5-2012

AN EVALUATION OF STOCKING AND HABITAT INFLUENCES ON CHANNEL CATFISH IN LENTIC ECOSYSTEMS OF THE GREAT PLAINS

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Chizinski, Lindsey K., "AN EVALUATION OF STOCKING AND HABITAT INFLUENCES ON CHANNEL CATFISH IN LENTIC ECOSYSTEMS OF THE GREAT PLAINS" (2012). *Dissertations & Theses in Natural Resources*. 43.
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AN EVALUATION OF STOCKING AND HABITAT INFLUENCES ON CHANNEL CATFISH IN LENTIC ECOSYSTEMS OF THE GREAT PLAINS

By

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A THESIS

Presented to the Faculty of
The Graduate College at the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Master of Science

Major: Natural Resource Sciences

Under the Supervision of Professor Kevin L. Pope

Lincoln, NE

May, 2012

AN EVALUATION OF STOCKING AND HABITAT INFLUENCES ON CHANNEL CATFISH IN LENTIC ECOSYSTEMS OF THE GREAT PLAINS

Lindsey K. Chizinski, M.S.

University of Nebraska, 2012

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Channel catfish *Ictalurus punctatus* is an important sport fish, particularly in the Great Plains. In Nebraska, a majority of anglers target channel catfish, and fishing activities are a vital part of the state’s economy. Lentic water bodies provide the primary fishing opportunity for catfish anglers in Nebraska. Despite the popularity and economic importance of channel catfish, little is known of its population dynamics or habitat requirements, and existing studies often profile river populations. Current standards for sampling channel catfish in lentic systems often yield inadequate catch to assess populations. The objective of this study was to utilize a recently developed sampling method, tandem-set hoop nets, to collect channel catfish in sufficient quantities to describe the effects of stocking and habitat variability on populations in lentic ecosystems. Three lentic ecosystems common to the Great Plains were considered: sand pits, flood-control reservoirs, and irrigation/power-generation reservoirs. The influence of stocking on abundance and condition of channel catfish varied with ecosystem type. In sand pits, stocking negatively influenced fish condition, and only frequent stocking positively influenced abundance. In flood-control reservoirs, stocking did not influence fish condition, but was associated with greater abundance. Stocking did not influence fish condition or abundance in irrigation/power-generation reservoirs. Additionally, there was evidence that mortality and growth rates varied with ecosystem type. In general, populations from irrigation/power-generation reservoirs were predicted to experience slower growth and lower mortality, whereas populations from sand pits were predicted to experience the fastest growth and highest mortality. Catch rates of channel catfish were substantially less in this study compared to previous records of tandem-set hoop net surveys, but hoop nets were more efficient than the current standard gear, experimental gill nets, at capturing channel catfish (i.e., 100 fish could be captured with fewer hoop net sets than gill net sets). However, catch rates and size structure of channel catfish in tandem-set hoop nets varied within the sampling season and between years. Furthermore, length-frequency distributions of channel catfish were dissimilar between hoop nets and gill nets.

ACKNOWLEDGEMENTS

There are so many people who contributed to this project and supported me to its completion; I am increasingly grateful as I write this list and it continues to grow.

I thank my advisor, Dr. Kevin Pope, for his guidance and insight, for his faith in my abilities, and for his genuine interest in my well-being. Also, I thank him for introducing me to my husband during the Midwest Fish and Wildlife Conference in Columbus, Ohio. I thank my committee members Dr. Mark Pegg, Dr. Richard Holland, and Dr. Drew Tyre for their proposal and thesis comments. I thank my technicians Dan Dobesh, Nick Dobesh, Matt Gruntorad, and Anthony Miller, for their dedication and hard work through grueling mid-summer field seasons. Along with my field technicians, I thank Kate Rabe for long hours spent in the lab processing and aging catfish spines. I thank my fellow graduate students Dustin Martin, Ryan Lueckenhoff, Dustin Martin, Peter Spirk, and the rest of the 'Pope Lab' for assistance in the field and with help preparing posters and presentations. I thank Valerie Egger and Caryl Cashmere at the Nebraska Cooperative Fish and Wildlife Research Unit for keeping everything in order.

This project was supported by funds from Federal Aid in Sport Fish Restoration, project F-177-R and was administered by the Nebraska Game and Parks Commission (NGPC). I thank NGPC for entrusting me with this project, and for allowing me to pursue a graduate education while employed as a conservation technician. Specifically, I thank my supervisors Don Gabelhouse, Dave Tunink, and Jeff Jackson for their patience while I completed the project. I thank fisheries staff Tony Barada, Phil Chvala, Brad Eifert, Al Hanson, Caleb Huber, Jordan Katt, Tony Munter, Brad Newcomb, Larry Pape, Jeff Schuckman, and Mark Staab for their assistance in the field. I also thank the hatchery staff for their stocking efforts.

I firmly believe I would not be writing this now without the support of my family. I thank my parents, Ken and Tina Filbert, for their unconditional love and for teaching me more than I'll ever learn in school. I thank my sister Kate, my lifelong best friend, for encouraging me through example to be fearless and take risks. I also thank my grandmother, Joan Avey, for her example in academic excellence and strong character. I hope I will always make my family proud.

I feel as strongly about the influence of my friends. Though I've mentioned him once already, I thank my friend and mentor, Larry Pape, for guiding me through an undergraduate research project that resulted in my employment with NGPC and a desire to continue my education. I thank my friend and running partner, Cara Pesek, for her encouragement and for letting me dominate conversation with talk about work during countless runs.

Special thanks to my husband, Chris Chizinski, who was influential throughout this process in every way. He provided guidance on data analysis and wrote R code for me when I couldn't make SAS work. He kept the house in order and prepared dinners so I could I lock myself up in the office to finish my first draft. Most importantly, he continues to believe in my ability when I doubt myself and he lets me know he loves me every day.

Finally, I thank God for all of these people.

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CHAPTER 1 – INTRODUCTION

Channel catfish *Ictalurus punctatus* is an important sport fish, particularly in the Great Plains (Burlingame and Guy 1999). A 2006 survey of hunting and fishing activities by the U.S. Department of the Interior found that 7 million anglers nationwide, representing 28% of all freshwater anglers, spent 98.2 million days targeting channel catfish (USFWS 2007). Nationwide, ictalurids rated third in popularity amongst fish targeted by anglers (USFWS 2007). Regionally, channel catfish are the most targeted sport fish by anglers in Kansas and Iowa (Mosher et al. 2007, Flammang and Schultz 2007), and in Nebraska and Missouri, channel catfish are second in popularity only to black bass as a target sport fish species (Michaletz and Dillard 1999, USFWS 2007). During 2002, 57% of anglers targeted catfish while fishing Nebraska's waters (Hurley and Duppong Hurley 2007).

Additionally, fishing activities are a vital part of Nebraska's economy. During 2006, 198,000 anglers (≥ 16 years old) spent $181.3 million in total fishing expenditures and fished 3.1 million days. Of these anglers, 35% targeted ictalurids, suggesting that catfish angling supports a substantial portion of Nebraska's income from recreational activities.

Ecosystem characteristics

Though many rivers and streams in Nebraska support catfish fisheries, fishing access is often limited due to private land ownership (Barada 2009). Therefore, lentic water bodies on public land provide the primary opportunity for catfish anglers in Nebraska. Lentic water bodies throughout Nebraska are classified by the Nebraska Game and Parks Commission (NGPC) into one of five ecosystem types: irrigation/power-generation reservoirs, flood-control reservoirs, sand/gravel/barrow/reuse pits, Sandhill lakes, and oxbow lakes. Channel catfish are rarely found in Sandhill lakes and very few oxbow lakes are present in Nebraska, thus three ecosystem types provide a majority of the channel catfish sought by anglers.

Sand/gravel/barrow/reuse pits (hereafter referred to as sand pits) are water bodies created from excavated trenches that remain after sand or gravel mining operations (McCarraher et al. 1975). Due to the nature of these excavations, sand pits tend to have steep banks and narrow littoral zones. Most sand pits in Nebraska are located along the Platte River and its tributaries, and along the Interstate-80 roadway (Holz 2005). These sand pits generally have little or no watershed runoff due to the high hydraulic conductivity of the soils (Holz 2005). Sand pits are typically groundwater fed (Holz 2005) and water levels remain stable throughout the year. In Nebraska, sand pits and sand pit assemblages are often developed as State Recreation Areas. Sand pits represent the smallest water bodies in the state, with the exception of city ponds that are classified and managed separately as urban fisheries.

Flood-control reservoirs, constructed with dams that block surface-water flow to create retention pools, are primarily located in the eastern portion of the state where land use is dominated by row crop agriculture (Holz 2005), and where the state’s human population is most heavily concentrated. Water levels in flood-control reservoirs remain relatively stable, but experience mild seasonal fluctuations driven by precipitation. In general, flood-control reservoirs can be described as small (<200 ha) standing waters and are characterized by relatively shallow depths and restricted limnetic zones (Pope et al. 2009).

Irrigation and power-generation reservoirs, also constructed with dams that block surface-water flow to create retention pools, are primarily located in the south-central and western portions of Nebraska in rural areas dominated by grasslands. In general, irrigation and power-generation reservoirs can be described as large (>200 ha) standing waters, are characterized by having distinct littoral and limnetic zones, and are relatively deep (Miranda and

Boxrucker 2009). Irrigation and power-generation reservoirs can experience extreme seasonal fluctuations in water levels, resulting from releases for hydroelectric power or irrigation.

Channel catfish population characteristics

Despite the popularity and economic importance of channel catfish as a sport fish, little is known of its population dynamics or habitat requirements, and existing studies often profile river populations (Irwin et al. 1999). Relative abundance and size structure vary widely amongst populations, and no optima have been proposed for maintaining balanced channel catfish populations (Irwin et al. 1999; Barada 2009). Likewise, few studies report condition factors of channel catfish populations (Barada 2009). Growth patterns in channel catfish have not been related to habitat type (rivers, reservoirs, or streams), geographic range, or regional variation in water temperature (Hubert 1999), though there is some evidence that length-of-growing season may influence growth regionally (Durham et al. 2005). Channel catfish mortality and exploitation rates are difficult to estimate, and existing estimates of mortality range widely and are often derived from small samples (Hubert 1999).

Sampling methodology

Accurate assessments of populations are essential for aiding management determination of stocking protocols and fishing regulations. As noted, little is known of channel catfish population dynamics or habitat requirements, and assessment of management strategies is lacking (Irwin et al. 1999). Largely, the lack of assessment stems from collection methods that rarely yield samples sufficient for estimating standard population indices (Michaletz and Dillard 1999). For example, NGPC currently utilizes experimental gill nets set during autumn as the standard sampling methodology for channel catfish. Gill nets are the primary sampling method used by most state agencies to sample channel catfish in small impoundments and reservoirs, despite their known size selectivity and low, variable catch rates (Hubert 1983; Michaletz and Dillard 1999). This method typically yields samples that are inadequate for the assessment of population dynamics (recruitment, growth and mortality) and structure (abundance, size structure, and condition) (Michaletz and Dillard 1999). For example, the 1994 – 2006 statewide median catch from NGPC standard survey data for channel catfish was 21 fish/survey (generally consisting of four net-nights), far short of Anderson and Neumann's (1996) recommendation that at least 100 stock-length fish should be sampled for general stock assessment purposes. Vouken et al. (2001) also estimated that a sample of 300-400 channel catfish was necessary to construct an accurate and precise length-frequency distribution. Managers often express a need for more effective sampling methods that will provide adequate data to estimate abundance, age and size structure, and growth rates (Brown 2007; Michaletz and Dillard 1999; Vanderford 1984).

Poor assessments of population indices can lead to management practices that are detrimental to the target population. For instance, Hill (1984) expressed concerns that maintenance stockings in Iowa impoundments resulted in overpopulation and slow growth of channel catfish. In response, the Iowa Department of Natural Resources began to investigate sampling techniques that would best describe the population status of channel catfish in impoundments (Mitzner 1999).

Hoop nets have long been utilized to sample catfish in lotic systems, but until recently showed variable success in lentic systems (Michaletz and Dillard 1999). However, new methods for deployment have been developed in recent years by several Midwest state agencies, and numerous agencies currently recommend the use of baited, tandem-set hoop nets to assess channel catfish populations in small impoundments (Sullivan and Gale 1999; Michaletz and

Sullivan 2002; Flammang and Schultz 2007; Mosher et al. 2007; and Buckmeier and Schlechte 2009).

In the course of developing standard use recommendations, several gear evaluations have been conducted for tandem-set hoop nets in lentic systems. These evaluations considered the influence of sampling season (Flammang and Schultz 2007), hoop net and mesh size (Walker et al. 1994; Sullivan and Gale 1999; Flammang and Schultz 2007), length of bridles connecting individual nets (Michaletz and Sullivan 2002), configuration of throat entrance to the cod end (Porath et al. 2011), duration of set (Neely and Dumont 2011), and type of bait (Flammang and Schultz 2007) on catches of channel catfish. A sampling protocol based on these evaluations is now the standard for sampling channel catfish with tandem-set hoop nets in Iowa, Kansas, and Missouri; however, there has been little repetition of these evaluations in subsequent studies.

Objectives

With this study, my intent was to utilize tandem-set hoop nets to collect large samples (>100 fish) of channel catfish from water bodies in Nebraska in order to make adequate assessments of population dynamics (recruitment, growth and mortality) and structure (abundance, size structure, and condition). My specific objective was to describe the effects of stocking variability and habitat variability on channel catfish population structure and dynamics. I also intended to investigate the utility of NGPC ecosystem classifications in making inferences regarding the physical and biological characteristics of a water body and characteristics of the channel catfish population therein.

An additional objective was to investigate the utility of tandem-set hoop nets as a standard channel catfish sampling methodology for NGPC fishery managers. In doing so, my aim was to determine if tandem-set hoop nets captured more fish than the current methodology (experimental gill nets), whether similar trends existed for catch rates of channel catfish between gears, and whether size structure of captured fish differed between gears. I also intended to investigate whether a temporal influence existed on catch within the recommended summer sampling season to further develop an existing protocol for tandem-set hoop net surveys of channel catfish.

The NGPC invests a great deal of money on statewide stocking programs for channel catfish. Information gathered in this study will help managers determine the need for future stockings of channel catfish in Nebraska water bodies so that state hatchery-reared fish will be utilized in the most efficient manner, thereby minimizing cost to the state and maximizing return to the angler. This study will also inform fishery managers in Nebraska on the most appropriate sampling methodologies to collect data with which to make those determinations.

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CHAPTER 2 – MULTIVARIATE ANALYSIS OF CHANNEL CATFISH POPULATIONS FROM THREE ECOSYSTEM TYPES WITH THREE STOCKING STRATEGIES

Introduction

Channel catfish *Ictalurus punctatus* is an important sport-fish species, particularly in the Great Plains (Burlingame and Guy 1999). A 2006 survey of hunting and fishing activities by the U.S. Department of the Interior (USFWS 2007) found that 7 million anglers nationwide, representing 28% of all freshwater anglers, fished 98.2 million days targeting channel catfish. Nationwide, ictalurids ranked third in popularity amongst fish targeted by anglers (USFWS 2007). Regionally, channel catfish are the most targeted sport fish by anglers in Kansas and Iowa (Mosher et al. 2007, Flammang and Schultz 2007), and in Nebraska and Missouri, channel catfish are second only to black bass in popularity as a target sport fish species (Michaletz and Dillard 1999, USFWS 2007). During 2002, 57% of anglers targeted catfish while fishing Nebraska's waters (Hurley and Duppong Hurley 2007).

Additionally, fishing activities are a vital part of Nebraska's economy. In 2006, 198,000 anglers (≥ 16 years old) spent \$181.3 million in total fishing expenditures and fished 3.1 million days. Of these anglers, 35% targeted ictalurids, suggesting that catfish angling supports a substantial portion of Nebraska's income from recreational activities.

Accurate assessments of populations are essential in aiding management determination of stocking protocols and fishing regulations. Despite the popularity and economic importance of channel catfish as a sport fish, little is known of its population dynamics or habitat requirements, and assessment of management strategies is lacking (Irwin et al. 1999). Largely, the lack of assessment stems from collection methods that rarely yield samples sufficient for estimating standard population indices (Michaletz and Dillard 1999). For example, the Nebraska

Game and Parks Commission (NGPC) currently utilizes experimental gill nets set during autumn as the standard sampling methodology for channel catfish. This protocol typically provides small sample sizes that are inadequate for the assessment of population dynamics (recruitment, growth, and mortality) and structure (abundance, size structure, and condition) (Michaletz and Dillard 1999). The statewide median catch for 1994 – 2006 NGPC standard survey data for channel catfish was 21 fish/survey (generally consisting of four net-nights), far short of Anderson and Neumann's (1996) recommendation that at least 100 stock-length fish should be sampled for general stock-assessment purposes. Vouken et al. (2001) also estimated that a sample of 300-400 channel catfish was necessary to construct an accurate and precise length-frequency distribution.

Poor assessments of population indices can lead to management practices that are detrimental to the target population. For instance, Hill (1984) expressed concern that maintenance stockings in Iowa impoundments resulted in overpopulation and slow growth of channel catfish. In response, the Iowa Department of Natural Resources began to investigate sampling techniques that would best describe the population status of channel catfish in the state's impoundments (Mitzner 1999).

Hoop nets have long been utilized to sample catfish in lotic systems, but until recently showed variable success in lentic systems (Michaletz and Dillard 1999). However, new methods for deployment have been developed in recent years by several Midwest states. Michaletz and Sullivan (2002) reported in a 2001 survey of 66 small impoundments in Missouri that a tandem-set hoop-net series consisting of three nets, baited with waste cheese and fished for 72 h, captured an average of about 90 channel catfish. Similarly, Flammang and Schultz (2007) report that tandem-set hoop nets captured an average of about 100 channel catfish/series in summer surveys of 72 h duration using nets baited with soybean cake.

With this study, my intent was to utilize tandem-set hoop nets to collect large samples of channel catfish from water bodies in Nebraska, in order to make adequate assessments of population dynamics (recruitment, growth and mortality) and structure (abundance, size structure, and condition). My specific objective was to describe the effects of stocking variability and habitat variability on channel catfish population structure and dynamics.

Methods

Experimental design

Ecosystem type

Lentic water bodies throughout Nebraska are classified by the NGPC into one of five ecosystem types: irrigation/power-generation reservoirs, flood-control reservoirs, sand/gravel/barrow/reuse pits, Sandhill lakes, and oxbow lakes. Channel catfish are rarely found in Sandhill lakes and very few oxbow lakes are present in Nebraska; thus, this study focused on irrigation/power-generation reservoirs, flood-control reservoirs, and sand/gravel/barrow/reuse pits.

Sand/gravel/barrow/reuse pits (hereafter referred to as sand pits) are water bodies created from excavated trenches that remain after sand or gravel mining operations (McCarraher et al. 1975). Due to the nature of these excavations, sand pits tend to have steep banks and narrow littoral zones. Most sand pits in Nebraska are located along the Platte River and its tributaries, and along the Interstate-80 roadway (Holz 2005). These sand pits generally have little or no watershed runoff due to the high hydraulic conductivity of the soils (Holz 2005). Sand pits are typically groundwater fed (Holz 2005) and water levels remain stable throughout the year. In Nebraska, sand pits and sand-pit assemblages are often developed as State Recreation Areas. Sand pits represent some of the smallest bodies of water in the state, with the exception of city ponds that are classified and managed separately as urban fisheries. In this study, sand pits ranged from 3 to 20 ha, with a median size of 8 ha (Table 2-1).

Flood-control reservoirs, constructed with dams that block surface water flow to create retention pools, are primarily located in the eastern portion of the state where a high percentage of land use is devoted to row crop agriculture (Holz 2005), and where the state's human population is most heavily concentrated. In this study, one reservoir (Wellfleet) was located in the southwest region of the state. Water levels in flood-control reservoirs generally experience mild seasonal fluctuations driven by precipitation, but remain relatively stable. In general, flood-control reservoirs can be described as small (<200 ha) standing waters and are characterized by relatively shallow depths and restricted limnetic zones (Pope et al. 2009). In this study, flood-control reservoirs ranged in size from 20 to 299 ha, with a median size of 82 ha (Table 2-1). Two reservoirs included in this study were larger than 200 ha (Willow Creek, 283 ha and Pawnee, 299 ha) but maintain the characteristics of small standing waters. In a statewide classification survey of 92 Nebraska reservoirs, Holz (2005) found that those located in the eastern third of the state tended towards lower alkalinity, conductivity, and nitrogen to phosphorous (N:P) ratios than reservoirs located in the western two-thirds of the state, though some reservoirs in the eastern portion of the state had higher conductivity and higher total nitrogen concentrations.

Irrigation and power-generation reservoirs (hereafter referred to as irrigation reservoirs), also constructed with dams that block surface water flow to create retention pools, are primarily located in the south-central and western portions of the state in rural areas dominated by grasslands. The two geographic exceptions in this study were Lewis and Clark Lake on the northeast border of Nebraska and South Dakota, and Lake North in the eastern third of the state. In general, irrigation reservoirs can be described as large (>200 ha) standing waters, are characterized by having distinct littoral and limnetic zones, and are relatively deep (Miranda and Boxrucker 2009). Two irrigation reservoirs in this study (Gallagher Canyon, 74 ha and Lake North, 81 ha) are better described as small standing waters. Irrigation reservoirs can experience extreme seasonal fluctuations in water levels, resulting from releases for hydroelectric power or irrigation. Holz (2005) found that reservoirs in the western two-thirds of the state tended towards higher conductivity, higher N:P ratios, lower total suspended solids, lower total phosphorous and higher secchi depth than those located in the eastern third of the state. Reservoirs in this study consisted primarily of irrigation reservoirs (excepting Lewis and Clark Reservoir and Lake North), and range from 74-12,141 ha, with a median size of 766 ha (Table 2-1).

Stocking strategy

We also classified water bodies based on stocking strategies for channel catfish (Table 2-1). We defined three stocking strategies: frequently stocked (stocked four or five years during 2003-2007), infrequently stocked (stocked one, two, or three years during 2003-2007) and not stocked (stocked zero years during 2003-2007). We did not consider stocking density when determining stocking strategy.

Sampling schedule

A single survey was conducted at each of 36 water bodies during July-August of 2008 and 2009 (Table 2-1, Figure 2-1). The selected experimental design provided nine treatment combinations (3 ecosystem types X 3 stocking strategies). We elected, based on logistical constraints, to replicate the 3 X 3 factorial four times (two times each during 2008 and 2009). Water bodies scheduled for NGPC standard autumn gill-net surveys during 2008 and 2009 were given priority for inclusion in this study in order to conduct a gear comparison (see Chapter 6); the remaining water bodies were randomly selected to achieve our desired number of study water bodies. When nets yielded a low catch of channel catfish and time permitted, a supplementary survey was conducted to increase sample size for analyses of size structure, condition, age, growth and mortality.

Gear

Channel catfish were sampled with tandem-set hoop nets (Figure 2-2) in accordance with methodology established for small impoundments in Missouri and Iowa (Michaletz and Sullivan 2002, Flammang and Schultz 2007). Tandem-set hoop nets consisted of three nets, attached bridle to cod end, an anchor, and two weights. A 6.8-kg winged anchor was attached to the rear net, and a 4.5-kg concrete weight was attached between the front and middle nets to reduce buoyancy. An additional 4.5-kg weight was attached to the bridle of the front net to improve stability and increase tension during fishing. Nets were baited with soybean cake pellets as a fish attractant (Flammang and Schultz 2007). Hoop nets measured approximately 3.4-m in length and were constructed of #15 twine with 25.4-mm bar mesh and seven fiberglass hoops, the largest of which was 0.8-m in diameter and equipped with a bridle of 1-m rope. Two-fingered crow foot throats were attached to the second and fourth hoops. To reduce escapement from the cod end, the rear throat was constricted with plastic zip ties (Porath et al. 2011). Nets were set parallel to the shoreline along a constant depth profile, above the thermocline and at a depth of 1 – 6 m. Orientation of net mouths was randomly determined (uplake or downlake) for each set. Using existing bathymetric maps and aerial photographs, sampling sites were randomly selected from points marked at approximately 60-m intervals along the perimeter of the water body. Randomly selected sites that were unsuitable (i.e., proved to have steep slopes, heavy vegetation, or significant development [e. g., boat docks or swimming beaches]) were substituted with another randomly selected site. The number of tandem-set sites on a water body was determined by size of water body: four for water bodies ≤ 20 ha, six for water bodies > 20 and ≤ 60 ha, and eight or nine for water bodies > 60 ha. When possible, extra nets were set subjectively in order to maximize catch of channel catfish for estimates of age, growth, and mortality; catches in these nets were not included in estimates of catch rate. Tandem-set hoop nets were fished undisturbed for three consecutive nights (approximately 72 h).

Data Collection

Total length of channel catfish was recorded to the nearest mm, weight was recorded to the nearest g, and pectoral spines were removed for age determination from up to 10 channel catfish per cm length group. Length group only was noted for all channel catfish captured in excess of 10 per length group. All fish were released after data were collected.

Colombo et al. (2010) concluded that ages derived from the articulating process of the pectoral spine are similar to those derived from otoliths and that estimation of recruitment patterns, von Bertalanffy growth models, and mortality rates did not differ between age estimates derived from the two structures. Additionally, removal of the pectoral spine causes little to no mortality in channel catfish (Stevenson and Day 1987; Michaletz 2005), whereas otolith removal is lethal. Therefore, due to concern expressed by NGPC district managers with regard to the sacrifice of large numbers of channel catfish, we elected to collect spines for this study.

Collected spines were stored in deep freeze to dry, then cross-sectioned according to NGPC standard procedure (Leonard and Sneed 1951; Sneed 1951). Two or three cross sections were made at the articulating process of the pectoral spine using a mounted Dremel high-speed rotary tool equipped with a # 409 cut-off wheel. Cross sections were coated in mineral oil, placed inside a clear plastic coin envelope, and viewed through a stereo microscope with low magnification. Spine cross-sections were viewed independently or in concert by two readers who estimated channel catfish ages by counting the number of annuli. When viewed in concert, age estimates were recorded independently, without discussion between readers. Estimates were then compared, and when there was disagreement, readers reviewed cross-sections to either reach a consensus or omit the individual specimen from analysis. When age was determined, annuli were measured for back calculation using the posterior process of the spine cross-section (Michaletz et al. 2009), and the Dahl-Lea model (Dahl 1907; Lea 1910) was used to determine back calculated length at age:

$$\mathrm{L_t} = \mathrm{L_T}\left(\frac{\mathrm{B_t}}{\mathrm{B_T}}\right)$$

where L_t is the back-calculated length at age t, L_T is the length at the time of capture, B_t is the radius of the bony structure at annulus t, and B_T is the radius of the bony structure at time of capture. An age length key was developed to correct for subsampling bias (Devries and Frie 1996) and provide an age structure of all captured channel catfish.

Population variables

Population characteristics used to effectively assess and manage fish populations include relative abundance, size structure, and condition (Ney 1999). Relative abundance was quantified as catch per unit effort (CPUE) and was calculated as the number of channel catfish caught per 72 h tandem-set net series. Tandem-set hoop nets do not capture fish < 250 mm in proportion to their abundance (Michaletz and Sullivan 2002; Buckmeier and Schlechte 2009). Accordingly, we chose to consider only stock-length channel catfish (≥ 280 mm) for analyses.

Initially, we suggested a minimum collection of 100 stock-length channel catfish from each water body to provide adequate estimates of population characteristics. We found it necessary to revise our sample threshold in order to maintain sample sizes within groups that were sufficient for comparison because total catch was less than the *a priori* threshold in nearly 70% of the surveys. We decided that water bodies with a minimum total catch (inclusive of supplemental surveys) of 25 stock-length fish (N=32) would be included in the analysis.

Minimum total lengths of channel catfish for stock (S), quality (Q), preferred (P), memorable (M), and trophy (T) lengths are 280, 410, 610, 710, and 910 mm, respectively (Gabelhouse 1984). Size structure was quantified using proportional size distribution (PSD) and PSD of P- and M-length fish (Guy et al. 2006). We calculated PSD as:

$$\mathrm{PSD} = \frac{\#\ \mathrm{of\ quality} - \mathrm{length\ fish}}{\#\ \mathrm{of\ stock} - \mathrm{length\ fish}} * 100,$$

PSD-P was calculated as:

$$\mathrm{PSD} - \mathrm{P} = \frac{\#\ \mathrm{of\ preferred} - \mathrm{length\ fish}}{\#\ \mathrm{of\ stock} - \mathrm{length\ fish}} * 100,$$

and PSD-M was calculated as:

$$\mathrm{PSD} - \mathrm{M} = \frac{\#\ \mathrm{of\ memorable} - \mathrm{length\ fish}}{\#\ \mathrm{of\ stock} - \mathrm{length\ fish}} * 100.$$

In 25 of 36 surveys, channel catfish catch was insufficient for PSD, PSD-P, and PSD-M estimation (i. e., < 100) as -recommended by Anderson and Neumann (1996). Therefore, to assemble sufficient estimates to compare size structure of channel catfish populations between ecosystem types and stocking strategies, we elected to calculate PSD, PSD-P, and PSD-M for water bodies with a total catch (inclusive of supplemental surveys) that exceeded 25 channel catfish. Body condition was quantified when total catch exceeded 24 channel catfish (inclusive of supplemental surveys) using relative weight (W_r):

$$\mathrm{W_r} = (\mathrm{W}/\mathrm{W_s}) \times 100,$$

where W = weight in grams, and W_s= standard weight. The standard weight-length regression was:

$$\mathrm{Log}_{10}\,\mathrm{W_s} = -5.800 + 3.294\,\log_{10}\mathrm{TL},$$

where W_s = weight in g, and TL = total length in mm (Brown et al. 1995).

In addition to indices of population structure we considered indices of population dynamics. Growth rates and asymptotic maximum length were estimated for each population using a von Bertalanffy (1938) growth model:

$$\mathrm{L_t} = \mathrm{L_\infty}\left(1 - \mathrm{e}^{-\mathrm{K}(\mathrm{t}-\mathrm{t_0})}\right),$$

where $\mathrm{L_t}$ = length at time t, $\mathrm{L_\infty}$ = theoretical maximum length, K = growth coefficient, and t_0 = time when $\mathrm{L_t}$ is equal to 0 mm. This model was fitted to back-calculated lengths using the Ford-Walford method (Ford 1933, Walford 1946). Stocking can confound catch curve analysis, particularly when stocking densities and frequencies vary (Miranda and Bettoli 2007). Therefore we estimated mortality (Z) using a length-based model (Pauly 1984). We regressed the logarithm of the number of fish (N_i) in each 10 mm length interval against the relative age $\mathrm{t_i'}$ of the fish in the interval:

$$\log_e(\mathrm{N_i}) = \mathrm{a} - \mathrm{b}\mathrm{t_i'},$$

where $\mathrm{t_i'} = -\log_e(1 - [\mathrm{L_{mid}}/\mathrm{L_\infty}])$, and $\mathrm{L_{mid}}$ is the midpoint of the length interval. The slope (b) of this regression represents 1 – (Z/K), and thus Z = K(1 – b) (Miranda and Bettoli 2007). Age and growth and mortality analysis was limited in some water bodies by the low numbers of channel catfish captured. Growth and mortality estimates were calculated for water bodies where total catch (inclusive of supplemental surveys) exceeded 24 channel catfish.

Data Analysis

We assembled a suite of population characteristics representative of channel catfish population structure (Table 2-2) and dynamics (Table 2-3) and employed a multivariate analysis of variance (MANOVA, R Core Developmental Team 2011) to assess the influences of ecosystem type, stocking strategy and their associated interaction. To select representative variables for analysis, we screened for correlation and used best judgment to exclude one of the inter-correlated variables when appropriate. Characteristics with missing data were also excluded. Analysis of variance is an inappropriate test for proportional variables such as PSD, therefore we excluded size distributions from this analysis. As a surrogate for PSD values, we considered measures of abundance for two size groups within a population. We selected seven population characteristics, CPUE of stock- to quality-length fish ($CPUE_{S\text{-}Q}$); CPUE of quality- to preferred-length fish($CPUE_{Q\text{-}P}$); mean back-calculated total length at age 4 (TL_4); the number of year classes present in the population greater than age 2 (YC); maximum TL (TL_{max}); mean W_r of stock-length fish; and the growth coefficient K for analysis (Table 2-4). If the interaction in the MANOVA was significant, we employed a univariate approach (ANOVA) for further analysis of individual population characteristics. When significant differences were detected between ecosystem types or stocking strategies, Tukey's post hoc tests were employed to make pairwise comparisons. Additionally, we used ANOVA for analysis of abundance of all stock-length channel catfish ($CPUE_{stock}$). To avoid bias in the univariate analysis of abundance, we included CPUE data from all 36 water bodies (exclusive of supplemental surveys). Statistical significance was assumed at $\alpha = 0.10$ for all assessments.

Results

A total of 3,668 stock-length channel catfish was sampled from single collections at 36 water bodies. Amongst all water bodies, median CPUE was 7 channel catfish/series and ranged from 0 to 103 fish/series in individual surveys. Contrary to expectations, total catch was < 100 fish at 25 reservoirs. Supplemental collections at water bodies where catch was exceptionally low, and collections from water bodies sampled repeatedly for other objectives (see Chapter 5) increased the number of channel catfish sampled by 2,625 (N = 6,293). Data from supplemental collections were used to boost the data sets for analysis of age and growth, size structure, condition, and mortality but were not included in estimates of abundance. Pectoral spines were collected from 3,554 stock-length channel catfish; 3,298 fish were included in analyses of age and growth and mortality, and 246 fish were omitted from analysis. Individuals were omitted from analysis when readers could not come to agreement on age or when spines were damaged during removal or preparation. For most water bodies, omitted spines accounted for a small percentage of the total spine collections, ranging from 0% to 20% of individual collections. Exceptions include Whitney, Conestoga, East Twin, and Gallagher Canyon, where omitted spines accounted for a greater percentage of the total spine collections, ranging from 38% to 50% of individual collections. With minor exceptions, length distribution of omitted fish did not differ from the distribution of those included in the analysis. Exceptions include Johnson Park Lake and Sherman Reservoir, where readers could not come to agreement on the age of the largest individual collected.

Summary of population characteristics

Sand pits

In sand pits, median PSD was 15 and ranged from 3 to 38. Median CPUE of stock-length fish ($CPUE_{stock}$) was 10.6 and ranged from 0.0 to 62.3. Median $CPUE_{S\text{-}Q}$ was 7.9 and ranged from 0.0 to 54.0. Median $CPUE_{Q\text{-}P}$ was 2.5 and ranged from 0.0 to 6.3. Median TL_4 was 365 mm and ranged from 308 to 470 mm. Median YC was 8 and ranged from 4 to 12. Median TL_{max} was 635 mm and ranged from 510 mm to 765 mm. Median W_r was 81 and ranged from 77 to 87. Median K was 0.23 and ranged from 0.13 to 0.95.

Flood-control reservoirs

In flood-control reservoirs, median PSD was 32 and ranged from 5 to 68. Median $CPUE_{stock}$ was 14.1 and ranged from 1.0 to 102.7. Median $CPUE_{S\text{-}Q}$ was 7.8 and ranged from 0.3 to 65.2. Median $CPUE_{Q\text{-}P}$ was 5.2 and ranged from 0.2 to 32.7. Median TL_4 was 393 mm and ranged from 297 mm to 543 mm. Median YC was 7 and ranged from 4 to 10. Median TL_{max} was 726 mm and ranged from 493 mm to 845 mm. Median W_r was 83 and ranged from 77 to 93. Median K was 0.23 and ranged from 0.07 to 0.77.

