CATFISH POPULATION DYNAMICS IN THE PLATTE RIVER, NEBRASKA

by

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Catfish angling is popular throughout North America and catfish are the most sought after fish species in the Platte River. However, catfish management in the Platte River is minimal as little is known about current populations. My objective was to determine the current status of channel catfish and flathead catfish populations in the central and lower Platte River. Specifically, I evaluated population characteristics including relative abundance, size structure, condition, age, growth and mortality. Channel catfish are much more abundant than flathead catfish in the Platte River. The current Platte River channel catfish population appears to be comparable to many Nebraska and Midwestern rivers. Population characteristics displayed considerable variation along the Platte River and some longitudinal patterns were evident. Channel catfish in the central Platte River had lower relative abundances, higher condition, greater size structure, faster growth and lower mortality compared to lower Platte River channel catfish. Key factors likely influencing differences in channel catfish population characteristics are prey availability, flow modifications, habitat characteristics, tributary inflows and angler exploitation. Water manipulations from the Loup River Power Canal were also identified as a possible negative influence on lower Platte River channel catfish populations because hydropeaking is likely creating a stressful environment. However,

channel catfish in the central Platte River appear to have benefited from recent high flows that likely increased productivity and food availability in the central Platte River.

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TABLE OF CONTENTS

ABSTRACT ii

ACKNOWLEDGEMENTS iv

LIST OF TABLES viii

LIST OF FIGURES xi

LIST OF APPENDICES xix

CHAPTER 1 - GENERAL INTRODUCTION 1

Catfish Population Characteristics 3

Objectives 7

References 9

CHAPTER 2 - RELATIVE ABUNDANCE, SIZE STRUCTURE, AND CONDITION OF CATFISH IN THE PLATTE RIVER 18

Introduction 18

Methods 20

Study Area 20

Field Collections 21

Data Analyses 24

Results 27

Relative Abundance 28

Size Structure 29

Condition 31

Flathead Catfish 33

Discussion 34

References 45

CHAPTER 3 - AGE, GROWTH, AND MORTALITY OF CATFISH IN THE PLATTE RIVER 93

Introduction 93

Methods.....95

Study Area 95

Field Collections.....96

Laboratory Preparation 99

Data Analyses 99

Results.....101

Discussion 104

References 111

CHAPTER 4 - FUTURE RESEARCH AND MANAGEMENT RECOMMENDATIONS 142

Management Recommendations 143

References 148

LIST OF TABLES

Table 2-1. Sampling effort (gear deployments) by site and season using 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}), high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2007 and 2008.....56

Table 2-2. Fish species composition and total abundance captured with all gears in the Platte River during 2007 and 2008. 57

Table 2-3. Habitat characteristics (depth, temperature, dissolved oxygen, turbidity, conductivity and water discharge) by site and river reach recorded during fish collections in the Platte River during 2007 and 2008. 59

Table 2-4. Catch per unit effort (CPUE) by turbidity, depth and presence/absence of large woody debris (LWD) of channel catfish collected with high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2007 and 2008. 61

Table 2-5. Size structure indices, including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P), memorable (PSD-M) and trophy (PSD-T) channel catfish collected with 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}), high frequency pulsed-DC electrofishing (EF_{60}), low frequency pulsed-DC electrofishing (EF_{15}), setlines (SL) and rod and reel (RR) in the Platte River during 2007 and 2008.....62

Table 2-6. Size structure indices by site, including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P), memorable (PSD-M) and trophy (PSD-T) channel catfish collected using all standard sampling gears in the Platte River during 2008. 63

Table 2-7. Size structure indices by river reach, including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P), memorable (PSD-M) and trophy (PSD-T) channel catfish collected with 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}), high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2008. 64

Table 2-8. Summary statistics, including relative abundance (mean CPUE), size structure (PSD, PSD-P) and length-weight relation, of current and historical channel catfish investigations in the Platte River. Previous studies include Peters et al. (1992), Holland and Peters (1992a), Holland and Peters (1992b) and Holland and Peters (1994). 65

Table 3-1. Instantaneous mortality (Z), total annual mortality (A) and theoretical maximum age (Max Age) of channel catfish collected with all standard sampling gears in the Platte River during 2007, 2008 and both years combined.....118

Table 3-2. Instantaneous mortality (Z), total annual mortality (A) and theoretical maximum age (Max Age) of channel catfish collected with HN_{25}, HN_{38}, EF_{60} and EF_{15} in the Platte River during 2007 and 2008 combined.....119

Table 3-3. Mean back-calculated length at age for channel catfish collected in the central and lower Platte River (**Bold**) during 2007 and 2008 compared to standard growth percentiles for channel catfish across their geographic range. Percentiles provided by Hubert (1999). Superscripts following lengths delineate central (^{C}) and lower (^{L}) Platte River channel catfish. 120

Table 3-4. Annual mortality rates of channel catfish populations in the central Platte River and lower Platte River compared to other North American river populations. 121

LIST OF FIGURES

Figure 2-1. Study area including sampling locations in the central (Sites 7-10) and lower (Sites 1-6) Platte River, Nebraska. 66

Figure 2-2. Mean monthly discharge of the Platte River near Grand Island, NE (USGS gauge 06770500) during 2003-2008. Bold plots represent discharge during the current study (2007-2008). 67

Figure 2-3. Mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different letters above plots indicate differences in CPUE among gears. 68

Figure 2-4. Seasonal mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE. 69

Figure 2-5. Monthly mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE. 70

Figure 2-6. Mean catch per unit effort (CPUE) by temperature of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE. 71

Figure 2-7. Mean catch per unit effort (CPUE) by discharge of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Relative water discharge was delineated as percent difference from mean daily discharge for low (<75 %), normal (75-125 %) and high (>125 %) water conditions. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE. 72

Figure 2-8. Mean catch per unit effort (CPUE) by sample site of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE. 73

Figure 2-9. Mean catch per unit effort (CPUE) by river reach of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE. 74

Figure 2-10. Mean catch per unit effort (CPUE) by depth for channel catfish collected with high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among EF_{60} CPUE and different lowercase letters indicate differences among EF_{15} CPUE.....75

Figure 2-11. Length-frequency distributions of channel catfish collected with all gears in the Platte River during 2007 (A) and 2008 (B). 76

Figure 2-12. Length-frequency distributions of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; B), high frequency pulsed-DC electrofishing (EF_{60}; C) and setlines (SL; D) in the Platte River during 2007.....77

Figure 2-13. Length-frequency distributions of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; B), high frequency pulsed-DC electrofishing (EF_{60}; C), low frequency pulsed-DC electrofishing (EF_{15}; D), rod and reel (RR; E) and setlines (SL; F) in the Platte River during 2008. 78

Figure 2-14. Length-frequency distributions by site for channel catfish collected with all standard gears in the Platte River during 2008. 79

Figure 2-15. Length-frequency distributions of channel catfish collected with all standard gears in the central Platte River (A) and lower Platte River (B) during 2008.....80

Figure 2-16. Length-frequency distributions of channel catfish collected with 25-mm hoop nets (HN_{25}; A) and 38-mm hoop nets (HN_{38}; B) in the central Platte River and HN_{25} (C) and HN_{38} (D) in the lower Platte River during 2008.....81

Figure 2-17. Length-frequency distributions of channel catfish collected with high frequency pulsed-DC electrofishing (EF_{60}; A) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the central Platte River and EF_{60} (C) and EF_{15} (D) in the lower Platte River during 2008. 82

Figure 2-18. Log_{10}-transformed length-weight relation of channel catfish collected in the central Platte River (A) and lower Platte River (B) during 2007 and 2008. 83

Figure 2-19. Mean relative weight (W_r) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P), preferred-memorable (P-M) and memorable-trophy (M-T) channel catfish collected in the Platte River during 2007 and 2008. Different letters above plots indicate mean W_r differences between length categories.....84

Figure 2-20. Mean relative weight (W_r) by season of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P) and preferred-memorable (P-M) channel catfish collected in the Platte River during 2007 and 2008. 85

Figure 2-21. Mean relative weight (W_r) by site of sub-stock (S-S) and stock-quality (S-Q) channel catfish collected in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate mean W_r differences among S-S channel catfish and different lowercase letters indicate mean W_r differences among S-Q channel catfish. 86

Figure 2-22. Mean relative weight (W_r) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P) and preferred-memorable (P-M) channel catfish collected in the central Platte River and lower Platte River during 2007 and 2008. A '*' indicates differences in mean W_r between river reaches. 87

Figure 2-23. Mean catch per unit effort (CPUE) of flathead catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008.....88

Figure 2-24. Mean catch per unit effort (CPUE) of flathead catfish collected with pulsed-DC electrofishing in the central Platte River and lower Platte River during 2007 and 2008. 89

Figure 2-25. Length-frequency distribution, mean length, Proportional Size Distribution (PSD) and PSD of preferred (PSD-P) and memorable (PSD-M) flathead catfish collected with all gears in the Platte River during 2007 and 2008. 90

Figure 2-26. Length-weight relation of flathead catfish captured with all gears in the Platte River during 2007 and 2008. 91

Figure 2-27. Mean relative weight (W_r) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P), preferred-memorable (P-M) and memorable-trophy (M-T) flathead catfish collected in the Platte River during 2007 and 2008. Different letters above plots indicate mean W_r differences between length categories.....92

Figure 3-1. Study area including sampling locations in the central (Sites 7-10) and lower (Sites 1-6) Platte River, Nebraska.....122

Figure 3-2. Mean monthly discharge of the Platte River near Grand Island, NE (USGS gauge 06770500) during 2003-2008. Bold plots represent discharge during the current study (2007-2008). 123

Figure 3-3. Age distribution of channel catfish collected with all gears in the Platte River during 2007 (A) and 2008 (B). 124

Figure 3-4. Age distribution of channel catfish collected with all standard gears in the central Platte River (A) and lower Platte River (B) during 2008. 125

Figure 3-5. Age distirbution of channel catfish collected with all standard gears at each site in the Platte River during 2008. 126

Figure 3-6. Individual length at capture (A), mean length at capture and von Bertalanffy growth function (B) of channel catfish collected in the Platte River during 2007 and 2008. 127

Figure 3-7. Mean back-calculated length at age and von Bertalanffy growth functions of channel catfish collected in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007 and 2008. A '*' indicates differences in mean back-calculated length at age between the central Platte River and lower Platte River. 128

Figure 3-8. Mean back-calculated length at Age-1 (A), Age-2 (B), Age-3 (C), Age-4 (D), Age-5 (E) and Age-6 (F) channel catfish collected at each site in the Platte River during 2007 and 2008. Different letters above plots indicate differences among mean-back calculated lengths. 129

Figure 3-9. Mean annual growth increment of channel catfish collected in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007 and 2008. A '*' indicates differences in mean annual growth increments. 130

Figure 3-10. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007. P-values are reported for ANCOVA testing differences in regression line slopes (instantaneous mortality, Z).....131

Figure 3-11. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the entire Platte River (A), central Platte River and lower Platte River (B) during 2008. P-values are reported for ANCOVA testing differences in regression line slopes (instantaneous mortality, Z).....132

Figure 3-12. Weighted regression catch curves for channel catfish collected from 25-mm hoop nets (HN_{25}; A) and 38-mm hoop nets (HN_{38}; B) in the central Platte River and lower Platte River during 2007 and 2008. P-values are reported for ANCOVA testing for differences in regression line slopes (instantaneous mortality, Z).....133

Figure 3-13. Weighted regression catch curves for channel catfish collected from high frequency pulsed-DC electrofishing (EF_{60}; A) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the central Platte River and lower Platte River during 2007 and 2008. P-values are reported for ANCOVA testing for differences in regression line slopes (instantaneous mortality, Z).....134

Figure 3-14. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007 and 2008. P-values are reported for ANCOVA testing for differences in regression line slopes (instantaneous mortality, Z). 135

Figure 3-15. Age distribution of flathead catfish collected with all sampling gears in the Platte River during 2007 and 2008. 136

Figure 3-16. Weighted regression catch curve, instantaneous mortality, total annual mortality and theoretical maximum age of flathead catfish collected from all sampling gears in the Platte River during 2007 and 2008. 137

Figure 3-17. Mean back-calculated length at age and von Bertalanffy growth function of flathead catfish collected in the Platte River during 2007 and 2008. 138

Figure 3-18. Mean annual growth increment of flathead catfish collected in the Platte River during 2007 and 2008. 139

Figure 3-19. Central Platte River and lower Platte River channel catfish von Bertalanffy growth functions compared to other Nebraska rivers (data provided by Steve Schainost, Nebraska Game and Parks Commission). 140

Figure 3-20. Central Platte River and lower Platte River channel catfish von Bertalanffy growth functions compared to the standard channel catfish growth function (standard von Bertalanffy growth function provided by Jackson et al. 2008). ... 141

LIST OF APPENDICES

APPENDIX A. EVALUATION OF TROTLINES TO CATCH CHANNEL CATFISH AND FLATHEAD CATFISH IN THE PLATTE RIVER, NEBRASKA 152

APPENDIX B. ENCLOSURE EXPERIMENTS TO EVALUATE CATFISH GEAR EFFICIENCY IN A LOTIC SYSTEM 170

APPENDIX C. BIAS AND PRECISION OF OTOLITHS AND PECTORAL SPINES USED FOR CHANNEL CATFISH AGE ESTIMATION 183

CHAPTER 1 - GENERAL INTRODUCTION

Recreational fishing has been and continues to be a favorite American pastime. A recent survey found 13% of the United States adult population and 14% of Nebraska residents went fishing in 2006 (USFWS 2007). A total of 198,000 anglers (resident and non-resident) fished 3,096,000 days in Nebraska during 2006. Undoubtedly, sportfishing and associated activities provided a great economic input during this time as total expenses reached $181 million in Nebraska (USFWS 2007).

Catfish angling is especially common throughout the United States where 28% of all anglers and 23% of the fishing effort in 2006 was spent directly targeting catfish (USFWS 2007). The catfishes, namely channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictis olivaris*, are an even more desirable group to Nebraska anglers. For example, more than 50% of Nebraska anglers fished for catfish in 1981 and 1982 (Zuerlein 1984) and 57% of Nebraska anglers sought catfish during 2002 (Hurley and Duppong Hurley 2005). Furthermore, 35% (69,000) of Nebraska anglers targeted catfish over any other species during 2006 (USFWS 2007).

River and stream fisheries are very important in Nebraska, but fishing access can be difficult due to private land ownership in contrast to many public lakes and reservoirs. However, 462,000 days (15%) were spent fishing in Nebraska's rivers and streams in 2006 (USFWS 2007). The Platte River ranks second, only to the Missouri River, in angler use for Nebraska rivers (Zuerlein 1984, Hurley and Duppong Hurley 2005). Channel catfish have been the most consistently sought after fish in the lower Platte River representing 67% in 1992 and 73% in 1993 of anglers' most desirable fish (Holland and

Peters 1994). Flathead catfish are also very popular being the third most sought after species (Holland and Peters 1994).

Harvest is an important aspect of most catfish fisheries throughout the North America (Miranda 1999, Stanovick 1999). Nebraska anglers have generally demonstrated a harvest mentality with catfish and often display more harvest oriented attitudes compared to other anglers (Hurley and Duppong Hurley 2007). Peters and Parham (2008) reported channel catfish to be one of the most commonly caught species in the Platte River and Holland and Peters (1994) found channel catfish to be the most harvested fish species. Consequently, localized harvest rates have become a concern for fish management in the Platte River (personal communication, J. Jackson, Nebraska Game and Parks Commission,).

The Platte River, Nebraska spans from east to west across the state providing numerous recreational opportunities. Angling, wildlife viewing, hunting, canoeing, recreational airboating, swimming, morel mushroom hunting, and camping are the dominant outdoor activities (Holland and Peters 1994). Angling on the lower Platte River provides a large economic contribution with anglers spending more than $500,000 on fishing related activities during 1992 and 1993 (Holland and Peters 1994). Given this valuable natural resource, assessing, maintaining and managing fish populations for recreation is important for sustaining or improving angler success. Especially important are issues concerning channel catfish and flathead catfish population characteristics in the Platte River.

Catfish Population Characteristics

General population characteristics are often included in a manager's initial assessment of a fish population. Population characteristics used to effectively manage fish populations include relative abundance, size structure, condition, age, growth, mortality, and recruitment (Willis and Murphy 1996, Ney 1999, Van Den Avyle and Hayward 1999, Vokoun and Rabeni 1999). Individual parameters are useful in population investigations. However, examining multiple population characteristics and their interactions is a more reliable approach for overall population assessment.

Channel catfish and flathead catfish relative abundances have been thoroughly investigated throughout their range. Hesse et al. (1979) used hoop net catch per unit effort (CPUE) to determine if larger populations of channel catfish exist in areas upstream of the confluence of the Niobrara and Missouri rivers compared to downstream. Driscoll et al. (1999) compared electrofishing CPUE between habitats and found higher relative abundances of flathead catfish in main channels of the Mississippi River compared to secondary channels. Additionally, Peters et al. (1992) used hoop nets to sample channel catfish populations in the Platte River and found CPUE to vary greatly among sampling sites (0.27 fish/net-night to 3.64 fish/net-night).

Differences in size structure among populations can be attributed to numerous factors including population density, growth, predator-prey relations, recruitment and mortality (Carline et al. 1984, Willis and Scalet 1989, Johnson et al. 1992, Willis et al. 1993). Managers are often interested in evaluating how a particular fish population compares to balanced populations (Willis et al. 1993). Swingle (1950) described a balanced fish population as a population that can sustain a harvest of good-sized fish in

proportion to the productivity of the water. Proportional Size Distribution (PSD) is often used as a numerical descriptor of length-frequency data (Gabelhouse 1984, Anderson and Neumann 1996, Guy et al. 2007). Channel catfish and flathead catfish size structures vary between populations. However, no objective PSD ranges have been proposed for balanced channel catfish or flathead catfish populations.

Size selectivity of collection techniques is evident (Nelson and Little 1986, Holland and Peters 1992b, Brown 2007); therefore caution should be taken when comparing population size structures. Makinster (2006) found longitudinal variation in flathead catfish size structure collected with low frequency electrofishing in the Kansas River with PSD ranging from 0 to 52 and PSD-P ranging from 0 to 13 among four river segments. Additionally, flathead catfish population size structure was high (PSD = 58, PSD-P = 28) in a relatively unexploited northern U.S. river (Daugherty and Sutton 2005). Colombo et al. (2008) examined channel catfish populations in the Wabash River comparing size structure between sampling methods. Electrofishing displayed the highest PSD and PSD-P and 25-mm hoop nets displayed the lowest. Holland and Peters (1992a) reported low PSD (4-11) for channel catfish collected with hoop nets and electrofishing in the lower Platte River.

Fish condition is a measure of wellness generally intended to be an indicator of tissue energy reserves (Pope and Kruse 2007). Wege and Anderson (1978) developed relative weight (W_r), as a measure of condition, and is commonplace in fisheries assessments today (Blackwell et al. 2000). However, few studies have reported W_r values for channel catfish and flathead catfish populations. A likely explanation for lack of W_r use is the relatively recent developments of standard weight (W_s) for channel

catfish (Brown et al. 1995) and flathead catfish (Bister et al. 2000) compared to more popular species (i.e., centrarchids). Makinster (2006) reported differences in mean W_r values for age-1, sub-adult and adult flathead catfish in the Kansas River. An inverse relation was observed between W_r and total length for flathead catfish in a Michigan river (Daugherty and Sutton 2005). Doorenbos et al. (1999) observed a skewed-U-shaped W_r pattern for channel catfish populations from four South Dakota rivers with smallest individuals exhibiting highest W_r. Holland and Peters (1992a) did not calculate W_r values for lower Platte River channel catfish. However, Fulton-type condition factors (K) were reported and ranged from 0.612 to 1.056 with no statistical differences between season or sex.

Catfish age and growth determinations have been made using vertebrae (Appelgat and Smith 1951, Marzolf 1955), sagittal otoliths (Nash and Irwin 1999, Buckmeier et al. 2002), dorsal fin spines (Layher 1981) and pectoral fin spines (Mayhew 1969, Holland and Peters 1992a, Shephard and Jackson 2006). Otoliths are the recommended structure because of their accuracy and low variability in estimating age (Buckmeier et al. 2002); whereas, the use of spines have been documented to underestimate fish age (Nash and Irwin 1999). However, fish must be euthanized to remove otoliths. Pectoral spine removal from channel catfish (and presumably flathead catfish) causes little if any mortality (Stevenson and Day 1987, Michaletz 2005). Therefore, extracting pectoral spines is preferred when euthanizing the fish is undesirable.

Substantial variation in growth of channel catfish among populations occurs across the geographic range of the species. For example, age-3 mean lengths ranged from 157 to 429-mm among 102 age and growth studies reviewed by Hubert (1999).

Channel catfish from the Platte River tend to have relatively slow growth with age-3 mean length of 202-mm (Holland and Peters 1992a). However, this slow growth is comparable to other channel catfish populations in Nebraska and the Great Plains as it takes approximately four to six years for channel catfish to reach maturity (~ 300 mm) in Nebraska rivers (Holland et al. 1999).

Growth patterns across the channel catfish's geographic range are not evident (Hubert 1999) and growth rates within the same river system have shown no river-wide latitudinal (Pegg and Pierce 2001) or longitudinal (Holland and Peters1992a) trends. However, Durham et al. (2005) provided some evidence that channel catfish growth may be related to length of growing season on a regional level. Age-23 channel catfish have been collected but are uncommon with most research reporting a maximum of age-8 (Hubert 1999). Age-18 channel catfish have been documented from the lower Platte River although the majority of channel catfish collected has been less than age-10 (Holland and Peters 1992a).

Flathead catfish also display great variation in growth rates across their range with no apparent latitudinal effects (Jackson 1999). Flathead catfish growth is thought to be system specific and the length of the growing season may not be a reliable predictor of growth rate (Daugherty and Sutton 2005). Maximum age of flathead catfish is also variable between water bodies. Age-17 flathead catfish have been documented in lower St. Joseph River, Michigan (Daugherty and Sutton 2005) and age-13 fish were captured in the Des Moines River, Iowa (Mayhew 1969). No age and growth information has been reported for flathead catfish in the Platte River although flathead catfish from the

Kansas River, similar in physical characteristics to the Platte River, have reached age-21 (Makinster 2006).

Channel catfish and flathead catfish growth may depend on specific water body characteristics, such as food availability, habitat features and intra- and interspecific competition (Andrews and Stickney 1972, Quist and Guy 1998, Hubert 1999, Jones and Noltie 2008). Holland and Peters (1992a) suggested stressful environment factors (i.e. fluctuating hydrograph and extremely high water temperatures) may be the cause of slow growth in lower Platte River channel catfish.

Investigating catfish mortality is also important in understanding population dynamics for management purposes. Estimated annual mortality of channel catfish in the relatively unexploited Powder River, Wyoming was 23% (Gerhardt and Hubert 1991) and estimates of 11-28% total annual mortality have been made for flathead catfish populations in the Kansas River (Makinster 2006). Temporal changes in mortality rates was documented in the Missouri River where mortality of age-2 and age-3 channel catfish dropped from 72% in 1975 to 35% in 1996 as result of a commercial fishing closure (Mestl 1999). Channel catfish collected from hoop nets in the Platte River have exhibited annual mortality rates ranging from 16 to 59% (Peters et al. 1992).

Objectives

We gained valuable information about catfish populations in the Platte River through previous studies (Bunnell 1988, Peters et al. 1989, Holland and Peters 1992a, Holland and Peters 1992b, Peters et al. 1992, Holland and Peters 1994, Peters and Holland 1994, Chapman 1995). However, much of this research focused on channel

catfish and took place in the lower Platte River. Population characteristics of flathead catfish have largely been overlooked and research in the central Platte River has been limited. Further, the most recent catfish investigations on the Platte River were conducted over 15 years ago and great environmental variability, in the form of floods and drought, has been observed during this time period.

Accurate assessments of Platte River catfish populations are essential in aiding management decisions to achieve specific goals for the fishery. Therefore, my objective was to determine the present status of catfish populations in the Platte River. Specifically, I evaluated population dynamics, including relative abundance, size structure and condition (Chapter 2) in addition to age, growth and mortality (Chapter 3), to determine the present status of channel catfish and flathead catfish populations in the central and lower Platte River.

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CHAPTER 2 - RELATIVE ABUNDANCE, SIZE STRUCTURE, AND CONDITION OF CATFISH IN THE PLATTE RIVER

Introduction

Recreational fishing has been and continues to be a favorite American pastime. Catfish angling is especially common throughout the United States where 28% of all anglers and 23% of the fishing effort in 2006 was spent directly targeting catfish (USFWS 2007). The catfishes, namely channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictis olivaris*, are an even more desirable group to Nebraska anglers. For example, more than 50% of Nebraska anglers fished for catfish in 1981 and 1982 (Zuerlein 1984) and 57% of Nebraska anglers sought catfish during 2002 (Hurley and Duppong Hurley 2005). Furthermore, 35% (69,000) of anglers targeted catfish over any other species in Nebraska during 2006 (USFWS 2007).

The Platte River ranks second, only to the Missouri River, in angler use for Nebraska rivers (Zuerlein 1984, Hurley and Duppong Hurley 2005). Channel catfish and flathead catfish have been the most consistently sought after species in the lower Platte River (Holland and Peters 1994). Recreational fishing in the Platte River is economically important where anglers spent more than $500,000 on fishing and related activities during 1992 and 1993 (Holland and Peters 1994). Nebraska anglers have also demonstrated a harvest mentality with catfish and often display more harvest oriented attitudes compared to anglers seeking other species (Hurley and Duppong Hurley 2007). Peters and Parham (2008) found channel catfish to be one of the most commonly caught species in the lower Platte River and Holland and Peters (1994) found channel catfish to be the most harvested fish species. The effects of these angling efforts are largely

unknown and localized harvest rates have become a concern for fish management in the Platte River (personal communication, J. Jackson, Nebraska Game and Parks Commission). Given this valuable natural resource, assessing, maintaining and managing fish populations is important. Especially important are issues concerning channel catfish and flathead catfish population characteristics in the Platte River.

We gained valuable information about catfish populations in the Platte River through previous studies (Bunnell 1988, Peters et al. 1989, Holland and Peters 1992a, Holland and Peters 1992b, Peters et al. 1992, Holland and Peters 1994, Peters and Holland 1994, Chapman 1995). However, much of this research focused on channel catfish in the lower Platte River. Population characteristics of flathead catfish have largely been overlooked and research in the central Platte River has been limited. Furthermore, the most recent catfish investigations were conducted over 15 years ago. Great environmental variability, in the form of drought and floods, has been observed during this time period. Accurate assessments of catfish populations are essential in aiding management decisions for the Platte River fishery. Population characteristics desired to effectively assess and manage fish populations include relative abundance, size structure and condition (Ney 1999). Therefore, my objective was to determine the present status of catfish populations in the Platte River, specifically evaluating relative abundance, population size structure and condition of channel catfish and flathead catfish in the central and lower Platte River.

Methods

Study Area

The Platte River, Nebraska (Figure 2-1), formed by the confluence of the North Platte and South Platte rivers, is an alluvial, sand-bottomed, warmwater, braided river system. The Platte River is a dynamic system with shifting sand that creates and moves sand bars, alters channel dimensions, and continually changes habitat quantity, quality and availability (Sidle et al. 1989, Simons 2000). In-stream flow fluctuations further contribute to habitat characteristics in the Platte River. Large runoff events can occur during the spring with extreme low flow and even no flow periods during the summer.

Drastic differences in hydrology are also observed between the central Platte River and lower Platte River. Low annual rainfall resulted in drought conditions along the Platte River in the years leading up to this study. Drought conditions coupled with water diversions ultimately led to extended periods of very low and no flow conditions in areas along the central Platte River (Figure 2-2). Shoreline and island vegetation (i.e., *Phragmites australis*) establishment and encroachment have been documented during low flow periods and have constricted water into narrow channels. However, central Platte River water levels rebounded and were at or above normal flow during the two years of my investigations (Figure 2-2).

The lower Platte River, defined as the reach from the Loup River confluence near Columbus to the confluence with the Missouri River (Figure 2-1), exhibits a much different flow regime. This reach is characterized by continuous but variable flows year round with a significant portion of the base flow coming from the groundwater-fed Loup and Elkhorn rivers (Galat et al. 2005). The Loup River Power Canal, a diversion off the

Loup River, also provides a considerable proportion of flow to the lower Platte River. The canal creates drastic downstream diel changes in water depth, current velocity and cover availability due to hydropeaking to meet electricity demands (Holland and Peters 1989, Holland and Peters 1992b).

Field Collections

I used a fixed site sampling approach to assess catfish populations throughout the Platte River. Sites in the central Platte River include Elm Creek (Site 10, river kilometer [rkm] 370), Bassway Strip WMA (north channel; Site 9, rkm 328), Whooping Crane Trust (Site 8, rkm 290) and Clarks (Site 7, rkm 219). Sites in the lower Platte River include Columbus (Site 6, rkm 161), Schuyler (Site 5, rkm 132), North Bend (Site 4, rkm 113), Leshara (Site 3, rkm 77), Louisville (Site 2, rkm 35) and Plattsmouth (Site 1, rkm 1; Figure 2-1). Most site locations are similar to those used during previous Platte River studies (Holland and Peters 1992b and Holland and Peters 1994) to facilitate temporal comparisons of catfish populations and assure river access via public lands (Nebraska Game and Parks Commission) or cooperative landowners (Whooping Crane Trust). The river kilometer listed for each site was used as a center point of a ± 0.5-km site (1-km total) to ensure suitable habitat for deployment of all gears.

A suite of gears were used to assess the overall catfish population in the Platte River. These gears included cheese-baited hoop nets, trotlines and an electrofisher. Trotlines deployed in 2007 exhibited extremely low capture rates and did not provide sufficient numbers of fish for statistical analysis (Appendix A). Therefore trotlines were dropped from standard sampling during 2008.

All sites were sampled by standard gears once per season when possible. Season delineations were spring (March-May), summer (June-August) and fall (September-November). Winter assessment was not conducted due to ice flow. Adverse flows and other logistical constraints also prevented sampling intermittently throughout the year.

I used 25-mm mesh hoop nets (HN_{25}) and 38-mm mesh hoop nets (HN_{38}) in an attempt to capture different size ranges of catfish. Hoop nets were 1.3-m in length, equipped with four 0.5-m diameter fiberglass hoops with two square throats. Nylon bait bags, 3-mm mesh, were filled with scrap cheese and placed inside the cod end of the hoop nets. Hoop nets were set parallel with the river current in pools and runs along bank and in-stream habitat where available. Anchors were attached to the net and placed 1-m upstream. Anchors were also secured to the bank (i.e., tree limb, rock, etc.) to further restrict net displacement. Effort per sampling trip at each site consisted of 10-15 deployments of each hoop net size. Hoop nets were set in the afternoon and retrieved the next morning; therefore, catch per unit effort (CPUE) was expressed as fish per net-night.

Electrofishing was conducted using a cataraft (River King Catarafts, Port Ludlow, Washington) equipped with a MBS-2D Wiscosnsin box (ETS Electrofishing LLC, Madison, Wisconsin) powered by a 5500 W/240 V generator to provide pulsed-DC current. Anode poles, equipped with steel cable droppers, were attached to the front pontoons of the cataraft. A cathode array was positioned at the mid-section of the cataraft where cable droppers hung between the pontoons to contact water. High frequency (EF_{60}; 4-8 A, 180-240 V, 60 pulses/s, 50% pulse width) and low frequency (EF_{15}; 3-5 A, 180-240 V, 15 pulses/s, 20% pulse width) settings were alternately used during sampling. Electrofishing was conducted in a downstream fashion sampling bank

habitat and any available in-stream structure. Shallow areas were sampled by walking and pulling the cataraft unit like a tote barge electrofisher, while two netters walked alongside the electrode droppers capturing fish. The cataraft was used similar to a boat electrofisher in non-wadeable sections of the river where the operator controlled the cataraft from within using a tiller motor and individuals netted fish from the bow of the vessel. I conducted five, 10-minute runs for each electrofishing frequency at each site. A frequency (EF_{60} or EF_{15}) was randomly selected for the initial electrofishing run and frequencies were alternated for subsequent runs moving downstream. Electrofishing time (minutes) and distance (meters) were recorded for each run; therefore, CPUE was calculated as fish per hour and fish per 100-m.

