a certain number to avoid overexploitation. Case studies of these regulations have shown variable success and when examined in a meta-analysis, protected slot limits were more effective at increasing size structure, while minimum size limits increased catch rates (Wilde 1997). There have been many examples of minimum size limits maintaining or increasing growth or catch of largemouth however often times growth can decrease and abundance of desired size of fish does not improve (see Wilde et al. 1997). Largemouth bass regulations often do not achieve the desired changes and without monitoring and evaluation could cause undesired effects. In order for regulations to be effective, managers need to have specific goals that incorporate the recruitment, growth and mortality of largemouth bass and conduct studies to evaluate changes (Novinger 1984; Johnson and Martinez 1995). Many regulation decisions are not influenced by information available on black bass biology (Paukert et al. 2007). There is a need for further research examining the effects of angling regulations (Novinger 1984; Wilde 1997; Paukert et al. 2007). In previous studies, we began to compile data on a number of regulations. In the current study, we continue to expand the database and evaluate the use and success of the different regulation employed in Illinois. We will provide management recommendations based on the results of this analysis that can help guide future management.

Procedures:

We evaluated largemouth bass regulations utilized in Illinois lakes. In this study, we compiled ten years of data collected by Illinois DNR biologists in fall electrofishing samples. Fall electrofishing data from 2002 through 2012 was acquired through the FAS database and mean catch rates were calculated for largemouth bass for all sampling that occurred in this period. Data was only included in the analysis if it was sampled using AC shoreline electrofishing conducted in the fall. The lakes were categorized using their existing regulations into eight categories, over/under (bag limit above and below a specified size), catch-and release (no harvest allowed), standard (14" length limit, 6 fish creel), lowered bag (14" length limit, < 6 fish bag limit), raised length (>14" length limit, 6 fish bag limit), raised length/lowered bag (> 14" length limit, < 6 fish bag limit), no length (no minimum size limit, 6 fish bag), and slot (no harvest slot). These lakes were then compared across regulation type for differences in CPUE of young-of-year largemouth bass, largemouth bass greater than 14 inches, and proportional stock density (PSD) with stock size being 200 mm and quality size being 300 mm. In addition we determined the number of preferred (> 379 mm and < 510 mm) and memorable (>510 mm) sized fish in electrofishing samples. We used ANOVA to determine if there were any significant differences in catch rates among the different regulations for each size class of largemouth bass.

Findings:

We summarized 10 years of FAS data to evaluate electrofishing catch rates and size structure of largemouth bass among differing management regulations. We calculated CPUE from fall electrofishing in all lakes reported in the FAS database from 2002 - 2012 resulting in catch rates for 230 lakes. Regulation data was then compiled from the Illinois Department of Natural Resources (IDNR) fishing regulations guide for these same lakes. Regulations were grouped into 8 categories (Table 102.1). The most common regulation was that of no length limit with a 6 fish bag limit. This is the regulation in place if there is no specified regulation in the Illinois fishing regulations and therefore most lakes are not being managed differently than the state default. The second most common regulation type was the raised length and lowered bag limit. When biologists are imposing regulations on a lake in an attempt to manage largemouth bass populations, they tend to impose more restrictive regulations probably due to a perceived problem with the fishery. The standard regulation is the third most common regulation with a 14-inch length limit and 6 fish bag limit. Slot, lowered bag, catch and release, and raised length limits were utilized the least in Illinois.

We examined differences in largemouth bass catch rates among the 6 of 8 different regulations. Over/under and catch and release regulated lakes were removed from the analyses due to the low number of lakes in these treatments (n = 2). Despite the different regulation types on Illinois lakes, there were no resulting differences in largemouth bass populations among regulation categories. Slot limit lakes had the highest overall CPUE for largemouth bass followed by no length, however, there were no significant differences among regulation types (F = 1.06; P = 0.38; Figure 102.1). Slot and No length regulations also had the highest number of young-of-year largemouth bass with No limit being the highest, but again no significant differences were observed (F = 1.58; P = 0.17; Figure 102.1). Raised Length limits had the highest catch rates for both largemouth bass over 14 inches and preferred sized fish, followed by no length and standard regulations, but no significant differences were detected (Over 14" F = 0.69; P = 0.63; preferred F = 0.77; P = 0.57; Figure 102.2). There were also no significant differences among regulations for fish of memorable size (F = 0.82; P = 0.54). Slot limits had the highest CPUE of memorable fish, but due to the high variation, it was not significantly different from other regulations (Figure 102.3).

Recommendations:

There are many potential harvest regulation strategies that can be used to help manage sportfish populations, including size limits, closed seasons, and spawning refuges. Each of them can have a different impact on the population, either by affecting size structure or density. Some regulations have the potential to impact recruitment more than others, but right now, we cannot make accurate predictions. This study has begun to provide information on the success of regulations on largemouth bass populations throughout Illinois. Regulations vary greatly in Illinois reservoirs. Our analysis thus far shows that no apparent differences exist in the catch rates of different size classes of largemouth bass. We expected to find some differences among lakes that are not intensively managed and those with restrictive regulations. Slot limits are in place to protect fish in a vulnerable size class and you would either expect these fish to be found in a density different than lakes that do not require this regulatory action. There is a good deal of variation among largemouth bass populations over a ten year period both within lakes and among those with similar regulations. Variation among lakes could mask differences between regulation types. In addition, we do not know the level of harvest largemouth bass populations are undergoing. Catch and release angling is very common for largemouth bass, but many regulations require some level of harvest to be successful (e.g. slot limits). If restrictive regulations do not reduce the level of harvest either because anglers are not compliant or little harvest occurs regardless of the regulation, you would not expect to observe differences among regulations. Future segments will explore the role of harvest of largemouth bass and how harvest differs among regulations.

Future research should examine time series data to determine how populations change as regulations are implemented. If possible, data before and after regulation changes should be examined and the length of time a regulation has been implemented will be evaluated. We plan to continue this research in future segments. We will utilize creel data that is available as part of F-69-R to determine the level of harvest associated with each regulation and if harvest rates are high enough to induce changes in fish populations. We will continue to incorporate lakes with FAS data and INHS sampling to develop a long term database of lakes with fish community data and creel sampling. The number and frequency of lakes where angling creels were performed will limit the number of lakes that can be included in this aspect of the study. We will create an extensive database that can be used to examine differences in electrofishing catch, and a reduced database including creel data. We will contact DNR district biologists and determine when regulations were initiated and use creel and FAS data to compare catch rates of anglers, CPUE from electrofishing and size structure of largemouth bass in these lakes before and after the regulation were put in effect. In doing so, we hope to better understand the value of differing management regulations on lakes throughout Illinois. These data can then be used to guide future discussions about various management experiments that might be implemented.

Job 102.2: Evaluation of crappie harvest regulations in Illinois lakes.

Objectives: To evaluate the success of current harvest regulations in managing for or maintaining quality crappie fisheries in Illinois.

Introduction:

Crappie anglers primarily fish for harvest and release is limited to small fish or those protected by a regulation. Differences in regulation types and their success can be expected between crappie and other species such as largemouth bass. There are a large variety of angling regulations on lakes throughout Illinois and very few statewide guidelines are available for management regulations on a lake for these species. There is a need for studies involving multiple lakes with long-term databases to determine the success of different types of regulations throughout the state of Illinois. This study will provide data for use in developing regulation standards and guidelines for Illinois.

Crappie regulations were rarely used for crappie populations prior to 1990 because of the worry of limited harvest leading to high densities of stunted fish (Mitzner 1984; Webb and Ott 1991). Managers began more recently to incorporate minimum length limits to lower fishing mortality and protect larger fish (Bister et al 2002). Minimum length limits have been shown to increase the catch rates of larger crappie as well as mean size in some systems (Colvin 1991; Webb and Ott 1991). However, limiting harvest can cause adverse effects if prey resources are limited or natural mortality is high (Colvin 1991; Larson et al. 1991; Reed and Davies 1991; Allen and Miranda 1995; Hale et al. 1999; Bister et al. 2002). Crappie regulations can be difficult to evaluate because of the high variation in recruitment (Colvin 1991; Maceina et al. 1998; Allen and Pine 2000). A number of additional regulations exist for crappies in Illinois that have not been as well studied, including size specific bag limits. Size specific bag limits control the number of fish that can be harvested both above and below a particular size. There is a need for evaluation of regulations currently in use in Illinois using long-term data on multiple lakes.

Procedures:

In this segment, we obtained electrofishing data from the FAS database from IDNR biologist sampling. Electrofishing data from 2002 – 2012 was compiled and included in the analysis. Lakes were included if they were electrofished with AC at any time during the 10 year period. CPUE was calculated separately for black and white crappie and the mean was reported for all years of sampling. CPUE was calculated for different size classes of crappie based on the American Fisheries Society categories derived from angler preference. The size categories were: Total (all fish), stock (130 - 199 mm), quality (200 - 249 mm), preferred (250 – 299 mm), memorable (300 – 379 mm), and trophy (380 mm and over). CPUE of different size classes of black and white crappie were compared among different regulations to evaluate their effectiveness. Regulations were summarized for all lakes in Illinois from the 2012 Illinois Fishing Information guide distributed by the IDNR Division of Fisheries. Regulations were categorized into groups based on how they limit angler harvest. The categories were bag (limits the number that can be harvested), length (limits the size that can be harvested), length/bag (limits both size and number), over/under (limits the number that can be harvested above and/or below a certain size), and no regulation (not limited). CPUE of crappie was compared among regulation groups using ANOVA and differences were parsed using least squared means.

Findings:

In this first segment, we analyzed the historical data from 2002 to 2012 for electrofishing from the FAS database in order to understand how crappie populations vary among regulation types. Eliminating lakes that had not been sampled or where crappie were not present in samples resulted in a database of 327 lakes. Of these lakes, 46 had only white crappie present, 137 had only black crappie present, and 144 had both species present. Mean CPUE of crappie in the study lakes was 127.8 fish per hour of electrofishing. White crappie were captured at a higher rate than black crappie (127.8 fish/hour and 73.8 fish/hour, respectively) and the abundance of both species decreased with increasing size category (Table 102.2). A majority of lakes in the analysis have no crappie regulations and the most common regulation types were the bag limit and length/bag limit (Table 102.3 A.). Bag limits ranged from ranged from 5 -30 fish per day and length limits were either 9 or 10 inches (Table 102.3 B). Five lakes have under/over limits, which allow for a certain number of fish under and over a designated length to be kept. Schuy-Rush Lake is the only lake in the state with a length limit but no bag limit. Due to the low number of length only limits and over/under, they were excluded from the comparison of regulation types. There were significant differences in total CPUE among regulation types ($F = 8.75$; $df = 2, 319$; $P = 0.0002$; Figure 102.4). We found that lakes with length/bag regulations have significantly higher CPUEs than lakes with bag limits ($t = 2.13$; $P=0.034$) or lakes with no regulations ($t = 4.15$; $P < 0.0001$). CPUE of crappie from lakes with bag limits was not different than unregulated lakes ($t = 0.89$; $P = 0.38$). Proportional stock density (PSD) was calculated for all lakes and then compared across regulations but no significance was found within individual species or when combining both species.

Recommendations:

Several regulation types are currently in effect for crappie in Illinois, but little is known about how successful they are at improving population abundance or size structure. It is possible that certain regulations could work better on some lakes more than others, or could serve different means (numbers versus size). In future segments we will incorporate FAS fyke net data from IDNR sampling to better evaluate crappie catch rates. We will examine differences in size structure among regulation types to determine if there are differences in quality, preferred of memorable crappie depending upon regulation. We will also examine differences between black and white crappie populations to determine if the species respond differently to regulations. Time series analyses are limited by their lack of a control. To address these limitations, we will examine lakes where regulations have changed using a before/after/control/impact (BACI) design and determine if regulations affect crappie populations. We will attempt to incorporate creel data when available to determine the amount of harvest and how regulation relates to catch rates. Findings will be used to make recommendations regarding different regulations and how they affect a crappie population. With this work, we hope to develop a framework for crappie regulation management that can be used to maintain and improve crappie fisheries throughout the state.

Job 102.3: Assessing the impact of tournament angling on largemouth bass populations.

Objectives: To assess the impact of tournament angling on largemouth bass populations.

Introduction:

In addition to recreational angling, a substantial competitive tournament fishery for largemouth bass has developed and has grown rapidly over the past several years. Previous work has shown high levels of mortality associated with these tournaments in other parts of the United States, but tournament procedures continue to improve. In addition to mortality, several sub lethal effects of tournament angling have been identified and can contribute to reduced growth and fitness of fish. Tournaments conducted during the spring have been shown to cause abandonment of nests when male bass are removed by anglers, resulting in reduced or no reproductive output from the nest. It is unknown if failure of nests that were influenced by tournaments can result in reduced recruitment on a whole lake scale. It is also unknown what the combined effects of tournament mortality, stress, and nest abandonment can have on a fish population and the life history traits of individual fish. These effects could vary depending upon the number and size of tournaments and what time of year tournament activity is conducted. There is a need to evaluate largemouth bass populations in lakes where spring tournaments exist as well identify how the intensity of tournament activity can influence largemouth bass populations.

The growth in the popularity of competitive angling events targeting black bass has been substantial in the United States over the last 40 years with exceptional growth occurring in the past decade (Duttweiler 1985; Schramm et al. 1991; Kwak and Henry 1995; Noble 2002). Highlighting this recent growth, about 18,000 events were estimated to occur in North America in 2000 whereas over 32,000 were estimated to occur in 2005 in the United States alone (Kerr and Kamke 2003; Schramm and Hunt 2007). Although tournament rules require the release of captured bass following the conclusion of the "weigh-in," high mortality (>50%) has been reported during tournaments within the last 10 years (Neal and Lopez-Clayton 2001; Gilliland 2002; Wilde et al. 2002), necessitating investigations into strategies to minimize mortality during these events. Mortality can be capture-related (i.e. hooking mortality) but can also be due to the collective impact of several sub-lethal stressors incurred by bass throughout the tournament process (Kwak and Henry 1995) such as the disturbances sustained during livewell confinement or the weighing procedure. In addition, the sub-lethal physiological disturbances incurred by bass that ultimately survive the tournament process can negatively impact growth (Wendelaar Bonga 1997) and fitness (Schreck et al. 2001; Ostrand et al. 2004) and increase susceptibility to disease (Pickering et al. 1989). Clearly, identifying factors that influence the sub-lethal and lethal consequences of tournaments on largemouth bass and potential avenues to mitigate these impacts is important for the sustainable use of bass fisheries.

Removal of spawning males by angling has been shown to reduce the reproductive success of an individual largemouth bass, often causing brood reduction and nest abandonment (Philipp et al. 1997; Diana et al. 2012). However, the population-level impact of reduced reproductive success of some individuals is unclear. In the spring, male largemouth bass build solitary, highly visible (depending on water clarity) saucer-shaped nests in the substrate in order to court and spawn with females (Kramer and Smith 1962; Pflieger 1966; Coble 1975). Once spawning is completed, females leave the nesting area and the male remains to provide all parental care of the developing offspring, a period that may last four or more weeks (Ridgway

1988; Cooke et al. 2002). While male bass are providing parental care for their broods, they are extremely aggressive (Ridgway 1988; Cooke et al. 2002) and, therefore, highly vulnerable to many angling tactics (Neves 1975; Kieffer et al. 1995). Even though this vulnerability has never been assessed accurately, many fisheries management agencies have invoked closed fishing periods, catch-and-release regulations, and various length and harvest limit scenarios in an effort to enhance or promote bass reproduction and recruitment (see Schramm et al. 1995). The strategy of maximizing reproductive success by protecting successful spawning bass from angling assumes that there is a positive relationship between reproductive success and recruitment, which has not been specifically determined. Also, density-dependent interactions in young-of-the-year largemouth bass may cause populations to compensate for the lost reproductive success of some individuals. Models have demonstrated the potential for tournament angling to cause a high level of mortality when tournament catch exceeds harvest (Allen et al. 2004). In previous studies, we have shown that tournament angling of nest guarding largemouth bass cause almost all individuals to abandon the nest (Diana eta al. in 2012). We have also demonstrated that when these individuals abandon the nest, there is a reduction in total recruitment and year-class strength in ponds (Diana et al. 2011). However, there is a need to assess the population level consequences of angling fish from the nest in lakes. Little is known about how varying tournament angling pressure can influence the life history traits of largemouth bass populations and the population implications of these effects.

Procedures:

Tournament angling for largemouth bass has been shown to cause nest abandonment for fish angled off the nest. However the population level effects of nests abandonment have not been examined. In this study we conducted an experiment at Ridge Lake examining the effects of tournament-style angling of nesting largemouth bass in a population previously unexploited during the spawning season. Ridge Lake has a controlled creel operated by the Illinois Natural History Survey. The lake has traditionally been closed to fishing until mid-May and no tournaments have been conducted at Ridge Lake prior to the beginning of this experiment. In this segment we conducted spring largemouth bass tournaments during the period of bass spawning as an additional year of tournament treatments at Ridge Lake. These tournaments were combined with those conducted in the early spring of 2007 and 2010 during the spawning season (April 22 - May 22, 2007; April 17 – May 17, 2010) on Ridge Lake, prior to the opening of the regular public angling season. During each tournament, anglers fished for four hours targeting largemouth bass. All fish caught were brought back to the dock, measured for total length, weighed, and scales were collected. The fish were then kept in a lakeside pen for 2 hours following the tournament when they were released back into the lake. Recruitment of largemouth bass was measured as the relative CPUE from fall electrofishing samples and mean density of young-of-year largemouth bass collected in seines in late August and early September. Additionally, a complete creel census has been conducted on Ridge Lake during the open angling season of each year. Prey resources were also monitored at Ridge Lake throughout the season (zooplankton, larval fish, seine, benthos cores, and water quality; see job 103.1 for detailed methods). We will monitor largemouth bass populations and prey resources in Ridge Lake through both tournament and non-tournament years and examine the relationship between spring angling tournaments and lake wide recruitment. No tournaments were conducted in 2006, 2008, 2009, 2011, and 2012 and these years will be used as a comparison with the years where tournaments were conducted.

We continued to evaluate how varying tournament pressure is related to the population abundance and size structure of largemouth bass populations. We identified sixteen lakes where we could obtain information on largemouth bass tournaments. Electrofishing transects were performed in each lake in the spring of 2013 and many lakes have data from electrofishing transects back to 1998. On each sampling date, largemouth bass were collected, measured for total length and weighed. Scales were collected from each largemouth bass and were aged by two independent readers to determine mean length at age for fish in each lake. In spring electrofishing samples, sex was determined when possible as well as maturity status (mature or immature) and spawning status (ripe, running, or spent). Largemouth bass were collected from each lake for size ranges that were too small to determine sex and maturity status in the field and returned to the laboratory. Catch per unit effort was calculated for largemouth bass of all sizes, young-of-year (< 200 mm), larger than 14 inches (> 355 mm), or memorable (> 509 mm or 20 inches). Tournament pressure was determined for lakes where we could identify all tournament activity on a lake. In this segment, results from largemouth bass tournaments were obtained for 2012 and discussions were conducted to arrange for data collection in 2013. We coordinated with DNR biologists, lake managers and tournament organizers to obtain records of all tournaments conducted on a number of lakes. We also worked with tournament organizers and lake managers to obtain tournament results and weigh-in data for all tournaments conducted. In addition we obtained past data from additional lakes and included them in the analysis, expanding our past database. Data was combined and summarized to create mean tournament activity and demographics for each lake. When all weigh-in results were not available, we estimated them using similar tournaments from the same lake. We examined the intensity of tournament activity at each lake and evaluated the abundance and size structure of the associated largemouth bass population. This information was used to categorize lakes as high tournament pressure, low pressure, or no tournament pressure lakes. We compared fish populations and recruitment of largemouth bass among these categories to determine how they are related to tournament pressure.

Findings:

In this segment, we conducted spring tournaments on Ridge Lake from 4/23/2013 through 5/19/2013. A total of 140 largemouth bass were angled over 196 angler hours in 10 tournaments resulting in a catch rate of 0.71 fish per angler hour. Angling pressure was similar to that observed in other Illinois lakes and should result in similar effects on largemouth bass communities. Largemouth bass were observed on the nest and during this period many fish were caught off the nest, resulting in potential for brood loss. Data from the 2013 tournaments were combined with those conducted in the spring of 2007 and 2010 on Ridge Lake. In 2007, 7 tournaments were conducted and anglers caught 448 largemouth bass over 168 angler hours for a mean tournament CPUE of 2.67 fish/angler-hour (range 1.00 – 4.42 fish/angler-hour). In 2010 a total of 7 tournaments were conducted and the average angler hours per tournament was 22.3 hours. The anglers caught 167 fish totaling 180.9 pounds. Recent population estimates at Ridge Lake averaged 311 largemouth bass suggesting a large portion of the spawning fish were captured in the three years of tournament angling and that the spring tournament angling is affecting a majority of the population. Largemouth bass recruitment was evaluated for 2007, 2010 and 2013 and was compared to non-tournament years in 2006, 2008, 2009, 2011 and 2012 (Table 102.4). In addition, fish populations and prey resources were compared in tournament and non-tournament years. Recruitment was assessed as CPUE of young-of-year largemouth bass from fall electrofishing. There was no significant difference between tournament and non-tournament years for CPUE of young-of-year largemouth bass ($F = 0.18$; $P = 0.69$), CPUE of largemouth bass greater than 200 mm ($F < 0.01$; $P = 0.96$) or CPUE of bluegill ($F = 0.11$; $P = 0.75$) from fall electrofishing samples (Figure 102.5). We also observed no significant differences in prey resources in tournament and non-tournament years ($P > 0.05$ for larval fish, zooplankton, and benthic invertebrate densities). We have not observed thus far any influence of spring tournaments on largemouth bass recruitment or subsequent populations. We plan to continue to alternate years of tournament and non-tournament spring angling at Ridge Lake to continue to examine the influence of tournaments on largemouth bass populations.

Information from tournaments conducted on 12 lakes was used to evaluate population effects of varying tournament pressure. All tournament activity was recorded for each lake and tournament results are used to evaluate the tournament pressure (Table 102.5). In addition we identified 4 lakes where no largemouth bass tournaments occur and used these lakes as a control to compare largemouth bass populations across varying tournament pressure. Tournament pressure was calculated as angler hours per acre and varied from 0 to 21.8 hours/acre. The mean number of tournaments held on a lake was 19 and ranged from 0 to 57 tournaments. We also calculated the mean tournament demographics including the size and length of tournaments, size of fish caught, catch rates, and angler success (Table 102.6). The mean number of participants across tournament lakes was 37.7 anglers and the average tournament was 6.6 hours long. On average, tournaments weighed in 5.7 fish for every hour of tournament and anglers caught from 0.04 to 0.29 fish per hour. When examining only the lakes with tournaments, lake size was significantly correlated with the number of anglers per tournament ($r = 0.70$; $P = 0.01$). Larger lakes tended to have larger tournaments with a higher number of participants. Despite having larger tournaments, the size of the lake was not significantly correlated with total tournament pressure on a per area basis (angler hours per acre; $r = -0.08$; $P = 0.81$) or the number of tournaments ($r = 0.40$; $P = 0.33$). Catch rate measured as fish caught per angler was significantly correlated with tournament pressure ($r = 0.71$; $P = 0.05$). No relationships existed between catch rate and the number of tournaments, length of tournaments, and number of anglers in a tournament ($P > 0.05$). The mean weight of fish caught did not vary with any measure of catch rate or tournament pressure ($P > 0.05$).

Catch per unit effort was calculated from spring electrofishing transects for all largemouth, young-of-year, largemouth bass over 14 inches, and memorable fish in each lake. The CPUE of memorable sized fish was the only fish population variable that was significantly correlated to tournament pressure ($r = -0.87$; $P = 0.01$). When lakes were separated into categories of tournament pressure, CPUE of memorable sized largemouth bass was also the only variable that was different among groups ($F = 38.02$; $P < 0.0001$). Lakes categorized as low tournament pressure had higher CPUE for memorable fish than both no tournament and high tournament lakes (Figure 102.6). All other measures of largemouth bass catch rates were not different among categories ($P > 0.05$) including young-of-year, fish over 14-inch, and trophy sized largemouth bass. We did not detect any changes in abundance or size structure of largemouth bass vulnerable to tournament angling or production of young-of-year fish related to tournament pressure. However, these data are preliminary and are based on two years of data. We will continue to collect tournament and largemouth bass population data on these lakes and add additional lakes to this analysis as part of future segments to further understand the influence of tournaments on largemouth bass populations.

Recommendations:

We will continue to evaluate largemouth bass tournaments and their procedures and assess how they affect fish populations. Results from the experiment at Ridge Lake have not shown any evidence of reduction in recruitment of young-of-year largemouth bass due to springtime tournaments or changes in adult populations. To assess the effects of angling practices and tournaments on largemouth bass reproduction and recruitment we will continue these experiments as part of future segments. Experimental angling tournaments were conducted on Ridge Lake in 2007 and 2010. A third season of tournament angling in the spring of 2013 was conducted providing assessment of 3 years of largemouth bass recruitment in years with tournament angling to compare to 3 years of non-tournament angling.

There is potential for angling to have a large influence on sportfish populations. In particular, the magnitude and frequency of largemouth bass angling tournaments have the potential to impact fish populations. This study has begun investigating the influence of tournament activity and how it varies throughout the year. We quantified tournament pressure for a number of lakes and did not observe any relationships between tournament pressure and catch rate of young of year or total largemouth bass. We did observe a negative relationship between the number of large fish (> 20 inches) in a lake and the total tournament pressure. Reduced numbers of large fish may be due to the pressure put on larger fish by being targeted by tournament anglers and culling of smaller fish. These were the only relationships or effects we observed with tournament pressure. In future segments, we will incorporate FAS data from DNR biologist electrofishing sampling to supplement INHS electrofishing data. We will continue to determine sex and ages of largemouth bass in lakes with varying fishing exploitation. We will examine how angling activities influence sex specific characteristics such as growth, longevity, and age of maturity. Using this data, we will be able to make predictions about how angling will affect recruitment of largemouth bass and adult populations allowing us to identify the potential impacts of tournaments and harvest to life history characteristics in largemouth bass populations. We will continue to expand the number of lakes and tournaments we gather information from as we develop more working relationships with lake managers and tournament directors. The more lakes incorporated into this analysis, the better we will be able to determine if tournament angling has any measurable effect on largemouth bass populations on a lake wide scale. Ultimately managers may be able to regulate tournament activity based on data from other lakes and reduce the impact of tournament angling on largemouth bass populations.

Study 103: Habitat Restoration

Job 103.1: Evaluation of habitat manipulations on largemouth bass recruitment in Illinois lakes.

Objectives: To determine the influence of vegetation on largemouth bass recruitment and evaluate vegetation management techniques.

