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Gear Specific Catch Rates and Population Dynamics of Channel Catfish in the Mississippi River

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GEAR SPECIFIC CATCH RATES AND POPULATION DYNAMICS OF CHANNEL CATFISH IN THE MISSISSIPPI RIVER

A Master's Thesis

Presented to

The Graduate College of

Missouri State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science, Biology

By

Colby Glenn Gainer

August 2020

GEAR SPECIFIC CATCH RATES AND POPULATION DYNAMICS OF CHANNEL CATFISH IN THE MISSISSIPPI RIVER

Biology

Missouri State University, August 2020

Master of Science

Colby Glenn Gainer

ABSTRACT

Perpetual anthropogenic alterations have imposed deleterious effects on aquatic ecosystems. In the Mississippi River, channelization, dams, and loss of floodplain connectivity have all been reputed as detrimental. Dynamic rate functions (i.e., recruitment, growth, and mortality) are the driving forces behind fish populations. Understanding population dynamics is important for guiding management decisions. Knowledge of vital rates can provide pivotal information that will determine spatiotemporal population-level changes within the system. In the Mississippi River, Channel Catfish are a commercially and recreationally important species. However, limited population demographic information currently exists in the Upper Mississippi River. We sought to determine the most effective gear in collecting a representative sample of Channel Catfish, quantify Channel Catfish population dynamics in the Mississippi River, as well as the use of Channel Catfish as a bioindicator. Channel Catfish were collected by tandem hoop nets. Hoop nets were set according to the United States Army Corps of Engineers Mississippi River Restoration Program's Long Term Resource Monitoring (LTRM) element sampling protocol. Quantifying population demographics provides managers a baseline for restoration. We see that Channel Catfish populations in Pool 4 and Pool 8 are longer lived, grow to larger sizes, but at a slower rate, and have more variable recruitment than the Channel Catfish populations in Pool 26 and the Open River Reach, while Channel Catfish populations in Pool 13 and the La Grange Pool of the Illinois River are experience more intermediate growth rate, size, and recruitment. These differences in life history can provide managers with baselines for assessing the overall population in the face of perturbations.

KEYWORDS: Channel Catfish, gear, population dynamics, hoop net, Mississippi River

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In the interest of academic freedom and the principle of free speech, approval of this thesis indicates the format is acceptable and meets the academic criteria for the discipline as determined by the faculty that constitute the thesis committee. The content and views expressed in this thesis are those of the student-scholar and are not endorsed by Missouri State University, Graduate College, or its employees.

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TABLE OF CONTENTS

LIST OF TABLES

Chapter 3

LIST OF FIGURES

Chapter 2

Chapter 3

CHAPTER 1: OVERVIEW

The following thesis examines the most effective methods of sampling Channel Catfish, and Channel Catfish populations in the Mississippi and Illinois Rivers. This thesis is separated into two chapters that are written to be published separately. Chapter 2 looks at several gear types commonly used to collect Channel Catfish in rivers in North America, quantifying which gear likely provides highest Standardized Catch per Unit Efforts (Fish per unit effort) and broadest range of lengths from 1993 to 2017. Chapter 3 focuses on the vital rates of Channel Catfish in the Mississippi River. The information in Chapter 3 will be critical in creating a baseline of population status and can be used as a comparison in the future.

CHAPTER 2: GEAR SPECIFIC CATCH RATES AND SIZE STRUCTURE OF CHANNEL CATFISH IN THE UPPER MISSISSIPPI RIVER

INTRODUCTION

Channel Catfish *Ictalurus punctatus* have a great impact in the upper Mississippi River culturally, economically and ecologically (Quinn 2011). In the Mississippi River Channel Catfish have been termed “most sought after of the Mississippi River fishes” (Quinn 2011). Commercially, Channel Catfish account for 33% of the total economic value of all fish harvested in the United States (Quinn 2011). Due to high levels of commercial and recreational harvest Channel Catfish are subject to simultaneous harvest, which can lead to overharvest without proper management (Quinn 2011). Major decreases in population size as well as overall fish size occurred from 1960 to 1980 (Krogman 2011). When exploitation rates on large individuals become very high, size structure begins to decrease, eventually the fish can no longer effectively replace themselves (Froese 2004). There are two types of overfishing that can occur, the first is growth overfishing, followed by recruitment overfishing. Growth overfishing is characterized by fish being harvested before they reach maximum size (Cushing 1972). Recruitment overfishing often follows growth overfishing, which occurs when fish are harvested before reaching sexual maturity (Froese 2004). Both of these situations can be detrimental to a fishery as a whole.

Due to the high levels of harvest of Channel Catfish fisheries managers must be aware of how the population is behaving. One common way to assess the population is the dynamic rate functions (i.e., recruitment, growth, mortality). Understanding of the dynamic rate functions is essential in characterizing a population and preventing overfishing. This stands true with

Channel Catfish in the Upper Mississippi River. Since Channel Catfish have high economic value and harvest rates may be high the population must be accurately sampled. Capture efficiency is important to maximize the catch for each standard unit effort. Sampling bias (the unequal probability of sampling members of a population) must be avoided, as this will lead to inaccurate estimation of dynamic rate functions (Fischer and Quist 2014).

Sampling methods include low frequency pulsed DC boat electrofishing (Gilliland 1988; Cunningham 1995; Justus 1996), hoop nets of different sizes, a combination of several hoop nets (Sullivan and Gale 1999) or a multigear approach (Schwanke and Hubert 2004). Contradictory estimates of population demographics can be seen when using hoop nets versus electrofishing (Colombo et al. 2008). Each of these techniques has shown varying catch rates and size distributions and can often include sampling bias. Gear selectivity causes inaccurate estimates of population demographics, and ultimately incorrect management decisions (e.g., Ricker 1969; 1975; Bayley and Austen 2002). The sheer amount of time and cost for sampling leads biologist and researchers to want to maximize catch while minimizing cost and time, but a representative sample must be garnered. A study by Brown (2007) indicated that 61% of biologist sought to gain knowledge on gear selectivity and gear efficiency. Brown (2007) also reported that 87% of biologists have a need for acquiring population data (i.e., recruitment, growth and mortality). The need for accurate population data can only be acquired with a prior knowledge of gear selectivity. The objective of this study is to analyze which sampling method is the most efficient in regards of catch per unit effort (CPUE) as well as capturing a representative sample of Channel Catfish in the Upper Mississippi River.