All captured catfish were measured for total length (TL; mm) and mass (g) then returned to the river. Non-target fish were identified, measured for TL then returned to the river. Electrofishing samples resulted in many small individuals; therefore most non-game fish collected were preserved and taken back to the lab for identification.

Information from area fishing club tournaments was also collected to supplement standard sampling. Angler tournaments provided an excellent opportunity to gain valuable information about the fishery from the viewpoint of local anglers and allowed collection of quality information from harvested fish. Tournaments also allowed data collection on fish size ranges not commonly captured with standard sampling. The Fremont Airboat Club hosts a catfish outing each spring over Memorial Day weekend where anglers use setlines to capture catfish. Setlines (SL) generally had 1-2 hooks baited with live fathead minnows. Additionally, rod and reel catfish tournaments were held sporadically throughout the year. Rod and reel (RR) setups usually consisted of a

plastic worm or sponge rig dipped in ‘stink bait’. Set lines were fished overnight while rod and reel tournaments were held from sun-up to approximately 12:00 PM. Angler caught catfish were measured for TL and mass at the angler check-in and tagged with individually numbered floy tags (Floy Tag Inc., Seattle, Washington) before being cleaned by fisherman. The heads (floy tags intact) of filleted catfish were then kept on ice and transported back to the laboratory for spine and otolith extraction. Hard structures were then used to examine age and growth characteristics (Chapter 3).

General physical and chemical data were collected at all sites when sampled. Measurements were taken at the middle point of each site during the day of hoop net retrieval or electrofishing. Water temperature, dissolved oxygen and conductivity were recorded using a YSI Model 85 (YSI Inc., Yellow Springs, Ohio) and turbidity was measured using a Hach 2100P turbidimeter (Hach Co., Loveland, Colorado). Water discharge from the nearest USGS gauging station was also recorded. General physical habitat characteristics (i.e., depth, pools, revetted banks, large woody debris) were also noted for each hoop net deployment or electrofishing run.

Data Analyses

Gear catch rates, relative abundances, population size structure and fish condition were included in analyses. Flathead catfish catches were inadequate to conduct full analysis; therefore, analyses focused mainly on channel catfish. However, flathead catfish population characteristics are provided where data are sufficient.

Gear-specific catch rates were compared across seasons, months, temperatures and discharges to identify best sampling periods for future monitoring. Temperature

effects were analyzed comparing mean CPUE between temperature ranges (<15, 15-20, 20-25 and >25°C). Percent difference from mean daily discharge was calculated to examine catch rates in high (>125% of mean daily discharge), low (<75%) and normal (75-125%) water conditions. I assumed fish were associated with specific habitats when sampled by electrofishing, instead of being attracted from downstream habitats as is the case with baited hoop nets (Pierce et al. 1981, Gerhardt and Hubert 1989). Thus, electrofishing catch rates were also compared across habitat characteristics. Electrofishing mean CPUE was compared between depth ranges (<1.0, 1.0-1.5, 1.5-2.0, >2.0-m), turbidity ranges (<100, 100-200, 200-300, >300 NTU) and presence/absence of large woody debris (LWD).

I also investigated longitudinal patterns in relative abundance using mean CPUE for each gear by site (1-10) and river reach (central vs. lower). Differences in relative abundances were analyzed using Student's t-test and analysis of variance (ANOVA), where appropriate. Multiple comparisons were made using Tukey's studentized range (HSD) test when ANOVA results were significant. Catch data were $\log_{10}$ (CPUE + 1) transformed to meet normality assumptions for parametric tests.

Population size structure was compared between years, gears, sites and river reaches using Proportional Size Distribution indices (PSD; Anderson and Neumann 1996, Guy et al. 2007), based on length categories (stock, 280-mm; quality, 410-mm; preferred 610-mm; memorable, 710-mm; trophy, 910-mm for channel catfish and stock, 350-mm; quality, 510-mm; preferred, 710; memorable, 860; trophy, 1,020-mm for flathead catfish) described by Gabelhouse (1984) and Quinn (1991). Proportional Size Distribution was calculated as:

$$\text{PSD} = \frac{\#\,\text{fish} \geq \text{minimum quality length}}{\#\,\text{fish} \geq \text{minimum stock length}} * 100$$

Additional Proportional Size Distribution indices (i.e., PSD-P) were calculated as:

$$\text{PSD-P} = \frac{\#\,\text{fish} \geq \text{minimum preferred length}}{\#\,\text{fish} \geq \text{minimum stock length}} * 100$$

Differences in size structure indices were statistically analyzed using chi-square (χ^2) tests and differences in length-frequency distributions were compared using Kolmogorov-Smirnov (KS) nonparametric tests (Neumann and Allen 2007). A Bonferonni correction for the P-values was applied for multiple comparisons to adjust for experimentwise error rate (i.e., $\alpha = 0.05/3 = 0.017$ for three comparisons).

I calculated relative weight (W_r) to assess fish condition as:

$$W_r = \frac{W}{W_s} * 100,$$

where W is the observed weight and W_s is the length-specific standard weight for the species. The standard weight for channel catfish (Brown et al. 1995) was calculated as:

$$\log_{10}(W_s) = -5.800 + 3.294\log_{10}(TL)$$

and the standard weight of flathead catfish (Bister et al. 2000) was calculated as:

$$\log_{10}(W_s) = -5.542 + 3.23\log_{10}(TL),$$

where W_s is the length-specific standard weight (g) and TL (mm) is the total length of the individual. Recommended minimum lengths were 70-mm for channel catfish and 130-mm for flathead catfish. Mean W_r differences by fish length, season and site were analyzed using ANOVA with Tukey's HSD multiple comparisons when significant differences were identified. Incremental length categories were used for W_r comparisons and included sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P), preferred-

memorable (P-M) and memorable-trophy (M-T) size groups. Student's t-tests were used for river reach comparisons. River reach differences were further analyzed by examining $\log_{10}$-transformed length-weight linear regressions. Analysis of covariance (ANCOVA) was used to test for differences in length-weight relation slopes and intercepts between river reaches (Pope and Kruse 2007). All analyses were conducted using SAS (SAS Institute 2004) where significance was determined at $\alpha = 0.05$, unless otherwise noted.

Results

A total of 1,285 gear deployments were conducted between April 2007 and October 2008 (Table 2-1). Fish collections included 16,190 individuals from 49 different species (Table 2-2). The most commonly captured species were red shiner (N = 9,703), channel catfish (N = 2,222) and sand shiner (N = 1,087).

Habitat characteristics varied spatially and temporally across the river. Mean depth at gear deployment ranged from 0.3 to 3.0-m with a general pattern of deeper mean depths moving downstream (Table 2-3). Temperature ranged from 7.0 (November 2007) to 32.2 °C (July 2007). Dissolved oxygen ranged from 4.2 to 14.9 mg/L. Turbidity ranged from 5.8 to 1,806 NTU, overall. However, mean turbidity levels were greater in the lower Platte River (194 NTU) compared to the central Platte River (83 NTU; $P < 0.01$). Conductivity ranged from 232 to 1073 µS, but mean conductivity levels also differed between the central Platte River (913 µS) and lower Platte River (442 µS; $P < 0.01$). Mean daily discharges for each sampling trip varied by site and season with a range of 232-11,000 cubic feet per second (cfs). Percent difference from average daily discharge ranged from 88% below to 206% above normal mean daily flows.

Relative Abundance

Channel catfish dominated hoop net catches, comprising 89% of HN_{25} and 80% of HN_{38} total catch. Specific hoop net catch rates varied with HN_{25} having higher ($P < 0.01$) mean CPUE (1.96 fish/net-night) compared to HN_{38} (0.61 fish/net-night; Figure 2-3). Further, 55 % of deployed HN_{25} captured zero channel catfish compared to 71 % of HN_{38} deployments. Seasonal differences in mean CPUE for HN_{25} were apparent where fall had higher catch rates compared to summer ($P = 0.03$; Figure 2-4). Additionally, HN_{38} catch rates were lower during the summer compared to other seasons. Monthly comparisons of mean CPUE resulted in no differences in HN_{38} catch rates and only differences between September (2.57 fish/net-night) and June (1.52 fish/net-night) for HN_{25} (Figure 2-5). No differences were detected for HN_{25} catch rates compared across temperature ranges. However, HN_{38} had significantly greater mean CPUE at temperatures between 15-20°C compared to <15°C (Figure 2-6). Highest catch rates were observed during normal water discharges for HN_{38} (Figure 2-7).

Hoop net catch rates displayed a general pattern of increasing relative abundance from Site 10 downstream to Site 4 (Figure 2-8). However, after Site 4, mean CPUE decreased moving downstream to near the confluence with the Missouri River (Site 1). Greater relative abundances of channel catfish were also observed in the lower Platte River compared to the central Platte River ($P < 0.01$; Figure 2-9).

Channel catfish comprised only 4% of the total catch for EF_{60} and EF_{15}. Catch rates were not significantly different between EF_{60} (14.4 fish/hour, 3.46 fish/100-m) and EF_{15} (13.2 fish/hour, 3.33 fish/100-m; Figure 2-3). Different methods for calculating CPUE (i.e., fish/hour, fish/100-m) displayed similar relations. Therefore, only CPUE

calculated as fish/hour was used for additional comparisons. Highest mean CPUE was observed during the spring for both frequencies but no significant differences were detected among seasons (Figure 2-4). Electrofishing catch rates also varied by month but no significant differences were detected for either frequency (Figure 2-5). Intermediate temperatures had the highest electrofishing catch rates. Electrofishing runs in water temperatures of 15-20°C and 20-25°C had significantly higher mean CPUE compared to <15°C (Figure 2-6). Catch rates did not differ when analyzed by turbidity or LWD presence/absence (Table 2-4). Low flow conditions exhibited highest electrofishing catch rates (Figure 2-7). Mean CPUE declined as mean depths increased where samples taken in mean depths <1.0-m had significantly higher catch rates compared to all other depth ranges (1.0-1.5, 1.5-2.0, >2.0-m) for EF_{60} and EF_{15} (Figure 2-10).

Electrofishing relative abundance estimates varied longitudinally but no patterns were apparent. Highest relative abundances were observed at Site 3 where mean CPUE was 21.5 fish/hour for EF_{60} and 39.0 fish/hour for EF_{15} (Figure 2-8). Lowest relative abundances occurred at Site 4 and Site 1, both in the lower Platte River. The Site 4 abundances contradict observations from hoop nets. No significant differences in electrofishing relative abundance estimates were found between river reaches (Figure 2-9).

Size Structure

Channel catfish TL ranged from 53 to 970-mm in 2007 and 19 to 765-mm in 2008 using all gears (Figure 2-11). Mean and median lengths were greater during 2007 (mean = 286-mm, median = 262-mm) compared to 2008 (mean = 241-mm, median = 236-mm).

Most channel catfish (58% for 2007, 63% for 2008) were less than minimum stock length (280-mm) and PSD was 35 for 2007 compared to 24 for 2008 (Table 2-5).

I found gear-related size bias for gears used during 2007 ($P < 0.01$). Both HN_{25} and HN_{38} had similar size ranges (~ 50-600-mm) while EF_{60} sizes encompassed the entire size range (40-710-mm) except for a few large fish caught by SL (Figure 2-12). Mean lengths across gear types ranged from 191-mm (EF_{60}) to 554-mm (SL). Median lengths ranged from 150-mm (EF_{60}) to 557-mm (SL). Size structure indices varied by gear type where PSD for SL was greater compared to all other gears ($P < 0.01$; Table 2-5). However, EF_{60} and HN_{38} had similar PSD values ($P = 0.75$) but were higher compared to HN_{25} ($P < 0.01$).

Fish collections during 2008 included EF_{15} and RR in addition to 2007 methods (Figure 2-13). All length-frequency distributions were significantly different except EF_{60} and EF_{15} distributions ($P = 0.88$). Largest size ranges were observed for EF_{60} and EF_{15}, but these methods did not collect fish in the same proportion as other gears. Channel catfish 50-150-mm in length were most effectively sampled by EF_{60} and EF_{15}; whereas, HN_{25} collected large samples of 150-300-mm fish. Mean lengths across gear types ranged from 161-mm (EF_{15}) to 533-mm (SL). Median lengths ranged from 137-mm (EF_{15}) to 538-mm (SL) and PSD for SL was significantly higher compared to all other gears ($P < 0.01$). Lower PSD values were observed for RR and HN_{25} compared to all other gears ($P < 0.01$). Size structure indices (PSD, PSD-P and PSD-M) did not differ between EF_{60} and HN_{38} ($P > 0.09$).

Site and river reach size structure analyses were performed using only 2008 data because these data provided comparable effort of gears at all sites (Table 2-1).

Collections from angler tournaments (SL and RR) were also excluded from analyses because fish were not captured at designated sampling sites. Mean lengths ranged from 185-mm (Site 3) to 298-mm (Site 8; Figure 2-14). Median lengths ranged from 151-mm (Site 3) to 290-mm (Site 8). Sites 5, 6 and 7 had similar length-frequency distributions ($P = 0.07$). Lowest PSD estimates were observed at Site 4 and Site 5 while Site 2 and Site 10 had highest PSD (Table 2-6). Site 7 exhibited highest PSD-P estimates. However, PSD-P at Site 7 was only significantly greater than Site 5 and Site 6 ($P < 0.01$). Channel catfish of memorable size (≥ 710-mm) were only collected at Site 3 and Site 4.

Length-frequency distributions, mean lengths and size structure indices also differed between the central Platte River and lower Platte River (Figure 2-15). Length-frequency distribution comparisons (i.e., central Platte River HN_{25} catch vs. lower Platte River HN_{25} catch) for all gear types were significantly different ($P < 0.01$). Mean lengths were consistently higher in the central Platte River compared to the lower Platte River for HN_{25}, HN_{38} (Figure 2-16), EF_{60} and EF_{15} (Figure 2-17). Size structure indices were also greater in the central Platte River where few small channel catfish were collected (Table 2-7). Electrofishing length-frequency peaks were around 150-mm for the central Platte River compared to 50-mm for the lower Platte River.

Condition

Channel catfish collected during 2007 and 2008 represent an exponential length-weight relation, $W = (0.000009)TL^{2.956}$. Incremental weight gains with increasing length were not different between central Platte River and lower Platte River channel catfish (ANCOVA, $P = 0.09$). However, channel catfish in the central Platte River are

consistently heavier at a given length compared to channel catfish in the lower Platte River (ANCOVA, $P < 0.01$; Figure 2-18).

Comparisons of W_r suggest sub-stock (S-S) channel catfish had the highest relative weight compared to all other length categories (Figure 2-19). Mean W_r (±SE) decreased sharply from 104 (±1.02) to 85 (±0.47) between S-S and stock-quality (S-Q) fish. Fish condition subsequently improved with increasing size above the S-Q size group.

Seasonal variation in W_r was evident for channel catfish in the Platte River. However, patterns differed by length categories. Fish of S-S and S-Q size were in best condition during the summer compared to spring and fall (Figure 2-20). However, quality-preferred (Q-P) and preferred-memorable (P-M) channel catfish had highest mean W_r values during the spring decreasing through the summer and fall.

Considerable variation in mean W_r of S-S and Q-P channel catfish was observed between sites. Mean W_r for S-Q fish followed a general decreasing trend moving downstream from Site 10. However, S-S channel catfish displayed a U-shaped pattern with highest mean W_r at the furthest upstream and downstream sites (Figure 2-21). Spatial patterns by site were not analyzed for preferred-size fish (i.e., P-M, M-T) due to low sample sizes at each site. All length categories of channel catfish exhibited better condition in the central Platte River compared to the lower Platte River when mean W_r was analyzed by river reach (Figure 2-22).

Flathead Catfish

A total of 106 flathead catfish were collected during 2007 and 2008. Most flathead catfish were collected by electrofishing (N = 71) but no differences were observed between EF_{60} and EF_{15} mean catch rates (Figure 2-23). Hoop net catch rates were extremely low at 0.032 fish/net-night for HN_{25} and 0.015 fish/net-night for HN_{38} (Figure 2-22). Electrofishing data were pooled (EF_{60} and EF_{15}) to increase sample size for river reach comparisons. No differences were observed between central Platte River and lower Platte River relative abundance estimates (Figure 2-24).

Flathead catfish sizes ranged from 38 to 1,002-mm with mean length of 312-mm and median length of 289-mm (Figure 2-25). Large flathead catfish collected during setline tournaments coupled with low samples from standard gears inflated overall size structure indices, but PSD was 36 for all flathead catfish sampled.

Flathead catfish collected in the Platte River represent an exponential length-weight relation, $W = (0.127350)TL^{2.965}$ (Figure 2-26). Condition of flathead catfish displayed similar length related patterns as channel catfish (Figure 2-27) where mean W_r (±SE) was highest for S-S fish (106 ±2.5) and lowest for fish S-Q size (84 ±2.6). Insufficient data were available for detailed W_r analyses at site or reach level.

Many years have passed since the most recent catfish investigations on the Platte River. Documenting temporal change in population characteristics is important for researchers and managers alike. Summary statistics and comparisons of channel catfish population characteristics from previous Platte River catfish studies and the current study are displayed in Table 2-8. Hoop net catch rates appear to be similar between studies. However, previous studies had higher mean electrofishing CPUE. Additionally, size

structure indices for the central Platte River and lower Platte River are generally higher at present, compared to historical data. Present length-weight relations fall within the range observed during previous studies.

Discussion

I observed considerable variability in relative abundance, size structure and condition of channel catfish along the Platte River. However, several longitudinal patterns appear to exist. Lowest relative abundances were observed at the most upstream and downstream sites with the lower Platte River exhibiting higher relative abundances compared to the central Platte River. Consequently, channel catfish in the central Platte River displayed larger size structures and higher conditions compared to the lower Platte River. Additionally, seasonal and size-specific patterns in fish condition were observed. Sampling methods used to collect channel catfish in the Platte River appear to influence estimates of population characteristics depending on season and habitat characteristics. These findings highlight the complexity of the Platte River system where numerous biotic and abiotic factors are likely influencing channel catfish population characteristics throughout the Platte River.

Channel catfish relative abundances in the Platte River were comparable to other Midwestern rivers. Hesse et al. (1979a) used hoop nets similar in dimension (25-mm mesh, 1.47-m length, 0.6-m diameter) to nets used during this study and observed comparable relative abundances in the unchannelized Missouri River (0.2 – 2.3 fish/net-night) and the Niobrara River (0.1 – 5.9 fish/net-night). Similarly, Quist and Guy (1998) reported hoop net (dimensions: 13-mm mesh, 1.1-m length) catch rates in the Kansas

River ranging from 1.5 to 2.6 fish/net-night. Electrofishing relative abundances were also similar in the Platte River compared to some reaches of the Wabash River (15.46 fish/hour; Colombo 2007). These comparisons suggest that channel catfish abundances in the Platte River are average compared to other systems in the region.

Relative abundance estimates displayed a longitudinal pattern along the Platte River. Lowest relative abundances were generally observed most upstream (Sites 8-10) and downstream (Sites 1-2) in our study area. Highest relative abundances were documented generally in the middle reaches (Sites 3-5). Makinster (2006) found similar patterns for flathead catfish in the Kansas River, where lowest relative abundances were observed at the lowermost (near confluence with the Missouri River) and uppermost sampling reaches. Some of the differences in relative fish densities could be attributed to habitat availability (i.e., spawning and refuge) in certain reaches of the river. Habitat suitable for juvenile and adult catfish is readily available in the lowest reaches of the Platte River (Peters and Holland 1994), though more preferable habitat (i.e., rock revetment, deep scour holes behind wing dikes) may exist in the nearby Missouri River. Missouri River habitat may attract channel catfish from the Platte River during certain times of the year. In fact, channel catfish have been documented to immigrate to the Missouri River from numerous tributaries including the Niobrara River (Hesse et al. 1979a), Little Nemaha River (Hesse et al 1979b), Big Sioux River (Newcomb 1989), Perche Creek (Dames et al. 1989) and the Platte River (Peters et al. 1992). Peters et al. (1992) found minimal use of the lower 30 miles (encompassing Sites 1 and 2 in the current study) of the Platte River by channel catfish implanted with radio transmitters. The low relative abundances observed at Site 1 and Site 2 during my study coupled with

movement patterns previously documented suggest the lowest reaches of the Platte River may be an area used as temporary refuge for transitory fish moving between the Missouri and Platte rivers.

Temporal changes in relative abundance estimates appear to be minimal. Peters et al. (1992) and Holland and Peters (1994) observed annual variability in hoop net catch rates between sites and river reaches that were comparable to my findings (Table 2-8). Electrofishing catch rates were higher during previous studies. However, Peters et al. (1992) cited a number of 'high catch' anomalies that likely inflated overall catch rates.

Striking differences in channel catfish size structure were observed between river reaches. Longer mean lengths, greater Proportional Size Distributions (PSD) and lower abundances of small channel catfish characterized the central Platte River. Low abundances of small channel catfish suggest limited recruitment in the central Platte River. Low recruitment may be due to higher predator abundances and specific habitat characteristics. Higher relative densities of predators, namely largemouth bass *Micropterus salmoides*, were observed in the central Platte River during my study. Additionally, turbidity levels in the central Platte River are less than the lower Platte River. The impact of predation risk is reduced in turbid aquatic ecosystems (Abrahams and Kattenfeld 1997). Therefore, low turbidity levels in the central Platte River could facilitate sight-feeding bass predation on YOY channel catfish. Further, Krummrich and Heidenger (1973) found channel catfish, up to 178-mm, to be highly vulnerable to largemouth bass predation. This information suggests that young channel catfish in the central Platte River are susceptible to predation, possibly hindering recruitment.

Another possible reason the central Platte River exhibits a larger size structure compared to the lower Platte River could be the amount of suitable habitat available for adult channel catfish. Peters and Holland (1994) indicated the need for cover as suitable habitat for adult channel catfish. My observations in the field suggest cover in the form of aquatic macrophytes, in-stream log jams and overhanging trees and vegetation is more abundant in the central Platte River. This is especially prevalent with the present flows that are inundating terrestrial vegetation and encouraging growth of emergent vegetation. Additionally, the central Platte River has experienced a rapid transformation from a historically shallow, unvegetated, highly braided system to a deeper, well vegetated, narrow channeled river (Sidle et al. 1989, Simons 2000, USDOI 2006). Therefore, highly vegetated islands and numerous cut-channels likely provide more bank cover/surface water interface, providing more suitable habitat for large channel catfish.

Fishing mortality, or lack thereof, could also be playing a key role in structuring channel catfish populations. Anglers often target the largest individuals in a population and if size-selective angling occurs, size and age distributions may be truncated (Lewin et al. 2006). The lower Platte River has historically supported a recreational channel catfish fishery (Holland and Peters 1994). However, potential over-exploitation has been a concern. Little is known about recreational fishing and its effect on fishes in the central Platte River. However, results from a single survey question showed fishing pressure was much lower in the central Platte River compared to the lower Platte River during 1992 and 1993 (Holland and Peters 1994). Therefore, the central Platte River may not see cropping of larger individuals in the population resulting in greater size structures.

Observations of length-weight relations indicate that fish length, season, and location all have an effect on channel catfish condition in the Platte River. Similar patterns of length related fish condition have been documented for channel catfish in South Dakota rivers (Doorenbos et al. 1999). Kansas River channel catfish populations exhibited similarly low W_r for S-Q channel catfish (77-80), but failed to display a pattern of increasing W_r in Q-P fish (Quist and Guy 1998) as I observed. Comparing Platte River channel catfish W_r to W_r distribution statistics provided by Brown et al. (1995), S-S fish condition is higher than normal (~75th percentile); whereas all other length categories are slightly below normal (25th – 50th percentile). This relation may indicate differences in food availability for specified length groups. Channel catfish of S-S size feed primarily on insects and plant material in rivers (Zuerlein 1982, Armstrong and Brown 1983, Weisberg and Janicki 1990). McBride (1995) and Peters and Parham (2008) documented a diversity of macroinvertebrates in the Platte River that suggest food availability is not limited for smaller catfish.

Seasonal variation in channel catfish condition is evident and could be explained by food availability and/or stress, especially for juveniles. In a review of seasonal dynamics of fish sampling, Pope and Willis (1996) noted that seasonal changes in immature fish condition may be attributed to feeding conditions during the winter and spring. Smallest channel catfish (S-S) had lowest W_r in the spring increasing to highest condition in the summer during the present study. Similarly, Woodward and Wilson (1989) found reduced W_r of young saugeye in the spring with increasing condition in summer.

Seasonal variations in adult condition may better be explained by gonadal development and spawning. Large channel catfish (Q-P and P-M) W_r peaked during the spring, subsequently decreasing through summer and fall. Generally, channel catfish mature at lengths of 300 – 375-mm and spawn in the spring and early summer when temperatures reach 21 – 29 °C (Hubert 1999). Therefore, seasonal condition patterns of mature channel catfish could be a function of spawning behavior in the Platte River where condition is high prior to spawning and drops shortly after. This pattern of declining W_r after spawn is well documented for numerous species and regions (Gablehouse 1991, Guy and Willis 1991, Neumann and Murphy 1991, Austen et al. 1994, Neely 2008).

Spatial differences in channel catfish condition could also be influenced by a recent nutrient upsurge in the central Platte River creating more secondary production and available forage. Reservoirs experiencing low water levels where growth of terrestrial vegetation takes place in exposed areas, followed by flooding of vegetation, can simulate a nutrient upsurge and increase productivity (Summerfelt 1999). The central Platte River may be experiencing similar effects where higher water events during my study (Figure 2-2) have increased terrestrial plant inundation, possibly increasing production and available forage. The central Platte River also exhibits lower turbidity levels that may promote increased macrophyte growth. Invertebrate production and the production of insectivorous fishes have been directly correlated to attachment surface area (Pardue 1973) and macrophyte density (Wiley et al. 1984). This information suggests increased productivity, including plants, invertebrates and forage fish, is likely a positive influence on channel catfish condition in the central Platte River.

Food availability, and therefore fish condition, in the lower Platte River may be negatively affected by water manipulations of the Loup River Power Canal. Hesse et al. (1982a) stated that the widely fluctuating stage of the Missouri River was the greatest threat to its channel catfish populations. The effects of changes in flow are broad, influencing riverine plants, invertebrates and fish (Bunn and Arthington 2002). Fluctuations in river discharge have been reported to limit community biomass and energy, drastically reducing epiphyton (Blinn et al. 1995) and macroinvertebrate abundance (Gislason 1985, Blinn et al. 1995, Haxton and Findlay 2008). Additionally, hydropeaking could cause highly variable habitat conditions further stressing fish searching for food and suitable habitat. Therefore, lower Platte River catfish populations are likely experiencing stressful habitat conditions with varying and low food availability due to water manipulations, ultimately resulting in reduced fish condition.

Sampling methods used to collect catfish in the Platte River displayed varying catch rates between gears, seasons and habitat characteristics. Additionally, size selectivity was observed for sampling methods as seen in variable size structure estimates. Investigating these possible biases is important when considering further monitoring of a population to ensure comparability of data.

Small mesh hoop nets (HN_{25}) displayed higher catch rates compared to large mesh hoop nets (HN_{38}). These results were congruent with previous investigations (Hesse et al. 1982b, Holland and Peters 1992a, Walker et al. 1994, Colombo et al. 2008). Electrofishing catch rates did not differ by season; whereas hoop net catches were highest in the spring and fall. Similar seasonal trends in hoop net catches were observed in previous Platte River studies and may be due to the increased mobility of channel catfish

in the Platte River during these periods (Bunnell 1988, Holland and Peters 1992a, Holland and Peters 1994, Peters et al. 1992, Chapman 1995).

Catch rates for all sampling methods were greatest at intermediate water temperatures (15-25°C) and electrofishing conducted during the coldest temperatures (<15°C) yielded the lowest catch rates. Our results are consistent with other studies investigating temperature effects on electrofishing catch rates (Quinn 1986, Justus 1994, Grussing et al. 1999). Quinn (1986) stated that electrofishing efficiency was significantly reduced in temperatures less than 20°C and Justus (1994) described an optimal temperature range to collect channel catfish of 22-27°C. However, conflicting results for hoop net catches have been documented in the Missouri River. Hesse et al. (1982c) suggested that channel catfish activity in the Missouri River was greatest during July when warmest annual water temperatures led to the highest hoop net catch rates. Therefore, seasonal behavior of channel catfish may differ between river systems.

Sampling during relatively high water discharges was not effective. Catch rates were highest during normal flows for hoop nets and low flows for electrofishing. Additionally, shallow water depths provided the best catches for electrofishing. Differing electrofishing techniques could be the reason for this trend. At depths generally less than 1.5-m, dip netting and cataraft maneuvering could be done by walking in the river. This method may cause relative efficiency to increase because netters are not restricted and have much wider netting ranges. However, depths greater than 1.5-m forced crew members to net fish and control the cataraft from within. This caused greater difficulty positioning anode droppers near shore and in-stream cover as well as positioning netters to catch all surfacing fish. Furthermore, fish may be able to avoid the electric field more

easily and not surface as quickly when electrofishing in deeper water. Portt et al. (2006) stated that electrofishing boats become less efficient in deeper water where fish can avoid the electric field by sounding. However, it is possible that higher abundances of channel catfish actually inhabit shallower waters. For example, depths 0.5 to 0.7-m were reported as the most suitable habitat for juvenile channel catfish in the Platte River (Peters and Holland 1994).

Generally, small individuals (< 100-mm) were most effectively sampled using EF_{60} and EF_{15}, intermediate lengths (150-400-mm) using HN_{25}, HN_{38} and RR and largest fish (> 400-mm) using SL. Electrofishing also collected the widest size range of channel catfish. Santucci et al. (1999) documented that electrofishing selected for smaller channel catfish compared to actual abundances in an Illinois Lake. However, Colombo et al. (2008) collected very few young, small channel catfish using electrofishing. Both studies used AC electrofishing, further suggesting differences and biases of specific electrofishing currents and frequencies. However, EF_{60} and EF_{15} sampled similar size distributions of channel catfish during my study. It appears that size structure index estimates are consistently similar for EF_{60} and HN_{38}, indicating either method could be used singly when analyzing population size structure. Mean length of channel catfish captured by HN_{25} was smaller compared to HN_{38} caught fish. The pattern of increasing mean length with increasing mesh size was similar in previous studies (Hesse et al. 1982b, Holland and Peters 1992a, Jackson and Jackson 1997, Colombo et al. 2008).

Tournament anglers were selective for large channel catfish when using SL. Set lines and trotlines are well known to collect the largest catfish in a population (Santucci et al. 1999, Stauffer and Koenen 1999, Vokoun and Rabeni 1999, Arterburn and Berry

2002). Angler catches from RR displayed intermediate lengths. Santucci et al. (1999) found anglers catch channel catfish in similar proportion to their actual abundance and suggested using angler data to supplement gill net catches during population assessment. Though this appears to be a good suggestion, populations of channel catfish in the Platte River are likely more dynamic than a stocked, non-reproducing population of channel catfish in a small lake. Nonetheless, the importance of angler catch data (SL and RR) shouldn't be understated. The information obtained from these sources is very important as it displays exploitation of large individuals in the population and it documents the presence of these fish in the system. Long-term data collection from tournaments could be beneficial in understanding dynamics of the largest, oldest individuals in the population.

My analyses indicate that individual gears provide inconsistent estimates of population characteristics and the use of only one gear may provide biased results further complicating management decisions. Sampling methods chosen for field assessments often reflect research and management objectives (Vokoun and Rabeni 1999). Based on gear-specific catch rates and size structures, I recommend spring sampling (avoiding high flow events) using HN_{25} and EF_{60} to assess channel catfish populations in the Platte River with the objective of gaining information about general population characteristics (i.e., CPUE, size structure, condition, etc.). Supplemental angler tournament (SL and RR) collections would also be beneficial for overall population assessment. This sampling approach differs from recommended sampling for prairie streams (Vokoun and Rabeni 2001) but is similar to suggestions made for a large Midwestern river (Colombo et al. 2008). However, the physical characteristics of the Platte River appear to fall somewhere

between these systems. I believe using this multi-gear approach will provide sufficient information for precise population monitoring. Further, this sampling approach could be implemented to assess and monitor catfish populations in the many shallow braided rivers throughout the Midwest.