Irrigation reservoirs

In irrigation reservoirs, median PSD was 37 and ranged from 6 to 94. Median $CPUE_{stock}$ was 5.5 and ranged from 2.1 to 18.5. Median $CPUE_{S\text{-}Q}$ was 3.3 and ranged from 0.0 to 14.3. Median $CPUE_{Q\text{-}P}$ was 2.4 and ranged from 0.4 to 6.0. Median TL_4 was 336 mm and ranged from 191 mm to 492 mm. Median YC was 9 and ranged from 3 to 12. Median TL_{max} was 693 mm and ranged from 446 mm to 829 mm. Median W_r was 83 and ranged from 79 to 96. Median K was 0.14 and ranged from 0.06 to 0.37.

Not stocked

In unstocked water bodies, median PSD was 38 and ranged from 13 to 68. Median $CPUE_{stock}$ was 7.5 and ranged from 0.0 to 18.5. Median $CPUE_{S\text{-}Q}$ was 4.3 and ranged from 0.0 to 14.3. Median $CPUE_{Q\text{-}P}$ was 2.4 and ranged from 0.0 to 10.4. Median TL_4 was 308 mm and ranged from 191 mm to 393 mm. Median YC was 8 and ranged from 7 to 11. Median TL_{max} was 678 and ranged from 586 to 826. Median W_r was 84 and ranged from 79 to 87. Median K was 0.15 and ranged from 0.06 to 0.25.

Infrequently stocked

In infrequently stocked water bodies, median PSD was 29 and ranged from 3 to 94. Median $CPUE_{stock}$ was 8.9 and ranged from 0.8 to 52.8. Median $CPUE_{S\text{-}Q}$ was 5.4 and ranged from 0.0 to 50.1. Median $CPUE_{Q\text{-}P}$ was 2.2 and ranged from 0.0 to 12.8. Median TL_4 was 383 mm and ranged from 316 mm to 493 mm. Median YC was 7 and ranged from 3 to 12. Median TL_{max} was 688 mm and ranged from 493 mm to 845 mm. Median W_r was 81 and ranged from 77 to 87. Median K was 0.23 and ranged from 0.08 to 0.77.

Frequently stocked

In frequently stocked water bodies, median PSD was 26 and ranged from 6 to 50. Median $CPUE_{stock}$ was 24.8 and ranged from 1.1 to 102.7. Median $CPUE_{S\text{-}Q}$ was 18.1 and ranged from 0.4 to 65.2. Median $CPUE_{Q\text{-}P}$ was 3.9 and ranged from 0.4 to 32.7. Median TL_4 was 378 mm and ranged from 282 mm to 543 mm. Median YC was 8.5 and ranged from 4 to 12. Median TL_{max} was 679 mm and ranged from 446 mm to 838 mm. Median W_r was 83 and ranged from 77 to 96. Median K was 0.25 and ranged from 0.07 to 0.95.

Multivariate analysis

An interaction of ecosystem type and stocking strategy was a significant factor influencing channel catfish populations (*F*=1.54, df=4, *P*=0.0786). Of the population characteristics included in the MANOVA, $CPUE_{S\text{-}Q}$, $CPUE_{Q\text{-}P}$, and W_r were significantly different between groups (Table 2-5). Population characteristics that did not differ significantly between groups were YC, TL_{max}, TL_4, and K (Table 2-5, Figures 2-3 and 2-4).

The interaction of ecosystem type and stocking strategy significantly influenced abundance of stock- to quality-length channel catfish, as indexed by $CPUE_{S\text{-}Q}$ (F=2.18, df=4, P=0.0980). In sand pits, frequent stocking was associated with increased $CPUE_{S\text{-}Q}$, whereas in flood-control reservoirs, infrequent stocking and frequent stocking were associated with increased $CPUE_{S\text{-}Q}$ (Figure 2-5). In irrigation reservoirs, stocking did not influence $CPUE_{S\text{-}Q}$ (Figure 2-5). Likewise, the interaction of ecosystem type and stocking strategy similarly influenced overall channel catfish abundance, as indexed by $CPUE_{stock}$ (*F*=2.43, df=4, *P*=0.0825, Figure 2-6).

Abundance of quality- to preferred-length fish, as indexed by $CPUE_{Q\text{-}P}$, was influenced by ecosystem type (*F*=2.80, df=2, *P*=0.0765). Tukey's *post hoc* test indicated that catch rates of quality- to preferred-length channel catfish were greater in flood-control reservoirs than in sand pits or irrigation reservoirs ($P< 0.05$, Figure 2-3). Catch rates of quality- to preferred-length channel catfish did not differ significantly between sand pits and irrigation reservoirs.

The interaction of ecosystem type and stocking strategy also significantly influenced W_r of channel catfish (*F*=3.15, df=4, *P*=0.0352). Channel catfish from stocked sand pits (infrequent and frequent) were in relatively poor condition, whereas channel catfish in frequently stocked irrigation reservoirs were in relatively good condition (Figure 2-7). Condition of channel catfish in sand pits that were stocked was poor in relation to condition of channel catfish in sand pits that were not stocked (Figure 2-7). Condition of channel catfish in flood-control reservoirs was intermediate compared to other ecosystem types, and was relatively similar for all stocking strategies.

Discussion

Catch rates

Total catch of stock-length channel catfish was far less than expected for nearly all surveys. Based on published literature and personal communication with other state agencies, we expected to routinely capture channel catfish in excess of 100 fish/series. Therefore, we initially suggested a minimum total collection of 100 stock-length channel catfish from each water body, and were confident that tandem-set hoop nets would collect sufficient samples to provide estimates of population characteristics. However, we collected a minimum of 100 fish in only 25% of sand pits, 58% of flood-control reservoirs, and 8% of irrigation reservoirs. Mean CPUE in this study was 17 channel catfish/series, which is substantially lower than reported catch rates of 90-100 channel catfish/series in Iowa and Missouri (Flammang and Schultz 2007, and Michaletz and Sullivan 2002). Michaletz (2009) surveyed 60 impoundments, ranging in size from 5 – 332 ha, three times over five years, and averaged 436 channel catfish/survey. In this study, median total catch was 55 fish/survey. Tandem-set hoop nets have not been previously evaluated in large standing waters; however, for small standing waters, catch rates were substantially lower in our study than in previous gear evaluations. However, not all lentic tandem-set hoop net surveys of channel catfish yield high catch rates. For example, Holley et al. (2009) attempted to use hoop nets as described by Sullivan and Gale (1999) to sample channel catfish and blue catfish at Lake Wilson, Alabama, but discontinued their use after two seasons with virtually zero success.

Catch rates were highly variable within water bodies. We regularly captured the majority of channel catfish in one or two net-series, while other series were empty or nearly empty of channel catfish. In contrast, variability of catch with tandem-set hoop nets within water bodies was comparatively small for surveys in Iowa and Missouri (Michaletz and Sullivan 2002; Flammang and Schultz 2007). It is likely that variability in physical and biological environmental conditions influencing channel catfish behavior were responsible for the high variability in catch of channel catfish with tandem-set hoop nets (Stoner 2004). For example, limited suitable habitat in reservoirs can induce channel catfish to migrate upstream from a reservoir to spawn, and most spawning activity in the Midwest occurs during June and July (Hubert 1999). Perhaps channel catfish were absent from some areas of a water body during sampling as a result of spawning behavior. Additionally, channel catfish are known to concentrate where food is abundant (Hubert 1999). Perhaps variability in CPUE within a water body is associated with the distribution of prey species. Stoner (2004) notes that low catch rates are observed in marine systems in areas where natural prey is abundant, and conversely that catch rates are high where prey density is patchy.

The relatively low catch rates observed in this study may indicate differences in density between Nebraska’s populations and populations in other Midwest states. However, highly variable CPUE may also be indicative of behavioral differences between populations. In a review of the potential limitations in using bait-dependent surveys for stock assessments, Stoner (2004) noted that the behavior of a target species in response to environmental variables could have a greater influence on CPUE than abundance, and that CPUE data from bait-dependent surveys can often reflect variation in fish catchability rather than unbiased measures of abundance. He asserted that physical and biological environmental conditions can trigger changes in activity, feeding motivation, scent detection of bait, searching behavior, and location of natural bait, all of which influence CPUE. Additionally, variation in catch may be indicative of an unidentified discrepancy in sampling methodology (e.g., a manufacturing difference in bait or variation in net deployment).

Mortality, growth, and size structure

We did not detect significant differences in indices of growth, mortality, or size structure in the multivariate analysis. However, failure to detect a significant difference should not be considered evidence that populations are similar between groups. Low catch rates in individual water bodies, small sample sizes (N=4 or less for each treatment combination of waterbody type and stocking strategy) and the necessary exclusion of some population characteristics from the analysis due to insufficient data may have influenced the analysis. For example, mortality estimates were unreliable in many individual water bodies due to small sample sizes. Thus, we found it necessary to substitute the number of year classes present in a population as a proxy for mortality and recruitment. Populations with many year classes indicate low mortality; however, few year classes could indicate either high mortality (few year classes present consisting of only younger age groups) or low mortality coupled with low recruitment (few year classes present consisting of only older age groups). Reliable estimates of recruitment and mortality would be more useful indices to discern differences in mortality amongst population groups. It is possible that growth is influenced by an interaction of ecosystem type and stocking strategy, but was undetected in these data due to the variability in catch and small sample sizes at many individual water bodies. Additionally, though TL_{max}, an index of size structure, did not differ between groups (i.e., large fish were present in all groups), differences may still exist within the length range of populations. For example, abundance of stock- to quality-length channel catfish was greatest in frequently stocked sand pits (Figure 2-5), but overall abundance was greatest in frequently stocked flood-control reservoirs (Figure 2-6), indicating that size structure of channel catfish populations differed between ecosystem types. We further explored the potential influence of ecosystem type on channel catfish populations using exploratory analysis (see Chapter 3), and the influence of stocking on populations using catch curves (see Chapter 4).

Abundance and condition

Of the population characteristics chosen for multivariate analysis, only indices of abundance and condition varied between groups. The influence of stocking strategy on channel catfish abundance varied between ecosystems. In sand pits, overall channel catfish abundance, as indexed by $\mathrm{CPUE}_{\mathrm{stock}}$, was only influenced by stocking when stocking occurred frequently (Figure 2.6). In frequently stocked sand pits, abundance was more than six times greater than in those that were infrequently stocked or not stocked. In flood-control reservoirs, stocking influenced overall channel catfish abundance at both infrequent and frequent occurrences (Figure 2.6). In infrequently stocked flood-control reservoirs, abundance was more than four times greater than in reservoirs that were not stocked, and in frequently stocked flood-control reservoirs, abundance was nearly six times greater than in reservoirs that were not stocked. Stocking did not influence overall abundance of channel catfish populations in irrigation reservoirs (Figure 2.6).

It is not surprising that stocking had little influence on abundance in irrigation reservoirs. Channel catfish are stocked in irrigation reservoirs at low densities (Table 2.1) that are unlikely to influence abundance in populations with natural recruitment. Additionally, channel catfish populations in large reservoirs are typically adequately maintained through natural recruitment as a function of water quality, habitat diversity, and relatively low predator densities (Mosher et al. 2007).

Infrequent stocking appears to be inadequate to compensate for a lack of natural recruitment in sand pit systems, yet adequate to increase abundance in flood-control systems. Both systems are stocked at high densities (Table 2.1). Flood-control reservoirs have characteristically more complex habitat than sand pits, and channel catfish often have access to upstream refugia for spawning. Spawning habitat availability coupled with low largemouth bass densities observed in some flood-control reservoirs may result in some occurrence of natural reproduction that is absent in sand pits. In fact, natural reproduction was observed in some reservoirs in this study, where stocking could not account for the presence of age-1 channel catfish captured in hoop nets. For example, NGPC standard surveys indicate low largemouth bass densities at Stagecoach reservoir (mean CPUE = 55 fish/hour in 2006-2009 spring electrofishing surveys) and nearly 300 sub-stock channel catfish (assumed to be age-1 fish) were captured in the July 2008 hoop net survey for this study.

In addition to recruitment variability between systems, it is likely that harvest varies between systems. For example, in 2010, channel catfish fishing pressure at Fremont Lakes SRA (a sand pit complex composed of 19 individual water bodies ranging in size from 0.6 to 20.8 ha, not included in this study) was 51 hr/ha, and harvest was 16 channel catfish/ha (Christopher J. Chizinski, Nebraska Cooperative Fish and Wildlife Research Unit, unpublished report). In contrast, channel catfish fishing pressure at Willow Creek (a flood-control reservoir included in this study) was 18 hr/ha, and harvest was 8 channel catfish/ha (Chizinski et al. 2011). Channel catfish fishing pressure at Harlan County Reservoir (an irrigation reservoir included in this study) was 3 hr/ha, and harvest was 1 channel catfish/ha (Chizinski et al. 2011).

The influence of stocking strategy also varied between ecosystems with regard to channel catfish condition. In sand pits, condition of channel catfish, as indexed by W_r, was influenced by stocking at both infrequent and frequent occurrences. Channel catfish in stocked sand pits (infrequent and frequent) were in poor condition relative to channel catfish in sand pits that were not stocked. Condition is often density dependent, therefore it follows that populations in stocked sand pits would exhibit a decrease in condition that coincides with an increase in abundance. In infrequently stocked sand pits, however, condition suffered with stocking, but there was no associated increase in abundance. Harvest likely influenced this dynamic; i.e., harvest rates may have masked a stocking effect on abundance in these systems.

In flood-control reservoirs, channel catfish condition was not influenced by the increased abundance associated with stocking (infrequent and frequent). This likely indicates that current stocking practices do not cause abundance to exceed the threshold at which density-dependent mechanisms influence condition in flood-control reservoirs. This may indicate that the relatively complex habitat available in flood-control reservoirs compared to sand pits better suits the habitat requirements of channel catfish; i.e., that the habitat available supports a greater standing stock of channel catfish in flood-control reservoirs.

In irrigation reservoirs, only frequent stocking influenced channel catfish condition. Though stocking negatively impacted channel catfish condition in sand pits, condition was better in frequently stocked irrigation reservoirs, relative to those that were stocked infrequently or not stocked. Fisheries managers typically choose to concentrate stocking efforts in desirable reservoirs (e.g., reservoirs that exhibit good water quality and habitat) (NGPC 1989). Irrigation reservoirs in Nebraska are often stocked with channel catfish primarily to spark angler interest in fishing opportunity rather than to maintain or supplement the existing catfish population (personal communication, Nebraska Game and Parks Commission, Dean Rosenthal). Therefore, it is likely that the relatively good condition exhibited in channel catfish populations from frequently stocked irrigation reservoirs is an artifact of reservoir quality; that is, channel catfish are stocked most frequently in irrigation reservoirs that are capable of producing healthy populations.

Currently, exploitation of channel catfish in Nebraska is poorly understood. Until recently, all standard creel surveys were conducted between the hours of 8 am and midnight or from sunrise to sunset, excluding the overnight hours that many catfish anglers consider prime fishing opportunity. Though creel surveys in the southeastern portion of the state shifted to 24 hour creels in 2009, the majority of the state's creels continue to be conducted in 18 hour windows or from sunrise to sunset. It is likely that a significant component of channel catfish harvest is not reflected in Nebraska's standard creel surveys. Additionally, exploitation is particularly difficult to estimate in sand pits, in part because existing creel sampling methodology often miss or deliberately exclude trips of short duration that are likely a primary component of the fishing pressure on sand pit systems (personal communication, Nebraska Game and Parks Commission, Keith Hurley). It is suspected that exploitation can be great in sand pits, as many are located near human population centers or in state recreation areas that are easily accessed from the interstate highway, though this exploitation is not always reflected in the creel surveys. Furthermore, given the small size (< 20 ha) and simple morphology of these systems, the angler's likelihood of encounter with channel catfish is potentially greater than in larger, more complex systems. Therefore, even under similar angling pressure, harvest may be greater in sand pits than in larger systems. For example, Santucci et al. (1994) found that anglers harvested up to 92% of channel catfish stocked in a 5.6 ha lake. Relatively greater harvest in sand pits compared to flood-control reservoirs may account for the differing influence of stocking in these systems, on both abundance and condition; however, an accurate measure of exploitation is necessary to determine the influence of harvest on abundance.

Management implications

Despite smaller than expected yields of channel catfish, tandem-set hoop nets do provide larger samples than experimental gill nets, the current NGPC standard method of collection. In this study, 27% of collections exceeded 100 channel catfish, and 73% of collections exceed 25 fish. In gill net collections at 26 water bodies, none exceeded 100 channel catfish, and only 19% exceeded 25 channel catfish (Chapter 6). Additionally, while variability associated with hoop net catch was high, it did not differ from variability associated with gill net catch (Chapter 6). Tandem-set hoop nets can provide channel catfish collections sufficient to make reliable population estimates, particularly if managers are able to increase effort to address variability in catch.

It is likely that exploitation of channel catfish varies greatly between sand pits, flood-control reservoirs, and irrigation reservoirs. In addition to wide variation in angling pressure, in terms of angling hours and angler density, harvest rates can vary as a function of the likelihood of angler encounter, which is influenced by the population base, water body size, accessibility, morphology, and a host of environmental variables that influence fish behavior (Stoner 2004). For example, Cole et al. (1991) recorded harvest rates that decreased with reservoir size in New Mexico reservoirs, ranging from a rate of 187 channel catfish/ha harvested in a 10.7 ha reservoir to 6 channel catfish/ha harvested in a 2,600 ha reservoir. Therefore, in order to define stocking protocols specific to ecosystem types, harvest rates should be factored into management decisions.

It is clear that a measure of exploitation is necessary to gain a better understanding of channel catfish population characteristics in Nebraska’s standing waters. However, with the information currently available, we can make some judgments regarding the effectiveness of current standards for stocking channel catfish. In sand pits, stocking positively influences abundance only when frequent stocking occurs. Therefore, if the management goal is to increase abundance, sand pits should be stocked annually at high densities. However, stocking to increase abundance in sand pits can result in a negative impact on channel catfish condition. Flood-control reservoirs, like sand pits, are stocked at high or very high densities even when stocked infrequently. Unlike sand pits, both infrequent and frequent stocking positively influence abundance in these systems without significantly reducing condition. It appears that the current stocking protocol is adequate to increase abundance in these flood-control reservoirs, and perhaps infrequent stocking of flood-control reservoirs may be sufficient to maintain desirable channel catfish populations. Irrigation reservoirs are typically stocked at low densities even when stocked frequently, and stocking does not appear to influence abundance in these populations. In order to significantly influence abundance, stocking density should be greatly increased, but given the propensity for natural recruitment in these systems, supplemental stocking of channel catfish in irrigation reservoirs may be unnecessary. Michaletz and Dillard (1999) found that less than 20 states routinely stocked channel catfish in large reservoirs, largely because self-sustaining populations were more common in large reservoirs than in small impoundments. Additionally, Mosher et al. (2007) noted that stocking channel catfish is generally not required to maintain populations in large reservoirs and rivers. Sometimes stocking is not intended to increase abundance. In fact, NGPC production managers note that stocking activity in irrigation reservoirs is often utilized as a public relations effort rather than a direct management tool (personal communication , Nebraska Game and Parks

Commission, Dean Rosenthal). For such purposes, stocking irrigation reservoirs at low rates may be advisable; further, managers could consider stocking fingerlings rather than advanced catfish over-wintered in the hatcheries, to reduce production costs.

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Table 2-1. Summary of 36 Nebraska water bodies surveyed during 2008 – 2009, classified by ecosystem type (sand/gravel/barrow/reuse pits = SP, flood-control reservoirs = FC, and irrigation/power-generation reservoirs = IR) and stocking strategy (not stocked = N, infrequently stocked = I, and frequently stocked = F) with Nebraska Game and Parks Commission identifier code, size (ha), stocking rate (low = L [<50/ha], high = H [≥ 50 and <250/ha], very high = V [≥250/ha] or variable = VAR [i.e., stocking rates included more than one category]), and mean annual stocking density (#/ha) of channel catfish stocked during 2003-2007.

Water body	Code	Year	Size	Ecosystem type	Stocking strategy	Stocking rate	Stocking density
Windmill 1	6023	2009	3	SP	N	-	0
Willow Island	6240	2009	10	SP	N	-	0
Blue Hole	6180	2008	10	SP	N	-	0
Eagle Scout	6718	2008	17	SP	N	-	0
Bassway Strip West	6150	2008	4	SP	I	H	41
Cheyenne	6075	2009	7	SP	I	H	44
Pawnee Slough	4277	2008	12	SP	I	H	63
Fremont 15	3080	2009	20	SP	I	H	41
Two Rivers 1 & 2	5046	2008	3	SP	F	V	573
Lexington City Park	6710	2009	3	SP	F	H	119
Johnson Park	3302	2008	6	SP	F	VAR	115
NorthPlatte I-80	4720	2009	11	SP	F	H	90
Standing Bear	5725	2009	55	FC	N	-	0
East Twin	5325	2008	85	FC	N	-	0
Conestoga	5115	2008	93	FC	N	-	0
Pawnee	5125	2009	299	FC	N	-	0
Wellfleet	4500	2008	20	FC	I	H	62
Stagecoach	5130	2008	79	FC	I	H	15
Zorinsky	5728	2009	103	FC	I	VAR	37
Wagon Train	5135	2009	127	FC	I	H	59
Skyview	3535	2009	20	FC	F	VAR	53
Walnut Creek	5729	2008	28	FC	F	H	60
Summit	3325	2009	77	FC	F	H	88
Willow Creek	3335	2008	283	FC	F	L	28
Gallagher Canyon	6525	2008	74	IR	N	-	0
Lake North	3440	2009	81	IR	N	-	0
Sherman	6925	2008	1,151	IR	N	-	0

Table 2-1. Continued.

Water body	Code	Year	Size	Ecosystem type	Stocking strategy	Stocking rate	Stocking density
Lewis & Clark	3710	2009	12,141	IR	N	-	0
Elwood	6530	2009	538	IR	I	L	5
Red Willow	4910	2009	659	IR	I	L	4
Swanson	4920	2008	2,013	IR	I	L	2
Harlan	6915	2009	5,463	IR	I	L	2
Whitney	1805	2008	364	IR	F	L	10
Box Butte	1600	2009	647	IR	F	L	3
Minatare	1645	2008	873	IR	F	L	3
Merritt	2740	2008	1,176	IR	F	L	15

Table 2-2. Abundance, size structure and condition of stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits [sand], flood-control reservoirs [flood], and irrigation/power-generation reservoirs [irrigation]) and stocking strategy (N = not stocked, I = infrequently stocked, and F = frequently stocked). Abundance was characterized by sample size (N), mean and SE of catch per unit effort (catch per 72-h tandem-set series) for stock-length fish (CPUE; SE_{CPUE}), stock- to quality-length fish (280- to 409-mm TL; CPUE-SQ; $\text{SE}_{\text{CPUE-SQ}}$), quality- to preferred-length fish (410- to 609-mm TL; CPUE-QP; $\text{SE}_{\text{CPUE-QP}}$), preferred- to memorable-length fish (610- to 709-mm TL; CPUE-PM; $\text{SE}_{\text{CPUE-PM}}$), memorable- to trophy-length fish (710- to 909-mm TL; CPUE-MT; $\text{SE}_{\text{CPUE-MT}}$), and trophy-length fish (≥910-mm TL; CPUE-SQ; $\text{SE}_{\text{CPUE-SQ}}$). Size structure was characterized by sample size (N_{a}), proportional size distribution (PSD), PSD of preferred-length fish (PSD-P), PSD of memorable-length fish (PSD-M), and minimum (TL_{min}), maximum (TL_{max}) and average (TL_{mean}) total lengths. Condition was characterized by sample size (N_{a}) and relative weight of stock-length fish (W_{r}), stock- to quality-length fish (W_{r}-SQ), quality- to preferred-length fish (W_{r}-QP), preferred- to memorable-length fish (W_{r}-PM), and memorable-length fish (≥710-mm TL; W_{r}-M). Values are not reported when N_{a} < 25.

Code	Stock	N	CPUE	SE_{CPUE}	CPUE-SQ	$\text{SE}_{\text{CPUE-SQ}}$	CPUE- QP	$\text{SE}_{\text{CPUE-QP}}$	CPUE-PM	$\text{SE}_{\text{CPUE-PM}}$	CPUE-MT	$\text{SE}_{\text{CPUE-MT}}$
Sand pit												
6023	N	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6240	N	3	0.8	0.8	0.0	0.0	0.0	0.0	0.3	0.3	0.5	0.5
6180	N	35	8.8	5.2	5.5	3.2	3.0	2.1	0.3	0.3	0.0	0.0
6718	N	49	12.3	4.9	10.8	4.5	1.5	0.9	0.0	0.0	0.0	0.0
6150	I	3	0.8	0.3	0.5	0.3	0.0	0.0	0.0	0.0	0.3	0.3
6075	I	11	2.8	1.8	2.5	1.6	0.3	0.3	0.0	0.0	0.0	0.0
4277	I	34	8.5	5.5	6.5	4.5	2.0	1.2	0.0	0.0	0.0	0.0
3080	I	83	13.8	2.5	9.2	2.1	4.3	0.9	0.3	0.2	0.0	0.0
5046	F	82	20.5	14.9	16.3	11.3	3.5	2.9	0.8	0.8	0.0	0.0
6710	F	118	29.5	19.8	25.0	18.8	4.5	1.4	0.0	0.0	0.0	0.0
3302	F	145	36.3	5.6	31.8	5.1	4.3	1.4	0.3	0.3	0.0	0.0
4720	F	249	62.3	11.8	54.0	11.0	6.3	1.6	2.0	0.7	0.0	0.0

Table 2-2. Continued.

Code	CPUE-T	SE_{CPUE-T}	N_a	PSD	PSD-P	PSD-M	TL_{min}	TL_{max}	TL_{mean}	W_r	W_r-SQ	W_r-QP	W_r-PM	W_r-M
Sand pit														
6023	0.0	0.0	0	[A]	[A]	[A]	-	-	-	[A]	[A]	[A]	[A]	[A]
6240	0.0	0.0	3	[A]	[A]	[A]	709	779	730	[A]	[A]	[A]	[A]	[A]
6180	0.0	0.0	37	38	3	0	318	635	404	85	84	88	86	-
6718	0.0	0.0	60	13	0	0	286	586	359	87	86	93	-	-
6150	0.0	0.0	40	3	13	8	304	765	413	81	80	72	80	91
6075	0.0	0.0	11	[A]	[A]	[A]	371	427	395	[A]	[A]	[A]	[A]	[A]
4277	0.0	0.0	56	29	0	0	307	510	377	77	77	77	-	-
3080	0.0	0.0	108	35	2	0	285	703	383	81	82	79	98	-
5046	0.0	0.0	82	17	4	0	285	660	362	83	80	88	96	-
6710	0.0	0.0	118	15	0	0	281	542	355	77	76	79	-	-
3302	0.0	0.0	145	12	1	0	280	629	355	82	82	80	108	-
4720	0.0	0.0	249	10	3	0	280	700	345	77	77	75	83	-

Table 2-2. Continued.

Code	Stock	N	CPUE	$\mathrm{SE}_{\mathrm{CPUE}}$	CPUE-SQ	$\mathrm{SE}_{\mathrm{CPUE\text{-}SQ}}$	CPUE- QP	$\mathrm{SE}_{\mathrm{CPUE\text{-}QP}}$	CPUE-PM	$\mathrm{SE}_{\mathrm{CPUE\text{-}PM}}$	CPUE-MT	$\mathrm{SE}_{\mathrm{CPUE\text{-}MT}}$
Flood												
5725	N	6	1.0	0.3	0.3	0.2	0.2	0.2	0.5	0.2	0.0	0.0
5115	N	25	3.9	1.8	1.8	0.6	2.0	1.6	0.1	0.1	0.0	0.0
5125	N	81	10.1	2.7	5.5	1.7	3.8	1.1	0.9	0.6	0.0	0.0
5325	N	138	15.3	4.6	4.8	1.6	10.4	3.4	0.1	0.1	0.0	0.0
5135	I	90	12.9	4.4	5.3	1.9	6.6	2.8	0.7	0.3	0.3	0.3
5130	I	106	11.8	3.2	10.0	2.7	1.8	0.7	0.0	0.0	0.0	0.0
4500	I	198	49.5	15.2	35.8	9.9	12.8	5.7	1.0	0.6	0.0	0.0
5728	I	422	52.8	20.9	50.1	20.7	2.4	0.9	0.0	0.0	0.3	0.2
3325	F	9	1.1	0.5	0.4	0.3	0.4	0.3	0.3	0.3	0.1	0.1
3535	F	116	29.0	4.1	19.8	2.8	9.3	4.6	0.0	0.0	0.0	0.0
3335	F	363	49.1	8.4	25.1	5.8	23.4	3.3	0.5	0.2	0.1	0.1
5729	F	616	102.7	83.3	65.2	52.7	32.7	27.6	3.0	2.1	1.8	1.1
Irrigation												
6925	N	26	3.3	1.3	0.5	0.2	2.4	1.1	0.1	0.1	0.3	0.2
6525	N	49	6.1	2.1	3.8	1.2	2.4	0.9	0.0	0.0	0.0	0.0
3440	N	94	11.8	2.7	5.4	1.1	6.0	2.4	0.3	0.2	0.1	0.1
3710	N	148	18.5	12.3	14.3	10.2	3.4	2.1	0.6	0.3	0.3	0.3
6530	I	17	2.1	0.7	1.5	0.6	0.5	0.3	0.1	0.1	0.0	0.0
4920	I	33	4.1	2.7	0.0	0.0	4.1	2.7	0.0	0.0	0.0	0.0
6915	I	56	7.0	3.2	5.4	2.8	1.3	0.5	0.4	0.2	0.0	0.0
4910	I	74	9.3	2.0	3.6	0.9	4.1	1.3	1.0	0.3	0.5	0.4
1600	F	34	4.3	2.3	1.8	1.1	2.3	1.0	0.3	0.3	0.0	0.0
1645	F	37	4.6	2.6	2.8	1.6	1.9	1.1	0.0	0.0	0.0	0.0
2740	F	38	4.8	2.6	3.0	2.0	1.5	0.8	0.3	0.2	0.0	0.0
1805	F	53	6.6	2.8	6.3	2.6	0.4	0.3	0.0	0.0	0.0	0.0

Table 2-2. Continued.

Code	CPUE-T	SE_{CPUE-T}	N_a	PSD	PSD-P	PSD-M	TL_{min}	TL_{max}	TL_{mean}	W_r	W_r-SQ	W_r-QP	W_r-PM	W_r-M
Flood														
5725	0.0	0.0	9	[A]	[A]	[A]	360	671	487	[A]	[A]	[A]	[A]	[A]
5115	0.0	0.0	35	51	3	0	282	611	418	83	82	85	81	-
5125	0.0	0.0	109	33	11	1	280	789	410	82	80	82	93	96
5325	0.0	0.0	138	68	1	0	284	678	447	85	77	87	93	-
5135	0.0	0.0	107	50	7	3	284	732	473	87	88	85	90	98
5130	0.0	0.0	106	15	0	0	280	696	349	83	81	83	-	-
4500	0.0	0.0	198	26	2	0	294	638	370	80	80	79	84	-
5728	0.0	0.0	422	5	0	0	281	845	308	79	79	80	84	84
3325	0.0	0.0	40	20	13	8	287	739	442	93	89	94	99	104
3535	0.0	0.0	116	32	0	0	281	577	367	77	76	77	-	-
3335	0.0	0.0	393	48	1	0	280	726	408	80	81	79	88	81
5729	0.2	0.2	616	32	3	2	297	838	399	83	79	83	92	94
Irrigation														
6925	0.0	0.0	47	64	4	4	304	826	469	84	80	84	100	95
6525	0.0	0.0	90	36	0	0	281	604	396	79	77	83	-	-
3440	0.0	0.0	94	51	2	1	280	763	403	80	80	80	88	96
3710	0.0	0.0	148	23	5	0	280	761	368	86	87	84	83	95
6530	0.0	0.0	31	19	0	0	325	645	395	79	80	77	69	-
4920	0.0	0.0	96	94	2	0	362	688	471	81	86	81	82	-
6915	0.0	0.0	85	31	5	0	281	670	411	81	81	81	84	-
4910	0.0	0.0	109	41	11	0	280	829	455	85	83	85	88	101
1600	0.0	0.0	38	50	11	0	283	697	432	94	96	93	96	-
1645	0.0	0.0	56	38	0	0	281	574	400	96	98	93	-	-
2740	0.0	0.0	57	33	9	0	308	706	430	92	91	91	93	-
1805	0.0	0.0	102	6	0	0	280	446	311	82	81	87	-	-

Table 2-3. Population dynamics of stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs) and stocking strategy (N = not stocked, I = infrequently stocked, and F = frequently stocked) where N is the total number of fish captured and N_a is the number of fish used to make estimates of age, growth, and mortality. Mortality was characterized by maximum age group present in the population (Age_{max}), the number of year classes present in the population (YC), and the instantaneous mortality rate (Z). Age and growth was characterized by asymptotic maximum length from the von Bertalanffy growth equation (L_∞), von Bertalanffy growth rate (K), mean back-calculated length at age 3 (TL_3), and mean back-calculated length at age 4 (TL_4).

Waterbody	Strategy	N	N_a	Age_{max}	YC	Z	L_∞	K	TL_3	TL_4
Sand pit										
Windmill 1	N	0	0	-	-	[A]	[A]	[A]	[A]	[A]
Willow Island	N	3	3	12	3	[A]	[A]	[A]	[A]	[A]
Blue Hole	N	35	35	14	7	0.46	886	0.38	606	695
Eagle Scout	N	49	50	11	8	0.19	698	0.15	247	308
Bassway Strip West	I	3	38	9	7	[A]	785	0.23	389	470
Cheyenne	I	11	11	4	3	[A]	[A]	[A]	[A]	[A]
Pawnee Slough	I	34	50	5	9	0.34	543	0.24	280	336
Fremont 15	I	83	116	11	8	0.31	746	0.20	341	416
Two Rivers 1 & 2	F	82	159	11	10	0.16	989	0.13	322	404
Johnson Park	F	118	153	8	7	0.83	422	0.50	328	365
Lexington City Park	F	145	130	7	5	1.12	363	0.95	342	355
NorthPlatte I-80	F	249	123	14	12	0.40	554	0.29	323	381
Flood control										
Standing Bear	N	6	9	7	4	[A]	[A]	[A]	[A]	[A]
Conestoga	N	25	37	8	7	0.51	575	0.25	304	364
Pawnee	N	81	102	11	8	0.14	1033	0.12	312	393
East Twin	N	138	160	10	8	0.15	624	0.16	243	301
Wagon Train	I	90	112	8	6	0.27	754	0.23	372	450
Stagecoach	I	106	150	6	4	0.94	468	0.43	337	383
Wellfleet	I	198	126	7	5	1.01	517	0.77	465	493
Zorinsky	I	422	115	11	9	0.08	1411	0.08	290	373
Summit	F	9	40	7	5	[A]	864	0.25	453	543
Skyview	F	116	111	6	5	0.21	804	0.17	322	398
Willow Creek	F	393	259	13	10	0.10	1008	0.09	232	297
Walnut Creek	F	616	341	11	10	0.37	812	0.25	424	509

Table 2-3. Continued.