Methods

We evaluated Channel Catfish catch rates obtained by several gears during sampling conducted by the United States Army Corps of Engineers' Long-Term Resource Monitoring Element. Channel Catfish were collected by field station staff at Lake City, MN, La Crosse, WI, Bellevue, IA, Brighton, IL, Jackson, MO and Havana, IL as part of the Long-Term Resource Monitoring (LTRM) element of the Upper Mississippi River Restoration program from 1993 to 2017. The LTRM element utilizes standardized random stratified sampling spatially and temporally to assess the Upper Mississippi River ecosystem. The sampling methods being compared are day electrofishing, small hoop nets, large hoop nets and tandem hoop nets.

Day electrofishing was done in fifteen minute transects, pulsed direct current, using standardized boat and output configurations (Gutreuter et al. 1995). Catch per unit effort (CPUE) was generated as number of Channel Catfish per 15-minutes of electrofishing. Hoop nets were also used to collect Channel Catfish. Two sizes are hoop nets were used. The large hoop nets have 7 fiberglass hoops with diameter 1.1-1.2 m, 4.8 m long and 3.7 cm nylon mesh. The small hoop nets have 7 fiberglass hoops with diameter 0.5-0.6 m, 3 m long and 1.8 cm nylon mesh. The hoops nets are deployed simultaneously within a specific sampling site and baited with 3 kg of soybean cake. The unit of effort is a net-day, which is 24 hours of effort by both nets. Tandem hoop net CPUE was calculated as the catch from small and large hoop nets set in simultaneously, and the effort was 48-hours. Standardized catch per unit effort was calculated for each gear (e.g., 24-hour hoop net set and each 15-minute electrofishing transect). While comparing gears it was assumed that equal effort in terms of man power was spent deploying each gear type (Phelps et al. 2009). An analysis of variance (ANOVA) was used to compare catch per unit effort among

gear types. Tukey's Honestly Significant Difference test was used for pairwise comparisons between gear types. Two-sample Kolmogorov-Smirnov tests were used to detect difference between length-frequency distributions of gear type collecting Channel Catfish.

Results

In the 24 years of data collection 7,643 small hoop nets, 7,648 large hoop nets, 15,291 tandem hoop nets and 13,159 electrofishing sampling events occurred. Across all gear types and sampling events a total of 65,222 Channel Catfish were captured. By gear 39,713, 13,700, 53,413 and 11,809 fish were collected using small hoop nets, large hoop nets, tandem hoop nets and day electrofishing, respectively. Catch rates varied among all gear types (Figure 1) ($p < 0.0001$). Highest catch rates were observed when using small hoop nets (small) with 5.19 (SE=0.23) fish per net-night. Large hoop nets (large) caught 1.79 (SE =0.06) fish per net-night. Tandem hoop nets (tandem) caught 3.48 (SE=0.12) fish per net-night. Electrofishing had the lowest catch rates only catching 0.89 (SE=0.02) fish per 15 minutes of electrofishing (EF).

Channel Catfish ranged from 10mm-889mm (Figure 2). Channel Catfish size distribution varied by gear ($p < 0.0001$) with tandem hoop nets having the broadest size distribution. The average size of Channel Catfish collected using small hoop nets was 254 mm (SE=0.51). The mean size for large hoop nets was 444 mm (SE=0.82). Mean size of Channel Catfish using tandem hoop nets was 303 mm (SE=1.56). Day electrofishing had a mean catch size of 329 mm (SE=1.60). All Kolmogorov-Smirnov test demonstrated differences between length-frequency distributions between all gear types (Figure 3). Small hoop nets rarely (<10%) captured fish over 400mm. Large hoop nets rarely (<10%) captured fish under 350 mm. Electrofishing rarely (<10%) captured fish between 100 mm and 300 mm.

Discussion

Channel Catfish size selectivity and gear selectivity have been observed in previous studies (Colombo et al. 2008; Buckmeier and Schlechte 2009), but no studies have evaluated gear selectivity at this scale (e.g., large sample size, long-term standardized sampling design, widely distributed spatially). Differences in catch rates and size structures were observed when comparing Channel Catfish sampling gears (i.e. small hoop nets, large hoop nets, tandem hoop nets and electrofishing). Small hoop nets and tandem hoop nets had the highest catch rates, while large hoop nets and electrofishing were less effective at capturing Channel Catfish. Tandem hoop nets are collecting the broadest size distribution of Channel Catfish in the Upper Mississippi River, likely providing the most accurate representation of the population.

The results of this study demonstrated that tandem hoop nets are likely capturing the most representative view of the Upper Mississippi River Channel Catfish populations. As such, we suggest that any Channel Catfish collected for demographic assessments (i.e. recruitment, growth and mortality) should be collected using tandem hoop nets. Ultimately, this will lead to more effective management of this ecologically, commercially and recreationally important species.

This study highlights the importance of collecting standardized long-term data using a suite of gears, in many different areas. Standardized sampling can allow for comparison of data over a long time period as shown in this study. The LTRM data set is likely one of the largest and most thorough fisheries data sets throughout the entire United States and likely the world (Ickes et al. 2014). This data collection allows researchers to analyze biological trends across broad spatial and temporal scales (e.g., Phelps et al. 2017). Additionally, long-term data collection allows for gear comparisons. Obtaining a representative sample is imperative for

proper management and conservation (Ricker 1975). Understanding catch efficiency and sampling biases has broad applications and can guide researchers in developing effective sampling protocols.