This study addressed initial questions regarding the status of channel catfish populations in the Platte River. However, new information is needed. I attempted to quantify actual gear bias and selectivity through a number of experiments (Appendix B). However, more research is needed on gear efficiency, especially in lotic systems. Specific investigations concerning prey availability, food habits, and recruitment would be beneficial in understanding factors influencing channel catfish relative abundance, size structure and condition in the Platte River. Researching human dimensions of the Platte River fishery, including angler exploitation and angler expectations, would also provide insight for specific management strategies and objectives. Further, assessing different management actions (i.e., minimum length limit, bag limit) through simulations could also be beneficial in determining best management strategies for the fishery.

Channel catfish are a popular sportfish in the Platte River and throughout Nebraska. However, minimal management efforts have been implemented for catfish populations, especially in lotic systems (Michaletz and Dillard 1999). My study provides insights on factors potentially influencing channel catfish populations in a large warmwater braided river. This information, along with system-specific characteristics, could be used by managers to make best management decisions for a given fishery.

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Table 2-1. Sampling effort (gear deployments) by site and season using 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}), high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2007 and 2008.

	2007								
	HN_{25}			**HN_{38}**			**EF_{60}**		
Site	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1	4	9	9	3	10	10	0	0	0
2	0	10	10	0	10	10	0	0	0
3	0	10	10	0	10	10	0	7	5
4	0	10	9	0	7	10	0	0	5
5	0	8	8	0	9	4	0	5	0
6	0	10	7	0	9	6	0	0	0
7	5	8	0	4	8	0	0	6	0
8	5	8	0	5	10	0	0	0	0
9	4	10	0	4	10	0	0	0	0
10	5	9	0	5	10	0	0	0	0

	2008											
	HN_{25}			**HN_{38}**			**EF_{60}**			**EF_{15}**		
Site	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1	15	15	15	15	15	15	0	5	5	0	5	5
2	15	15	15	15	15	15	0	5	5	0	5	5
3	15	15	15	15	15	15	6	10	5	0	5	5
4	15	15	15	15	15	14	0	5	5	0	5	5
5	15	15	6	15	15	15	0	3	5	0	3	5
6	13	15	13	14	15	15	0	5	5	0	5	5
7	0	15	0	0	15	0	0	5	5	0	5	5
8	15	14	0	14	14	0	0	5	0	0	5	0
9	15	14	0	15	15	0	0	5	5	0	5	5
10	13	14	0	15	15	0	0	5	5	0	5	5

Table 2-2. Fish species composition and total abundance captured with all gears in the Platte River during 2007 and 2008.

Species	**Number of Individuals**
Shovelnose sturgeon *Scaphirhynchus platorynchus*	14
Longnose gar *Lepisosteus osseus*	31
Shortnose gar *Lepisosteus platostomus*	9
Goldeye *Hiodon alosoides*	8
Gizzard shad *Dorosoma cepedianum*	83
Minnow spp. *Cyprinidae*	1
Central stoneroller *Campostoma anomalum*	1
Speckled chub *Macrhybopsis aestivalis*	1
Silver chub *Macrhybopsis storeriana*	9
Flathead chub *Platygobio gracilis*	70
Creek chub *Semotilus atromaculatus*	76
Red shiner *Cyprinella lutrensis*	9703
Golden shiner *Notemigonus crysoleucas*	1
Emerald shiner *Notropis atherinoides*	37
River shiner *Notropis blennius*	580
Bigmouth shiner *Notropis dorsalis*	81
Sand shiner *Notropis stramineus*	1087
Suckermouth minnow *Phenacobius mirabilis*	13
Bluntnose minnow *Pimephales notatus*	4
Fathead minnow *Pimephales promelas*	19
Common carp *Cyprinus carpio*	548
Carpsuker spp. *Carpiodes*	5
River carpsucker *Carpiodes carpio*	235
Quillback *Carpiodes cyprinus*	18
White sucker *Catostomus commersoni*	74
Blue sucker *Cycleptus elongatus*	21
Smallmouth buffalo *Ictiobus bubalus*	2
Bigmouth buffalo *Ictiobus cyprinellus*	1
Shorthead redhorse *Moxostoma macrolepidotum*	14
Black bullhead *Ameiurus melas*	19
Yellow bullhead *Ameiurus natalis*	58
Blue catfish *Ictalurus furcatus*	4
Channel catfish *Ictalurus punctatus*	2222
Flathead catfish *Pylodictis olivaris*	106
Stonecat *Noturus flavus*	1

Table 2-2 Continued

Species	**Number of Individuals**
Plains killifish *Fundulus zebrinus*	18
Western mosquitofish *Gambusia affinis*	28
Brook silverside *Labidesthes sicculus*	46
Brook stickleback *Culaea inconstans*	1
White bass *Morone chrysops*	1
Sunfish spp. *Centrarchidae*	2
Sunfish spp. (no crappie) *Lepomis*	1
Green sunfish *Lepomis cyanellus*	184
Orangespotted sunfish *Lepomis humilis*	34
Bluegill *Lepomis macrochirus*	123
Largemouth bass *Micropterus salmoides*	241
Crappie spp. *Pomoxis*	3
White crappie *Pomoxis annularis*	20
Black crappie *Pomoxis nigromaculatus*	17
Iowa darter *Etheostoma exile*	1
Sauger *Sander canadensis*	2
Walleye *Sander vitreus*	1
Freshwater drum *Aplodinotus grunniens*	311
Total	**16190**

Table 2-3. Habitat characteristics (depth, temperature, dissolved oxygen, turbidity, conductivity and water discharge) by site and river reach recorded during fish collections in the Platte River during 2007 and 2008.

	Depth (m)				**Temperature (°C)**				**Dissolved Oxygen (mg/L)**			
Site	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
1	1.51	0.04	0.50	2.50	21.37	0.38	12.60	27.00	6.81	0.02	6.60	6.88
2	1.31	0.04	0.40	2.50	21.17	0.41	12.70	27.70	8.26	0.19	6.11	14.90
3	1.20	0.04	0.40	2.30	22.59	0.36	10.00	30.30	8.57	0.18	7.90	12.80
4	1.23	0.04	0.40	2.50	20.81	0.33	7.00	24.20	7.76	0.14	5.31	10.90
5	1.07	0.04	0.30	2.50	20.72	0.63	10.20	32.20	7.27	0.15	4.20	8.27
6	1.11	0.04	0.40	3.00	20.05	0.36	15.00	26.80	9.23	0.17	7.05	10.60
Lower	**1.26**	**0.02**	**0.30**	**3.00**	**21.16**	**0.17**	**7.00**	**32.20**	**8.13**	**0.08**	**4.20**	**14.90**
7	1.02	0.04	0.30	2.00	23.12	0.44	12.90	27.20	9.67	0.08	8.75	10.10
8	1.05	0.05	0.40	2.00	21.19	0.58	13.60	28.00	6.83	0.10	6.46	7.87
9	1.00	0.04	0.40	2.50	19.25	0.43	9.90	24.50	6.24	0.17	5.63	8.02
10	1.10	0.04	0.40	2.50	19.81	0.37	10.60	27.40	7.38	0.18	5.68	8.74
Central	**1.04**	**0.02**	**0.30**	**2.50**	**20.71**	**0.24**	**9.90**	**28.00**	**7.68**	**0.12**	**5.63**	**10.10**
Overall	**1.19**	**0.01**	**0.30**	**3.00**	**21.02**	**0.14**	**7.00**	**32.20**	**8.01**	**0.07**	**4.20**	**14.90**

Table 2-3. Continued.

	Turbidity (NTU)				Conductivity (µS)				Discharge (ft^3/sec)			
Site	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
1	255.49	15.24	63.0	517.0	474.21	8.51	378	680	6856	167.87	3420	11000
2	179.54	8.93	71.0	398.0	523.50	5.12	452	613	7354	148.58	4420	10100
3	112.75	4.99	64.0	189.0	455.02	11.78	342	575	4447	124.09	1010	7650
4	196.75	7.51	61.0	337.0	368.25	4.70	252	470	4268	151.06	1280	6060
5	123.16	14.67	43.0	550.0	481.13	13.46	232	648	4841	165.00	454	8320
6	289.80	51.34	62.0	1806.0	359.40	4.50	303	416	3153	123.96	860	5660
Lower	**193.80**	**8.04**	**43.0**	**1806.0**	**441.96**	**3.98**	**232**	**680**	**5154**	**75.49**	**454**	**11000**
7	171.42	40.10	5.8	1380.0	831.84	12.50	585	946	1491	44.53	380	1920
8	55.38	3.55	40.0	125.0	926.66	10.90	745	997	1258	76.04	471	2530
9	48.18	2.14	24.5	75.0	918.07	7.60	770	990	712	28.00	360	1350
10	55.71	3.56	14.0	151.0	967.19	10.29	665	1073	864	60.40	232	1810
Central	**83.28**	**10.61**	**5.8**	**1380.0**	**913.31**	**5.67**	**585**	**1073**	**1067**	**31.33**	**232**	**2530**
Overall	**156.90**	**6.60**	**5.8**	**1806.0**	**613.17**	**7.54**	**232**	**1073**	**3928**	**72.43**	**232**	**11000**

Table 2-4. Catch per unit effort (CPUE) by turbidity, depth and presence/absence of large woody debris (LWD) of channel catfish collected with high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2007 and 2008.

	Sampling Gear			
	EF_{60}		**EF_{15}**	
Parameter	**CPUE**	**SE**	**CPUE**	**SE**
Turbidity (NTU)				
< 100	14.34	2.25	15.90	4.47
100 - 200	22.20	11.41	17.70	6.86
200 - 300	12.92	6.15	9.69	4.63
> 300	8.40	2.98	9.12	2.38
Depth (m)				
< 1.0	30.44	8.58	23.50	7.10
1 - 1.5	12.10	2.50	18.00	4.67
1.5 - 2.0	10.08	3.61	6.30	2.36
> 2.0	4.15	2.83	2.18	1.22
LWD				
Present	13.32	3.24	13.55	4.31
Absent	14.38	3.07	13.40	2.89

Table 2-5. Size structure indices, including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P), memorable (PSD-M) and trophy (PSD-T) channel catfish collected with 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}), high frequency pulsed-DC electrofishing (EF_{60}), low frequency pulsed-DC electrofishing (EF_{15}), setlines (SL) and rod and reel (RR) in the Platte River during 2007 and 2008.

2007						
	N	**% stock**	**PSD**	**PSD-P**	**PSD-M**	**PSD-T**
HN_{25}	371	38	13	0	0	0
HN_{38}	85	51	51	0	0	0
EF_{60}	75	17	46	31	0	0
SL	42	100	88	21	7	2
ALL	573	42	35	5	1	0

2008						
	N	**% stock**	**PSD**	**PSD-P**	**PSD-M**	**PSD-T**
HN_{25}	649	28	15	2	1	0
HN_{38}	228	31	42	1	0	0
EF_{60}	205	16	41	6	0	0
EF_{15}	255	21	38	8	2	0
SL	34	100	91	15	3	0
RR	277	88	10	1	1	0
ALL	1648	37	24	3	1	0

Table 2-6. Size structure indices by site, including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P), memorable (PSD-M) and trophy (PSD-T) channel catfish collected using all standard sampling gears in the Platte River during 2008.

Site	N	% stock	PSD	PSD-P	PSD-M	PSD-T
1	44	27	33	0	0	0
2	94	21	50	0	0	0
3	295	21	38	5	2	0
4	285	17	12	2	2	0
5	158	30	10	0	0	0
6	193	27	17	0	0	0
7	121	31	41	11	0	0
8	58	59	26	3	0	0
9	67	34	35	4	0	0
10	22	18	50	0	0	0

Table 2-7. Size structure indices by river reach, including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P), memorable (PSD-M) and trophy (PSD-T) channel catfish collected with 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}), high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2008.

Gear	Reach	N	% stock	PSD	PSD-P	PSD-M	PSD-T
HN_{25}	Central	100	50	22	4	0	0
	Lower	549	24	13	1	1	0
HN_{38}	Central	14	86	50	2	0	0
	Lower	214	28	41	2	0	0
EF_{60}	Central	83	28	43	15	0	0
	Lower	172	17	33	3	3	0
EF_{15}	Central	71	18	54	9	0	0
	Lower	134	14	32	7	0	0
All	Central	268	37	35	6	0	0
	Lower	1069	23	24	2	1	0

Table 2-8. Summary statistics, including relative abundance (mean CPUE), size structure (PSD, PSD-P) and length-weight relation, of current and historical channel catfish investigations in the Platte River. Previous studies include Peters et al. (1992), Holland and Peters (1992a), Holland and Peters (1992b) and Holland and Peters (1994).

		Current Study		Previous Studies	
		HN	EF	HN	EF
Relative Abundance (mean CPUE)					
Central		1.14	13.89	0.69 - 1.65	N/A
Lower		2.3	15.56	0.44 - 4.2	25.2 - 110.4
Season (highest catch rates)		spring/fall	spring	late spring/ early fall	late summer/ fall
Size Structure					
Central					
	PSD	22	43	8 - 15	N/A
	PSD-P	4	15	1 - 2	N/A
Lower					
	PSD	13	33	3 - 27	7 - 11
	PSD-P	1	0	0-4	0
Length-weight relation					
Central		LogWt = -5.060 + (2.989 * LogTL)		N/A	
				Range	
Lower		LogWt = -4.983 + (2.933 * LogTL)		LogWt = -4.720 + (2.821 * LogTL)	
				LogWt = -5.812 + (3.263 * LogTL)	

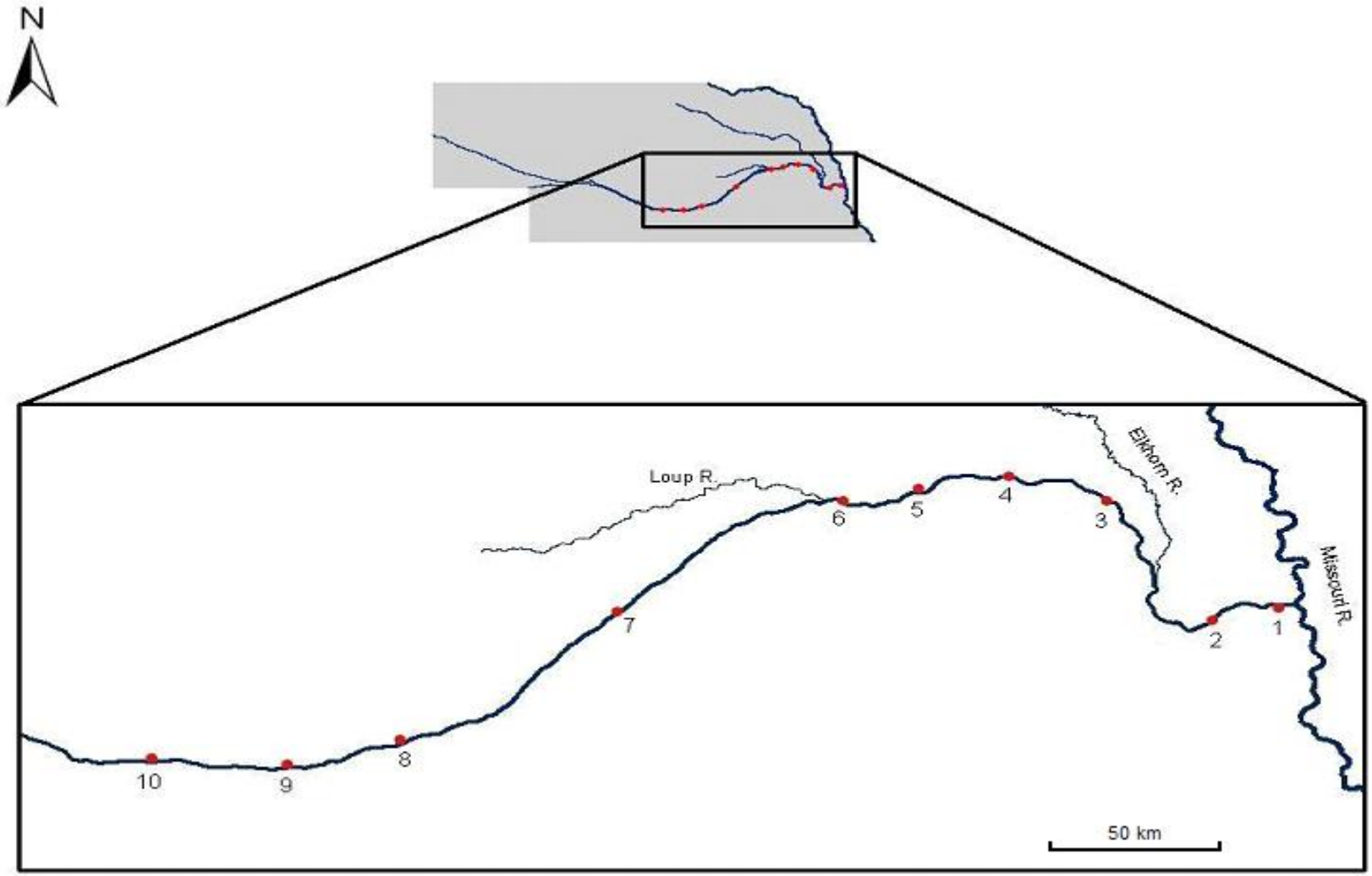

Figure 2-1. Study area including sampling locations in the central (Sites 7-10) and lower (Sites 1-6) Platte River, Nebraska.

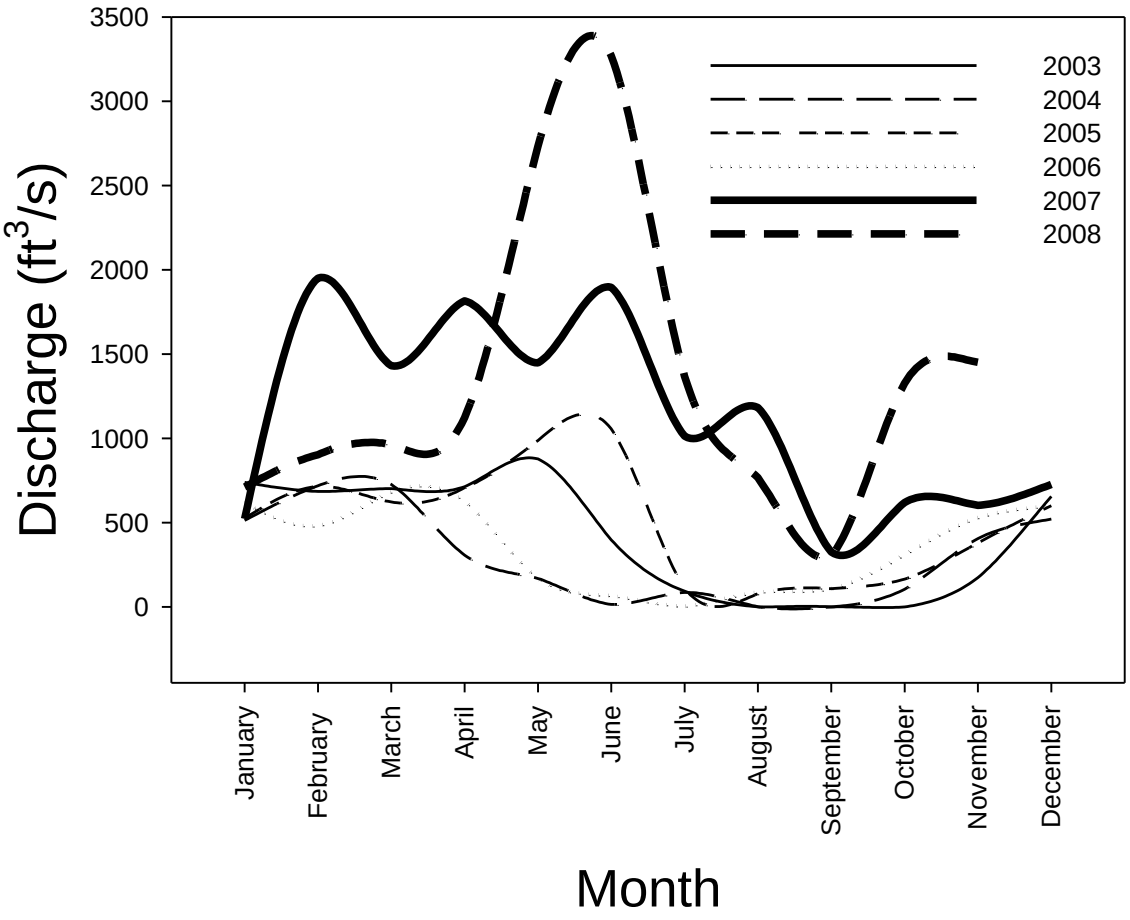

Figure 2-2. Mean monthly discharge of the Platte River near Grand Island, NE (USGS gauge 06770500) during 2003-2008. Bold plots represent discharge during the current study (2007-2008).

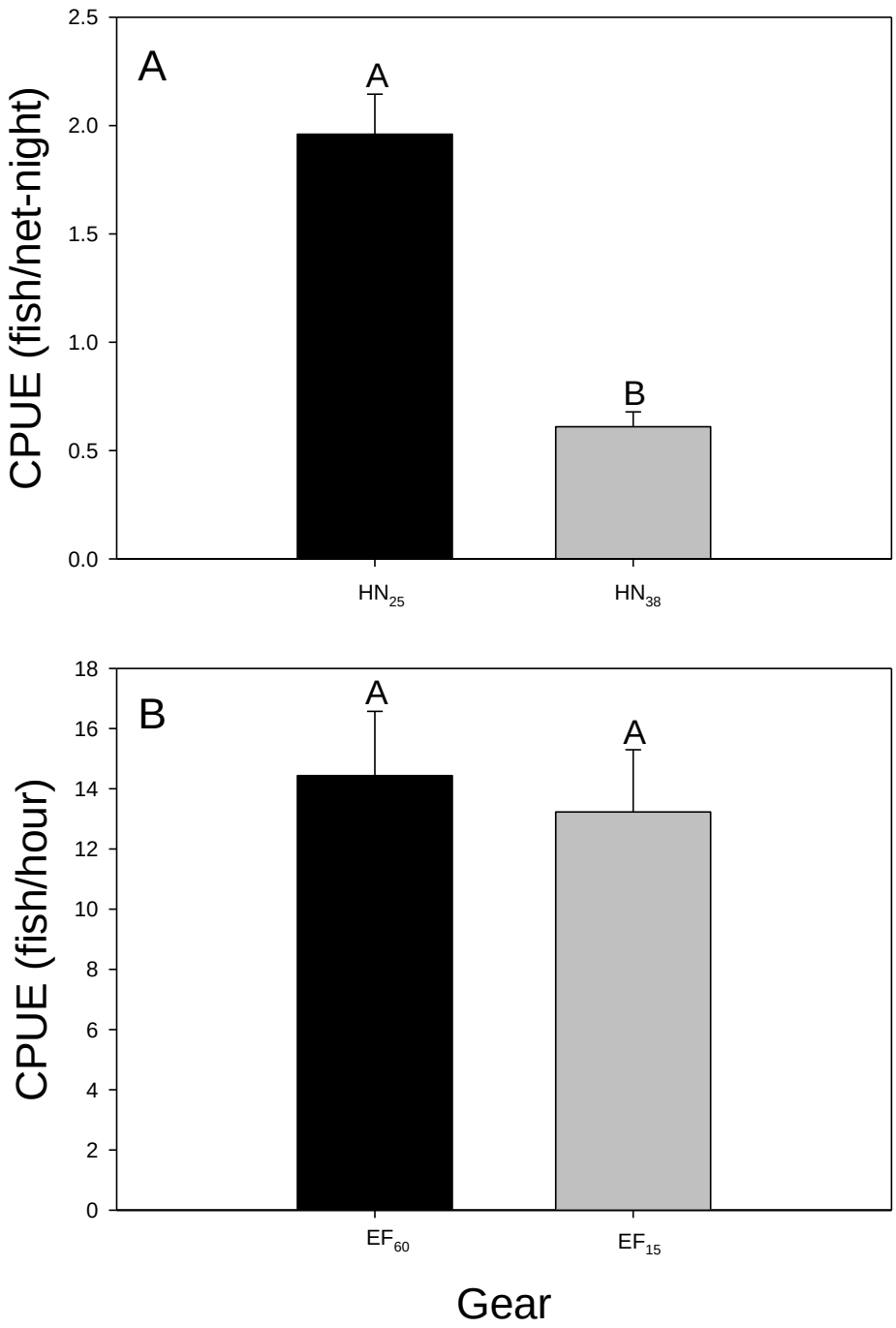

Figure 2-3. Mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different letters above plots indicate differences in CPUE among gears.

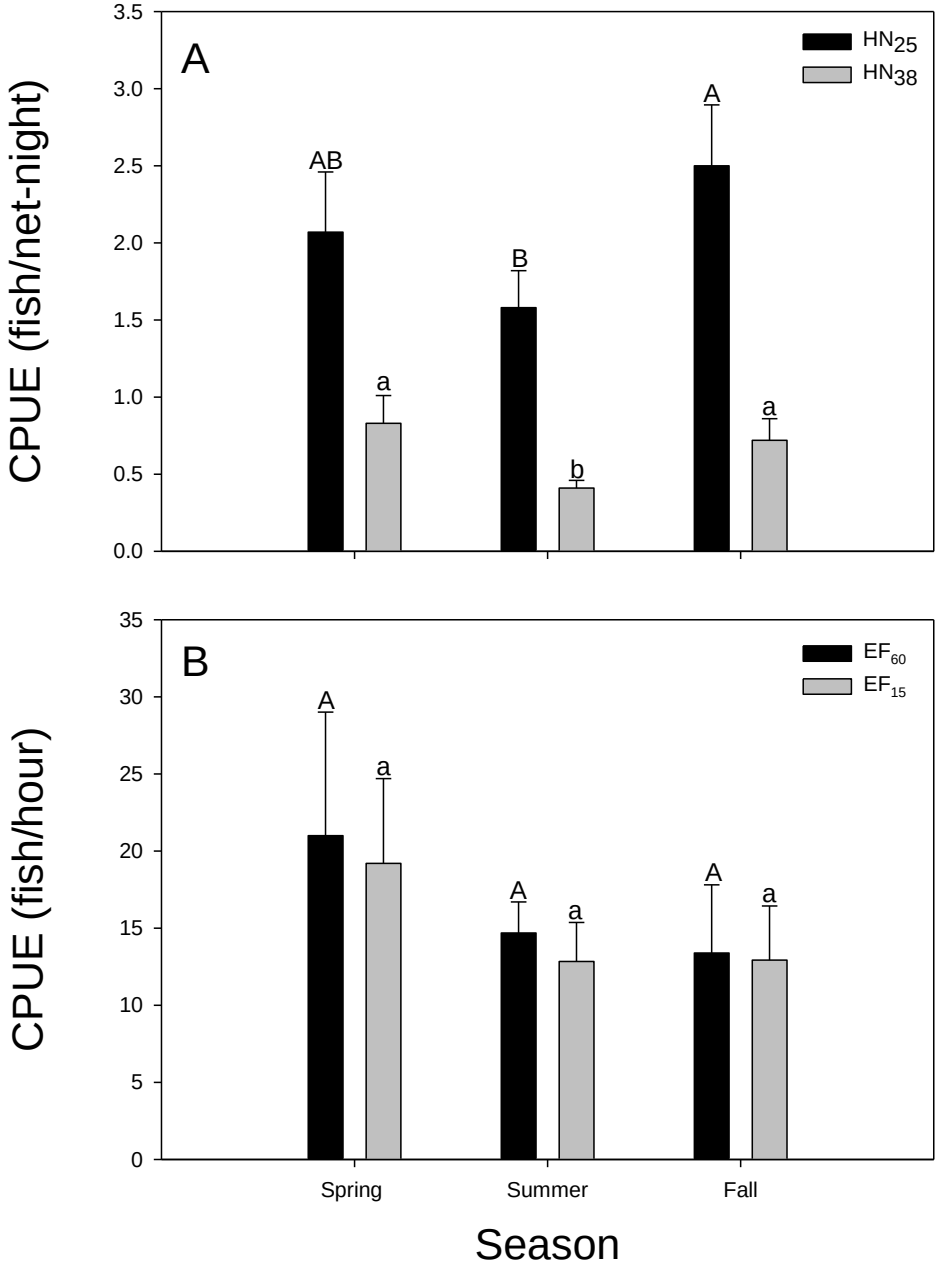

Figure 2-4. Seasonal mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE.

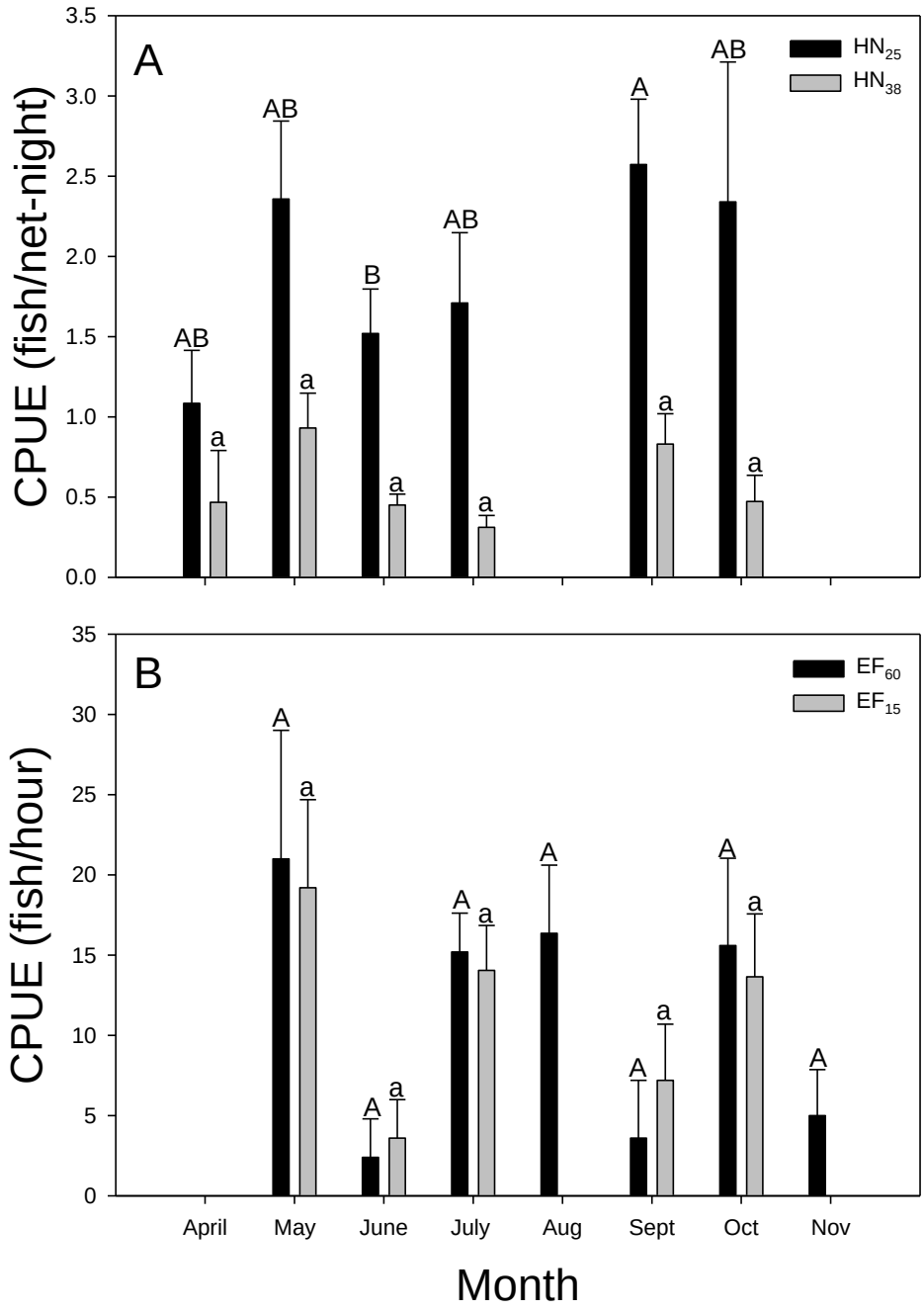

Figure 2-5. Monthly mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE.