Introduction:

Largemouth bass *Micropterus salmoides*, similar to other fish species, experience variable recruitment among populations and years (Jackson and Noble 2000). In general, reproductive capacity of the adult population (Ricker 1954; Rutherford 2002), food availability during the larval life stage, and predation on early life stages (Houde 1987) are general mechanisms of fish recruitment. With slight modifications, these three hypotheses could apply to the specific case of largemouth bass recruitment. The reproductive behavior of largemouth bass potentially complicates any relationship between spawning stock and recruitment. Besides spawning, largemouth bass reproductive behavior includes nest construction, courtship, and brood defense. Typically, spawning stock is the abundance of all fish of a specific age or size range associated with sexual maturity. However, for a species with courtship, territoriality, and parental care, a much smaller fraction of mature fish may be responsible for the majority of surviving young of the year (YOY), therefore, typical estimates of spawning stock may inadequately assess the reproductive capacity of the adult population (Raffeto et al. 1990). Furthermore, conditions (e.g., temperature) and human behaviors (e.g., angling) that affect nest success influence reproductive output and, potentially, recruitment (Philipp et al. 1997; see also Job 101.5).

An important factor in the environment of any developing YOY fish is the availability of food. Ultimately, food availability within a given system is driven by its productivity. The reliance of larval fish on zooplankton is often the critical relationship influencing recruitment strength (Hjort 1914). With fish species that are primarily piscivorous as adults, such as largemouth bass, a successful transition from invertebrate to fish prey during the first year of life could be critical for future survival and success (Mittelbach and Persson 1998). The availability of both invertebrate prey during the earliest life stages and vulnerable fish prey are likely to be important for the consistent and timely development of piscivory (Olson 1996). The growth advantage gained by a switch to piscivory should be important to recruitment due to the size-dependent nature of YOY mortality.

Size-dependent mortality of YOY may be especially important for largemouth bass recruitment due to either selective predation on smaller bass or size-specific winter mortality. Predation often exacts a heavy toll on YOY fishes, potentially influencing recruitment strength (Houde 1987). Typically, the most important form of predation on YOY largemouth bass is cannibalism by earlier hatched individuals and largemouth bass from previous year classes (Post et al. 1998; Parkos and Wahl 2002). Predation pressure may also influence mortality of YOY largemouth bass during their first winter, when they are dependent on their bodies' lipid reserves for survival (Miranda and Hubbard 1994; Ludsin and DeVries 1997). Winter mortality may be the most important recruitment bottleneck for YOY largemouth bass, but no evidence for this relationship has been previously found for Illinois populations (Fuhr et al. 2002).

Aquatic vegetation is a habitat feature that influences the abiotic and biotic conditions that determine largemouth bass recruitment strength. Aquatic vegetation is often an important habitat feature for age-0 fishes and recruitment (Wright 1990; McRae and Diana 2005). Aquatic vegetation can benefit fish by decreasing turbidity, providing substrate for spawning, increasing structure for avoiding predators, and acting as habitat for important prey (Savino and Stein 1982; Carpenter and Lodge 1986; Scheffer et al. 1993). Previous examinations of the effects of aquatic vegetation on largemouth bass growth and recruitment have been mixed. Whether or not aquatic vegetation has a positive or negative effect on YOY largemouth bass is likely to be dependent on the level of vegetation coverage. Too much vegetation will negatively influence YOY largemouth bass foraging efficiency and subsequent growth (Anderson 1984; Caliteux et al. 1996; Sammons et al. 2003), while a moderate amount of coverage could positively affect YOY survival (Miranda and Pugh 1997). Any benefits provided will also vary by the type of structure offered by different vegetation species (Havens et al. 2005). In this job, we are evaluating the role of vegetation by relating densities and types with largemouth bass recruitment.

Procedures:

We continued a multiple lake experiment to evaluate different vegetation management strategies. In this segment, we continued field sampling of the 11 lakes including six for control conditions, three for rehabilitation conditions and two for vegetation removal. Largemouth bass populations, vegetation, prey resources, and fish communities were monitored. Three AC electrofishing transects were sampled on two dates in the spring and two in the fall at each lake. All fish were identified to species and measured for total length. Largemouth bass were also weighed and scales were taken for age and growth estimation. Benthic invertebrates were sampled two times annually in June and August at six sites using a stovepipe sampler. Zooplankton, larval fish and seine samples were performed bimonthly on 8 lakes and monthly on the remaining 5 lakes. Larval fish were collected using a 0.5 m diameter plankton push net with a 500um mesh and a 1:5 width to length ratio. Larval pushes were sampled for 5 minutes and total water sampled was measured using a torpedo flow meter mounted in the center of the net. Zooplankton was sampled using vertical tows at 4 inshore and 4 offshore locations at each lake using 0.5 m diameter plankton net with 63 um mesh and a 1:3 width to length ratio. All samples were preserved and brought to the laboratory where they were identified and counted. Seine samples were taken at 4 shoreline locations on each lake using a 1.2 x 9.1 m seine with a 1.2 x 1.2 m bag. The width, length, and depth of each transect were recorded to determine the volume of water seined. All fish collected were identified to species and a minimum of 50 individuals were measured for total length and additional fish were counted.

Lakes were mapped for vegetation in June and August using GPS mapping techniques. In this segment, GPS was used to trace the vegetated edge and waypoints to identify transitions in types and densities of vegetated areas. GPS data was then converted into GIS layers and digitized in ArcGIS 9.1. Once areas of homogenous vegetation were identified, density and mass of each species was measured. Ten rings of 0.5 m diameter were distributed throughout the different vegetated areas. All vegetation in a ring was removed (excluding the root mass), separated and identified to species and weighed. The mass of each vegetation type in a ring was used as a representative sample for the vegetated area. These rings will be used to estimate densities and biomass of each vegetation type present. GIS tools were then used to calculate vegetated area and vegetated perimeter of the lake. Vegetation rings were used to assign densities and mass of each vegetation type to polygons of homogenous vegetation.

Management to increase vegetation has continued on Dolan Lake, Lake Paradise, and Woods Lake. Dolan Lake was drawn down in winter of 2006-2007 and treated with rotenone in an attempt to remove carp and gizzard shad and expose the seed bank to promote vegetation growth. Successful reduction or removal of carp coupled with establishing new vegetated areas should increase overall vegetated cover in Dolan Lake. In this segment, we continued to evaluate a large vegetation planting effort in Lake Paradise through cooperation with Illinois District Biologist Mike Mounce and the City of Mattoon Water Department. Lake Paradise was planted with 5 different types of submerged vegetation that were protected by cages of various sizes designed to exclude turtles and common carp beginning in 2008. Exclosures were constructed using varying lengths of PVC coated wire fencing. Fencing was shaped into a cylinder and closed using cable ties. Lengths of rebar were driven into the substrate and attached to the fencing cylinders using heavy duty wire ties to secure the exclosure in place. After attachment to the rebar, the cage was driven into the substrate an additional 50 to 100 mm (depending upon substrate) to seat the exclosure and ensure no fish passage under the fencing. Cages were planted with wild celery, sago pondweed, American pondweed, chara, and coontail. Two sizes of cages were planted, large exclosures constructed of 6.1 m of fencing creating an exclosure with a 2.0 m diameter (area = 3.0 m^2) and small exclosures constructed from 3.0 m of fencing creating an exclosure with a 1.0 m diameter (area = 0.7 m^2 approximately ¼ the size of large exclosures). Small cages were constructed I n clusters of 4 or dispersed. For all treatments, planting location was along low sloping shoreline, with adequate sunlight, and shorelines protected from southern wind in order to promote successful establishment and growth of aquatic vegetation. Exclosures were visited in summer 2008-2011 to evaluate planting success, fish abundance, and macroinvertebrate density and results of these plantings were discussed in previous studies. In this segment we mapped vegetation and collected data on prey densities and fish populations to evaluate changes throughout the experimental planting treatment. Woods Lake was drawn down in 2012 and the fishery was opened to total harvest and then rotenone treatment was applied in order to remove common carp and gizzard shad and expose seed banks. Woods Lake remained drawn down in 2012 through 2013 and no sampling was conducted in this segment. The lake will be refilled in 2014 and post-manipulation sampling will begin in future segments.

We have been monitoring two lakes as part of the vegetation removal treatment. Stillwater Lake and Airport Lake have high vegetation densities and are in need of treatment to remove vegetation. Monitoring of pre vegetation management began in previous segments and continued in this segment. Treatment for vegetation began in the spring of 2010. Sonar was applied to Stillwater with the intention of completely removing Eurasian milfoil from the lake as well as other vegetation which has become overabundant. Eurasian milfoil is the dominant vegetation type and is invasive in Illinois. Airport Lake was treated in 2010 with Reward two times, once in the spring and once in July. Reward is being applied to reduce the vegetation lake wide and was targeted to remove Eurasian milfoil which had begun to establish in the lake. We will monitor changes in largemouth bass populations and prey organisms throughout and following the treatment period. Control lakes will be used to compare changes in largemouth bass populations to lakes where vegetation is being manipulated to determine the effects of vegetation management. Control lakes include 3 levels of vegetation (high, medium, and low) based on percent cover.

Findings:

In this segment, we continued to monitor 11 lakes to examine the role of vegetation in determining largemouth bass recruitment. Vegetative cover ranged from 0-100% in the study lakes (Table 103.1). Lake vegetation has varied among lakes across years, but control lakes with no vegetation manipulations maintained their relative vegetation coverage. Percent of the lake area that was vegetated was not significantly correlated with the perimeter of the shore that is vegetated in June ($r = -0.14$; $P = 0.71$), but was correlated in August ($r = 0.66$; $P = 0.04$). Vegetated area was significantly correlated from June to August ($r = 0.67$; $P = 0.04$), but not vegetated perimeter ($r = 0.38$; $P = 0.28$). Vegetated area measured in June was significantly correlated with total zooplankton density ($r = 0.65$; $P = 0.04$) and macrozooplankton density ($r = 0.95$; $P < 0.0001$). Vegetated area in June was negatively related to largemouth bass CPUE from electrofishing in the fall ($r = -0.81$; $P = 0.005$), but this was the only fish abundance measure that was related to vegetation coverage. Young-of year (YOY) largemouth bass CPUE from electrofishing was not significantly correlated with any measure of vegetation density in the 11 study lakes in 2012 ($P > 0.05$).

In order to evaluate differences in largemouth bass recruitment related to varying vegetation densities, we separated the 11 study lakes into categories based on the proportion of the lake area and perimeter that was vegetated in 2012. The categories were low (n=3; 0-10%), medium (n=4; 20-80%), and high (n = 4; 90-100%). We performed an ANOVA to determine if there as a significant difference in YOY and adult (>200 mm) largemouth bass CPUE from fall electrofishing among groups. There were no significant differences in CPUE among vegetation groups for YOY ($F = 0.76$; $P = 0.50$) or adult ($F = 0.45$; $P = 0.65$) largemouth bass in 2012. We will continue to monitor vegetation densities, largemouth bass populations, fish assemblages, prey resources and lake characteristics in control and vegetation treatment lakes including addition and removal.

In this segment, we evaluated the rehabilitation effort at Dolan Lake by examining the catch rates of gizzard shad and common carp, the fish targeted in rotenone treatments. CPUE of gizzard shad from electrofishing dropped from a mean of 14.2 fish/hour in 2001 – 2005 prior to the rehabilitation, to 2.1 fish/hour in 2007 – 2012 (Table 103.2). Despite this initial drop, the catch rates of gizzard shad increased to 27.3 fish/hour in 2011 and were the highest we have observed in Dolan in 2012 at 108.3 fish/hr. The gizzard shad population has rebounded in Dolan Lake to higher levels than before the drawdown and rotenone treatment. CPUE for common carp in Dolan Lake dropped from a mean of 1.2 fish/hour in 2001-2005 to no carp being sampled from 2007 -2012. The drawdown and rotenone has successfully reduced the number of carp in the lake to a level that we have been unable to detect them in electrofishing or larval fish samples. Decreases in gizzard shad and carp densities should allow water quality changes and reduce feeding and uprooting of vegetation allowing the density of plants to increase.

Before the drawdown and rotenone treatment, Dolan had a mean of 1.7% of the surface area and 6.5% of the perimeter vegetated in the fall from 2002 through 2005. In 2007 following the treatment, 76% of Lake Dolan's shoreline contained vegetation. Vegetated shoreline increased to a mean of 84% and vegetated area increased to 20.2% in the years following the treatment (2007-2012). Concurrent with the increase in vegetation, CPUE of largemouth bass also increased following the treatment (Figure 103.1). Mean CPUE of YOY largemouth bass increased from 7.4 fish/hour (2001 – 2005) to 24.0 fish per hour (2007-2012). In addition adult (> 200 mm) largemouth bass also increased from 7.6 fish/hour to 47.9 fish/hour. It appears that the rehabilitation efforts at Dolan Lake have resulted in an increase in vegetation and an increase in the number of YOY and adult largemouth bass. We will continue to monitor Dolan Lake as the lake has been opened again to angling to determine if the largemouth bass population can sustain higher numbers.

In spring of 2012, both Airport Lake and Stillwater were again treated chemically to remove vegetation. The treatment in Airport Lake in 2012 occurred shortly following our spring vegetation assessment. We have observed some decrease in vegetation area with only 20% area vegetated in the fall of 2012, however the shoreline has remained entirely vegetated and any decrease in vegetation is short lived. In all previous years fall assessments of vegetation (2007 – 2011) showed 100% vegetative cover at Airport Lake despite treatment (Table 103.3). CPUE of YOY fish has decreased since treatments were initiated in 2010 from a mean of 38.7 fish/hour in 2007 – 2009 to 8.9 fish/hour in 2010 – 2012. Adult populations have fluctuated, but have not changes over the course of the treatment. Airport was treated again in the spring of 2013 and we will report findings in future segments.

Stillwater Lake was treated in 2012 following our spring vegetation assessment. The coverage of vegetation in Stillwater Lake was very high in the years prior to treatment (100% cover and 100% perimeter 2007 – 2009). Once chemical treatment began in 2010, the portion of the lake that was vegetated decreased significantly (Table 103.3). Although the shoreline became vegetated by 2011, the lake retained open water area and the lake was not 100% covered with vegetation. Largemouth bass abundance has not changed thus far over the course of the treatment. Mean CPUE of YOY largemouth bass was 20.6 fish/hour both before and after treatment. Mean adult CPUE was 11.3 fish/hour prior to treatment and 14.7 fish per hour following treatment. The lack of change in the largemouth bass population suggests that you can treat a lake to remove vegetation for recreational purposes without negatively influencing largemouth bass populations. Stillwater Lake is closed to fishing, so we cannot predict how the population would react with angling mortality. We will continue to follow vegetation changes in these two lakes and evaluate changes in largemouth bass recruitment through spring and fall sampling.

We have performed major vegetation planting efforts at Lake Paradise, but had little success in increasing lake wide vegetation. There is some plant survival in the predator exclosures, but there is little evidence of the vegetation expanding outside of the protective barriers. New plant colonies may be able to establish in other parts of the lake from the parent colonies we have planted, but there is little evidence at this time. Percent vegetated lake area and shoreline has remained constant (% Area pre = 13; post = 4.6; % Shoreline pre = 51; post = 42.4). Largemouth bass catch rates have remained constant throughout the treatment period and have shown no increase due to planting efforts (Table 103.3). We will continue to monitor Lake Paradise to document if the established plant colonies spread to other parts of the lake and if so how it influences the largemouth bass population.

RECOMMENDATIONS:

Additional information on the role of aquatic vegetation to largemouth bass recruitment has been identified as an important goal for management in Illinois. There are a number of potential management strategies for manipulating vegetation that are of interest to managers in Illinois, including chemical treatment to reduce overabundant vegetation and/or nuisance vegetation (e.g. Eurasian milfoil) and habitat restoration to increase vegetation where it is lacking. We have continued a multi lake experiment examining lakes with a range of vegetation densities and have been measuring recruitment of largemouth bass in those systems. We have begun to treat vegetation in Stillwater and Airport Lakes and will continue to monitor changes of vegetation for several years. Vegetation removal in these lakes has been accomplished primarily through chemical treatments appropriate to reduce the dominant problem vegetation. Although we have experienced difficulty reducing vegetation in Airport Lake, we have successfully reduced lake wide vegetation cover in Stillwater without negatively affecting the largemouth bass population. One concern of chemically treating vegetation is that it will result in reduced water quality resulting in decreasing fish populations. In future segments we will further examine how water quality has changed in these lakes to determine if the vegetation treatment has any effects on the nutrient loading and the food web in each lake.

We will continue to monitor the vegetation in these lakes and evaluate the success of the removal process. We will continue to monitor fish exclusion fences and transplanted vegetation at Lake Paradise and assess if increases in vegetation are observed. During the next several years, we will monitor the lake-wide implications of these vegetation enhancement efforts. In Dolan Lake, the water level was drawn down in an attempt to eliminate carp and gizzard shad. We expect through the removal of these fish and the exposing of the seed bank, that vegetation will increase in the lake. Initial measurements of carp and gizzard shad indicated the fish removal efforts had been successful at reducing their numbers. However, gizzard shad numbers have increased since the initial treatment and they have reestablished at greater numbers than prior to treatment. Vegetation at Dolan Lake has increased since the drawdown and fish removal has coincided with increases in largemouth bass populations. Largemouth bass populations were restocked in the lake and the fishery was closed to harvest for multiple years. It is unclear if the reduction of carp and increase in vegetation is the cause of the improved fishery or if the population will remain high now that harvest is allowed. We will continue to monitor the largemouth bass population in Dolan Lake to evaluate the success of the rehabilitation.

We will continue to monitor control and treatment lakes and relate changes in largemouth bass recruitment, growth, and abundance to management practices. Although largemouth bass catch rates in the fall were inversely related to spring vegetation density in 2012, it has not traditionally not been a negative relationship. Extremely high densities of vegetation can be detrimental to largemouth bass populations and the reason for the vegetation removal treatments in this study. There is however a need for vegetated habitat for both young-of-year and adult largemouth bass for both cover from predators and for habitat of prey. We will continue to assess vegetation cover and how it relates to largemouth bass populations to guide vegetation management on Illinois Lakes. We will evaluate largemouth bass recruitment, abundance and growth in lakes with varying vegetation densities in order to identify critical levels of vegetation to target for management.

Job 103.2: Habitat value in mid-sized rivers in Illinois.

Objectives: To develop standard sampling techniques and evaluate the influence of habitat on sportfish in mid-size rivers.

Introduction:

Habitat restoration is also commonly employed in rivers and streams and Illinois is interested in developing a plan for habitat restoration in mid-sized rivers. The IDNR current sampling procedures make relating sportfish populations to habitat structure difficult. Sportfish and habitat sampling procedures must be developed that allow direct comparison of the two, aiding in the identification of restoration needs and methods for evaluating restoration techniques.

Local habitat conditions have traditionally been used to explain fish populations in streams and rivers (Wiley et al. 1997; Diana et al. 2006; Shea and Peterson 2007; Rowe et al. 2009; Neebling and Quist 2010). Temperature, substrate, available cover, velocity, vegetation, competition and predation, channel morphology, and flow have all been related to fish presence and reproduction (Gordan and MacCrimmon 1982; Fausch et al. 1988; Pusey et al. 2000; Diana et al. 2006; Remshardt and Fisher 2009). The scale which habitat is assessed can influence the observed relationship with fish and restoration and conservation objectives (Lewis et al. 1996; Dauwalter et al. 2007; Bouchard and Boisclair 2008; Schwartz and Herricks 2008; Le Pichon et al. 2009; Flotemersch et al 2011). It is important to limit the scale of assessment by breaking habitats into small enough segments to relate to fish use (Schwartz and Herricks 2008; Flotemersch et al 2011) as well as include large enough areas to consider all habitats available (Dauwalter and Fisher 2008). Both site scale habitat and landscape scale habitat variables have been shown to influence fish densities and distribution and both should be considered (Creque et al. 2005). In order to relate habitat to sportfish communities, it is important to consider the size of the habitat unit and examine multiple spatial scales.

Many factors can influence sportfish communities observed in stream and river systems. Fish movements in river systems can be large allowing them to utilize different habitats (Bunt and Cooke 2001; Lyons and Kanehl 2002). Habitat use of fish can shift depending upon the time of year due to food availability, reproduction, and refuge (Schlosser 1991; Schlosser 1995; Lyons and Kanehl 2002; Dauwalter and Fisher 2008; Paukert and Makinster 2009). Connectivity to lentic systems can also be important as fish can move between systems yet there may be distinct separate populations of river and lake oriented fish based on habitat preference and reproductive traits (Barthel et al. 2008). Fish can also alter the habitat (e.g. prey availability) if it is dynamically affected by densities and availability will depend on past and present fish communities (Hayes et al. 1996). All of these factors must be considered when attempting to relate fish to habitat.

The river continuum concept suggests habitat shifts for fish as one moves from headwaters to the mouth of streams resulting in varying biotic and abiotic factors (Vannote et al. 1980). Species distribution is closely related to position along the up-stream to downstream gradient primarily due to habitat shifts (Buisson et al. 2008; Johnson et al. 2009; Paukert and Makinster 2009). While large rivers and small streams have been heavily studied, less attention is given to mid-sized rivers and their habitat and fish communities (Lyons et al. 2001; Neebling and Quist 2010). Fish communities and their utilization of habitats could vary greatly compared to those observed in larger or smaller systems. Most work that has been done with sportfish and river habitat has focused on smallmouth bass (Walters and Wilson 1996; Dauwalter et al. 2007; Barthel et al. 2008; Dauwalter and Fisher 2008; Johnson et al. 2009; Remshardt and Fisher 2009) with few studies on largemouth bass and other species (Freund and Hartman 2005; Wallace and Hartman 2006; Love 2011; Johnson et al. 2009) and rarely examined in mid-sized rivers. Few studies have examined how sportfish populations relate to habitat in rivers and streams other than when sportfish are lumped into community metrics or diversity assessments (except see Gutreuter 2004). There is a need to identify habitat use by sportfish and critical habitat needs and how they relate to the need for and evaluation of habitat restoration.

Procedures:

In this study, the upper Kaskaskia will be defined as upstream of Lake Shelbyville and the middle Kaskaskia is defined as the Kaskaskia River downstream of the dam at Lake Shelbyville and upstream of Lake Carlyle. The sections of interest in the Kaskaskia River are characterized by the physiographic region of the Springfield Plain. The Springfield plain is a flat plain crossed by low, broad end moraines. The total drainage area is 5800 square miles. Agriculture is the major land use in the watershed, although it is partially forested. The relief is not large which leads to a meandering system in areas that haven't been channelized. The River originates in Champaign County, Illinois and flows 302 miles southwest until the confluence with the Mississippi River in Randolph County (INHS Kaskaskia River Technical Report, 1999). The slope of the upper River (upstream of Lake Shelbyville) is slight (averages 1.5 ft/mile). Below the dam at Shelbyville, the slope decreases, averaging 1.0 feet per mile.

Habitat will be sampled at identified sites during low flow conditions in summer of 2013 on the upper and middle reaches of the Kaskaskia River. At all points, depth, substrate, instream cover, distance to nearest woody debris, flow velocity, temperature, dissolved oxygen, and distance to nearest shore, wetted width and bankfull width, and bathymetric slope will be measured. Each variable will be measured at one location at each point centered between the electrofishing booms. Slope will be determined by measuring the depth at the boat and at the outer extent of the electrofishing booms. Depth will be measured to the nearest 10 cm with a stadia rod, or in areas too deep for the stadia rod, with a weighted rope. Substrate will be determined visually where possible or by using an Eckman grab. The substrate will be broken into percentage of total substrate into catagories using a modified Wentworth scale. Substrate classes will be defined as fine (<0.06 mm), sand (0.06–2 mm), gravel fine (2–16 mm), gravel coarse (16–64 mm) and cobble (64–250 mm) (Fisher and Paukert 2008). Instream cover at the point (wetted woody habitat, aquatic macrophytes, undercut banks, and overhanging vegetation) will be ranked on a scale of (0–4) of five cover classes; absent (0%), sparse (0–10%), moderate (10–40%), dense (40–75%) and very dense (>75%) (Lazorchak et al. 1998). Flow velocity (m/s) will be measured at 60% of the depth at each point using a Marsh McBurney flow meter. Temperature (degrees C) and dissolved oxygen (mg/L) will be measured with a YSI temperature/DO meter. Bankfull and wetted width will be measured with a metered rope laterally at each point. If the point is a snag point, the area of the woody cover will be measured, the diameter of the main beam will be measured, and the structure will be scored based on complexity (1-5, log – new fall branches). These categories will be estimated visually and a subset of the sites will be measured to correct for sampler bias.

Fish will be sampled at multiple special scales. Microhabitat will be defined by areas of distinct habitat characteristics identified by the presence/absence of wood, depth, flow, river unit classification (riffle, run, pool), the location in the channel (thalweg, inside bend, outside bend, channel margin), and the substrate size. Electrofishing transects will be conducted by boat using DC pulsed 240V electrofishing. Habitat segments will be electrofished in an ambush style where the boat is moved into the habitat and the electrical current is engaged. The area will be sampled until fish are no longer observed. Time and area of each sampling segment will be measured to assess catch per unit effort. Fish and habitat data will be analyzed at multiple special scales to determine the most appropriate method of assessment. Sampling areas will be analyzed individually as well as pooled into reaches and river segments and fish communities and abundance will be related to habitat types present at that scale. We will make recommendations based on spatial scale, fish/habitat associations, and sampling methods.

Findings:

In this segment, we developed side scan sonar mapping methods and mapped the upper segments of the Kaskaskia River. The segments were navigated using a Humminbird 1190 side imaging sonar unit. Transects covered the entire river channel and was done at high water level and will include substrate that is normally outside of the wetted width of the channel. All maps were downloaded into GIS and overlayed onto landuse and elevation layers (Figure 103.2). Habitat classification will be conducted once side scan images are ground truthed while conducting in-stream habitat sampling (Figure 103.3). Habitat types will be quantified throughout the reach where transects were conducted. High water in the early part of 2013 has fish and additional habitat sampling into the next segment. We are prepared to conduct these sampling efforts as soon as the high water recedes.