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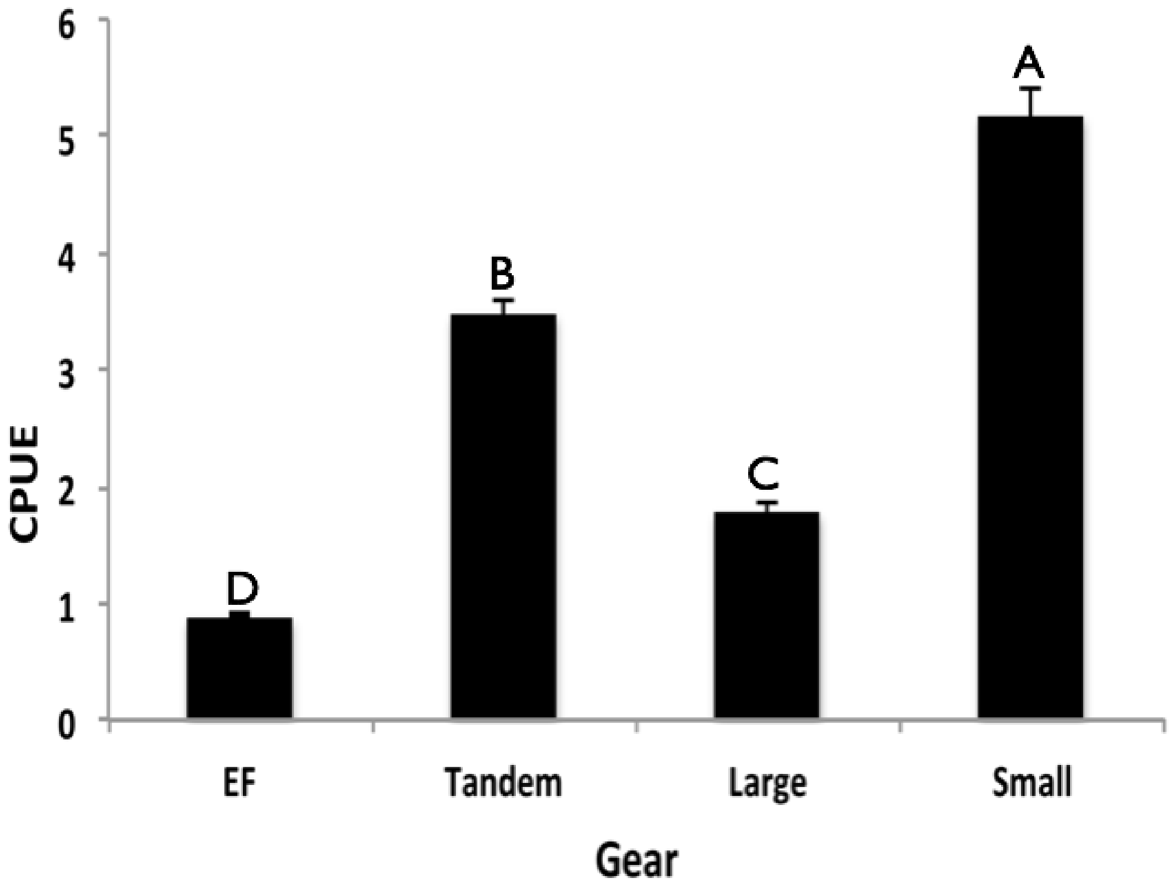

Figure 1. Channel Catfish catch rates across gear types. Different letters indicate significant differences in catch rates. Electrofishing is represented as EF calculated as fish per 15-minute electrofishing. All other gear is fish per-net-night. Generally, catch rates were highest using small hoop nets and tandem hoop nets while electrofishing and large hoop nets had lower rates.

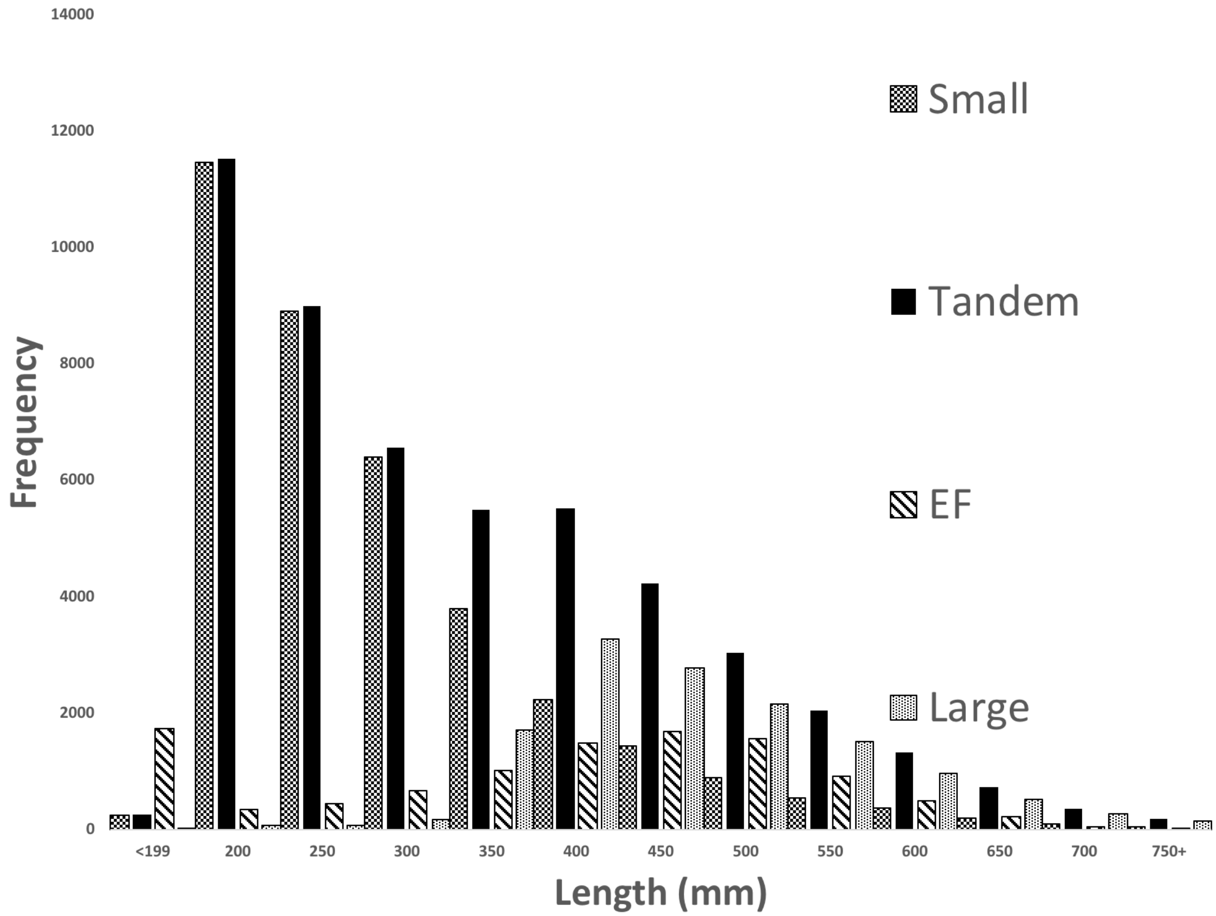

Figure 2. Length frequency distributions for Channel Catfish using different gears. Fish ranged from 10mm – 889mm.