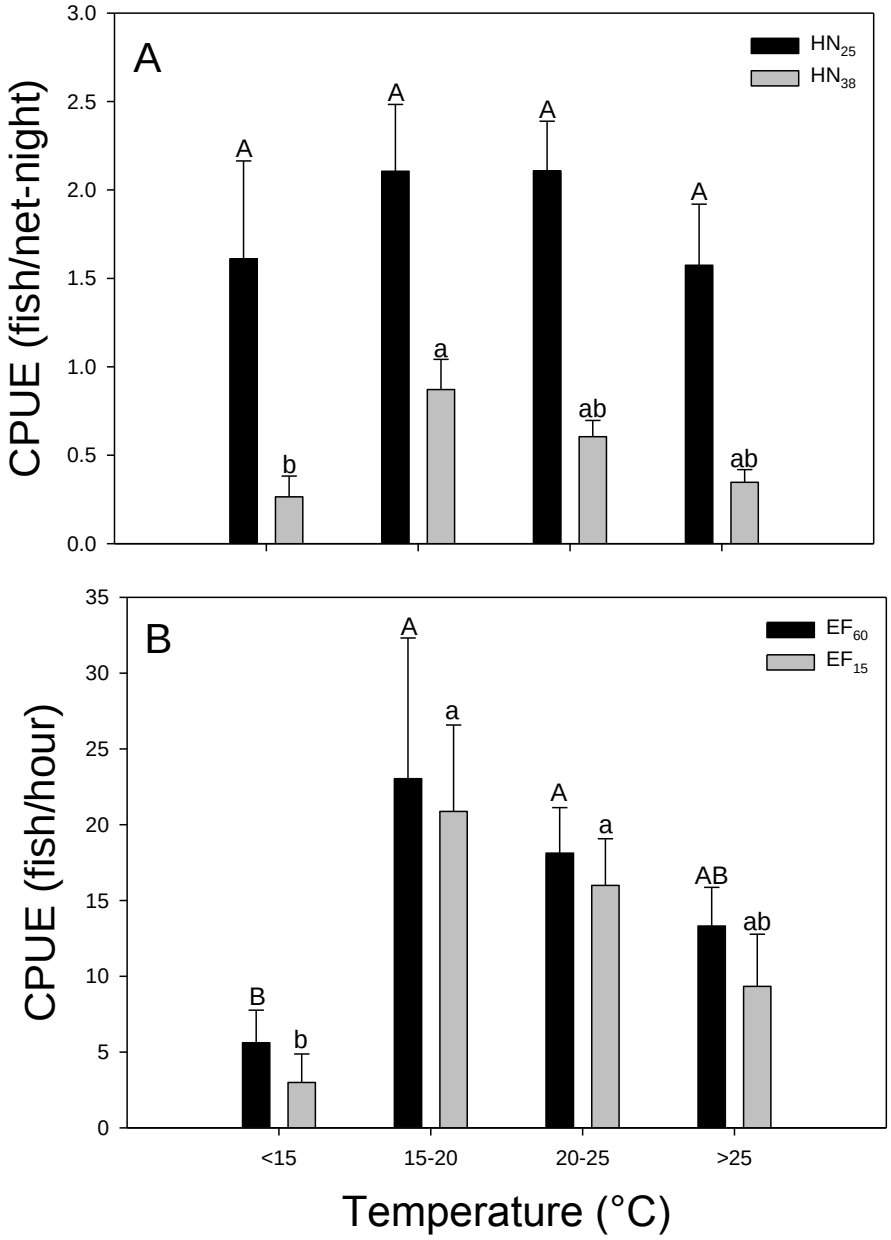

Figure 2-6. Mean catch per unit effort (CPUE) by temperature of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE.

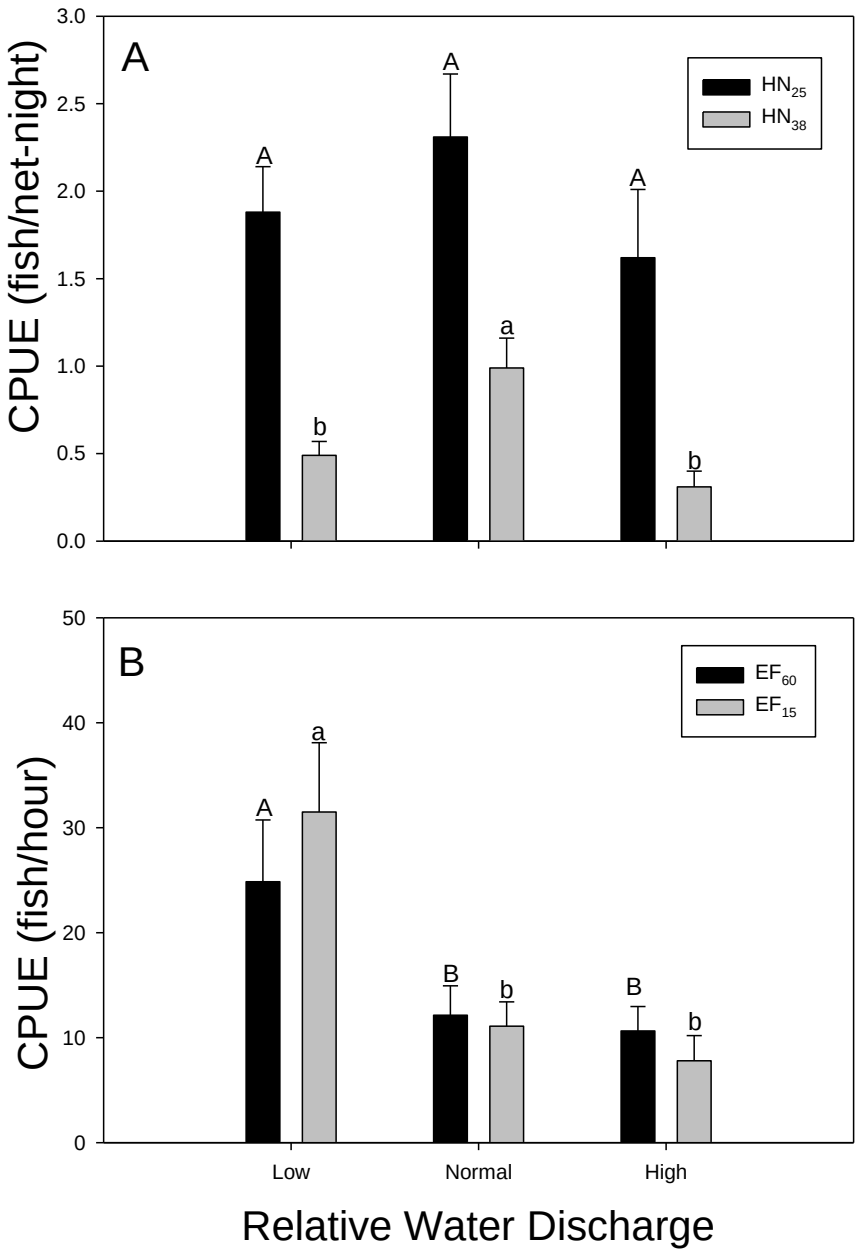

Figure 2-7. Mean catch per unit effort (CPUE) by discharge of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Relative water discharge was delineated as percent difference from mean daily discharge for low (<75 %), normal (75-125 %) and high (>125 %) water conditions. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE.

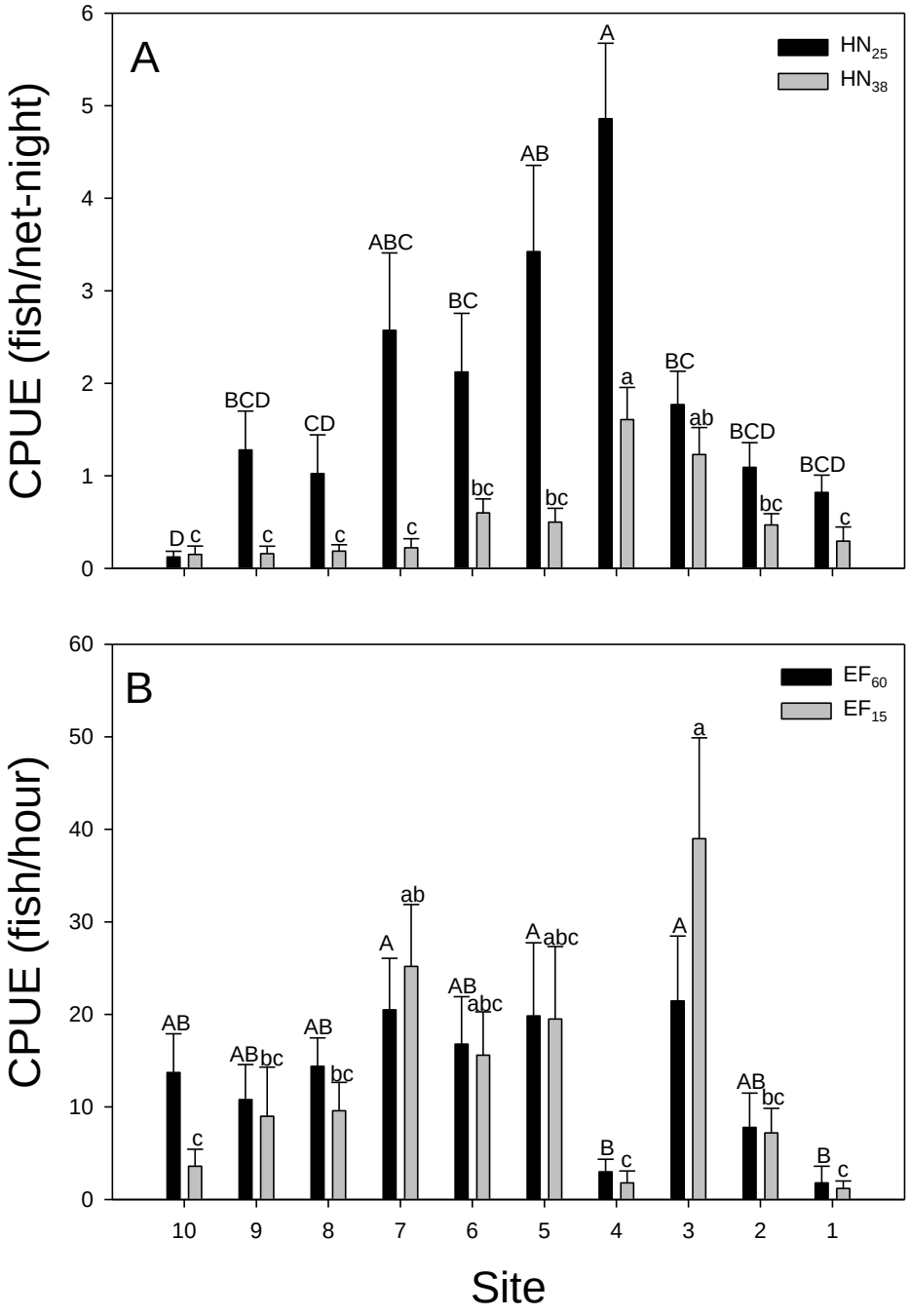

Figure 2-8. Mean catch per unit effort (CPUE) by sample site of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE.

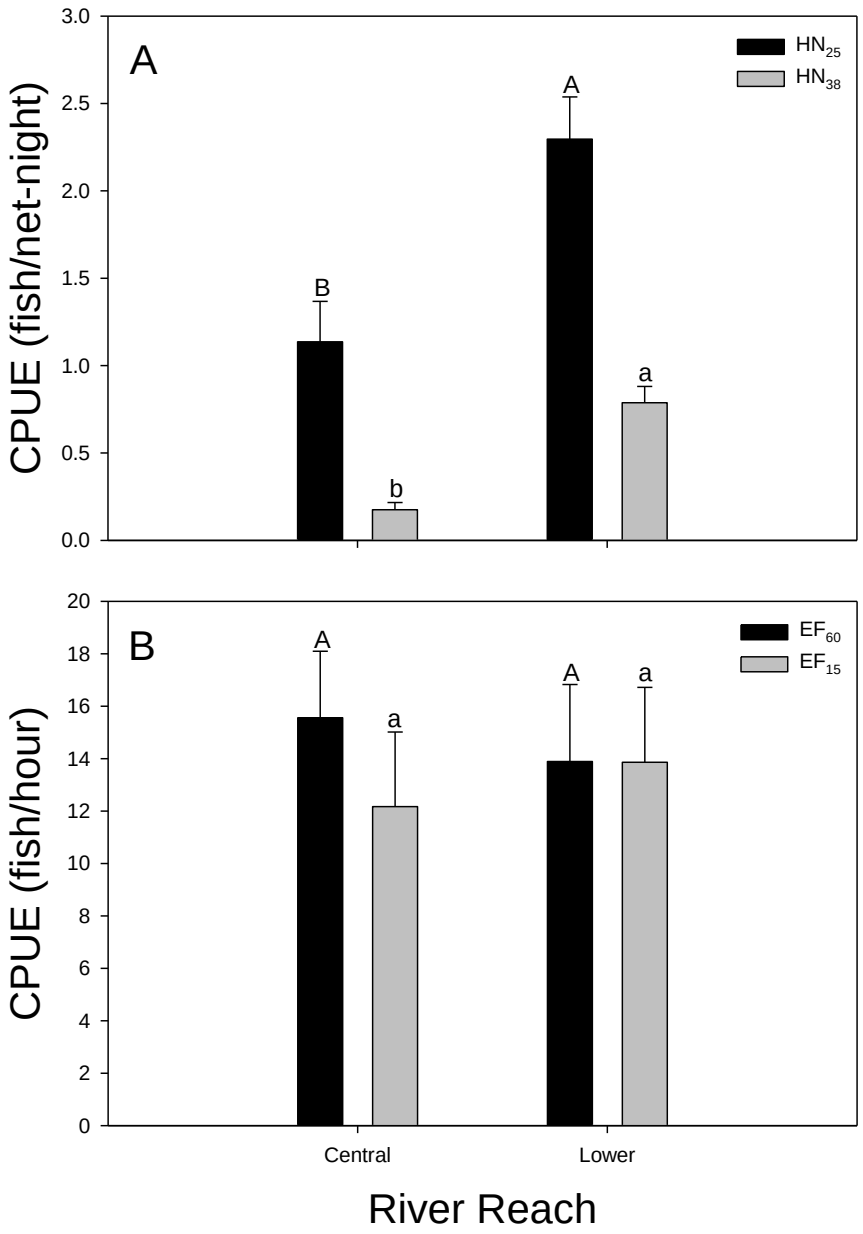

Figure 2-9. Mean catch per unit effort (CPUE) by river reach of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among HN_{25} (A) or EF_{60} (B) CPUE and different lowercase letters indicate differences among HN_{38} (A) or EF_{15} (B) CPUE.

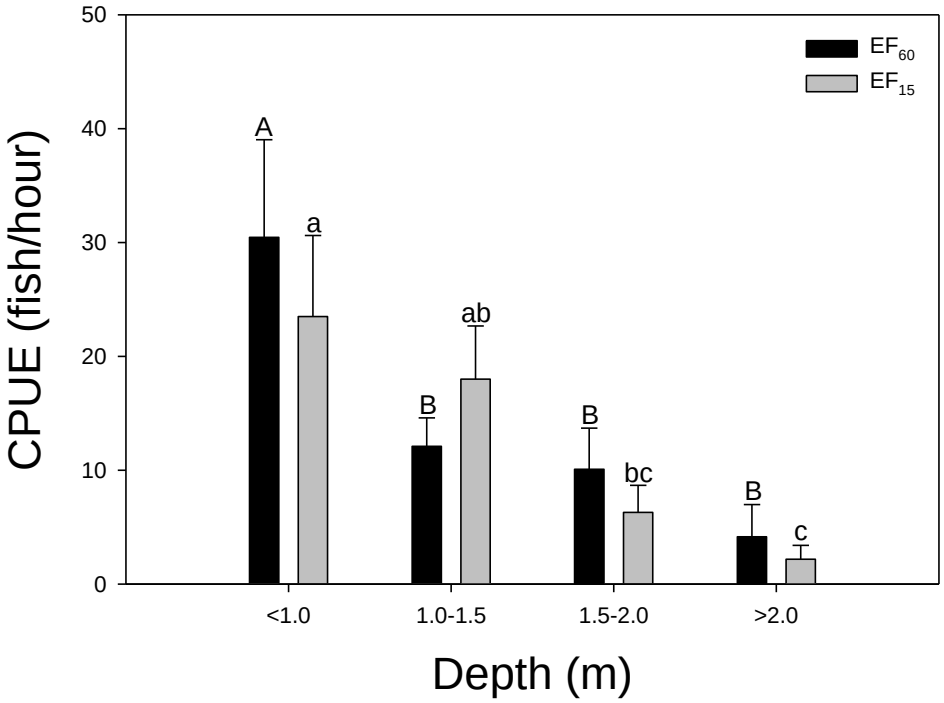

Figure 2-10. Mean catch per unit effort (CPUE) by depth for channel catfish collected with high frequency pulsed-DC electrofishing (EF_{60}) and low frequency pulsed-DC electrofishing (EF_{15}) in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate differences among EF_{60} CPUE and different lowercase letters indicate differences among EF_{15} CPUE.

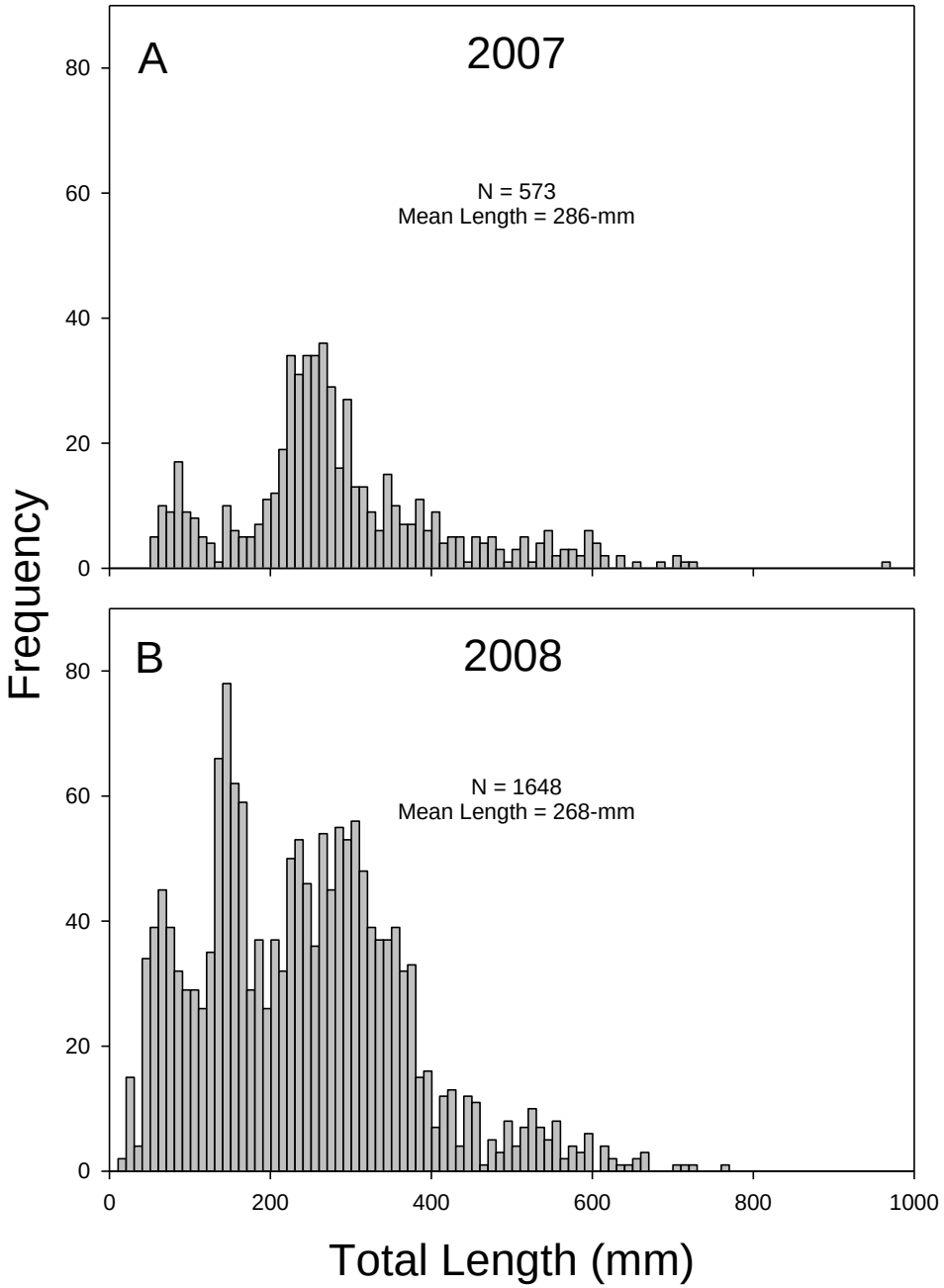

Figure 2-11. Length-frequency distributions of channel catfish collected with all gears in the Platte River during 2007 (A) and 2008 (B).

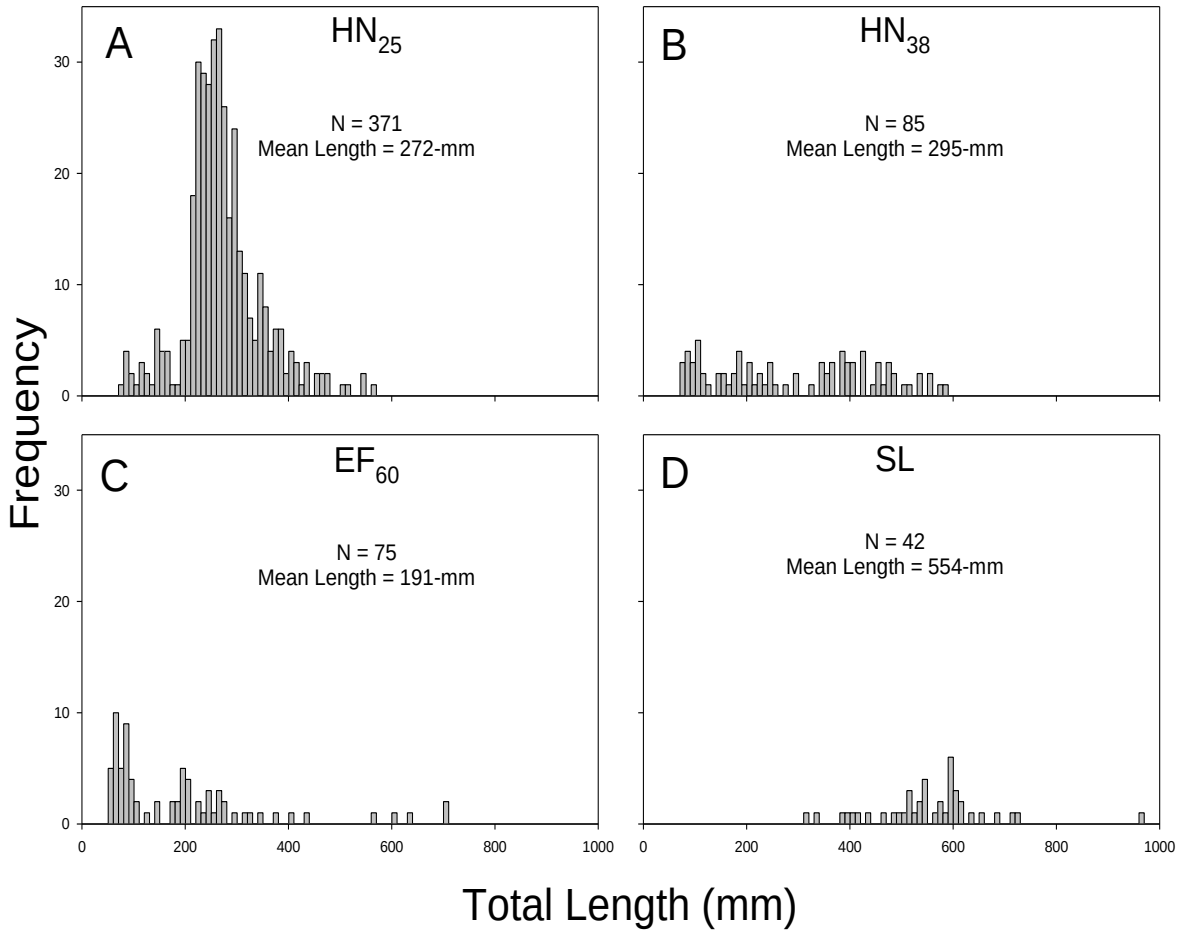

Figure 2-12. Length-frequency distributions of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; B), high frequency pulsed-DC electrofishing (EF_{60}; C) and setlines (SL; D) in the Platte River during 2007.

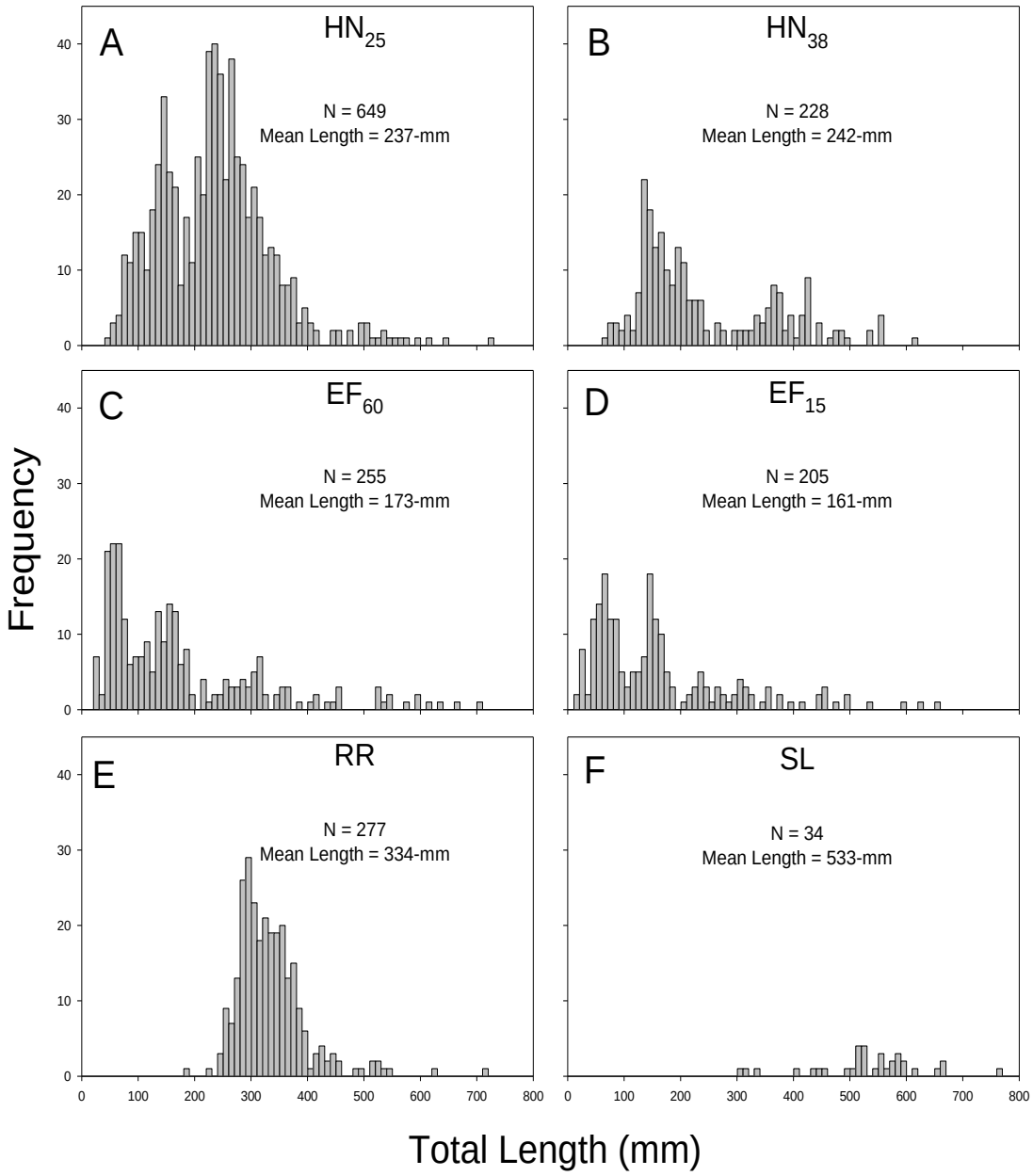

Figure 2-13. Length-frequency distributions of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; B), high frequency pulsed-DC electrofishing (EF_{60}; C), low frequency pulsed-DC electrofishing (EF_{15}; D), rod and reel (RR; E) and setlines (SL; F) in the Platte River during 2008.

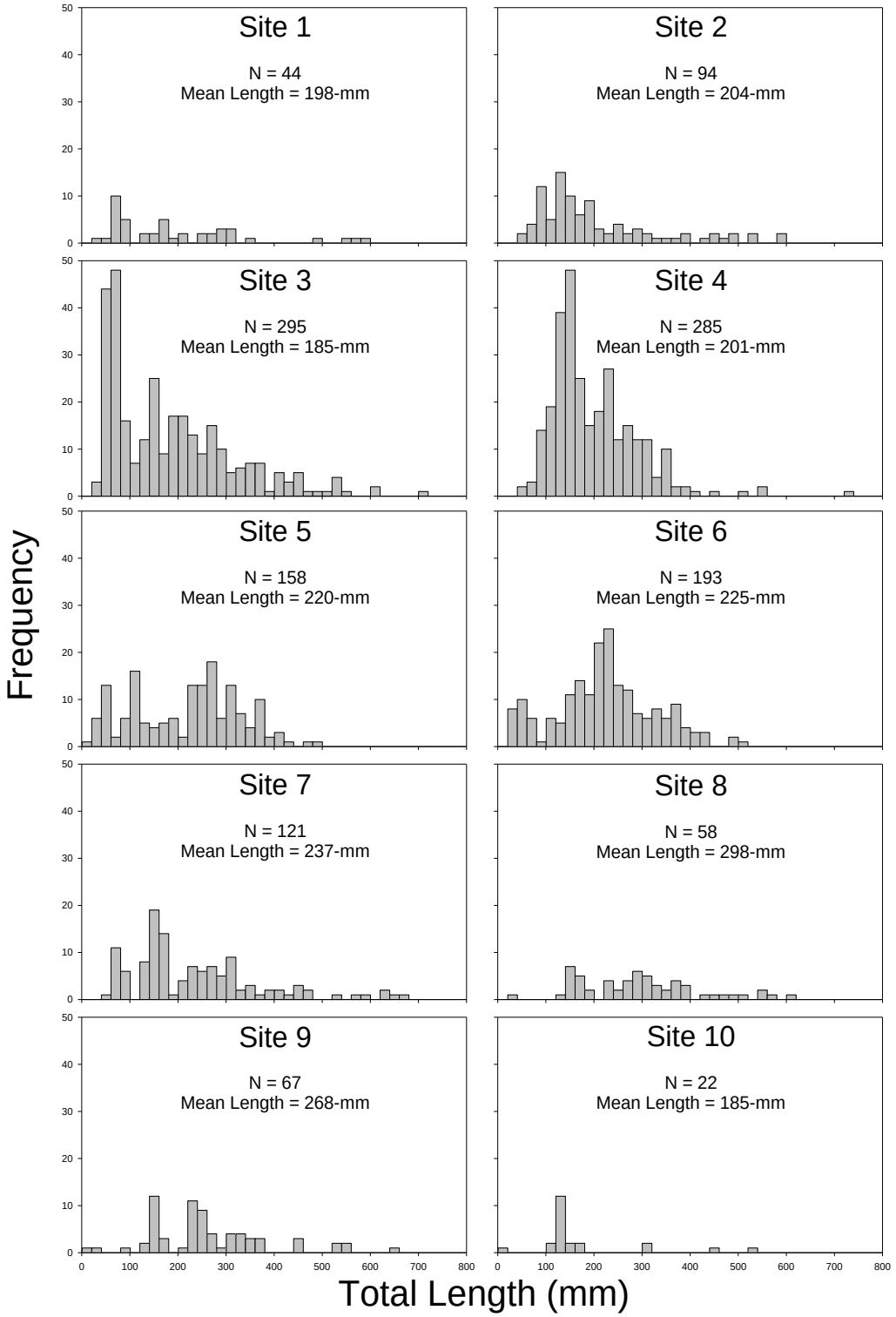

Figure 2-14. Length-frequency distributions by site for channel catfish collected with all standard gears in the Platte River during 2008.