Recommendations:

We will develop methods for sampling fish in mid-sized rivers that will allow for direct comparison with habitat assessments. We will determine the size of sampling units required to associate sportfish with different habitat types. Guidelines will be developed for conducting habitat sampling based on standard procedures and compared with work done outside of Illinois. We will evaluate the current sampling used by the IDNR and examine data collected as part of previous monitoring. Data will initially be collected on both habitat and fish populations in the Kaskaskia River. We will expand to additional rivers (e.g. Embarras, Fox, Kankakee) in future segments. Data will be used to determine the potential value in evaluating sportfish associations with habitat. We have compared the methods currently used to those commonly used in the literature and by other states and will make recommendations on the need for improving or adjusting the current collection methods. Habitat assessments and electrofishing sampling will be conducted at varying scales to determine what level of refinement is needed to develop relationships between habitat and sportfish. We will utilize rapid habitat assessment techniques, transect habitat measurements, landscape habitat identification using GIS, and riffle/run/pool measurements to assess habitat. Electrofishing transects will be performed at short durations and habitat targeted and compared to data collected from longer electrofishing transects. Varying the assessment type and scale will allow tests of the sample requirements for relating sportfish to habitat type. We will identify important habitats for sportfish and assess the potential for habitat restoration projects by determining the availability of different habitats and identifying which may be limited. The information resulting from this study will be used to develop a standardized sampling procedure for collecting habitat and fish population data in mid-sized rivers in Illinois that can also be used in evaluating habitat restoration projects in the future.

Study 104: Recruitment of Sportfish

Job 104.1: Evaluation of the effect of spawning refuges on largemouth bass recruitment.

Objectives: To evaluate the effects of fish refuges on Illinois bass recruitment and size structure.

Introduction:

Recruitment of sportfish is one of the main factors influencing the structure of adult fish populations. Understanding the factors that influence recruitment in sportfish is paramount to managing populations and predicting future fisheries. Many fish species undergo survival bottlenecks that are caused by limitations in their environment. Managing for conditions that are beneficial to survival should enhance fish populations. While recruitment in some fish species is widely studied, it is not well understood for all species of sportfish. In particular, additional research is needed to understand what factors influence recruitment in crappie, channel catfish, and flathead catfish. Although some studies examining crappie species have been conducted, different factors have contributed to recruitment success and in general it is highly variable, making their populations difficult to manage or predict. Most studies are conducted on a limited number of systems and there is a need for a robust study including multiple lakes.

The factors influencing largemouth bass recruitment have been studied in greater detail than other species. In previous studies, we have identified that largemouth bass angling can greatly reduce the reproductive potential of fish especially if they are removed from the nest. Fish that are harvested at small sizes will also be eliminated from the spawning population. The combined effects of angling may result in reduced recruitment success for largemouth bass populations. One potential management strategy is to restrict angling in areas of the lake and provide a refuge for spawning fish where recruitment will be unaltered by angling. Refuges have been established in multiple lakes in Illinois, but there is little information on how they have influenced recruitment both inside the refuge and on a lake wide scale. There is a need for investigating the effects of refuges closed to angling and their potential to increase largemouth bass recruitment for an entire lake. We have implemented angling refuges on two lakes in Illinois in order to examine their utility at improving largemouth bass populations through protecting nesting fish from brood loss due to removal from the nest. In addition fishing mortality will be eliminated in this part of the lake potentially leading to increased survival of adult fish.

Procedures:

We examined largemouth bass populations in two lakes before and after the implementation of fishing refuges. In this segment, we continued to assess changes in largemouth bass recruitment and abundance due to two refuges on Otter Lake. In the summer of 2010, two refuges were closed to fishing in Otter Lake by running a buoy line with a no fishing marker attached. We began post-refuge sampling in Otter Lake in 2011 because the buoy lines were put in place after largemouth bass spawning was completed in 2010. Samples conducted in 2007 through 2010 were considered pre refuge conditions and samples collected from 2011 through 2013 are considered post refuge conditions.

Sampling was conducted on two dates in the spring and two dates in the fall for each year. On each sampling date, one 30 minute electrofishing transect and one seine haul were conducted in each refuge location. DC electrofishing (240V, 60Hz) was conducted on one date in the spring and one date in the fall and AC 3-phase electrofishing (240V) was conducted on an alternate date in the spring and the fall. Seines were conducted using a 9.2-m bag seine pulled along the shoreline at fixed transects. In addition, three control sites were sampled (1 electrofishing transect and 1 seine haul in each) within the lake. One reference was located near each proposed refuge, and the final reference location at the midpoint between the refuge sites. Fish were identified to species and total length was recorded. All fish were counted and up to 50 fish were measured for each species. All largemouth and smallmouth bass collected inside refuge sites were given an upper caudal fin clip in order to determine if fish in the refuge move into adjacent areas of the lake. Catch per unit effort (CPUE) was then calculated as the number of fish per hour of electrofishing and number per square meter area seined. These data will be compared to Clinton Lake where sampling during 1999 – 2001 represents pre-refuge and 2002 to 2012 represents post-refuge.

Findings:

We continued to monitor refuge and reference sites in Otter Lake during this segment. In pre-refuge monitoring in the spring and fall of 2007- 2010, we observed lower catch rates of largemouth bass in the proposed refuge sites compared to the control sites (Table 104.1). The proposed refuge sites appeared to be in areas where largemouth bass were abundant and spawning was taking place, but did not have as many fish as the control sites. After the refuges were closed, electrofishing CPUE of largemouth bass in 2011 through 2013 remained lower in the refuges than the control sites (Figure 104.1). We did not observe a change in abundance of largemouth bass either in the closed refuges or in the control sites. Very few young-of-year largemouth bass were collected in either the refuge sites or the control sites following the closing of the refuges (Table 104.2). There is little evidence that closing these areas to angling has led to increased reproduction or enhanced largemouth bass populations in the first 3 years following implementation of the refuge. This contradicts what was observed at Clinton Lake where both young-of-year and adult largemouth bass were observed in greater numbers inside the closed refuge. It is not clear why the refuge in Otter Lake has not resulted in increased largemouth bass populations at this time. We will continue to assess if limiting disturbance of these fish during nesting may increase spawning success and yield larger year classes in future segments.

Recommendations:

There are many potential harvest regulation strategies that can be used to manage bass populations, including size and creel limits, closed seasons, and spawning refuges. Thus far we have been evaluating a spawning/fishing refuge on Clinton and Otter Lakes. Largemouth bass populations inside the refuges at Clinton Lake had large increases in the number of adult fish after they were closed to fishing. However largemouth bass populations outside of the refuge did not increase and there is no evidence of fish leaving the refuge and moving into the main lake. The refuge on Clinton Lake has resulted in enhanced recruitment and survival of largemouth bass, but may not increase catch rates lakewide for anglers. At this time we have not observed any changes in the largemouth bass population in Otter Lake as a result of the refuges. Neither the number of fish inside the refuges or the throughout the lake have increased. Refuges have the potential to increase largemouth bass recruitment and the abundance of adult largemouth bass inside of an area closed to angling. We did not observe any changes in lake wide bass populations at either lake. The utility of closed fishing refuges may be limited to lakes with high angling pressure where recruitment may be limited by angling. The effects of the refuge may be limited to the area closed to fishing which does not directly benefit anglers. We will continue to follow the largemouth bass population in Otter Lake to determine if the refuges will result in better largemouth bass populations and continue to make recommendations to managers regarding the use of refuges in management.

Job 104.2: Assessment of the importance of spillway escapement in determining the survival of stocked muskellunge.

Objectives: To quantify the level of escapement in Illinois reservoirs and determine what factors influence escapement.

Introduction:

Escapement of sportfish from reservoirs decreases abundance and poses a threat to downstream systems. The factors influencing the magnitude of muskellunge escapement are not known. Previous studies of dam escapement focused on abundant species of reservoir fish. Lewis et al. (1968) found that 31% of largemouth bass stocked into a new impoundment escaped within the year. In a two year period 10,000 fish were estimated to have escaped from a 65 ha lake in Illinois (Louder 1958). Losses of fish over spillways have been shown to be species-specific in a given lake, but patterns between lakes have not been consistent (Lewis et al.1968; Paller et al. 2006). Size-specific losses have also been identified, and often adults of the population are more vulnerable to escapement (Navarro 1993; Lewis et al 1968; Paller et al. 2006). There is limited information on escapement of low-density top-predators such as muskellunge, despite anecdotal evidence and preliminary data suggesting escapement of the species is widespread. At this point we do not have a clear understanding of the mechanisms and magnitude of muskellunge spillway escapement that would be integral to developing and implementing mitigation efforts and making management decisions. Important data must be collected on the conditions (season, flow, diel period, temperature, and spillway design) associated with escapement, the traits of fish (sex, size, maturity) that are the most susceptible to escapement, and how reservoir characteristics and spillway design influence escapement. Estimates of the proportion of a population that are lost annually from reservoirs are also of great management importance and these figures will aide in making management decisions and justifying specific remedial actions.

Emigration of fish out of managed systems can influence recruitment of sportfish. One potentially major source of emigration is through dam escapement. Losses of fish over spillways are highly variable, unpredictable, and a concern to fish managers (Axon and Whitehurst 1985; Paller et al. 2006; Wahl 1999; Hergenrader and Bliss 1971). In western North America both upstream and downstream dam passage of salmonids is universally considered to be positive (Connor et al. 2000), and is often accommodated for (Raymond 1988; Champman et al. 1997). But in the Midwest “dam escapement”, the permanent emigration of fish past the impounding barrier of a reservoir, is a major detractor from the goal of establishing and maintaining abundant sportfish populations (Louder 1958; Wahl 1999). Factors thought to contribute to dam escapement of sport fishes include movement related to spawning or foraging, spillway design, habitat preference, and amount of overflow (Louder 1958; Lewis et al. 1968; Paller et al. 2006). In many scenarios these losses are costly in consideration of the resources invested into stocking sportfish (Szendrey and Wahl 1995).

In some large tailwaters high density fisheries can be created where escaping fish are caught by anglers at high rates. Indeed, escapement has been described as essentially an annual stocking program for downstream systems (Trammell et al. 1993; Schultz et al. 2003), and when sufficient outflow creates consistent riverine conditions large bodied fishes often thrive (Harrison and Hadley 1979). But while the potential exists for productive tailwater fisheries, the influx of unwanted and often nonnative fish also carries a risk of negative effects on resident fish communities (Martinez et al. 1994; Spoelstra et al. 2008). Consequences for escapees can also be dire as habitat, prey availability, and thermal conditions in the outflow of smaller impoundments are often not adequate to support large-bodied fish.

Muskellunge are often stocked into reservoirs to create recreational fishing opportunities. Muskellunge escapement over spillways is frequently observed and reported anecdotally across the Midwest (Storck and Newman 1992; Wahl 1999). Because these fish are stocked in low numbers, have limited potential for natural reproduction in many reservoirs (Dombeck et al. 1984), and preventative barriers are often infeasible or ineffective at high flows (Plosila and White 1970), escapement could be one of the primary factors limiting development of abundant reservoir populations (Louder 1958). Preliminary examinations recorded a large percentage of a muskellunge population escaped from an Illinois reservoir and have also shown that PIT tag antennas can be effectively used to collect real-time data on escaping fish and generate estimates of escapement. To address these issues we conducted field evaluations at two Illinois reservoirs to quantify conditions under which muskellunge escapement occurs and describe the traits and proportion of muskellunge escaping from a reservoir.

Procedures:

Muskellunge were sampled on Lakes Sam Dale (Wayne County) in the spring of both 2012 and 2013 while they were sampled on Lake Mingo (Vermillion County) in the spring of 2012 and 2013. Data on both lakes were also collected in previous studies in 2011 and that data will be compared. Fish were captured each spring using fyke nets and boat electrofishing. A population estimate was generated for each lake during sampling using mark recapture methods. All fish captured were measured, weighed, sexed, aged, and given a uniquely numbered PIT tag. A Peterson mark-recapture population estimate was conducted with a marking period followed by a period for redistribution and then a recapture period. We used a Peterson model with the Chapman modification (Chapman 1951) to calculate population size (equation 1).

Equation 1. $\hat{N} = \frac{(M+1)(n+1)}{(m+1)} - 1$

where $\hat{N}$ is the estimated population size, M is the number of marked fish from the first sample that were returned to the population, n is the number of fish in the second sample, and m is the number of marked fish in the second sample. Based on the proportion of marked fish in the recapture sample, a binomial confidence interval for this population estimate was calculated (Seber 1982) using equation 2.

Equation 2. $\hat{N} \pm Z * SE_{\frac{m}{n}}$

where SE is standard error, m is the number of marked fish in the second sample, and n is the number of fish in the second sample.

Antennas capable of capturing PIT tag information were used to gather data on escaping muskellunge. Antennas were constructed from 10 gauge THHN wire fixed to high strength tech cord. The antennas span the width of each spillway (Sam Dale 16’, Mingo 46’) and cover approximately 3’ of overflow height. Concrete anchors were used to attach antennas to the spillways. Antennas were tuned and operated using RFID interrogating and datalogging components from Oregon RFID (Portland, OR). The Lake Sam Dale antenna was powered by 2 marine 12V batteries housed in a weatherproof box along with the datalogger. The Lake Mingo antenna was powered by the main power grid using a DC converter. Each antenna was tuned for the specific inductance of that system and was checked for gaps in antennae coverage manually and was repaired as needed. At Lake Mingo, the PIT tag antenna suffered from de-tuning in 2011 that occurred as a result of storms and severely decreased the ability of the system to detect escapement events. However, many of the muskie escaping from Lake Mingo remained in the plunge pool at the base of the dam due to the small size of the drainage exiting the lake. These fish were examined for PIT tags and were used as a conservative estimate of escapement.

Correction factors can be developed to estimate total fish passage at an antenna when detection efficiency is less than 100%. We used an outflow structure from an experimental pond facility to develop a correction factor for detection of downstream passage of fish in a spillway setting from the PIT tag antenna. Thirty six trials were conducted at each of three outflow water velocities (25, 50, and 90 cm/s, N=108 total) to simulate variability and intensity of flow that would be present in an actual spillway. For each fish passage, observations of body orientation in relation to the antennae were made and tag detection was noted. Detection efficiency was calculated as the proportion of passages resulting in a successful tag capture during these trials. A correction factor for the detection efficiency of our system was then calculated as the inverse of detection efficiency. The correction factor was then used to estimate the total number of escaping fish in the field (i.e. number of detected fish escaping x correction factor = estimated total number of fish escaping).

Data was collected on the magnitude and patterns of escapement of muskellunge from these reservoirs. Estimates of escapement for each lake were determined by total number of tags captured by each antenna in comparison to the tagged population. Demographics of escaping fish was determined by matching tag numbers to data collected from each fish at the time of sampling. Chi-square tests were used to assess differences in escapement rates between adults/juveniles and males/females. Timing of escapement were determined by time stamps made for each escaping fish carrying a tag, comparisons of escapement between daytime and nighttime were made using a chi-square test. Correlations between timing of escapement and environmental conditions including precipitation, waterlevel, turbidity, and water temperature were also made.

<u>Findings</u>:

In Lake Sam Dale, tagged fish in 2011 (N = 118) ranged in length from 415 to 964 mm and were comprised of 16 age 1, 15 age 2, 53 age 3, and 34 age 4 individuals. Mark-recapture methods estimated 186 (confidence interval 142-257) muskellunge were present in Lake Sam Dale at the time of sampling. Long-term (one year) tag retention was 100% (N = 10), similar to rates in the literature (Younk et al. 2010). In 2012, 21 fish were captured over 2, 10-day fyke net sampling periods. Of those fish no fish were recaptured within 2012 and a population estimate was therefore not possible. In Lake Mingo, tagged fish in the 2011 (N = 106) range in length from 337 to 1050 mm and were comprised of 7 age 1, 13 age 2, 16 age 3, 22 age 4, 17 age 5, 9 age 6, and 22 of undetermined age individuals. Mark-recapture methods estimated 189 (confidence interval 114-274) muskellunge were present in Lake Mingo. Low water levels prevented any fyke netting at Lake Mingo in 2012 and therefore no population estimate was possible.

In the detection efficiency experiments, 50% of fish had the axis of their body oriented at a 70-90º angle from the antenna (swimming parallel to the flow either upstream or downstream). Fish passing at this orientation had an associated 86% detection efficiency. Another 31% of fish passed the antennae at an orientation of 21-69º with an associated detection efficiency of 81%. Only 19% of fish passed with their body axis oriented at a 0-20º angle, and as anticipated based on limitations of the technology, the antenna had lower detection efficiency (71%) of these fish. Detection efficiency actually increased with velocity (72% at 25 cm/s, 82% at 50 cm/s, and 92% at 90 cm/s) which can be attributed to fish being more likely to have a body orientation that was parallel to the direction of flow as velocity increased. We estimated an 81.6% overall detection efficiency of downstream passing fish across varying water velocity. By dividing the probability of complete capture success (100%) by the detection efficiency determined in our trials (81.6%) we obtained a correction factor of 1.23.

At Lake Sam Dale, the PIT tag antenna and data logger were activated on February 22, 2011 when flow first passed over the spillway. In the spring of 2011, 24 individual tags were detected by the antennae between March 10 and May 3 (Figure 104.2). The actual number of tags detected accounts for 20.3% of the tagged population. By applying the correction factor for antenna efficiency we estimate escapement of the tagged population at 25.0% (20.3 x 1.23). By applying this rate to the estimated population size we estimate that 47 (CI 36-64) muskellunge escaped from Lake Sam Dale. In June of 2011, 27 tagged muskie were recovered below the dam at Lake Mingo (only 1 of these fish was detected by the PIT tag antenna), representing 25.4% of the tagged population of muskies in Lake Mingo. These most likely underestimate the total number due to some fish moving beyond the plunge pool. However, with this conservative estimate applied to the estimated population of Lake Mingo, we estimate that 48 (CI 29-70) muskellunge escaped from Lake Mingo during the spring of 2011. In 2012 the conditions were unusually dry and as a result there were few opportunities for muskellunge to escape from either lake. Despite the antenna being active throughout the spring and summer, there were no tag detections during this time for Lake Sam Dale or Lake Mingo.

At Lake Sam Dale, the mean length and age of escaping fish (811 ± 32 mm, 3.3 ±0.25 years) were significantly higher than those for the tagged population as a whole (744 ±26 mm, 2.9 ±0.17 years, $P = 0.03$ and 0.04 respectively, Figure 104.3). None of the tagged age-1 fish (N = 16, 400-450 mm) were detected escaping the reservoir (Figure 104.4), with disproportionately higher escapement of adults compared to juvenile fish (Chi square = 4.22, $P = 0.04$). The sex ratio of escaping fish (11F:13M) was similar to the ratio of the tagged population as a whole (53F:49M, Chi-square = 0.04, $P \geq 0.05$). At Lake Mingo, the mean length and age of escaping fish (827.3 ± 30 mm, 3.7 ± 0.28 years) was also higher than the population as a whole (804.8 ± 17 mm, 3.6 ± 0.16 years) but these differences were not significantly different. The sex ratio of escaping fish from Lake Mingo was (7F:14M) which was similar to the ratio of the tagged population as a whole (28F:39M, Chi-square = 0.9, P ≥ 0.05)

Precipitation events in the area around Lake Sam Dale typically resulted in an increase in overflow at the spillway within 24 hours but the duration of overflow varied. Duration and maximum height of overflow was variable and presumably related to rainfall intensity, duration, ground saturation, and delayed runoff from previous events. From late February to mid-May there was an almost continuous baseline flow of water over the spillway (~5 cm overflow height) between pulses from specific precipitation events. Two fish escaped on days in March that were not associated with a specific precipitation event (cumulative precipitation <0.1 cm for 3 days prior, Figure 1). The majority of escapement (22 of 24 fish) followed two events in early and late

April that had 2 and 5.5 cm, respectively, daily rainfall at their peak (Figure 1). Exact peak overflow heights were difficult to determine, but these precipitation events led to >13 cm and >25 cm of overflow height, respectively.

The water level of Lake Sam Dale dropped several inches below normal pool during the summer due to evaporative processes which resulted in no summer days with spillway overflow. Precipitation throughout the fall gradually raised the water level until late November when several days of overflow occurred. A single precipitation event of > 4 cm resulted in an overflow height of >15 cm. However, during this period no tagged muskellunge escaped (Figure 1). As such, all muskellunge escapement detected by the antenna occurred near what has been observed as the spawning season (Parsons 1959).

A majority of fish at Lake Sam Dale escaped during daylight hours (19 of 24), with peak escapement happening in the afternoon and evening (Figure 3). The observed numbers of escaping fish during daylight hours was significantly higher than that expected if escapement occurred randomly throughout the diel cycle (Chi square 5.12, $P = 0.03$). Water clarity (secchi depth) values were highly correlated to precipitation (Pearson Correlation Coefficient, $r = 0.34$, $P < 0.01$) and temperature ($r = 0.39$, $P < 0.01$), whereas precipitation and temperature values were marginally correlated to one another ($r = 0.20$, $P = 0.06$). Because of the collinearity of these variables it is difficult to determine the influence of each variable independently. Escapement of muskellunge occurred on 11 days in the spring and no escapement was observed on 73 days. Mean secchi depth was significantly lower on days when escapement of muskellunge occurred (0.32 cm) than on days when escapement did not occur (0.44 cm, $P < 0.01$). Similarly, daily precipitation values were higher (3.9 cm for that day and 2 d prior) when escapement occurred than when escapement did not occur (1.0 cm, $P < 0.01$). Finally, mean daily temperature was higher on days when escapement occurred (15.8°C) than on days when escapement did not occur ($P = 0.04$, 13.1°C).

Recommendations:

Our results indicate that up to 25% of the muskellunge population in these two reservoirs can escape in a single year. However, in a year marked by drought we detected no escapement in these same reservoirs. Therefore, it appears escapement is linked to precipitation events and daily movement behaviors of the fish. Fish were more likely to escape in the spring when large pulses in precipitation occur and are also more likely to escape in the day. The data suggest that utilization of barriers and other reservoir water regulation techniques might be effective especially during the day and around high precipitation events. However, further data is needed to determine if these patterns occur across the two reservoirs and across years with different seasonal patterns. We will continue to monitor the escapement patterns of muskellunge in both Lake Sam Dale and Lake Mingo in the next segment and further refine accuracy using the PIT tag antenna system deployed at each lake. Data gathered in this study will enhance the success of muskellunge stocking and help maintain populations which will improve angling in Illinois lakes stocked with muskellunge.

Job 104.3: Evaluating factors that influence crappie recruitment in Illinois lakes.

Objectives: To identify factors that influence crappie recruitment.

Introduction:

White crappie (*Pomoxis annularis*) and black crappie (*P. nigromaculatus*) are collectively two of the most sought after sportfish species in North America (Beam 1983; McDonough and Buchanan 1991; Sammons and Bettoli 1998; Boxrucker and Irwin 2002). Crappie populations are often plagued by variable, quasi-cyclical recruitment with strong year classes existing every 2-5 years (Thompson 1941; Swingle and Swingle 1967; Allen and Miranda 2001). As with most freshwater fishes, adult abundance has been linked to number of recruits (Hilborn and Walters 1992; Bunnell et al. 2006). Recent studies suggest that a combination of spawning stock characteristics and environmental variables are probably the most influential metrics for explaining and predicting recruitment variability in crappie (Dockendorf and Allen 2005; Bunnell et al. 2006).

A number of studies have identified environmental variables as being important to crappie recruitment (Jenkins 1955; Goodson 1966; Mathur et al. 1979; Bunnell et al. 2006). Factors such as water temperature, time of spawning, water level, turbidity, landscape characteristics, substratum, productivity (chlorophyll a), zooplankton composition and abundance, and wind have been identified as being important to crappie year-class strength and early growth (Mitzner 1991; Guy and Willis 1995; DeVries 1998; Pine and Allen 2001; Sammons et al. 2001; Bunnell et al 2006; Reed and Pereira 2009). Water level has emerged as one of the most important factors to crappie recruitment in a number of studies, suggesting that water level manipulation may be a viable management practice for influencing year-class strength (Pope et al. 1996; Maceina and Stimpert 1998; Maceina 2003; St. John and Black 2004).

Recent studies have attempted to create predictive models for crappie recruitment and have been met with varying success (e.g. Bunnell et al. 2006; St. John and Black 2004). Recruitment in modeled crappie populations suggests that both population dynamics and environmental fluctuation are important in driving recruitment trends (Allen and Miranda 2001). Research that incorporates stock-recruitment models as well as environmental variables has been relatively successful at predicting crappie recruitment in lakes (Dockendorf and Allen 2005; Bunnell et al. 2006). In largemouth bass (Post et al. 1998) and crappie (Bunnell et al. 2006), models incorporating multiple life history stages have provided better insight into which developmental stages are most crucial for recruitment. Additional research is required to determine what developmental stages, spawning stock characteristics, and environmental factors are important to crappie recruitment success in Illinois.

Procedures:

In this job, we are assessing crappie populations on a set of lakes (N = 10) and determining what factors influence year-class strength. We assessed crappie populations by conducting three AC electrofishing transects on each lake on two dates in the spring and two in the fall. We supplemented the electrofishing with spring trap netting on each lake. All fish were identified and measured for total length, and crappie species were also weighed and scales taken for age and growth estimates. As an initial indicator of recruitment success, larval fish were collected using a 0.5 m diameter plankton push net with 500 um mesh and a 1:5 width to length ratio. Larval pushes were conducted for 5 minutes and total water sampled was measured using a torpedo flow meter mounted in the center of the net.

We sampled lake conditions and prey resources in each lake to determine how they influence crappie recruitment. Benthic invertebrates were sampled two times annually in June and August at six sites using a stovepipe sampler. Zooplankton, larval fish and seine samples were performed twice per month on the ten study lakes. Zooplankton was sampled using vertical tows at 4 inshore and 4 offshore locations at each lake using a 0.5 m diameter plankton net with 63 um mesh and a 1:3 width to length ratio. All samples were preserved and brought to the laboratory where they will be identified and counted. Seine samples were taken at 4 shoreline locations on each lake using a 1.2 x 9.1 m seine with a 1.2 x 1.2 m bag. The width, length, and depth of each transect was recorded to determine the volume of water seined. All fish collected were identified to species and a minimum of 50 individuals per species were measured for total length, with additional fish being counted. Age-0 crappie abundance will be estimated from fall trap netting.

We will determine variation in crappie recruitment and relate recruitment success to environmental, prey, and predator variables over multiple years. Initial recruitment success will be assessed through larval fish abundance, pooling black and white crappie because of difficulties distinguishing the two (Siefert 1969). We will identify critical stages for crappie survival and what factors are important to growth. These data will be used to recommend management strategies for use in enhancing and evaluating crappie recruitment.

Findings:

In this segment, CPUE was determined for adult black and white crappie from fall and spring electrofishing (Table 104.3). For lakes sampled in both seasons ($N = 7$), fall and spring CPUE differed significantly for black crappie (Wilcoxon signed rank, $W = -10.5$, $P = 0.03$) and marginally for white crappie (Wilcoxon signed rank, $W = 7.5$, $P = 0.06$). When comparing spring electrofishing CPUE in sympatric populations of black and white crappie, the highest catch rates of each species were inversely related (Figure 104.5). Lakes tend to be dominated by either black or white crappie, possibly resulting from differences in environmental characteristics between systems. In the next segment, we will compare relative abundance and size structure of black and white crappie to environmental conditions in the lakes.