Water body	Strategy	N	N_a	Age_{max}	YC	Z	L_∞	K	TL_3	TL_4
Irrigation/Power										
Sherman	N	26	39	13	11	0.09	623	0.14	215	268
Gallagher Canyon	N	49	62	13	10	0.17	558	0.15	197	246
Lake North	N	94	92	13	9	0.07	990	0.06	143	191
Lewis & Clark	N	148	132	12	9	0.11	1055	0.09	256	327
Elwood	I	17	29	8	3	[A]	672	0.24	344	413
Swanson	I	33	94	9	4	0.11	1054	0.10	275	349
Harlan	I	56	82	11	8	0.33	554	0.26	299	357
Red Willow	I	74	106	14	12	0.17	855	0.12	250	316
Box Butte	F	34	38	7	4	0.06	1591	0.07	291	375
Minatare	F	37	56	13	10	0.31	536	0.26	289	345
Whitney	F	53	57	14	10	0.63	367	0.37	245	282
Merritt	F	38	57	7	6	0.36	772	0.25	411	492

[A] Insufficient data to calculate

Table 2-4. Characteristics representative of population structure and dynamics used in multivariate analysis of variance (MANOVA, R v2.12.1) of Nebraska channel catfish populations from three ecosystem types with three stocking strategies.

Variable	Description	Index
$CPUE_{S\text{-}Q}$	Catch per unit effort of stock- to quality- length fish	Abundance
$CPUE_{Q\text{-}P}$	Catch per unit effort of quality- to preferred- length fish	Abundance
W_r	Relative weight	Condition
TL_{max}	Maximum total length	Size structure
TL_4	Back-calculated length at age-4	Growth
K	Growth rate	Growth
YC	Number of year classes present (>2)	Mortality/Recruitment

Table 2-5. Summary statistics from analysis of variance for stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs) and stocking strategy (0 = not stocked, 1 = infrequently stocked, and 2 = frequently stocked). Statistics assessed were catch per unit effort (catch per 72-h tandem-set series) for stock- to quality-length fish (280- to 409-mm TL; CPUE$_{S\text{-}Q}$) and quality- to preferred-length fish (410- to 609-mm TL; CPUE$_{Q\text{-}P}$), relative weight (W$_r$), maximum TL (TL$_{max}$), mean back-calculated length at age-4 (TL$_4$), growth rate (K) from the von Bertalanffy growth model, and the number of year classes present in the population (YC).

Population characteristic	*F*	df	*P*	
CPUE$_{S\text{-}Q}$				
Ecosystem type				
Stocking strategy				
Ecosystem type*Stocking strategy	2.18	4	0.0980	*
CPUE$_{Q\text{-}P}$				
Ecosystem type	2.80	2	0.0765	*
Stocking strategy	1.44	2	0.2516	
Ecosystem type*Stocking strategy	1.73	4	0.1721	
W$_r$				
Ecosystem type				
Stocking strategy				
Ecosystem type*Stocking strategy	3.15	4	0.0335	*
TL$_{max}$				
Ecosystem type	0.97	2	0.3949	
Stocking strategy	0.17	2	0.8473	
Ecosystem type*Stocking strategy	0.83	4	0.5208	
TL$_4$				
Ecosystem type	1.85	2	0.1788	
Stocking strategy	1.56	2	0.2317	
Ecosystem type*Stocking strategy	0.25	4	0.9094	
K				
Ecosystem type	0.15	2	0.8589	
Stocking strategy	1.43	2	0.2604	
Ecosystem type*Stocking strategy	1.41	4	0.2618	
YC				
Ecosystem type	0.78	2	0.4700	
Stocking strategy	0.48	2	0.6247	
Ecosystem type*Stocking strategy	0.47	4	0.7589	

* Indicates a significant difference at α=0.10.

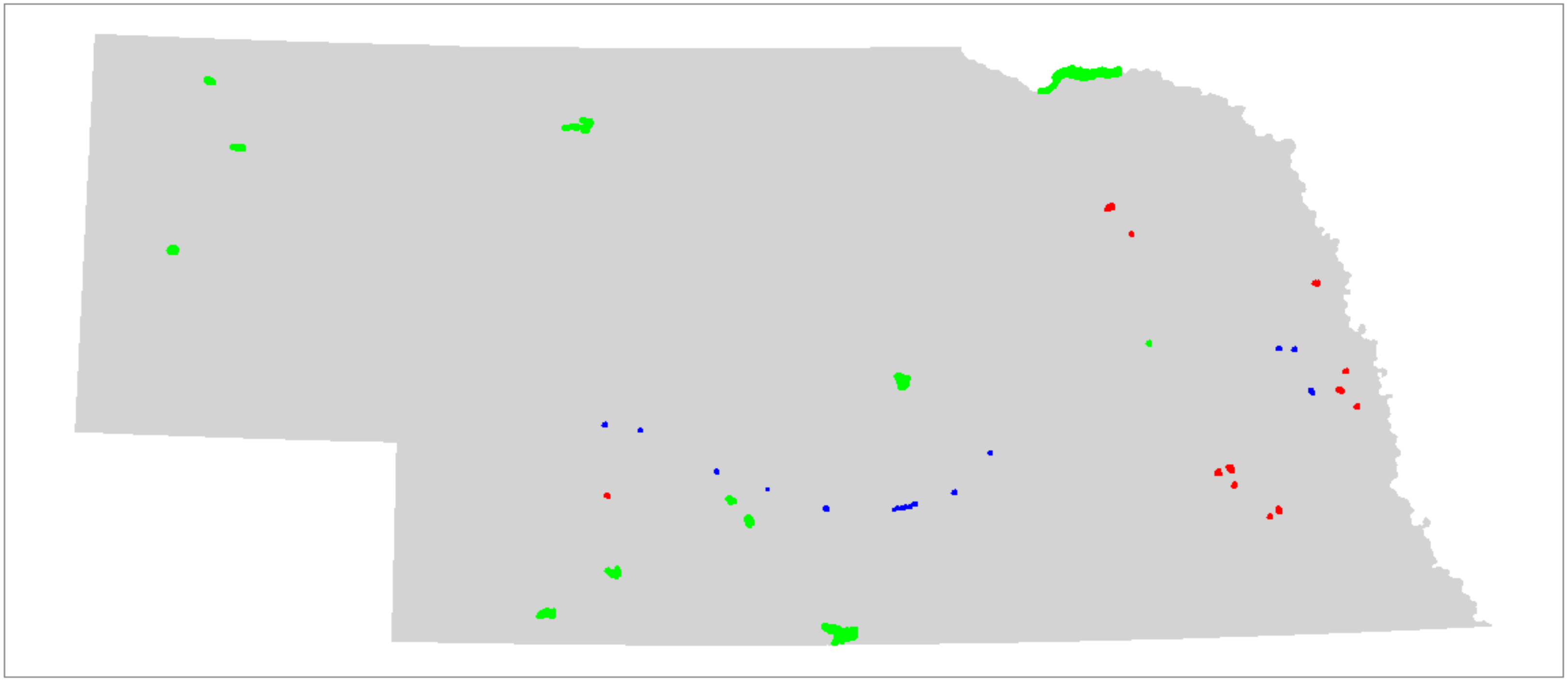

Figure 2-1. Map of Nebraska showing 36 water bodies selected as study sites for sampling channel catfish populations. Colors indicate three ecosystem types: blue = sand pit/gravel/barrow/reuse pits, red = flood-control reservoirs, and green = irrigation/power-generation reservoirs.

Figure 2-2. Example of a tandem-set hoop net series used to collect channel catfish during 2008 and 2009 from 36 Nebraska reservoirs.

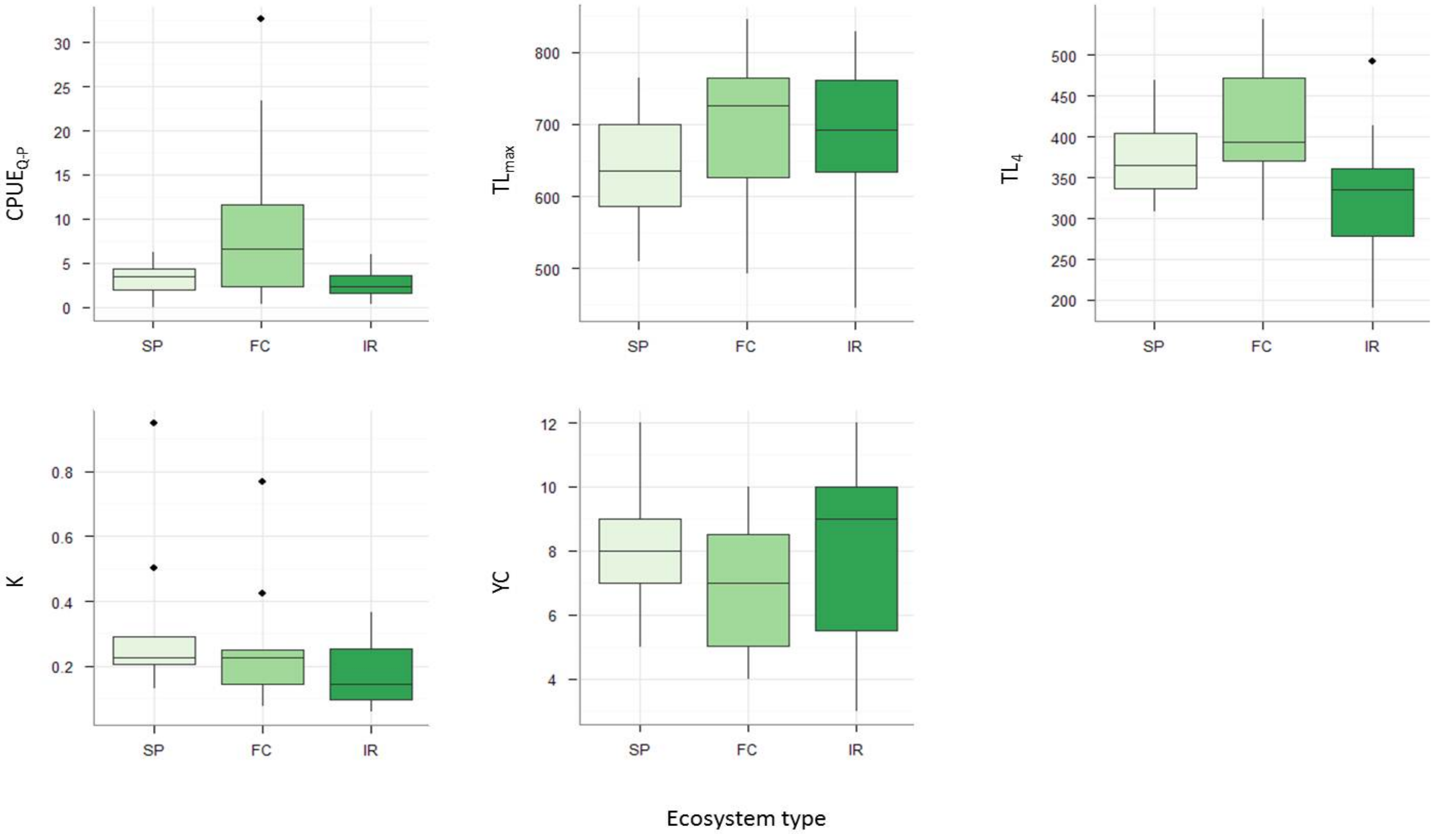

Figure 2-3. Box plots of population characteristics for stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs). Characteristics assessed were catch per unit effort (catch per 72-h tandem-set series) for quality- to preferred-length fish (410- to 609-mm TL; CPUE$_{Q-P}$), maximum TL (TL$_{max}$), mean back-calculated length at age-4 (TL$_4$), growth rate (K) from the von Bertalanffy growth model, and the number of year classes present in the population (YC).

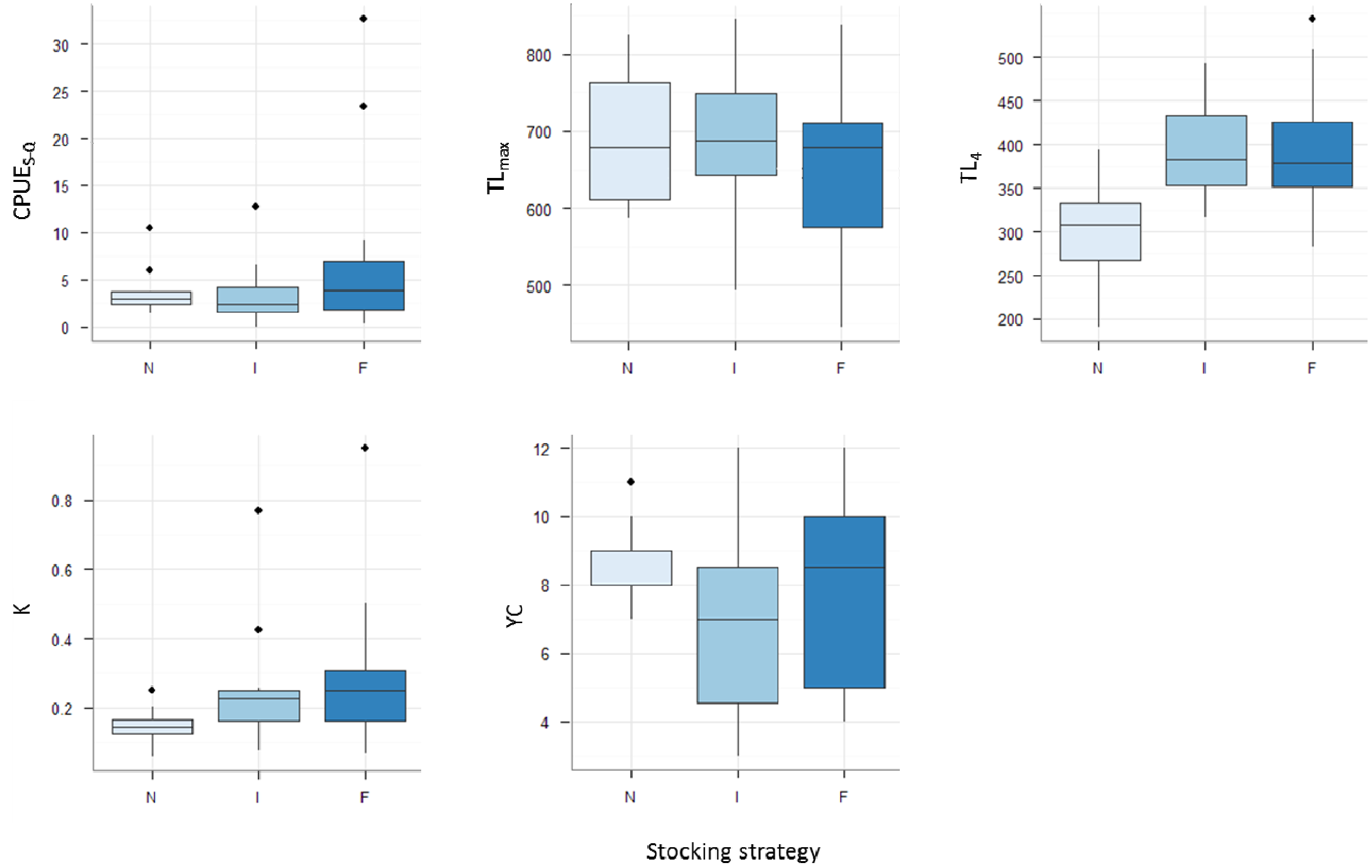

Figure 2-4. Box plots of population characteristics for stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by stocking strategy (0 = not stocked, 1 = infrequently stocked, and 2 = frequently stocked). Characteristics assessed were catch per unit effort (catch per 72-h tandem-set series) for quality- to preferred-length fish (410- to 609-mm TL; $CPUE_{Q-P}$), maximum TL (TL_{max}), mean back-calculated length at age-4 (TL_4), growth rate (K) from the von Bertalanffy growth model, and the number of year classes present in the population (YC).

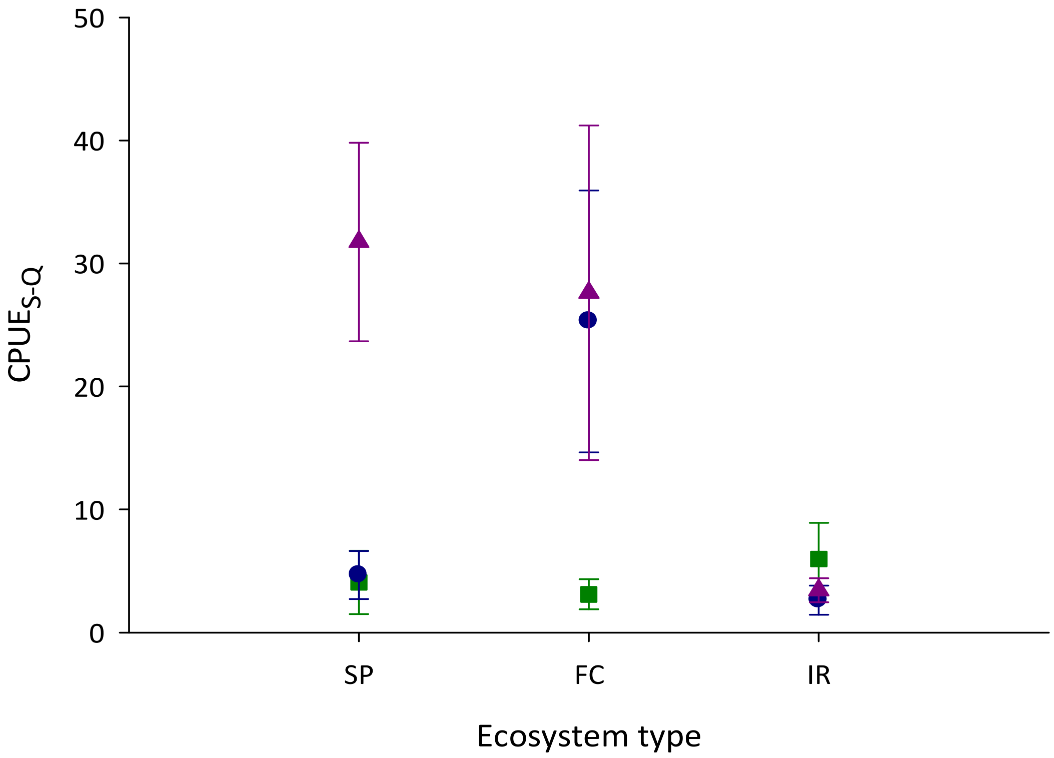

Figure 2-5. Mean catch per unit effort (catch per 72-h tandem-set series) for stock- to quality-length (280- to 409-mm total length) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (SP = sand/gravel/barrow/reuse pits, FC = flood-control reservoirs, and IR = irrigation/power-generation reservoirs [green triangle]) and stocking strategy (not stocked [green square], infrequently stocked [blue circle], and frequently stocked [pink triangle]).

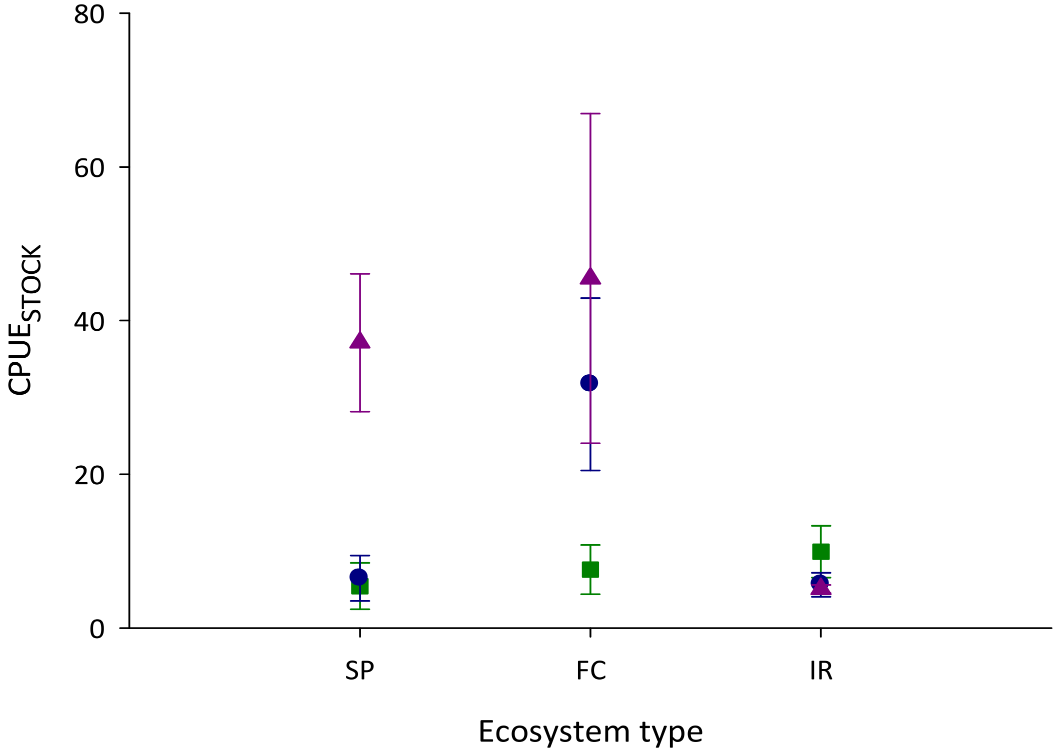

Figure 2-6. Mean catch per unit effort (catch per 72-h tandem-set series) for stock-length (≥ 280-mm total length) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (SP = sand/gravel/barrow/reuse pits, FC = flood-control reservoirs, and IR = irrigation/power-generation reservoirs) and stocking strategy (not stocked [green square], infrequently stocked [blue circle], and frequently stocked [pink triangle]).

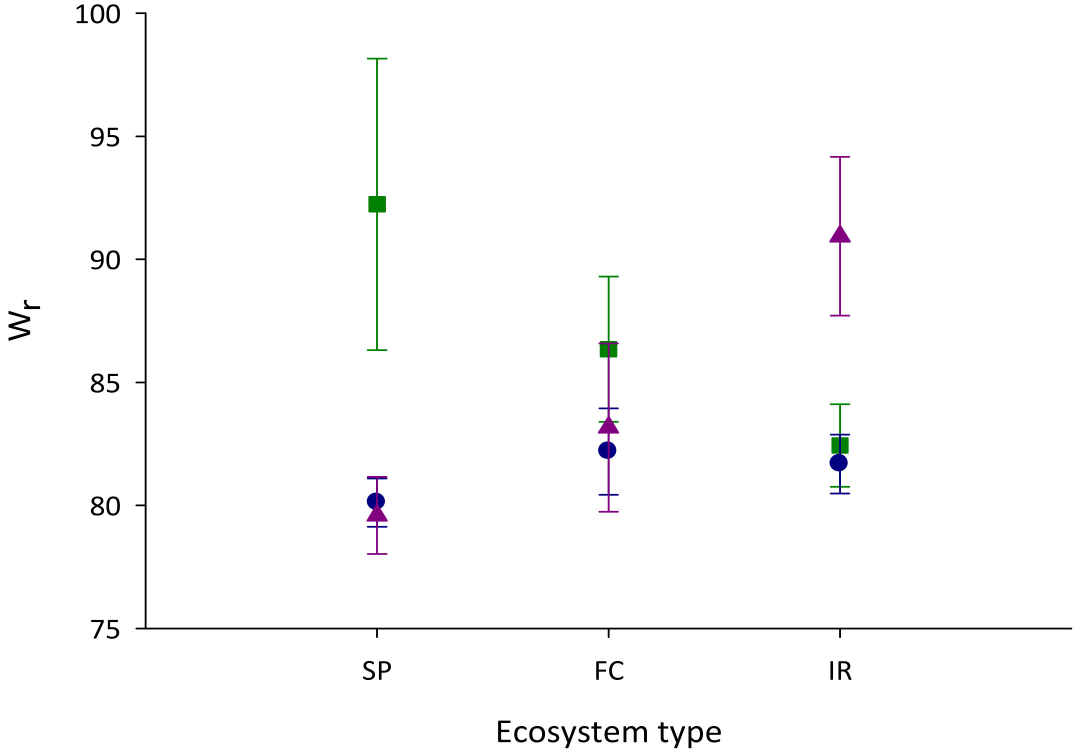

Figure 2-7. Mean relative weight (W_r) for stock-length (≥ 280-mm total length) channel catfish from tandem-set hoop net surveys (2008-2009) of 32 Nebraska water bodies (four water bodies were excluded because samples were insufficient for W_r estimation) classified by ecosystem type (SP = sand/gravel/barrow/reuse pits, FC = flood-control reservoirs, and IR = irrigation/power-generation reservoirs) and stocking strategy (not stocked [green square], infrequently stocked [blue circle], and frequently stocked [pink triangle]).

CHAPTER 3 – EXPLORATORY ANALYSIS OF CHANNEL CATFISH POPULATIONS FROM THREE ECOSYSTEM TYPES

Introduction

Little is known of the population dynamics and habitat requirements of channel catfish *Ictalurus punctatus* (Irwin et al. 1999). Additionally, assessment of management strategies can be challenging because channel catfish collections often yield small samples (Michaletz and Dillard 1999), yet accurate assessments of populations are essential in aiding management determination of stocking protocols and fishing regulations. In fact, poor assessments of population indices can lead to management practices that are detrimental to the target population (Hill 1984).

To address this need we collected data from 36 lentic channel catfish populations (Figure 2-1) in Nebraska during 2008 and 2009, and employed multivariate analysis of variance (MANOVA) in R (R Core Developmental Team 2011) to assess the effects of stocking variability and habitat variability on population structure and dynamics (see Chapter 2). The influence of habitat variability was assessed by comparing channel catfish populations from three ecosystem types, as classified by the Nebraska Game and Parks Commission (NGPC) (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs), each with a stocking strategy of not stocked, infrequently stocked, or frequently stocked. Results indicated that the influence of stocking on channel catfish populations varied with ecosystem type; however, it was necessary to exclude some water bodies from that analysis due to insufficient collections of channel catfish, effectively reducing the sample for some combinations of ecosystem type and stocking strategy to two representative water bodies. To further investigate the influence of habitat variability on channel catfish populations in Nebraska's lentic systems, we conducted an exploratory analysis of physical and biological characteristics of the 36 water bodies included in the initial assessment. With this analysis we were able to consider water bodies that were excluded from the MANOVA analysis.

Using exploratory analysis, our intent was to determine the utility of NGPC classifications in describing the physical and biological characteristics of ecosystem types; i.e., to determine whether water bodies within a NGPC classified ecosystem type were similar. Additionally, we intended to assess whether characteristics of channel catfish populations could be related to those physical and biological characteristics of water bodies. We also investigated whether channel catfish population characteristics could be utilized to identify similarities between water bodies. Finally, we investigated whether the density at which channel catfish were stocked had a notable influence on channel catfish population characteristics. This information can be useful to fisheries managers who wish to make management decisions based on water body characteristics, and can help determine the need for future stockings of channel catfish in Nebraska's water bodies so that state hatchery-reared fish are utilized in the most efficient manner.

Methods

Sampling

A single survey was conducted at each of 36 water bodies during July – August of 2008 and 2009 (except when nets yielded a low catch of channel catfish and time permitted, a supplementary survey was conducted to increase sample size for analyses of size structure, condition, age, and growth). Channel catfish were sampled with tandem-set hoop nets in accordance with methodology established for small impoundments in Missouri and Iowa (Michaletz and Sullivan 2002, Flammang and Schultz 2007, see Chapter 2). Water bodies were categorized using NGPC ecosystem classifications. Twelve water bodies each were representative of sand/gravel/barrow/reuse pits (hereafter referred to as sand pits), flood-control reservoirs, and irrigation/power-generation reservoirs (hereafter referred to as irrigation reservoirs).

Ecosystem classification

Sand pits are water bodies created from excavated trenches that remain after sand or gravel mining operations (McCarraher et al. 1975). Due to the nature of these excavations, sand pits tend to have steep banks and narrow littoral zones. Most sand pits in Nebraska are located along the Platte River and its tributaries, and along the Interstate-80 roadway (Holz 2005). These sand pits generally have little or no watershed runoff due to the high hydraulic conductivity of the soils (Holz 2005). Sand pits are typically groundwater fed (Holz 2005) and water levels remain stable throughout the year. In Nebraska, sand pits and sand-pit assemblages are often developed as State Recreation Areas. Sand pits represent some of the smallest bodies of water in the state, with the exception of city ponds that are classified and managed separately as urban fisheries. In this study, sand pits ranged from 3 to 20 ha, with a median size of 8 ha (Table 2-1).

Flood-control reservoirs, constructed with dams that block surface water flow to create retention pools, are primarily located in the eastern portion of the state where a high percentage of land use is devoted to row crop agriculture (Holz 2005), and where the state's population is most heavily concentrated. In this study, one reservoir (Wellfleet) was located in the southwest region of the state. Water levels in flood-control reservoirs generally experience mild seasonal fluctuations driven by precipitation, but remain relatively stable. In general, flood-control reservoirs can be described as small (<200 ha) standing waters and are characterized by relatively shallow depths and restricted limnetic zones (Pope et al. 2009). In this study, flood-control reservoirs ranged in size from 20 to 299 ha, with a median size of 82 ha (Table 2-1). Two reservoirs included in this study were larger than 200 ha (Willow Creek, 283 ha and Pawnee, 299 ha) but maintain the characteristics of small standing waters. In a statewide classification survey of 92 Nebraska reservoirs, Holz (2005) found that those located in the eastern third of the state tended towards lower alkalinity, conductivity, and nitrogen to phosphorous (N:P) ratios than reservoirs located in the western two-thirds of the state, though some reservoirs in the eastern portion of the state had higher conductivity and higher total nitrogen concentrations.

Irrigation reservoirs, also constructed with dams that block surface water flow to create retention pools, are primarily located in the south-central and western portions of the state in rural areas dominated by grasslands. The two exceptions in this study were Lewis and Clark Lake on the northeast border of Nebraska and South Dakota, and Lake North in the eastern third of the state. In general, irrigation reservoirs can be described as large (>200 ha) standing waters and are characterized by having distinct littoral and limnetic zones (Pope et al. 2009), and are relatively deep (Miranda and Boxrucker 2009). Two irrigation reservoirs in this study (Gallagher Canyon, 74 ha and Lake North, 81 ha) are better described as small standing waters. Irrigation reservoirs can experience extreme seasonal fluctuations in water levels, resulting from releases for hydroelectric power or irrigation. Holz (2005) found that reservoirs in the western two-thirds of the state tended towards higher conductivity, higher N:P ratios, lower total suspended solids, lower total phosphorous and higher secchi depth than those located in the eastern third of the state. Reservoirs in this study consisted primarily of irrigation reservoirs (excepting Lewis and Clark Reservoir and Lake North), and ranged from 74 to 12,141 ha, with a median size of 766 ha (Table 2-1).

Data Collection

Climate data including precipitation, air temperature, and growing degree days were obtained for each water body from the nearest climate center. Temperature, dissolved oxygen, pH, conductivity, and turbidity measures were recorded at each site prior to setting nets and again upon net retrieval. Depth of net set was also recorded upon deployment. Water quality and climate data were averaged over the 72-hr period of net deployment. Shoreline development index (SDI) was calculated as:

$$\mathrm{SDI} = \frac{\mathrm{L}}{2\sqrt{\mathrm{A}\pi}}$$

where L = shoreline length (m) and A = area (m^2) (McMahon et al. 1996).

Total length of channel catfish was recorded to the nearest mm, weight was recorded to the nearest g, and pectoral spines were removed for age determination from up to 10 channel catfish per cm length group. Length group only was recorded for all channel catfish captured in excess of 10 per length group. Bycatch species were measured and recorded to the nearest cm. All fish were released after data were collected. Channel catfish spines were aged according to NGPC standard procedure (see Chapter 2), and the Dahl-Lea model (Dahl 1907; Lea 1910; Michaletz et al. 2009) was used to determine back calculated length at age:

$$\mathrm{L_t} = \mathrm{L_T}\left(\frac{\mathrm{B_t}}{\mathrm{B_T}}\right)$$

where L_t is the back-calculated length at age t, L_T is the length at the time of capture, B_t is the radius of the bony structure at annulus t, and B_T is the radius of the bony structure at time of capture. An age-length key was developed to correct for subsampling bias (DeVries and Frie 1996) and provide an age structure of all captured channel catfish.

Channel catfish population characteristics

Minimum total lengths of channel catfish for stock (S), quality (Q), preferred (P), memorable (M), and trophy(T) lengths are 280, 410, 610, 710, and 910 mm, respectively (Gabelhouse 1984). Tandem-set hoop nets do not capture fish < 250 mm in proportion to their abundance (Michaletz and Sullivan 2002; Buckmeier and Schlechte 2009). Accordingly, we chose to consider only stock-length fish for analyses. Relative abundance was quantified as catch per unit effort (CPUE) and was calculated as the number of channel catfish caught per 72-hour tandem-set net series. Size structure was quantified using proportional size distribution (PSD, Guy et al. 2006) and was calculated as:

$$\mathrm{PSD} = \frac{\#\ \mathrm{of\ quality-length\ fish}}{\#\ \mathrm{of\ stock-length\ fish}} * 100.$$

In 25 of 36 surveys, channel catfish catch was insufficient for PSD estimation (i.e., < 100) as recommended by Anderson and Neumann (1996). Therefore, in order to assemble sufficient estimates we elected to calculate PSD for water bodies with a total catch (inclusive of supplemental surveys) that exceeded 25 channel catfish. Body condition was quantified using relative weight (W_r):

$$\mathrm{W_r} = (\mathrm{W}/\mathrm{W_s}) \times 100,$$

where W = weight in grams, and W_s= standard weight. The standard weight-length regression was:

$$\mathrm{Log_{10}\,W_s} = -5.800 + 3.294\,\mathrm{log_{10}\,TL},$$

where W_s = weight in g, and TL = total length in mm (Brown et al. 1995).

Growth rates and asymptotic maximum length were estimated for each population using a von Bertalanffy (1938) growth model:

$$\mathrm{L_t} = \mathrm{L_\infty}\left(1 - \mathrm{e}^{-\mathrm{K}(\mathrm{t}-\mathrm{t_0})}\right),$$

where L_t = length at time t, L_∞ = theoretical maximum length, K = growth coefficient, and t_0 = time when TL is equal to 0 mm. This model was fitted to back calculated lengths using the Ford-Walford method (Ford 1933, Walford 1946). Age and growth analysis was limited in some water bodies by the low numbers of channel catfish captured, therefore estimates were calculated for water bodies where total catch (inclusive of supplemental surveys) exceeded 24 channel catfish.

Data Analysis

Non-metric multidimensional scaling

Physical and biological characteristics were compiled for each water body (Table 3-1). Characteristics that were highly inter-correlated or lacked variation across water bodies were excluded, and a suite of six parameters was selected for analysis including bluegill *Lepomis macrochirus* CPUE ($CPUE_{BLG}$), pH, turbidity, conductivity, growing degree days (January – June), and latitude. Multivariate ordination was used to explore the relationship of ecosystem type (sand pit, flood-control reservoir, or irrigation reservoir) and selected water body characteristics.

Non-metric multidimensional scaling (NMDS) arranges a set of data points in multi-dimensional space according to similarities of measured traits. The NMDS ordination was created using the ‘metaMDS’ function in the vegan package (Oksanen et al. 2011) for R (R Development Core Team 2011). Values of selected parameters were standardized using Wisconsin double standardization. From these values, a distance matrix was created using a Bray-Curtis dissimilarity index (Table 3.x). This index quantifies the compositional difference between two sites with a single value calculated from measured dissimilarity of the selected parameters where 0 represents complete similarity and 1 represents complete dissimilarity. The ‘metaMDS’ procedure locates sites on the ordination by randomly placing the first site and then locating the remaining sites based on values from the distance matrix. The ‘metaMDS’ procedure created a maximum of 100 random starts (i.e., up to 100 random placements of the first site on the ordination) in search of a stable solution. A stress value was measured for each random start. Stress represents the mismatch between the Bray-Curtis dissimilarity values and measured distances on the ordination plot. The random start with the lowest stress was selected and the ordination was reconfigured until the stress value reached a minimum. A Monte Carlo permutation test, using 1000 iterations, assessed the significance of the final stress statistic. The number of ordination axes was determined from a scree plot of stress against number of axes. The appropriate number of axes was recognized as the point where the change in slope was greatest.