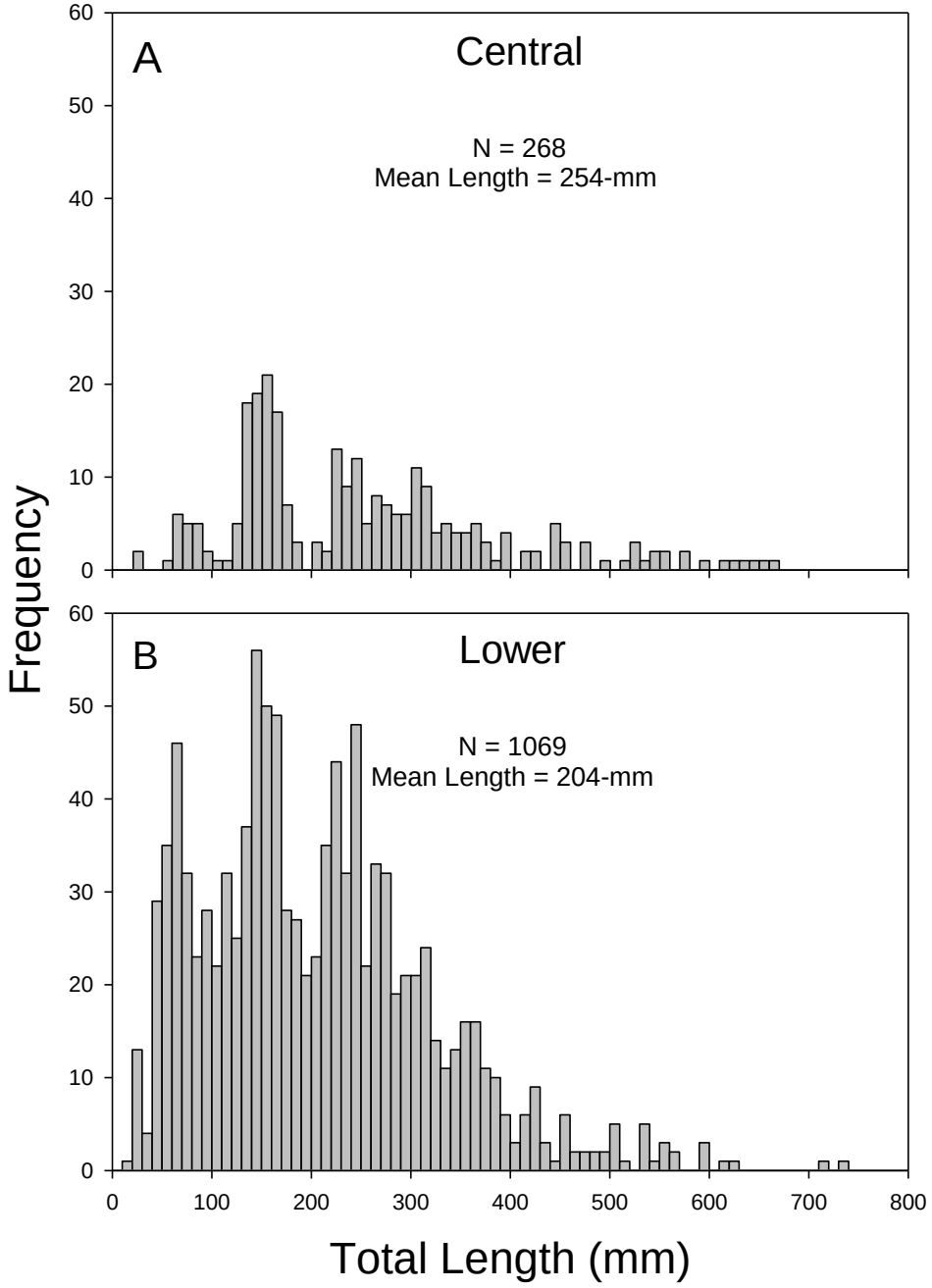

Figure 2-15. Length-frequency distributions of channel catfish collected with all standard gears in the central Platte River (A) and lower Platte River (B) during 2008.

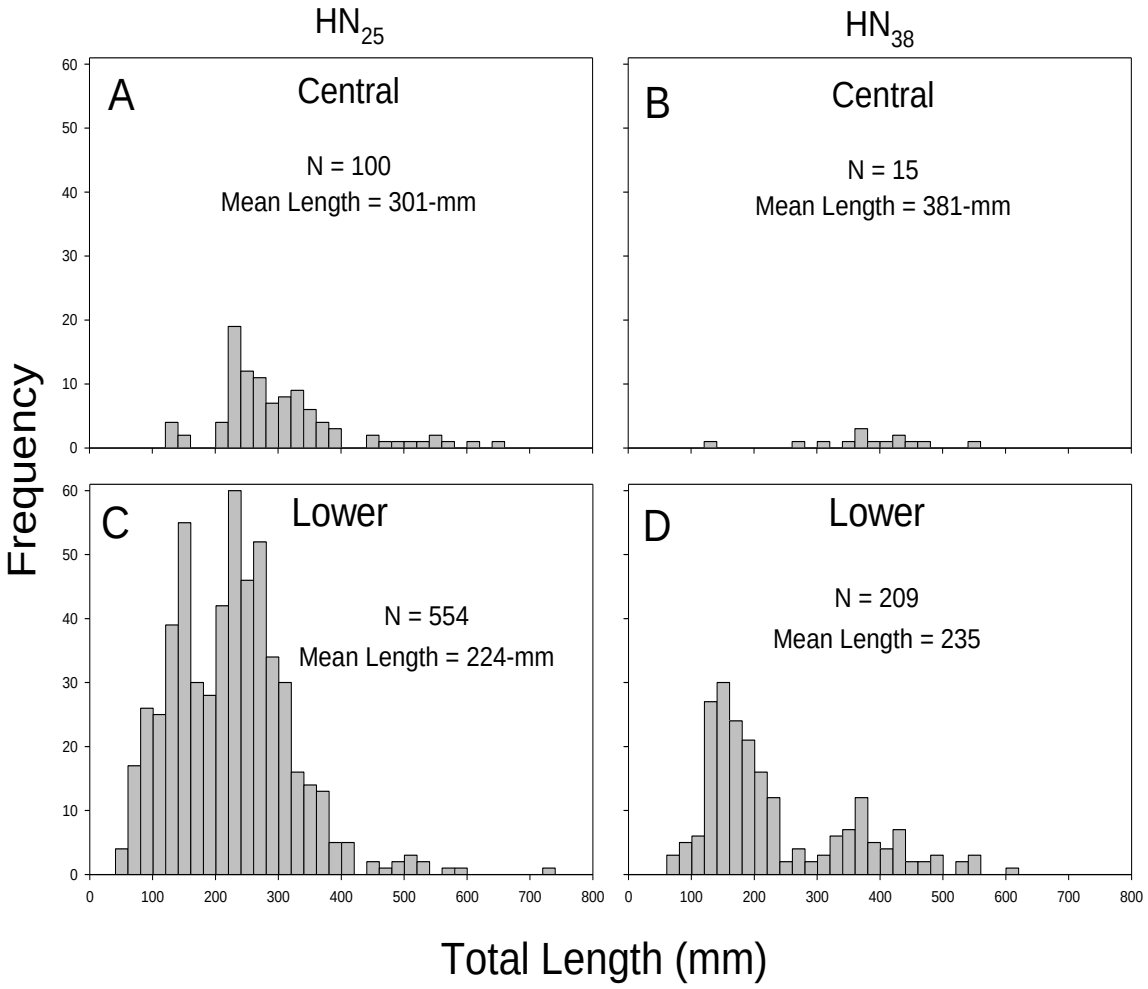

Figure 2-16. Length-frequency distributions of channel catfish collected with 25-mm hoop nets (HN_{25}; A) and 38-mm hoop nets (HN_{38}; B) in the central Platte River and HN_{25} (C) and HN_{38} (D) in the lower Platte River during 2008.

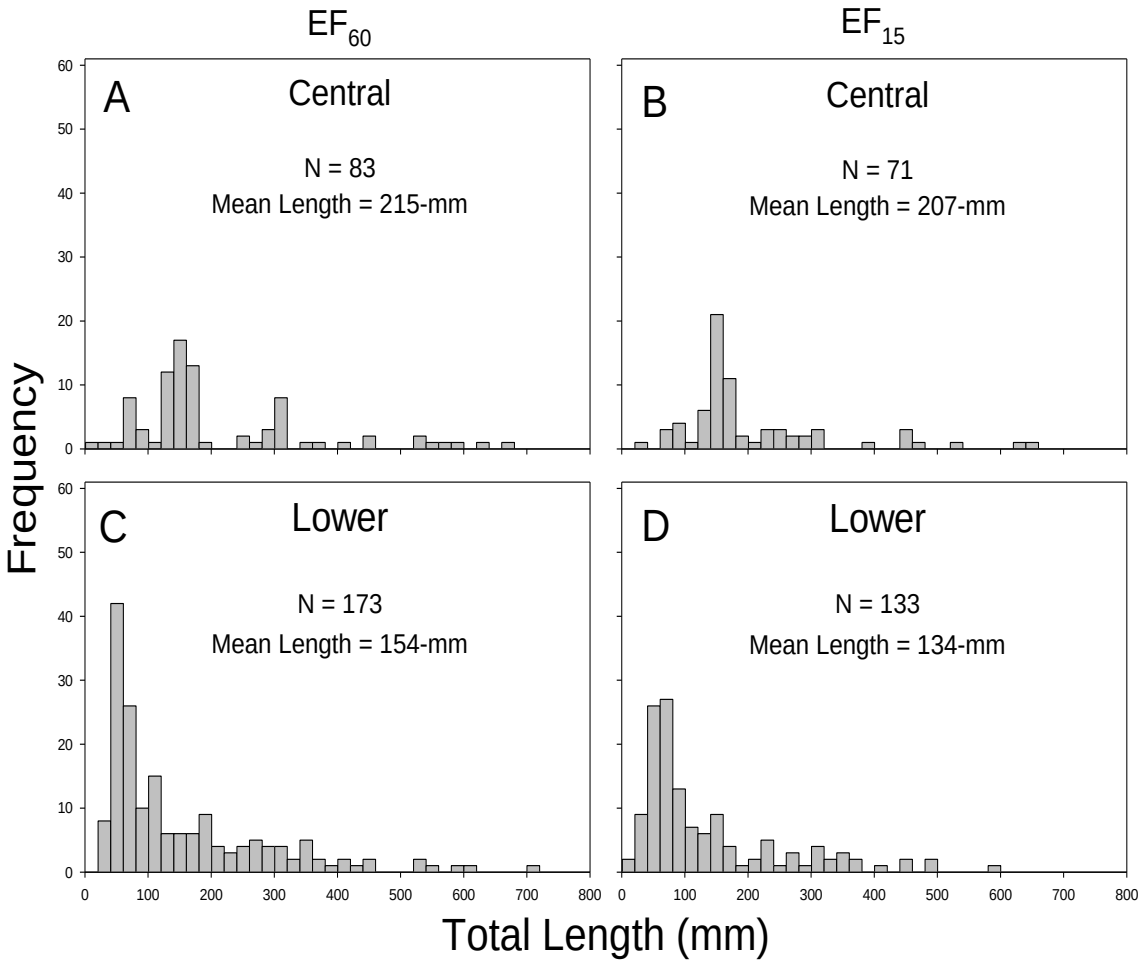

Figure 2-17. Length-frequency distributions of channel catfish collected with high frequency pulsed-DC electrofishing (EF_{60}; A) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the central Platte River and EF_{60} (C) and EF_{15} (D) in the lower Platte River during 2008.

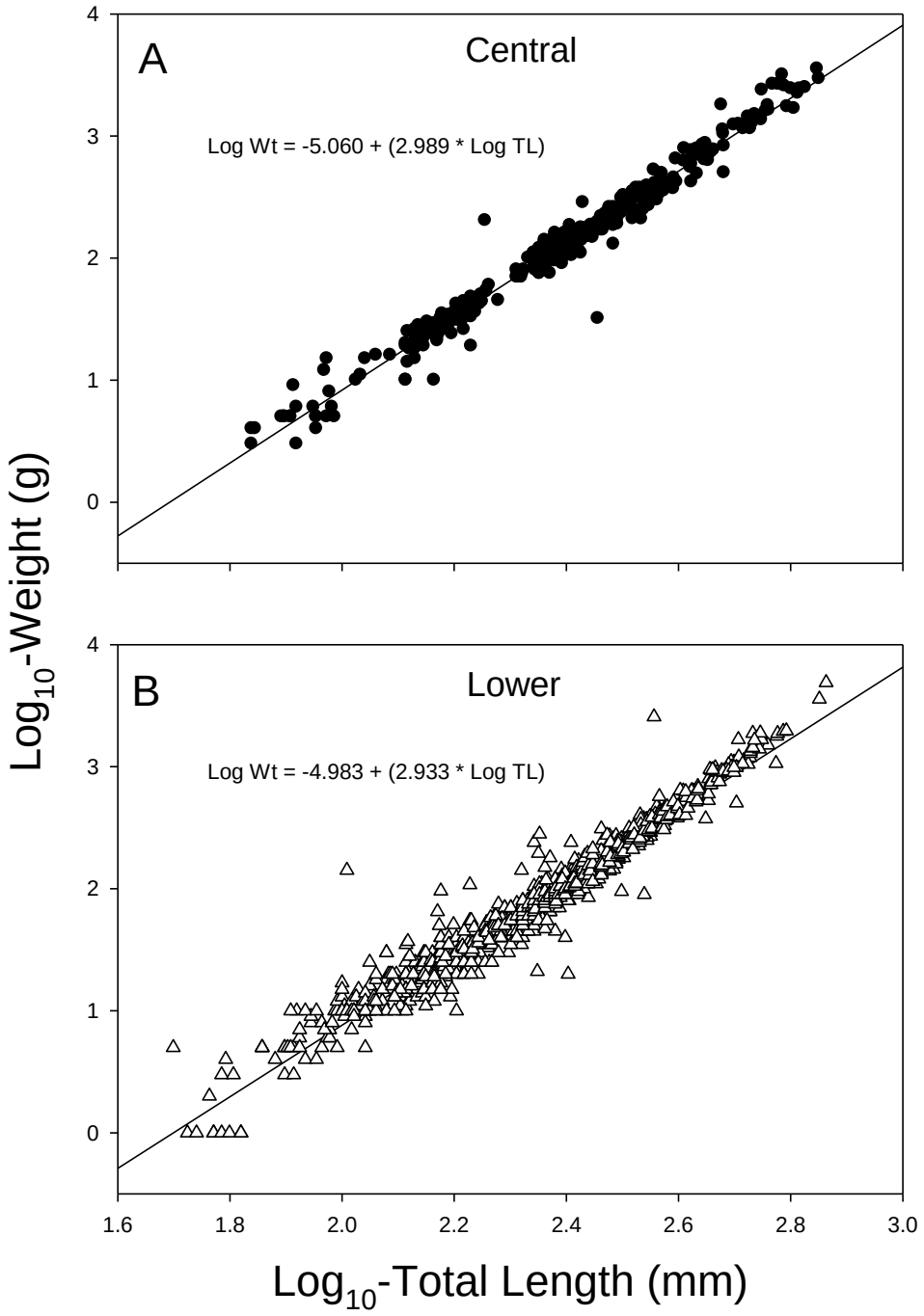

Figure 2-18. Log_{10}-transformed length-weight relation of channel catfish collected in the central Platte River (A) and lower Platte River (B) during 2007 and 2008.

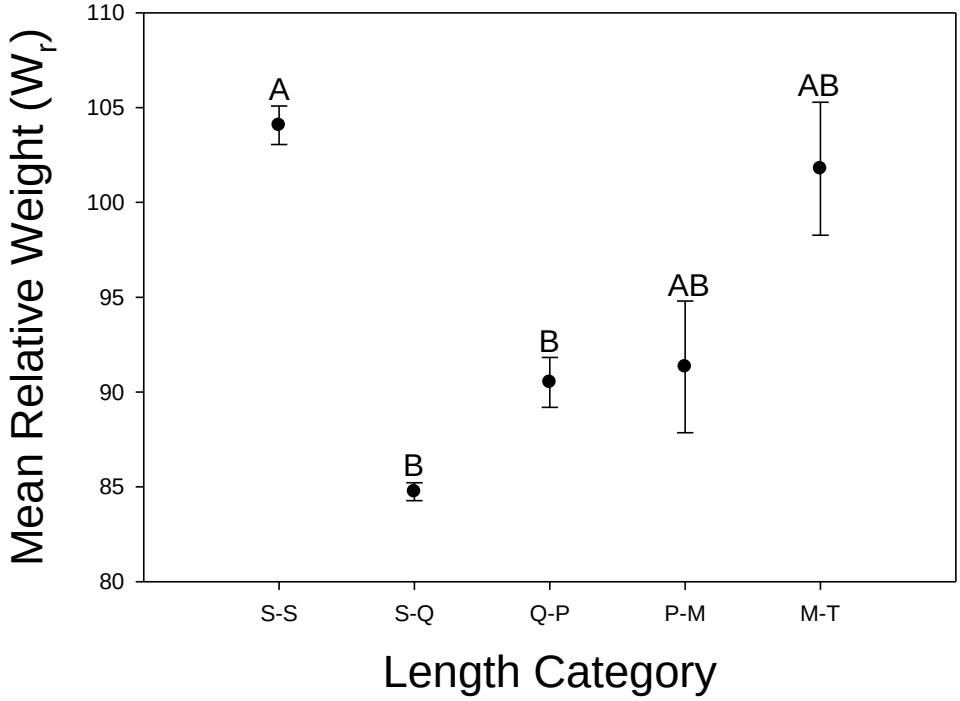

Figure 2-19. Mean relative weight (W_r) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P), preferred-memorable (P-M) and memorable-trophy (M-T) channel catfish collected in the Platte River during 2007 and 2008. Different letters above plots indicate mean W_r differences between length categories.

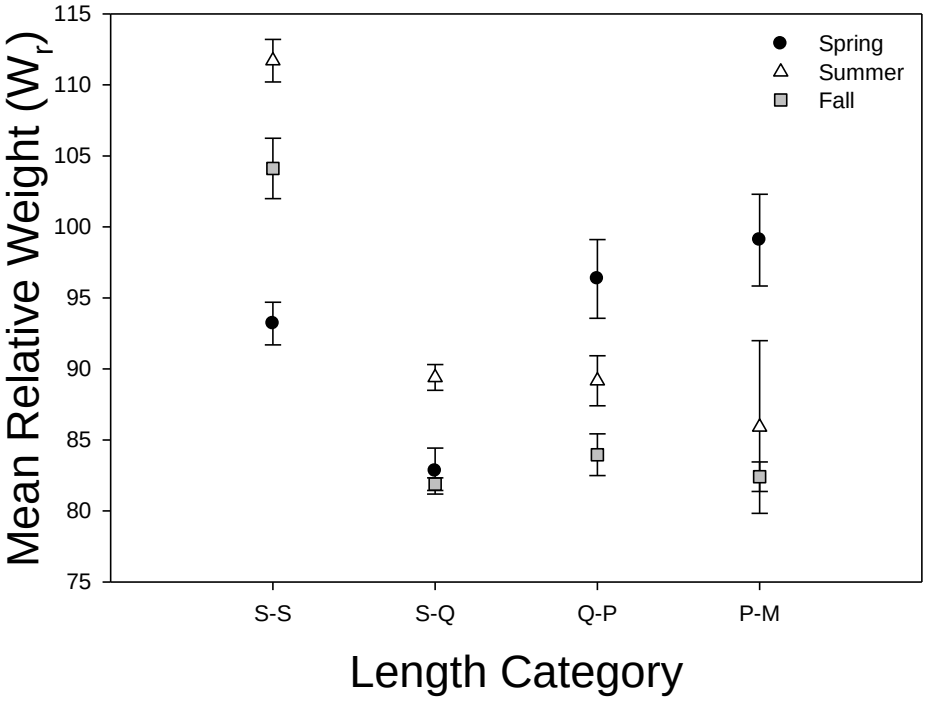

Figure 2-20. Mean relative weight (W_r) by season of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P) and preferred-memorable (P-M) channel catfish collected in the Platte River during 2007 and 2008.

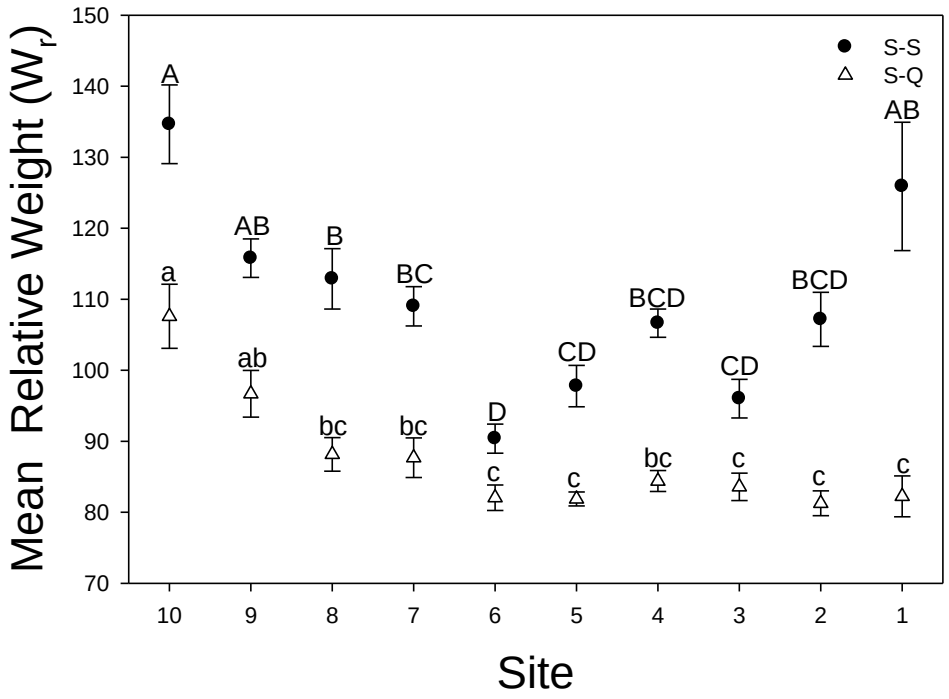

Figure 2-21. Mean relative weight (W_r) by site of sub-stock (S-S) and stock-quality (S-Q) channel catfish collected in the Platte River during 2007 and 2008. Different uppercase letters above plots indicate mean W_r differences among S-S channel catfish and different lowercase letters indicate mean W_r differences among S-Q channel catfish.

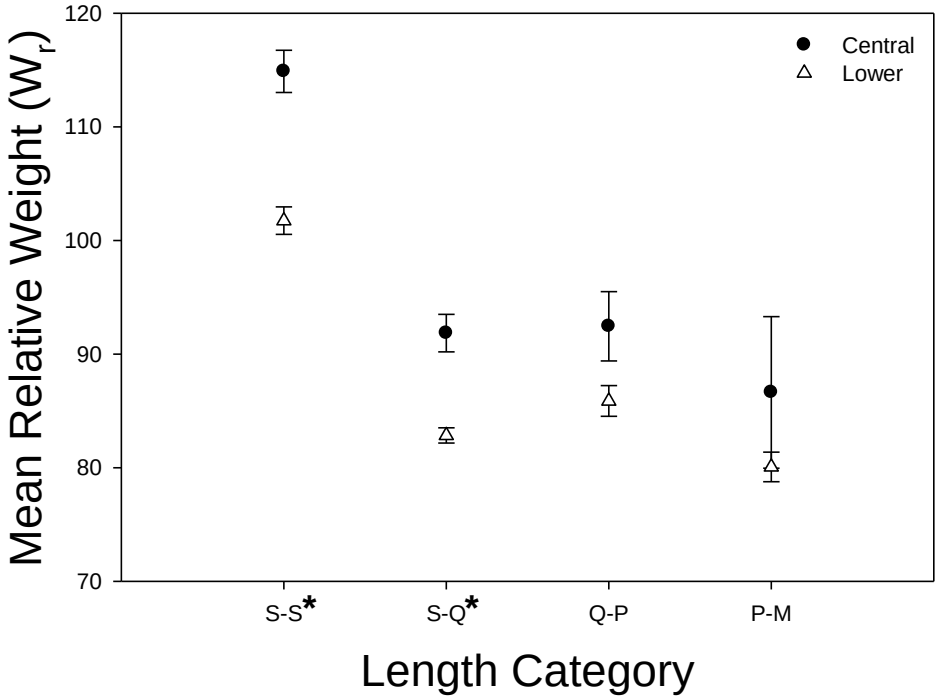

Figure 2-22. Mean relative weight (W_r) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P) and preferred-memorable (P-M) channel catfish collected in the central Platte River and lower Platte River during 2007 and 2008. A '*' indicates differences in mean W_r between river reaches.

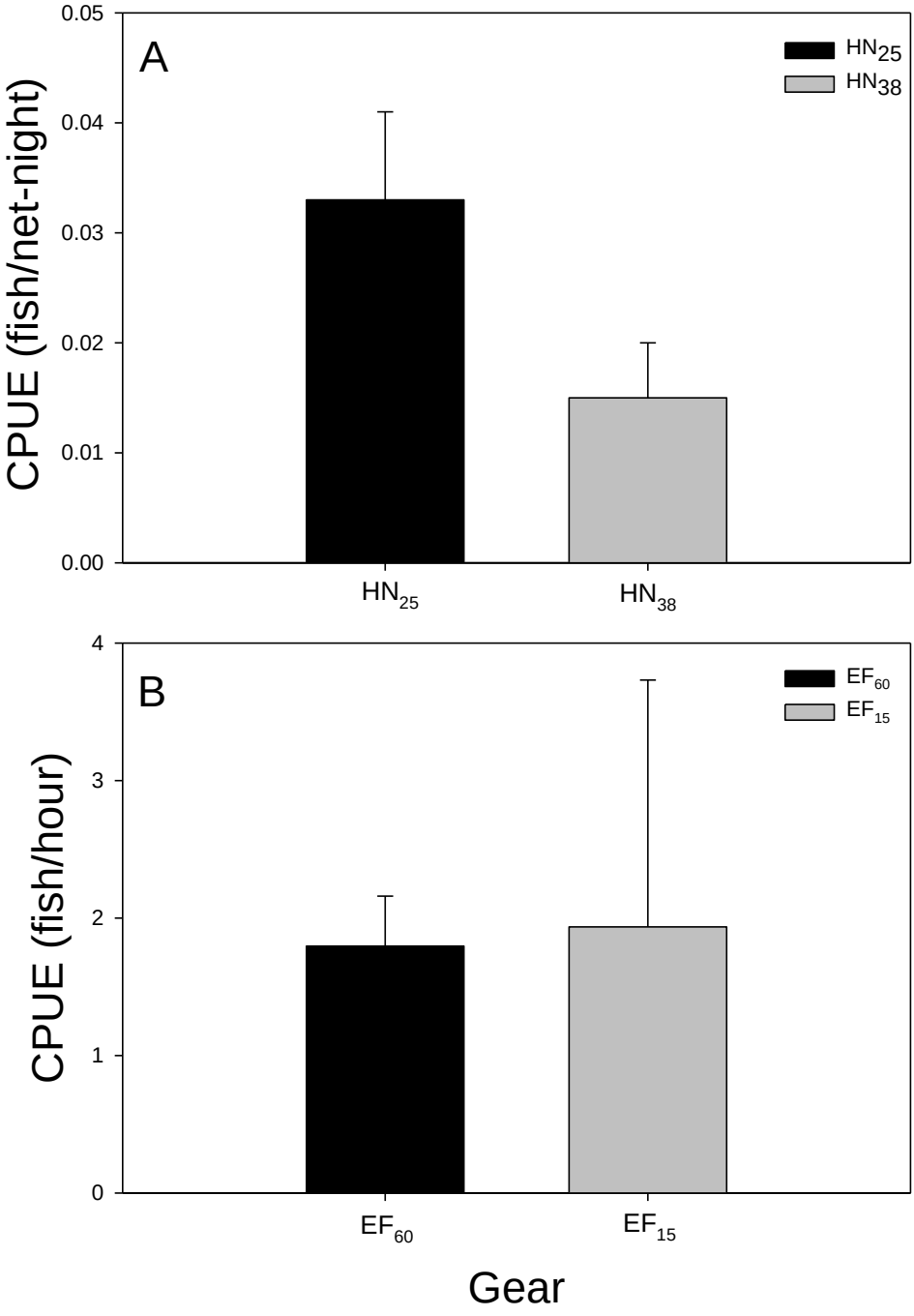

Figure 2-23. Mean catch per unit effort (CPUE) of flathead catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; A), high frequency pulsed-DC electrofishing (EF_{60}; B) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the Platte River during 2007 and 2008.

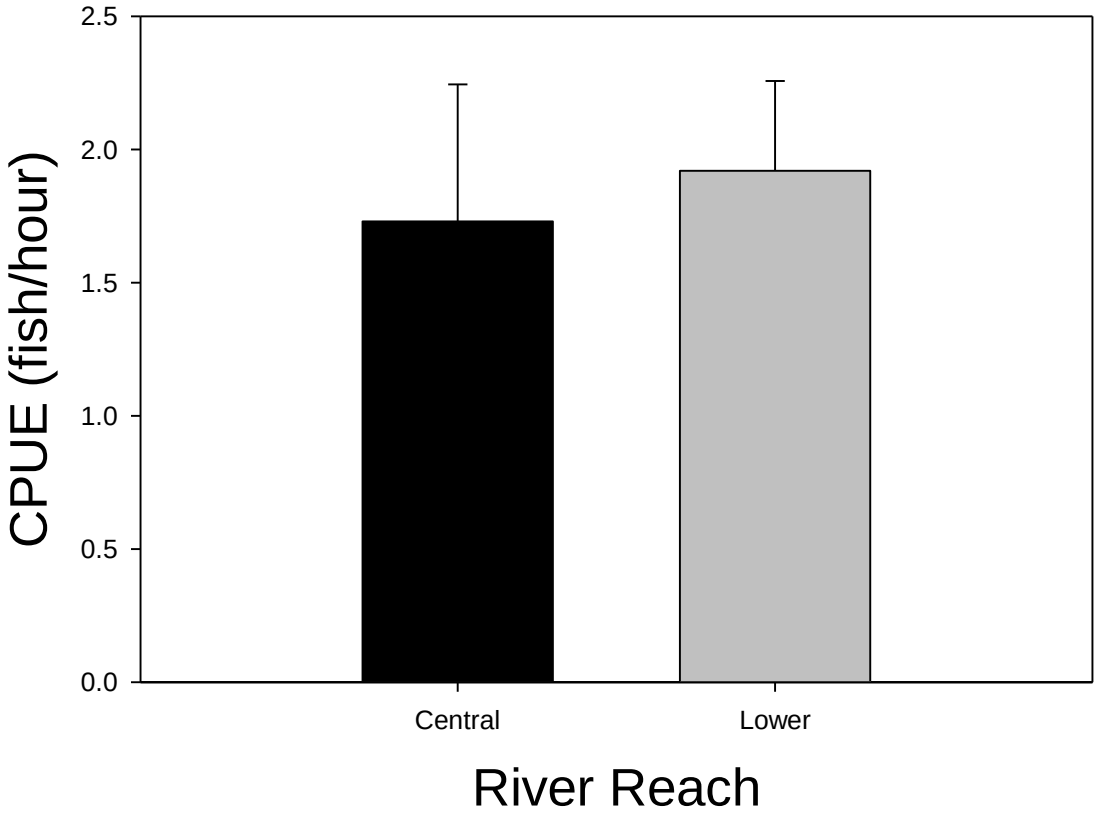

Figure 2-24. Mean catch per unit effort (CPUE) of flathead catfish collected with pulsed-DC electrofishing in the central Platte River and lower Platte River during 2007 and 2008.