Recommendations:

We will continue to evaluate fluctuating crappie recruitment patterns in a number of lakes and identify factors that are responsible. Study lakes were selected to encompass lakes with both good and poor recruitment in order to assess which factors have the greatest effect on year-class strength. Future analyses will incorporate multiple developmental stages (spawning stock, larvae, and age-0 juveniles) in order to evaluate which stages are most crucial for recruitment in Illinois systems. Furthermore, we will evaluate the influence of environmental factors and spawning stock characteristics on crappie recruitment. Collection and analysis of environmental variables are ongoing. These data will allow recommendations of management practices that will help stabilize crappie populations and increase recruitment to improve fishing consistently.

We will also evaluate the efficiency of sampling gear (fall trap netting vs. fall electrofishing) and time of year (spring vs. fall) for estimating adult crappie abundance in Illinois lakes. Our initial analysis suggests that season affects black crappie CPUE from electrofishing and possibly white crappie CPUE. Sampling difficulties have been a reoccurring issue with estimating crappie abundance (e.g. Miranda et al. 1990; Maceina and Stimpert 1998). In the next segment, we will evaluate the variation between gear type and season and its effect on spawning stock abundance estimates. These findings will allow recommendations of sampling techniques for adult crappie in Illinois lakes, specifically for spawning stock estimates.

Study 105: Sportfish Sampling Efficiency

Job 105.1: Comparison of AC and DC electrofishing for sampling fish populations in Illinois lakes.

Objectives: To evaluate differences in catch rate and efficiency for sportfish sampling with AC and DC electrofishing gears.

Introduction:

Electrofishing is a common tool used by biologists to sample fish populations. There are multiple gear types and settings that can be used when electrofishing and different reasons for using each. Traditionally the IDNR has used AC electrofishing for standardized sampling of fish populations in lakes throughout the state. However the use of DC electrofishing is becoming more common as the costs are declining and the benefits are better understood. DC electrofishing has been shown to be more efficient for use with certain fish species and biologists have begun using this gear more often. There is a need for research comparing these two gear types in order to determine if comparisons can be made and to develop standardized sampling. These comparisons are critical for using historical data for observing long-term trends. In addition more information is needed regarding the efficiency and limitations of each gear type and how it differs with each fish species.

Electrofishing is one of the most common gears employed for sampling of littoral fish populations. Electrofishing gear can employ three types of current to immobilize fish, alternating current (AC), direct current (DC) or pulsed direct current (PDC). The accepted generality is that AC has the greatest level of mortality for fish, followed by PDC and finally DC (Hauck 1949; Lamarque 1990; Reynolds 1996; Snyder 2003). Although the effects of the different types of gears are universally accepted, there is little research directly comparing the three currents (Snyder 2003).

Lab experiments comparing all three currents found the highest mortality occurred with AC (4%), followed by PDC (0.3%) and no mortality in DC treatments (Taylor et al. 1957). Two additional studies observed higher mortality in a number of fish species when subjected to AC current compared to DC current (Pratt 1955; DeMont 1971). Alternatively, Spencer (1967) found no differences in mortality for bluegill subjected to either 115 V AC or 115 V DC in concrete ponds. Only two studies directly compared differences in injury rates between AC and DC current types and found a slightly higher rate of spinal injuries and muscle hemorrhages in AC treatments (Taube 1992; Spencer 1967). Despite the negative impressions of AC electrofishing, mortality and injury levels are generally reported as low and have been shown to produce no long term decrease in survival or growth compared to other collection techniques (Schneider 1992). Although there are a large number of studies examining the effects of different electrofishing fields and varying settings on fish species, they are difficult to compare and direct comparisons are limited (Snyder 2003). In addition these studies are primarily focused on stream systems and sensitive salmonid species (Snyder 2003) and only recently have included non-game fish (see Miranda and Kidwell 2010; Janac and Jurajda 2011). Electrofishing catch rates of sportfish have been demonstrated to be related to density in reservoirs (Serns 1982; Serns 1983; Hall 1986; Gabelhouse 1987). When pulsed AC catch rates of largemouth bass were compared to pulsed DC in small ponds, it was determined that pulsed AC catch rates were much higher and more directly related to population estimates of largemouth bass (Hill and Willis

1994). To our knowledge, no studies have examined differences in catch rates or efficiency of AC and pulsed DC gear in lakes. There is a need for research to directly compare catch rates of the two gears and determine the advantages and disadvantages of using one over the other.

Procedures:

We conducted electrofishing samples on four lakes using both AC and DC electrofishing gear. AC electrofishing was conducted using 240V 3 phase AC generator and two poles with three droppers on each wired in sequence for 3 phase. Pulsed DC electrofishing was conducted using a Smith Root type VI electrofishing box utilizing 2 poles with circular probes containing 8 cable droppers on each at a voltage of 240V adjusting the pulse width to target 6-9A. These setups are the same as those used by biologists in the IDNR and all data collected will be comparable. In this segment we conducted one fall sample and one spring sample of both AC and DC electrofishing on each lake. The four lakes sampled were Charleston, Homer, Mingo, and Otter Lakes. AC or DC electrofishing was chosen randomly on each trip to ensure that the order of the gears used varied by lake. We conducted three thirty minute transects on each date and collected all fish species. We took lengths on all species and weights on largemouth bass. We calculated CPUE of major fish species of interest and compared catch rates of AC to DC gear. In addition to data collected in this segment, we used AC and DC electrofishing data from these four lakes collected from 2011 and 2012 in the analyses. We developed relationships between gears and determined what corrections may be required. We will make recommendations for which gear is more appropriate for each species and identify situations where one may be preferred over the other.

Findings:

In this segment we electrofished the four study lakes with AC and DC gear both in the fall of 2012 and the spring of 2013. We combined these results from AC and DC electrofishing in these lakes in previous years. The result was 3 spring and 2 fall samples for each gear type in each lake for a total of 20 AC samples and 20 DC sampling trips. Preliminary analyses found significant correlations in catch per unit effort between gear types for young-of year ($r = 0.60$; $P = 0.006$) and adult largemouth bass ($r = 0.53$; $P = 0.02$), bluegill ($r = 0.60$; $P = 0.008$), white crappie ($r = 0.61$; $P = 0.008$) and black crappie ($r = 0.65$; $P = 0.004$). Catch rates were not correlated for gizzard shad ($r = 0.44$; $P = 0.06$) and common carp ($r = 0.43$; $P = 0.07$). Catch rates of largemouth bass were very similar between gears for both young-of-year and larger largemouth bass (Figure 105.1). The relationship between catch rates was very close to the 1:1 ratio line indicating that AC and DC gear caught largemouth bass at similar rates. Crappie followed a different pattern with both white and black crappie caught in higher numbers in DC gear when populations were low (Figure 105.2), but when large numbers of crappie were captured, AC gear sampled them at a higher rate. DC gear never caught more than 37 white crappie per hour, whereas AC gear had catch rates extending to 65 fish per hour. Black crappie were not abundant in these lakes, so it is difficult to assess their catch rates, but a similar pattern was observed as with white crappie. DC gear was more efficient at catching both gizzard shad and common carp than AC gear (Figure 105.3). Both species tend to avoid electrofishing current and DC has been noted to better draw running fish toward the dropper array than AC, possibly contributing to the higher catch rates observed.

Recommendations:

Catch rates for the sportfish species examined in this segment were similar between gears and the catch rates were significantly related. Largemouth bass catch rates were very similar between gear types for both young-of-year and adult fish. We did observe some variation in catch rates depending on the density of fish especially in crappie populations where AC gear caught more fish at high densities. Both gizzard shad and common carp had differences in catch rates between AC and DC gear and they were not significantly related. These preliminary analyses identified both similarities and differences between AC and DC electrofishing. Analyses in future segments will focus on if these differences are significant and if conclusions on the status of a fishery would be biased by gear selection. We will expand the analyses to include more species and examine size distribution differences between gear types. We will determine if the IDNR can compare data collected with DC gear to historical data collected using AC gear and identify areas where discrepancies may occur. Recommendations on the use of AC or DC gear will be based on the species of interest and the tradeoffs of each gear. Ultimately this information will guide the IDNR in development of sampling protocols and allow for changes in gear type that allow comparison with historical data.

References

Allan, M.S., M.W. Rogers, R.A. Myers, and W.M. Bivin. 2004. Simulated impacts of tournament-associated mortality on largemouth bass fisheries. North American Journal of Fisheries Management 24(4) 1252-1261.

Allen, M. S., and L. E. Miranda. 1995. An evaluation of the value of harvest restrictions in managing crappie fisheries. North American Journal of Fisheries Management 15:766–772.

Allen, M.S. and Leandro E. Miranda. 2001. Quasi-cycles in crappie populations are forced by interactions among population characteristics and environment. Canadian Journal of Fisheries and Aquatic Sciences 58: 594–601.

Allen, M.S., and W.E. Pinne III. 2000. Detecting Fish Population Responses to a Minimum Length Limit: Effects of Variable Recruitment and Duration of Evaluation. North American Journal of Fisheries Management 20:672–682.

Anderson, O. 1984. Optimal foraging by largemouth bass in structured environments. Ecology 65(3): 851-861.

Anderson, R.O. 1976. Management of small warm water impoundments. Fisheries 1:5-7, 26-28.

Angilletta, M. J., T. D. Steury, and M. W. Sears. 2004 Temperature, growth rate, and body size in ectotherms: fitting pieces of a life-history puzzle. Integrative and Comparative Biology 44:498-509.

Annett, C., Hunt, J., and E.D. Dibble. 1996. The complete bass: habitat use patterns of all stages of the life cycle of largemouth bass. American Fisheries Society Symposium 16:306-314.

Arterburn, J.E., D.J. Kirby, and C.R. Berry. 2002. A survey of angler attitudes and biologist opinions regarding trophy catfish and their management. Fisheries 27(5):10–21.

Axon, J. R. and D. K. Whitehurst. 1985. Striped Bass Management in Lakes with Emphasis on Management Problems. Transactions of the American Fisheries Society 114(1):8-11.

Bailey, W. M. 1975. An evaluation of striped bass introductions in the southeastern United States. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 28:53–68.

Barthel, B. L., S. J. Cooke, J. H. Svec, C. D. Suski, C. M. Bunt, F. J. S. Phelan, and D. P. Philipp. 2008. Divergent life histories among smallmouth bass Micropterus dolomieu inhabiting a connected river–lake system. Journal of Fish Biology 73: 829–852.

Barwick, D.H.. 2004. Species richness and centrarchids abundance in littoral habitats of three southern U.S. reservoirs. North American Journal of Fisheries Management. 24: 76-81.

Beam, J. H. 1983. The effect of annual water level management on population trends of white crappie in Elk City Reservoir, Kansas. North American Journal of Fisheries Management 3:34–40.

Bettoli, P.W., M.J. Maceina, R.L. Noble, and R.K. Betsill. 1993. Response of a Reservoir Fish Community to Aquatic Vegetation Removal. North American Journal of Fisheries Management 13:110-124.

Bister, T.J., D.W. Willis, A.D. Knapp and T.R. St. Sauver. 2002. Evaluation of a 23-cm Minimum Length Limit for Black and White Crappies in a Small South Dakota Impoundment, North American Journal of Fisheries Management 22: 1364-1368.

Blackburn, T.M., K.J. Gaston, and N. Loder. 1999. Geographic gradients in body size: a clarification of Bergmann's rule. Div. Distrib. 5:165-174.

Bolding, B., S. Bonar, and M. Divens. 2004. Use of artificial structure to enhance angler benefits in lakes, ponds, and reservoirs: A literature review. Reviews in Fisheries Science 12:75-96.

Bouchard, J., and D. Boisclair. 2008. The relative importance of local, lateral, and longitudinal variables on the development of habitat quality models for a river. Canadian Journal of Fisheries and Aquatic Sciences 65:61-73.

Boxrucker, J. C. 1986. Evaluation of supplemental stocking of largemouth bass as a management tool in small impoundments. North American Journal of Fisheries Management 6:391-396.

Buchanan, J. P., and H. E. Bryant. 1973. The occurrence of a predorsal stripe in the black crappie, Pomoxis nigromaculatus. Journal of the Alabama Academy of Science 44:293–297.

Buckmeier, D.L. and R.K. Betsill. 2002. Mortality and dispersal of stocked fingerling largemouth bass and effects on cohort abundance. Pages 667-676 in D.P. Phillip and M.S. Ridgway, editors. Black Bass: Ecology, Conservation, and Management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Buckmeier, D.L., J.W. Schlechte, and R.K. Betsill. 2003. Stocking fingerling largemouth bass to alter genetic composition: efficacy and efficiency of three stocking rates. 23:523-529.

Buisson L, L. Blanc, G. Grenouillet 2008. Modeling stream fish species distribution in a river network: the relative effects of temperature versus physical factors. Ecology of Freshwater Fish 2008: 17: 244–257.

Bunnell, D.B., R.S. Hale, M.J. Vanni and R.A. Stein. 2006. Predicting Crappie Recruitment in Ohio Reservoirs with Spawning Stock Size, Larval Density, and Chlorophyll Concentrations. North American Journal of Fisheries Management, 26: 1-12.

Bunt, C.M., and S.J. Cooke. 2001. Post-spawn movements and habitat use by greater redhorse, Moxostoma valenciennesi. Ecology of Freshwater Fish 10: 57-60.

Burkett, D. P., P. C. Mankin, G. W. Lewis, W. F. Childers, and D. P. Philipp. 1986. Hook-and-line vulnerability and multiple recapture of largemouth bass under a minimum total-length limit of 457 mm. North American Journal of Fisheries Management 6:109-112.

Buynak, G. L., and B. Mitchell. 1999. Contribution of stocked advanced-fingerling largemouth bass to the population and fishery at Taylorsville Lake, Kentucky. North American Journal of Fisheries Management 19:494-503.

Buynak, G.L., L.E. Kornman, A. Surmont and B. Mitchell. 1991. Evaluation of a Differential-Harvest Regulation for Black Bass in Cave Run Lake, Kentucky. North American Journal of Fisheries Management. 11: 277-284.

Caliteux, R.L., W.F. Porak, S. Crawford, and L.L. Connor. 1996. Food habits and growth of largemouth bass in vegetated vs. unvegetated lakes in central Florida. Proceedings of the Annual Conference, Southeastern Association of Fish and Wildlife Agencies.

Carpenter, S.R. and Lodge, D.M. 1986. Effects of submersed macrophytes on ecosystem processes. Aquatic Botany 26(3-4): 341-370.

Chapman, D., C. Carlson, D. Weitkamp, G. Matthews, J. Stevenson and M. Miller. 1997. Homing in Sockeye and Chinook Salmon Transported around Part of Their Smolt Migration Route in the Columbia River. North American Journal of Fisheries Management17(1):101-113.

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

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

Coble, D.W. 1975. Smallmouth bass. pp. 21-33 in H.E. Clepper and R.H. Stroud (eds) Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Colombo, R.E., Q.E. Phelps, J.E. Garvey, R. C. Heidinger and T. Stefanavage. 2008. Gear-Specific Population Demographics of Channel Catfish in a Large Midwestern River, North American Journal of Fisheries Management, 28: 241-246.

Colvin, M. A. 1991. Population characteristics and angler harvest of white crappies in four large Missouri reservoirs. North American Journal of Fisheries Management 11:572–584.

Connor, W. P., R. K. Steinhorst, and H. L. Burge. 2000. Forecasting Survival and Passage of Migratory Juvenile Salmonids. North American Journal of Fisheries Management 20(3):651-660.

Conover, G. A., and R. J. Sheehan. 1996. Evaluation of oxytetracycline marks in sagittal otoliths of juvenile black crappies. North American Journal of Fisheries Management 16:686–688.

Cooke, S.J., D.P. Philipp, and P.J. Weatherhead. 2002. Parental care patterns and energetics of smallmouth bass (Micropterus dolomieu) andblargemouth bass (Micropterus salmoides) monitored with activity transmitters. Canadian Journal of Zoology 80: 756–770

Cooke, S.J.; Philipp, D.P.; Weatherhead, P.J. 2002. Parental care patterns and energetics of smallmouth bass (Micropterus salmoides) monitored with activity transmitters. Canadian Journal of Zoology 80 (4): 756-770.

Crance. J. H., and L. G. McBay. 1966. Results of tests with channel catfish in Alabama ponds. Progressive Fish-Culturist 28:193-200.

Creque, S.M., E.S. Rutherford and T.G. Zorn. 2005. Use of GIS-Derived Landscape-Scale Habitat Features to Explain Spatial Patterns of Fish Density in Michigan Rivers, North American Journal of Fisheries Management, 25: 1411-1425.

Daugherty, D.J., Sutton TM. 2005. Seasonal movement patterns, habitat use, and home range of flathead catfish in the Lower St. Joseph River, Michigan. North American Journal of Fisheries Management 25: 256–269.

Dauwalter, D.C., and J.R. Jackson. 2005. A re-evaluation of U.S. state fish-stocking recommendations for small, private, warmwater impoundments. Fisheries 30 :18-28.

Dauwalter, D.C., and W.L. Fisher. 2008. Spatial and Temporal Patterns in Stream Habitat and Smallmouth Bass Populations in Eastern Oklahoma, Transactions of the American Fisheries Society. 137: 1072-1088.

Dauwalter, D.C., D.K. Splinter, W.L. Fisher, and R.A. Marston. 2007. Geomorphology and stream habitat relationships with smallmouth bass [Micropterus dolomieu] abundance at multiple spatial scales in eastern Oklahoma. Canadian Journal of Fisheries and Aquatic Sciences 64:1116-1129.

Davis, J. 1959. Management of channel catfish in Kansas. University of Kansas Museum of Natural History Miscellaneous Publication 21.

DeMont, D.J.. 1971. Physical factors affecting electrofishing in conductive waters: Master's thesis, Humboldt State College, Arcadia, Calif.Dettmers et al. 1996

Dent, R. J. 1986. Results of a black bass 15.0-in minimum length limit on Pomme de Terre Lake, Missouri. Pages 309-310 in Hall and Van Den Avyle (1986).

Dettmers, J. M., and R. A. Stein. 1996. Quantifying Linkages among Gizzard Shad, Zooplankton, and Phytoplankton in Lakes. Transactions of the American Fisheries Society 125(1):27-41.

Dettmers, J. M., R. A. Stein, and E. M. Lewis. 1998. Potential regulation of age-0 gizzard shad by hybrid striped bass in Ohio reservoirs. Transactions of the American Fisheries Society 127(1):84-94.

DeVries, D. R., M. T. Bremigan, and R. A. Stein. 1998. Prey selection by larval fishes as influenced by available zooplankton and gape limitation. Transactions of the American Fisheries Society 127:1040–1050.

Diana, M., J. D. Allan, and D. Infante. 2006. The influence of physical habitat and land use on stream fish assemblages in southeastern Michigan. Pages 359–374 in R. M. Hughes, L. Wang, and P. W. Seelbach, editors. Influences of landscapes on stream habitats and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

Diana, M.J., and D.H.Wahl. 2008. Long-term stocking success of largemouth bass and the relationship with natural populations. Pages 413-426 in M.S. Allen S. Sammons, and M.J. Maceina, Editors. Balancing Fisheries Management and Water Uses for Impounded River Systems. American Fisheries Society, Symposuim 62, Bethesda, Maryland.

Diana, M.J., D.H. Wahl. 2009. Growth and survival of four sizes of stocked largemouth bass. North American Journal of Fisheries Management 29:1653–1663.

Diana, M.J., M.A. Nannini, C.S. Deboom, J.J. Mulhollem, D.P. Philipp, and D.H. Wahl. 2011. Factors influencing largemouth bass recruitment: Implications for the Illinois management and stocking program. Division of Fisheries, Illinois Department of Natural Resources, Federal Aid in Fish Restoration, F-135-R, Annual Report.

Diana, M.J., A.L. Larsen, M.J. Siepker, and D.H. Wahl. In Press. Effects of Tournament Compared to Catch and Release Angling on Nest Abandonment of Largemouth Bass. Transactions of the American Fisheries Society.

Dillard, J. G., and G. D. Novinger. 1975. Stocking largemouth bass in smallimpoundments. Pages 459-474 in H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Dockendorf, K.J., and M.S. Allen. 2005. Age-0 Black Crappie Abundance and Size in Relation to Zooplankton Density, Stock Abundance, and Water Clarity in Three Florida Lakes, Transactions of the American Fisheries Society, 134: 172-183.

Dombeck, M. P., B. W. Menzel and Paul N. Hinz. 1984. Muskellunge Spawning Habitat and Reproductive Success. Transactions of the American Fisheries Society 113(2)205-216.

Eder, S. 1984. Effectiveness of an imposed slot limit of 12.0-14.9 inches on largemouth bass. North American Journal of Fisheries Management 4: 469-478.

Fausch, K. D., C. L. Hawkes, and M. G. Parsons. 1988. Models that predict standing crop of stream fish from habitat variables: 1950–1985. U.S. Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-213, Portland, Oregon.

Fielder, D.G. 1992. Evaluation of stocking walleye fry and fingerlings and factors affecting their success in lower Lake Oahe, South Dakota. North American Journal of Fisheries Management 12: 336-345

Flotemersch, J.E., J.B. Stribling, R.M. Hughes, L. Reynolds, M.J. Paul, and C. Wolter. 2011. Site length for biological assessment of boatable rivers. River Research and Applications 27:520-535.

France, R.L. 1996. Macroinvertebrate colonization of woody debris in Canadian shield lakes following riparian clearcutting. Conservation Biology 11(2):513-521.

Freund, J.G. and K.J. Hartman. 2005. Largemouth Bass Habitat Interactions among Off-Channel and Main River Habitats in an Ohio River Navigation Pool, Journal of Feshwater Ecology 20: 735-742.

Gabelhouse, D. W., Jr. 1987. Response of largemouth bass and bluegills to removal of surplus largemouth bass from a Kansas pond. North American Journal of Fisheries Management 7:81-90.

Gilliland ER. 2002. Livewell operating procedures to reduce mortality of black bass during summer tournaments. American Fisheries Society Symposium 31:477–487.

Gilliland, E. R. 1992. Experimental stocking of Florida largemouth bass into small Oklahoma reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 46:487-494.

Goodson, L. F. 1966. Crappie. Pages 312–322 in A. Calhoun, editor. Inland fisheries management. California. Department of Fish and Game, Sacramento.

Gordan, D. J., and H. R. MacCrimmon. 1982. Juvenile salmonid production in a Lake Erie nursery stream. Journal of Fish Biology 21:455–473.

Gutreuter, S. 2004. Challenging the assumption of habitat limitation: an example from centrarchid fishes over an intermediate spatial scale. River Research and Applications 20: 413–425

Guy, C.S., and D.W. Willis. 1995. Population characteristics of black crappies in South Dakota waters: a case for ecosystemspecific management. N. Am. J. Fish. Manage. 15: 754–765.

Hale, R. S., M. E. Lundquist, R. L. Miller, and R. W. Petering. 1999. Evaluation of a 254-mm minimum length limit on crappies in Delaware Reservoir, Ohio. North American Journal of Fisheries Management 19:804–819.

Hall, T. J. 1986. Electrofishing catch rate per hour as an indicator of largemouth bass density in Ohio impoundments. North America Journal of Fisheries Management 6:397-400.

Harrison, E. J., and W. F. Hadley. 1979. Biology of Muskellunge (Esox masquinongy) in the Upper Niagara River. Transactions of the American Fisheries Society 108:444-451

Hauck, F. R. 1949. Some harmful effects of the electric shocker on large rainbow trout. Transactions of the American Fisheries Society 77:61–64.

Havens, K.E., D. Fox, S. Gornak and C. Hanlon. 2005. Aquatic vegetation and largemouth bass population responses to water-level variations in Lake Okeechobee, Florida (USA). Hydrobiologia 539(1): 225-237.

Hayes, D. B., C. P. Ferreri, and W. W. Taylor. 1996. Linking fish habitat to their population dynamics. Canadian Journal of Fisheries and Aquatic Sciences. 53 (Supplement 1):383–390.

Heidinger, R.C., D.R. Helms, T I. Hiebert, and P. H. Howe. 1983. Operational comparison of three electrofishing systems. North American Journal of Fisheries Management 3:254–257.

Hergenrader G. L. and Q. P. Bliss. 1971. The White Perch in Nebraska. Transactions of the American Fisheries Society 100(4)734-738

Hickey C.W. and C. Kohler. 2004. Comparison of bluegill consumption rates by largemouth bass and sunshine bass in structures and nonstructured artificial environments. Transactions of the American Fisheries Society 133:1534-1528.

Hill, T.D., D.W. Willis. 1994. Influence of Water Conductivity on Pulsed AC and Pulsed DC Electrofishing Catch Rates for Largemouth Bass. North American Journal of Fisheries Management 14:202-207.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in light of biological research. Rapports et Proce`s-Verbaux des Re´unions, Conseil International pour l'Exploration de la Mer 20:1–228.Isermann, D.A., P.W. Bettoli, S.M. Sammons & T.N. Churchill. 2002. Initial Poststocking Mortality, Oxytetracycline Marking, and Year-Class Contribution of Black-Nosed Crappies Stocked into Tennessee Reservoirs. North American Journal of Fisheries Management. 22: 1399-1408.

Hoffman, J.J. and P.W. Bettoli. 2005. Growth, dispersal, mortality, and contribution of stocked largemouth bass stocked into Chickamauga Lake, Tennessee. North American Journal of Fisheries Management 25:1518-1527.

Holland, R. S., and E. J. Peters. 1992. Differential catch by hoop nets of three mesh sizes in the lower Platte River. North American Journal of Fisheries Management 12:237–243.

Holley, M. P., M. D. Marshall, and M. J. Maceina. 2009. Fishery and population characteristics of blue catfish and channel catfish and potential impacts of minimum length limits on the fishery in Lake Wilson, Alabama. North American Journal of Fisheries Management. 29:1183–1194.

Houde, E. D. 1987. Fish early life dynamics and recruitment variability. American Fisheries Society Symposium 2:17-29.

Irwin, E.R, Noble R.L., and J.R. Jackson. 1997. Distribution of age-0 largemouth bass in relation to shoreline landscape features. North American Journal of Fisheries Management 17:882-893.

Isermann, D. A., P. W. Bettoli, and S. M. Sammons. 1999. Efficacy of identifying stocked crappies in a Tennessee reservoir using oxytetracycline marking. North American Journal of Fisheries Management 19:1122–1123.

Jana´cˇ, M. and P. Jurajda. 2011. Mortality induced by electrofishing and handling in five young-of-the-year cyprinids: effect of the fish size, species and anode size. Journal of Applied Ichthyology. 27: 990–994.