To describe the relationship of channel catfish populations to water body characteristics, characteristics representative of channel catfish population structure and dynamics were overlaid on the NMDS plot. Population characteristics selected for multivariate analysis (see Chapter 2) were included in NMDS analysis, with the exception of CPUE of quality- to preferred-length fish ($CPUE_{Q\text{-}P}$, Table 3-2). For the MANOVA (see chapter 2), we included measures of abundance for two size groups in a population as an index of size structure. For NMDS, PSD served as an index of size structure, and therefore CPUE of stock- to quality-length fish ($CPUE_{S\text{-}Q}$) was the only measure of abundance included in analysis.

Generalized additive models (GAM; Wood 2006) were used to create contour lines that depict the relationship of channel catfish characteristics to the placement of water bodies on the ordination. Smoothed surfaces are accomplished by splitting the data on the ordination into a number of segments, or knots, then joining each segment using differential equations (Zuur et al. 2009). The fitted, smooth surfaces on the ordination were calculated with the ‘ordisurf’ function in the vegan package in R (Oksanen et al. 2011) using thin-plate splines. Only models with a significant smoothed term ($\alpha = 0.10$) were considered. To determine if residuals from the GAM model varied with ecosystem type, we used analysis of variance (ANOVA, $\alpha = 0.05$) of the residuals of GAM expected values and observed values for each ecosystem type. Four water bodies (Cheyenne, Standing Bear, Windmill 1, and Willow Island) were omitted from the ANOVA due to missing values (Table 3-2).

Cluster analysis

Cluster analysis was used to explore the relationship of channel catfish population characteristics (Table 3-2) among water bodies to determine whether similar population groups coincided with or existed outside the bounds of the *a priori* ecosystem classification. This multivariate method attempts to group catfish populations based on similarities, and results are typically displayed as a dendrogram. An agglomerative hierarchal clustering using an average linkage with the Euclidean measure of dissimilarity was completed with the 'hclust' function in R (R Development Core Team, 2011). Briefly, this method creates a hierarchy that originates with individual populations and progressively merges populations into more general clusters. A scree plot of the number of clusters plotted against the associated dissimilarity was used to help decide the optimal number of clusters. The optimal number of clusters was recognized as the point where the change in slope was greatest. Four water bodies were excluded from this analysis due to missing values for some population characteristics (Table 3-2).

Once clusters were determined, population characteristics and selected water body characteristics of the groups were compared using box plots of median, minimum, maximum, and quartile values. Water body characteristics included all characteristics selected for NMDS as well as SDI, maximum depth at which nets were deployed ($\text{Depth}_{\text{max}}$, as an index of water body depth), and longitude. We also considered the density (fish/ha) at which channel catfish were stocked in 2003-2007 (Table 2-1).

Results

Non-metric multidimensional scaling

A scree plot (Figure 3-1) indicated that a two-dimensional solution best fit the water body data (final stress = 0.108), and the Monte Carlo test indicated that the final solution was significant ($P<0.01$). There was an association to the *a priori* ecosystem classification within the ordination (Figure 3-2). Flood-control reservoirs were primarily grouped together in a central band within the ordination. Sand pits were primarily grouped in a similar manner below the flood-control reservoirs on the ordination, and irrigation reservoirs were primarily grouped together at the left of the ordination. Stagecoach reservoir (flood-control, code = 5130), located towards the bottom and left of the ordination (Figure 3-2), displayed poor goodness of fit to the model. Other reservoirs that displayed a general lack of fit were Bassway Strip West (sand pit, code = 6150), located at the center of the ordination, and Minatare (irrigation reservoir, code = 1645), located in the upper left of the ordination (Figure 3-2). Merritt (irrigation reservoir, code = 2740), Walnut Creek, and Conestoga (flood-control reservoirs, codes = 5729 and 5115, respectively) displayed only moderate goodness of fit to the model (Figure 3-2).

Channel catfish characteristics with a significant fit of the smooth terms on the water body ordination included the number of year classes present in the population (YC), mean back calculated total length at age 4 (TL_4), and the von Bertalanffy growth coefficient K (Table 3-3). The fit for each characteristic was largely linear (Figures 3-3 – 3-5). Channel catfish characteristics that were not significantly fit to the water body ordination included PSD, $CPUE_{S\text{-}Q}$, maximum total length (TL_{max}), and relative weight (W_r) (Table 3-3).

Functioning as an index of recruitment and mortality, YC was expected to be least in water bodies located near the bottom and right of the ordination, and to be greatest in water bodies located near the top and left of the ordination (Figure 3-3). Channel catfish populations in flood-control reservoirs were primarily expected to have 6 – 8 year classes present. Irrigation reservoirs were expected to have the greatest number of year classes present, with a minimum YC = 7. Expected YC varied most in sand pits, but the majority (75%) were expected to have 4 – 7 year classes present. There was no significant difference ($P > 0.05$) in residuals of expected and observed values of YC between ecosystem types, indicating that the contour was similarly fit to each ecosystem type. However, in sand pits and irrigation reservoirs the residuals of expected and observed YC tended to be positive, whereas in flood-control reservoirs the residuals of expected and observed YC tended to be negative; i.e., the model predicted fewer year classes than were observed in sand pits and irrigation reservoirs and more than were observed in flood-control reservoirs (Figure 3-6). In sand pits, Lexington City Park Lake population exhibited significantly ($P < 0.05$) fewer year classes present than predicted by the model.

Functioning as an index of growth, TL_4 was expected to be least in water bodies located near the bottom and left of the ordination, and to be greatest in water bodies located near the top and right of the ordination (Figure 3-4). In sand pits, TL_4 was expected to range from 350 to 420 mm, whereas TL_4 in irrigation reservoirs was expected to range from 320 to 390 mm. In flood-control reservoirs, TL_4 was expected to range widely, but the majority of water bodies (75%) were expected to range from 350 to 420 mm. There was no significant difference ($P > 0.05$) in residuals of expected and observed TL_4 between ecosystem types. However, in sand pits and irrigation reservoirs, the residuals of expected and observed TL_4 tended to be negative, whereas in flood-control reservoirs, the residuals of expected and observed TL_4 tended to be positive; i.e., the model predicted age-4 channel catfish to be longer than was observed in sand pits and irrigation reservoirs and shorter than was observed in flood-control reservoirs (Figure 3-7).

The von Bertalanffy growth coefficient K was expected to be greatest in water bodies located near the bottom and right of the ordination, and to be least in water bodies located near the top and left of the ordination (Figure 3-5). The model predicted a wide range of growth rates in sand pits, but growth rates in irrigation reservoirs were expected to be relatively slow. In sand pits, K was expected to range primarily between 0.20 and 0.45. In flood-control reservoirs, K was expected to range primarily between 0.20 and 0.35. In irrigation reservoirs, K was expected to range between 0.15 and 0.30. There was no significant difference ($P > 0.05$) in residuals of expected and observed K between ecosystem types. However, in sand pits the residuals of expected and observed K were centered around zero, whereas in flood-control reservoirs and irrigation reservoirs, the residuals of expected and observed K tended to be negative; i.e., the model predicted faster growth than was observed in flood-control and irrigation reservoirs (Figure 3-8). In flood-control reservoirs, there were three significant residual outliers. Stagecoach and Wellfleet populations exhibited significantly slower growth ($P < 0.05$) than predicted by the model, and the Zorinsky population exhibited significantly ($P < 0.05$) faster growth than predicted by the model. In sand pits, the Lexington City Park Lake population exhibited significantly ($P < 0.05$) slower growth than predicted by the model.

Cluster analysis

The scree plot indicated eight clusters as the most appropriate grouping of water bodies (Figures 3-9 and 3-10). Cluster 1 was the largest group and consisted of 11 water bodies and included five sand pits, two flood-control reservoirs, and four irrigation reservoirs. Cluster 3, the second largest group, consisted of six water bodies and included two sand pits, three flood-control reservoirs, and one irrigation reservoir. Clusters 2, 4, and 6 each consisted of four water bodies. Cluster 2 included two sand pits, one flood-control reservoir and one irrigation reservoir. Cluster 4 included two flood-control reservoirs and two irrigation reservoirs. Cluster 6 included two flood-control reservoirs and two irrigation reservoirs. Three water bodies, Gallagher Canyon, Walnut Creek, and Lake North, were grouped individually in separate clusters.

Channel catfish population characteristics generally varied widely within and between clusters, though unique trends in some clusters were distinguishable (Figure 3-11). Channel catfish populations in Cluster 1 were largely intermediate to other populations in terms of the population characteristics considered, and some of the greatest variability was exhibited within this group. Channel catfish populations in Cluster 2 exhibited the fastest growth rates of all groups (median K = 0.4), but the smallest maximum lengths (median TL_{max} = 502 mm) as well as the lowest PSD (median = 15) and W_r (median = 79) values. Channel catfish populations in Cluster 3 exhibited the greatest length at age-4 (median TL_4= 481 mm), the fewest year classes present (median YC = 6), and generally lower abundance than other clusters (median $CPUE_{S-Q}$ = 4.1 channel catfish/net series). Cluster 4 channel catfish populations exhibited the greatest proportions of quality-length fish (median PSD = 58), and, along with Cluster 6, the slowest growth (median K = 0.1). Cluster 6 included channel catfish populations with the most year classes present (median YC = 10), the largest fish (median TL_{max} = 828 mm), and, along with Cluster 4, the slowest growth (median K = 0.1). Lake North (Cluster 5), an irrigation reservoir, appears to be isolated in the cluster analysis due to having very slow growth (TL_4 = 191 mm) with large fish (TL_{max} = 763 mm). Walnut Creek (Cluster 7), a flood-control reservoir, appears to be isolated in the cluster analysis due to having very high abundance ($CPUE_{S-Q}$ = 65.2 channel catfish/net series), with very fast growth (TL_4 = 509 mm), and very large fish (TL_{max} = 838 mm). Gallagher Canyon (Cluster 8), an irrigation reservoir, appears to be isolated in the cluster analysis due to having very slow growth (K = 0.15, and TL_4 = 246 mm) and an absence of large fish (TL_{max} = 604 mm).

Water body characteristics also varied widely within and between clusters (Figure 3-12). Water bodies in Cluster 3 exhibited the greatest bluegill abundance (median $CPUE_{BLG}$ = 32.4 fish/net series), whereas bluegill bycatch in Cluster 4 water bodies was negligible (median $CPUE_{BLG}$ = 2.1 fish/net series). Water bodies in Clusters 1 and 4 exhibited high conductivity relative to other clusters (median conductivity = 525 μs/cm and 610 μs/cm, respectively). Water bodies in Cluster 6 exhibited greater shoreline complexity (median SDI = 3.9), and experienced a longer growing season (median DD = 34.5) than other clusters. Water bodies in Clusters 1 and 6 exhibited low pH (median pH = 8.2 and 8.1, respectively) relative to other clusters. Water bodies in Cluster 4 exhibited high turbidity relative to other clusters (median NTU = 25.7). Water bodies in Cluster 2 were characterized by relatively shallow depths (median $Depth_{max}$ = 2.4 m). Water bodies in Clusters 2, 3, and 4 ranged widely in latitudinal distribution throughout the state, whereas those in Clusters 1 and 6 were, in general, closely distributed on a latitudinal gradient. Cluster 4 water bodies were closely distributed on a longitudinal gradient. Water bodies in Cluster 4 did not very greatly in growing degree days, whereas all other clusters exhibited a wide range of growing degree days. Water bodies in Cluster 1 exhibited the greatest variabililty in measures of bluegill abundance, conductivity, and growing degree days, whereas measures of latitude and turbidity were similar within the group. Water bodies in Cluster 4 ranged widely in pH levels, and turbidity ranged widely in Cluster 2 water bodies.

Stocking density varied within and between clusters; however, there were notable differences in stocking strategy between groups of clusters (Figure 3-12). Water bodies in Clusters 4 and 6, with the exception of one outlier in each group, were not stocked or were stocked with channel catfish at low density (< 50 channel catfish/ha), whereas water bodies in

Clusters 2 and 3 were stocked at high density (> 50 channel catfish/ha). There was substantial variation in stocking densities of water bodies in Cluster 1, ranging from 0 – 1,109 fish/ha.

Discussion

The NMDS indicated substantial variation in water body characteristics amongst ecosystem types, yet *a priori* ecosystem classifications (i.e., sand pits, flood-control reservoirs, and irrigation reservoirs) were, in general, representative of variation in physical and biological characteristics of water bodies. Additionally, the analysis indicated a loose association of water body characteristics with several channel catfish characteristics that index age structure and growth. Despite some association, the NMDS plots revealed that channel catfish characteristics primarily varied across a gradient of water body characteristics rather than within discrete ecosystem types. For instance, the models predicted that some populations from water bodies representing all ecosystem types would exhibit similar growth and age structure characteristics (e.g., some populations from all ecosystem types were expected to have between seven and nine year classes). On the ordination plot, latitude, pH, growing degree days, and turbidity tended to influence the placement of irrigation reservoirs, whereas conductivity appeared to influence the placement of sand pits, and bycatch of bluegill influenced the placement of both flood-control reservoirs and sand pits (Figure 3-2). Stagecoach (5130, a flood-control reservoir) displayed the poorest fit in the ordination. Turbidity measures at Stagecoach were exceptionally high (at least three times greater than turbidity measures at other water bodies) while other characteristics tended to be similar to other flood-control reservoirs, which likely influenced it's placement on the ordination. Despite poor fit to the ordination for some water bodies, there was no significant association of ecosystem classification in the residuals of the GAM fitting of ecosystem types, indicating that each ecosystem type fits the ordination equally.

The ordination of water bodies from this study holds potential as a tool to estimate channel catfish population characteristics for additional water bodies in Nebraska. For example, a channel catfish population in a water body known to have similar physical characteristics to a water body on the ordination plot can be expected to exhibit similar growth and age structure to that population. Additionally, general trends in population growth and age structure can be estimated based on ecosystem classification. Growth can be expected to be slower in irrigation reservoirs than in other ecosystem types, and populations in sand pits hold the potential to exhibit very fast growth. Similarly, growth can be expected to be slow for age groups 0-4 in irrigation reservoirs, and fast for age groups 0-4 in flood-control populations. Differences in growth rates may be due to differences in availability and accessibility of prey resources, particularly in early growth when channel catfish diet primarily consists of macroinvertebrates (Hubert 1999). Irrigation reservoirs can be expected to host populations with the most complex age structures, whereas sand pit populations tend to be structured with few year classes. Differences in age structure may be due to differences in natural recruitment and exploitation between systems.

The ordination of water bodies based on physical and biological characteristics provides support that growth and age structure vary between ecosystem types, despite a lack of significant difference in the multivariate analysis (see Chapter 2). For instance, the number of year classes present in a population was greatest in irrigation reservoirs (median YC = 9), and the NMDS generally expected irrigation reservoirs to have the most complex age structures. Also, growth rate and early growth were slowest in irrigation reservoirs (median $K = 0.17$, median $TL_4 = 336$ mm). Likewise, the NMDS generally expected the slowest growth in irrigation reservoirs.

Cluster analysis provided no evidence of an association between channel catfish population characteristics and *a priori* ecosystem types. The two largest clusters, accounting for

47% of the water bodies, were composed of populations representing all ecosystem types, and the remaining clusters were either composed of populations from two ecosystem types or consisted of a single water body. It is not surprising that population characteristics do not function as determinants of ecosystem type. Aquatic ecosystems are very complex and some of the physical and biological characteristics that define an ecosystem may not substantially influence channel catfish populations.

Though cluster analysis did not support the use of channel catfish population characteristics to predict ecosystem characteristics, it can provide insight into potential ecological factors that influence variation in population structure and dynamics. For instance, Cluster 6 populations were generally characterized with slower growth, complex age structure, and large fish. These water bodies were distinguished by relatively lower pH, longer growing seasons, and more complex shorelines than other groups. Conversely, Cluster 2 populations were generally characterized with fast growth, smaller fish, and poor relative weight. These water bodies were distinguished from other clusters by relatively shallow depths, and little shoreline complexity. Three water bodies did not conform to any cluster in the analysis, and in two of these, shoreline complexity was a distinguishing characteristic. Gallagher Canyon exhibited substantially greater shoreline complexity than any other water body. Similarly, Lake North exhibited substantially less shoreline complexity than any other water body. Perhaps this physical characteristic contributed to a unique suite of channel catfish population characteristics that distinguished these reservoirs from other water bodies.

Stocking density was compared amongst clusters to determine whether stocking influenced the groupings. Water bodies in Clusters 2 and 3 were stocked at high densities, and water bodies in Clusters 4 and 6 were stocked at low densities. We expected that heavily stocked water bodies would be characterized with relatively greater abundance and poorer condition than other water bodies. Contrary to expectations, channel catfish abundance did not differ greatly between groups. Condition was relatively poor in Cluster 2 populations, but relatively good in Cluster 3 populations. Based on the channel catfish characteristics considered in the cluster analysis, the influence of stocking on channel catfish populations is unclear.

Angler exploitation, though unaccounted for in this analysis, is often an important factor structuring channel catfish populations (Miranda 1999, Stanovick 1999). In Nebraska, catfish anglers tend towards a harvest mentality more than other angler groups (Hurley and Duppong Hurley 2007). Fisheries that are managed with high density stocking regimes likely experience a high rate of angling pressure. Perhaps stocking influence on these fisheries is masked by a strong exploitative influence.

To gain further understanding of the influence of ecosystem on channel catfish populations, it is necessary to obtain measures of exploitation. Exploitation rate may be related to water body characteristics (e.g., location, size, or fish community). Exploitation rates associated with ecosystem types will inform managers of the influence of harvest in shaping population structure and dynamics in Nebraska’s sand pits, flood-control reservoirs, and irrigation reservoirs.

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Table 3-1. Biological and physical characteristics of 36 Nebraska water bodies sampled during tandem-set hoop net surveys of channel catfish populations (2008-2009). Water bodies are coded with a Nebraska Game and Parks Commission identifier and classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs). Biological characteristics include catch per unit effort (CPUE) of bluegill (BLG), crappie (CRP), ictalurids other than channel catfish (ICT), cyprinids (CYP), and other species (OTH). Physical characteristics include temperature (Temp; C), pH, Turbidity (nephelometric turbidity units; NTU), dissolved oxygen (DO) at the surface (DOS), DO at depth of net set (DOD), mean depth of net set (Depth; m), maximum depth of net set ($\text{Depth}_{\text{max}}$; m), Conductivity (Cond; µs/cm), precipitation in January - June (Precip; cm), growing degree days in January - June (DD), shoreline development index (SDI), water body size (Area; ha), location (latitude and longitude) and day of year sampling occurred (DOY).

Water body	Code	CPUE_{BLG}	CPUE_{CRP}	CPUE_{ICT}	CPUE_{CYP}	CPUE_{OTH}	Temp	pH	NTU	DO_{S}	DO_{D}	Depth
Sand Pit												
Windmill 1	6023	150.5	89.5	0.3	0.8	0.5	25.3	8.1	9.1	9.2	8.7	1.6
Willow Island	6240	107.5	1.8	5.3	0.0	0.5	29.7	7.6	4.4	10.1	10.0	1.5
Blue Hole	6180	43.3	10.3	0.0	0.3	0.5	26.9	8.7	6.0	18.6	15.3	1.4
Eagle Scout	6718	29.5	61.5	0.3	1.3	2.5	27.8	9.0	13.0	16.6	12.0	1.8
Bassway Strip West	6150	33.3	6.5	3.8	0.0	0.3	29.1	8.8	2.6	12.2	13.2	2.6
Cheyenne	6075	100.3	3.5	0.0	0.0	0.0	26.0	8.3	3.2	9.7	8.3	2.5
Pawnee Slough	4277	9.8	0.0	0.0	0.0	0.3	23.7	9.3	3.4	11.1	11.6	1.3
Fremont 15	3080	0.3	10.7	0.0	0.0	2.2	27.2	7.7	13.7	10.9	9.0	2.5
Two Rivers 1 & 2	5046	12.8	3.0	0.3	0.0	0.0	29.2	8.6	7.6	9.2	8.9	1.6
Lexington City Park	6710	64.5	11.0	0.0	0.0	0.5	28.1	8.2	12.3	13.5	11.4	1.3
Johnson Park	3302	75.5	0.0	0.3	0.0	0.0	28.2	8.6	3.9	10.8	10.8	1.8
NorthPlatte I-80	4720	18.0	9.0	0.3	0.0	0.3	26.3	7.8	11.4	8.1	7.8	1.8

Table 3-1. Continued.

Water body	Depth$_{max}$	Cond	Precip	DD	SDI	Area	Latitude	Longitude	DOY
Sand Pit									
Windmill 1	1.8	895	3.2	33	1.3	3	40.704697	98.842983	223
Willow Island	2.0	1954	2.0	30	2.3	10	40.853797	100.010306	193
Blue Hole	2.4	1176	8.4	28	4.9	10	40.688406	99.387111	203
Eagle Scout	2.3	516	9.1	27	1.5	17	40.958303	98.36305	210
Bassway Strip West	3.4	948	8.4	28	1.6	4	40.686211	98.947025	211
Cheyenne	3.0	923	3.0	34	1.5	7	40.762783	98.592456	223
Pawnee Slough	1.6	318	6.4	26	2.0	12	41.081261	100.539172	231
Fremont 15	3.7	376	3.6	33	3.9	20	41.441733	96.544903	188
Two Rivers 1 & 2	1.9	517	4.2	68	2.9	3	41.216378	96.347275	217
Lexington City Park	1.4	1513	2.0	30	2.1	3	40.785578	99.750986	193
Johnson Park	2.1	870	2.9	30	0.9	6	41.434781	96.446625	216
NorthPlatte I-80	2.9	703	2.2	28	1.4	11	41.1087	100.759206	195

Table 3-1. Continued.

Water body	Code	CPUE$_{BLG}$	CPUE$_{CRP}$	CPUE$_{ICT}$	CPUE$_{CYP}$	CPUE$_{OTH}$	Temp	pH	NTU	DO$_{S}$	DO$_{D}$	Depth
Flood Control												
Standing Bear	5725	200.2	66.0	0.2	0.2	0.0	25.2	7.8	5.0	8.3	7.5	1.8
East Twin	5325	11.8	49.3	0.0	0.1	0.1	25.6	8.7	20.1	10.6	10.0	1.7
Conestoga	5115	86.2	51.8	5.1	3.4	0.2	24.8	8.0	16.1	6.9	6.0	1.6
Pawnee	5125	2.1	10.9	0.0	0.0	1.5	26.3	8.2	17.2	8.7	8.4	1.9
Wellfleet	4500	31.5	18.8	0.0	0.0	0.8	24.6	8.8	18.3	12.4	9.5	1.4
Stagecoach	5130	1.7	18.0	1.2	1.2	1.3	25.1	8.0	94.0	8.0	7.9	1.4
Zorinsky	5728	55.5	16.4	1.5	0.0	0.9	26.2	7.9	17.6	8.8	7.7	1.6
Wagon Train	5135	50.0	38.4	0.6	0.0	0.3	27.1	8.5	6.9	9.9	.	1.6
Skyview	3535	93.0	0.0	0.0	0.0	0.0	24.2	7.9	4.0	8.8	8.0	2.6
Walnut Creek	5729	199.2	7.7	0.0	0.0	0.0	26.5	8.9	9.4	12.4	10.4	1.8
Summit	3325	41.3	7.6	0.4	0.0	0.6	25.6	8.6	13.7	12.1	9.5	2
Willow Creek	3335	2.1	2.5	0.0	0.4	1.5	27.3	9.8	33.8	12.0	11.5	1.7
Irrigation/Power												
Gallagher Canyon	6525	0.5	10.5	0.0	1.3	0.9	27.3	8.9	18.9	13.6	10.8	2.4
Lake North	3440	0.1	29.5	0.1	0.1	1.1	26.6	7.6	36.7	6.3	6.3	2.9
Sherman	6925	0.8	14.8	0.1	0.0	0.9	27.2	8.9	12.3	9.0	8.7	2.2
Lewis & Clark	3710	2.0	2.5	0.1	0.0	2.0	24.0	7.9	29.3	8.6	8.5	3.1
Elwood	6530	0.9	0.6	0.0	0.0	1.6	25.3	8.2	13.8	7.2	7.0	2.9
Red Willow	4910	16.6	4.1	0.3	0.3	1.4	27.2	7.9	6.7	10.0	9.1	2.4
Swanson	4920	0.3	0.4	0.0	0.9	1.0	23.3	8.9	22.2	10.5	9.5	2.5
Harlan	6915	5.8	4.5	0.1	0.4	1.0	24.8	8.4	19.1	7.8	6.9	2.5
Whitney	1805	0.5	3.4	0.0	0.3	0.8	23.1	8.6	29.2	10.3	9.6	2.4
Box Butte	1600	13.1	0.5	0.0	0.4	2.1	24.1	7.7	7.4	9.0	8.3	2.8
Minatare	1645	0.0	0.1	0.0	0.0	2.6	22.3	8.6	10.7	10.0	8.8	3
Merritt	2740	14.1	5.4	0.0	0.1	0.5	23.5	9.5	19.5	11.4	13.2	2.5

Table 3-1. Continued.

Water body	Depth$_{max}$	Cond	Precip	DD	SDI	Area	Latitude	Longitude	DOY
Flood Control									
Standing Bear	2.6	430	5.4	36	2.0	55	41.314653	96.122144	186
East Twin	2.7	486	7.7	30	2.0	85	40.824897	96.946483	195
Conestoga	3.0	426	4.4	36	1.5	93	40.766703	96.846131	237
Pawnee	3.2	372	4.4	36	1.7	299	40.839756	96.865122	209
Wellfleet	1.8	366	6.4	26	2.3	20	40.750789	100.736392	224
Stagecoach	2.7	295	7.7	30	1.9	79	40.604467	96.636583	197
Zorinsky	2.1	484	5.4	36	2.4	103	41.220364	96.160994	208
Wagon Train	2.0	393	4.4	36	2.1	127	40.620586	96.582856	187
Skyview	3.5	443	3.8	31	1.7	20	41.037986	97.437103	219
Walnut Creek	2.7	330	4.2	68	3.6	28	41.143947	96.068492	196
Summit	2.9	331	3.5	35	2.4	77	41.766	96.284281	214
Willow Creek	3.4	275	5.7	29	2.0	283	42.179261	97.555078	218
Irrigation/Power									
Gallagher Canyon	4.9	927	10.2	26	10.4	74	40.734275	99.973339	202
Lake North	4.8	310	6.3	34	1.2	81	41.490842	97.354558	221
Sherman	4.2	225	6.3	26	7.3	1151	41.303292	98.881686	211
Lewis & Clark	5.3	735	1.7	30	4.2	12141	42.860614	97.485575	218
Elwood	5.1	832	2.0	30	9.1	538	40.635772	99.853375	222
Red Willow	3.6	443	4.2	33	5.5	659	41.357792	100.668428	194
Swanson	3.7	751	13.0	28	1.7	2013	40.162653	101.064744	230
Harlan	4.1	669	4.1	32	4.1	5463	40.067628	99.211892	236
Whitney	3.2	378	1.8	34	1.9	364	42.778917	103.311906	190
Box Butte	4.2	402	4.5	22	2.6	647	42.457464	103.075478	201
Minatare	4.9	525	2.1	26	1.6	873	41.918258	103.493292	189
Merritt	3.7	168	4.7	28	6.7	1176	42.632714	100.869089	232

Table 3-2. Population characteristics of stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs). Abundance was characterized by sample size (N) and mean catch per unit effort (catch per 72-h tandem-set series) for stock- to quality-length fish (280- to 409-mm TL; CPUE$_{S\text{-}Q}$). Size structure was characterized by sample size (N$_a$), proportional size distribution (PSD) and maximum TL (TL$_{max}$). Condition was characterized by sample size (N$_a$) and relative weight of stock-length fish (W$_r$). Growth was characterized by sample size (N$_a$), the mean back-calculated length at age 4 (TL$_4$), and the von Bertalanffy growth coefficient (K). Mortality was characterized by sample size (N$_a$) and the number of year classes present in the population (YC).

Water body	N	N$_a$	CPUE$_{S\text{-}Q}$	PSD	TL$_{max}$	W$_r$	TL$_4$	K	YC
Sand pit									
Windmill 1	0	0	0.0	[A]	[A]	[A]	[A]	[A]	[A]
Willow Island	3	3	0.0	[A]	[A]	[A]	[A]	[A]	[A]
Blue Hole	35	37	5.5	38	635	85	695	0.38	7
Eagle Scout	49	60	10.8	13	586	87	308	0.15	8
Bassway Strip West	3	40	0.5	3	765	81	470	0.23	7
Cheyenne	11	11	2.5	[A]	[A]	[A]	[A]	[A]	[A]
Pawnee Slough	34	56	6.5	29	510	77	336	0.24	9
Fremont 15	83	108	9.2	35	703	81	416	0.20	8
Two Rivers 1 & 2	82	82	16.3	17	660	83	404	0.13	10
Johnson Park	118	118	25.0	15	542	77	365	0.50	7
Lexington City Park	145	145	31.8	12	629	82	355	0.95	5
NorthPlatte I-80	249	249	54.0	10	700	77	381	0.29	12

Table 3-2. Continued.

Water body	N	N_a	$CPUE_{S-Q}$	PSD	TL_{max}	W_r	TL_4	K	YC
Flood control									
Standing Bear	6	9	0.3	[A]	[A]	[A]	[A]	[A]	[A]
Conestoga	25	35	1.8	51	611	83	364	0.25	7
Pawnee	81	109	5.5	33	789	82	393	0.12	8
East Twin	138	138	4.8	68	678	85	301	0.16	8
Wagon Train	90	107	5.3	50	732	87	450	0.23	6
Stagecoach	106	106	10.0	15	696	83	383	0.43	4
Wellfleet	198	198	35.8	26	638	80	493	0.77	5
Zorinsky	422	422	50.1	5	845	79	373	0.08	9
Summit	9	40	0.4	20	739	93	543	0.25	5
Skyview	116	116	19.8	32	577	77	398	0.17	5
Willow Creek	363	393	25.1	48	726	80	297	0.09	10
Walnut Creek	616	616	65.2	32	838	83	509	0.25	10
Irrigation/Power									
Sherman	26	47	0.5	64	826	84	268	0.14	11
Gallagher Canyon	49	90	3.8	36	604	79	246	0.15	10
Lake North	94	94	5.4	51	763	80	191	0.06	9
Lewis & Clark	148	148	14.3	23	761	86	327	0.09	9
Elwood	17	31	1.5	19	645	79	413	0.24	3
Swanson	33	96	0.0	94	688	81	349	0.10	4
Harlan	56	85	5.4	31	670	81	357	0.26	8
Red Willow	74	109	3.6	41	829	85	316	0.12	12
Box Butte	34	38	1.8	50	697	94	375	0.07	4
Minatare	37	56	2.8	38	574	96	345	0.26	10
Merritt	38	57	3.0	33	706	92	282	0.37	10
Whitney	53	102	6.3	6	446	82	492	0.25	6

[A] Values are not reported when $N_a < 25$.

Table 3-3. Results of the General Additive Model (GAM) of stock-length (≥280-mm total length [TL]) channel catfish population characteristics from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs) with approximate significance of smooth terms for proportional size distribution (PSD), catch per unit effort (catch per 72-h tandem-set series) of stock- to quality length fish ($CPUE_{S\text{-}Q}$), maximum TL (TL_{max}), relative weight (W_r), mean back-calculated total length at age-4 (TL_4), and the von Bertalanffy growth coefficient (K) fitted on an ordination of water bodies determined by physical and biological characteristics. Estimated degrees of freedom for the model terms (edf), estimated residual degrees of freedom (Res. Df), adjusted R^2 for the model (adj. R^2), F-value of the smoothed term (F), approximate significance of the smoothed term (P), and the proportion of the null deviance explained by the model (Deviance explained %) are identified for each characteristic. Significant values ($P < 0.10$) are indicated with an asterisk.

Characteristics	edf, Ref. df	adj. R^2	F	P		Deviance explained (%)
PSD	2,2		2.30	0.1180		13.7
$CPUE_{S\text{-}Q}$	2,2		0.85	0.4350		4.92
YC	2,2	0.18	5.09	0.0121	*	24.1
TL_4	2.2, 2.3	0.19	3.82	0.0279	*	23.1
TL_{max}	2,2		0.68	0.5120		4.1
W_r	2.5, 2.8		0.95	0.4240		10.6
K	2,2	0.10	2.80	0.0756	*	14.9

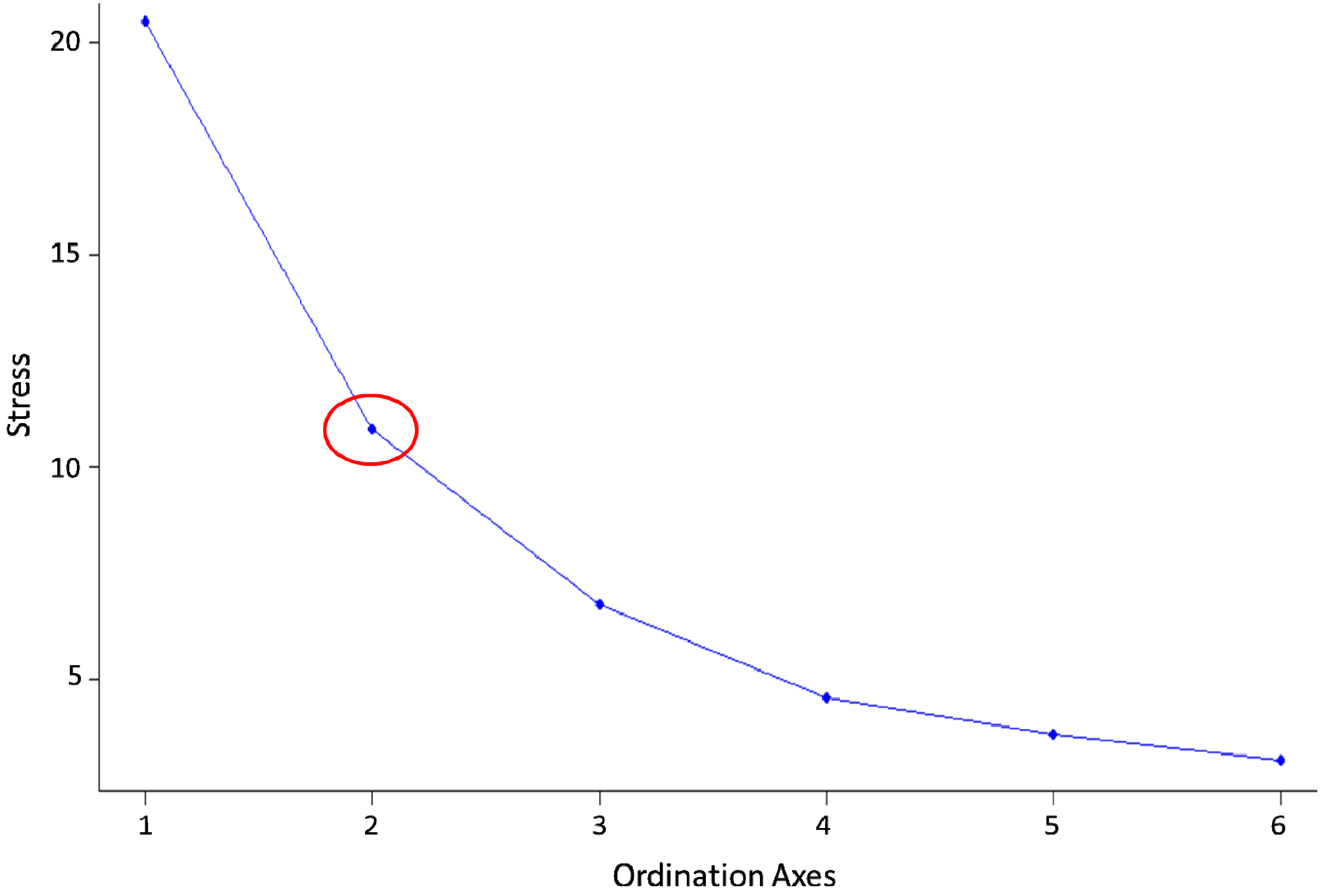

Figure 3-1. A scree plot of the associated stress for each number of ordination axes in the non-metric multidimensional scaling (NMDS) solution of physical and biological characteristics of 36 Nebraska water bodies surveyed during 2008-2009. The red circle indicates the number of axes chosen for the analysis.