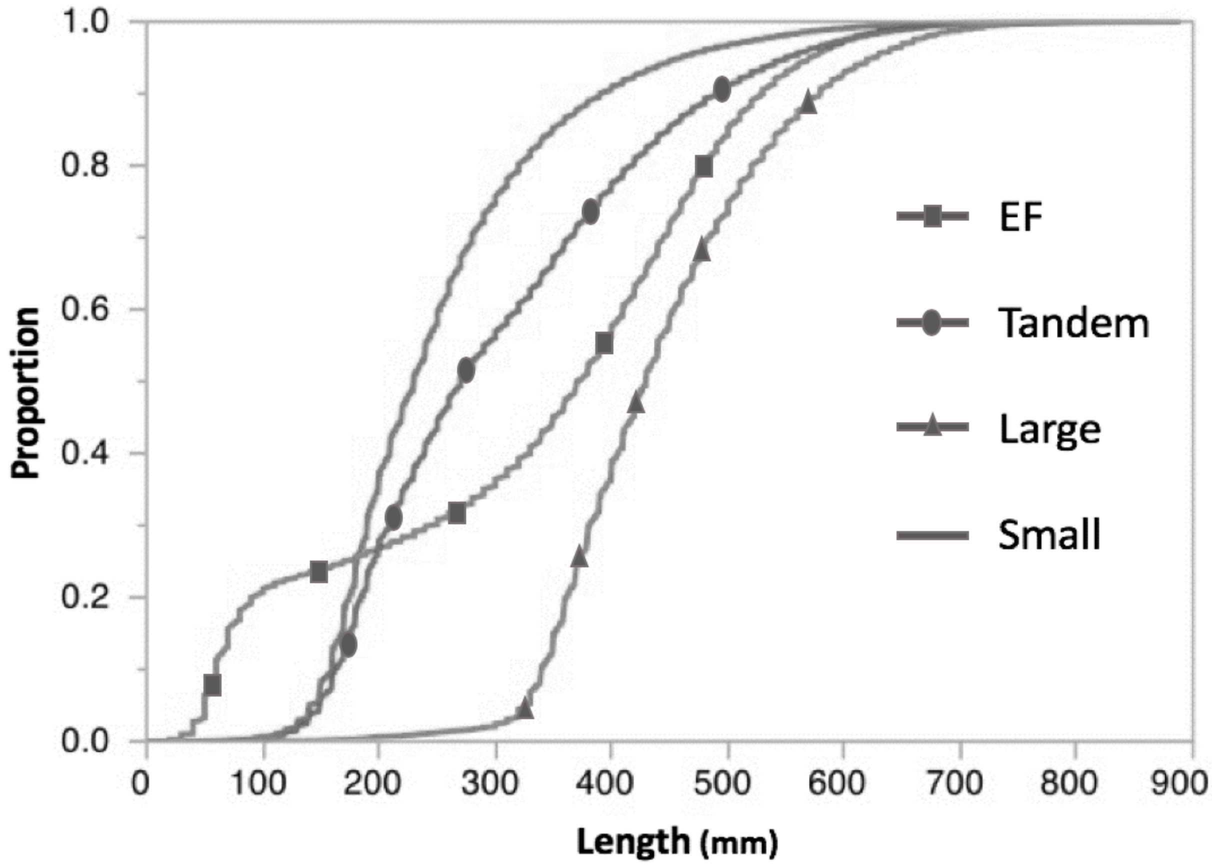

Figure 3. Two-sample Kolmogorov-Smirnov test detected difference in length-frequency distributions of gear type collecting Channel Catfish.

CHAPTER 3: POPULATION DYNAMICS OF CHANNEL CATFISH IN THE MISSISSIPPI RIVER AND ILLINOIS RIVERS

Introduction

Human perturbations have occurred throughout the world impacting the stability of ecosystems, and these changes are occurring more rapidly than they have in the past (Lake et al. 2000; Naiman et al. 2000; Tilman and Lehman 2001; Wang and Lyons 2006; Dolbeth et al. 2007). Disturbance of large riverine systems has occurred across the world and throughout the United States (Best 2019). Changes in river systems can have major effects on all organisms in affected ecosystems. Anthropogenic changes can have negative effects on fish, macroinvertebrates and aquatic plants (Tilman and Lehman 2001; Macura et al. 2016; Karrouch 2017). Specifically, these changes have occurred in the form of channelization, damming, loss of floodplain connectivity, agricultural runoff and contamination (Wohl 2005). As such, quantifying the effects of disturbance on these populations is imperative to ensure sustainability. Bioindicators are commonly used to detect changes occurring in a system. Quantifying the status of a bioindicator can help describe the entire system. Bioindicators can come in various forms and trophic levels (Bongers and Ferris 1999; Kevan 1999). Often macroinvertebrates are used as bioindicators in systems due to their short life span and quick regeneration time (Canning and Death 2019). Conversely, long-lived species may be used as bioindicators by monitoring changes in life history (Zhang and Ma 2011). Previous studies have demonstrated that fish can be effective indicators of river changes and pollution due to their habitat requirements, physiology

and spawning needs (Chovanec 2003). Assessing such bioindicators can lead to early detection and insight into changes occurring in the ecosystem.

Channel Catfish can act as a useful bioindicator in the Mississippi River. Channel Catfish is a well-studied species that can tolerate a wide-range of environmental conditions (i.e., dissolved oxygen and temperature) (Moss and Scott 1961; Andrews et al. 1979). Channel Catfish are opportunistic omnivores, feeding on dead and decaying plants and animals, aquatic and terrestrial insects, living animals and vascular plants (Marsh 1981). As an opportunistic omnivore, Channel Catfish can provide an important pathway for energy transfer in riverine systems. Furthermore, Channel Catfish are also widely distributed and inhabit a wide range of macrohabitats (e.g., main channel, side channel, tailwater) and mesohabitats (e.g., temperature, depth, velocity) (Layher and Maughen 1985). For these reasons Channel Catfish population dynamics may potentially serve as a bioindicator of change (i.e., pollution, climate change, habitat modification) throughout Upper Mississippi River (UMR) and other riverine systems.