Jeffrey W. Slipke, Allen D. Martin, John Pitlo Jr. & Michael J. Maceina. 2002. Use of the Spawning Potential Ratio for the Upper Mississippi River Channel Catfish Fishery. North American Journal of Fisheries Management 22: 1295-1300.

Jenkins, F. M. 1955. Expansion of the crappie population in Ardmore City Lake following a drastic reduction in numbers. Proceedings of the Oklahoma Academy of Science 36:70–73.

Johnson, B.M., and P.J. Martinez. 1995. Selecting harvest regulations for recreational fisheries: opportunities for research/management cooperation. Fisheries 20(10): 22-29.

Johnson, R.L., A.D. Christian, S.D. Henry, and S.W. Barkley. 2009. Distribution, Population Characteristics, and Physical Habitat Associations of Black Bass (Micropterus) in the Lower Eleven Point River, Arkansas. Southeastern Naturalist 8:653–670.

Kerr, S.J. and K.K. Kamke. 2003. Competitive fishing in freshwaters of North America. Fisheries 28(3):26–31.

Kieffer, J.D., M. R. Kubacki, F.J.S. Phelan, D.P. Philipp, and B.L. Tufts. 1995. Effects of catch-and-release angling on nesting male smallmouth bass. Transactions of the American Fisheries Society 124:70-76.

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

Kramer, R. H. and L. L. Smith. 1962. Formation of year class in largemouth bass. Transactions of the American Fisheries Society 91:29-41.

Kwak, T. J., and M. G. Henry. 1995. Largemouth bass mortality and related causal factors during live-release fishing tournaments on a large Minnesota lake. North American Journal of Fisheries Management 15:621–630.

Lamarque, P. 1990. Electrophysiology of fish in electric fields. Pages 4–33 in I. G. Cowx and P. Lamarque, editors. Fishing with electricity, applications in freshwater fisheries management. Fishing News Books, Oxford, UK.

Larson, S. C., B. Saul, and S. Schleiger. 1991. Exploitation and survival of black crappies in three Georgia reservoirs. North American Journal of Fisheries Management 11:604–613.

Lawson, C. S., and W. D. Davies. 1979. Effects of bass stocking and rates of fishing on a largemouth bass population. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 31:493-497.

Le Pichon, C., G. Gorges, J. Baudry, F. Goreaud, and P. Boet. 2009. Spatial metrics and methods for riverscapes: quantifying variability in riverine fish habitat patterns. Environmetrics 20(5):512-526.

Lewis, C.A., N.P. Lester, A.D. Bradshaw, J.E. Fitzgibbon, K. Fuller, L. Hakanson, and C. Richards. 1996. Considerations of scale in habitat conservation and restoration. Canadian Journal of Fisheries and Aquatic Sciences. 53 (Supplement 1): 440–445.

Lewis, W. M., R. Heidinger and M. Konikoff. 1968. Loss of Fishes Over the Drop Box Spillway of a Lake. Transactions of the American Fisheries Society 97(4):492-494.

Louder, D. 1958. Escape of Fish Over Spillways. The Progressive Fish-Culturist 20:38-41.

Love, J.W.. 2011. Habitat Suitability Index for Largemouth Bass in Tidal Rivers of the Chesapeake Bay Watershed. Transactions of the American Fisheries Society. 140: 1049-1059.

Lyons J., R.R. Piette and K.W. Niermeyer. 2001. Development, validation, and application of a fish-based index of biotic integrity for Wisconsins large warmwater rivers. Transactions of the American Fisheries Society 130: 1077–1094.

Lyons, J., and P. D. Kanehl. 2002. Seasonal movements of smallmouth bass in streams. Pages 149–160 in D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Maceina, M. J., and M. R. Stimpert. 1998. Relations between reservoir hydrology and crappie recruitment in Alabama. North American Journal of Fisheries Management 18:104–113.

Maceina, M. J., B. R. Murphy, and J. J. Isely. 1988. Factors regulating Florida largemouth bass stocking success and hybridization with northern largemouth bass in Aquilla Lake, Texas. Transactions of the American Fisheries Society 117:221-231.

Maceina, M. J., O. Ozen, M. S. Allen, and S. M. Smith. 1998. Use of equilibrium yield models to assess different lengths limits for crappie in Weiss Lake, Alabama. North American Journal of Fisheries Management 18:854–863.

Maceina, M.J. 2003. Verification of the Influence of Hydrologic Factors on Crappie Recruitment in Alabama Reservoirs. North American Journal of Fisheries Management. 23: 470-480.

Maceina, M.J. 2003. Verification of the Influence of Hydrologic Factors on Crappie Recruitment in Alabama Reservoirs. North American Journal of Fisheries Management 23: 470-480.

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

Marshall, M.D., Michael P. Holley & Michael J. Maceina. 2009. Assessment of the Flathead Catfish Population in a Lightly Exploited Fishery in Lake Wilson, Alabama, North American Journal of Fisheries Management, 29: 869-875.

Martin, M. 1988. Black and hybrid crappie culture and crappie management. Aquaculture 14:35–41.

Martinez, P. J., T. E. Chart, M. A. Trammell, J. G. Wullschleger and E. P. Bergersen. 1994. Fish Species Composition before and after Construction of a Main Stem Reservoir on the White River, Colorado. Environ. Biol. Fishes 40(3):227-239.

Marzolf, R. C. 1957. The reproduction of channel catfish in Missouri ponds. Journal of Wildlife Management 21:22-28.

Mather, D., P. L. McCreight, and G. A. Nardace. 1979. Variations in fecundity of white crappie in Conowingo Pond, Pennsylvania. Transactions of the American Fisheries Society 108:548–554.

McDonough, T. A., and J. P. Buchanan. 1991. Factors affecting abundance of white crappies in Chickamauga Reservoir, Tennessee, 1970–1989. North American Journal of Fisheries Management 11:513–524.

McRae, B.J. and J.S. Diana. 2005. Factors influencing density of age-0 brown trout and brook trout in the Au Sable River, Michigan. Transactions of the American Fisheries Society 134(1): 132-140.

Meals, K.O., and L. E. Miranda. 1991. Variability in abundance of age-0 centrarchids among littoral habitats of flood control reservoirs in Mississippi. North American Journal of Fisheries Management 11:298-304.

Michaelson, D.P., J.J. Ney, and T.M. Sutton. 2001. Largemouth Bass Predation on Stocked Striped Bass in Smith Mountain Lake, Virginia. North American Journal of Fisheries Management 21:326–332.

Milzner. L. 1984. Crappie management: problems and solutions. North American Journal of Fisheries Management 4:339-340.

Mitzner, L. 1981. Influence of floodwater storage on abundance of juvenile crappie and subsequent harvest at Lake Rathbun, Iowa. North American Journal of Fisheries Management 1:46-50.

Minckley W.L., and J.E. Deacon. 1959. Biology of flathead catfish in Kansas. Transactions of the American Fisheries Society 88: 344–355.

Miranda, L E. and R.H. Kidwell. 2010. Unintended Effects of Electrofishing on Nongame Fishes. Transactions of the American Fisheries Society 139: 1315-1321.

Miranda, L. E. and W. Hubbard. 1994. Winter survival of age-0 largemouth bass relative to size, predators, and shelter. North American Journal of Fisheries Management 14:790-796.

Miranda, L.E., Pugh, L.L. 1997. Relationship between vegetation coverage and abundance, size, and diet of juvenile largemouth bass during winter. North American Journal of Fisheries Management 17:601-610.

Mitchell, J. M., K. K. Sellers, W. D. Harvey, and L. T. Fries. 1991. Effects of stocking regime and harvest regulation on Florida largemouth bass stocking success. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 45:477-483.

Mitzner, L. 1991. Effect of environmental variables upon crappie young, year-class strength, and the sport fishery. North American Journal of Fisheries Management 11: 534–542.

Modde, T. 1980. State stocking policies for small warmwater impoundments. Fisheries 5:13-17.

Moore, C. M., R. J. Neves, and J. J. Ney. 1991. Survival and abundance of stocked striped bass in Smith Mountain Lake, Virginia. North American Journal of Fisheries Management 11:393–399.

Myers, R.A. and J.B. Rowe III. 2001. Pond Production and Poststocking Survival of Large Fingerling Black Crappies in Florida. North American Journal of Aquaculture 63: 45-48.

Myers,R.A., M.S. Allen and D.E. Colle. 2000. Survival of Fingerling Black Crappies Tagged with Microwire Tags Stocked in a Florida Lake. North American Journal of Fisheries Management. 20: 534-537.

Navarro, J. E., McCauley, D.J. 1993. Fish escapement from two storage reservoirs in Michigan Rivers 4(1):36-47.

Neal JW, Lopez-Clayton D. 2001. Mortality of largemouth bass during catch-and-release tournaments in a Puerto Rico reservoir. North American Journal of Fisheries Management 21:834–842.

Neebling, T.E., and M.C. Quist. 2010. Relationships between fish assemblages and habitat characteristics in Iowa's non-wadeable rivers. Fisheries Management and Ecology 17:369-385.

Neves, R. J. 1975. Factors affecting fry production of smallmouth bass (Micropterus dolomieui) in South Branch Lake, Maine. Transactions of the American Fisheries Society 104:83–87.

Noble, R. L. 2002. Reflections on 25 years of progress in black bass management. Pages 419–432 in D. P. Philipp and M. S. Ridgeway, editors. Black bass: biology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Novinger, G.D. 1984. Observations on the use of size limits for black bass in large impoundements. Fisheries 9(4): 2 – 6.

O'Connor, N.A. 1991. The effects of habitat complexity on the macroinvertebrates colonizing wood substrates in lowland streams. Oecologia 85:504-512.

Ostrand, K. G., S. J. Cooke, and D. H. Wahl. 2004. Effects of stress on largemouth bass reproduction. North American Journal of Fisheries Management.

Paller, M. H., D. E. Fletcher, M. M. Standora, T. B. Grabowski, T. A. Jones, S. A. Dyer and J. J. Isely. 2006. Emigration of Fish from Two South Carolina Cooling Reservoirs. North American Journal of Fisheries Management 26(4):976-982.

Parkos III, J. J. and D. H. Wahl. 2002. Towards an understanding of recruitment mechanisms in largemouth bass. Black bass 2000: ecology, conservation, and management. American Fisheries Society Symposium 31:25-46.

Parkos III, J. J. and D. H. Wahl. Intra- and Intersystem Variation in Largemouth Bass Recruitment: Reproduction, Prey Availability, and the Timing of Year-Class Establishment. Transactions of the American Fisheries Society 139:1372–1385.

Parsons, G. R., and K. Meals. 1997. Comparison of triploid hybrid crappie and diploid white crappie in experimental ponds. North American Journal of the Fisheries Management 17:803–806.

Paukert, C., M. McInerny, R. Schultz. 2007. Historical trends in creel limits, length-based limits, and season restrictions for black basses in the United States and Canada. Fisheries. 32(2): 62-72.

Paukert, C.P., and A.S. Makinster. 2009. Longitudinal patterns in flathead catfish relative abundance and length at age withing a large river: effects of an urban gradient. River Research and Applications 25: 861–873.

Pflieger, W.L. 1966. Reproduction of the smallmouth bass (Micropterus dolomieu) in a small Ozark stream. American Midland Naturalist 76:410-418.

Philipp, D. P., C. A. Toline, M. F. Kubacki, D. B. F. Philipp, and F. J. Phelan. 1997. The impact of catch-and-release angling on the reproductive success of smallmouth and largemouth bass. North American Journal of Fisheries Management 17: 557-567.

Pickering, A.D., T.G. Pottinger, and J.F. Carragher. 1989. Differences in the sensitivity or brown trout salmo-trutta L. and rainbow trout salmo-gairdneri Richardson to physiological doses of cortisol. Journal of Fish Biology 34: 757-768.

Pine, W. E., III, and M. S. Allen. 2001. Differential growth and survival of weekly age-0 black crappie cohorts in a Florida lake. Transactions of the American Fisheries Society 130:80–91.

Pitlo, J.R.. 1997. Response of Upper Mississippi River Channel Catfish Populations to Changes in Commercial Harvest Regulations, North American Journal of Fisheries Management, 17:848-859.

Plosila, D. S., and B. D. White. 1970. A Swinging Vertical Screen for Fish Barrier Dams. The Progressive Fish-Culturist 32(3)178-179.

Pope, K. L., D. W. Willis, and D. O. Lucchesi. 1996. Differential relations of age-0 black crappie and yellow perch to climatological variables in a natural lake. Journal of Freshwater Ecology 11:345–350.

Porak, W. F., W. E. Johnson, S. Crawford, D. J. Renfro, T. R. Schoeb, R. B. Stout, R. A. Krause, and R. A. DeMauro. 2002. Factors affecting survival of largemouth bass raised on artificial diets and stocked into Florida lakes. Pages 649–665 in D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Post, D., J. Kitchell, and J. Hodgson. 1998. Interactions among adult demography, spawning date, growth rate, predation, overwinter mortality, and the recruitment of largemouth bass in a northern lake. Canadian Journal of Fisheries and Aquatic Science 55:2588-2600.

Powell. D. H. 1976. Channel catfish as an additional sport fish in Alabama's state-owned and managed public fishing lakes. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 29(1975):265-278.

Pratt, V.S.. 1955. Fish mortality caused by electrical shockers. Transactions of the American Fisheries Society 84: 93–96.

Pusey, B. J., M. J. Kennard, and A. H. Arthingon. 2000. Discharge variability and the development of predictive models relating stream fish assemblage structure to habitat in northeastern Australia. Ecology of Freshwater Fish 9:30–50.

Racey, C.L. and S.E. Lochmann. 2002. Year-Class Contribution of White Crappies Stocked into Lake Chicot, Arkansas. North American Journal of Fisheries Management 22: 1409-1415.

Raymond, H. L. 1988. Effects of Hydroelectric Development and Fisheries Enhancement on Spring and Summer Chinook Salmon and Steelhead in the Columbia River Basin. North American Journal of Fisheries Management 8(1)1-24.

Redmond, L. C. 1986. The history and development of warmwater fish harvest regulations. Pages 186-195 in Hall and Van Den Avyle (1986).

Reed, J. R., and W. D. Davies. 1991. Population dynamics of black crappies and white crappies in Weiss Reservoir, Alabama: implications for the implementation of harvest restrictions. North American Journal of Fisheries Management 11:598–603.

Remshardt, W.J. and W.L. Fisher. 2009. Effects of variation in streamflow and channel structure on smallmouth bass habitat in an alluvial stream. River Research and Applications 25: 661–674.

Reynolds, J.B.. 1996. Electrofishing, in Murphy, B.R. and Willis, D.W., Fisheries techniques (2nd ed.): Bethesda, Md., American Fisheries Society, p. 221–253.

Richards, K. 1986. Evaluation of a 15.0-in minimum length limit for black bass at Lake of the Ozarks, Missouri. Page 309 in Hall and Van Den Avyle (1986).

Richards. K. 1986. Evaluation of a 15-inch minimum length limit for black bass at Lake of the Ozarks. Missouri. Page 309 in Hall and Van Den Avyle (1986).

Ridgway, M.S. 1988. Developmental stage of offspring and brood defense in smallmouth bass Micropterus dolomieu. Canadian Journal of Zoology 66 (8): 1722-1728.

Rieger, P. W., and R. C. Summerfelt. 1978. An evaluation of the introduction of Florida largemouth bass into an Oklahoma reservoir receiving a heated effluent. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 30:48-57.

Rowe, D.C., C.L. Pierce, and T.F. Wilton. 2009. Fish assemblage relationships with physical habitat In wadeable Iowa streams. North American Journal of Fisheries Management 29(5):1314-1332.

Ryan, M. J., M. A. Webb, and L. T. Fries. 1996. Contribution of largemouth bass reared in nursery ponds to year classes in two Texas reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 50:131-138.

Sammons, S. M., and P. W. Bettoli. 1998. Larval sampling as a fisheries management tool: early detection of year-class strength. North American Journal of Fisheries Management 18:137–143.

Sammons, S. M., P. W. Bettoli, and V. A. Greear. 2001. Early life history characteristics of age-0 white crappie in response to hydrology and zooplankton densities in Normandy Reservoir, Tennessee. Transactions of the American Fisheries Society 130:442–449.

Sammons, S.M., M.J. Maceina and D.G. Partridge. 2003. Changes in behavior, movement, and home ranges of largemouth bass following large-scale hydrilla removal in Lake Seminole, Georgia. Journal of Aquatic Plant Management 41: 31-38.

Santucci, V. J., Jr., D. H. Wahl, and T. W. Storck. 1994. Growth, mortality, harvest, and cost-effectiveness of stocked channel catfish in a small impoundment. N. Am. J. Fish. Manage. 14: 781-789.

Santucci, V.J., Jr., D.H. Wahl, and D.F. Clapp. 1999. Efficiency and selectivity of sampling methods used to collect channel catfish in impoundments. Pages 317–328 in E. R. Irwin, W. A. Hubert, C.F. Rabeni, H.L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Santucci, V.J.Jr., and D.H. Wahl. 1993. Factors influencing survival and growth of stocked walleye in a centrarchid-dominated impoundment. Canadian Journal of Fisheries and Aquatic Sciences 50:1548-1558.

Sass, G.G., J.F. Kitchell, S.R. Carpenter, T.R. Hrabik, A.E. Marburg, and M.G. Turner. 2006. Fish community and food web responces to a whole-lake removal of coarse woody habitat. Fisheries 31(7): 321-330.

Savino, J.F. and R.A. Stein. 1982. Predator-prey interaction between largemouth bass and bluegills as influenced by simulated, submersed vegetation. Transactions of the American Fisheries Society 111(3): 255-266.

Scheffer, M., S.H. Hosper, M.L. Meijer, B. Moss, and E. Jeppesen. 1993. Alternative equilibria in shallow lakes. Trends in Ecology & Evolution 8(8): 275-79.

Schlechte, J.W., R.K. Betsill, and D.L. Buckmeier. 2005. A laboratory evaluation of poststocking predatory losses for cultured largemouth bass. Transactions of the American Fisheries Society. 134:141–148.

Schlosser, I. J. 1991. Stream fish ecology: a landscape perspective. BioScience 41, 704–712.

Schlosser, I. J. 1995. Critical landscape attributes that influence fish population dynamics in head water streams. Hydrobiologia 303:71–81.

Schneider, J.C. 1992. Field Evaluations of 230-V AC Electrofishing on Mortality and Growth of Wannwater and Coolwater Fish. North American Journal of Fisheries Management 12:253-256.

Schramm HL Jr, Hunt KM. 2007. Issues, benefits, and problems associated with fishing tournaments in inland waters of the United States: a survey of fishery agency administrators. Fisheries 32(5) :234–243.

Schramm, H. L. Jr., P. E. McKeown, and D. M. Green. 1995. Managing black bass in northern waters. North American Journal of Fisheries Management 15:671–679.

Schramm, H. L., Jr., M. L. Armstrong, N. A. Funicelli, D. M. Green, D. P. Lee, R. E. Manns, Jr., B. D. Taubert, and S. J. Waters. 1991. The status of competitive fishing in North America. Fisheries 16(3): 4–12.

Schreck, C. B., W. Contreras-Sanchez, and M. S. Fitzpatrick. 2001. Effects of stress on fish reproduction, gamete quality, and progeny. Aquaculture 197:3–24.

Schultz, A.A., O.E. Maughan, S.A. Bonar & W.J. Matter. 2003. Effects of flooding on abundance of native and nonnative fishes downstream from a small impoundment. N. Amer. J. Fish. Man. 23: 503–511.

Schwartz, J.S., and E.E. Herricks. 2008. Fish use of ecohydraulic-based mesohabitat units in a low-gradient Illinois stream: implications for stream restoration. Aquatic Conservation: Marine and Freshwater Ecosystems 18(6):852-866.

Serns, S. L. 1982. Relationship of walleye fingerling density and electrofishing catch per effort in northem Wisconsin lakes. North American Journal of Fisheries Management 2:38-44.

Serns, S.L. 1983. Relationship between electrofishing catch per unit effort and density of walleye yearlings. North American Journal of Fisheries Management 3: 451-452.

Shaner, B.L., M.J. Maceina, J.J. McHugh, and S.F. Cook. 1996. Assessment of Catfish Stocking in Public Fishing Lakes in Alabama. North American Journal of Fisheries Management. 16: 880-887.

Shea, C.P., and J.T. Peterson. 2007. An evaluation of the relative influence of habitat complexity and habitat stability on fish assemblage structure in unregulated and regulated reaches of a large southeastern warmwater stream. Transactions of the American Fisheries Society 136: 943-958.

Shrader, T.M., B. Moody and M. Buckman. 2003. Population Dynamics of Channel Catfish in Brownlee Reservoir and the Snake River, Oregon. North American Journal of Fisheries Management 23: 822-834.

Smeltzer, J. F., and S. A. Flickinger. 1991. Culture, handling, and feeding techniques for black crappie fingerlings. North American Journal of Fisheries Management 11:485–491.

Smokorowski, K.E., T.C. Pratt, W.G. Cole, L.J. McEachern, and E.C. Mallory. 2006. Effects on periphyton and macroinvertebrates from removal of submerged wood in three Ontario lakes. Canadian Journal of Fisheries and Aquatic Sciences 63(9): 2038-2049.

Snyder, D. E. 2003. Electrofishing and its harmful effects on fish. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2003–0002, U.S. Government Printing Office, Denver.

Spencer, S.L. 1967. Internal injuries of largemouth bass and bluegills caused by electricity. Progressive Fish-Culturist 29: 168–169.

Spoelstra, J. A., R. A. Stein, J. A. Royle and E. A. Marschall. 2008. Movement of Reservoir-Stocked Riverine Fish between Tailwaters and Rivers. Transactions of the American Fisheries Society 137(5):1530-1542.

St. John, R.T. and W.P. Black. 2004. Methods for Predicting Age-0 Crappie Year-Class Strength in J. Percy Priest Reservoir, Tennessee, North American Journal of Fisheries Management, 24:4, 1300-1308.

Stahl, T. P., and R. A. Stein. 1994. Influence of larval gizzard shad (Dorosoma cepedianum) density on piscivory and growth of young-of-the-year saugeye (Stizostedion vitreum x S. canadense). Canadian Journal of Fisheries and Aquatic Sciences 51:1993-2002.

Stone, C. C. and T. Modde. 1982. Growth and survival of largemouth bass in newly stocked South Dakota ponds. North America Journal of Fisheries Management 4:326-333.

Storck, T. W. and D. L. Newman. 1992. Contribution of Tiger Muskellunge to the Sport Fishery of a Small, Centrarchid-Dominated Impoundment. North American Journal of Fisheries Management 12(1):213-221.

Storck, T., and D. Newman. 1988. Effects of size at stocking on survival and harvest of channel catfish. North American Journal of Fisheries Management 8:98-101.

Suboski, M. D., and J. J. Templeton. 1989. Life skills training for hatchery fish: social learning and survival. Fisheries Research 7:343–352.

Summerfelt, R.C. 1993. Lake and reservoir habitat management. Pages 231-261 in C.C.

Swingle, H.S., and Swingle, W.E. 1967. Problems in dynamics of fish populations in reservoirs. In Reservoir Fishery Resources Symposium. Reservoir Committee, Southern Division, American Fisheries Society, Bethesda, Md. pp. 229–243.

Szendrey, T. A. and D. H. Wahl. 1995. Effect of Feeding Experience on Growth, Vulnerability to Predation, and Survival of Esocids. North American Journal of Fisheries Management 15(3):610-620.

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

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

Taube, T.T. 1992. Injury, survival, and growth of rainbow trout captured by electrofishing. Master's thesis. University of Alaska, Fairbanks.

Taylor, G.N., L.S. Cole, and W.F. Sigler. 1957. Galvanotaxic response of fish to pulsating direct current. Journal of Wildlife Management 21: 201–213.

Terre, D. R., S. J. Magnelia, and M. J. Ryan. 1993. Year class contribution of genetically-marked Florida x northern largemouth bass stocked into three Texas reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 47:622-632.

Thompson, D.H. 1941. The fish production of inland streams and lakes. In A Symposium on Hydrobiology. University of Wisconsin Press, Madison, Wis. pp. 206–217.

Trammell, M. A., E. P. Bergersen and P. J. Martinez. 1993. Evaluation of an introduction of Colorado Squawfish in a main stem impoundment on the White River, Colorado. Southw. Natural. 38(4):362-369.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130–137.

Wahl, D. H. 1999. An Ecological Context for Evaluating the Factors Influencing Muskellunge Stocking Success. North American Journal of Fisheries Management 19(1):238-248.

Wahl, D. H., and R. A. Stein. 1993. Comparative population characteristics of muskellunge (Esox masquinongy), northern pike (E. lucius), and their hybrid (E. masquinongy × E. lucius). Canadian Journal of Fisheries and Aquatic Sciences 50:1961–1968.

Wahl, D. H., L. M. Einfalt, and M. L. Hooe. 1995b. Effects of experience with piscivory on foraging behavior and growth of walleyes. Transactions of the American Fisheries Society 124:756–763.

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

Wahl, D.H., R.A. Stein, and D.R. Devries. 1995a. An ecological framework for evaluating the success and effects of stocked fishes. American Fisheries Society Symposium 15:176-189.

Wallace, E.M. and K.J. Hartman. 2006. Habitat Utilization and Movement Patterns of Sub-Harvestable Largemouth Bass (Micropterus salmoides) in the Ohio River, Journal of Freshwater Ecology 21: 663-672.

Walters, J.P. and J.R. Wilson. 1996. Intraspecific Habitat Segregation by Smallmouth Bass in the Buffalo River, Arkansas, Transactions of the American Fisheries Society 125: 284-290.

Webb, M. A., and R. A. Ott, Jr. 1991. Effects of length and bag limits on population structure and harvest of while crappies in three Texas reservoirs. North American Journal of Fisheries Management 11: 614-622.

Weller, R.R, and L.D. Winter. 2001. Seasonal variation in home range size and habitat use of flathead catfish in Buffalo Springs Lake, Texas. North American Journal of Fisheries Management 21: 792–800.

Wendelaar Bonga, S. E. 1997. The stress response in fish. Physiological Reviews 77:591–625.

Wilde GR, Shavlik CE, Pope KL. 2002. Initial mortality of black bass in B.A.S.S. fishing tournaments. North American Journal of Fisheries Management 22:950–954.

Wilde, G. R. 1997. Largemouth bass fishery responses to length limits. Fisheries 22(6):14–23.

Wilde, G. R. 1997. Largemouth bass fishery responses to length limits. Fisheries 22(6):14–23.

Wiley, M. J., S. L. Kohler, and P. W. Seelbach. 1997. Reconciling landscape and local views of aquatic communities: lessons from Michigan trout streams. Freshwater Biology 37:133–148.

Wingate, P.J. 1986. Philosophy of muskellunge management. Pages 199-202 in G.E. Hall, editor. American Fisheries Society, Special Publication 15, Bethesda, Maryland.