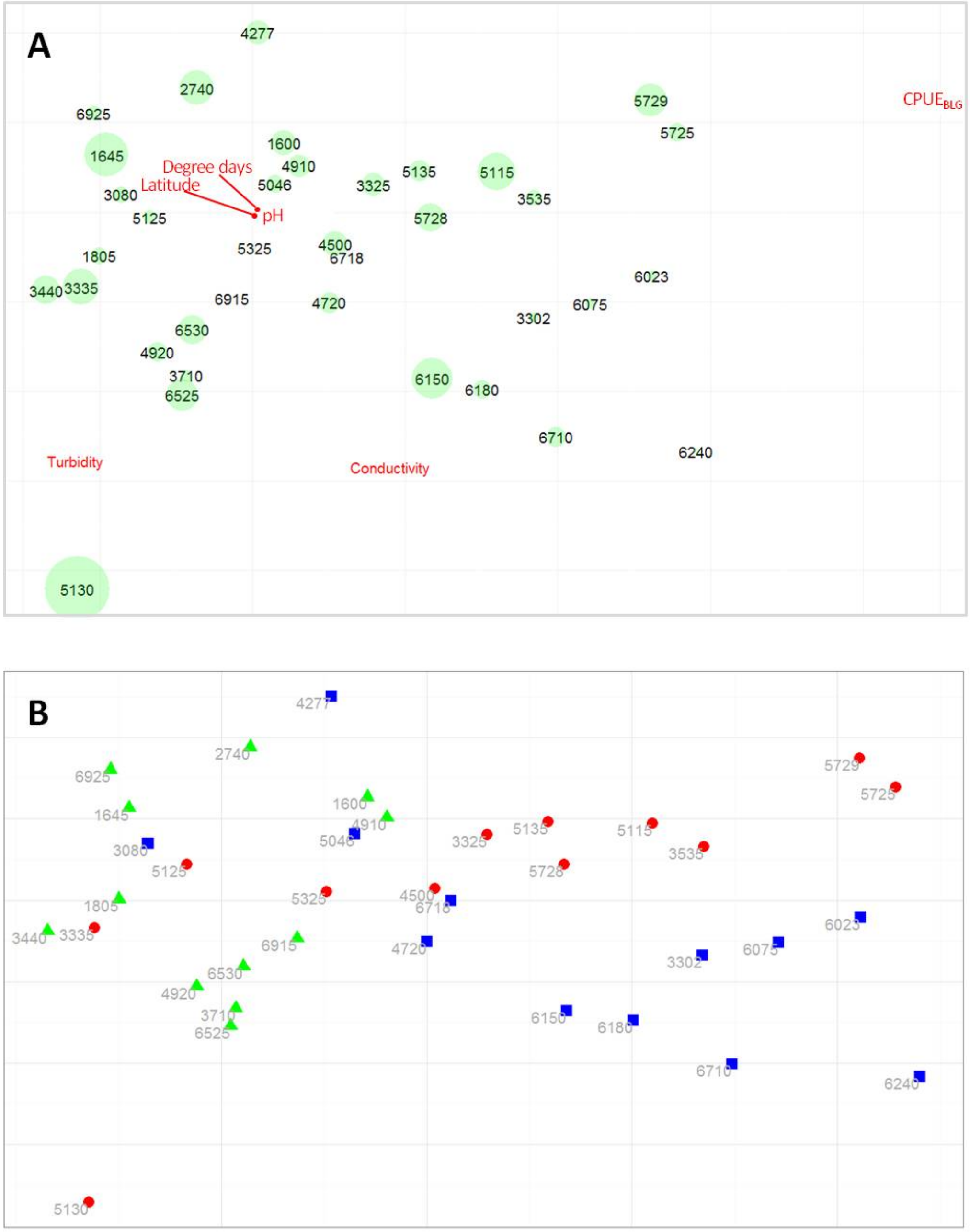

Figure 3-2. The two-dimensional non-metric multidimensional scaling (NMDS) ordination solution (stress = 0.12) of physical and biological characteristics from 36 Nebraska water bodies surveyed during 2008 – 2009. A) The NMDS ordination superimposed with Nebraska Game and Parks Commission (NGPC) identifier code (see Table 3-1) and relative goodness of fit (as indicated by diameter of the marker; i.e., larger circles indicate poorer fit) of each waterbody within the ordination. Environmental variables assessed were length of growing season (Degree days), latitude, turbidity, conductivity, and catch per unit effort (catch per 72-h tandem-set hoop net series) of bluegill (CPUE$_{BLG}$). B) The NMDS ordination superimposed with the NGPC identifier code and ecosystem type (blue squares = sand/gravel/barrow/reuse pits, red circles = flood-control reservoirs, and green triangles = irrigation/power generation reservoirs). Note the axes are arbitrary and are omitted on the plots.

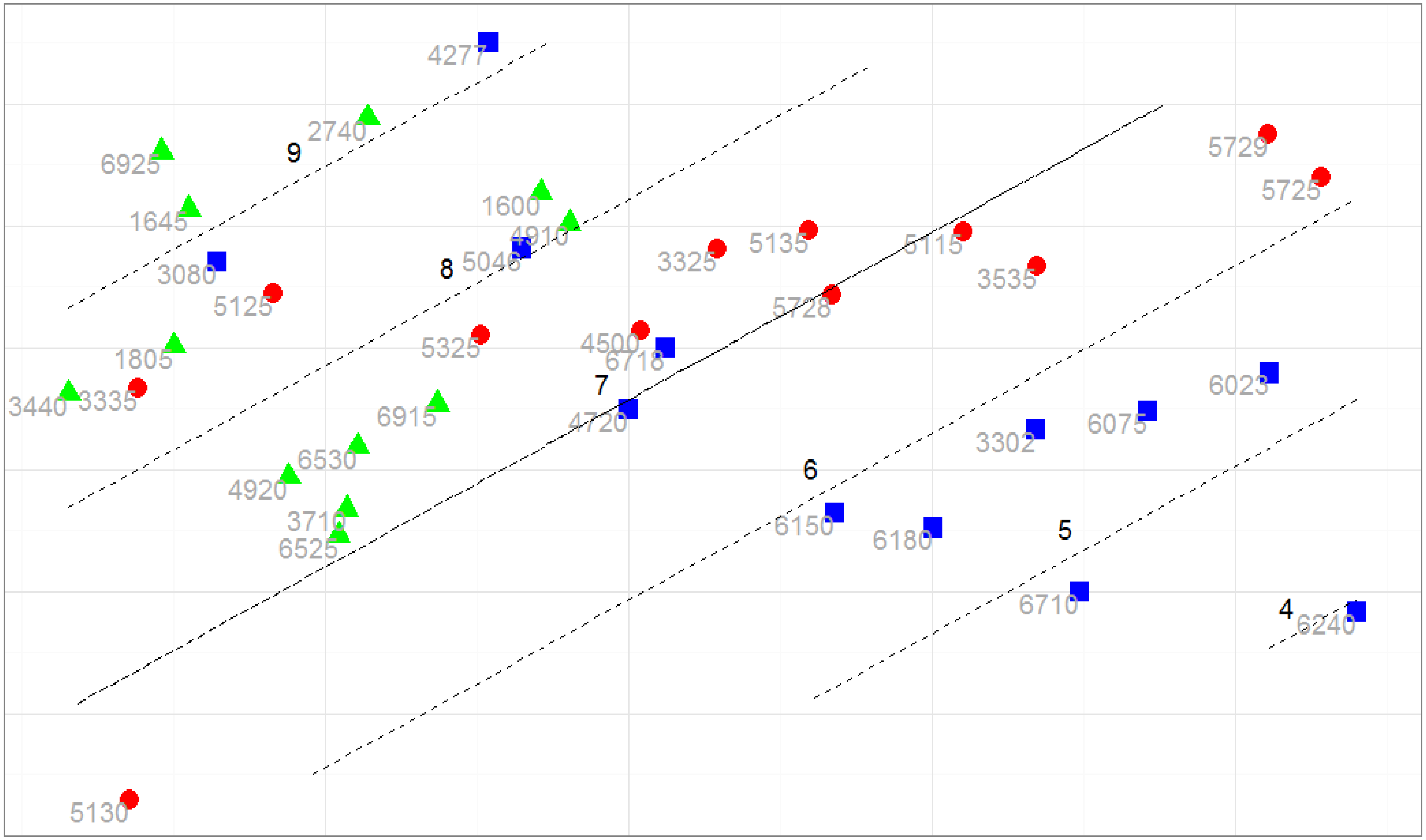

Figure 3-3. Non-metric multidimensional scaling (NMDS) ordination of physical and biological characteristics from 36 Nebraska water bodies surveyed for channel catfish with tandem-set hoop nets during 2008 – 2009 and classified by ecosystem type (blue squares = sand/gravel/barrow/reuse pits, red circles = flood-control reservoirs, and green triangles = irrigation/power generation reservoirs); see Fig. 3-2). Expected number of year classes present in a channel catfish population (4-9) is fitted as a smooth surface on the first and second dimensions of the NMDS ordination and is represented by the contours derived from a fitted polynomial surface.

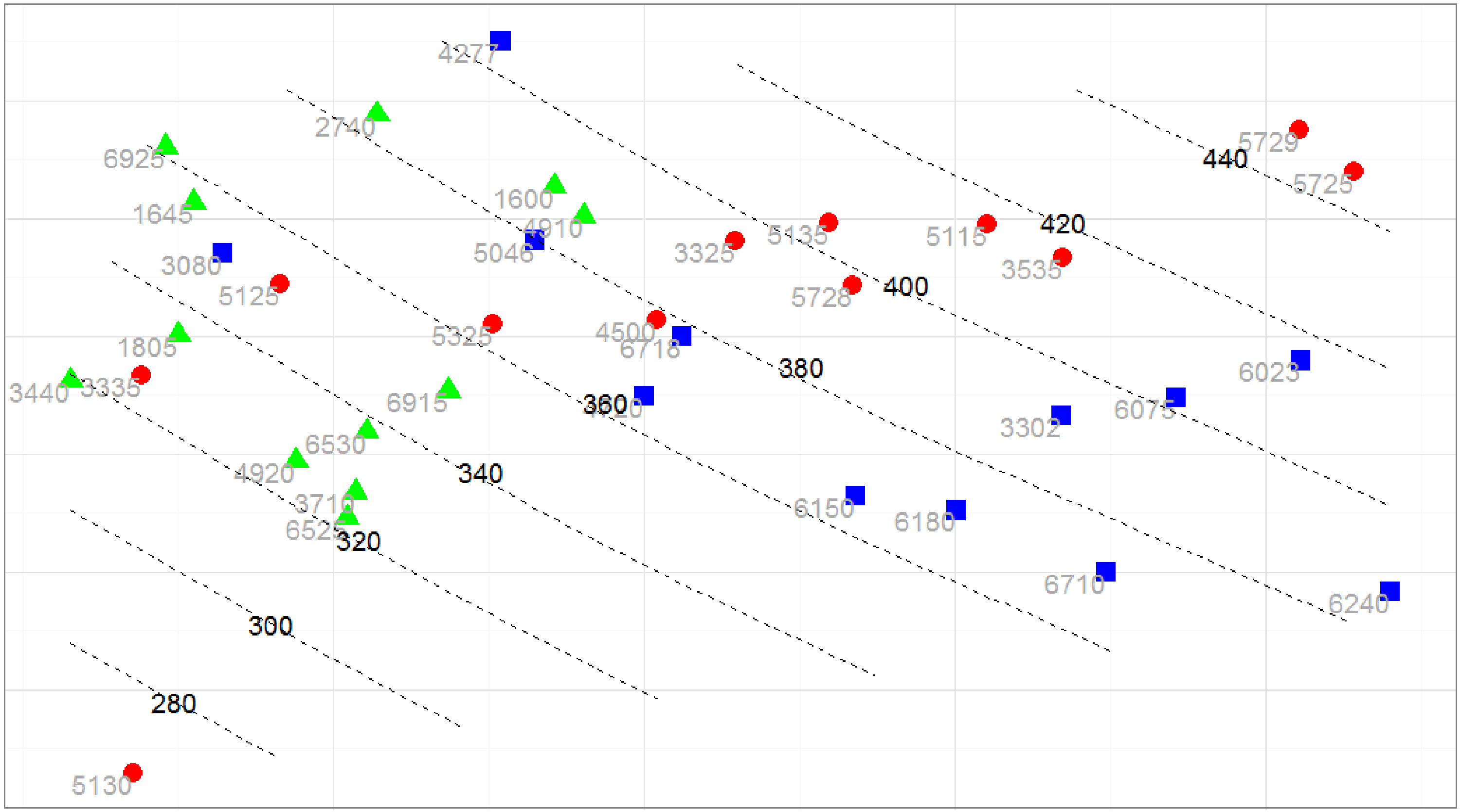

Figure 3-4. Non-metric multidimensional scaling (NMDS) ordination of physical and biological characteristics from 36 Nebraska water bodies surveyed for channel catfish with tandem-set hoop nets during 2008 – 2009 and classified by ecosystem type (blue squares = sand/gravel/barrow/reuse pits, red circles = flood-control reservoirs, and green triangles = irrigation/power generation reservoirs); see Fig. 3-2). Expected mean back-calculated total length of channel catfish (280-440 mm) is fitted as a smooth surface on the first and second dimensions of the NMDS ordination and is represented by the contours derived from a fitted polynomial surface.

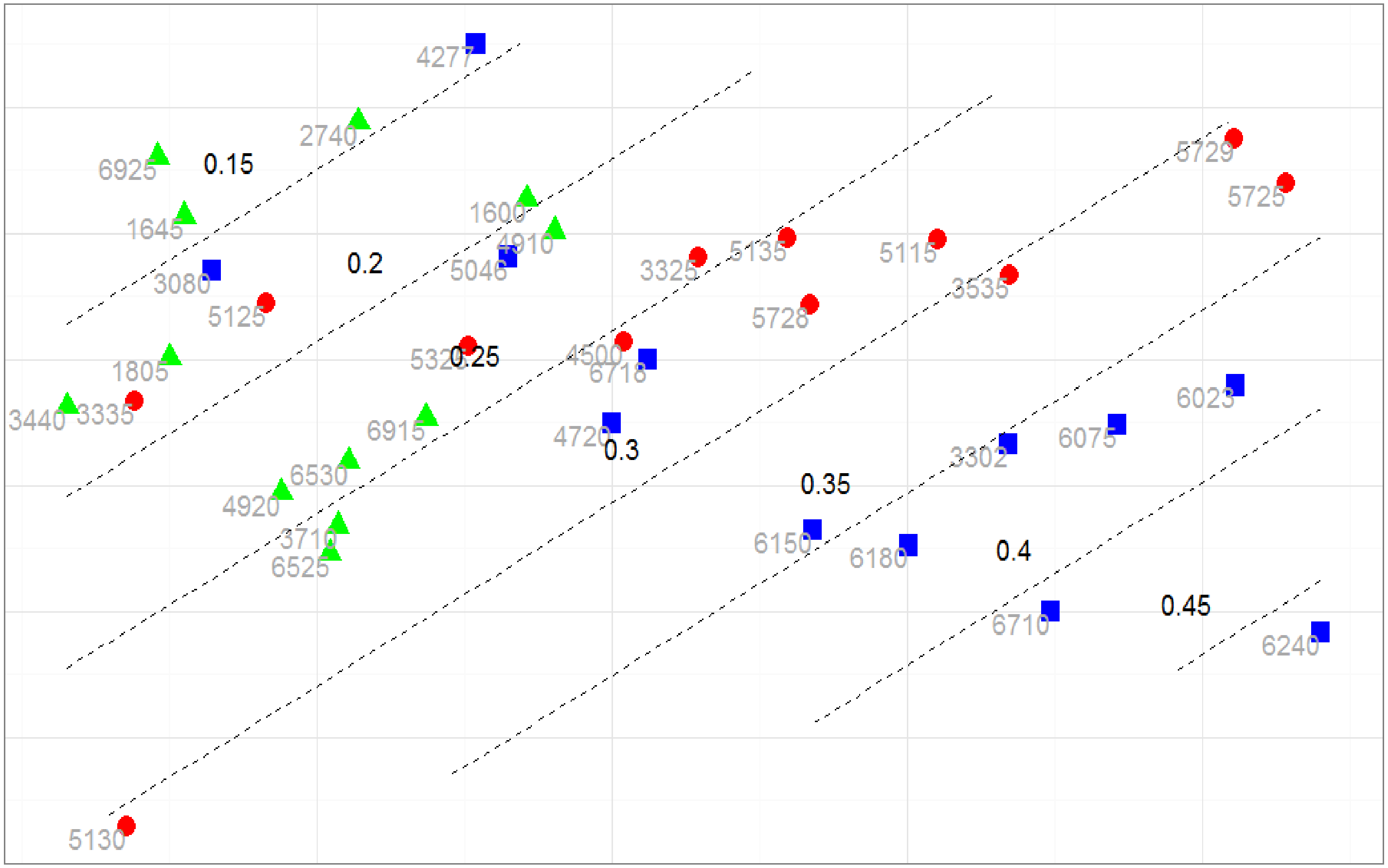

Figure 3-5. Non-metric multidimensional scaling (NMDS) ordination of physical and biological characteristics from 36 Nebraska water bodies surveyed for channel catfish with tandem-set hoop nets during 2008 – 2009 and classified by ecosystem type (blue squares = sand/gravel/barrow/reuse pits, red circles = flood-control reservoirs, and green triangles = irrigation/power generation reservoirs); see Fig. 3-2). Expected growth rate, K, from the von Bertalanffy growth equation (0.15 - 0.45) is fitted as a smooth surface on the first and second dimensions of the NMDS ordination and is represented by the contours derived from a fitted polynomial surface.

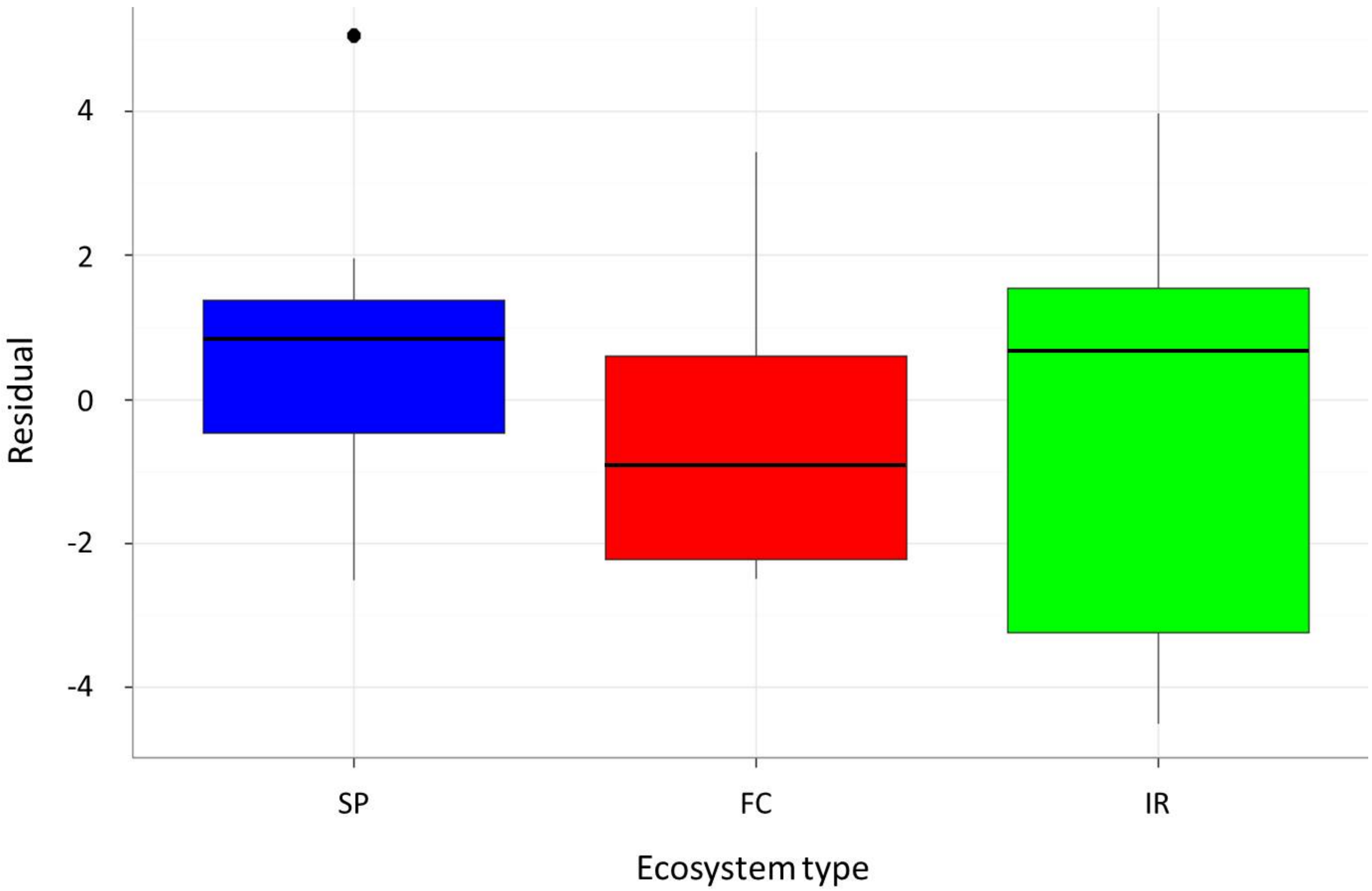

Figure 3-6. Box plots of residuals (observed – expected) of number of year classes present in a population for stock-length (≥280-mm total length) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs).

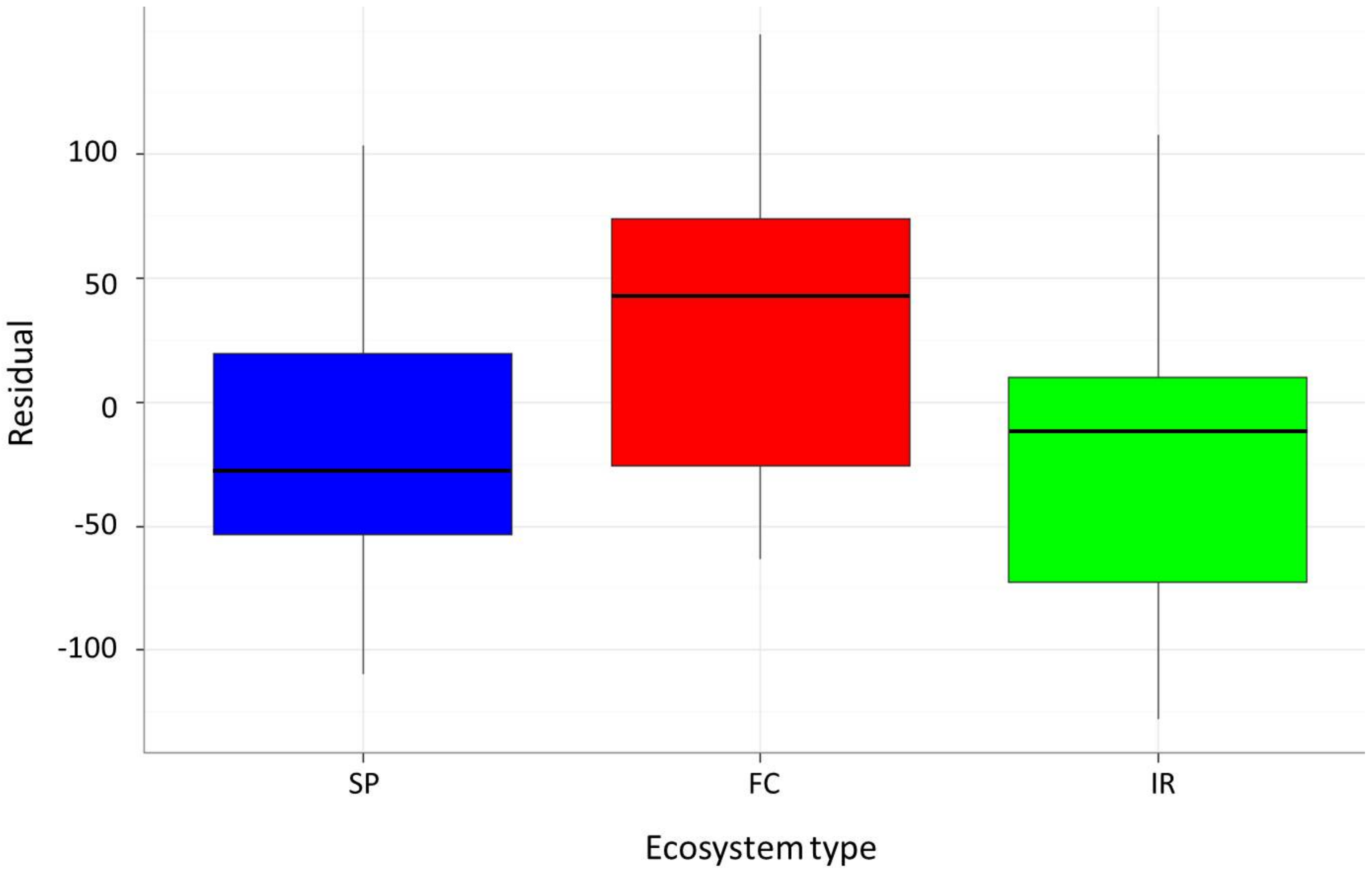

Figure 3-7. Box plots of residuals (observed – expected) of mean back calculated total length (TL, mm) at age 4 for stock-length (≥280-mm TL) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs).

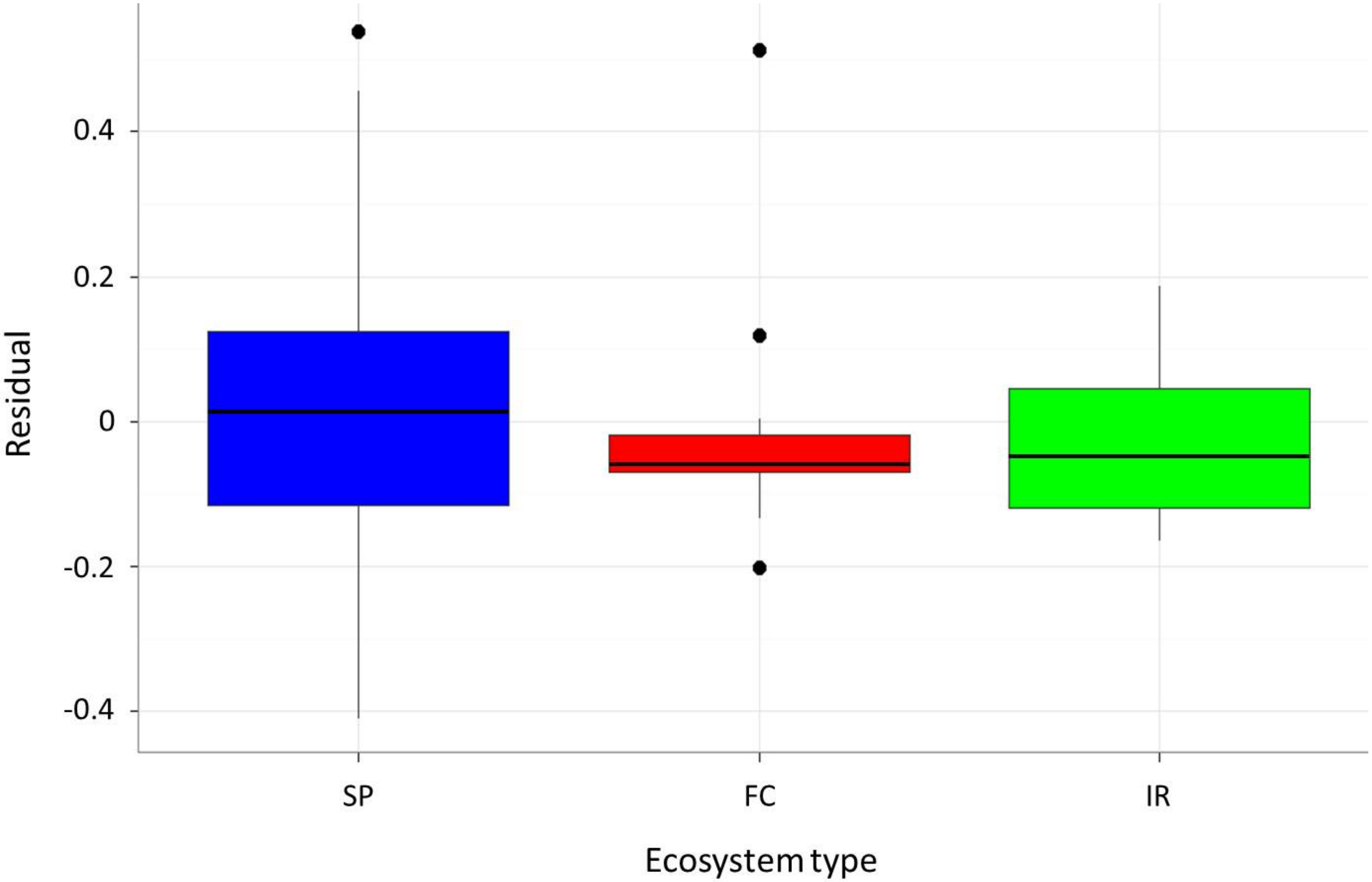

Figure 3-8. Box plots of residuals (observed – expected) of growth rate, K, from the von Bertalanffy growth equation for stock-length (≥280-mm total length) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies classified by ecosystem type (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs).

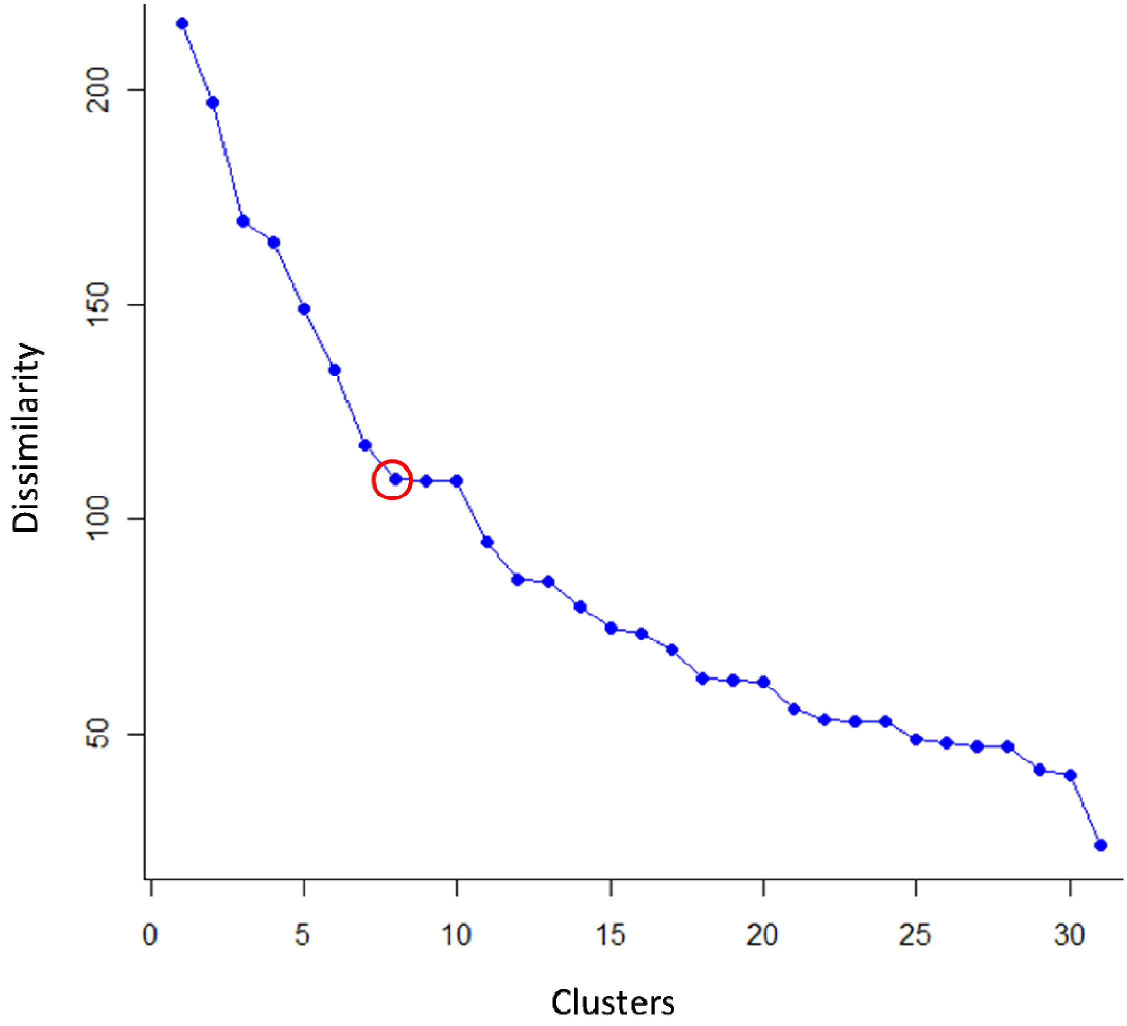

Figure 3-9. A scree plot of the associated dissimilarity for number of clusters in the cluster analysis of population characteristics for stock-length (≥280-mm total length) channel catfish from tandem-set hoop net surveys (2008-2009) of 36 Nebraska water bodies. The red circle indicates the number of clusters chosen for cluster analysis.