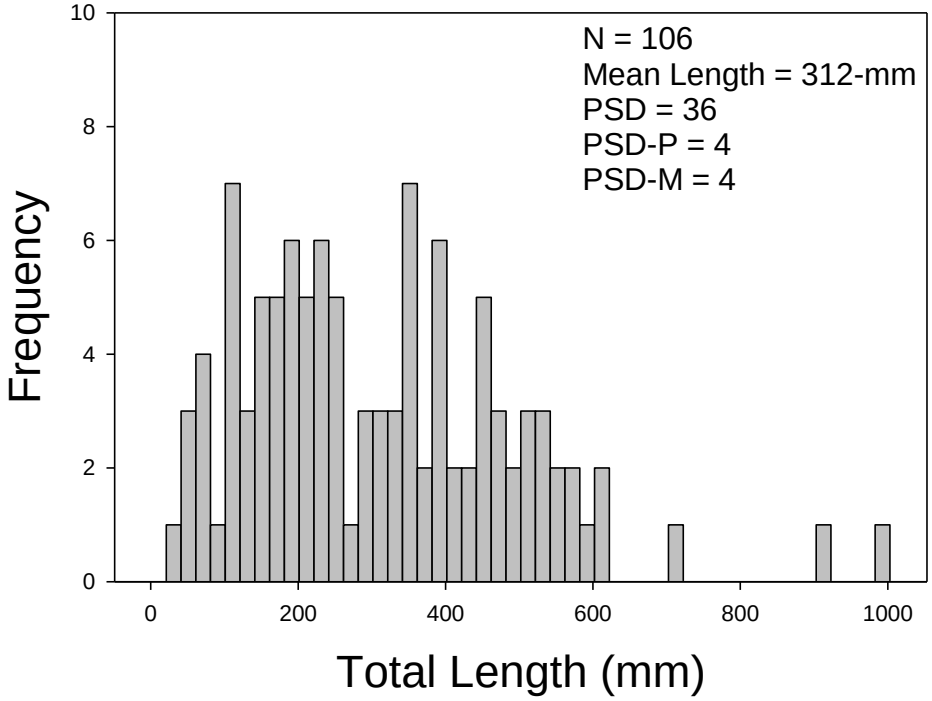

Figure 2-25. Length-frequency distribution, mean length, Proportional Size Distribution (PSD) and PSD of preferred (PSD-P) and memorable (PSD-M) flathead catfish collected with all gears in the Platte River during 2007 and 2008.

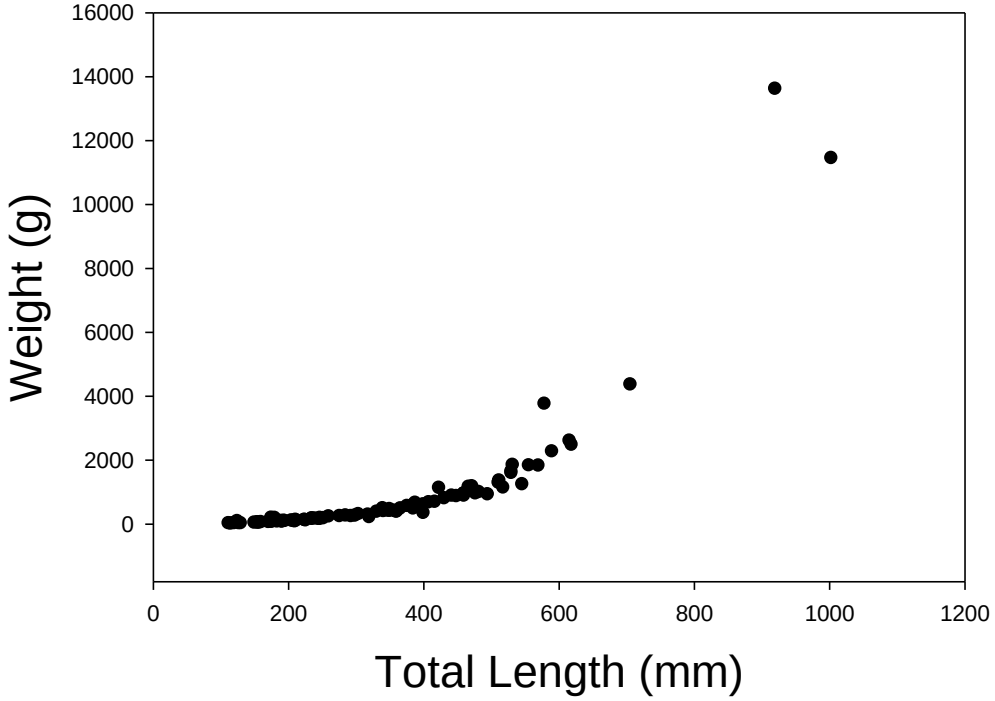

Figure 2-26. Length-weight relation of flathead catfish captured with all gears in the Platte River during 2007 and 2008.

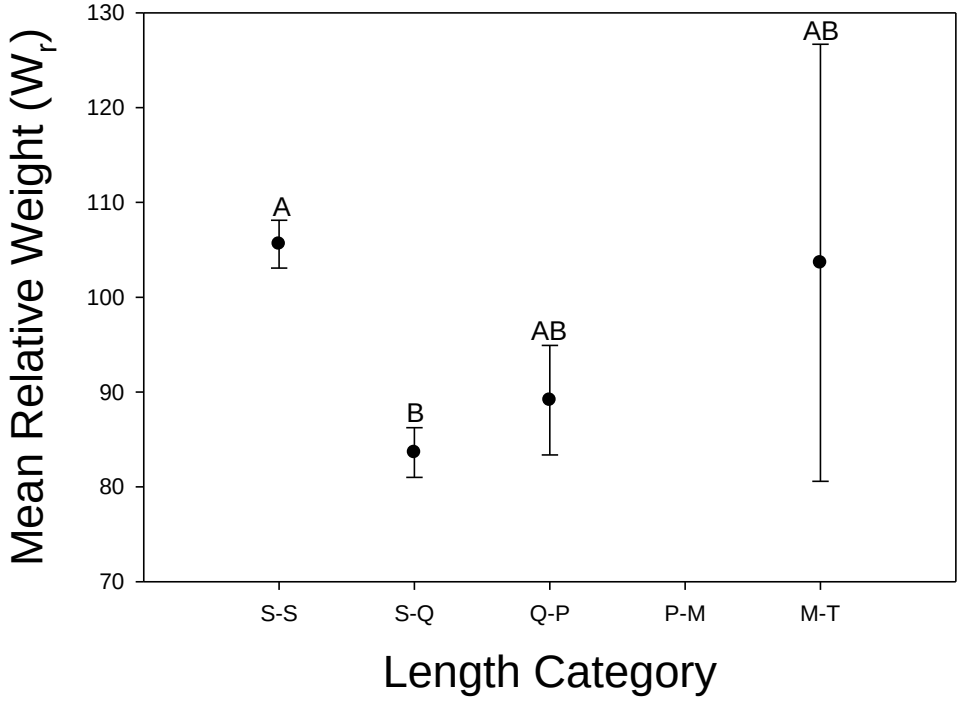

Figure 2-27. Mean relative weight (W_r) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P), preferred-memorable (P-M) and memorable-trophy (M-T) flathead catfish collected in the Platte River during 2007 and 2008. Different letters above plots indicate mean W_r differences between length categories.

CHAPTER 3 - AGE, GROWTH, AND MORTALITY OF CATFISH IN THE PLATTE RIVER

Introduction

Recreational fishing has been and continues to be a favorite American pastime. Catfish angling is especially common throughout the United States where 28% of all anglers and 23% of the fishing effort in 2006 was spent directly targeting catfish (USFWS 2007). The catfishes, namely channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictis olivaris*, are an even more desirable group to Nebraska anglers. For example, more than 50% of Nebraska anglers fished for catfish in 1981 and 1982 (Zuerlein 1984) and 57% of Nebraska anglers sought catfish during 2002 (Hurley and Duppong-Hurley 2005). Furthermore, 35% (69,000) of anglers targeted catfish over any other species in Nebraska during 2006 (USFWS 2007).

The Platte River ranks second, only to the Missouri River, in angler use for Nebraska rivers (Zuerlein 1984, Hurley and Duppong Hurley 2005). Channel catfish and flathead catfish have been the most consistently sought after species in the lower Platte River (Holland and Peters 1994). Recreational fishing in the Platte River is economically important where anglers fishing the lower Platte River spent more than $500,000 on fishing and related activities during 1992 and 1993 (Holland and Peters 1994). Nebraska anglers have also demonstrated a harvest mentality with catfish and often display more harvest oriented attitudes compared to anglers seeking other species (Hurley and Duppong Hurley 2005). Peters and Parham (2008) found channel catfish to be one of the most commonly caught species in the lower Platte River and Holland and Peters (1994) found channel catfish to be the most harvested fish species. The effects of these angling

efforts are largely unknown and localized harvest rates have become a concern for fish management in the Platte River (personal communication, J. Jackson, Nebraska Game and Parks Commission). Given this valuable natural resource, assessing, maintaining and managing fish populations is important. Especially important are issues concerning channel catfish and flathead catfish population characteristics in the Platte River.

We have gained valuable information about movement (Bunnell 1988, Chapman 1995), habitat use (Bunnell 1988, Peters et al. 1989, Peters and Holland 1994, Chapman 1995), population characteristics (Holland and Peters 1992a, Holland and Peters 1992b) and economic importance (Holland and Peters 1994) of catfish in the Platte River through previous studies (Peters et al. 1992). Only one study has examined catfish age and growth characteristics (Holland and Peters 1992b). However, this research focused solely on channel catfish in the lower Platte River. No information has been collected on flathead catfish age and growth in the Platte River or channel catfish inhabiting the central Platte River. Furthermore, the most recent catfish investigations were conducted over 15 years ago and great environmental variability, in the form of floods and drought, has been observed during this time period. Therefore, my objective was to determine the present status of catfish populations in the Platte River, specifically evaluating age, growth and mortality of channel catfish and flathead catfish in the central and lower Platte River.

Methods

Study Area

The Platte River, Nebraska (Figure 3-1), formed by the confluence of the North Platte and South Platte rivers, is an alluvial, sand-bottomed, warmwater, braided river system. The Platte River is a dynamic system with shifting sand that creates and moves sand bars, alters channel dimensions, and continually changes habitat quantity, quality and availability (Sidle et al. 1989, Simons 2000). In-stream flow fluctuations further contribute to habitat characteristics of the Platte River. Large runoff events can occur during the spring with extreme low flow and even no flow periods during the summer.

Drastic differences in hydrology are observed between the central Platte River and lower Platte River. Low annual rainfall resulted in drought conditions along the Platte River in the years leading up to this study. Drought conditions coupled with water diversions ultimately led to extended periods of very low and no flow conditions in areas along the central Platte River (Figure 3-2). Shoreline and island vegetation (i.e., *Phragmites australis*) establishment and encroachment have been documented during low flow periods and have constricted water into narrow channels. However, central Platte River water levels rebounded and were at or above normal flow during the two years of my investigations (Figure 3-2).

The lower Platte River, defined as the reach from the Loup River confluence near Columbus to the confluence with the Missouri River (Figure 3-1), exhibits a much different flow regime. This reach is characterized by continuous but variable flows year round with a significant portion of the base flow coming from the groundwater-fed Loup

and Elkhorn rivers (Galat et al. 2005). The Loup River Power Canal, a diversion off the Loup River, also provides a considerable proportion of flow to the lower Platte River creating drastic downstream, diel changes in water depth, current velocity and cover availability due to hydropeaking to meet electricity demands (Holland and Peters 1989, Holland and Peters 1992b).

Field Collections

I used a fixed site sampling approach to assess catfish populations throughout the Platte River. Sites in the central Platte River include Elm Creek (Site 10, river kilometer [rkm] 370), Bassway Strip WMA (north channel; Site 9, rkm 328), Whooping Crane Trust (Site 8, rkm 290) and Clarks (Site 7, rkm 219). Sites in the lower Platte River include Columbus (Site 6, rkm 161), Schuyler (Site 5, rkm 132), North Bend (Site 4, rkm 113), Leshara (Site 3, rkm 77), Louisville (Site 2, rkm 35) and Plattsmouth (Site 1, rkm 1; Figure 3-1). Most site locations are similar to those used during previous Platte River studies (Holland and Peters 1992b and Holland and Peters 1994) to facilitate temporal comparisons of catfish populations and assure river access via public lands (Nebraska Game and Parks Commission) or cooperative landowners (Whooping Crane Trust). The river kilometer listed for each site was used as a center point of a ± 0.5-km site (1-km total) to ensure suitable habitat for deployment of all gears.

I used cheese-baited hoop nets and an electrofisher to assess the catfish populations in the Platte River. All sites were sampled by standard gears once per season during 2007 and 2008 when possible. Season delineations were spring (March-May), summer (June-August) and fall (September-November). Winter assessment was not

conducted due to ice flow. Adverse flows and other logistical constraints also prevented sampling intermittently throughout the year.

I used 25-mm mesh hoop nets (HN_{25}) and 38-mm mesh hoop nets (HN_{38}) in an attempt to capture different size ranges of catfish. Hoop nets were 1.3-m in length, equipped with four 0.5-m diameter fiberglass hoops with two square throats. Nylon bait bags, 3-mm mesh, were filled with scrap cheese and placed inside the cod end of the hoop nets. Hoop nets were set parallel with the river current in pools and runs along bank and in-stream habitat where available. Anchors were attached to the net and placed 1-m upstream. Anchors were also secured to the bank (i.e., tree limb, rock, etc.) to further restrict net displacement. Effort per sampling trip consisted of 10-15 deployments of each hoop net size.

Electrofishing was conducted using a cataraft (River King Catarafts, Port Ludlow, Washington) equipped with a MBS-2D Wiscosnsin box (ETS Electrofishing LLC, Madison, Wisconsin) powered by a 5500 W/240 V generator to provide pulsed-DC current. Anode poles, equipped with steel cable droppers, were attached to the front pontoons of the cataraft. A cathode array was positioned at the mid-section of the cataraft where cable droppers hung between the pontoons to contact water. High frequency (EF_{60}; 4-8 A, 180-240 V, 60 pulses/s, 50% pulse width) and low frequency (EF_{15}; 3-5 A, 180-240 V, 15 pulses/s, 20% pulse width) settings were alternately used during sampling. Electrofishing was conducted in a downstream fashion sampling bank habitat and any available in-stream structure. Shallow areas were sampled by walking and pulling the cataraft unit like a tote barge electrofisher, while two netters walked alongside the electrode droppers capturing fish. The cataraft was used similar to a boat

electrofisher in non-wadeable sections of the river where the operator controlled the cataraft from within using a tiller motor and individuals netted fish from the bow of the vessel. I conducted five, 10-minute runs for each electrofishing frequency at each site. A frequency (EF_{60} or EF_{15}) was randomly selected for the initial electrofishing run and frequencies were alternated for subsequent runs moving downstream.

All captured catfish were measured for total length (TL; mm) and mass (g). Pectoral spines were removed from a subsample of channel catfish and flathead catfish for age and growth analysis. We attempted to collect ten spines from channel catfish and flathead catfish at each 10 mm length interval for each site.

Information from area fishing club tournaments was also collected to supplement standard sampling. Angler tournaments provided an excellent opportunity to gain valuable information about the fishery from the viewpoint of local anglers and allowed collection of quality information from harvested fish. Tournaments also allowed data collection on fish size ranges not commonly captured with standard sampling. The Fremont Airboat Club hosts a catfish outing each spring over Memorial Day weekend where anglers use setlines to capture catfish. Setlines (SL) generally had 1-2 hooks baited with live fathead minnows. Additionally, rod and reel catfish tournaments were held sporadically throughout the year. Rod and reel (RR) setups usually consisted of a plastic worm or sponge rig dipped in ‘stink bait’. Set lines were fished overnight while rod and reel tournaments were held from sun-up to approximately 12:00 PM. Angler caught catfish were measured for TL and mass at the angler check-in and tagged with individually numbered floy tags (Floy Tag Inc., Seattle, Washington) before being

cleaned by fisherman. The heads (floy tags intact) of filleted catfish were then kept on ice and transported back to the laboratory for spine and otolith extraction.

Laboratory Preparation

Pectoral spines used for age determination were cleaned and dried in the lab before sectioning. Spines were prepared using methods from Koch and Quist (2007) where the spine was embedded in epoxy to reduce damage and facilitate manipulation during sectioning. Three to four cross-sections, 0.7-mm thick, were cut at the distal end of the basal process of each spine (Sneed 1951) using a Buehler IsoMet low-speed saw (Buehler Inc., Lake Bluff, Illinois). Spine cross-sections were then mounted on glass slides using Cytoseal mounting medium (Richard-Allan Scientific, Kalamazoo, Michigan) and photographed using a high resolution digital camera. Digital images were then imported into image analysis software (FishBC, Doll and Lauer 2008) for manual aging and measurement of annuli distances. All fish were aged independently by two readers. Disagreements in age readings were resolved with a concert reading. Otoliths were processed following methods from Buckmeier et al. (2002) and used for age structure comparisons (Appendix C).

Data Analyses

Back-calculations were performed using the Dahl-Lea method as:

$$L_i = (L_c/R_c) * R_i,$$

where L_i = length at annulus i, L_c = length at capture, R_c = spine radius at capture, and R_i = spine radius at annulus i. Differences in mean back-calculated lengths and mean

annual growth increments were analyzed using a Student's t-test when comparing river reaches (i.e., central vs. lower) and using analysis of variance (ANOVA) when comparing among sites. Multiple comparisons were made using Tukey's studentized range (HSD) test when ANOVA results were significant. Size specific growth rates were fit to linear regression equations and compared between river reaches using analysis of covariance (ANCOVA).

Fishery Analysis and Simulation Tools (FAST, Slipke and Maceina 2000) software was used to fit von Bertalanffy growth functions as:

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

where L_t = length at time t, L_∞ = theoretical maximum length, K = growth coefficient, and t_0 = time when length equals 0-mm. Age-length keys were created using FishBC (Doll and Lauer 2008) and used to predict ages of non-aged fish. Age-frequency distributions were compared between years, reaches and sites using Kolmogorov-Smirnov (KS) nonparametric tests. Age structure data were also used to estimate instantaneous mortality (Z), total annual mortality (A) and theoretical maximum age using weighted regression in FAST. Mortality parameters were estimated for 2007, 2008 and both years combined using all gears. Additionally, mortality was estimated for HN_{25}, HN_{38}, EF_{60} and EF_{15} catches separately. Constant recruitment, one assumption when using catch curves, is rare in many fish populations (Van Den Avyle and Hayward 1999). Therefore, data from 2007 and 2008 were pooled for gear analysis to dampen the influence of erratic recruitment (Miranda and Bettoli 2007). Channel catfish were fully recruited to hoop nets at age-3 and electrofishing at age-2. Therefore, mortality estimates were made for age-3 and older fish using hoop net data and age-2 and older fish using

electrofishing data. Differences in instantaneous mortality between river reaches were examined using ANCOVA. All analyses were conducted using SAS (SAS Institute 2004) where significance was determined at $\alpha = 0.05$.

Low numbers of flathead catfish collected limited their age and growth analysis. Therefore, analyses focused mainly on channel catfish. However, flathead catfish growth characteristics are provided where data are sufficient.

Results

Totals of 2,222 channel catfish and 106 flathead catfish were collected during 2007 and 2008. Pectoral spines were removed from 1,932 channel catfish and 85 flathead catfish for age and growth analysis. Complete reader agreement increased from 46% during 2007 to 67% during 2008 resulting in an overall exact agreement of 61%. However, 95% of reader ages were within one year. Most disagreements were attributed to expansion of the central lumen in older fish that caused difficulty distinguishing the first annulus. Merging of outer annuli and double markings (possible false annuli) were also causes of reader disagreements.

Age-2 and age-3 channel catfish were most abundant in the Platte River while very few age-10 and older fish were collected during 2007 and 2008. Age-13 individuals were the oldest channel catfish collected. Age distributions differed between years ($P < 0.01$; Figure 3-3). However, channel catfish age distributions were similar for the central and lower Platte River ($P = 0.41$; Figure 3-4). Variation in age distribution was observed among sites. Very few age-0 and age-1 channel catfish were collected from furthest west sites (Sites 8-10) while Site 3 age distribution appeared to be shifted towards younger

individuals (Figure 3-5). No patterns were observed for distributions of older fish. However, only Site 6 and Site 10 lacked fish age-9 or older.

Individual growth rates varied greatly for channel catfish as indicated by differences in length at capture for all ages (Figure 3-6). No differences in back-calculated lengths were observed when compared between years ($P > 0.10$). Therefore, all data were pooled for mean back-calculated length at age analysis and comparisons. Mean back-calculated lengths at age display fastest growth in younger fish. On average, channel catfish grew to 82-mm by the end of their first year, 154-mm by their second and 221-mm by the end of their third year of growth. It took approximately 5 years for channel catfish to reach 300-mm in the Platte River (Figure 3-7).

Mean back-calculated lengths were significantly greater for age-1 to age-6 channel catfish collected in the central Platte River compared to the lower Platte River (Figure 3-7). However, no differences were observed between age-7 and older fish. A distinct longitudinal pattern was observed for age-1 to age-6 fish where the lowest mean back-calculated lengths at age were consistently observed in middle reaches of the river. Conversely, the greatest calculated lengths were found at most upstream and downstream sites (Figure 3-8).

Overall, decreasing annual growth increments were observed for channel catfish age-1 to age-12 (Figure 3-9). Mean annual growth increments differed for the youngest central Platte River and lower Platte River channel catfish. Central Platte River channel catfish grew 90-mm during their first year, 82-mm their second year and 78-mm their third year; whereas, lower Platte River catfish grew at much slower rates of 78-mm, 72-mm, and 67-mm over the same 3 years (Figure 3-9). A severe drop in mean annual

growth was observed between age-3 and age-4 channel catfish in the central Platte River. No differences in mean annual growth increments between river reaches were observed for age-4 to age-13 channel catfish. Additionally, no differences in size-specific growth rates were observed between the central Platte River and lower Platte River (ANCOVA, $P = 0.06$).

Estimates of instantaneous mortality (Z), total annual mortality (A) and theoretical maximum age varied by year, river reach (Tables 3-1) and sampling gear (Table 3-2). Overall, total annual mortality ranged from 26 to 44% during 2007 (Figure 3-10) and 33 to 43% during 2008 (Figure 3-11). Lowest total annual mortality was observed in the central Platte River at 15% using HN_{38} data. Highest mortality occurred in the lower Platte River using HN_{25} data (51%; Figure 3-12). Mortality rates estimated for EF_{60} and EF_{15} were not different between the central Platte River and lower Platte River (Figure 3-13). However, results from all other river reach comparisons indicate significantly different mortality rates (ANCOVA, $P < 0.03$). The overall total annual mortality for channel catfish in the Platte River, using data from all gears, years and river reaches, was calculated as 38% (Figure 3-14).

The most commonly collected flathead catfish were age-2. Very few old flathead catfish were observed in the population and the oldest flathead catfish captured was age-10 (Figure 3-15). Total annual mortality (A) using data from all gears and years was 33% (Figure 3-16). Growth rates for flathead catfish were rapid compared to channel catfish as it took only 4 years for flathead catfish to reach 400-mm (Figure 3-17). Mean annual growth increments were greater than 100-mm for the first 3 years of growth,

declining to 60-mm for the 5th-7th year of growth and 45-mm during the 8th-10th year of growth (Figure 3-18).

Discussion

I observed considerable variability in channel catfish age structure, growth rates and mortality along the Platte River. However, some interesting patterns appear to exist along this gradient. Channel catfish growth rates were consistently greater in the central Platte River compared to the lower Platte River, especially during early life stages. Examining longitudinal patterns on a finer scale (by site) showed that growth rates were noticeably slower in middle sites of the Platte River compared to extreme upstream and downstream locations. Mortality in the central Platte River was also consistently lower when compared to the lower Platte River.

Growth of channel catfish in the Platte River is similar to other Nebraska rivers (Figure 3-19). However, when compared to growth standards for the species (Hubert 1999), mean back-calculated lengths at age were consistently below the 50th percentile (Table 3-3). Similarly, von Bertalanffy growth functions for central Platte River and lower Platte River channel catfish exhibited slower growth when compared to the standard von Bertalanffy growth function for channel catfish (Jackson et al. 2008; Figure 3-20).

Holland and Peters (1992b) observed similar slow growth of channel catfish in the lower Platte River suggesting stressful environmental conditions as a possible source. The Platte River has experienced extreme environmental conditions within the last 10 years, the time period of growth observed for most individuals, where droughts and

floods have affected the hydrograph for extended periods of time. Previous studies on the Platte River suggested low water levels and extreme temperatures during the growing season coupled with a widely fluctuating hydrograph may slow growth of Platte River catfish (Holland and Peters 1992b). These factors are likely still influencing growth rates of current channel catfish populations in the Platte River.

Distinct differences in channel catfish growth were observed between the central Platte River and lower Platte River. Few studies have documented spatial patterns in channel catfish growth along Midwestern river systems. Pegg and Pierce (2001) did not detect any river-wide latitudinal trends in channel catfish growth in the Missouri River. Similarly, Holland and Peters (1992b) observed no longitudinal trends in the lower Platte River. However, Quist and Guy (1998) observed longitudinal differences in channel catfish growth in the Kansas River where fish collected furthest upstream displayed highest growth. They suggested prey availability was likely influencing differences in growth rates. The Kansas River is very similar in physical attributes to the Platte River and factors contributing to biological communities may be comparable. Therefore, greater prey availability and consumption may also be positively influencing catfish growth rates in the central Platte River. In fact, the central Platte River has recently experienced high water events (Figure 3-2) that have increased terrestrial plant inundation, possibly enhancing production and available forage. These effects may be comparable to a young reservoir experiencing nutrient upsurge when primary and secondary productivity increases, positively affecting numerous fish population characteristics, including growth (Summerfelt 1999).

Channel catfish collected from sites directly below the Loup River Power Canal exhibited the slowest growth rates compared to sites further upstream and downstream. Factors influencing growth (i.e., prey availability) may be negatively affected by flow manipulations. Gislason (1985) examined direct effects of diel fluctuation on aquatic insect density documenting benthic invertebrate abundances to be greatly reduced under diel fluctuations compared to stable flow conditions. Consequently, age-0 growth of coho salmon *Oncorhynchus kisutch*, chinook salmon *Oncorhynchus tshawytscha*, steelhead *Oncorhynchus mykiss*, and rainbow trout *Oncorhynchus mykiss* in the same system was greater during stable flow conditions compared to diel fluctuations (Gislason 1985). Since channel catfish are known to forage on aquatic invertebrates (Zuerlein 1982, Tyus and Nikirk 1990, Weisberg and Janicki 1990), it is likely that prey availability and subsequent consumption is reduced by canal hydropeaking in this area of the Platte River. Further, Weisberg and Burton (1993) suggested that increased feeding and growth of fish under a minimum flow requirement compared to a widely fluctuating hydrograph were responding to more consistent availability of depth and flow conditions conducive to foraging. Therefore, specific habitat conditions may also be influencing growth of channel catfish in the Platte River. Water discharges from the Loup River Power Canal provide a substantial proportion of flow to the Platte River accounting for 22-67% of the entire Platte River flow 49-km downstream at North Bend (Site 4; Holland and Peters 1989). These factors, when taken as a whole, provide some evidence that channel catfish growth and/or growth related factors may be negatively influenced downstream of the Loup River Power Canal. Reducing the magnitude and duration of

discharge peaks could be a possible management strategy to positively affect the entire biotic community downstream, including channel catfish.

Channel catfish growth rates in the lower Platte River were also consistently greater at furthest downstream sites. Physical and chemical characteristics of the Platte River are altered downstream of the Loup River Power Canal. Holland and Peters (1989) observed a conductivity gradient at least 75-km downstream of the canal. Additionally, examinations of USGS hourly water data indicate noticeable diel fluctuations in discharge and gauge height at least 84-km downstream at Leshara (Site 3). This indicates flow modifications could be influencing river biota substantial distances downstream. No major tributaries flow into the Platte River between the Loup River Power Canal and Site 3. However, the confluence of the Elkhorn River and Platte River occurs between Site 2 and Site 3 (Figure 3-1). Sites 1 and 2, downstream of the Elkhorn River, exhibited the highest growth rates in the lower Platte River. Therefore, tributary inflows may moderate the flow issues found upstream and allow for a more favorable environment for channel catfish in the Platte River. Increased habitat complexity and productivity, including increases in nutrients, algal biomass, consumers and predators, have been documented downstream of tributaries (Kiffney et al. 2006). Additionally, tributary inflows can moderate the variability and physico-chemical effects of flow changes and provide a natural flow regime to the main stem (Cushman 1985). If similar effects are being experienced in the Platte River downstream of the Elkhorn River inflow, channel catfish growth may be positively influenced by increased productivity, enhancing prey availability, and increased habitat complexity, providing more suitable areas for refuge

and feeding. This information reveals how important tributaries and a natural flow regime can be to the Platte River and similar riverine systems.

Prey availability, flow modifications, habitat conditions and tributary inflows are probably not the only factors influencing growth rates of channel catfish in the Platte River. Intra- and inter-specific competition (Carlander 1969, Colombo 2007, Michaletz 2009), temperature (Kilambi et al. 1971, Andrews and Stickney 1972, Suja et al. 2009) and watershed characteristics (Shephard and Jackson 2006) have also been documented to influence channel catfish growth. It is likely that a myriad of these factors and their interactions are playing a role in influencing channel catfish growth throughout the Platte River.

Annual mortality rates were consistently lower in the central Platte River compared to the lower Platte River. Central Platte River mortality was comparable to lightly exploited populations in other Midwest rivers (Gerhardt and Hubert 1991, Smith and Hubert 1988); whereas, lower Platte River annual mortality was less than heavily exploited channel catfish populations (Pitlo 1997, Graham and DeiSantie 1999, Mestl 1999; Table 3-4). Most recreational fishing is believed to occur in the lower Platte River, for a number of reasons including variable water levels and public perception of catfish presence. Our mortality estimates indicate the central Platte River is relatively unexploited and suggests low angler harvest rates compared to other fisheries in the United States (Graham and DeiSanti 1999, Santucci et al. 1994).

Varying degrees of fishing pressure have been documented in the lower Platte River (Holland and Peters 1994) and may be a cause of higher mortality rates in this reach. Peters et al. (1992) documented annual mortality rates as high as 59% for channel

catfish collected from hoop nets in the lower Platte River and identified potential over-exploitation as a concern. These findings are very similar to my results indicating angler exploitation may still be a driving force behind high annual mortality in the lower Platte River. However, issues of sampling constraints could be one caveat to these conclusions. Most sampling sites were located at public access points. Therefore, localized angling pressure could be high compared to other segments of the river and mortality estimates may not be representative of the entire river reach. Quantifying angler exploitation along the Platte River through creel surveys in conjunction with channel catfish population investigations would be useful in identifying differences in natural and fishing mortality.

Channel catfish populations in the Platte River exhibit relatively slow growth and spatial patterns in growth rates are evident along the longitudinal gradient of the Platte River. I highlighted prey availability, flow modifications, habitat conditions and tributary inflows, among others, as factors potentially influencing longitudinal trends in growth in this system. Additionally, annual mortality is relatively high in the lower Platte River and is likely being influenced by increased rates of angler exploitation.

Determining direct factors affecting growth and mortality is difficult because environmental variability is often high. Specific investigations concerning prey availability, food habits, angler exploitation and their spatial variability throughout the Platte River would be beneficial to determinine factors that are affecting channel catfish growth. Further, channel catfish are a mobile species (Bunnell 1988, Dames et al. 1989, Chapman 1995, Pellet et al. 1998) which may confound spatial comparisons. Reaches of the central Platte River were completely dry on an annual basis during the early 2000's. Therefore, most channel catfish collected from the central Platte River inhabited different

areas of the river or tributaries at some point during their life. It is apparent that these refuge areas are extremely important to central Platte River channel catfish populations. Gaining knowledge about the location and extent of these refugia is very important to sustain central Platte River channel catfish populations during periods of low water or extreme drought.