Vital rates (i.e., recruitment, growth, and mortality) are the driving forces behind every population, therefore, understanding the dynamic rate functions of Channel Catfish is imperative in evaluating the current status of the population and the system as a whole. Even with the known importance of population dynamics, comprehensive datum is lacking in the Mississippi and Illinois Rivers for Channel Catfish. Population demographics and their stability can quickly change across space and time (Hutchings 2005). As such, ecological disturbance in the system can be seen in the quantification and comparison of vitals rates. Yield Per Recruit (YPR) models are traditionally used to evaluate the effects of fishing pressure on fish populations (Beverton and Holt 1957); however, anthropogenic effects can be used as a surrogate to exploitation and can be described in YPR models. This difference in interpretation of typical YPR models allows for the

detection of sensitivity of Channel Catfish in the Mississippi River. As such, we postulate areas where Channel Catfish are most sensitive (i.e. longer lived, slower growing, less variable recruitment), the effects of riverine disturbance will be observed at lower levels of perturbation and with more drastic effects. This information will be critical in monitoring the effects of river modifications and climatic changes on Channel Catfish as well as the entire river system. Given the more frequent anthropogenic disturbances occurring in the Mississippi River we are unaware of any studies that have evaluated the utility of using Channel Catfish as a bioindicator to provide insight into entire ecosystems.

The objective of this study is to assess and quantify the differences in vital rates throughout the six study reaches in the Mississippi River. This information will be useful for informing current fisheries managers of Channel Catfish status in the Mississippi River. The quantification of vital rates is essential for current and future managers to make informed decisions regarding habitat needs, length limits and creel limits in these study reaches and in similar systems. Lastly, this information is pivotal in providing a baseline age structure of Channel Catfish. Baseline population data can be later compared to changes occurring in the system (i.e., habitat modification, temperature change and invasive species.

Methods

Study area

This study took place across five study reaches on the Mississippi River and one on the Illinois River (Figure 1). These six study reaches have had extensive monitoring of fish and water quality through the Long Term Resource Monitoring (LTRM) element of the Upper Mississippi River Restoration program. From north to south on the Mississippi River, the study reaches

include Pool 4 near Lake City, Minnesota, Pool 8 near La Crosse, WI, Pool 13 near Bellevue, IA, Pool 26 near Alton, IL, and the Open River reach near Cape Girardeau. The study reach on the Illinois River is the La Grange Pool near Havana, IL.

Collection

Channel Catfish were collected using tandem hoop nets (i.e., one large and one small hoop net) by Long Term Resource Monitoring (LTRM) staff in Lake City, MN, La Crosse, WI, Bellevue, IA, Alton, IL and Cape Girardeau MO, Havana IL of the Illinois River following LTRM standardized sampling protocol (Ratcliff et al. 2014). Each river reach was sampled following a stratified random sampling design to ensure sampling bias was minimized. The target was to collect 10 Channel Catfish of each centimeter length group in each of the 6 LTRM study reaches. Each fish was weighed to the nearest gram, measured to the nearest mm, and sexed.

Ageing

The otolith was selected as the ageing structure of choice as it provides the most accurate and reliable annuli formation (Casselman 1983; Edwards et al. 2005). Lapilli otoliths were removed by cranial dissection, cleaned and dried for at least two weeks. Subsequently, otoliths were sanded using 800-grit fine sandpaper dampened with water until the nucleus is visible (Buckmeier et al. 2002). Using a petri dish, otoliths were submerged in water to increase the clarity of annuli. Photographs of otoliths were captured using a microscope under a low magnification, with side illumination from a fiber optic light source (Colombo et al. 2011) and aged by two experienced independent readers. In the event of a disagreement, the two readers would examine the otolith in concert and if an agreement could not be reached the sample was discarded.

Analysis

Vital rates of the population were calculated from length, weight, and age data. A Kolomogrov-Smirnov test were used to detect differences in length-frequency distributions and age-frequency distributions between the six study reaches. Recruitment is described as the number of Channel Catfish entering into the population. Recruitment was calculated using residual sum of squares of the regression of catch on age data (Maceina 1997). Positive residual values indicate strong year class while negative values indicate a week year class. Relative strength or weakness of year classes (residual values) from the catch-curve regressions were cross-correlated using a Spearman Rank approach between all river reaches, to determine if recruitment patterns were similar among river reaches (Macenia 1997; Isermann et al. 2002). Mortality is the number of Channel Catfish leaving the system via harvest and natural death. Total annual mortality was calculated using a weighted catch curve (number of individuals at each age) (Miranda and Bettoli, 2007), and conditional natural mortality was calculated using an average of estimated values (Pauly 1980; Hoenig 1983; Peterson and Wroblewski 1984; Chen and Watanabe 1989; Jensen 1996; Quinn and Deriso 1999) available in Fisheries Analysis and Modeling Simulator (FAMS; Slipke and Maceina, 2010). To determine if differences in mortality occurred between all reaches for Channel Catfish, we compared the mortality rates using the homogeneity of slopes test (i.e., test of interaction using ANCOVA) (Sokal and Rohlf 1995). Growth was modeled using the Von Bertalanffy growth equation using mean length at age data (von Bertalanffy 1938). The overall growth curves generated for Channel Catfish at all river reaches were compared using the residual sums of squares from the coinciding von Bertalanffy models (Chen et al. 1992). Von Bertalanffy parameters (theoretical maximum length, and Brody growth coefficient) were compared at each site using residual sum of squares from

coinciding models (Chen 1992). Yield-per-Recruit modeling at each river reach was used to determine where Channel Catfish fully recruited to gear (200 mm) are most sensitive to ecological disturbance (e.g., surrogate for exploitation).

Results

A total of 1,253 Channel Catfish were collected and aged throughout the study. Lengths ranged from 75 to 804 mm and ages ranged from 0-19 years (Figures 2 and 3). Length frequency distributions were different between all field stations (all comparisons $P < 0.05$, $D > 0.3$). Larger fish were observed in Pool 4 and Pool 8 within Mississippi River. Age frequency distributions differed between all field stations (all comparisons $P < 0.05$ $D > 0.3$). Age decreased in a downstream direction. Older individuals were observed in Pool 4 and Pool 8, while Channel Catfish in Pool 13 and the La Grange Pool had more intermediate ages. Channel Catfish in the Open River Reach and Pool 26 were not more than 13 years old. Recruitment was more consistent in the Open River reach and Pool 26 and more variable recruitment was observed in Pools 4 and 8. Pool 13 and the La Grange Pool had an intermediate amount of variability in recruitment. (Table 1). Total annual mortality was different between all field stations (all comparisons $P < 0.05$). Higher mortality rates were observed in Open River reach and Pool 26, while lower mortality rates were observed in Pools 4 and 8, and intermediate mortality was observed in Pool 13 and the La Grange Pool (i.e., mortality rates increased in the downstream direction.) (Table 1). Mean length at age for all aged fish was sufficiently described by von Bertalanffy growth functions at all locations ($P < 0.0001$, $r^2 > 0.99$). Recruitment was asynchronous across reaches based on Spearman rank test ($P < 0.05$). Growth rates were different between all study reaches (all comparisons $P < 0.05$). Growth rate increased in a

downstream direction. Faster growth was observed in the Open River reach and Pool 26, intermediate growth was observed in Pool 13 and the La Grange Pool, and slower growth occurred in Pools 4 and 8 (Table 1).