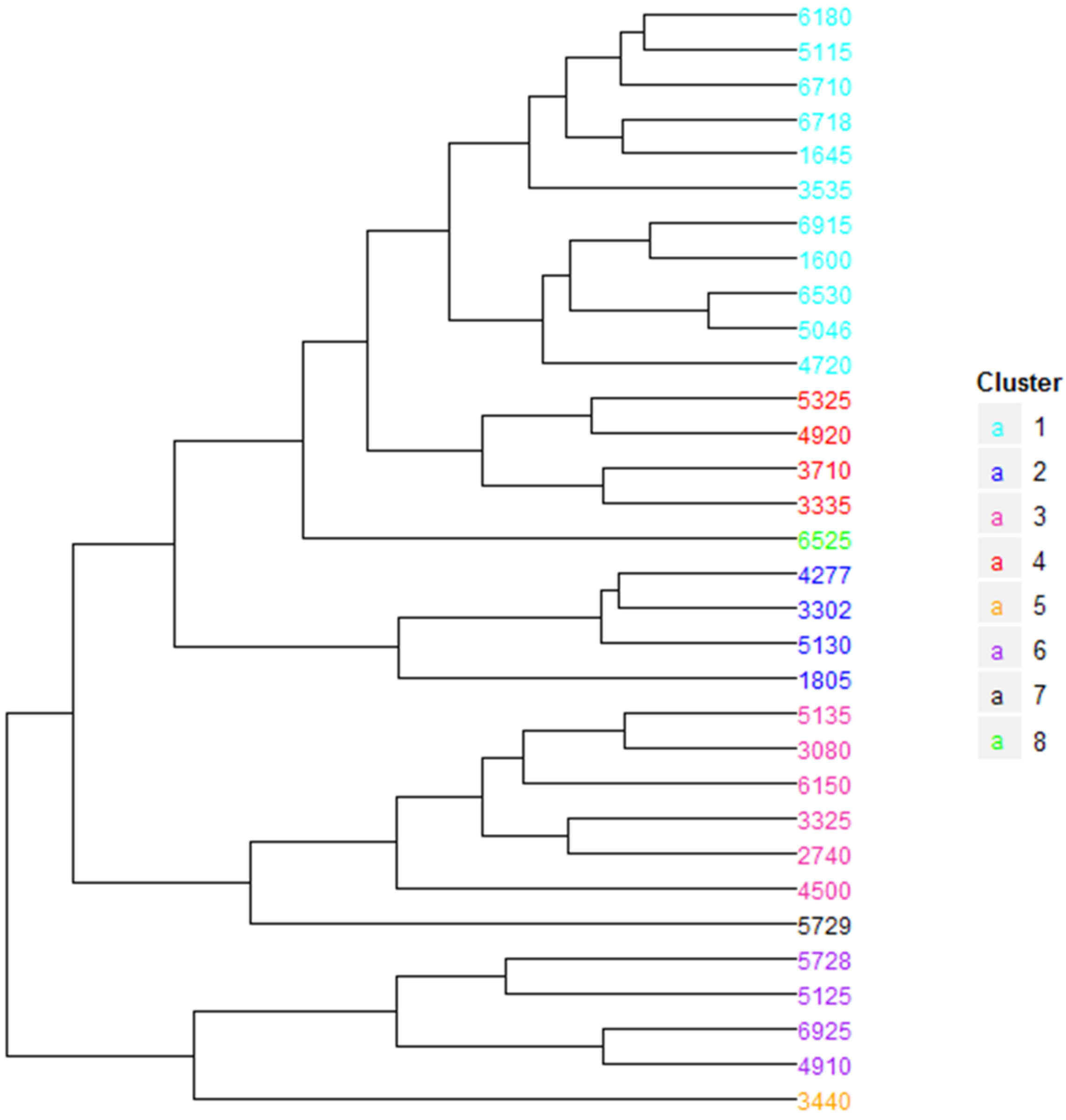

Figure 3-10. Cluster diagram of channel catfish populations from 36 Nebraska water bodies grouped by similarity of population characteristics for stock-length (≥280-mm total length) channel catfish collected during tandem-set hoop net surveys during (2008-2009) (see Table 3-2). Water bodies are identified by the Nebraska Game and Parks Commission identifier code (see Table 3-1) and colors indicate the cluster (1-8) each water body is associated with.

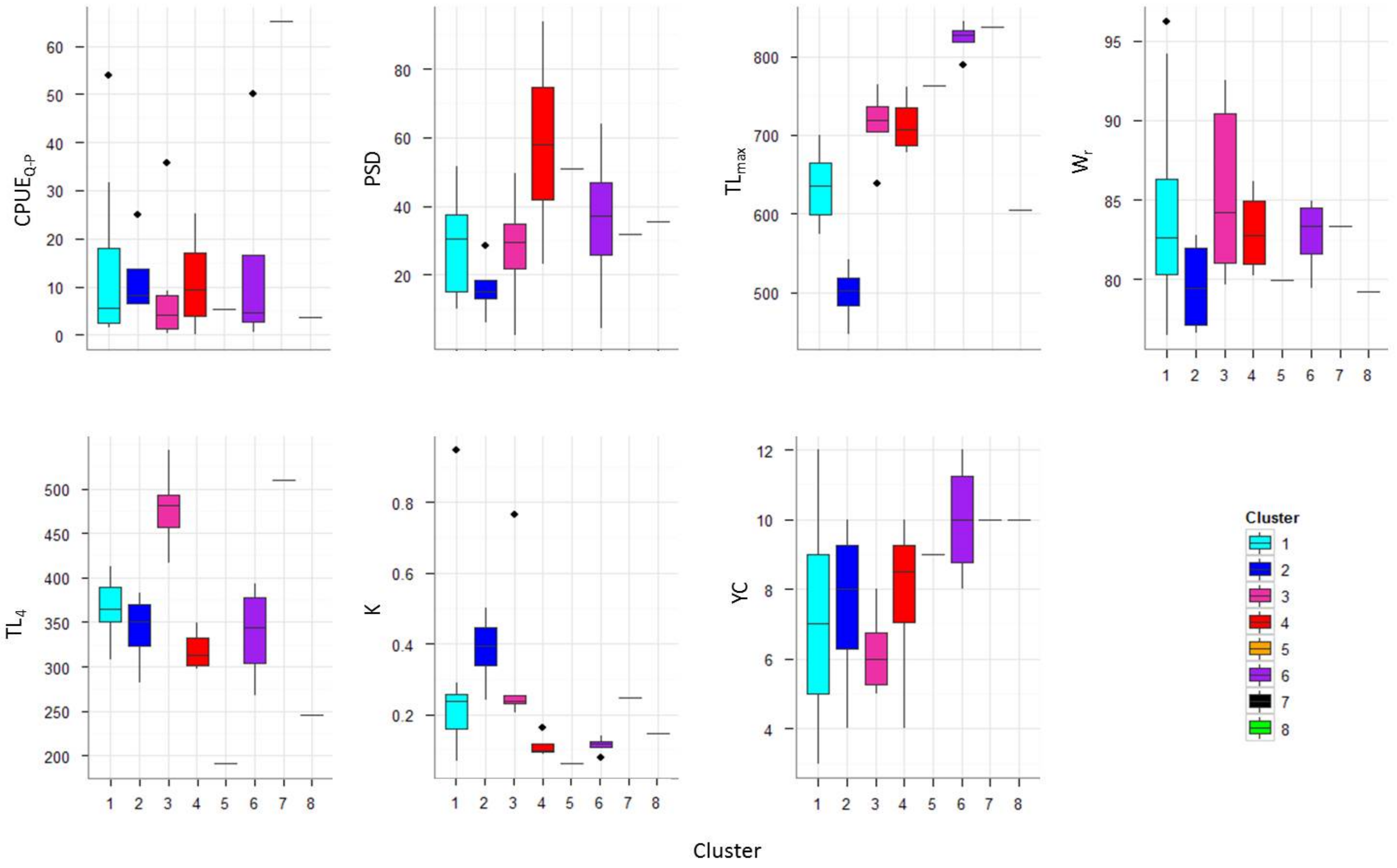

Figure 3-11. Box plots of population characteristics for stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 32 Nebraska water bodies grouped using cluster analysis (see figure 3-10). Characteristics assessed were catch per unit effort (catch per 72-h tandem-set series) for quality- to preferred-length fish (410- to 609-mm TL; CPUE$_{Q-P}$), proportional size distribution (PSD), maximum TL (TL$_{max}$; mm), growth rate (K) from the von Bertalanffy growth model, mean back-calculated length at age-4 (TL$_4$; mm), and the number of year classes present in the population (YC).

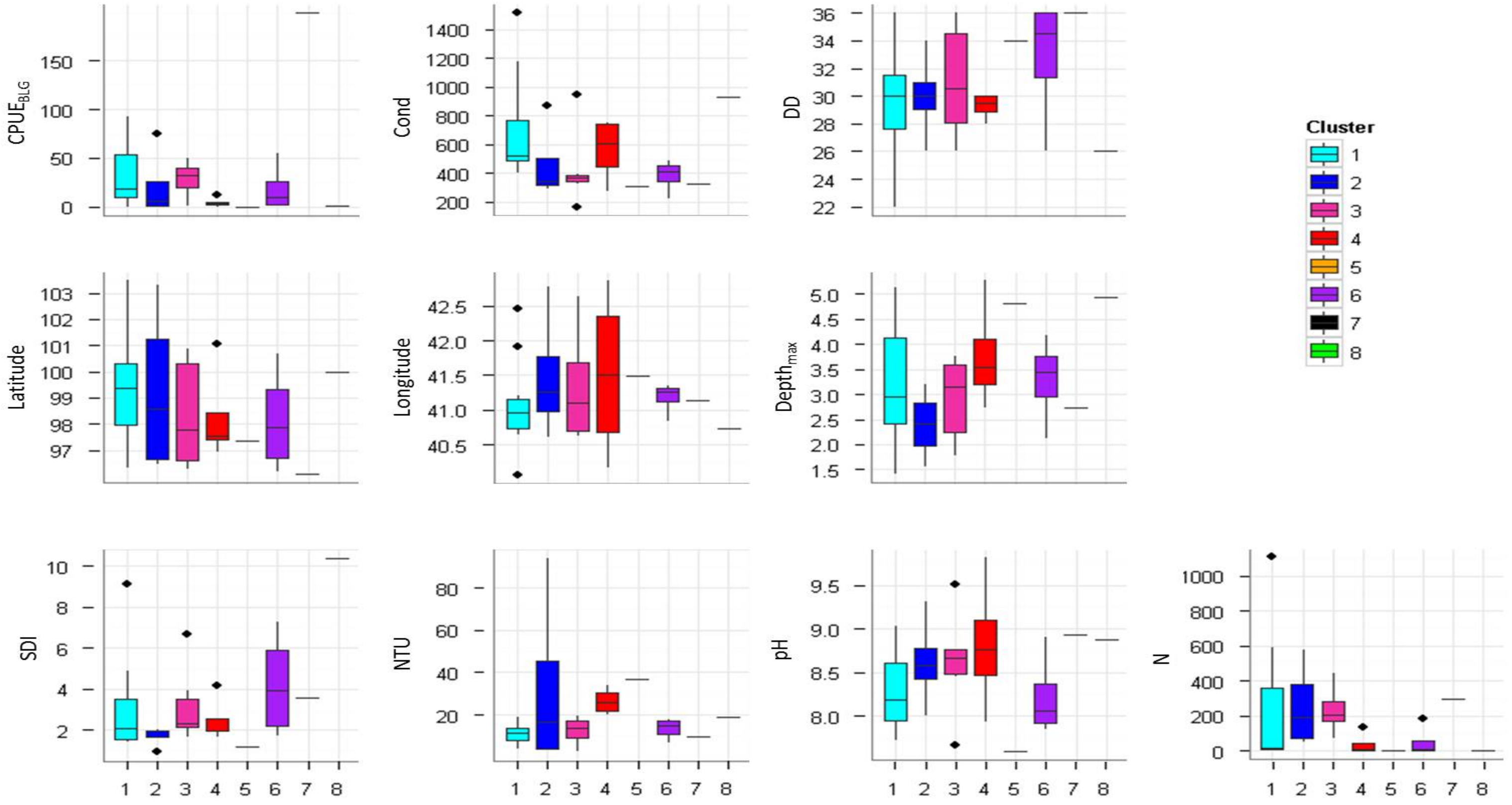

Figure 3-12. Box plots of physical and biological water body characteristics from tandem-set hoop net surveys (2008-2009) of 32 Nebraska water bodies grouped using cluster analysis (see figure 3-10). Biological characteristics assessed were catch per unit effort (catch per 72-h tandem-set series) of bluegill (CPUE$_{BLG}$) and density of channel catfish stocked in 2003-2007 (N; fish/ha). Physical characteristics assessed were pH, Turbidity (nephelometric turbidity units; NTU), conductivity (Cond; µs/cm), growing degree days in January - June (DD), shoreline development index (SDI), maximum depth at which nets were deployed (Depth$_{max}$; m) and location (latitude and longitude; [°]).

CHAPTER 4 – STOCKING EFFECT ON AGE FREQUENCY OF SAMPLED POPULATIONS

Introduction

Little is known of the population dynamics and habitat requirements of channel catfish *Ictalurus punctatus* (Irwin et al. 1999). Additionally, assessment of management strategies can be challenging because channel catfish collections often yield small samples (Michaletz and Dillard 1999), yet accurate assessments of populations are essential in aiding management determination of stocking protocols and fishing regulations. In fact, poor assessments of population indices can lead to management practices that are detrimental to the target population (Hill 1984).

To address this need, we collected data from 36 lentic channel catfish populations (Figure 2-1) in Nebraska during 2008 and 2009 to assess the effects of stocking variability and habitat variability on population structure and dynamics (see Chapters 2 and 3). The influence of habitat variability was assessed by comparing channel catfish populations from three ecosystem types (sand/gravel/barrow/reuse pits, flood-control reservoirs, and irrigation/power-generation reservoirs), as classified by the Nebraska Game and Parks Commission (NGPC), with three stocking strategies (not stocked, infrequently stocked, or frequently stocked). Multivariate analysis indicated that the influence of stocking on abundance and condition of channel catfish populations varied with ecosystem type; however, cluster analysis that considered stocking in terms of density (fish/ha) rather than frequency, did not provide evidence of an association between stocking and channel catfish abundance. It was necessary to exclude some water bodies from multivariate analysis (see Chapter 2) due to insufficient collections of channel catfish, effectively reducing the sample for some combinations of ecosystem type and stocking strategy to two representative water bodies. Small sample sizes may have influenced the outcome of our analyses.

Therefore, to further investigate the influence of stocking on channel catfish populations in Nebraska's lentic systems, using samples collected from the 36 water bodies included in the initial assessment, we compared frequency distribution of catch by age with NGPC stocking reports. Our intent was to determine whether stocking influenced abundance of year classes that coincided with stocking events.

Methods

A single survey was conducted at each of 36 water bodies during July – August of 2008 and 2009 (except when nets yielded a low catch of channel catfish and time permitted, a supplementary survey was conducted to increase sample size for analysis of age and growth). Channel catfish were sampled with tandem-set hoop nets in accordance with methodology established for small impoundments in Missouri and Iowa (Michaletz and Sullivan 2002, Flammang and Schultz 2007, see Chapter 2). Water bodies were categorized using NGPC ecosystem classifications. Twelve water bodies each were representative of sand/gravel/barrow/reuse pits (hereafter referred to as sand pits), flood-control reservoirs, and irrigation/power-generation reservoirs (hereafter referred to as irrigation reservoirs) (see Chapter 2). We further classified water bodies within the ecosystem types based on stocking strategies for channel catfish (see Table 2-1). We defined three stocking strategies: frequently stocked (stocked four or five years during 2003-2007), infrequently stocked (stocked one, two or three years during 2003-2007) and not stocked (stocked zero years during 2003-2007). We did not consider stocking density when determining stocking strategy, however we rated annual stocking events as low density (< 50 fish/ha), high density (>49 and <250/ha), or very high density (> 249/ha). A number of water bodies were stocked at variable rates in 2003-2007 (see Table 2-1).

Data Collection

Total length of channel catfish was recorded to the nearest mm, weight was recorded to the nearest g, and pectoral spines were removed for age determination from up to 10 channel catfish per cm length group. Length group only was noted for all channel catfish captured in excess of 10 per length group. An age length key was developed to correct for subsampling bias (DeVries and Frie 1996) and provide an age structure of all captured channel catfish. Channel catfish spines were aged according to NGPC standard procedure (see Chapter 2), and the Dahl-Lea model (Dahl 1907; Lea 1910; Michaletz et al. 2009) was used to determine back calculated length at age:

$$L_t = L_T \left(\frac{B_t}{B_T}\right)$$

where L_t is the back-calculated length at age t, L_T is the length at the time of capture, B_t is the radius of the bony structure at annulus t, and B_T is the radius of the bony structure at time of capture. Catch curves were developed by plotting age against the natural logarithm (Log_e) of frequency of occurrence. Age groups with a minimum of five representatives were plotted on the curve. Stocking records were retrieved from NGPC for each water body dating back 15 years from the time sampling occurred. Stocking occurrences were then overlaid on the catch for each water body.

Results and Discussion

A total of 3,668 stock-length channel catfish was sampled from single collections at 36 water bodies. Supplemental collections at water bodies where catch was exceptionally low, and collections from water bodies sampled repeatedly for other objectives (see Chapter 5) increased the number of channel catfish sampled by 2,625 (N = 6,293). Data from supplemental collections were used to boost the data sets for analysis of population age structure. Pectoral spines were collected from 3,554 stock-length channel catfish, and 3,298 fish were included in analyses. Age distributions varied widely between and within ecosystem types and stocking strategies (Figure 4-1 – Figure 4-3).

In sand pits, there was scant evidence that stocking influenced the abundance of year classes associated with stocking events (Figure 4-1). For example, at Bassway Strip, age group 3 was a strong presence on the catch curve, but there was no associated stocking event in the year that produced the associated year class. Stocking events occurred for year classes that coincided with age groups 2 and 4, but neither age group was represented on the catch curve. At Pawnee Slough, stocking occurred roughly every other year, yet no age groups were represented on the catch curve, in associated stocked years or otherwise. At Fremont 15 and North Platte 1-80 sand pits, age groups 2, 3, and 4 each had a strong presence on the catch curve, but stocking events occurred only in years that produced associated age groups 2 and 4. There was, however, some evidence that stocking influenced abundance of age groups in sand pits. For example, at Cheyenne, age groups 2 and 3 were represented in the catch curve. A stocking event occurred in the year that associated age group 3 fish were produced, and there was an associated increase in frequency for that age group compared to age group 2, which did not have an associated stocking event.

Likewise, in flood-control reservoirs, there was little evidence of stocking influence (Figure 4-2). Natural recruitment was evident in populations that were not stocked, and stocking events were rarely associated with age-group frequency. For instance, at Wellfleet, age group 3 was represented on the catch curve, but there was no associated stocking event that produced that age group. The reservoir was stocked in years that produced age groups 2 and 4, yet they were not represented on the catch curve. At Walnut Creek, age groups 2 – 9 were represented on the catch curve and frequency decreased linearly with increasing age, yet age groups 6 and 8 were not associated with a stocking event. There was, however, some evidence that stocking influenced abundance of age groups in flood-control reservoirs. At Zorinsky, the catch curve decreased with increasing age for age groups 2 – 6, and age group 3, the only age group not associated with a stocking event, was absent from the curve.

Irrigation reservoirs provided little evidence of stocking influence (Figure 4-3). Natural recruitment was evident in populations that were not stocked, and stocking events were rarely associated with age-group frequency. For example, at Swanson, age groups 4, 5 and 6 were represented in the catch curve. Age group 6, which was not associated with a stocking event, was the strongest presence on the curve. The catch curve at Red Willow, however, did provide evidence of stocking influence. Age groups 2 and 6 were the strongest presence on the catch curve, and stocking occurred in each of the years that produced those associated age groups.

In summary, there was little evidence of a stocking signature on the catch curves for water bodies in any ecosystem type. Likewise, density of stocking did not appear to influence the catch curve. There was evidence of natural reproduction in all three ecosystem types, though less so in sand pits than in flood-control reservoirs and irrigation reservoirs. In roughly one third of water bodies, catch curves were developed from samples of less than 50 fish, and it is questionable that these small samples provided a representative sample of the population. A likely explanation for the absence of some age groups that should have been present in the catch curves is harvest. The apparent lack of influence of stocking on age-frequency distribution of catch strengthens the argument that a measure of exploitation on these systems is necessary to make informed management decisions regarding stocking protocol.

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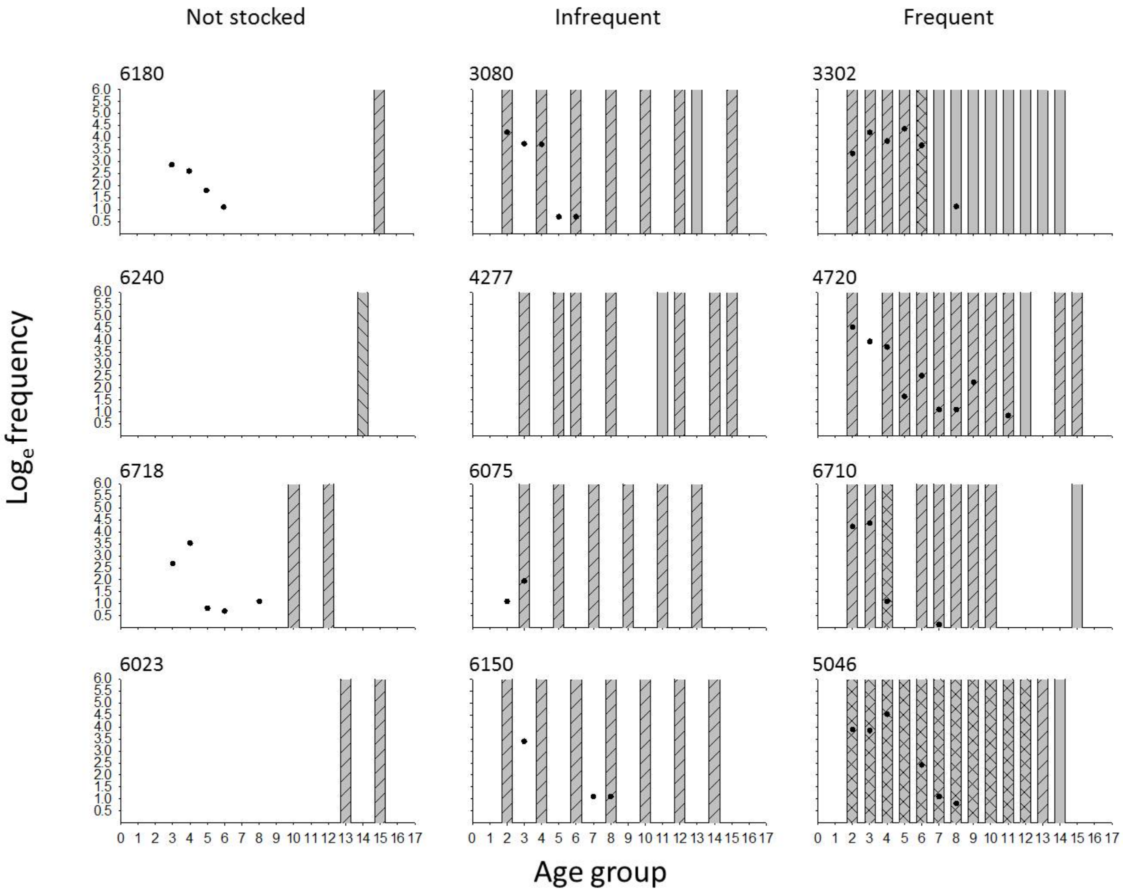

Figure 4-1. Log-transformed (base e) frequency of age class (baseline information needed for a catch curve) for stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 12 Nebraska sand pits (sand/gravel/barrow/reuse pits) classified by stocking strategy (not stocked, infrequently stocked, and frequently stocked). Stocking occurrences and rates (no bar = not stocked, grey bar = low [<50/ha], hatched bar = high [≥50 and <250/ha], cross-hatched bar = very high [≥250/ha]) are indicated for each age group (i.e., associated year class).

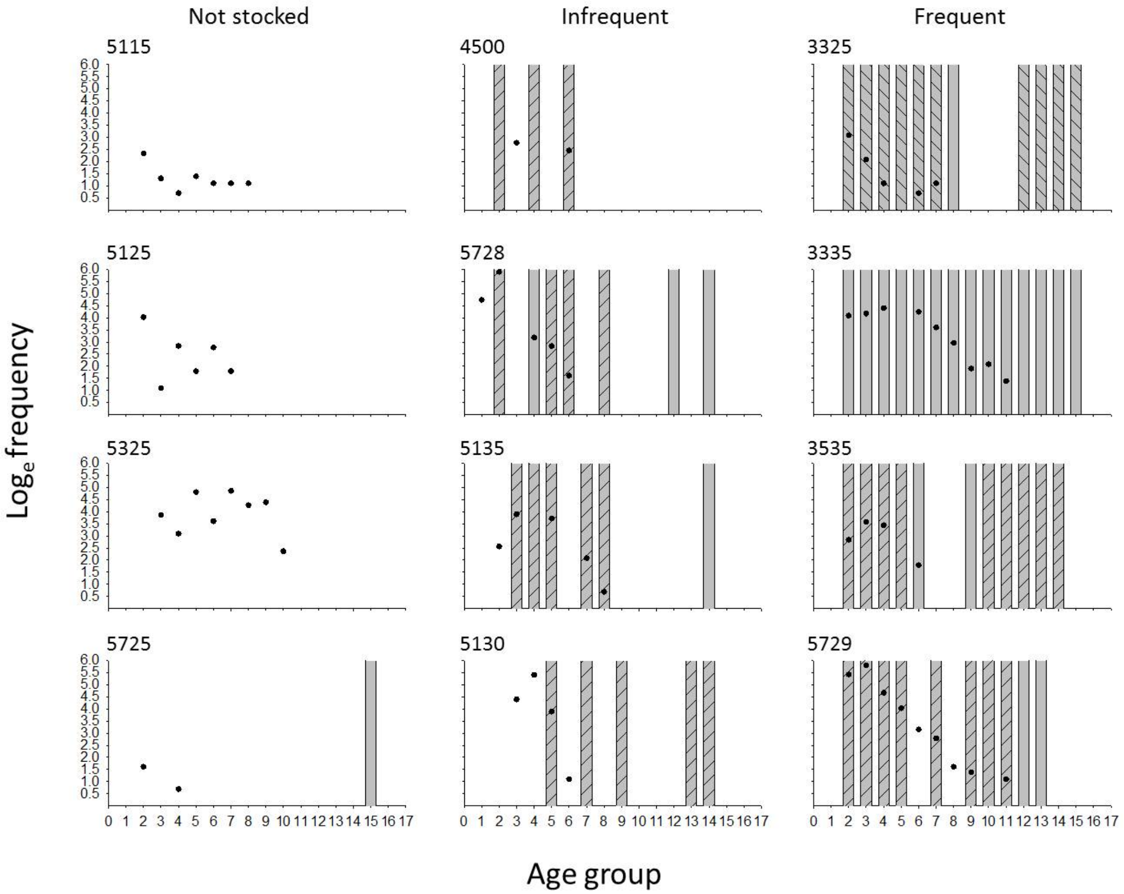

Figure 4-2. Log-transformed (base e) frequency of age group (baseline information needed for a catch curve) for stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 12 Nebraska flood-control reservoirs classified by stocking strategy (not stocked, infrequently stocked, and frequently stocked). Stocking occurrences and rates (no bar = not stocked, grey bar = low [<50/ha], hatched bar = high [≥50 and <250/ha], cross-hatched bar = very high [≥250/ha]) are indicated for each age group (i.e., associated year class).

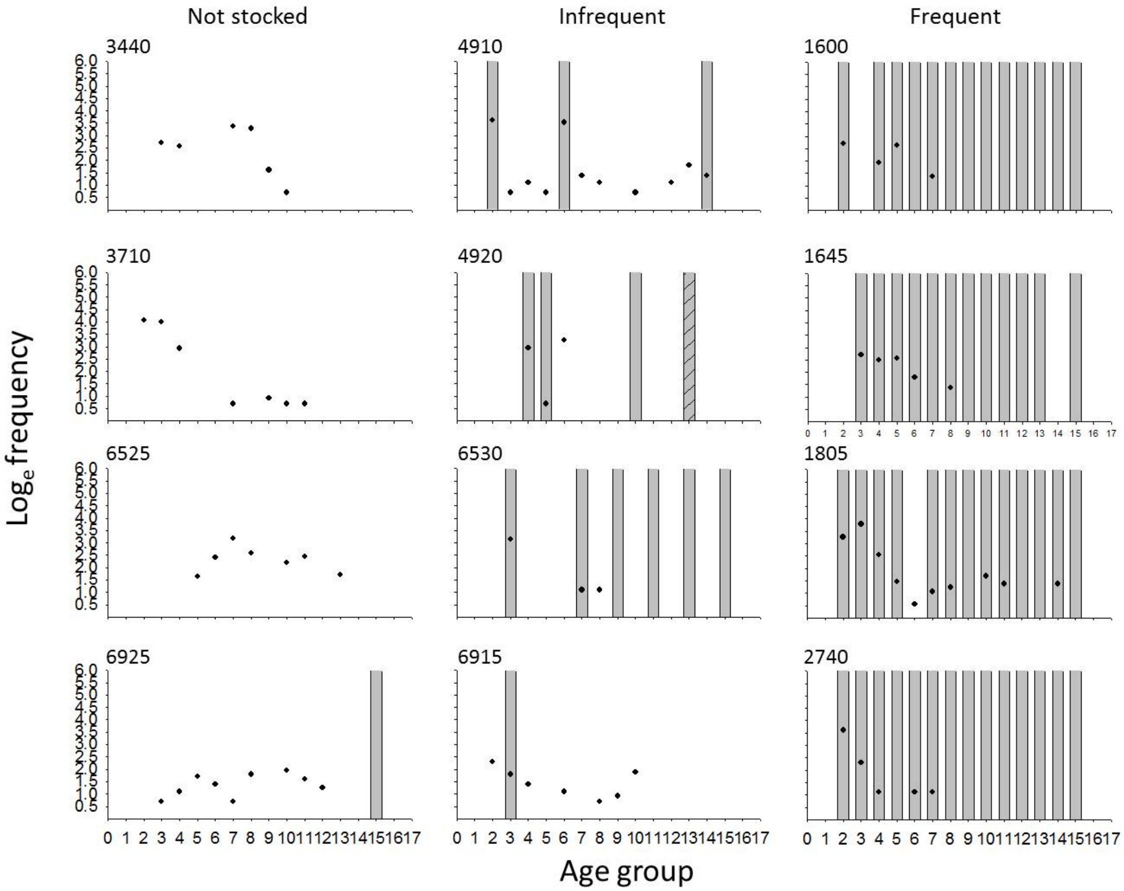

Figure 4-3. Log-transformed (base e) frequency of age group (baseline information needed for a catch curve) for stock-length (≥280-mm total length [TL]) channel catfish from tandem-set hoop net surveys (2008-2009) of 12 Nebraska irrigation/ power-generation reservoirs classified by stocking strategy (not stocked, infrequently stocked, and frequently stocked). Stocking occurrences and rates (no bar = not stocked, grey bar = low [<50/ha], hatched bar = high [≥50 and <250/ha], cross-hatched bar = very high [≥250/ha]) are indicated for each age group (i.e., associated year class).

CHAPTER 5 – SEASONAL COMPARISON OF CATCH OF CHANNEL CATFISH IN TANDEM-SET HOOP NETS

Introduction

Channel catfish *Ictalurus punctatus* are notoriously difficult to sample in lentic systems. Gill nets are the primary sampling method used by most state agencies to sample channel catfish in small impoundments and reservoirs, despite their known size selectivity and low, variable catch rates (Hubert 1983; Michaletz and Dillard 1999). Managers often express a need for more effective sampling methods that will provide adequate data to estimate abundance, size and age structure, and growth rates (Brown 2007; Michaletz and Dillard 1999; Vanderford 1984). Hoop nets have long been utilized to sample catfish in lotic systems, but until recently, showed variable success in lentic systems (Michaletz and Dillard 1999). However, new methods for deployment have been developed in recent years by several Midwest state agencies. Numerous agencies currently recommend the use of baited, tandem-set hoop nets to assess channel catfish populations in small impoundments (Sullivan and Gale 1999; Michaletz and Sullivan 2002; Flammang and Schultz 2007; Mosher et al. 2007; and Buckmeier and Schlechte 2009).

In the past decade, several gear evaluations have been conducted for tandem-set hoop nets in lentic systems. These evaluations considered the influence of sampling season (Flammang and Schultz 2007), hoop net and mesh size (Sullivan and Gale 1999; Flammang and Schultz 2007), length of bridles connecting individual nets (Michaletz and Sullivan 2002), configuration of throat entrance to the cod end (Porath et al. 2011), and type of bait (Flammang and Schultz 2007) on catches of channel catfish. Duration of set varied in early evaluations (2-d or 3-d sets, Sullivan and Gale 1999 and Michaletz and Sullivan 2002, respectively), and a 3-d set duration is now standard amongst agencies using tandem-set hoop nets to sample channel catfish, although Neely and Dumont (2011) recently found that catch was similar in two- and three-night set durations. A sampling protocol based on these evaluations is now the standard for sampling channel catfish with tandem-set hoop nets in Iowa, Kansas, and Missouri; however, there has been little repetition of these evaluations in subsequent studies.

Based on prior gear evaluations and reported successes in capturing large samples of channel catfish, we chose to utilize tandem-set hoop nets in a statewide assessment of channel catfish in Nebraska's standing waters (see Chapter 2). As such, we did not anticipate the need for additional gear evaluations as a component of our study. When we developed protocol for the statewide assessment, we initially proposed a sampling schedule of June – August, when water temperatures exceeded 24^{o}C. However, after June surveys in several water bodies yielded lower than expected catch rates that were highly variable, we modified the sampling schedule to include only the months of July – August, expecting that catch rates in those months would be greater with less variability. Tandem-set hoop nets are utilized in Missouri during May – June (Michaletz and Sullivan 2002) and in Iowa during July – August (Flammang and Schultz 2007). While channel catfish surveys conducted in June are appropriate for Missouri's growing season, we considered that perhaps June was too early to survey channel catfish within Nebraska's relatively shorter growing season. We hypothesized that channel catfish had not yet begun spawning activities in early June in Nebraska reservoirs, thus influencing their catchability with tandem-set hoop nets. Additionally, Flammang and Schultz (2007) reported that size structure of channel catfish captured in tandem-set hoop nets varied between spring (April – early-June) and summer (mid-July – mid-August). We considered that the temporal influence on channel catfish catch in June surveys might differ from mid and late summer surveys (i.e., that June surveys would be better classified as spring surveys). Therefore, we conducted monthly surveys at select water bodies throughout the summer months to determine if a temporal influence within the summer season existed on catches of channel catfish in tandem-set hoop nets.

Methods

Data collection

We selected three reservoirs from water bodies sampled in June 2008 for the statewide population assessment. Reservoirs with initial collections of > 100 channel catfish were given preference, in order to make reliable estimates of size structure (Anderson and Neumann 1996). Additionally, in order to address logistic constraints with sampling, preference was given to reservoirs near Lincoln, Nebraska. Therefore, three flood-control reservoirs (see Chapter 2) were selected for monthly channel catfish collections during the summers of 2008 and 2009.

Surveys were conducted in early-, mid-, and late-summer at Stagecoach Reservoir (79 ha), Walnut Creek Reservoir (28 ha), and East Twin Reservoir (85 ha) in 2008 and 2009. Early-summer collections were conducted in June, and mid-summer collections were conducted in July. In 2008, late-summer collections were conducted in the first week of September, as resources were unavailable in August due to the concurrent statewide population assessment. In 2009, late-summer collections were conducted in August.

Channel catfish were sampled with tandem-set hoop nets in accordance with methodology established for small impoundments in Missouri and Iowa (Michaletz and Sullivan 2002; Flammang and Schultz 2007, see Chapter 2). Total length of channel catfish was recorded to the nearest mm, and weight was recorded to the nearest g. Length group only was noted for all channel catfish captured in excess of 10 per length group. All fish were released after data were collected.