Wingate, P.J., and J.A. Younk. 2007. A program for successful muskellunge management-A Minnesota success story. Environmental Biology of Fishes 79: 163-169.

Wolter, M. H., Deboom, C.S., Diana, M.D., Wahl, D.H. 2011. Evaluation of growth and survival of different genetic stocks of muskellunge: implications for stocking programs in Illinois and the midwest. Illinois Natural History Survey Report, Champaign, IL.

Wright, R.M. 1990. The population biology of pike, Esox lucius L., in two gravel pit lakes, with special reference to early life history. Journal of Fish Biology 36(2): 215-229.

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

Zale, A.V. and T.G. Adornato. 1996. Comparative influence of abiotic variables on seasonal abundances of hybrid striped bass and white bass in the Grand Lake Tailwater, Oklahoma. Journal of Freshwater Ecology 11: 257-269.

Table 101.1: Stocking information for four lakes stocked with largemouth bass both at the boat ramp and dispersed into habitat throughout the lake. CPUE is catch per hour from electrofishing transects conducted in the fall after stocking and the subsequent spring.

Lake	Stocking Date	Boat Ramp Stocking			Dispersed Stocking		
		# Stocked	Fall CPUE	Spring CPUE	# Stocked	Fall CPUE	Spring CPUE
Charleston	8/15/2008	3500	2	0	3500	2	0.4
	8/25/2009	3500	0.8	0	3500	0	0.7
	9/2/2010	3500	1.3	0	3500	1.3	0
	8/12/2011	3500	0.7	0	3500	1.1	0
	8/3/2012	3500	0.7	0	3500	0	0
Homer	8/16/2007	1400	0.0	0.0	1400	0.3	0
	8/24/2009	1000	0.0	0.0	1000	0.3	0
	8/26/2010	1000	1.7	0.0	1000	0	0.7
	8/11/2011	1000	1.7	0.3	1000	2.3	1
	8/3/2012	1000	0.7	0.3	1000	1.3	0
Mingo	8/16/2007	3400	0.7	0	3400	2	0
	8/14/2008	2150	5.7	0	2150	3.7	0.7
	8/24/2009	2125	0	0	2125	0.3	0
	8/26/2010	2125	1.3	0	2125	0.3	0
	8/11/2011	2125	0.3	0	2125	0.7	0.3
	8/3/2012	2125	0.3	0.3	2125	0	0
Otter	8/15/2007	7650	0	0	7650	0	0
	8/13/2008	11400	0.8	0	11400	0.2	0
	8/25/2009	7650	0.4	0	7650	0	0
	8/25/2010	7650	0.9	1.7	7650	0.4	0
	8/15/2011	7650	0.6	0	7650	2	0.2
	8/2/2012	7650	0	0	7650	0.8	0
Mean Total			0.93	0.12		0.86	0.18

Table 101.2: 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 101.3: Adjusted catch-per-unit effort from spring trap netting surveys and statistical comparisons of survival to adulthood (Age-3) by year class of the Upper Mississippi River drainage stock, Ohio River drainage stock, and Illinois population of muskellunge sampled from Mingo, Pierce and Sam Dale Lakes, Illinois, during spring 2005-2013. 95% confidence limits are in parenthesis and letters represent significant differences following Tukey's means separation.

	Year Class	Mississippi River Drainage	Ohio River Drainage	Illinois Population	P Value
Mingo	2002	NA	1.34	0.76	
	2003	0.00	0.71	0.47	
	2004	0.09	2.35	1.06	
	2005	0.10	1.44	1.04	
	2006	NA	0.37	0.89	
	2007	0.00	0.09	1.07	
	Mean	0.05 (±0.05)[b]	1.05 (±0.73)[a]	0.88 (±0.21)[ab]	0.03
Pierce	2003	0.00	0.00	0.00	
	2004	0.00	0.69	1.11	
	2005	0.00	4.09	2.26	
	2006	NA	NA	1.35	
	2007	0.17	0.49	2.41	
	Mean	0.04 (±0.10)	1.32 (±2.21)	2.41 (±0.96)	0.23
Sam Dale	2007	0.14	0.73	1.48	
	2008	0.04	0.58	0.61	
	Mean	0.09 (±0.10)	0.66 (±0.15)	1.05 (±0.85)	0.16

Table 102.1: Largemouth bass regulation summary of the 230 lakes that were sampled by DNR biologists between 2002 and 2012.

Regulation Type	Number of Lakes
Catch and Release	2
Lowered Bag	9
No Length	118
Over Under	2
Raised Length	19
Raised Length Lowered Bag	39
Slot	11
Standard	30

Table 102.2: Catch per unit effort (CPUE, #/hr) of black and white crappie from IDNR biologist electrofishing sampling from 2002 – 2012 obtained from the FAS database. CPUE was calculated for each size class.

Size	White Crappie CPUE	Black Crappie CPUE
Total	127.8	73.8
Stock (130-199mm)	40.8	32.4
Quality (200-249mm)	49.2	26.4
Preferred (250-299mm)	29.4	6.6
Memorable (300-379mm)	6.6	0.6
Trophy (380mm+)	0	0

Table 102.3: The number of lakes in Illinois categorized by different crappie regulations in 2012 (A). The most common regulation type was bag and bag with length limits that varied by the number of fish and length of fish that can be harvested (B).

A.

Regulation	Number of Lakes
Bag	47
Length/Bag	40
Length	1
Over-Under	5
No Regs	93

B.

Limit/day	Length Limit	Number of Lakes
5	None	1
10	None	7
15	None	22
25	None	15
30	None	2
10	9 in	8
15	9 in	10
25	9 in	13
10	10 in	7
15	10 in	1
25	10 in	1

Table 102.4: Lake characteristics for Ridge Lake in 2006 – 2013 in years with spring largemouth bass tournaments and years that were closed to fishing.

Year	Type	Mean Fall Electrofishing CPUE (#/hour)			Larval Fish Density (#/L)	Zooplankton Density (#/L)	Benthos Density (#/m2)
		YOY LMB (<200mm)	BLG	LMB >200mm			
2013	Tournament	NA	NA	NA	NA	NA	NA
2012	Closed	27.0	58.1	20.9	0.5	385.4	18695.7
2011	Closed	12.0	69.9	42.9	1.4	612.1	936.2
2010	Tournament	18.1	66.0	15.6	3.4	135.1	10065.6
2009	Closed	52.5	80.6	19.2	9.2	1150.7	5127.3
2008	Closed	39.2	96.8	49.9	0.1	458.8	11502.1
2007	Tournament	59.2	67.2	52.3	1.2	399.4	7563.5
2006	Closed	29.1	50.8	41.0	0.5	352.2	3859.9

Table 102.5: The total tournament activity for 12 lakes in Illinois where all activity is thought to be known. Lakes were categorized based on angler hours per acre.

Lake	Category	Size (acre)	Number of Tournaments a Year	Number of Anglers a Year	Total Hours of Tournaments	Angler Hours	Angler Hours per Acre
Bloomington	Low	635	9	303	49	1742	2.74
Clinton	Low	4895	25	1280	232	6515	1.33
Coffeen	High	1070	31	1323	250	10584	9.89
Dawson	Low	148	4	100	13	349	2.36
Evergreen	Low	925	9	264	47	1575	1.70
Jacksonville	High	442	52	1180	137	9615	21.75
Sangchris	High	2321	57	3770	456	30160	12.99
Shelbyville	Low	11100	47	2769	381	22095	1.99
Walnut	None	52	0	0	0	0	0.00
Charleston	None	317	0	0	0	0	0.00
Lincoln Trail	None	137	0	0	0	0	0.00
Paradise	None	138	0	0	0	0	0.00

Table 102.6: Mean tournament demographics for 12 lakes in Illinois where tournament results have been obtained.

Lake	Number of Anglers Per Tournament	Mean Length of Tournament (hrs)	Number of Fish Weighed in per Tournament	Mean Big Fish Weight (lbs)	Mean Weight per fish Weighed In (lbs)	Angler Hours Per Tournament	Catch Per Angler	Catch Per Angler Per Hour
Bloomington	36.3	6.1	35.9	4.6	2.5	237.0	1.00	0.17
Clinton	26.8	5.1	20.4	4.4	3.0	105.2	1.10	0.21
Coffeen	42.3	8.0	59.1	4.2	2.3	256.6	1.75	0.22
Dawson	24.0	3.5	2.8	3.5	2.1	83.9	0.13	0.04
Evergreen	33.6	6.0	33.2	5.0	2.7	222.8	0.94	0.14
Forbes	38.4	7.1	28.3	5.5	2.2	180.7	0.99	0.23
Jacksonville	25.8	8.2	44.8	5.7	2.9	210.4	1.72	0.21
Mattoon	22.8	4.6	16.4	4.6	2.5	107.7	0.71	0.16
Mill	44.3	.	51.4	5.9	2.9	.	1.15	
Rend	55.8	8.3	87.2	5.2	2.2	464.7	1.57	0.19
Sangchris	42.4	8.0	60.5	4.6	1.7	298.4	2.29	0.29
Shelbyville	59.6	8.1	65.0	5.5	2.2	485.3	1.11	0.14

Table 103.1: Vegetated area and perimeter for all vegetation experimental lakes in spring and fall assessments in 2012.

Lake	Type	Lake Area (m^2)	Lake Perim. (m)	Area Vegetated				Percent of Lake Vegetated			
				Spring		Fall		Spring		Fall	
				Area (m^2)	Perim. (m)	Area (m^2)	Perim. (m)	Area (%)	Perim. (%)	Area (%)	Perim. (%)
Airport	Removal	89246	1171	89246	1171	17911	1173	100	100	20	100
Dolan	Drawdown	302869	5335	28048	2951	47057	3959	9	55	16	74
Forbes	Control	2056612	29364	215740	19527	167271	11625	10	66	8	40
Lincoln	Control	584546	10033	8585	82904	81666	9252	1	826	14	92
LOTW	Control	103090	2259	0	0	0	1	0	0	0	0
Paradise	Planted	706098	7287	12179	4458	13733	4330	2	61	2	59
Pierce	Control	647830	6406	168020	5941	144299	5982	26	93	22	93
Ridge	Control	44013	1132	22770	1484	22463	1484	52	131	51	100
Stillwater	Removal	89363	2215	64269	2217	69594	2216	72	100	78	100
Walnut	Control	215810	9396	2030	781	2087	849	1	8	1	9
Woods	Control	127217	3241	0	0	NA	NA	0	0	NA	NA

Table 103.2: Catch per unit effort from fall electrofishing samples and percent vegetation area and perimeter from fall vegetation assessments from Dolan Lake in 1998-2012. The lake was drawn down and rotenone treated to remove common carp and gizzard shad in 2006.

Year	Bluegill	Gizzard Shad	Common Carp	YOY LMB	Adult LMB	Fall Veg Area %	Fall Veg Perim %
2001	104.0	12.3	0.0	15.0	11.7	0.0	0.0
2002	Not Sampled in Fall Due to Drawdown.					1.7	7.7
2003	200.0	21.3	2.7	5.3	7.3	1.1	1.1
2004	89.7	7.0	0.7	4.7	8.7	NA	NA
2005	224.0	16.0	1.3	4.7	2.7	4.1	17.3
Mean	**154.4**	**14.2**	**1.2**	**7.4**	**7.6**	**1.7**	**6.5**
			TREATMENT				
2007	58.7	0.0	0.0	26.0	37.3	25.5	76.2
2008	42.7	0.7	0.0	25.3	60.7	20.0	97.0
2009	45.7	0.7	0.0	6.0	48.0	18.5	90.5
2010	26.0	7.0	0.0	6.7	60.0	25.8	84.4
2011	51.3	27.3	0.0	9.0	33.0	15.7	79.7
2012	99.2	108.3	0.0	10.5	48.7	15.5	74.2
Mean	**53.9**	**24.0**	**0.0**	**13.9**	**47.9**	**20.2**	**83.7**

Table 103.3: Largemouth bass CPUE of largemouth bass separated into young-of-year less than 200 mm (YOY) and adult fish greater than 199 mm (adult) from fall electrofishing samples in three lakes where vegetation was manipulated. In addition, the percent of the lake area and the percent of the lake perimeter that contained vegetation were calculated through GPS mapping. Lake treatments were chemical treatment to remove vegetation (Removal), planting to increase vegetation (Planting) or conditions before treatment (Pre).

Lake	Year	Treatment	YOY LMB CPUE	Adult LMB CPUE	% Area Vegetated	% Perimeter Vegetated
Airport	2007	Pre	22.2	33.3	100	100
Airport	2008	Pre	68.2	13.0	100	100
Airport	2009	Pre	25.8	3.0	100	100
Airport	2010	Removal	10.8	6.1	100	100
Airport	2011	Removal	12.4	29.3	100	100
Airport	2012	Removal	3.6	5.5	20	100
Stillwater	2007	Pre	26.2	13.7	100	101
Stillwater	2008	Pre	5.1	14.8	100	100
Stillwater	2009	Pre	30.5	5.3	100	100
Stillwater	2010	Removal	41.1	10.6	1	10
Stillwater	2011	Removal	19.1	23.6	21	100
Stillwater	2012	Removal	1.6	9.8	78	100
Paradise	2007	Pre	9.3	18.0	13	51
Paradise	2008	Planting	10.0	13.0	1	12
Paradise	2009	Planting	18.2	19.0	5	40
Paradise	2010	Planting	14.7	36.0	12	58
Paradise	2011	Planting	5.3	23.7	3	43
Paradise	2012	Planting	5.7	29.7	2	59

Table 104.1: Catch per unit effort of largemouth bass in refuge and non-refuge (lake) sites in Otter Lake from electrofishing samples performed in 2007-2013. Samples were collected prior to the implementation of the refuge (A) and after the two refuges were closed to angling (B).

A: Pre Refuge

Year	Season	Refuge	Lake
2007	FALL	13.1	24.6
2008	SPRING	9.1	15.2
2008	FALL	18.4	22.6
2009	SPRING	12.6	15
2009	FALL	24.4	31.4
2010	SPRING	13.8	19.8
Mean		15.2	21.4

B: Post Refuge

Year	Season	Refuge	Lake
2010	FALL	13.3	18.3
2011	SPRING	9.8	15.4
2011	FALL	17.6	22.8
2012	SPRING	12.4	16.2
2012	FALL	13.6	20
2013	SPRING	7.4	13.6
Mean		12.4	17.7

Table 104.2: Density of fish captured from seine hauls conducted inside 2 refuges and in 3 control sites in Otter Lake.

Year	Control Seine Density (#/m2)				Refuge Seine Density (#/m2)			
	Total	LMB	BLG	GZS	Total	LMB	BLG	GZS
				Pre Refuge				
2007.00	0.14	0.03	0.17	0.00	0.23	0.02	0.21	0.00
2008.00	0.27	0.02	0.28	0.00	0.10	0.00	0.13	0.00
2009.00	0.06	0.00	0.08	0.00	0.29	0.27	0.15	0.00
2010.00	0.10	0.02	0.09	0.00	0.05	0.00	0.05	0.00
Pre Mean	0.14	0.02	0.15	0.00	0.17	0.07	0.14	0.00
				Post Refuge				
2011.00	0.02	0.00	0.02	0.00	0.05	0.01	0.03	0.01
2012.00	0.07	0.01	0.05	0.00	1.54	0.00	0.12	0.00
2013.00	0.56	0.00	0.30	0.10	0.41	0.00	0.06	0.01
Post Mean	0.22	0.00	0.12	0.03	0.67	0.00	0.07	0.01

Table 104.3: Lake size (acres) and catch per unit of effort (#/hour) of adult white (WHC) and black (BLC) crappie from fall and spring electrofishing.

Lake	Surface Area (acres)	WHC CPUE (#/hr)		BLC CPUE (#/hr)	
		Fall 2012	Spring 2013	Fall 2012	Spring 2013
Paradise	138	16.7	20.7	0.7	0.0
Charleston	317	5.8	16.7	2.4	0.3
Forbes	508	2.7	8.7	0.0	0.0
Shelbyville	11100	1.3	2.5	10.0	0.5
Lincoln Trail	144	0.0	0.0	4.7	2.7
Pierce	147	0.0	0.3	4.7	1.0
Walnut Point	53	0.0	0.0	0.7	0.3
Clinton	4754	--	4.0	--	0.0
Mattoon	988	--	35.1	--	0.0
Mill Creek	731	--	2.5	--	1.4

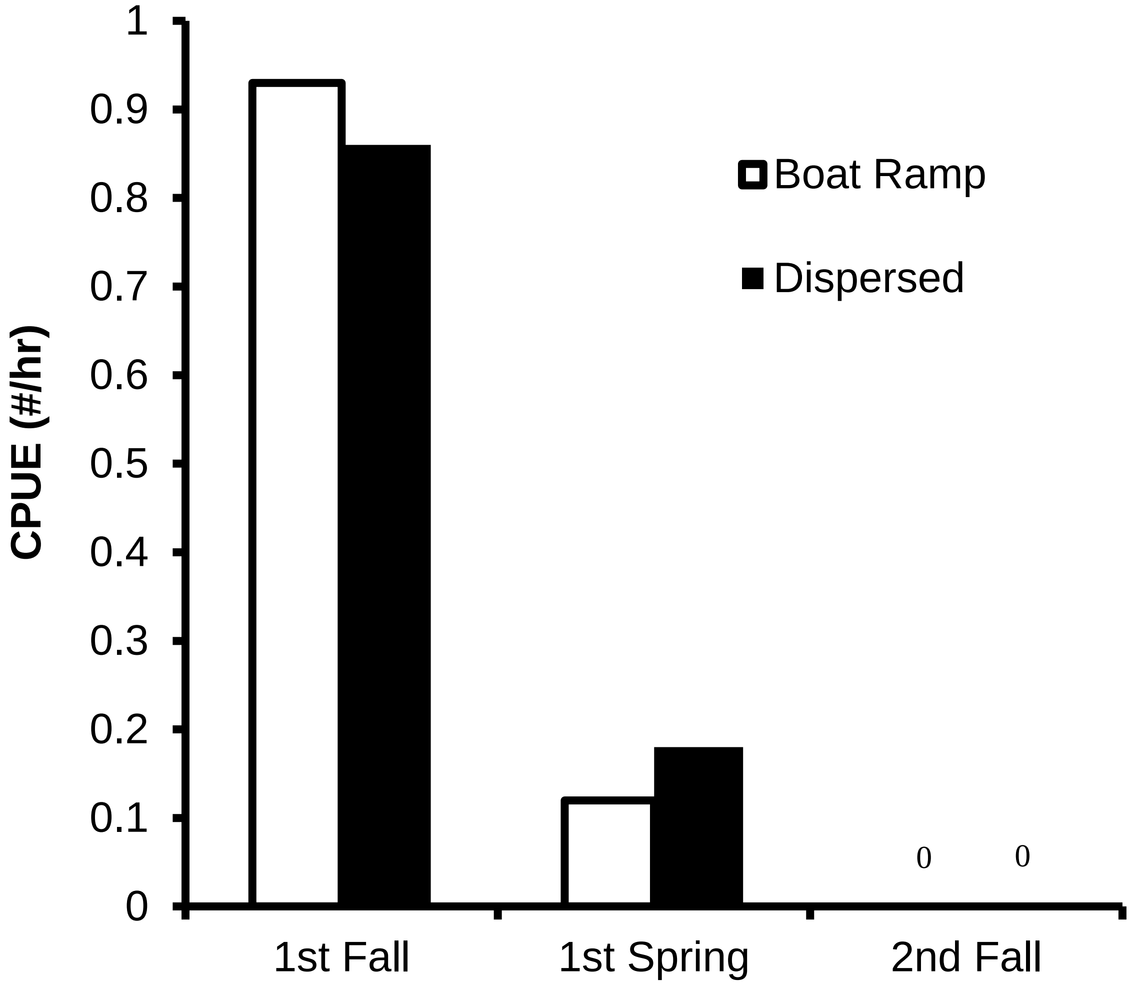


Figure 101.1: Mean CPUE of largemouth bass from Fall and Spring electrofishing samples following stocking at either boat ramp or dispersed stockings from 2008-2012.

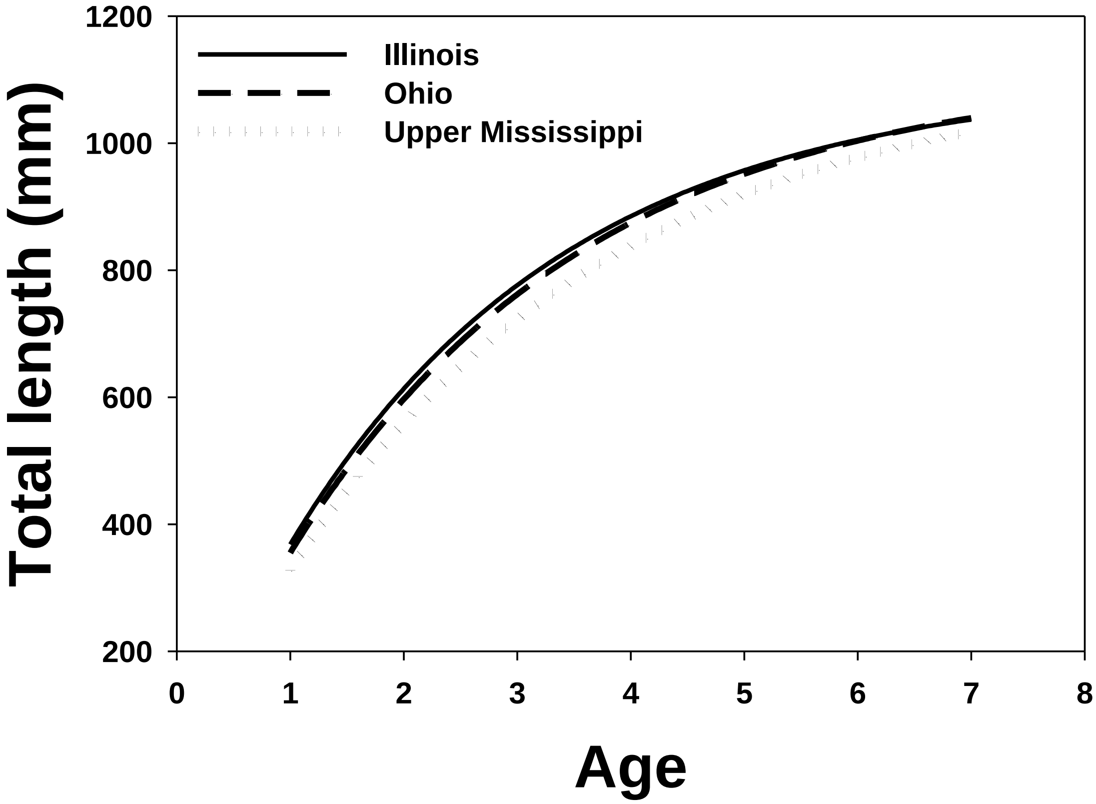


Figure 101.2: Fitted von Bertalanffy growth functions for female muskellunge from the Illinois population (solid line) the Ohio River drainage stock (long dashed line) and the Upper Mississippi River drainage stock sampled in Lake Mingo from fall 2003 through spring 2013. The growth function for the Upper Mississippi River drainage stock (short dashed line) was fit by pooling both genders due to low survival of this stock.

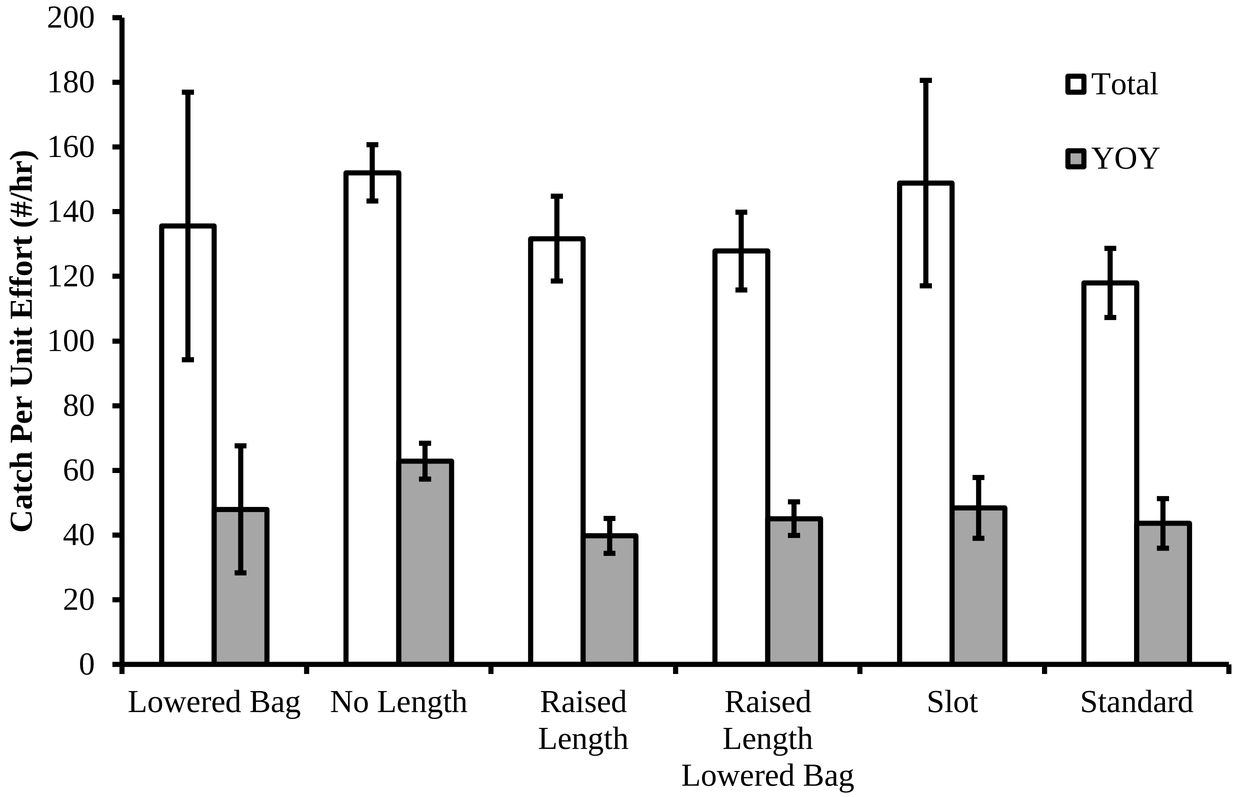


Figure 102.1: Catch per unit effort for all largemouth bass and young-of-year largemouth bass from fall electrofishing samples conducted by the Illinois DNR and entered into the FAS database. Catches are categorized by the type of regulation in place on each lake.