Our yield per recruit models identified that yield would decrease at lower percent ecological disturbance in Pool 4 and Pool 8 and 13. Yield would decrease at an intermediate percent in the La Grange Pool, and yield decreases at the highest percent in the Open River Reach and Pool 26. (Figure 4). In Pools 4 and 8 yield begins to decrease at 24% and 25% ecological disturbance. In the Open River reach and Pool 26 yield does not decrease until 37% and 35% ecological disturbance. Decreases in yield occurring at a lower percentage indicate greater sensitivity to ecological disturbance. These decreases occurring at lower percent disturbance indicate if the disturbance is occurring system-wide yield will decrease in Pool 4 and Pool 8 before the other study reaches. Furthermore a 20% decrease in yield is occurring in the Pool 4 and Pool 8 at a 45% ecological disturbance. In the Open River Reach and Pool 26 a 20% decrease in yield does not occur until nearly 90% disturbance.

Discussion

This study provides previously absent baseline population demographics at several long-term monitoring sites in the Mississippi and Illinois Rivers. Population dynamics are the basis for proper management decisions. Differences in population dynamics were observed throughout the six study reaches. Differences in population dynamics indicate that there is a continued need to sample the populations in each study reach for best management decisions. The differences in population dynamics in these six study reaches tend to follow a latitudinal trend. This trend can be observed in recruitment, growth and mortality, where Channel Catfish populations in northern reaches are growing more slowly but reaching larger maximum sizes and ages than populations

in southern reaches. Additionally, this trend holds true in regard to the susceptibility to ecological disturbance. Due to older maximum age, less consistent recruitment, and slower growth, Channel Catfish in the most upstream study reaches in the Mississippi River are more sensitive than their counterparts in downstream study reaches. Channel Catfish recruitment is more variable at higher latitudes potentially due to increased climactic variability (Lehodney et al. 2006), which is consistent with Freshwater Drum in the Upper Mississippi River (Abner and Phelps 2018). Latitudinal trends in fish growth rates are relatively common in literature (e.g., Belk and Houston 2002, Heibo et al. 2005), yet the idea of whether fish follow a growth gradient or a countergradient in regard to latitude is widely disputed. Weber et al. (2015) stated fish, being ectotherms, have slower growth in northern latitudes due to shorter growing seasons and colder temperatures. Rypel (2011) suggested ictalurids (e.g., Blue Catfish, Flathead Catfish, Black Bullhead and Brown Bullhead) follow a countergradient growth pattern, where individuals grow faster in southern latitudes than northern latitudes. The results of our study suggest that Channel Catfish, like other Ictalurids, are growing more slowly in northern latitudes than in southern latitudes. Our results are also consistent with literature that at higher latitudes, ectotherms tend to live longer than those at more southern latitudes (Munch and Salinas 2009).

Anthropogenic changes have had impacts throughout riverine ecosystems, from plants and macroinvertebrates to upper level predators (Macura et al. 2016). Monitoring the changes in population dynamics of Channel Catfish in the Mississippi and Illinois rivers will be valuable for the species, but also for other organisms throughout the river who may follow similar patterns. Anthropogenic alterations could negatively influence Channel Catfish size and age structure, as well as trophic interactions throughout the system. The assessment of a bioindicator can provide critical information regarding changes in the system, but these changes must be detected quickly

to make proper management decisions. Results from this study indicate that Channel Catfish recruitment, growth, and mortality vary from reach to reach. This suggests that studying Channel Catfish in one specific reach of the Mississippi River may not represent the entire Mississippi River, but could represent that specific reach. Further, Channel Catfish exhibit a wide range of habitat use, and a generalist feeding strategy (Braun and Phelps 2016). The long-lived nature of Channel Catfish provides an opportunity to analyze and capture subtle changes in recruitment, growth, and mortality. The findings in this study suggests that climactic and geographical features structure the population at a foundational level, but year-to-year variation in population dynamics are likely due to local scale factors (e.g., habitat) (Phelps et al. 2008) rather than broad scale factors. If changes in population dynamics are being observed in Channel Catfish populations throughout the entire study area, the cause of change is likely climactic. Conversely, if the change only occurs in one specific reach, the cause is more likely a local scale factor. Monitoring Channel Catfish at a population level is highly important due to the generalist nature of the species. If Channel Catfish vital rate changes are observed this will could indicate similar population or worse population level changes occurring in other species.

Lastly, mortality rates in Pool 4 and Pool 8 of the Mississippi River observed in this study are similar to findings of the trophy Channel Catfish fishery in the Red River in Manitoba, Canada (mortality =19%) (Siddons et al. 2016). Hubert (1999) reviewed 102 studies and found that only 7 studies identified fish older than age 15. The potential for Channel Catfish in Pool 4 and Pool 8 of the Mississippi River to reach ages approaching 20 years old provides opportunity to create a trophy fishery. It has been noted that more restrictive regulation has been useful in increasing Channel Catfish populations in the Upper Mississippi River (Pitlo 1997) as well as in other Channel Catfish populations (Mestl 1999). If angler desire in Pool 4 and Pool 8 of the

Mississippi River is to create a trophy Channel Catfish fishery, then more restrictive regulation in these reaches coupled with preexisting fish with the ability get very large and grow very old could be successful. Conversely, populations in the Open River Reach and Pool 26 are experiencing consistent recruitment, fast growth, and smaller fish overall. This suggests management objectives should be to encourage harvest (i.e., liberal bag limits and limited or no size restrictions) to prevent stunting of the population (van Poorten et al. 2013).

This study can be beneficial in the assessment and wellbeing of individual reaches as well as the entire river system. This study has provided baseline information regarding the life history of Channel Catfish throughout the Upper Mississippi River. With an ever changing and manipulated system, impacts on riverine species can be difficult to quantify. This study has provided a quantification of the status of this species and can be used in the future to determine if riverine modification and climactic change is positively or negatively impacting Channel Catfish. Similar assessments, as demonstrated in this study, should be carried out on various fishes as often as possible (e.g., every few years) in the Mississippi River to ensure ecosystem structure and function are not jeopardized through disturbance.