Data analysis

Studies indicate that tandem-set hoop nets do not capture fish < 250 mm in proportion to their abundance (Michaletz and Sullivan 2002; Buckmeier and Schlechte 2009). Accordingly, we chose to consider only stock-length (≥ 280 mm total length [TL]) fish for analyses. Size structure was quantified using proportional size distribution (PSD, Guy et al. 2006), and was calculated as:

$$\mathrm{PSD} = \frac{\#\text{ of quality} - \text{length } (\geq\ 410\text{ mm [TL]}) \text{ fish}}{\#\text{ of stock} - \text{length fish}} * 100,$$

Relative abundance was quantified as catch per unit effort (CPUE) and was calculated as the number of channel catfish caught per 72 h tandem-set net series.

To investigate the temporal influence within season on catch of channel catfish in tandem-set hoop nets, catch data were analyzed separately for each water body. We used pairwise Kolmogorov-Smirnov (K-S) tests to compare length-frequency distributions of channel catfish captured in June, July, and August. Surveys with a minimum total catch of 25 stock-length fish were included in the K-S analysis. We were unable to compare relative abundance amongst months because sample sizes were inadequate (N=3). We chose, instead, to compare the variability of total catch by net amongst months. We used Levene's test for homogeneity of variance to determine if the distribution of catch by net varied amongst months. We then used a chi-square (χ^2) analysis to determine if the frequency of empty nets in each survey differed amongst months. For all tests, 2008 and 2009 data were considered separately. Statistical significance was assumed at $\alpha = 0.05$ for all assessments.

Results

Channel catfish catch

East Twin

During 2008, mean ± SE CPUE for the season was 19.9 ± 3.1 channel catfish, and ranged from 15.3 in mid-summer to 25.6 in late-summer; and during 2009, mean CPUE for the season was 4.3 ± 3.4, and ranged from 0.8 in late-summer to 11.1 in early-summer (Figure 5-1, Table 5-1). During 2008, PSD increased throughout the season, and length-frequency distributions of channel catfish catch differed significantly between early-, mid-, and late-summer surveys (Figure 5-2, Table 5-2). During 2009, we were unable to observe any trends in size structure of catch, because early- and late-summer collections were insufficient (Table 5-1). During 2008, the distribution of catch amongst nine sets did not vary significantly between early-, mid-, and late-summer; and only one set, from the late-summer survey, was empty of channel catfish (Table 5-1). Median catch was 14 channel catfish, and ranged from 0 to 87 per set (Table 5-1). During 2009, however, the distribution of catch varied significantly between surveys (F=3.78, df=2, P=0.0375). Over 50% of sets were empty in both early- and late-summer surveys, and the distribution of empty sets varied significantly between surveys (χ^2=7.94, df=2, P=0.0189). During early-summer 2009, median catch was 5 channel catfish, and ranged from 1 to 41 per set. During mid-summer 2009, median catch was 0 channel catfish, and ranged from 0 to 5 per set. During late-summer 2009, median catch was 0 channel catfish, and ranged from 0 to 2 per set.

Stagecoach

During 2008, mean ± SE CPUE for the season was 13.2 ± 5.8 channel catfish, and ranged from 4 in late-summer to 23.8 in early-summer; and during 2009, mean CPUE for the season was 21.9 ± 8.1 and ranged from 10.6 in late-summer to 37.7 in early-summer (Figure 5-1, Table 5-1).

During 2008, PSD was greatest in mid-summer, but length-frequency distributions of channel catfish catch did not differ significantly between surveys (Figure 5-3, Table 5-2). During 2009, PSD was greatest in late-summer, and length-frequency distribution of channel catfish in the mid-summer survey differed significantly from the early- and late-summer surveys ($P<0.0001$ and $P=0.0473$, respectively), but early- and late- summer distributions did not differ from each other (Figure 5-3, Table 5-2). The distribution of catch amongst nine sets did not vary significantly between surveys in 2008 or 2009, and the number of empty sets did not influence differences in catch rates between surveys. During 2008, median catch was 4 channel catfish, and ranged from 0 to 139 per set (Table 5-1). During 2009, median catch was 12 channel catfish, and ranged from 0 to 208 per set (Table 5-1).

Walnut Creek

During 2008, mean ± SE CPUE for the season was 43 ± 30.1 channel catfish, and ranged from 1.2 in late-summer to 102.8 in mid-summer; and during 2009, mean CPUE for the season was 6.1 ± 4.5, and ranged from 0 in mid-summer to 14.8 in early-summer (Figure 5-1, Table 5-1). During 2008, PSD was similar in early- and mid-summer surveys, but length-frequency distributions of channel catfish catch were significantly different ($D=0.3305$, $P<0.0001$) (Figure 5-4, Table 5-2). We were unable to compare size structure across the entire season because catch was insufficient in the late-summer survey (Table 5-1). During 2009, we were unable to observe any trends in size structure of catch, because mid- and late-summer collections were insufficient (Table 5-1). The distribution of catch amongst six sets did not vary significantly between surveys in 2008, and while there were empty nets in all surveys, the number of empty nets did not influence differences in catch rates between surveys. During 2008, median catch was 2.5 channel catfish, and ranged from 0 to 516 per set (Table 5-1). In 2009, however, the distribution of catch varied significantly between surveys (F=13.51, df=2, P=0.0004). In the mid-summer survey, 100% of nets were empty of channel catfish, whereas 17% of sets were empty in the early- and late- summer surveys. The distribution of empty sets varied significantly between surveys (χ^2=11.25, df=2, P=0.0036). During early-summer 2009, median catch was 10 channel catfish, and ranged from 0 to 34 per set. During late-summer 2009, median catch was 4 channel catfish, and ranged from 0 to 5 per set.

Discussion

Size structure

We were not able to obtain accurate estimates of size structure at East Twin and Walnut Creek during 2009 due to insufficient samples. However, during 2008, length-frequency distributions varied significantly throughout the summer season at both water bodies. Size structure of the catch at Stagecoach was more stable. During 2008, length-frequency distributions were similar across the summer season, and during 2009, the distribution of the mid-summer survey differed when an exceptional number of small fish were captured, but the early- and late-summer surveys were similar. Size structure data was limited in this study and presented conflicting results; however, because length-frequency distributions varied within the summer season in all three water bodies, we suggest that comparisons of size structure using catch from tandem-set hoop nets be made with caution, and that annual surveys be conducted within a narrow time-frame (e.g., within a 30 day window) to minimize potential variability.

Catch rates

Contrary to expectations, there was no evident trend in CPUE as the summer season progressed in any of the three water bodies. We anticipated an increase in catch associated with the warmer temperatures of mid- and late-summer. The 2008 surveys at East Twin, where CPUE was greatest in late-summer, corresponded with our hypothesis that relatively cooler water temperature in early summer negatively influenced channel catfish catch rates. Similarly, the 2009 surveys at Stagecoach supported our hypothesis, where CPUE was greatest in mid-summer. The 2009 surveys at East Twin, however, yielded contradictory results to 2008, where catch rates were greatest in the early-summer survey; expressly, the early-summer survey was the only one with a sufficient sample for size structure estimates (N=100), having greater than 10x the number of fish captured in both mid- and late-summer surveys. Likewise, there was no consistency between years at Stagecoach, where, during 2008, catch rates were greatest in early-summer and decreased as the summer progressed. During 2008 surveys at Walnut Creek, catch rates were similar across the season, whereas during 2009, catch rates were greatest in early-summer and were negligible through the remainder of the season. Thus, catch rates of channel catfish in tandem-set hoop nets vary within the summer season, and the variation in catch is not predictable from year to year. Perhaps trends in catch rates would be apparent with additional years of data; however, from this study, it is apparent that catch rates from tandem-set hoop nets are not an appropriate measure of relative abundance for channel catfish populations in Nebraska’s standing waters.

Overall CPUE from the 18 surveys conducted in this study was 18 channel catfish/net series. This corresponds with the overall CPUE of 17 channel catfish/net series, from 36 surveys conducted in the statewide population assessment (Chapter 2). When compared with similar studies in Iowa and Missouri, however, CPUE in Nebraska water bodies is much lower. In a 2004 study at four small impoundments in Iowa, each sampled 3 times, overall CPUE with soy-baited tandem-set hoop nets was 94 channel catfish/net series (Flammang and Schultz 2007); and in a 2000 study at five small impoundments in Missouri, also sampled three times, overall CPUE with waste cheese-baited tandem-set hoop nets was 59 channel catfish/net series (Michaletz and Sullivan 2002). Moreover, in instances where catch rates were comparable, variability was much greater in Nebraska water bodies. For example, CPUE ± SE from the July 2008 survey at Walnut Creek was 103 ± 83.3, whereas from a survey conducted at Corydon Reservoir, Iowa, CPUE ± SE was 133 ± 26 (Flammang and Schultz 2007), and at Edwin A. Pape Lake, Missouri, CPUE ± SE was 129 ± 28.1 (Michaletz and Sullivan 2002).

The distribution of catch among nets varied between surveys at East Twin and at Walnut Creek during 2009. In each instance, there was a significant difference in the distribution of empty nets within surveys, indicating that the occurrence of empty nets in a survey is the driving factor in the heteroscedasticity of catch. Empty nets were common in this study; in 13 of 18 surveys conducted, at least one set was retrieved completely empty of channel catfish. Fully 20% of the nets retrieved in this study were empty of channel catfish. Results were similar in the statewide population assessment, where 23% of the sets retrieved were empty of channel catfish. Yet, empty nets are a rare occurrence in similar studies (P. Michaletz, Missouri Department of Conservation, personal communication).

Stoner (2004) noted that physical and biological environmental conditions influence a target fish’s activity, feeding motivation, scent detection of bait, searching behavior, and location of natural bait, all of which can influence catch. Factors influencing the greater variability in catch and the greater frequency of empty nets in Nebraska’s channel catfish surveys, relative to surveys conducted in other states, are unknown and outside the scope of this study. Known differences in environmental conditions (e.g., annual precipitation, average temperature, and watershed land use) between Nebraska and other Great Plains states likely influence channel catfish behavior, which may explain some of the variation in catch observed amongst states.

The use of tandem-set hoop nets for standing water surveys was developed primarily in Iowa and Missouri, and both states recommend their utility in channel catfish sampling. Initial surveys with this gear in Nebraska's standing waters indicate that we cannot expect similar results to the successes reported by Iowa and Missouri, due to the high variability of catch. Nebraska is not the only state to experience unsatisfactory results with tandem-set hoop nets. Holley et al. (2009) attempted to use hoop nets to sample channel catfish and blue catfish at Lake Wilson, Alabama, but discontinued their use after two seasons with virtually zero success. However, despite relatively limited success in Nebraska's water bodies, the gear still holds value to fisheries managers. The Nebraska Game and Parks Commission (NGPC) currently utilizes experimental gill nets set during autumn as the standard sampling methodology for channel catfish. The statewide median catch from 1994 to 2006 NGPC standard survey data for channel catfish is 21 fish/survey (generally consisting of four net-nights). The median catch from the 18 surveys conducted in this study was 103 fish/survey (generally consisting of 9 tandem-set series fished for 72-hr). Tandem-set hoop nets have the potential to capture channel catfish in much greater numbers than do gill nets, thus allowing fisheries managers to make more accurate assessments of populations than currently possible with data collected from gill nets.

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Table 5-1. Mean ± SE catch per unit effort (catch per 72-h tandem-set series) and catches of channel catfish by tandem-set hoop nets (N_1 through N_6 or N_9 and cumulative [N_{Total}]) from three Nebraska flood-control reservoirs during early (June), mid (July), and late (August/early September) summer 2008 and 2009.

			Tandem-set series								
Year	Reservoir	Period	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9
2008	East Twin										
		Early	15	23	23	2	27	11	9	43	14
		Mid	5	1	34	5	36	8	14	29	6
		Late	34	13	2	87	0	48	1	45	2
2009	East Twin										
		Early	8	31	3	41	5	1	1	8	2
		Mid	1	0	5	0	0	1	2	0	0
		Late	2	2	0	0	0	0	2	0	1
2008	Stagecoach										
		Early	2	3	0	33	26	7	4	0	139
		Mid	2	5	16	2	16	20	26	19	0
		Late	4	1	4	5	5	3	0	10	4
2009	Stagecoach										
		Early	18	17	4	42	10	3	27	15	37
		Mid	15	2	208	0	5	19	6	5	79
		Late	7	20	20	3	4	12	7	2	20
2008	Walnut Creek										
		Early	6	3	129	2	11	0			
		Mid	0	20	12	0	516	68			
		Late	3	1	1	2	0	0			
2009	Walnut Creek										
		Early	32	3	0	3	34	17			
		Mid	0	0	0	0	0	0			
		Late	0	2	4	5	4	5			

Table 5-1. Continued.

Year	Reservoir	Period	N_{Total}	CPUE	SE_{CPUE}
2008	East Twin				
		Early	167	18.6	4.0
		Mid	138	15.3	4.6
		Late	232	25.8	10.0
2009	East Twin				
		Early	100	11.1	4.9
		Mid	9	1.0	0.6
		Late	7	0.8	0.3
2008	Stagecoach				
		Early	214	23.8	14.9
		Mid	106	11.8	3.2
		Late	36	4.0	0.9
2009	Stagecoach				
		Early	173	17.4	4.2
		Mid	339	37.7	22.8
		Late	95	10.6	2.6
2008	Walnut Creek				
		Early	151	25.2	20.8
		Mid	616	102.7	83.3
		Late	7	1.2	0.5
2009	Walnut Creek				
		Early	89	14.8	6.2
		Mid	0	0.0	0.0
		Late	20	3.3	0.8

Table 5-2. Summary statistics from pairwise Kolmogorov-Smirnov tests of length-frequency distribution of stock-length (≥280-mm total length) channel catfish from tandem-set hoop net surveys from three Nebraska flood-control reservoirs during early (June), mid (July), and late (August/early September) summer 2008 and 2009. Statistical significance was assumed at $\alpha = 0.05$ and significant differences are indicated with an asterisk.

Year	Reservoir	Comparison	D-value	P-value	
2008	East Twin				
		early:mid	0.1630	0.0360	*
		mid:late	0.3349	0.0006	*
		early:late	0.2160	< 0.0001	*
2008	Stagecoach				
		early:mid	0.1488	0.0865	
		mid:late	0.2128	0.1753	
		early:late	0.1083	0.8630	
2009	Stagecoach				
		early:mid	0.3020	< 0.0001	*
		mid:late	0.1589	0.0473	*
		early:late	0.1521	0.1173	
2008	Walnut Creek				
		early:mid	0.3305	< 0.0001	*

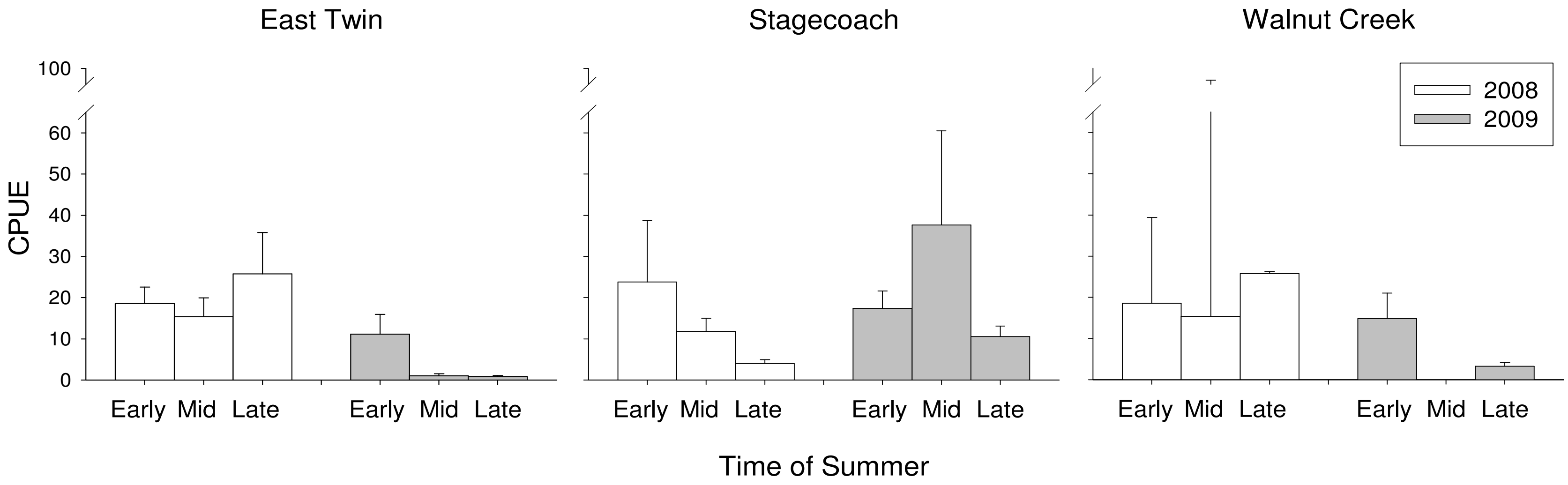

Figure 5-1. Mean ± SE catch per unit effort (catch per 72-h tandem-set series) of channel catfish by tandem-set hoop nets from three Nebraska flood-control reservoirs during early (June), mid (July), and late (August/early September) summer 2008 and 2009.

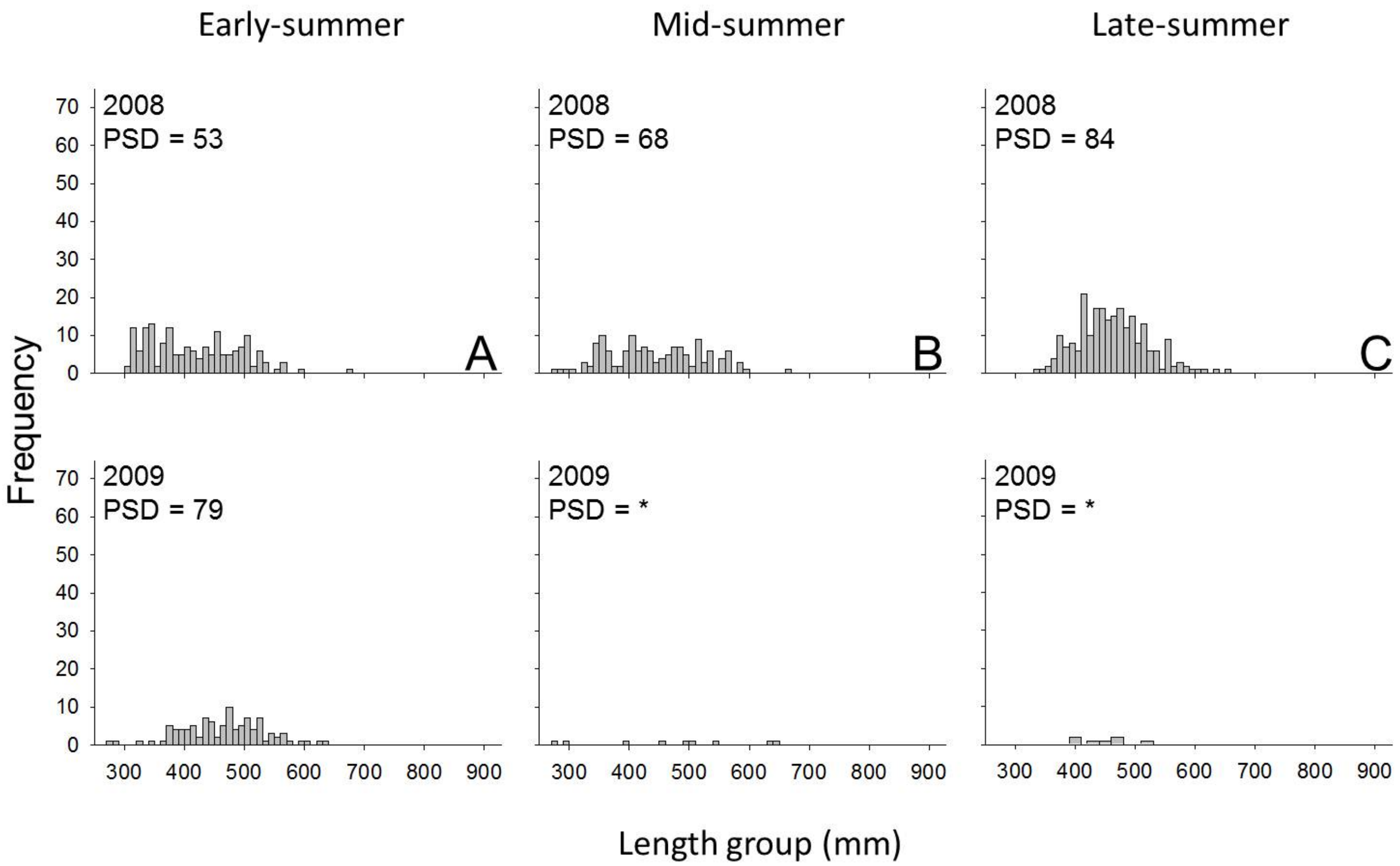

Figure 5-2. Length-frequency distributions of stock-length (≥280-mm total length) channel catfish captured with tandem-set hoop net surveys from East Twin Reservoir during early-(June), mid-(July), and late-(August/early September) summer 2008 and 2009. For 2008 surveys, length-frequency distributions with different letters are significantly different (Kolmogorov-Smirnov [K-S] test, α = 0.05). Surveys with a minimum total catch (N) of 25 stock-length fish were included in K-S analysis. Proportional size distribution (PSD) was calculated for each survey where N ≥ 25 (*indicates N < 25).

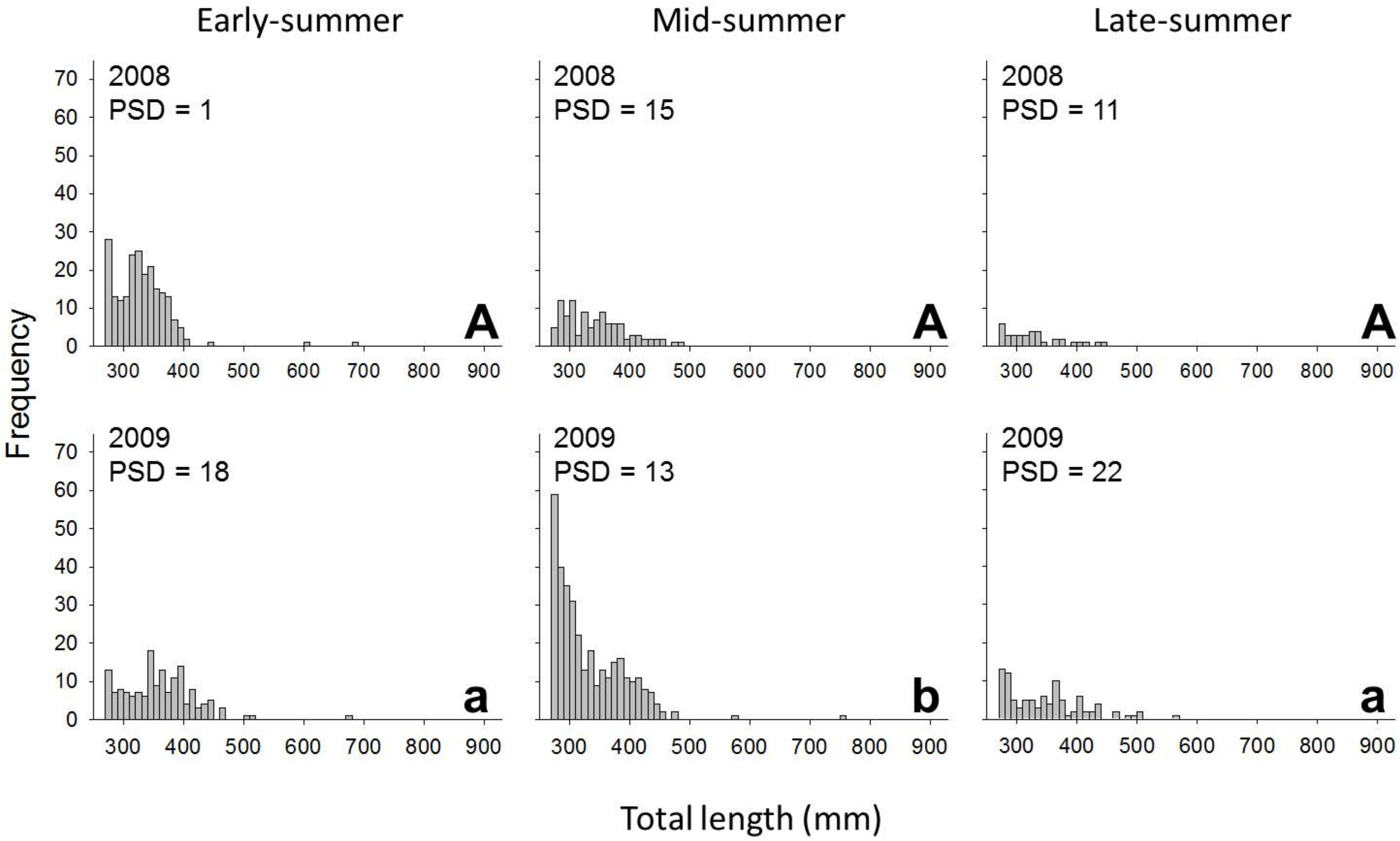

Figure 5-3. Length-frequency distributions of stock-length (≥280-mm total length) channel catfish captured with tandem-set hoop net surveys from Stagecoach Reservoir during early-(June), mid-(July), and late-(August/early September) summer 2008 and 2009. For each year, length-frequency distributions with different letters are significantly different (Kolmogorov-Smirnov [K-S] test, α = 0.05). Surveys with a minimum total catch (N) of 25 stock-length fish were included in K-S analysis. Proportional size distribution (PSD) was calculated for each survey where N ≥ 25.

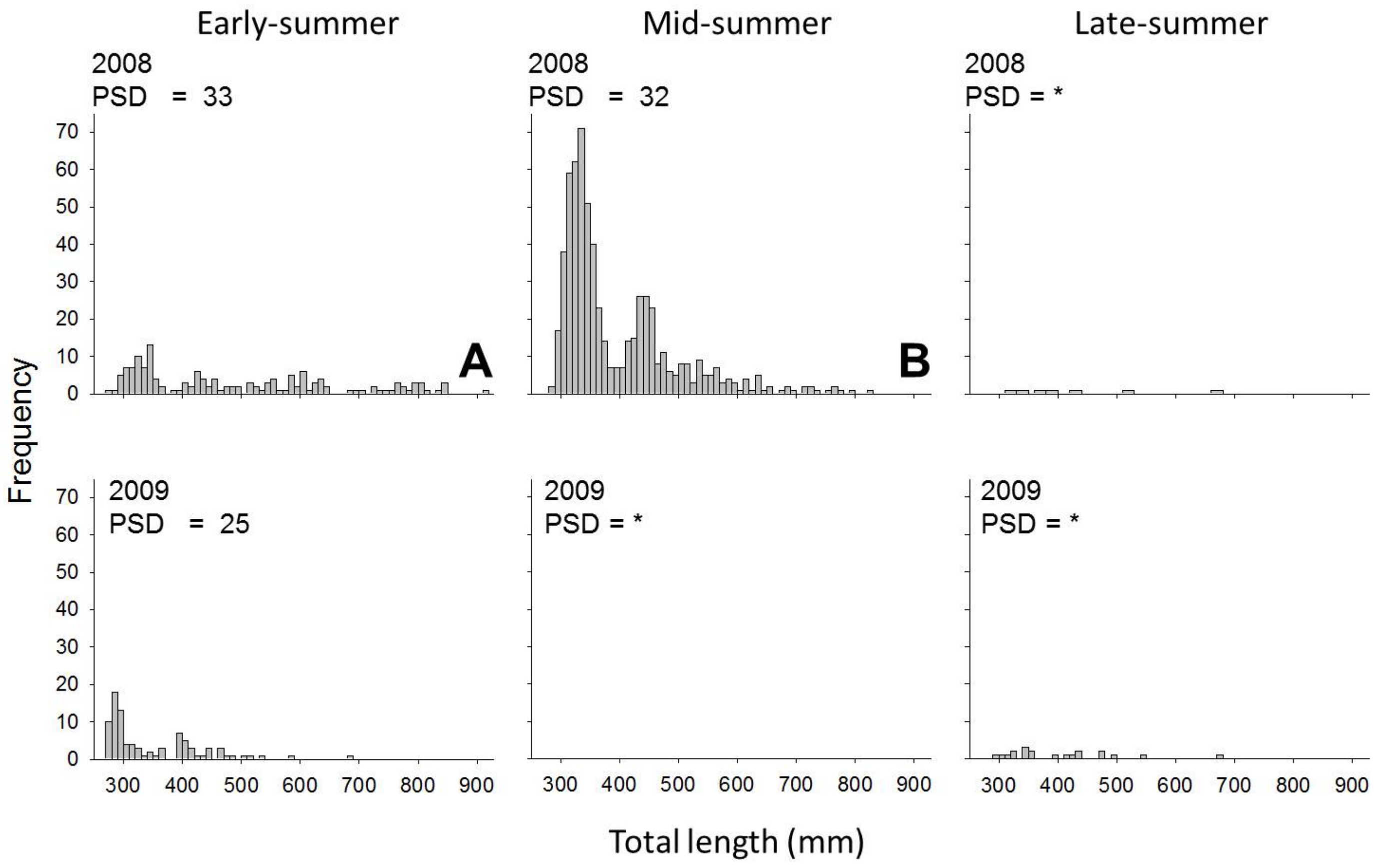

Figure 5-4. Length-frequency distributions of stock-length (≥280-mm total length) channel catfish captured with tandem-set hoop net surveys from Walnut Creek Reservoir during early-(June), mid-(July), and late-(August/early September) summer 2008 and 2009. For 2008, length-frequency distributions with different letters are significantly different (Kolmogorov-Smirnov [K-S] test, α = 0.05). Surveys with a minimum total catch (N) of 25 stock-length fish were included in K-S analysis. Proportional size distribution (PSD) was calculated for each survey where N ≥ 25.

CHAPTER 6 – COMPARISON OF CATCH FROM TANDEM-SET HOOP NETS AND EXPERIMENTAL GILL NETS

This chapter has been published in *Conservation, ecology, and management of worldwide catfish populations and habitats: the second international symposium* *with the following citation:*

Richters, L. K., and K. L. Pope. Pages 573-580 *in* P. H. Michaletz and V.H. Travnichek, editors. Conservation, ecology, and management of worldwide catfish populations and habitats: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Introduction

Channel catfish *Ictalurus punctatus* are notoriously difficult to sample in lentic systems. Gill nets are the primary sampling method used by state agencies to sample channel catfish in small impoundments and reservoirs, despite their known size selectivity and low, variable catch rates (Hubert 1983; Michaletz and Dillard 1999). Managers often express a need for more effective sampling methods that will provide adequate data to estimate abundance, size and age structure, and growth rates (Brown 2007; Michaletz and Dillard 1999; Vanderford 1984).

Recently, several Midwest agencies recommended the use of baited, tandem-set hoop nets to assess channel catfish populations in small impoundments (Sullivan and Gale 1999; Michaletz and Sullivan 2002; Flammang and Schultz 2007). Sullivan and Gale (1999) reported tandem-set hoop nets fished for 48 h yielded catch rates that were 5.6 times greater than experimental gill nets when catch rates were compared based on personnel-hours invested. Michaletz and Sullivan (2002) reported in a 2001 survey of 66 small impoundments in Missouri tha t a tandem-set hoop net series consisting of three nets, baited with waste cheese and fished for 72 h, captured an average of about 90 channel catfish. Similarly, Flammang and Schultz (2007) report that tandem-set hoop nets captured an average of about 100 channel catfish/series in summer surveys of 72 h duration using nets baited with soybean cake.

Though tandem-set hoop nets can be effective at capturing large quantities of channel catfish in small impoundments, there remains uncertainty as to their ability to capture fish in large standing waters. Our intent was to determine if similar trends existed for catch rates of channel catfish between tandem-set hoop nets and experimental gill nets fished in Nebraska's small and large standing waters. Additionally, we intended to determine whether size structure of captured fish differed between gears.

Methods

Channel catfish were collected during 2008 and 2009 from 26 water bodies using tandem-set hoop nets and experimental gill nets. Water bodies were classified as small ($\leq$ 200 ha) or large (> 200 ha) standing waters (Bonar et al. 2009). A single survey was conducted with each gear at 14 small standing waters and 12 large standing waters (Table 6-1). Small standing waters included flood-control reservoirs and excavated pits. Small flood-control impoundments are characterized by relatively shallow depths and restricted limnetic zones, whereas excavated pits are characterized by narrow littoral zones and steep sloping banks (Pope et al. 2009). Large standing waters included irrigation reservoirs and flood-control reservoirs, and are characterized by having two distinct environments, the littoral and limnetic zones (Miranda and Boxrucker 2009), and by relatively cooler summer temperatures than small standing waters (Pope et al. 2009). Irrigation reservoirs experience seasonal fluctuations in water levels, whereas flood-control reservoirs maintain relatively stable water levels.

Tandem-set hoop nets

Tandem-set hoop net surveys were conducted during June – August in accordance with methodology established for small impoundments in Missouri and Iowa (Michaletz and Sullivan

2002, Flammang and Schultz 2007). Tandem-set hoop nets consisted of three nets, attached bridle to cod end, an anchor, and two weights. A 6.8-kg winged anchor was attached to the rear net, and a 4.5-kg concrete weight was attached between the front and middle nets to reduce buoyancy. An additional 4.5-kg weight was attached to the bridle of the front net to prevent the series from collapsing. Nets were baited with soybean cake pellets as a fish attractant (Flammang and Schultz 2007). Hoop nets measured approximately 3.4-m in length and were constructed of #15 twine with 25.4-mm bar mesh and seven fiberglass hoops, the largest of which was 0.8-m in diameter and equipped with a bridle of 1-m rope. Two-fingered crow foot throats were attached to the second and fourth hoops. To reduce escapement from the cod end, the rear throat was constricted with plastic zip ties (Porath et al. 2011). Nets were set parallel to the shoreline along a constant depth profile, above the thermocline and at a depth of 1-6 m. Orientation of net mouths was randomly determined (uplake or downlake) for each set. Using existing bathymetric maps or aerial photographs, sampling sites were randomly selected from points marked at 200-foot intervals along the perimeter of the water body. Randomly selected sites that proved to have steep slopes, heavy vegetation, or significant development (i.e. boat docks or swimming beaches) were substituted with more appropriate, randomly selected sites. The number of tandem sets employed on a water body was determined by size of water body: four for water bodies ≤ 20 ha, six for water bodies > 20 and ≤ 60 ha, and eight or nine for water bodies >60 ha. Tandem-set hoop nets (hereafter referred to as hoop nets) were fished undisturbed for three consecutive nights (approximately 72 h).

Experimental gill nets

Experimental gill net surveys were completed during September – October, in accordance with Nebraska's standardized sampling protocol. Where available, sample sites were selected from Nebraska Game and Parks Commission (NGPC) standard survey locations (Zuerlein and Taylor 1985). Site selection by NGPC was intended to maximize catch of target species, often walleye. For water bodies that lacked standardized sampling sites for gill nets, sites were selected in open water areas with depths and benthic topography suitable for gill net deployment (Hubert 1983). Experimental gill nets were fished on the bottom, set perpendicular to shore, and oriented with the smallest mesh near-shore. Gill nets surveys were conducted after waters destratified, therefore thermocline was not a consideration in gill net placement. Nets were constructed from monofilament webbing; dimensions were 45 x 1.8 m with 9-m panels of 13-mm, 19-mm, 25-mm, 32-mm, and 38-mm bar measure mesh sizes. Gill net surveys consisted of four nets per water body, in accordance with Nebraska standards. Experimental gill nets (hereafter referred to as gill nets) were fished undisturbed overnight (approximately 24 h).