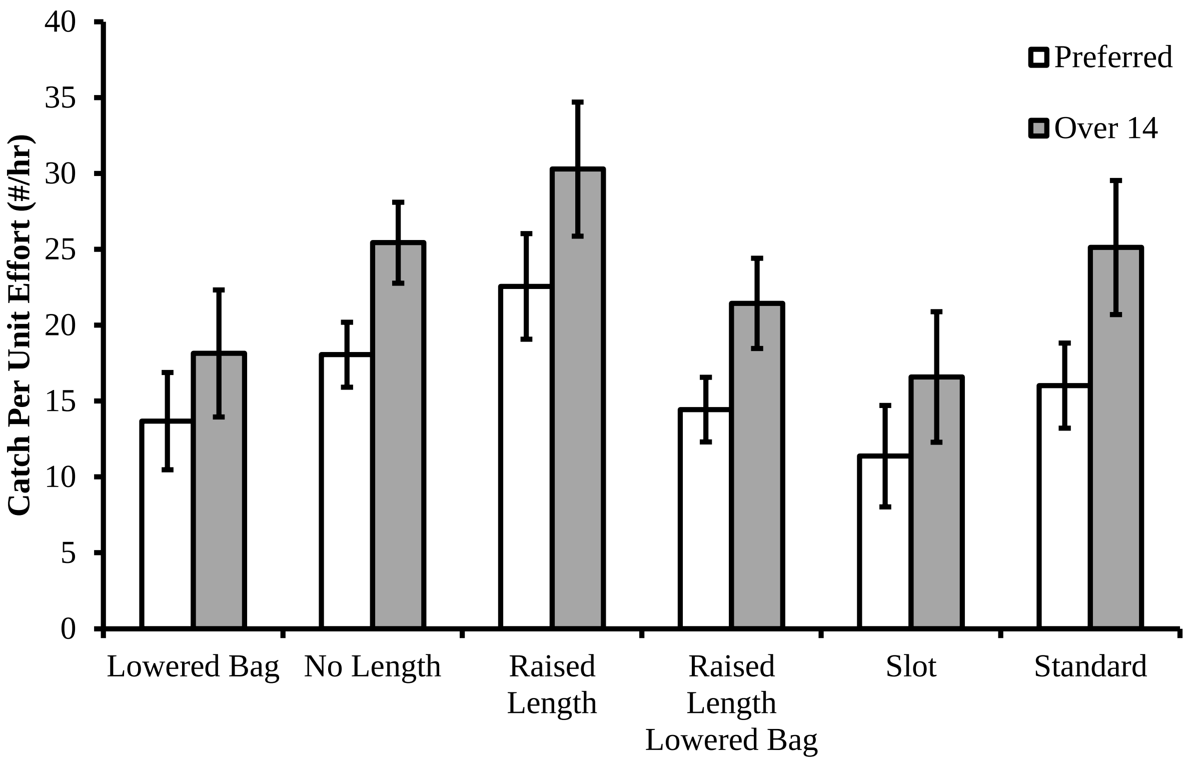


Figure 102.2: Catch per unit effort for all largemouth bass of preferred size and over 14-inch largemouth bass from fall electrofishing samples conducted by the Illinois DNR and entered into the FAS database. Catches are categorized by the type of regulation in place on each lake.

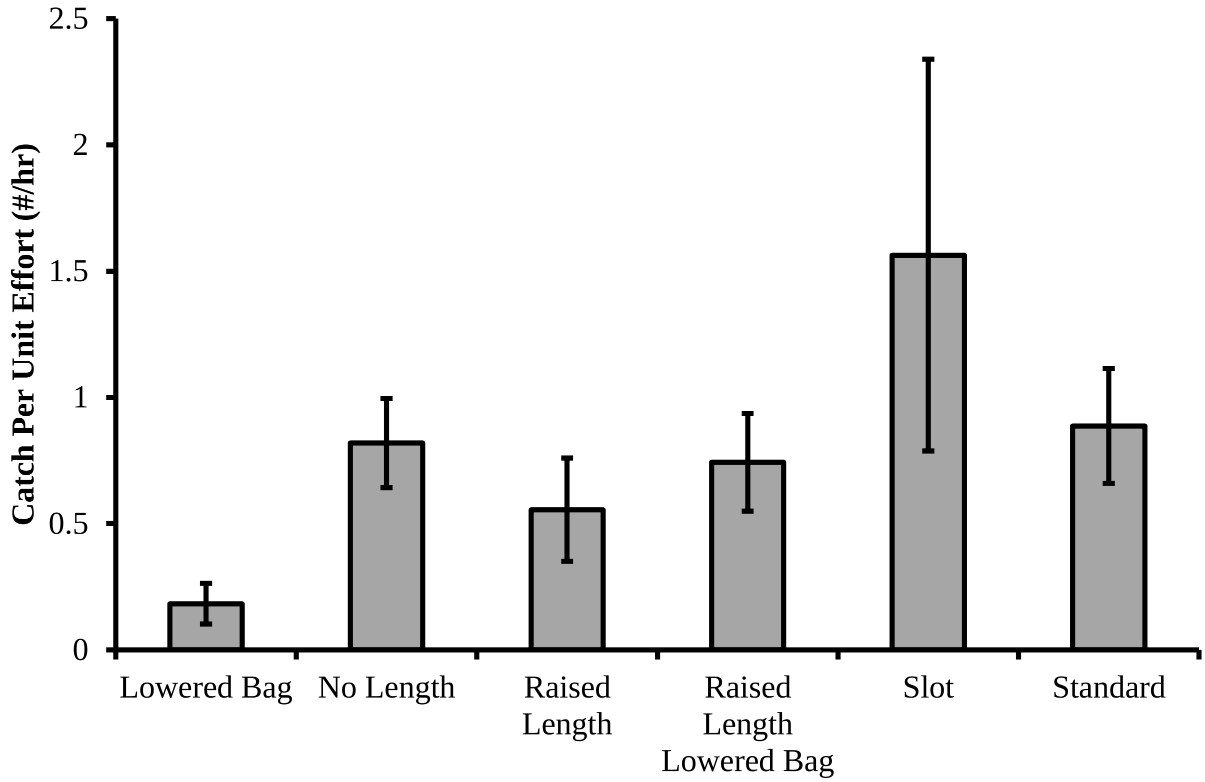


Figure 102.3: Catch per unit effort for largemouth bass of memorable length from fall electrofishing samples conducted by the Illinois DNR and entered into the FAS database. Catches are categorized by the type of regulation in place on each lake.

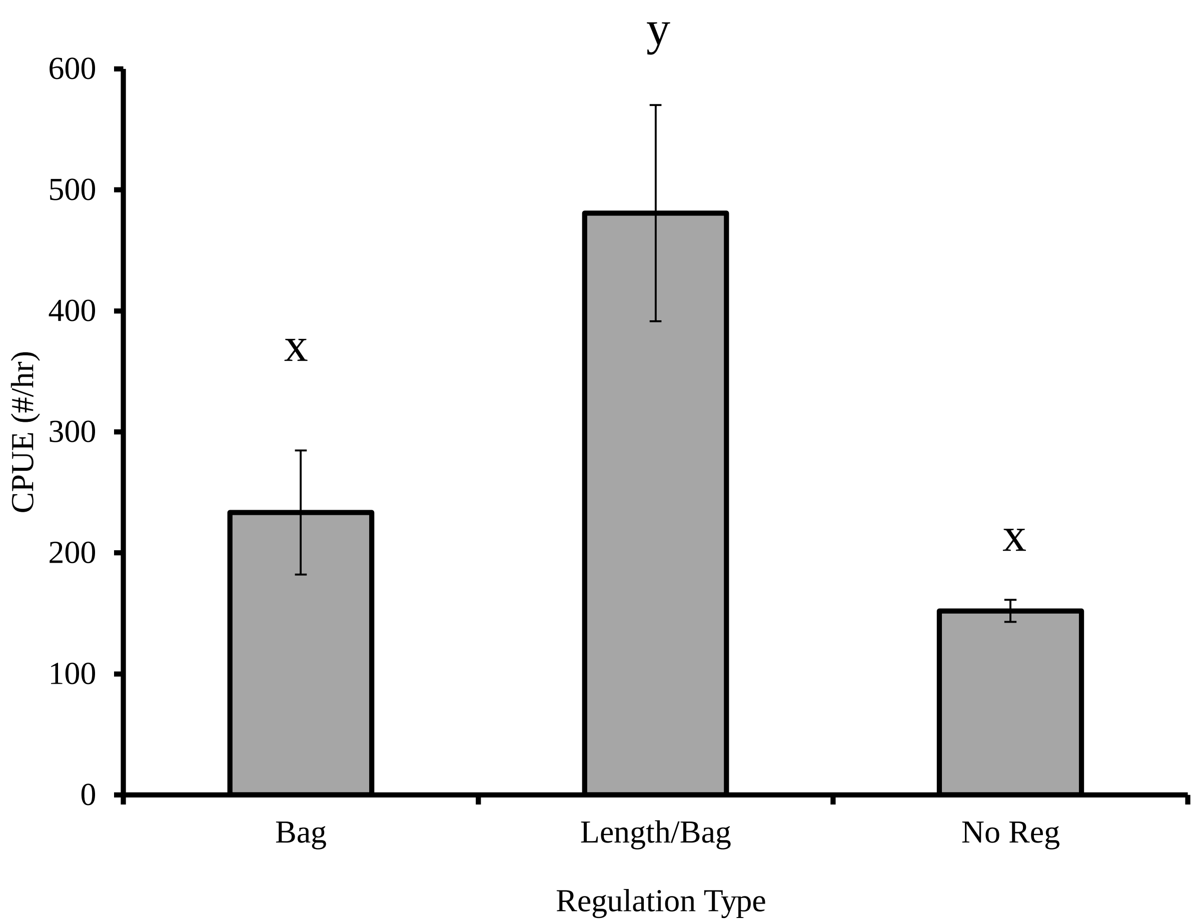


Figure 102.4: Mean catch per unit effort (CPUE) from electrofishing samples conducted by IDNR biologists from 2002-2012 on Illinois Lakes with varying regulations. Similar letters indicate bars that are not significantly different (P < 0.05).

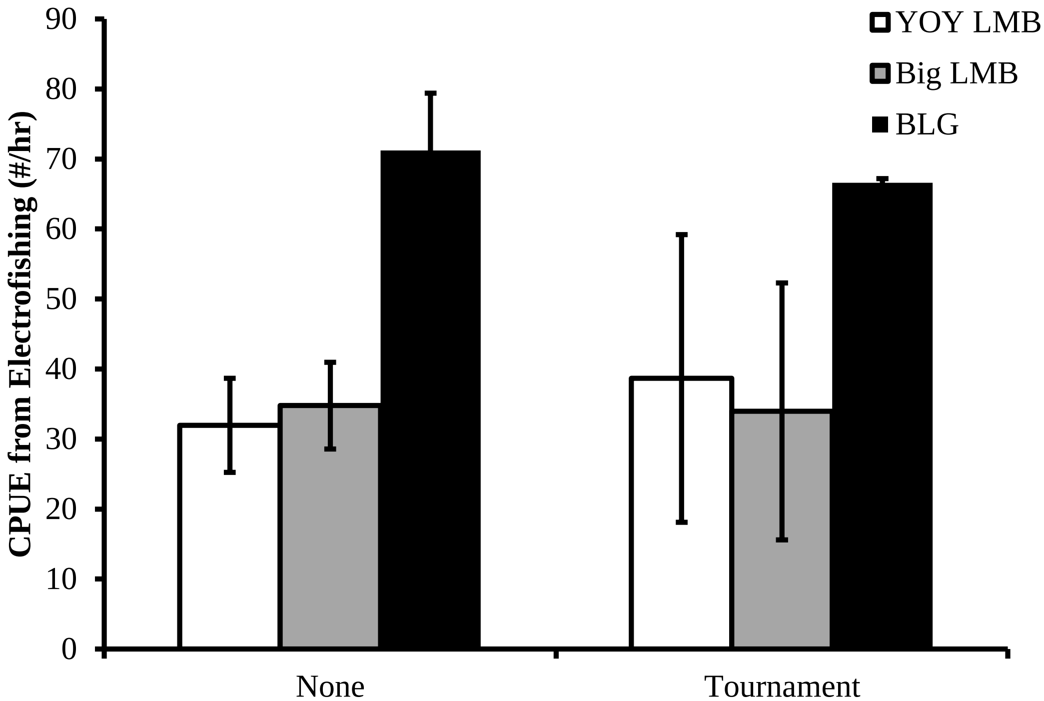


Figure 102.5: Catch per unit effort from spring electrofishing at Ridge Lake in years with tournaments and years without. Catch rates are reported form young-of-year (YOY) largemouth bass, Big Largemouth bass (>200 mm), and Bluegill (BLG).

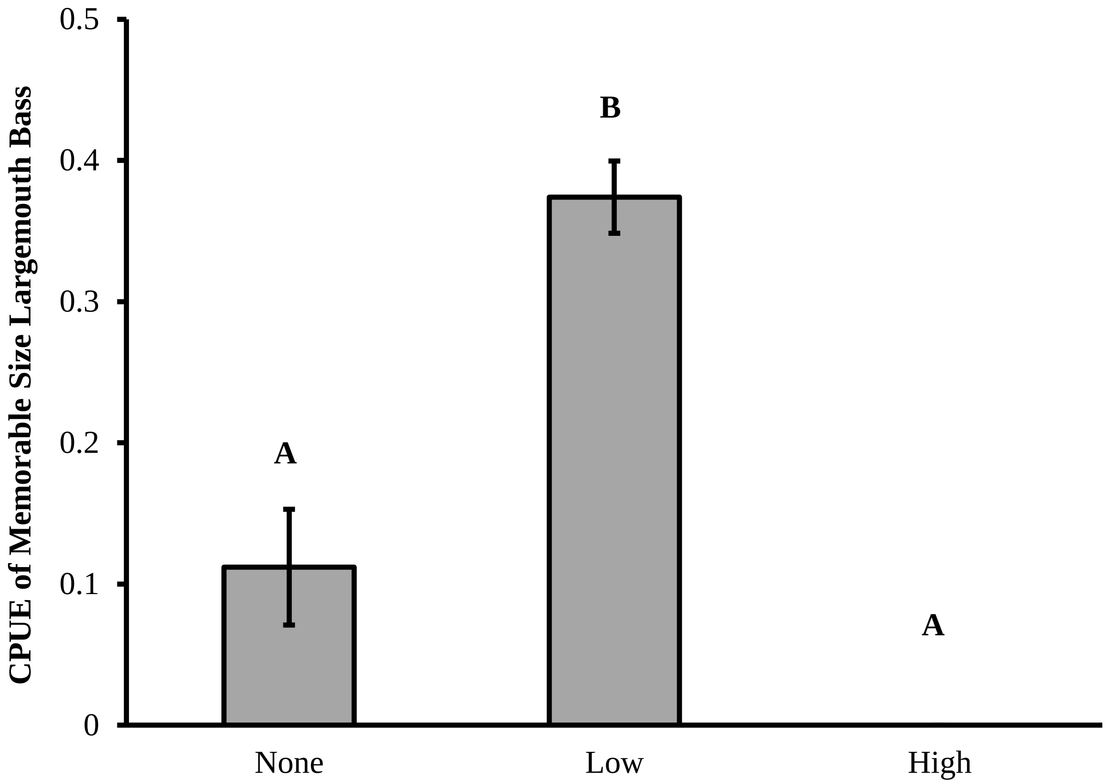


Figure 102.6: Mean catch per unit effort (CPUE) of memorable sized largemouth bass (> 509mm) in electrofishing samples in lakes with varying largemouth bass tournament pressure. Lakes were categorized based on tournament pressure of None (0 angler hours/acre), Low (0-3 angler hours/acre), or High (over 3 angler hours/acre). Similar letters indicate bars that are not significantly different (P > 0.05) and error bars indicate standard error.

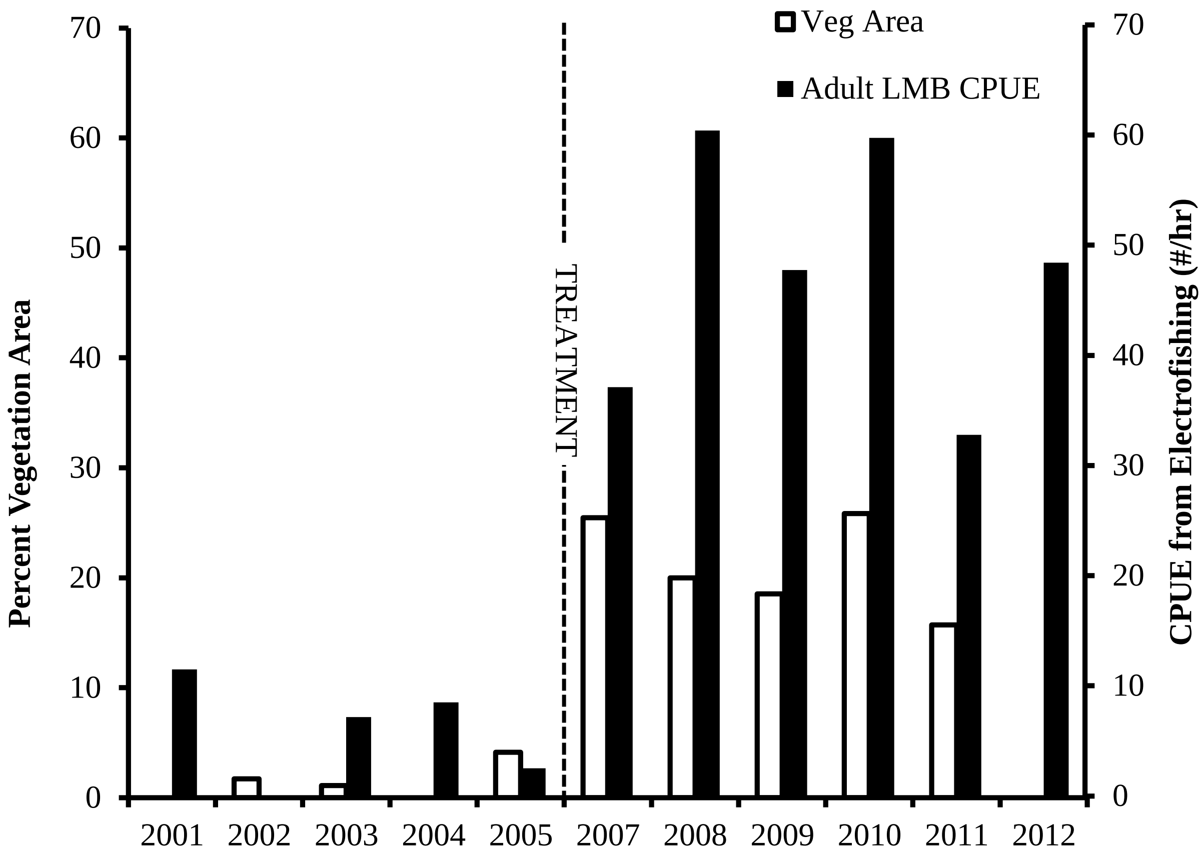


Figure 103.1: Fall vegetation coverage and CPUE of largemouth bass over 200 mm from fall electrofishing in Dolan Lake from 2001-2012. The lake was drawn down and rotenone treated to remove common carp and gizzard shad in 2006.

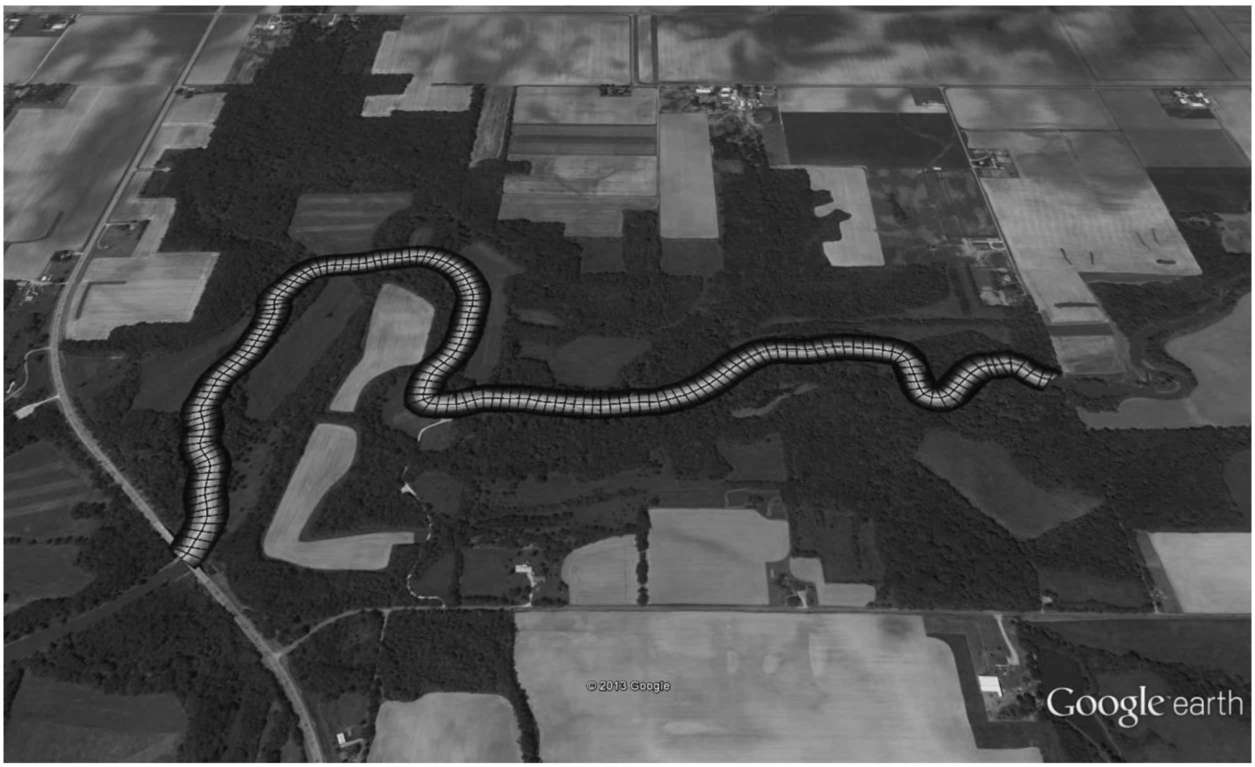


Figure 103.2: An example of the GIS maps created from side scan image files from the upper Kaskaskia River at the reach scale. Habitat will be quantified for the entire river segment by delineating habitat based on these images.

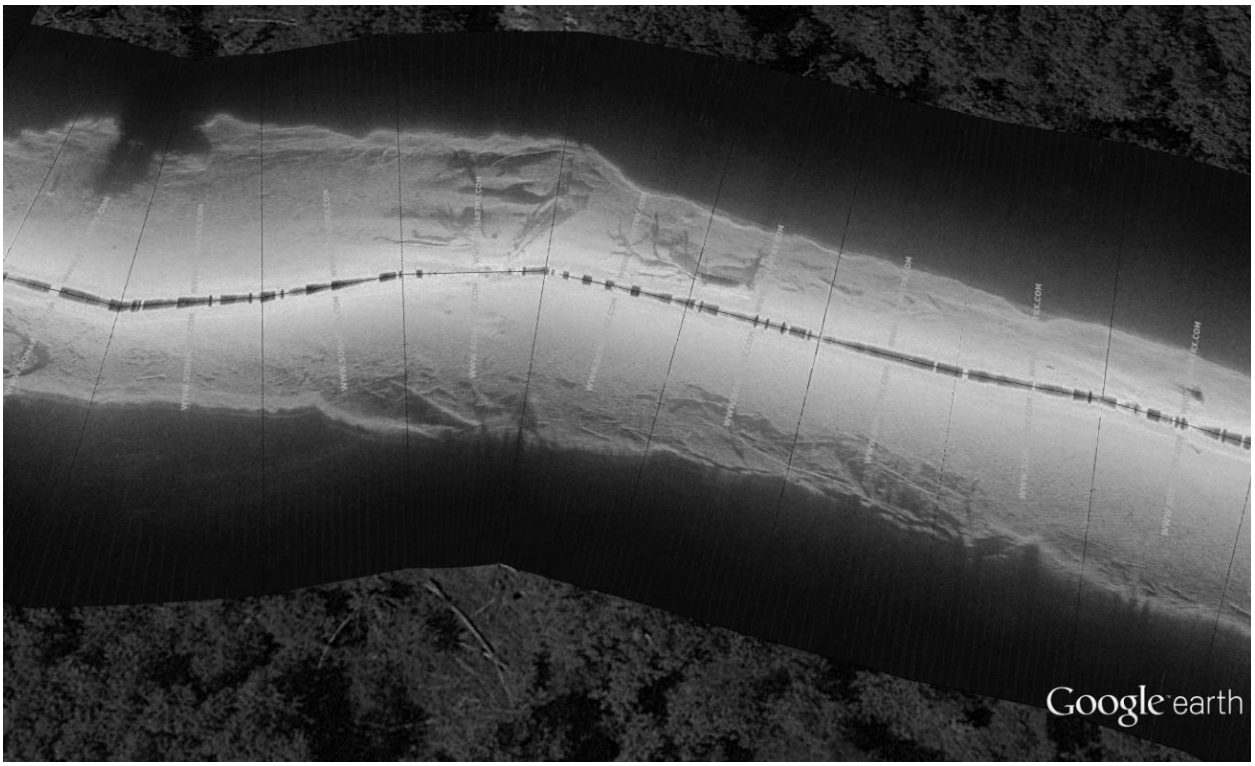


Figure 103.3: An example of the GIS maps created from side scan image files from the upper Kaskaskia River at the site scale. Habitat units can be delineated from these images and used to quantify habitat in areas sampled for in-stream habitat and fish.