Channel catfish are the most important recreational fishing species in the Platte River fishery. We have new insights on growth and mortality of channel catfish populations in the Platte River that suggest longitudinal trends are being influenced by numerous factors. However, temporal variation in these characteristics is common and factors influencing growth and mortality may change over time. Therefore, populations should be monitored on a regular basis in the Platte River as well as other river systems where channel catfish are important components of the fishery.

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Table 3-1. Instantaneous mortality (Z), total annual mortality (A) and theoretical maximum age (Max Age) of channel catfish collected with all standard sampling gears in the Platte River during 2007, 2008 and both years combined.

	2007			**2008**			**Cumulative**		
	central	lower	overall	central	lower	overall	central	lower	overall
Z	0.302	0.587	0.438	0.405	0.553	0.474	0.312	0.596	0.480
A	26%	44%	36%	33%	43%	38%	27%	45%	38%
Max Age	12.8	11.5	14.6	15.2	12.9	15.0	15.2	12.9	15.2

Table 3-2. Instantaneous mortality (Z), total annual mortality (A) and theoretical maximum age (Max Age) of channel catfish collected with HN_{25}, HN_{38}, EF_{60} and EF_{15} in the Platte River during 2007 and 2008 combined.

	HN_{25}		**HN_{38}**		**EF_{60}**		**EF_{15}**	
	central	lower	central	lower	central	lower	central	lower
Z	0.395	0.712	0.167	0.387	0.256	0.360	0.257	0.338
A	33%	51%	15%	32%	23%	30%	23%	29%
Max Age	11.8	10.9	11.1	13.1	11.0	11.7	10.9	10.7

Table 3-3. Mean back-calculated length at age for channel catfish collected in the central and lower Platte River (**Bold**) during 2007 and 2008 compared to standard growth percentiles for channel catfish across their geographic range. Percentiles provided by Hubert (1999). Superscripts following lengths delineate central (^{C}) and lower (^{L}) Platte River channel catfish.

	Growth Percentile									
Age	**5th**	**10th**		**25th**		**50th**		**75th**	**90th**	**95th**
3	172	192		211	**212^{L}**	238	**240^{C}**	282	310	331
4	217	243	**261^{L}**	268	**284^{C}**	291		332	387	396
5	240	271		307	**308^{L}, 334^{C}**	341		386	444	476
6	291	316		353	**356^{L}, 384^{C}**	386		429	504	537
7	303	331		388	**401^{L}, 420^{C}**	434		479	567	596
8	331	353		417	**439^{L}, 458^{C}**	469		513	595	620
9	340	379		456	**474^{L}, 487^{C}**	504		547	628	669
10	363	387	**484^{L}**	505	**509^{C}**	554		597	665	703

Table 3-4. Annual mortality rates of channel catfish populations in the central Platte River and lower Platte River compared to other North American river populations.

Water Body	Annual Mortality
Ottawa River[a]	16%
Powder River[b]	23%
Crazy Woman Creek[c]	25%
Central Platte River[d]	**15-33%**
Wabash River - non-commercially fished[e]	25-33%
Missouri River - non-commercially fished[f]	35%
Lower Platte River[d]	**29-51%**
Sacramento River[g]	56%
Mississippi River[h]	61%
Wabash River - commercially fished[e]	32-67%
Missouri River - commercially fished[g]	72%
Harry Truman Dam Tailwater[i]	33-83%

Annual mortality estimates from [a] Haxton and Punt 2004, [b] Gerhardt and Hubert 1991, [c] Smith and Hubert 1988, [d] current study, [e] Colombo 2007, [f] Mestl 1999, [g] McCammon and LaFaunce 1961, [h] Pitlo 1997, [i] Graham and Deisanti 1999.

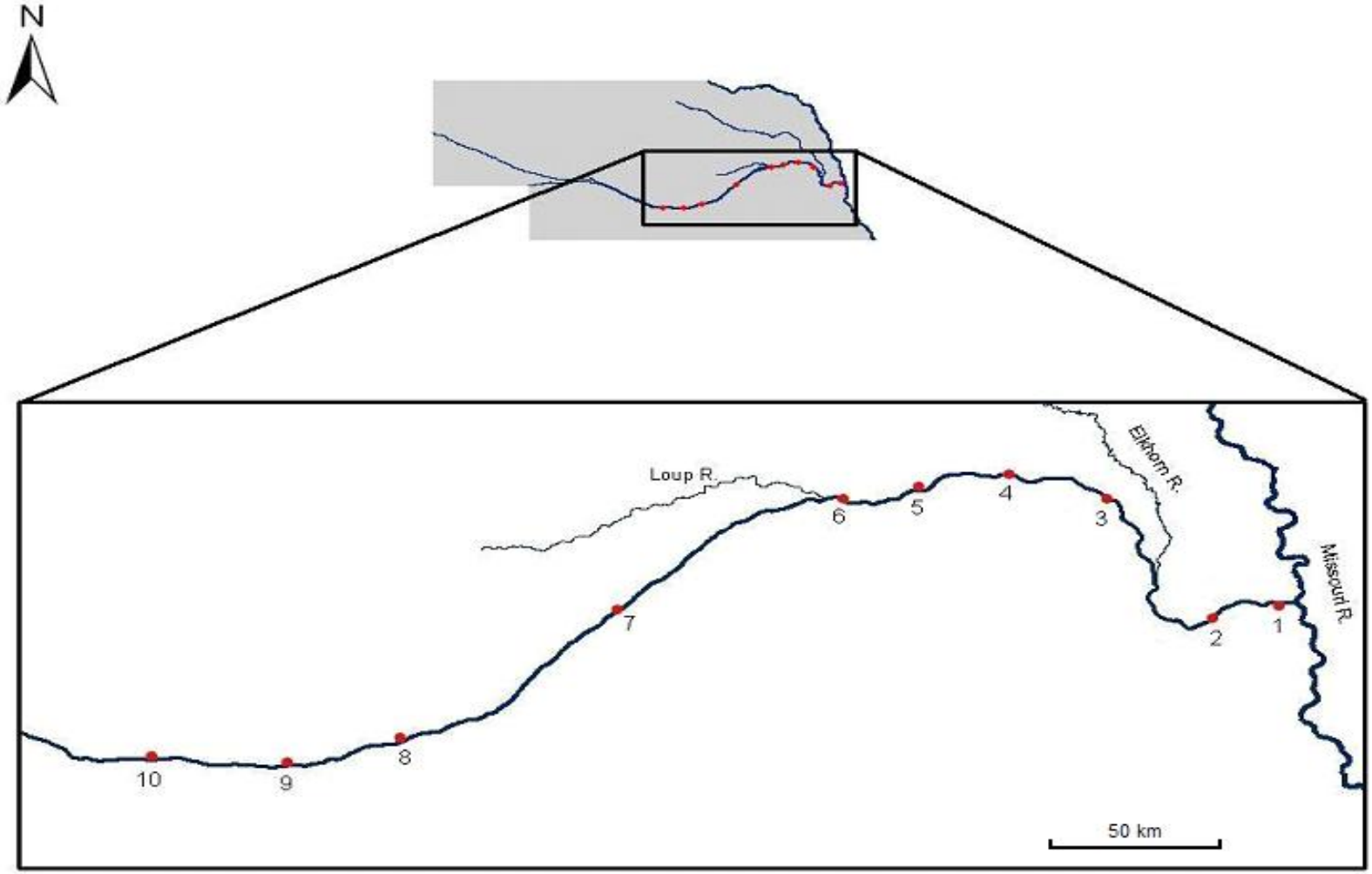

Figure 3-1. Study area including sampling locations in the central (Sites 7-10) and lower (Sites 1-6) Platte River, Nebraska.

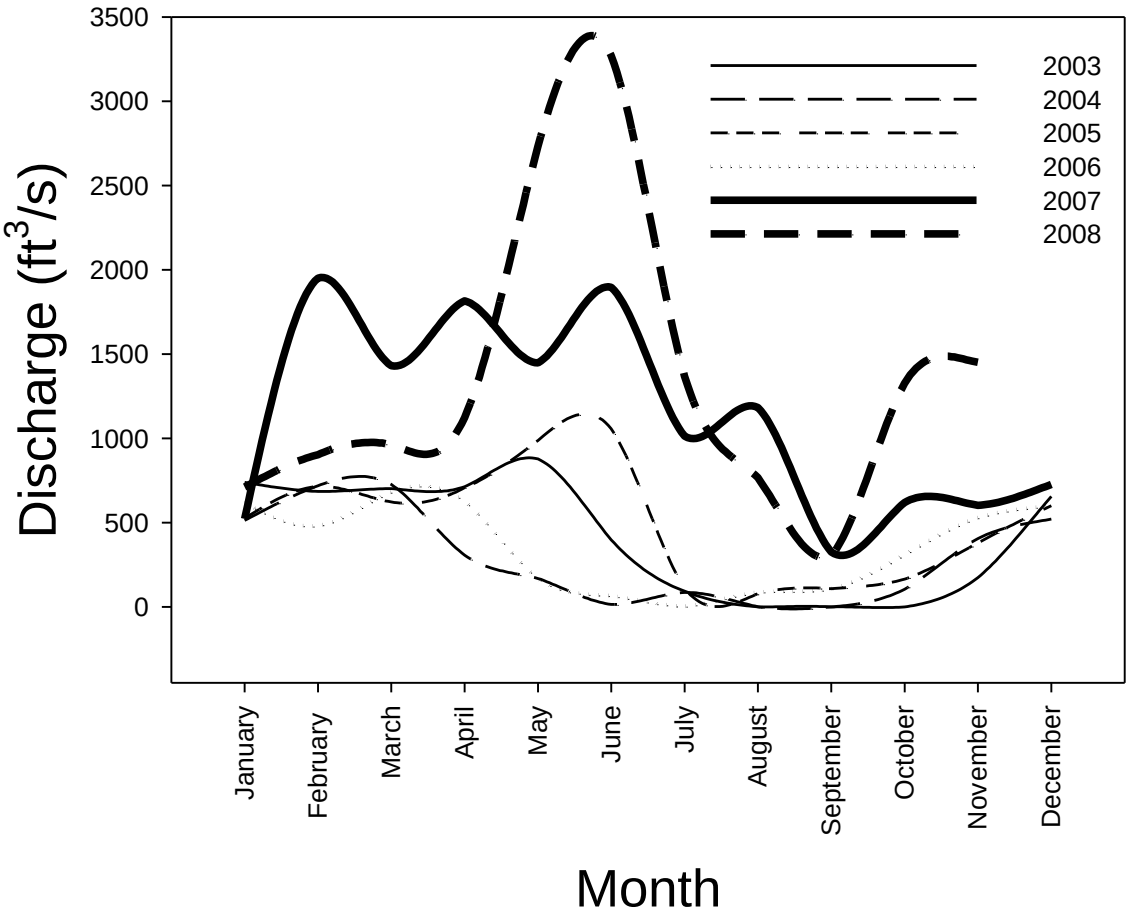

Figure 2. Mean monthly discharge of the Platte River near Grand Island, NE (USGS gauge 06770500) during 2003-2008. Bold plots represent discharge during the current study (2007-2008).

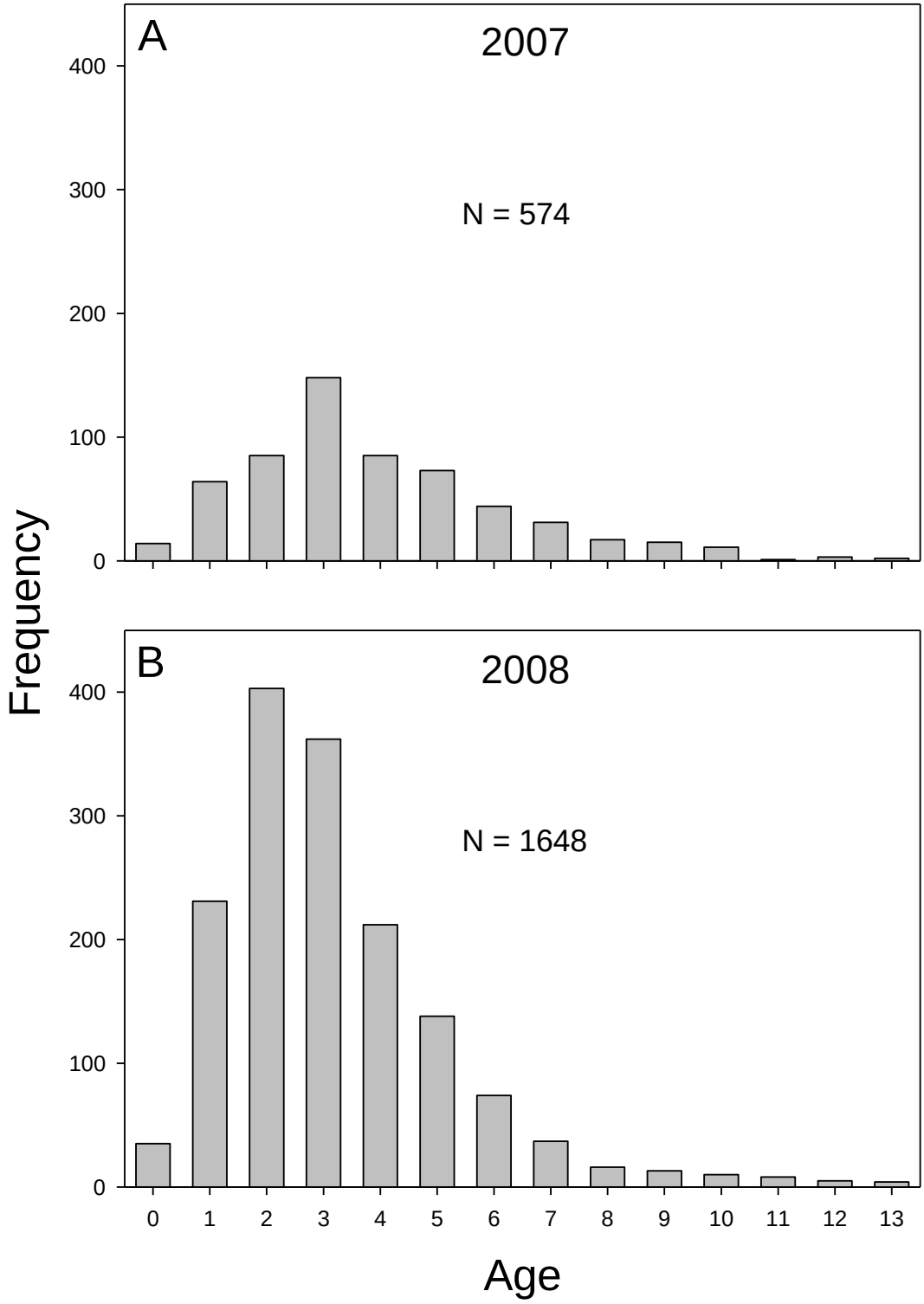

Figure 3-3. Age distribution of channel catfish collected with all gears in the Platte River during 2007 (A) and 2008 (B).

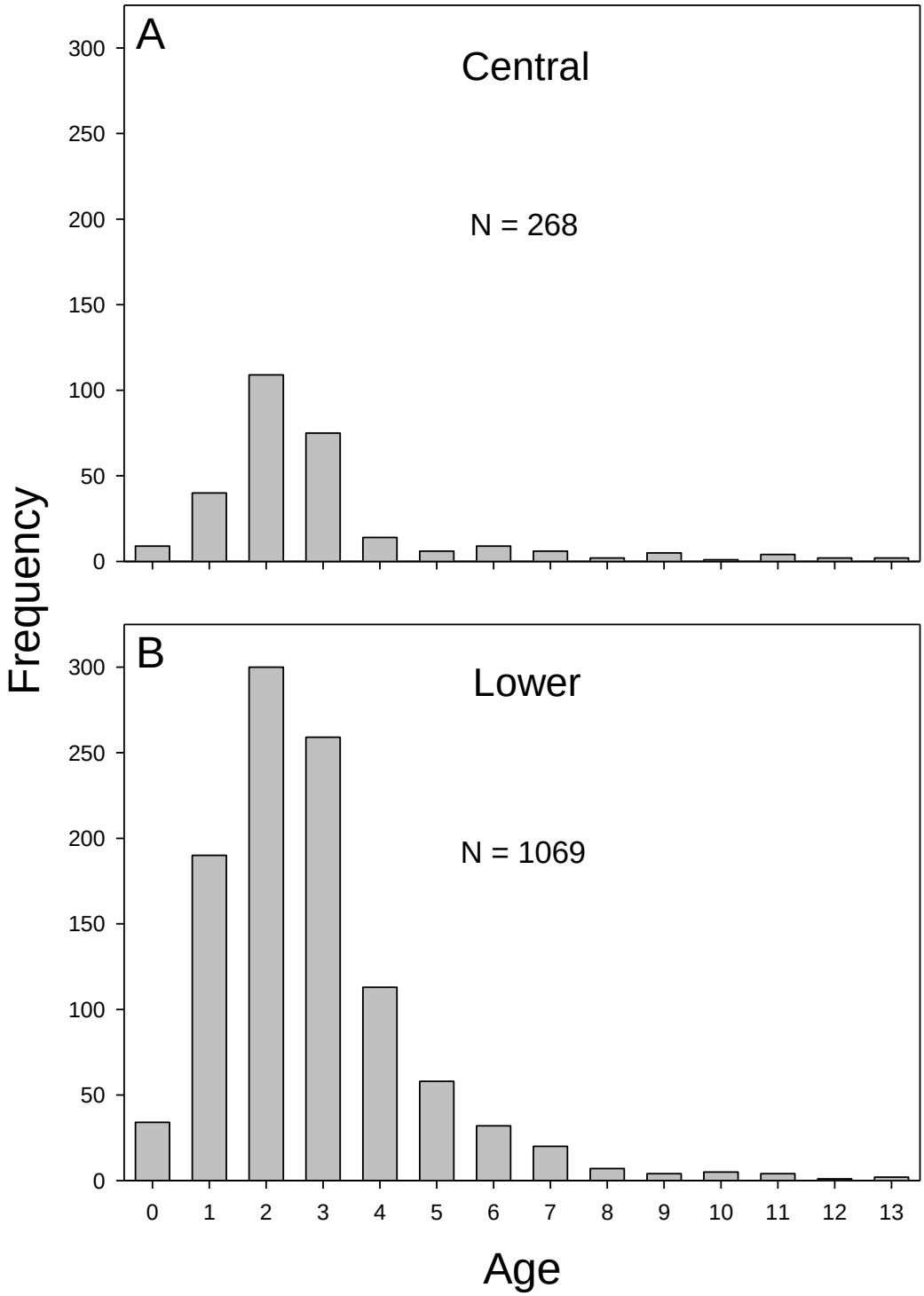

Figure 3-4. Age distribution of channel catfish collected with all standard gears in the central Platte River (A) and lower Platte River (B) during 2008.

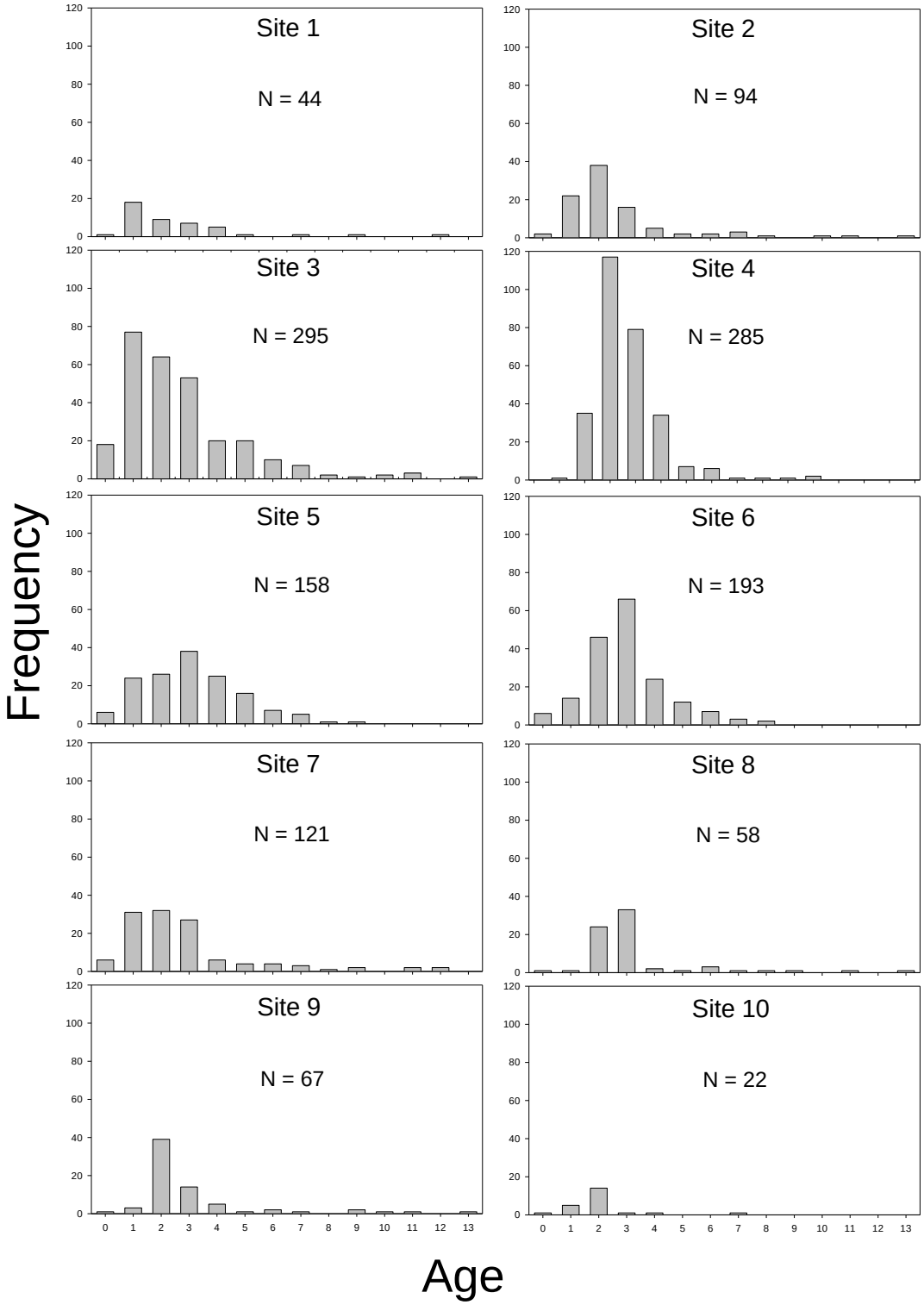

Figure 3-5. Age distirbution of channel catfish collected with all standard gears at each site in the Platte River during 2008.

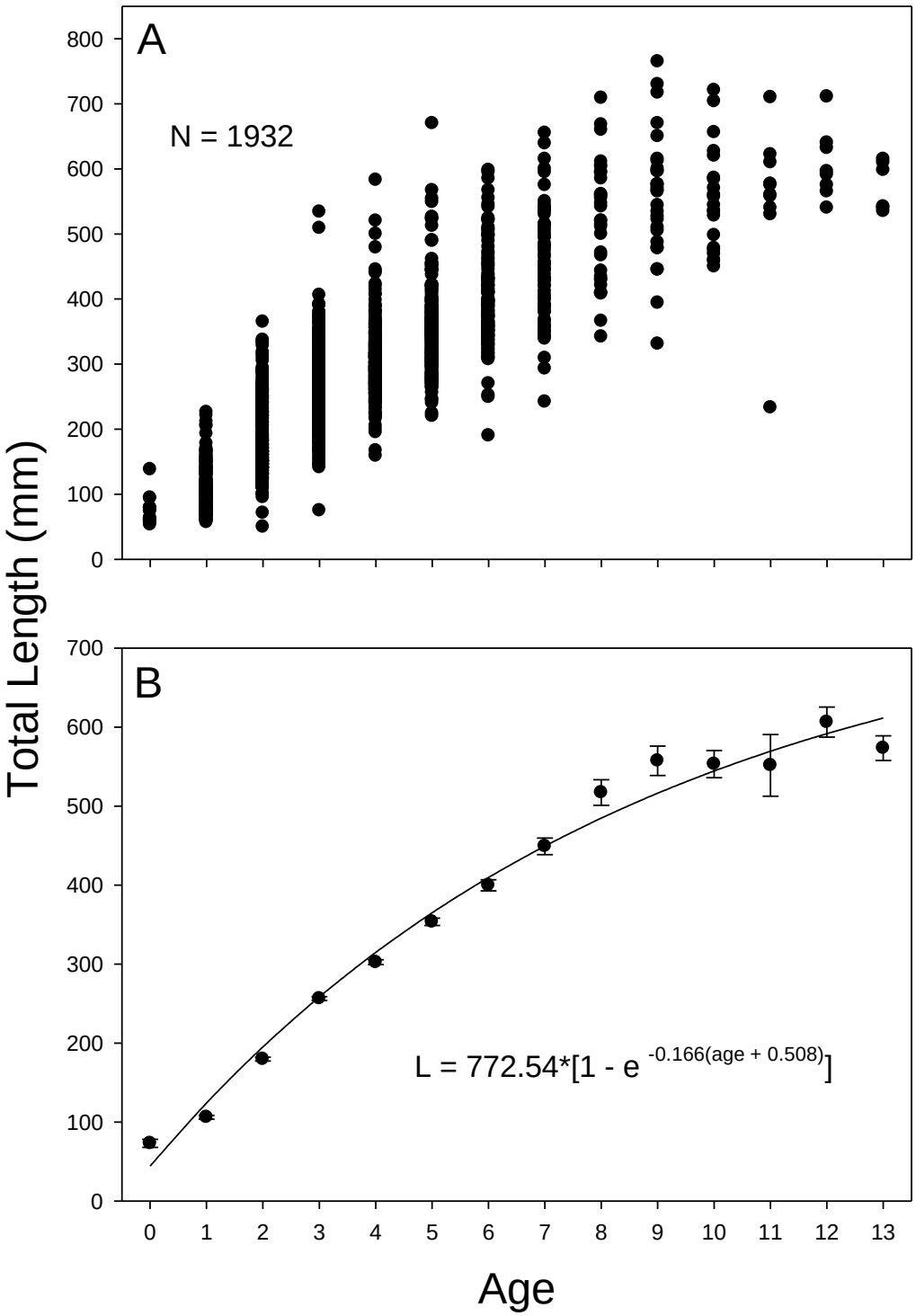

Figure 3-6. Individual length at capture (A), mean length at capture and von Bertalanffy growth function (B) of channel catfish collected in the Platte River during 2007 and 2008.

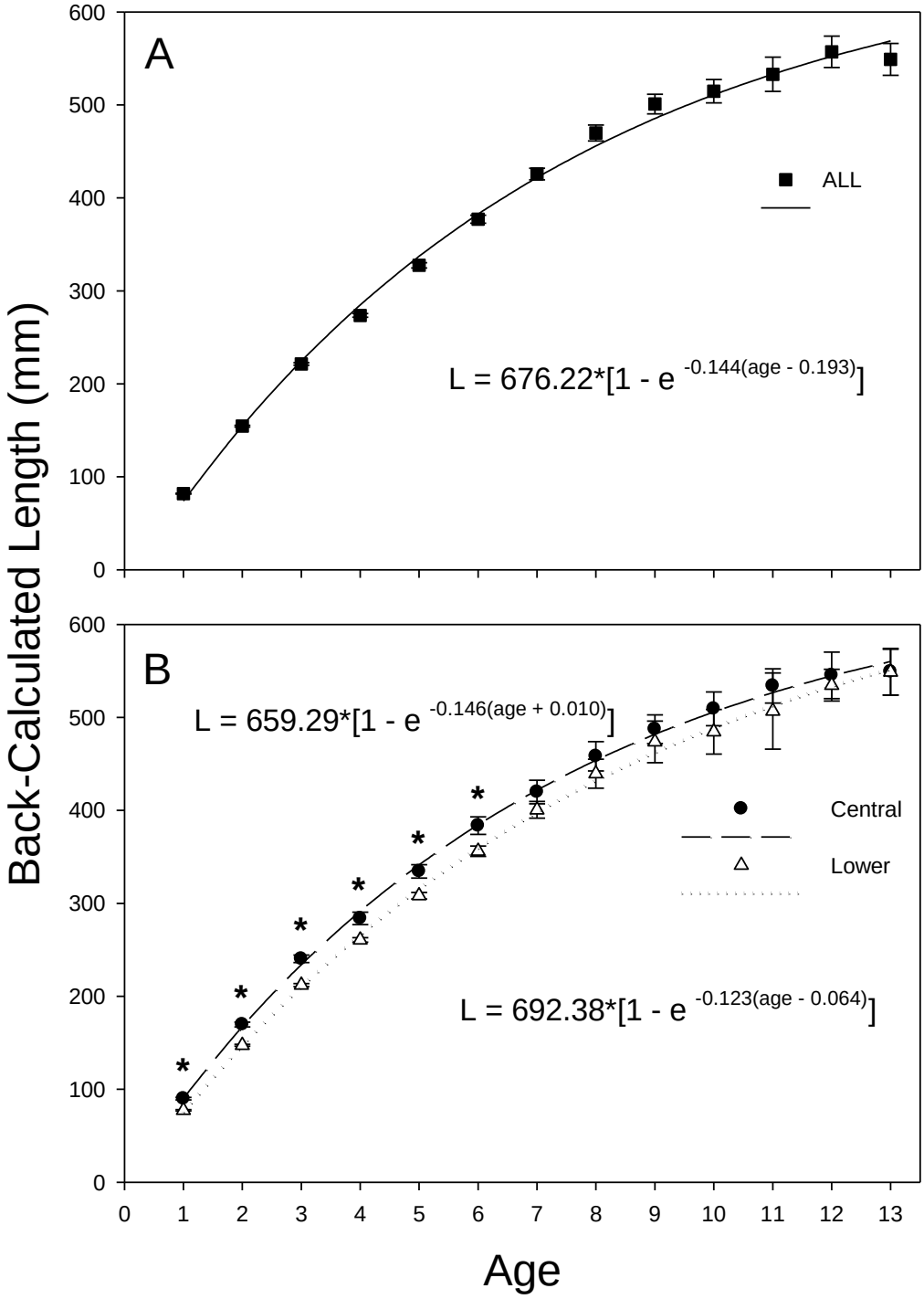

Figure 3-7. Mean back-calculated length at age and von Bertalanffy growth functions of channel catfish collected in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007 and 2008. A '*' indicates differences in mean back-calculated length at age between the central Platte River and lower Platte River.