Analysis

For hoop net and gill net surveys, total length (nearest mm) was measured for all fish captured. Studies indicate that tandem-set hoop nets do not capture fish < 250 mm in proportion to their abundance (Michaletz and Sullivan 2002; Buckmeier and Schlechte 2009). Accordingly, we chose to consider only stock-length fish for gear comparison. Minimum total lengths of channel catfish for stock– (S), quality– (Q), preferred– (P), and memorable– (M) lengths are 280, 410, 610, and 710 mm, respectively (Gabelhouse 1984).

Catch per unit effort (CPUE; number per net-night) was calculated as the number of channel catfish caught per 72 h tandem-series for hoop nets and per 24 h net set for gill nets. Pearson’s correlation was used to determine whether there was a relationship in catch rates of channel catfish sampled in hoop nets and gill nets for each ecosystem type. We used analysis of variance (ANOVA) to compare catch rates between ecosystem types for both gears. For this analysis, CPUE was log transformed to better meet the assumptions of normality and homogeneity of variances. Statistical significance was assumed at $\alpha = 0.05$ for all assessments.

To quantify gear efficiency, we used CPUE from each survey to determine the effort required to capture 100 channel catfish (E_{100}). In order to calculate an E_{100} value in instances where CPUE was zero, we added 1 to the total catch at each water body. We then recalculated CPUE and divided that estimate into 100 to calculate E_{100} for each water body. We chose an effort threshold of 100 fish based on Anderson and Neumann's (1996) recommendation that a sample of ≥ 100 fish is optimal for estimating proportional size distribution (PSD). Pearson's correlation was used to determine whether there was a relationship in the number of net-nights required to capture ≥ 100 channel catfish in hoop nets and gill nets.

Size structure was quantified using PSD, PSD of P-length fish (PSD-P), and PSD of M-length fish (PSD-M) (Guy et al. 2006). Channel catfish catch in gill nets was insufficient for PSD estimation (< 100) in all 26 surveys, and channel catfish catch in hoop nets was insufficient in 21 of 26 surveys. Therefore, PSD, PSD-P, and PSD-M were calculated for water bodies where total catch exceeded 25 channel catfish (Table 6-1). A Kolmogorov-Smirnov (K-S) test was used to compare length frequency distribution between gears in four water bodies (Harlan Co., Sherman, Stagecoach, and Wagon Train) where total catch exceeded 25 channel catfish in both hoop net and gill net surveys.

Results

Catch rates

Catch per unit effort of channel catfish was greater in hoop nets than gill nets for 21 of 26 water bodies (Figure 6-1). Amongst ecosystem types, channel catfish CPUE in hoop nets did not differ significantly between small and large standing waters (ANOVA, $F = 0.23$; df = 1,24; $P =$

0.63). Mean ± SE CPUE in hoop nets was 13.9 ± 3.5. Similarly, channel catfish CPUE in gill nets did not differ significantly between small and large standing waters ($F = 0.27$; df = 1,24; $P = 0.61$). Mean ± SE CPUE in gill nets was 3.8 ± 0.8. The CPUE of channel catfish in hoop nets was not correlated with CPUE in gill nets in small ($r = 0.17$; $N = 14$; $P = 0.57$) or large ($r = -0.28$; $N = 12$; $P = 0.39$) standing waters.

Gear efficiency

In small standing waters, median E_{100} values were 9 for channel catfish in hoop nets (25% quartile = 4 and 75% quartile = 81) and 32 in gill nets (25% quartile = 19 and 75% quartile = 100). In large standing waters, median E_{100} values were 21 for channel catfish in hoop nets (25% quartile = 13 and 75% quartile = 25) and 28 in gill nets (25% quartile = 14 and 75% quartile = 250). The E_{100} value ranged from 2-100 for channel catfish in hoop nets, and from 7-400 in gill nets (Table 6-2). The E_{100} values of channel catfish in hoop nets and in gill nets were not correlated in small ($r = 0.51$; $N = 14$; $P = 0.06$) or large ($r = -0.23$; $N = 12$; $P = 0.47$) standing waters. Hoop nets were more efficient (i.e., the E_{100} value was less) in 20 of 26 water bodies, and gill nets were more efficient in 5 of 26 water bodies. In most instances, efficiency values did not differ greatly between gears; however, in five of 26 water bodies, hoop nets greatly outperformed gill nets (i.e., E_{100} of channel catfish in gill nets was 10-200 times greater than in hoop nets) (Table 6-2, Figure 6-2).

Size structure

Length frequency distributions were estimated for channel catfish from Harlan County, Sherman, Stagecoach, and Wagon Train reservoirs, and were significantly different between gears ($P < 0.03$) at each water body (Figure 6-3). In small standing waters, PSD was greater for channel catfish in gill nets than hoop nets at both Wagon Train and Stagecoach Reservoirs (PSD_{gill} = 91; PSD_{hoop} = 59 and PSD_{gill} = 8; PSD_{hoop} = 2, respectively). In large standing waters, PSD for channel catfish was greater in gill nets than hoop nets at Harlan County Reservoir (PSD_{gill} = 71; PSD_{hoop} = 23), and was greater in hoop nets than gill nets at Sherman Reservoir (PSD_{gill} = 31; PSD_{hoop} = 85) (Table 6-1).

Discussion

In 20 of 26 surveys, hoop nets were more efficient than gill nets (i.e., 100 fish could be captured with fewer hoop net sets than gill net sets). Perhaps this is a function of the longer soak time (72 h to 24 h). We did not consider personnel hours invested for this study, though Sullivan and Gale (1999) found that hoop nets catch more fish than gill nets with similar personnel effort due to the large amount of by-catch associated with gill nets and the time invested in untangling and removing fish (by-catch and target species). For hoop net surveys, longer soak time and an increased number of nets, as compared to gill net surveys, is not associated with an increase in personnel effort. Additionally, mortality is greatly reduced in hoop nets. For example, Sullivan and Gale (1999) reported no channel catfish mortality and 8% by-catch mortality in hoop nets; in gill nets, they reported 8% channel catfish mortality and 82% by-catch mortality. Similarly, Michaletz and Sullivan (2002) reported only 0.3% channel catfish mortality in hoop nets. Therefore, while greater catch in hoop nets may be a function of longer soak time, this information is of value to management because increased catch without an associated increase in effort, as well as the low mortality associated with hoop nets, are desirable.

Though we found that hoop nets captured more fish than gill nets (total catch was greater in hoop nets for 23 of 26 water bodies), we did not observe catch rates that approached those of previous studies, where channel catfish CPUE in hoop nets averaged 90 – 100 fish per series (Michaletz and Sullivan 2002; Flammang and Schultz 2007). Even with the inclusion of substock-length (< 280 mm) channel catfish, average CPUE did not approach 100 fish per series. The mechanism causing comparatively lower catch rates in this study is unknown. While it is possible that lower catch rates of channel catfish with hoop nets reflect regional variability in populations, our catch rates of channel catfish with gill nets were similar to other recorded catches. For example, Sullivan and Gale (1999) reported a median catch rate of 14.1 channel catfish per gill net-night at Longview Lake, Missouri, and in this study, median catch rate (inclusive of substock-length channel catfish) was 12.5 channel catfish per gill net-night.

Our study did not address whether hoop nets capture channel catfish in proportion to their true abundance, but Buckmeier and Schlechte (2009) found that channel catfish samples collected with hoop nets provide accurate estimates of size structure and relative abundance. Additionally, they reported that length distribution of captured fish was similar between hoop nets and gill nets. In contrast, among the four water bodies that we assessed in this study, length frequency distributions of channel catfish were dissimilar between gears. It is difficult to state the nature of these differences due to the small sample sizes of channel catfish collected during our surveys; however, these findings suggest that comparisons of channel catfish size structure between hoop nets and gill nets should be made with caution.

In general, hoop nets are effective for capturing channel catfish in small impoundments (Flammang and Schultz 2007; Michaletz and Sullivan 2002). In this study, hoop nets captured enough fish for PSD estimates in 6 of 14 surveys of small standing waters and 1 of 12 surveys of large standing waters. Additionally, hoop nets were more efficient in small standing waters (median $E_{100} = 9$) than in large standing waters (median $E_{100} = 21$). However, CPUE of channel catfish in hoop net surveys did not differ between small and large standing waters, suggesting that while hoop nets may be less efficient at capturing fish in large water bodies, with increased effort they can be an effective sampling method in both small and large standing waters.

We found that catch rates of channel catfish with hoop nets in a single survey of 4 - 8 tandem sets are often not sufficient to estimate standard population indices. For example, Vokoun et al. (2001) recommend a minimum 300 fish for an accurate description of population size structure. Michaletz and Sullivan (2002) agreed that 300 channel catfish can provide sufficient information for size structure of the population vulnerable to the sampling method (i.e., fish ≥ 250 mm). In this study, hoop nets captured a minimum of 300 stock-length channel catfish in only 2 of 26 water bodies. Nonetheless, hoop nets capture more channel catfish than gill nets and can be a useful tool for managers wishing to gather data to inform a management decision. In Nebraska, if hoop nets are to be used for standard surveys, it may be necessary to increase effort to capture enough fish to make useful temporal comparisons of population indices, particularly in large water bodies. Hoop nets have previously been proven effective for capturing channel catfish in small standing waters, and they have potential utility for sampling channel catfish in large standing waters as well.

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Table 6-1. Size structure of stock-length channel catfish from tandem-set hoop net and gill net surveys (2008-2009) of 26 Nebraska water bodies representing two ecosystem types, small standing waters (SSW) and large standing waters (LSW). N is the total number of fish captured. Range is the minimum and maximum 10 mm length groups in which fish were sampled. Minimum lengths of channel catfish for stock (S)–, quality (Q)–, preferred (P)–, and memorable (M)–lengths are 280, 410, 610 mm, and 710 mm, respectively. Proportional size distribution (PSD), PSD-P, and PSD-M were calculated for surveys where N > 25.

	Hoop nets				
Water body	N	Range	PSD	PSD-P	PSD-M
SSW					
Wagon Train	90	280-720	59	8	2
Zorinsky	422	280-900	5	0	0
Conestoga	35	280-610	54	3	0
East Twin	167	310-680	54	1	0
Stagecoach	214	280-690	2	1	0
Summit	9	280-730	[A]	[A]	[A]
Standing Bear	6	390-670	[A]	[A]	[A]
Walnut Creek Lake	151	280-920	61	28	16
North Platte I-80	249	280-700	13	3	0
Willow Island	3	700-770	[A]	[A]	[A]
Blue Hole	35	310-630	37	3	0
Cheyenne	11	370-420	[A]	[A]	[A]
Bassway Strip West	3	320-730	[A]	[A]	[A]
Two Rivers	162	280-750	35	12	4
LSW					
Harlan	56	280-670	23	5	0
Swanson	33	410-590	100	0	0
Merritt	38	340-700	37	5	0
Sherman	26	310-820	85	12	8
Minatare	37	310-570	41	0	0
Branched Oak	19	280-670	[A]	[A]	[A]
Red Willow	74	280-820	61	16	5
Box Butte	33	280-640	58	6	0
Elwood	17	320-640	[A]	[A]	[A]
Whitney	53	280-440	6	0	0
Pawnee	81	280-680	46	9	0
Willow Creek Lake	393	280-720	49	2	1

Table 6-1. Continued.

	Gill nets				
Water body	N	Range	PSD	PSD-P	PSD-M
SSW					
Wagon Train	55	300-780	91	51	20
Zorinsky	22	280-790	[A]	[A]	[A]
Conestoga	7	280-590	[A]	[A]	[A]
East Twin	11	340-510	[A]	[A]	[A]
Stagecoach	26	300-700	8	4	0
Summit	6	290-550	[A]	[A]	[A]
Standing Bear	3	430-660	[A]	[A]	[A]
Walnut Creek Lake	14	340-530	[A]	[A]	[A]
North Platte I-80	0				
Willow Island	0				
Blue Hole	8	300-700	[A]	[A]	[A]
Cheyenne	3	290-530	[A]	[A]	[A]
Bassway Strip West	1	330	[A]	[A]	[A]
Two Rivers	24	280-720	[A]	[A]	[A]
LSW					
Harlan	38	280-720	71	29	5
Swanson	0				
Merritt	0				
Sherman	55	290-750	31	2	2
Minatare	17	280-640	[A]	[A]	[A]
Branched Oak	29	310-710	45	7	3
Red Willow	13	340-730	[A]	[A]	[A]
Box Butte	0				
Elwood	5	300-730	[A]	[A]	[A]
Whitney	14	380-360	[A]	[A]	[A]
Pawnee	13	290-660	[A]	[A]	[A]
Willow Creek Lake	0				

[A] Insufficient data to calculate PSD values.

Table 6-2. Summary of stock-length channel catfish catches (2008-2009) using two gears in 26 Nebraska water bodies representing two ecosystem types, small standing waters (SSW) and large standing waters (LSW). Catch per unit effort (CPUE) is the mean catch per 72 h tandem-set series (hoop) or per net night (gill). Range is the minimum and maximum catch per survey. E_{100} is the effort required to capture 100 channel catfish.

	Area	Hoop				Gill			
Waterbody	(ha)	Effort	CPUE	Range	E_{100}	Effort	CPUE	Range	E_{100}
SSW									
Wagon Train	127	7	12.9	1-35	8	4	13.8	11-17	7
Zorinsky	103	8	52.8	4-187	2	4	5.5	3-8	17
Conestoga	93	9	3.9	0-17	25	3	2.3	1-5	38
East Twin	85	9	18.6	2-43	5	3	3.7	0-8	25
Stagecoach	79	9	23.8	0-139	4	4	6.5	3-15	15
Summit	77	8	1.1	0-3	80	3	2.0	1-3	43
Standing Bear	55	6	1.0	0-2	86	4	0.8	0-2	100
Walnut Creek	28	6	25.2	0-129	4	4	3.5	1-7	27
North Platte I-80	11	4	62.3	30-84	2	2	0		200
Willow Island	10	4	0.8	0-3	100	2	0		200
Blue Hole	10	4	8.8	0-20	11	2	4.0	3-5	22
Cheyenne	7	4	2.8	0-8	33	2	1.5	1-2	50
Bassway Strip West	4	4	0.8	0-1	100	2	0.5	0-1	100
Two Rivers	3	4	40.5	2-96	2	4	6.0	2-9	16
LSW									
Harlan	5463	8	7.0	0-28	14	4	9.5	4-16	10
Swanson	2013	8	4.1	0-22	24	4	0		400
Merritt	1176	8	4.8	0-22	21	2	0		200
Sherman	1151	8	3.3	0-10	30	4	13.8	10-17	7
Minatare	873	8	4.6	0-17	21	4	4.3	1-9	22
Branched Oak	728	9	2.1	0-14	45	4	7.3	5-9	13
Red Willow	659	8	9.3	0-19	11	4	3.3	2-5	29
Box Butte	647	8	4.1	0-20	24	4	0		400
Elwood	538	8	2.1	0-5	44	3	1.7	1-2	50
Whitney	364	8	6.6	0-19	15	4	3.5	0-11	27
Pawnee	299	8	10.1	2-21	10	2	6.5	5-8	14
Willow Creek Lake	283	8	49.1	17-92	2	4	0		400

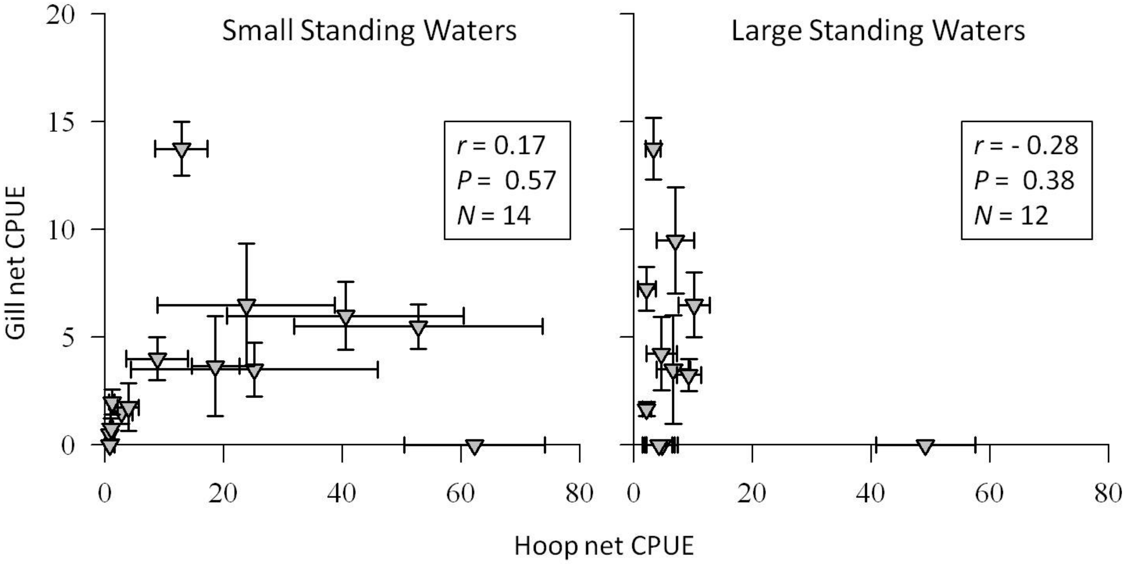

Figure 6-1. Mean ± SE catch per unit effort (CPUE; number per net-night) for stock-length channel catfish captured with tandem-set hoop nets and gill nets during 2008 and 2009 from 26 Nebraska water bodies representative of two ecosystem types: small standing waters (N = 14) and large standing waters (N = 12). Pearson's correlation statistics comparing channel catfish CPUE in hoop nets and gill nets are indicated for each ecosystem type.

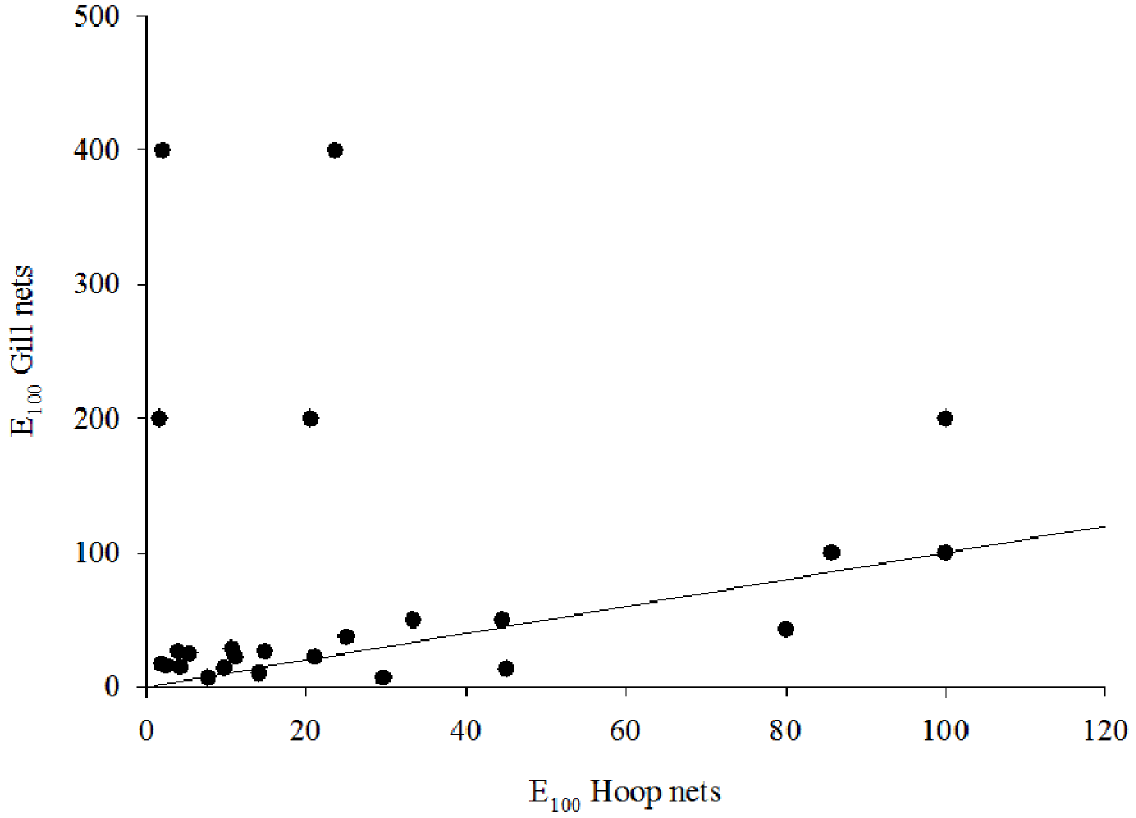

Figure 6-2. Efficiency (E_{100}; number of net-nights required to capture ≥ 100 fish) of tandem-set hoop nets and gill nets for capturing channel catfish during 2008 and 2009 in 26 Nebraska water bodies. Reference line (1:1) indicates equal E_{100} between these two gears.

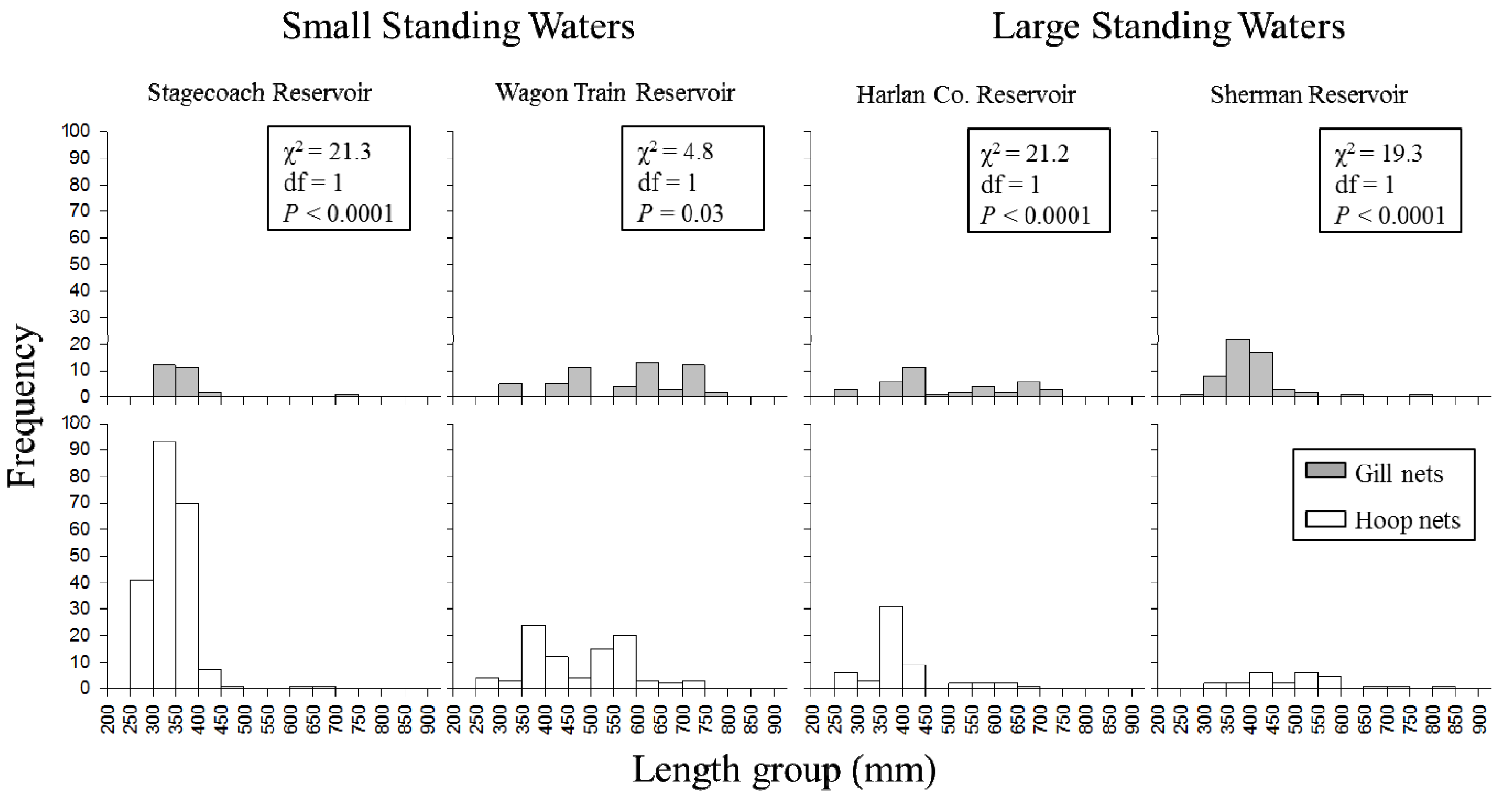

Figure 6-3. Length-frequency distributions of stock-length channel catfish captured with tandem-set hoop nets and gill nets during 2008 and 2009 from four Nebraska water bodies representing two ecosystem types: small standing waters and large standing waters. Kolmogorov-Smirnov test statistics comparing hoop net and gill net catches are indicated for each water body.

CHAPTER 7: CONCLUSION AND MANAGEMENT RECOMMENDATIONS

Channel catfish *Ictalurus punctatus* is an important sport fish species. In Nebraska, channel catfish are targeted by anglers more than any other sport fish, except black bass (USFWS 2007). Despite the popularity and economic importance of channel catfish, little is known of its population dynamics or habitat requirements, and assessment of management strategies is lacking (Irwin et al. 1999). Largely, the lack of assessment stems from collection methods that yield insufficient samples for estimating standard population indices (Michaletz and Dillard 1999), thereby providing little information on which to base management decisions. Therefore, my primary objective was to utilize tandem-set hoop nets to collect large samples of channel catfish from lentic water bodies in Nebraska necessary to make adequate assessments of population dynamics (recruitment, growth and mortality) and structure (abundance, size structure, and condition). My intent was to describe the effects of stocking variability and habitat (i.e., ecosystem) variability on channel catfish population structure and dynamics. Additionally, my secondary objectives were to investigate the utility of tandem-set hoop nets as a standard sampling methodology for channel catfish by Nebraska Game and Parks Commission (NGPC) fisheries managers, as well as the utility of using NGPC ecosystem classifications to make inferences regarding characteristics of channel catfish populations.

Channel catfish populations

The influence of stocking on relative abundance of channel catfish varied between ecosystems. In sand pits, channel catfish abundance was greater in water bodies that were stocked frequently than in those that were stocked infrequently or were not stocked. In flood-control reservoirs, channel catfish abundance was greater in water bodies that were stocked (infrequently and frequently) than in those that were not stocked. Stocking did not influence abundance of channel catfish populations in irrigation reservoirs. Additionally, the influence of stocking on channel catfish condition varied between ecosystem types. In sand pits, stocking negatively influenced condition, whereas in flood-control reservoirs, no stocking influence on condition was detected. In irrigation reservoirs, frequent stocking was positively correlated with channel catfish condition.

There was evidence that ecosystem type also influenced channel catfish growth and age structure. Relatively slow growth could be expected in populations from irrigation reservoirs, whereas greater growth potential for channel catfish could be expected in sand pits. Similarly, growth in ages 0 through 4 was expected to be slow in irrigation reservoirs and could be very fast in flood-control reservoirs. Additionally, irrigation reservoirs were expected to host populations with the most complex age structures, whereas sand pits were expected to host populations with few year classes, indicating that mortality rates were relatively low in irrigation reservoirs and relatively high in sand pits.

In Nebraska, channel catfish are primarily stocked with the intent to maintain or increase abundance. Management recommendations are made here accordingly. To influence abundance in sand pits, channel catfish should be stocked annually at current standard rates for sand pits (i.e., ≥ 50 fish/ha). In contrast, to influence abundance in flood-control reservoirs, channel catfish need only be stocked every other year at current standard rates for flood control reservoirs (i.e., ≥ 50 fish/ha). In irrigation reservoirs, abundance of channel catfish does not respond to stocking. Therefore, current stocking standards in irrigation reservoirs (i.e., infrequent and frequent stockings of < 50 fish/ha) are not recommended. Trends in growth and age structure of channel catfish in irrigation reservoirs suggest that stocking is not necessary to maintain abundance in this ecosystem.

Tandem-set hoop nets

Though catch rates were substantially less in this study (median catch per unit effort in 36 water bodies = 7 channel catfish/tandem-set series) compared to previous records of tandem-set hoop net surveys (e.g., Michaletz and Sullivan 2002; Flammang and Schultz 2007), hoop nets were more efficient than gill nets at capturing channel catfish (i.e., 100 fish could be captured with fewer hoop net sets than gill net sets). Additionally, amongst water bodies, hoop nets were more efficient at capturing channel catfish in small standing waters (≤200 ha) than in large standing waters. However, we found that catch rates and size structure of channel catfish in tandem-set hoop nets varied within the summer season and between years. Furthermore, length-frequency distributions of channel catfish were dissimilar between hoop net and gill net catch.

Experimental gill nets are considered standard sampling methodology for channel catfish in Nebraska; however, *Sander* and *Morone* are the target species in most NGPC gill net surveys, whereas channel catfish are considered a secondary species. Standard sampling sites are selected to maximize catch of the target species. Thereby, channel catfish are effectively bycatch of walleye and white bass surveys, yet data collected in gill nets surveys are utilized to make management recommendations for channel catfish. As such, the low capture efficiency observed in gill net surveys conducted during this study is not surprising. Gill nets surveys categorically fail to capture channel catfish in sufficient numbers to make meaningful assessments of populations; furthermore, it is inappropriate to make stock assessments using data collected in surveys that target other species with dissimilar behavior patterns and life histories. Therefore, use of data collected from NGPC standard gill net surveys to make management decisions for channel catfish should cease.

If gill net surveys are no longer utilized for channel catfish data collection, what is the best alternative sampling method? Based on recent gear evaluations, we expected this study to identify tandem-set hoop nets as a superior sampling method for Nebraska's lentic systems, with no necessity for continued evaluation of the gear. While the study did provide evidence that hoop nets are preferable to gill nets for channel catfish sampling, hoop nets did not capture fish in abundances reported by other Midwest states. This may indicate a true difference of abundance in Nebraska's populations. However, it may also indicate unperceived differences in sampling methodology. As such, population estimates are recommended for representative lentic ecosystems of Nebraska in order to compare populations from similar systems in other Midwest states to determine if true differences in abundance explain the comparatively low catch rates observed in this study.

Further gear evaluations of tandem-set hoop nets are recommended prior to adoption of the gear as a standard channel catfish sampling method in Nebraska. In light of the seasonal variability of catch noted in this study, further evaluation of sampling season is recommended. The summer months, which encompass the spawning period for channel catfish, may not be ideal for sampling the species in Nebraska waters. Surveys conducted during spring, prior to the spawning season, may reduce within-season variability, as well as within-survey variability between nets. It is hypothesized that the presence of a spawning female in a net will attract many males to the net, whereas a net with no female presence will lack such a lure, thereby creating a situation in which nets are 'baited' unequally.

The intent of this study was to conduct population surveys rather than a gear evaluation; therefore, net placement within lake was determined by random site selection, and nets were deployed at random, facing uplake or downlake parallel to shore. Intentional placement of nets in or near habitats likely to attract channel catfish may increase catch rates.

Additionally, intentional placement of nets in an effort to maximize the bait plume created by wave action may positively influence catch. For instance, placing the mouth of the net-series according to predominant winds or according to short-term wind forecasts may influence the effectiveness of the bait. Further evaluation of net deployment is recommended.

Bait recommendations for tandem-set hoop nets vary amongst state agencies. Baits range from extruded soy pellet to commercially prepared soy and cheese logs to waste cheese. A single bait comparison has been conducted for tandem-set hoop nets comparing extruded soy pellet to waste cheese, in which soy was found to be as effective as waste cheese as a fish attractant (Flammang and Schultz 2007). Extruded soy pellets, widely available as a livestock feed, can vary greatly in composition, and no standard has been recommended for its usage as channel catfish bait. With a lack of standardization, it is not surprising that opinions differ amongst agencies regarding the performance of soy pellet as a channel catfish attractant. In this study, soy pellet was not deemed particularly effective. Perhaps the composition of the extrusion (e.g., percent crude protein) influenced the pellet’s utility as catfish bait. Further evaluation of bait usage is recommended.

Although numerous gear evaluations have been completed for tandem-set hoop nets, there is need for further refinement of standards. In addition to the above recommended evaluations of sampling season, net deployment, and bait selection, there is room for continued evaluation of previously addressed variables (e.g., net construction, the number of nets set in tandem, throat configuration, bycatch influence, and soak duration). Existing evaluations are primarily conducted in isolated studies at a single water body or ecosystem type (e.g., small impoundments). In fact, in published reports, tandem-set hoop nets are utilized almost exclusively in small impoundments. Evaluations should be expanded to include a variety of lentic systems.

This study indicated conflicting results in catch comparisons between gears. For example, although Buckmeier and Schlechte (2009) found that length distribution of channel catfish catch was similar in hoop nets and gill nets, this study presented evidence that size structure of catch differed between gears. Such discrepancies further solidify the recommendation that additional evaluations are necessary.

Finally, whereas previous studies were conducted on small standing waters (≤ 200 ha), this study also included surveys of large standing waters (> 200 ha). Results indicated that hoop nets may not be suitable for channel catfish sampling in large water bodies. If hoop nets are used to survey channel catfish populations in large standing waters, it may be necessary to increase effort to a point where it becomes impractical to conduct surveys due to time constraints and substantial expense in man hours.

Ecosystem classifications

Ecosystem classifications (i.e., sand pits, flood-control reservoirs, and irrigation reservoirs) were generally representative of variation in physical and biological characteristics of water bodies. Additionally, as described above, there was an association of channel catfish population characteristics with ecosystem classification. Therefore, it is appropriate to formulate general management strategies specific to these ecosystems.

Channel catfish populations differed among ecosystems. Thus, inferences regarding populations or gear evaluations should not be made beyond the system in which the study was conducted. Therefore, it is recommended that the suggested gear evaluations and further population assessments be conducted for each ecosystem type.

Harvest estimates are needed to gain a better understanding of channel catfish population characteristics in Nebraska’s standing waters. Angler exploitation is often an important factor structuring channel catfish populations (Miranda 1999, Stanovick 1999), and it is likely that exploitation of channel catfish varies greatly among sand pits, flood-control reservoirs, and irrigation reservoirs. In addition to wide variation in angling pressure, in terms of angling hours and angler density, harvest rates can vary as a function of the likelihood of angler encounter, which is influenced by water body size, accessibility, morphology, and a host of environmental variables that influence fish behavior (Stoner 2004).

Movement patterns are needed to gain a better understanding of channel catfish behavior, to optimize the efficiency of tandem-set hoop nets as a sampling method. Channel catfish movement patterns can vary widely between populations (Irwin et al. 1999). It is likely that movement patterns vary among ecosystem types considered in this study. Movement influences the rate of a fish's encounter with a net or bait plume, thereby potentially influencing catch rates differently for each system. Knowledge of channel catfish behavior can inform further standardization of gear deployment.

Conclusion

Tandem-set hoop nets hold potential as an effective gear for sampling channel catfish in Nebraska's lentic systems. Data collected with this gear were sufficient to formulate general stocking recommendations specific to ecosystem type. Such recommendations would have been difficult or impossible to make using data collected with gill nets. As such, continued use of tandem-set hoop nets is recommended, with further evaluation and standardization.

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