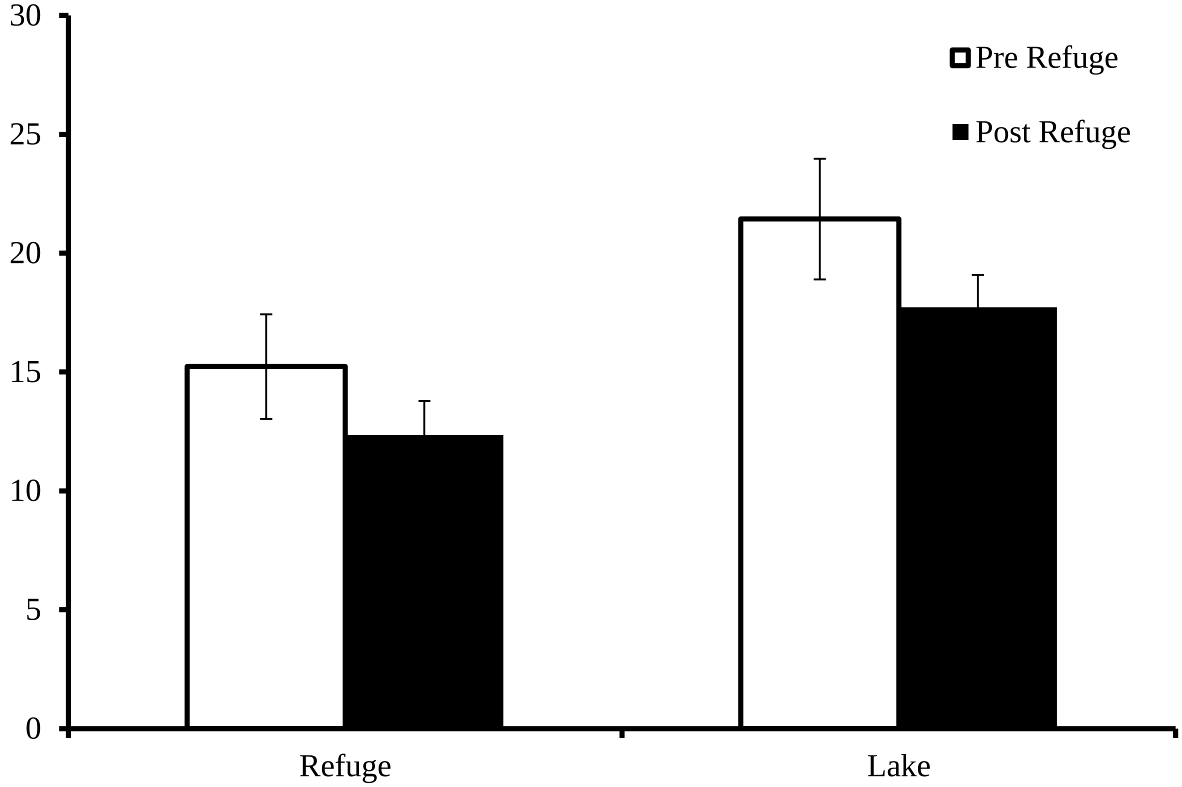


Figure 104.1: Catch per unit effort (CPUE) of largemouth bass in spring and fall electrofishing transects in Otter Lake in refuge sites that were closed to angling compared to lake sites that were not closed to angling. Pre refuge samples were collected in 2007-2010 and post refuge samples were collected in 2011 – 2013. Error bars represent standard error.

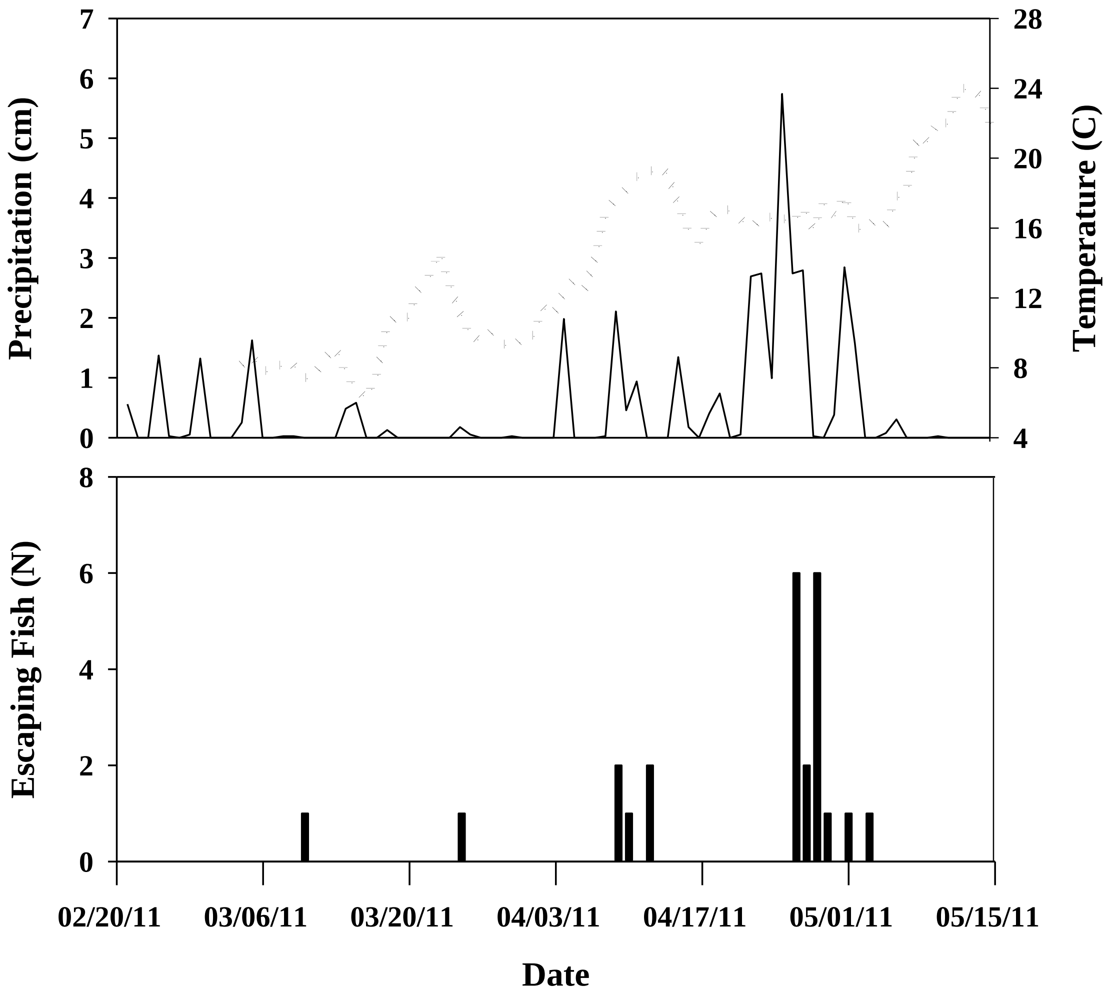


Figure 104.2: Daily precipitation (solid line) and water temperature (dotted line) in the spring and fall at Lake Sam Dale, Illinois (top panel). Daily number of fish escaping over the dam is shown as vertical bars (lower panel). Escapement was determined by tag detections on a PIT tag antennae covering the lower portion of the spillway.

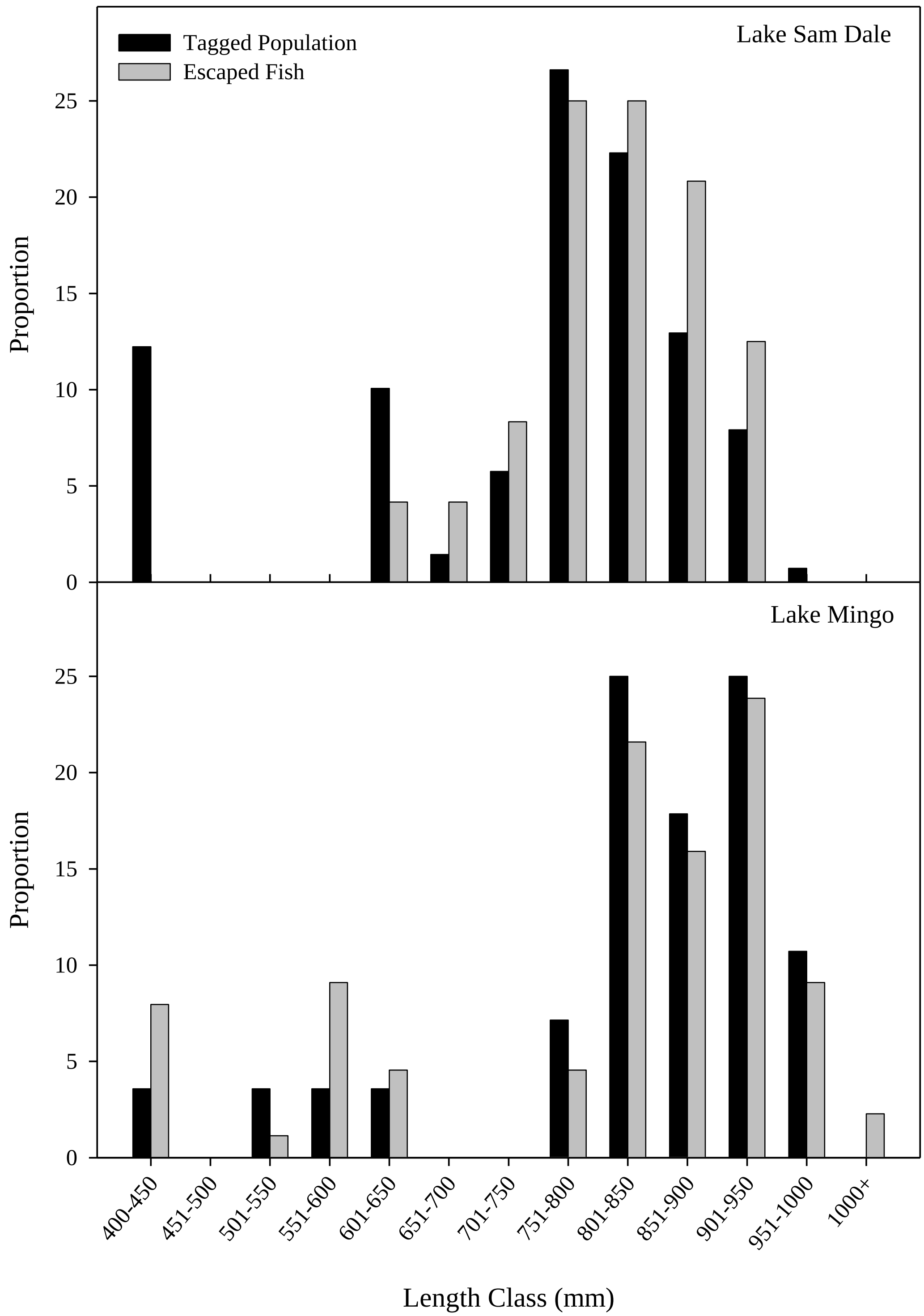


Figure 104.3: Length histogram of the tagged and escaped portion of the muskellunge population in Lake Sam Dale and Lake Mingo through 2012.

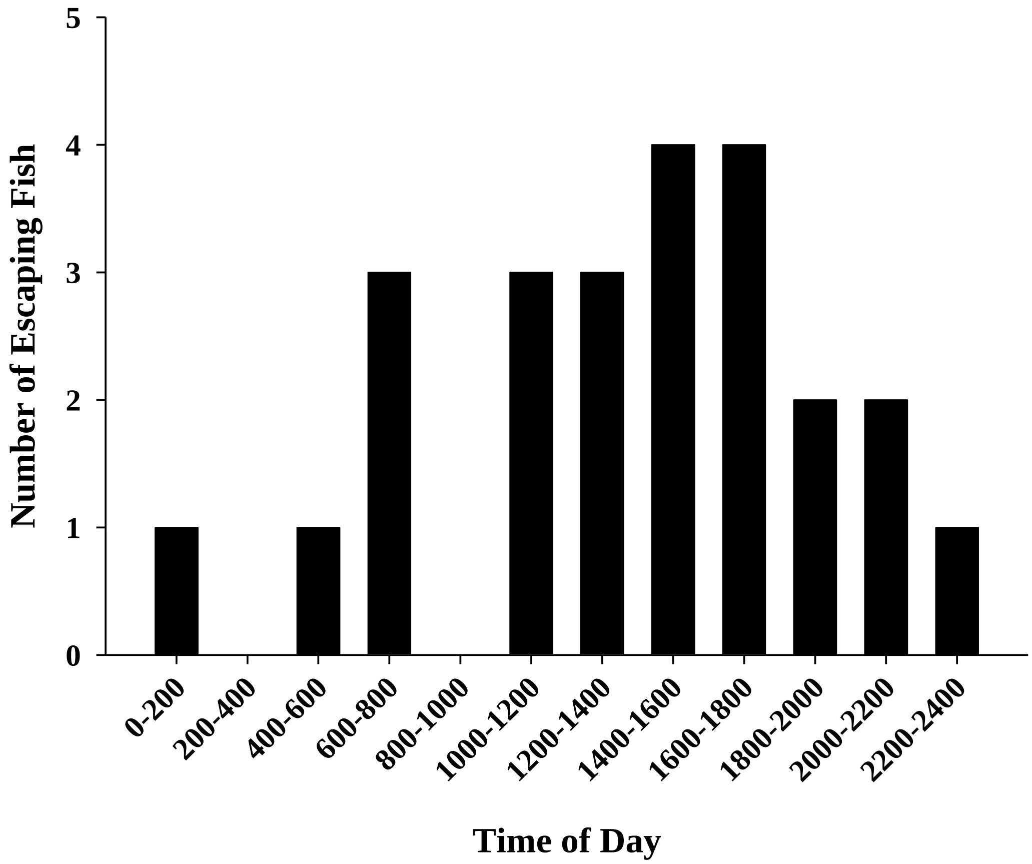


Figure 104.4: Ordinal timing of escapement for muskellunge leaving Lake Sam Dale, Illinois in the spring. Escapement timing was determined by first detection of PIT tags by an antenna covering the spillway below the dam.

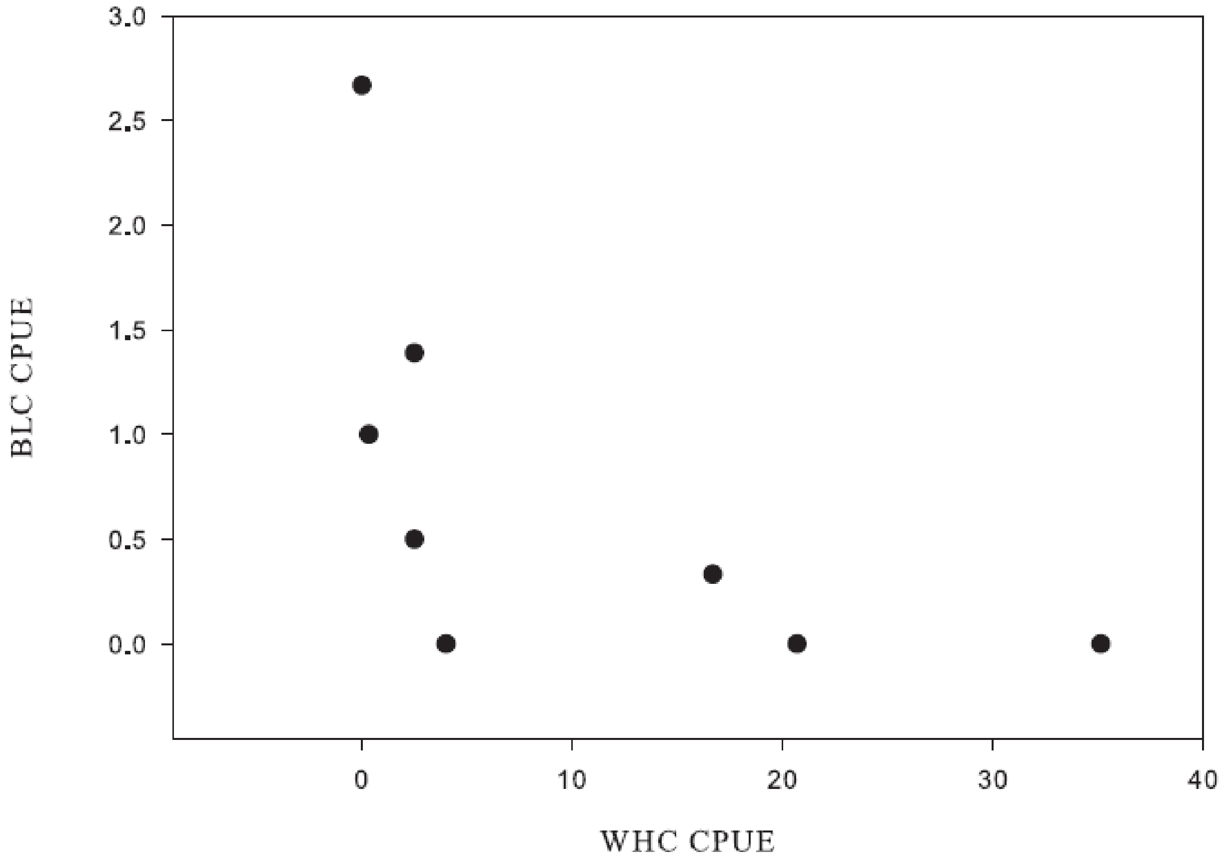


Figure 104.5: Black crappie (BLC) catch per unit of effort (#/hour) against white crappie (WHC) catch per unit of effort from spring electrofishing. Each data point represents an individual lake.

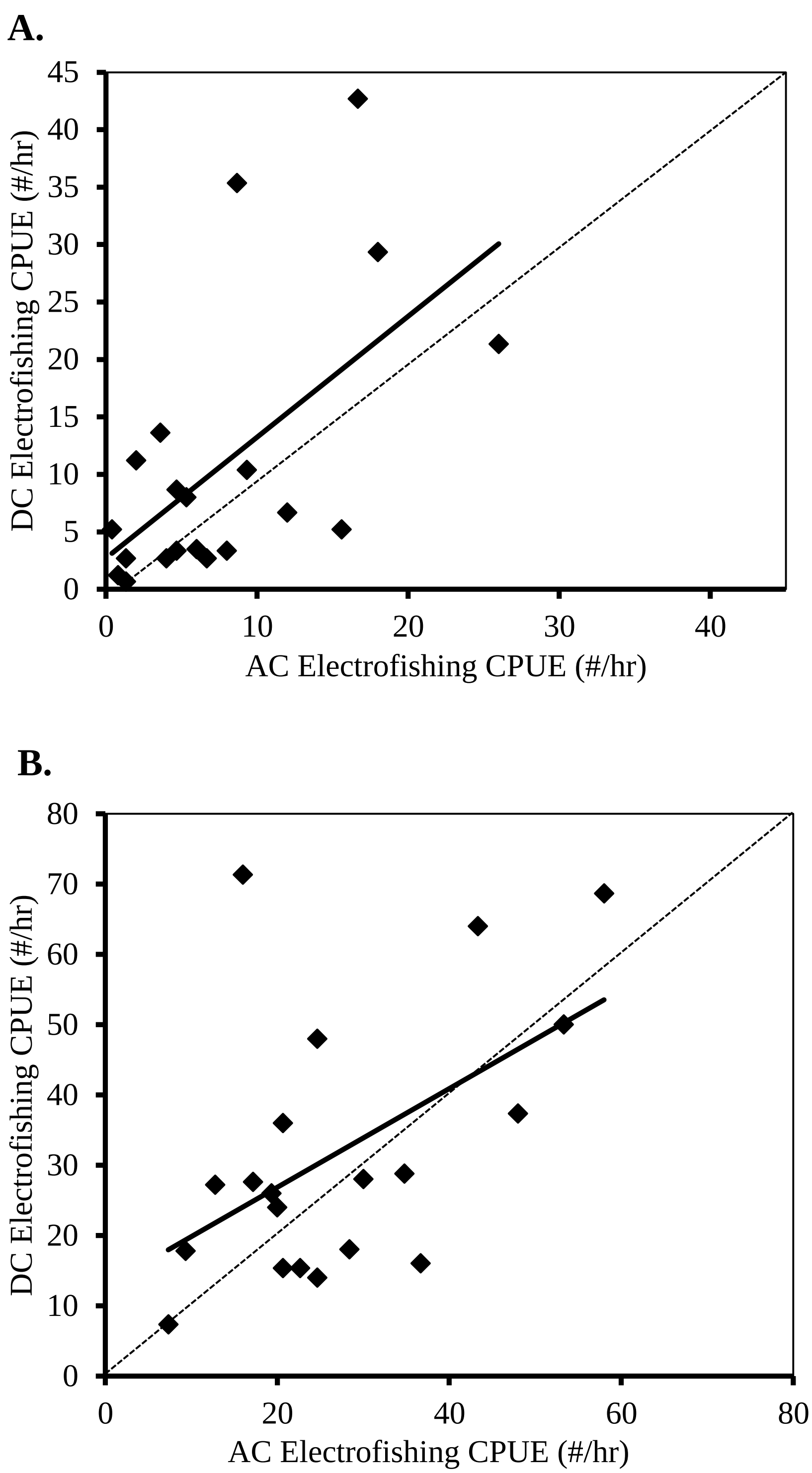


Figure 105.1: Catch per unit effort of A. young-of year and B. adult (>200 mm) largemouth bass from AC and DC electrofishing samples conducted on four lakes in spring and fall of 2011 through 2013. The black line represents the regression line and the dotted line indicates the 1:1 relationship line for reference.

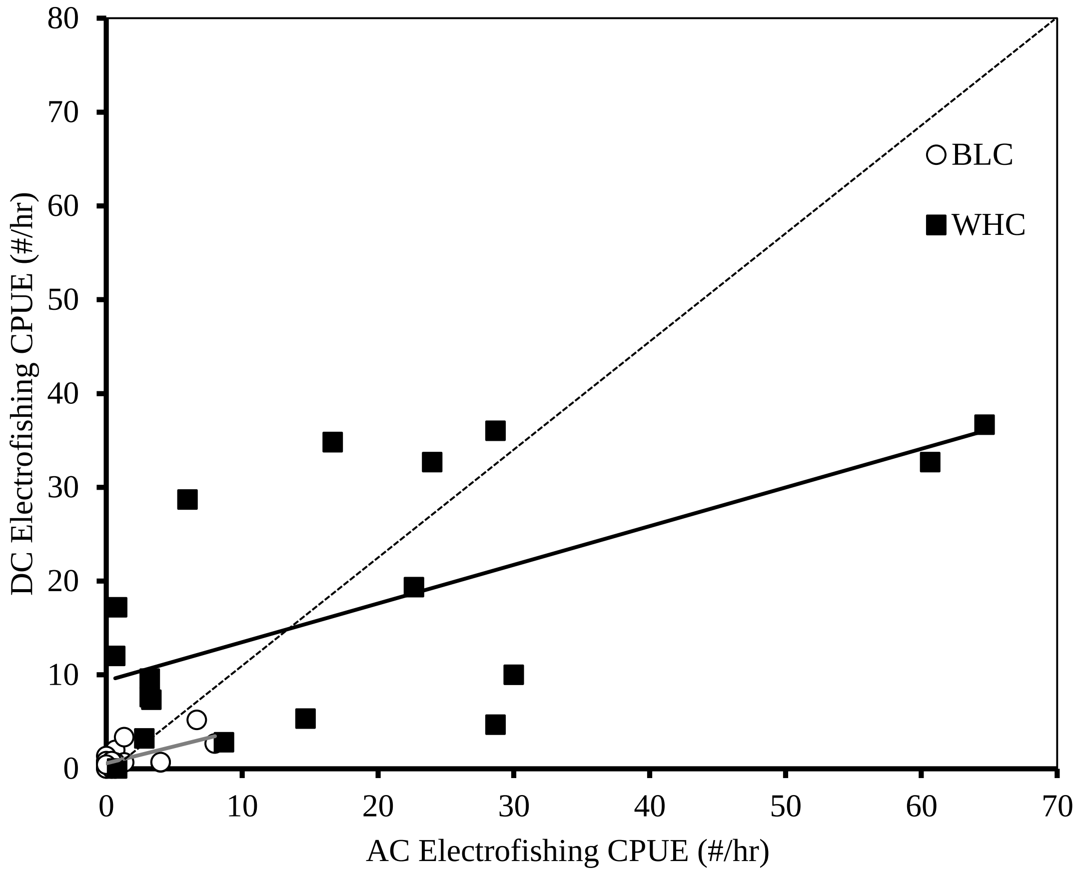
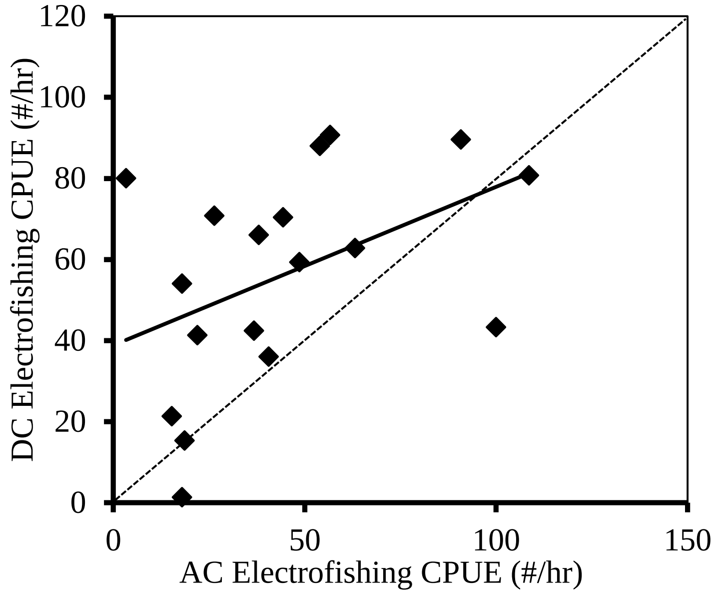


Figure 105.2: Catch per unit effort of white crappie (black squares) and black crappie (grey circles) from AC and DC electrofishing samples conducted on four lakes in spring and fall of 2011 through 2013. The black line represents the regression line and the dotted line indicates the 1:1 relationship line for reference.

A.



B.

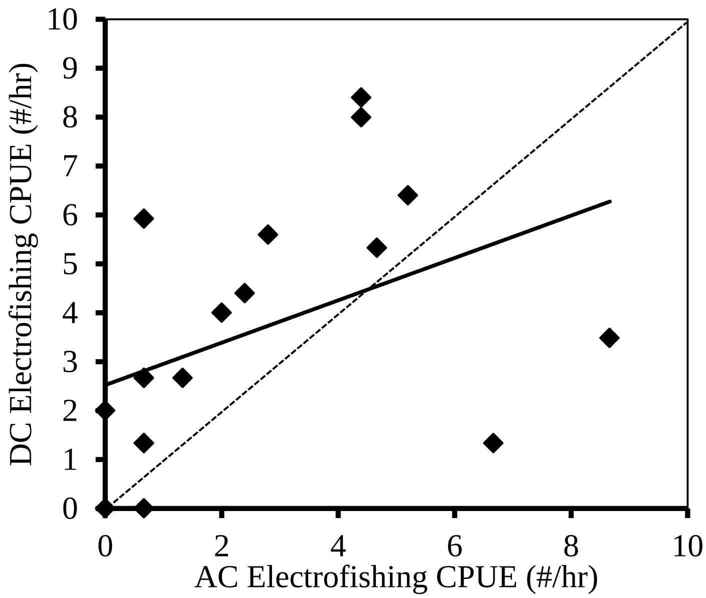


Figure 105.3: Catch per unit effort of A. gizzard shad and B. common carp from AC and DC electrofishing samples conducted on four lakes in spring and fall of 2011 through 2013. The black line represents the regression line and the dotted line indicates the 1:1 relationship line for reference.