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Table 1. Life history parameters of Channel Catfish populations used for yield-per-recruit modeling at Pool 4, Pool 8, Pool 13, Pool 26, and the Open River Reach, and the La Grange Pool of the Illinois River.

River Reach	Total fish aged	Max age	RCD[a]	L_∞[b]	K[c]	A[d]
Pool 4	87	19	0.74	743	0.123	15%
Pool 8	263	18	0.72	748	0.125	20%
Pool 13	215	16	0.77	725	0.131	23%
Pool 26	269	13	0.94	650	0.132	29%
Open River Reach	53	11	0.87	585	0.135	33%
La Grange Pool	364	13	0.85	710	0.133	27%

[a]RCD=Parameter of catch curve
[b]L=Theoretical maximum length at time = ∞ (mm)- Parameters of the von Bertalanffy growth curve.
[c]K=Growth coefficient- Parameters of the von Bertalanffy growth curve.
[d]A=Total annual mortality calculated from catch curve

Figure 1. Five study reaches in the Mississippi River and one study reach in the Illinois River.

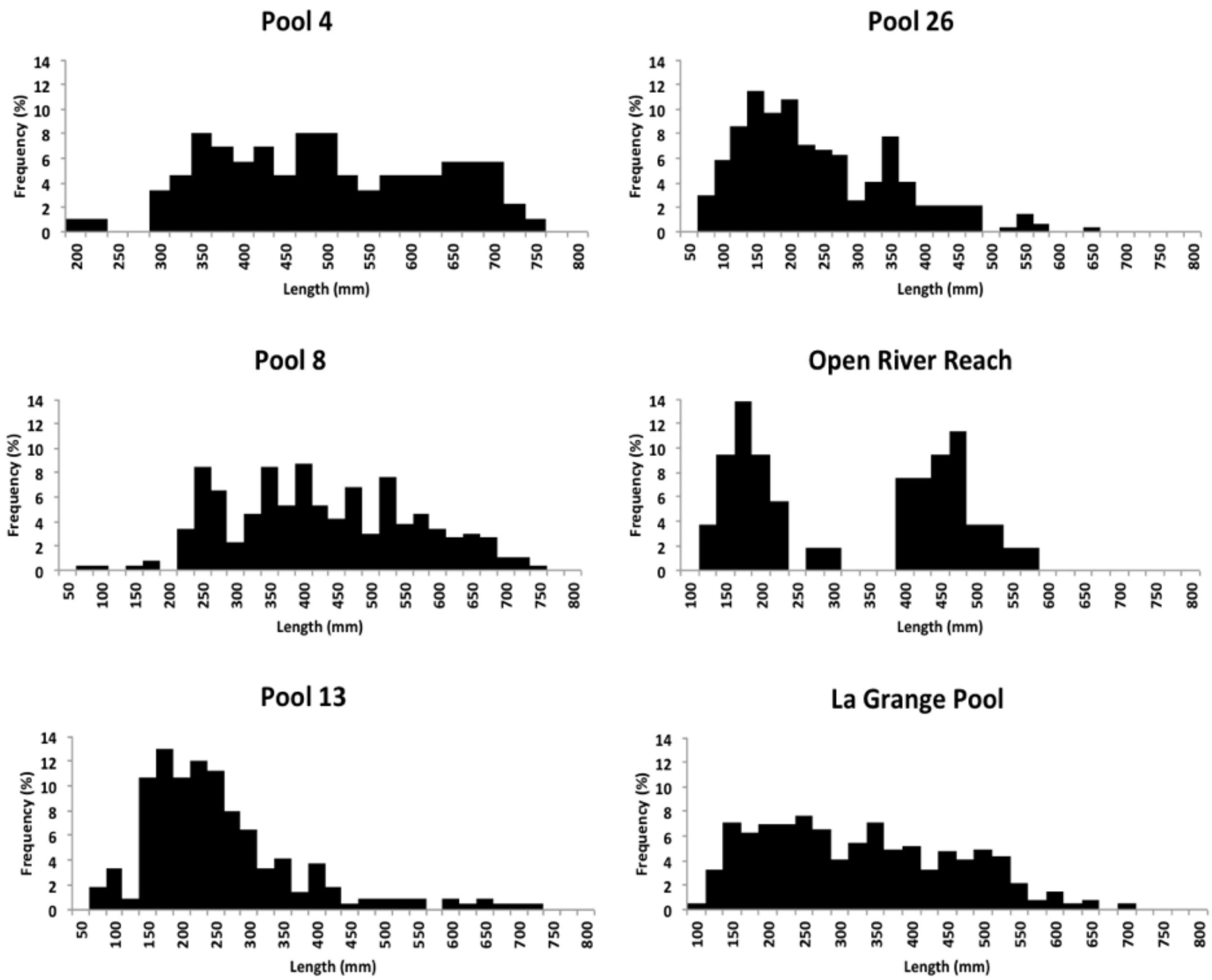

Figure 2. Length–frequency distributions of Channel Catfish sampled in the Mississippi River at Pool 4, Pool 8, Pool 13, Pool 26, and the Open River Reach, and the La Grange Pool of the Illinois River. All fish were collected in 2018, with one large and one small hoop nets.

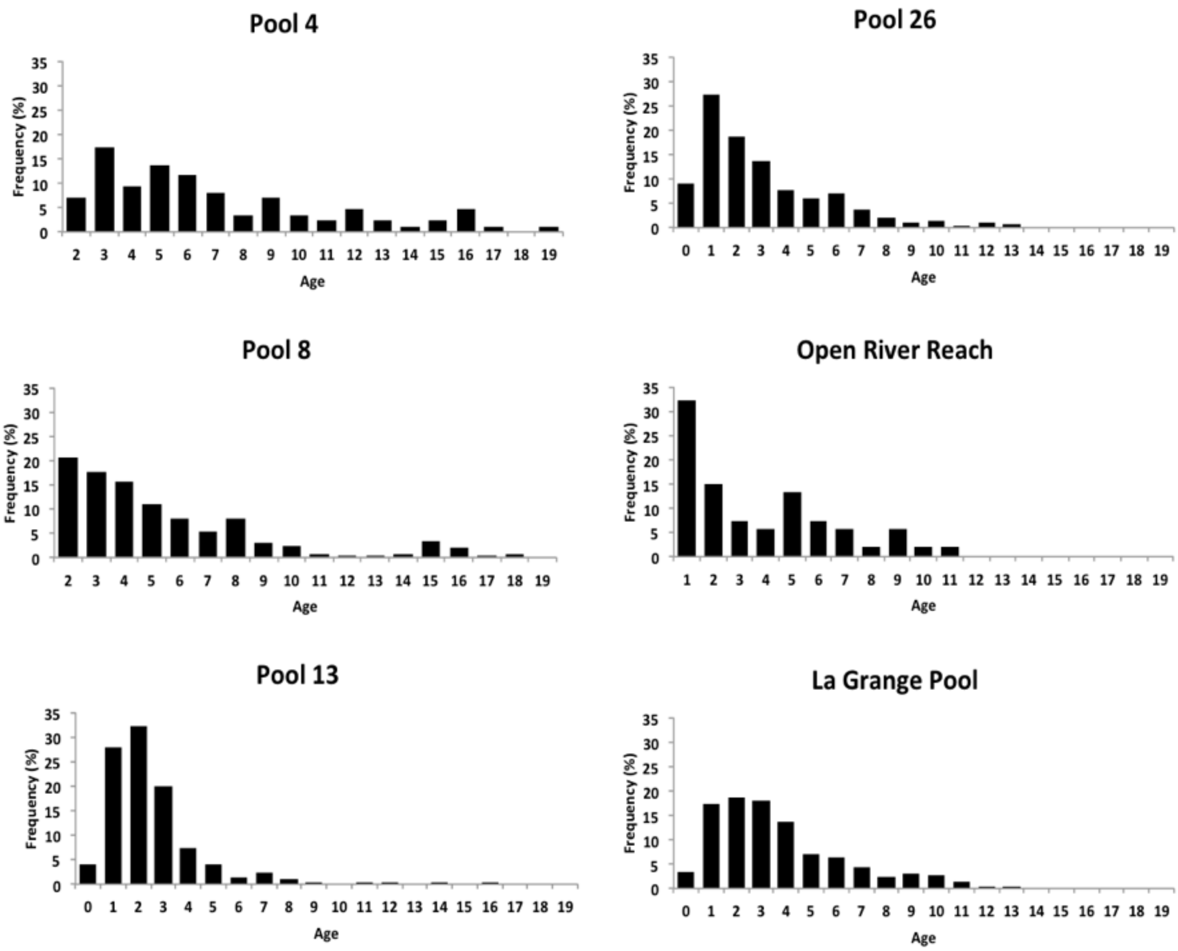

Figure 3. Age–frequency distributions of Channel Catfish sampled at Pool 4, Pool 8, Pool 13, Pool 26, and the Open River Reach, and the La Grange Pool of the Illinois River. in 2018, using large and small hoop nets.

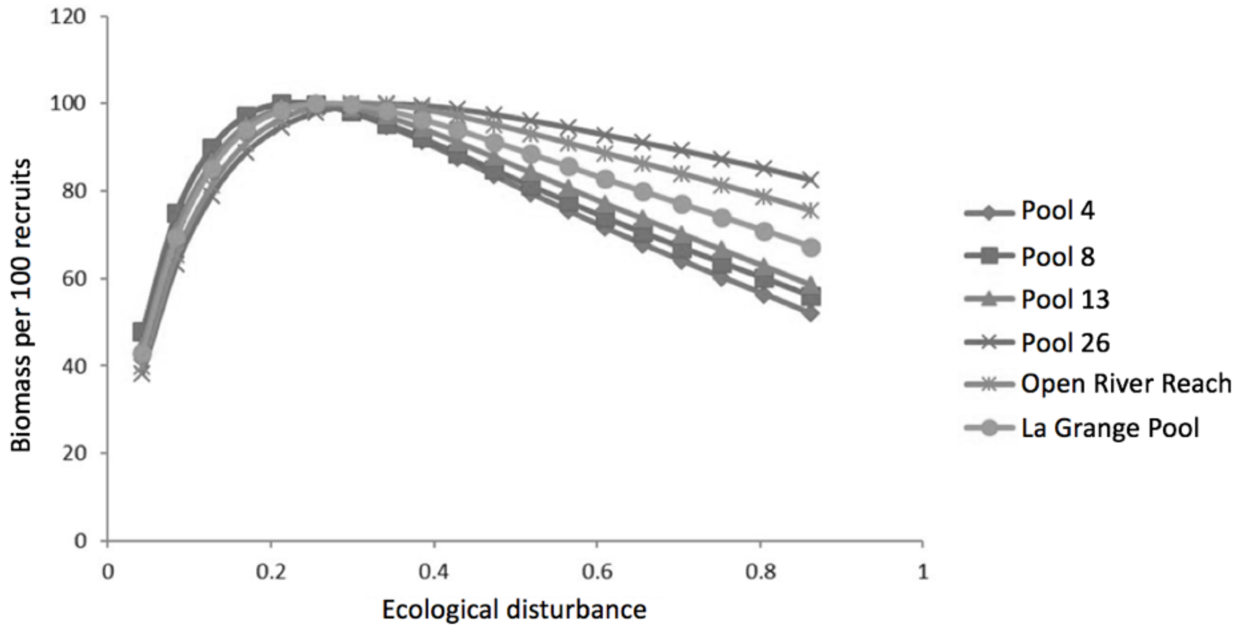

Figure 4. Yield-per-Recruit model based on 100 recruits at Pool 4, Pool 8, Pool 13, Pool 26, and the Open River Reach, and the La Grange Pool of the Illinois River.

CHAPTER 4: SUMMARY

This research identifies the need for standardized sampling across a wide range spatially and temporally. This thesis is a portion of a larger project, where vital rates can be quantified for several additional species over a three-year period. As a whole this can help to identify if trends are occurring in population dynamics throughout the study area. This study highlights the need for multiple jurisdiction cooperation. Without the collaboration of numerous state agency this database or project would not exist. Standardized sampling is of upmost importance when sampling fish populations. Standardized sampling allows for the comparison not only within a specific area but can be used to compare in other bodies of water. Comparing population dynamics over time can quantify positive changes in the system (e.g. habitat restoration) as well as negative changes (e.g. channelization, loss of flood plain connectivity). Further monitoring and comparison of Channel Catfish population dynamics to other species in the system can indicate whether species are following similar trends. If multiple species are behaving similarly then sampling a specific species could indicate the status of many more species.