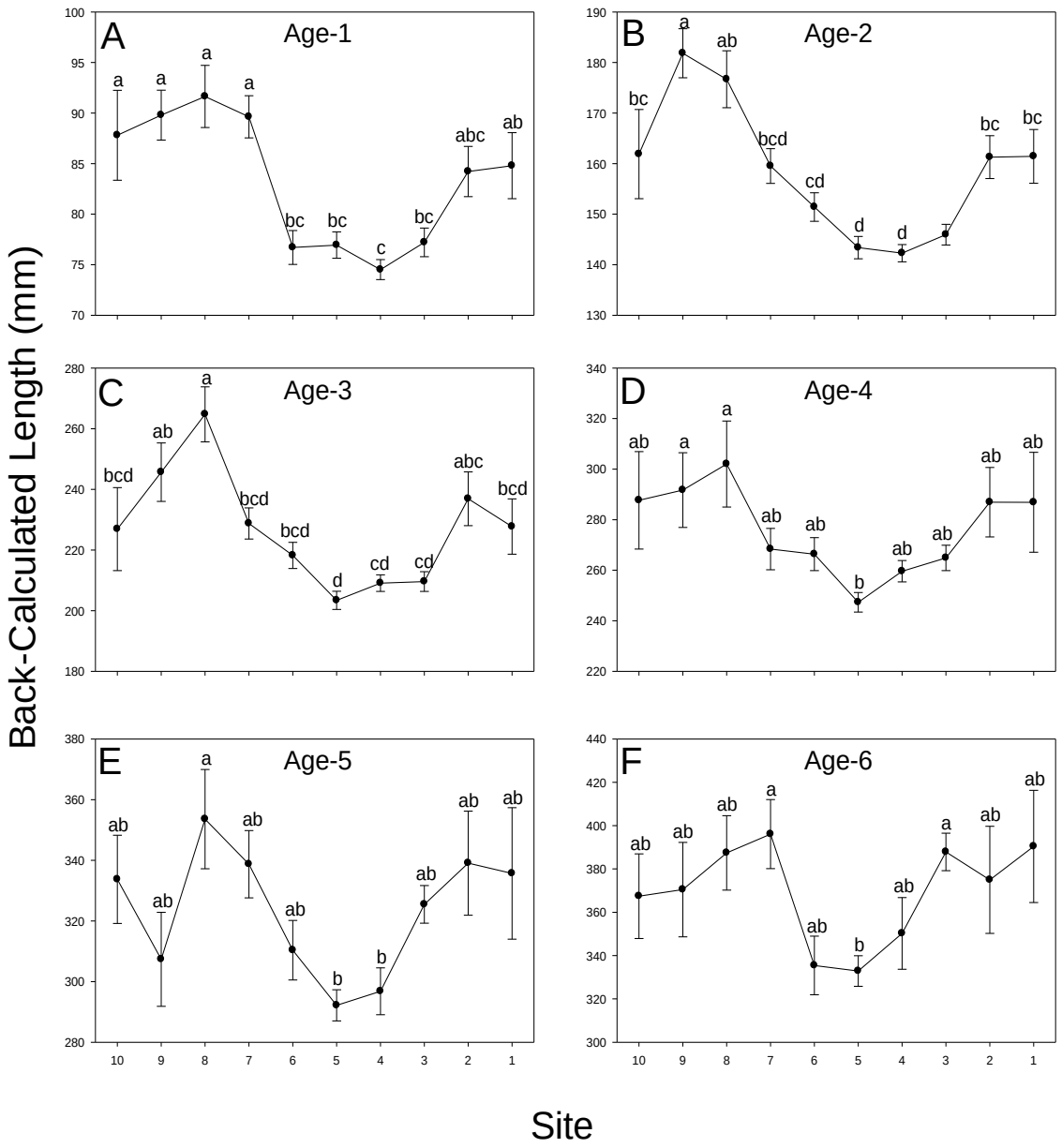

Figure 3-8. Mean back-calculated length at Age-1 (A), Age-2 (B), Age-3 (C), Age-4 (D), Age-5 (E) and Age-6 (F) channel catfish collected at each site in the Platte River during 2007 and 2008. Different letters above plots indicate differences among mean-back calculated lengths.

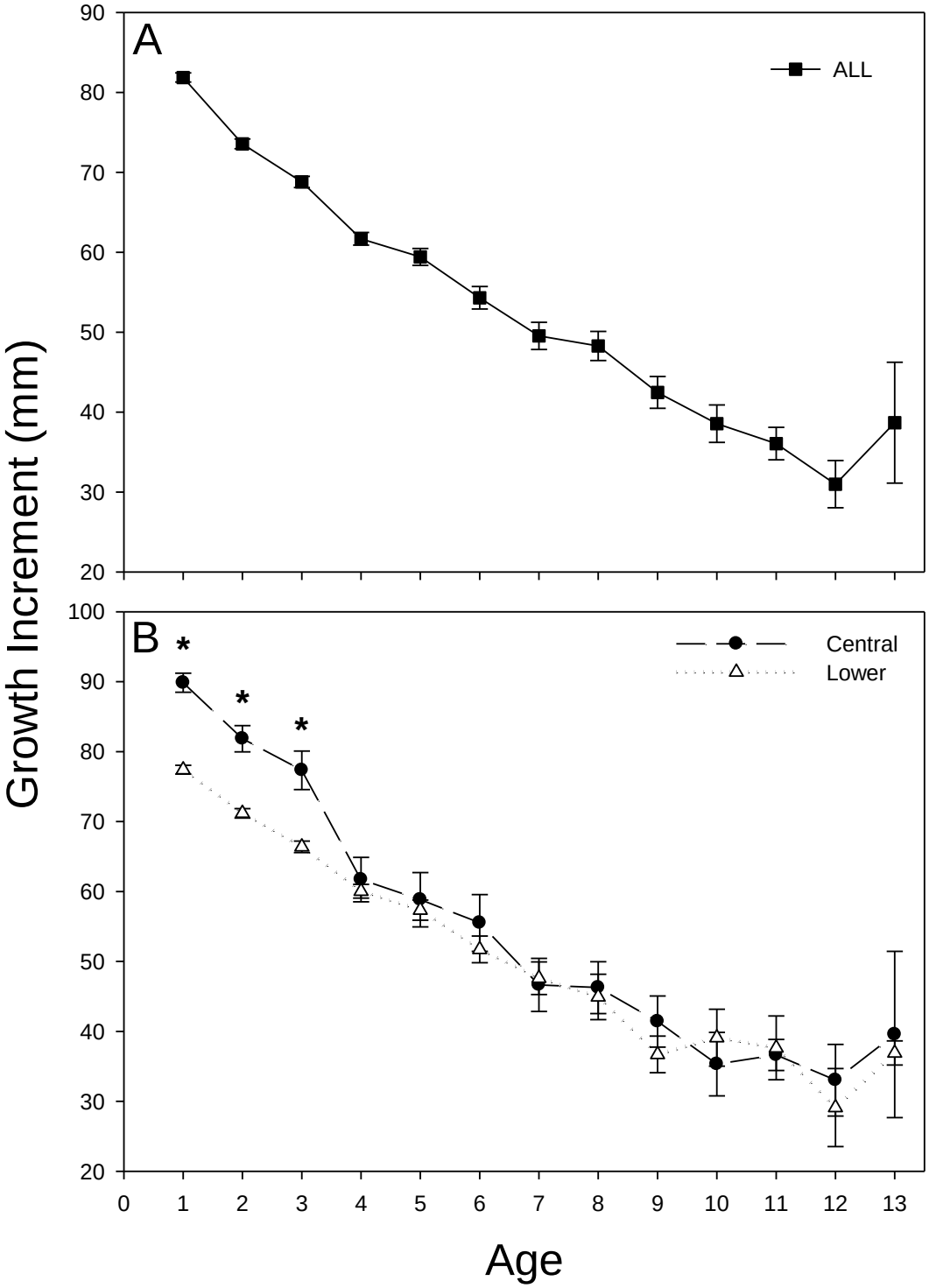

Figure 3-9. Mean annual growth increment of channel catfish collected in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007 and 2008. A '*' indicates differences in mean annual growth increments.

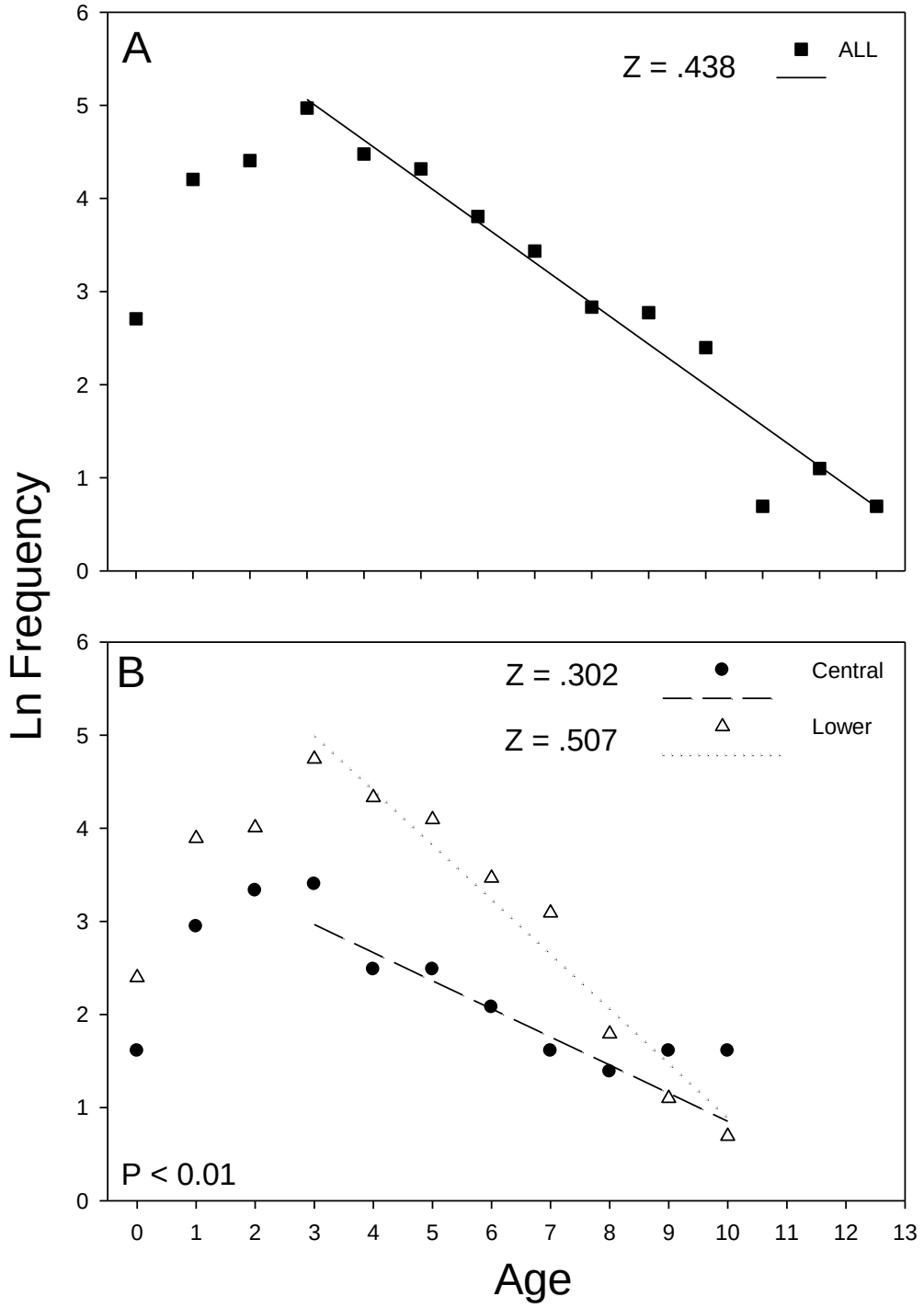

Figure 3-10. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007. P-values are reported for ANCOVA testing differences in regression line slopes (instantaneous mortality, Z).

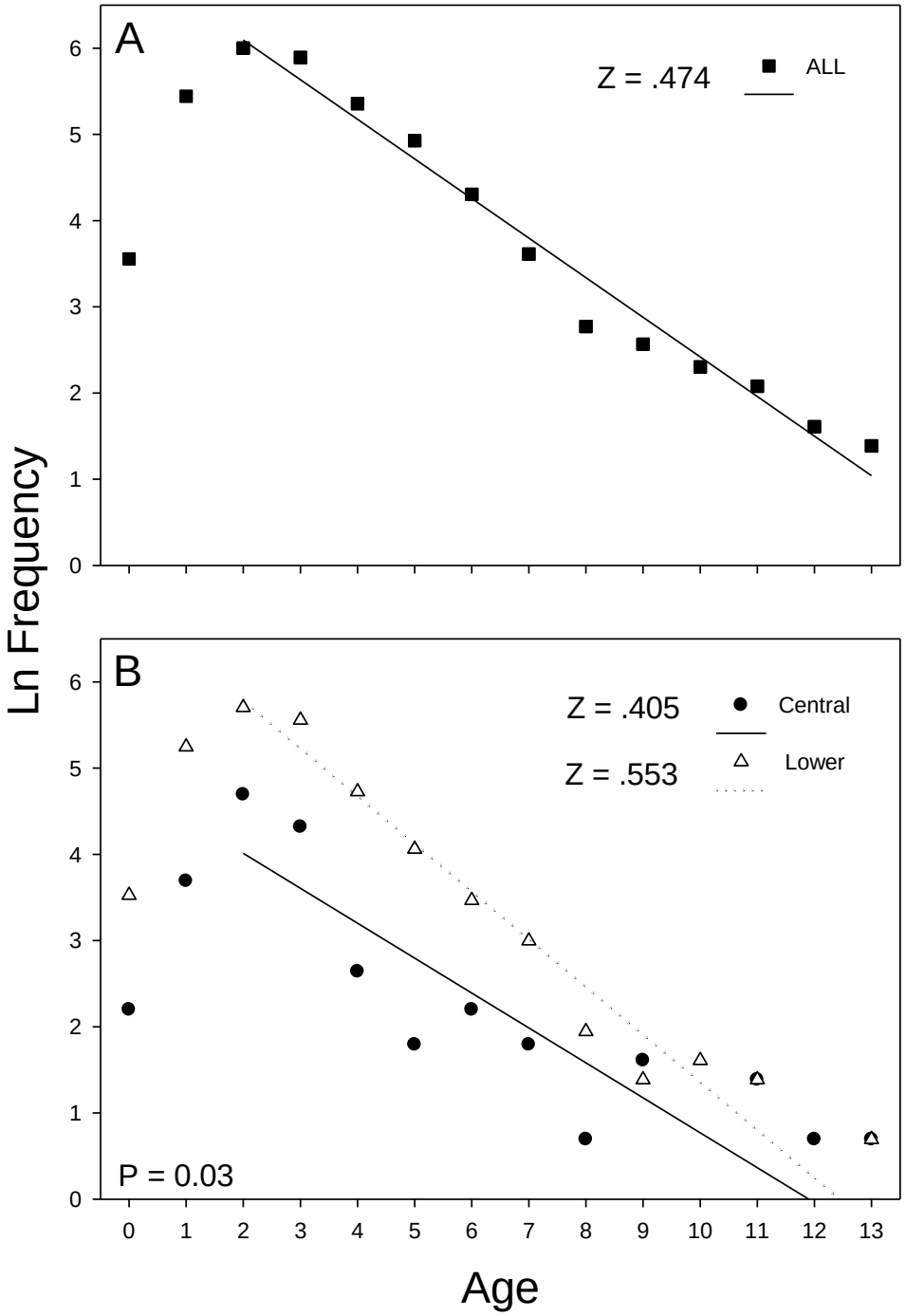

Figure 3-11. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the entire Platte River (A), central Platte River and lower Platte River (B) during 2008. P-values are reported for ANCOVA testing differences in regression line slopes (instantaneous mortality, Z).

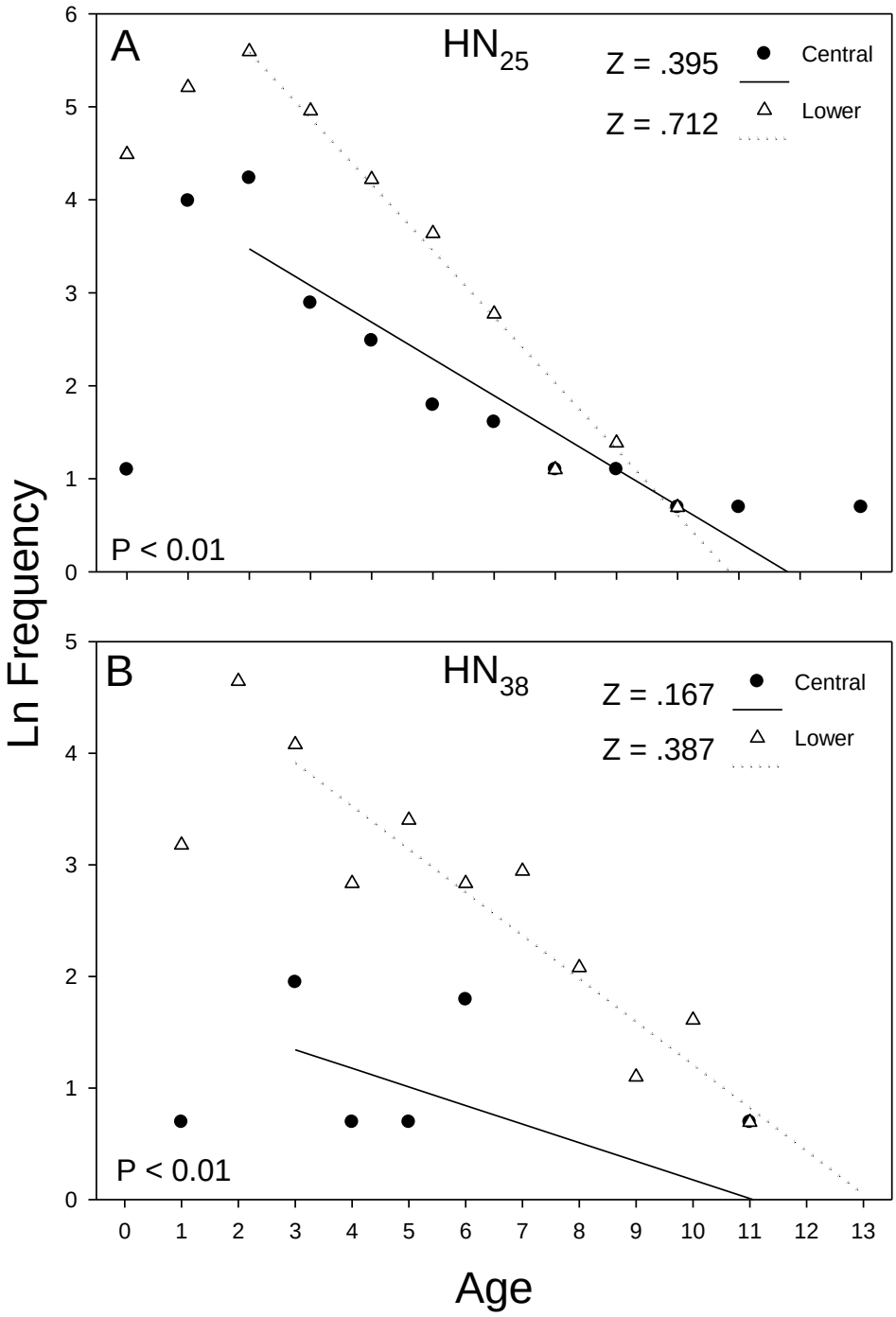

Figure 3-12. Weighted regression catch curves for channel catfish collected from 25-mm hoop nets (HN_{25}; A) and 38-mm hoop nets (HN_{38}; B) in the central Platte River and lower Platte River during 2007 and 2008. P-values are reported for ANCOVA testing for differences in regression line slopes (instantaneous mortality, Z).

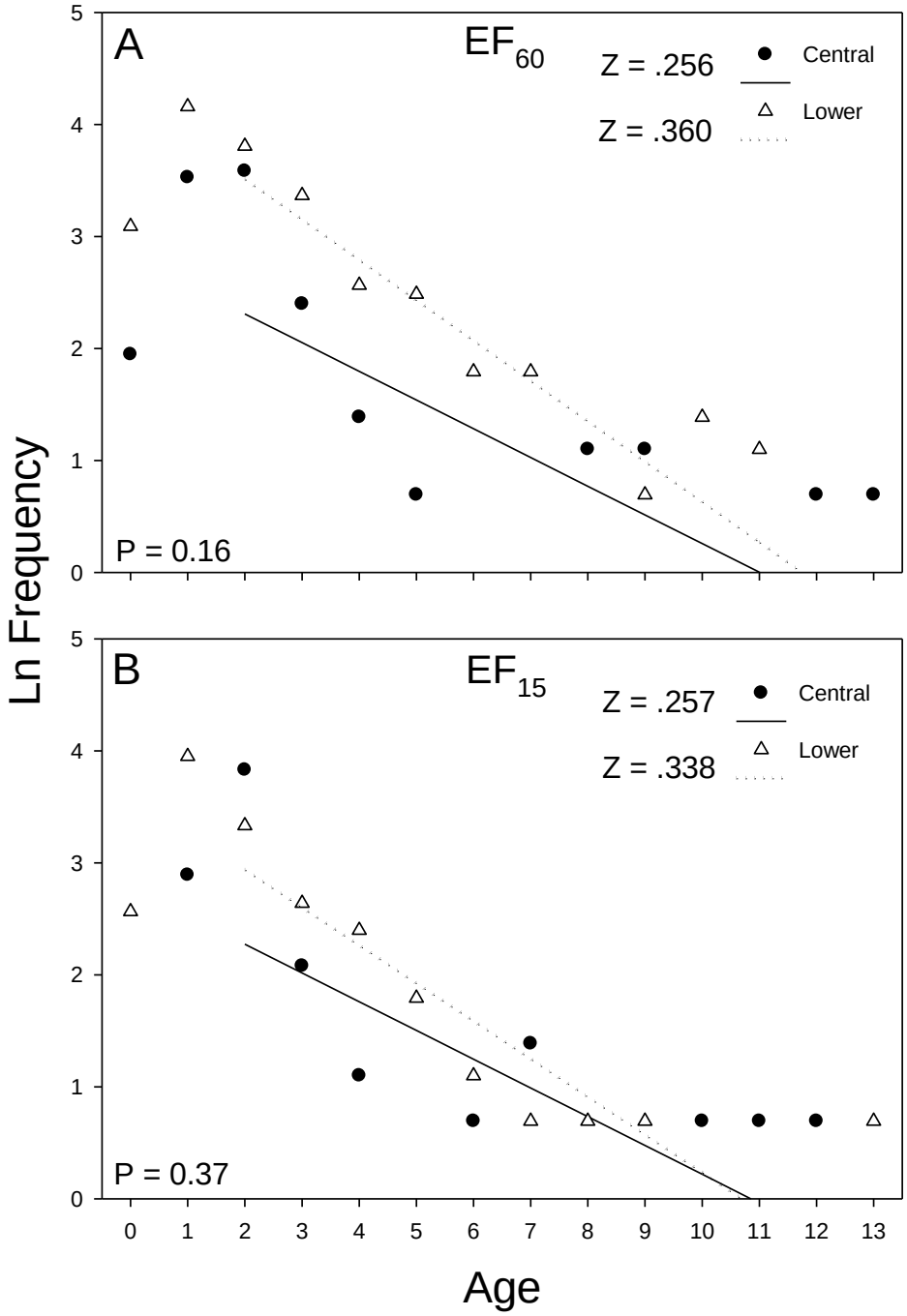

Figure 3-13. Weighted regression catch curves for channel catfish collected from high frequency pulsed-DC electrofishing (EF_{60}; A) and low frequency pulsed-DC electrofishing (EF_{15}; B) in the central Platte River and lower Platte River during 2007 and 2008. P-values are reported for ANCOVA testing for differences in regression line slopes (instantaneous mortality, Z).

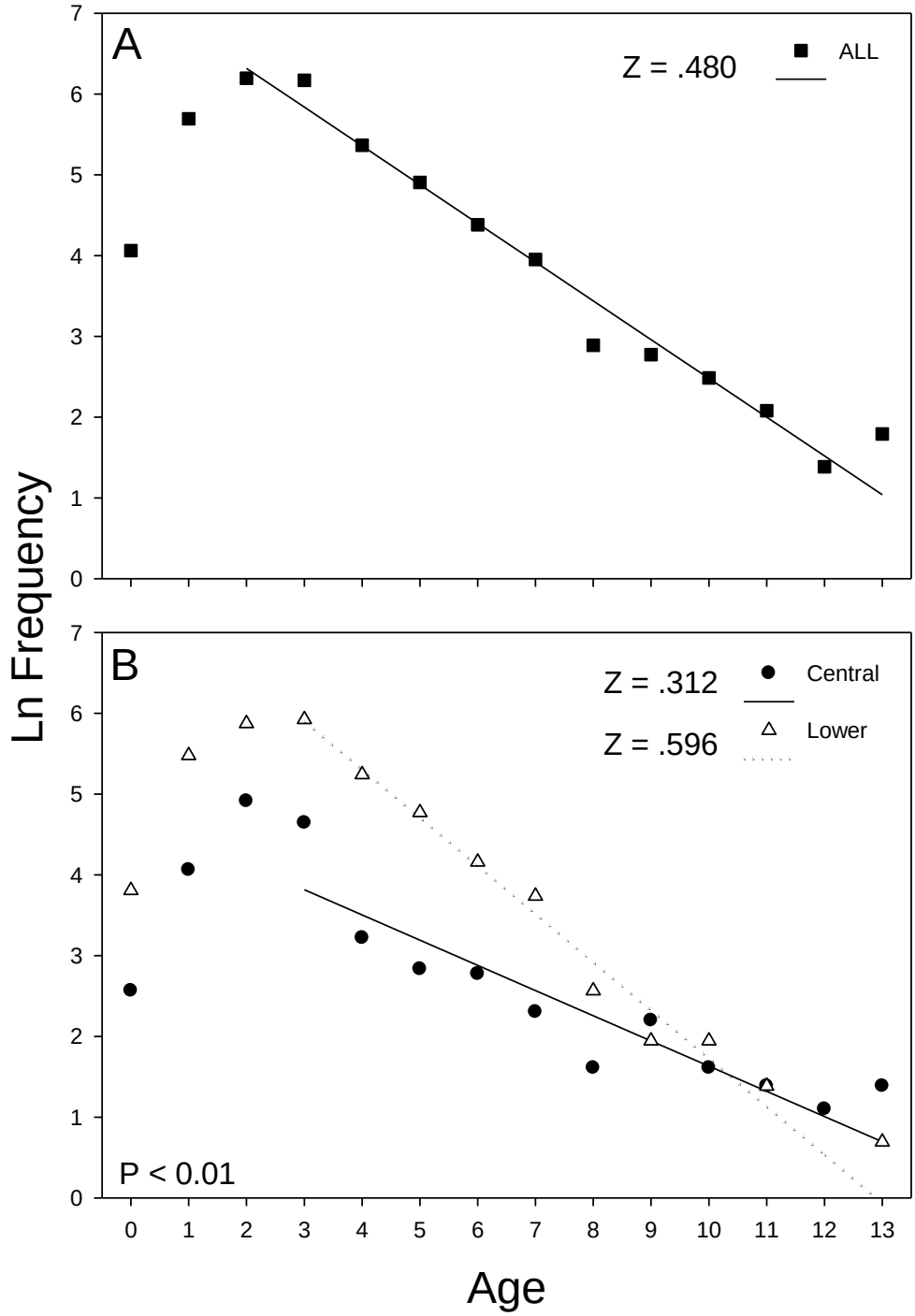

Figure 3-14. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the entire Platte River (A), central Platte River and lower Platte River (B) during 2007 and 2008. P-values are reported for ANCOVA testing for differences in regression line slopes (instantaneous mortality, Z).

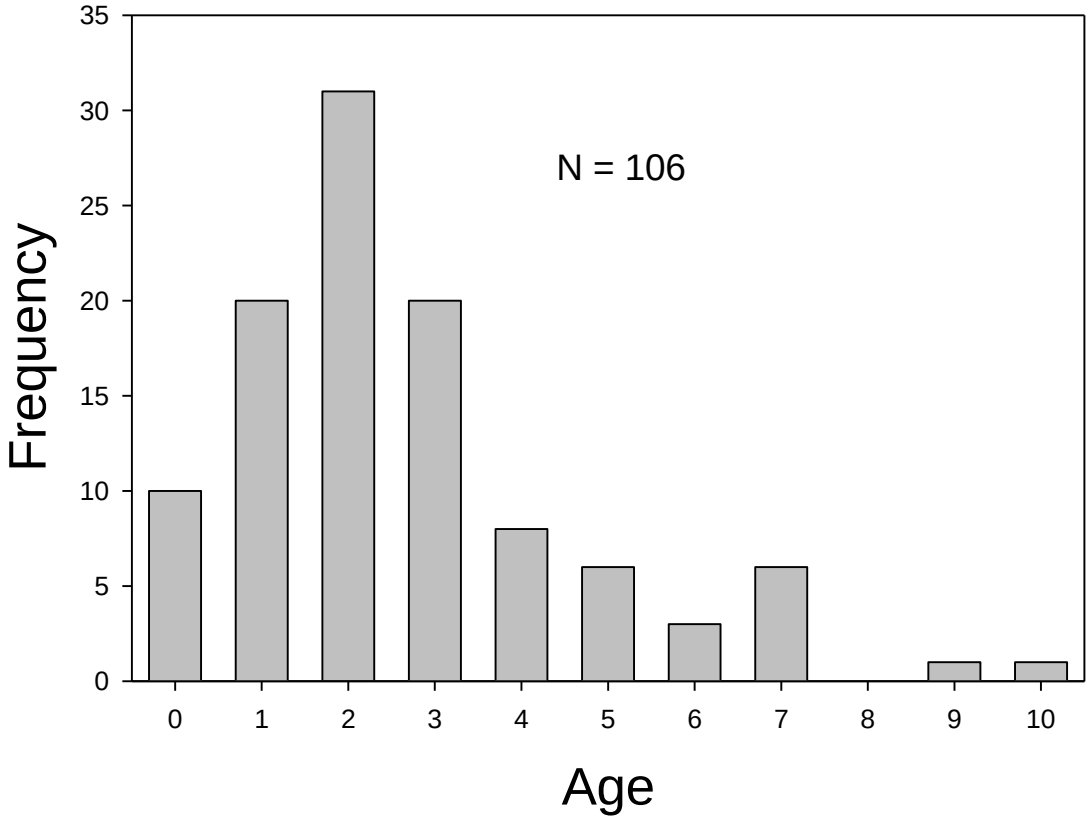

Figure 3-15. Age distribution of flathead catfish collected with all sampling gears in the Platte River during 2007 and 2008.

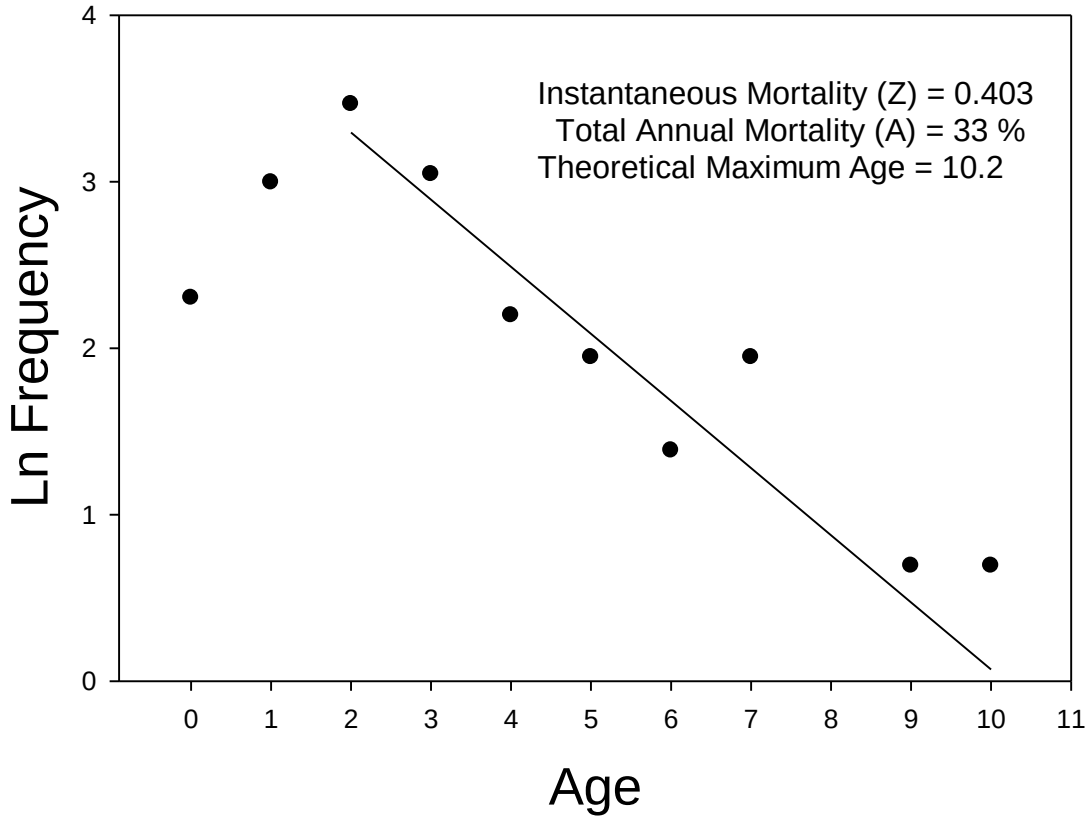

Figure 3-16. Weighted regression catch curve, instantaneous mortality, total annual mortality and theoretical maximum age of flathead catfish collected from all sampling gears in the Platte River during 2007 and 2008.

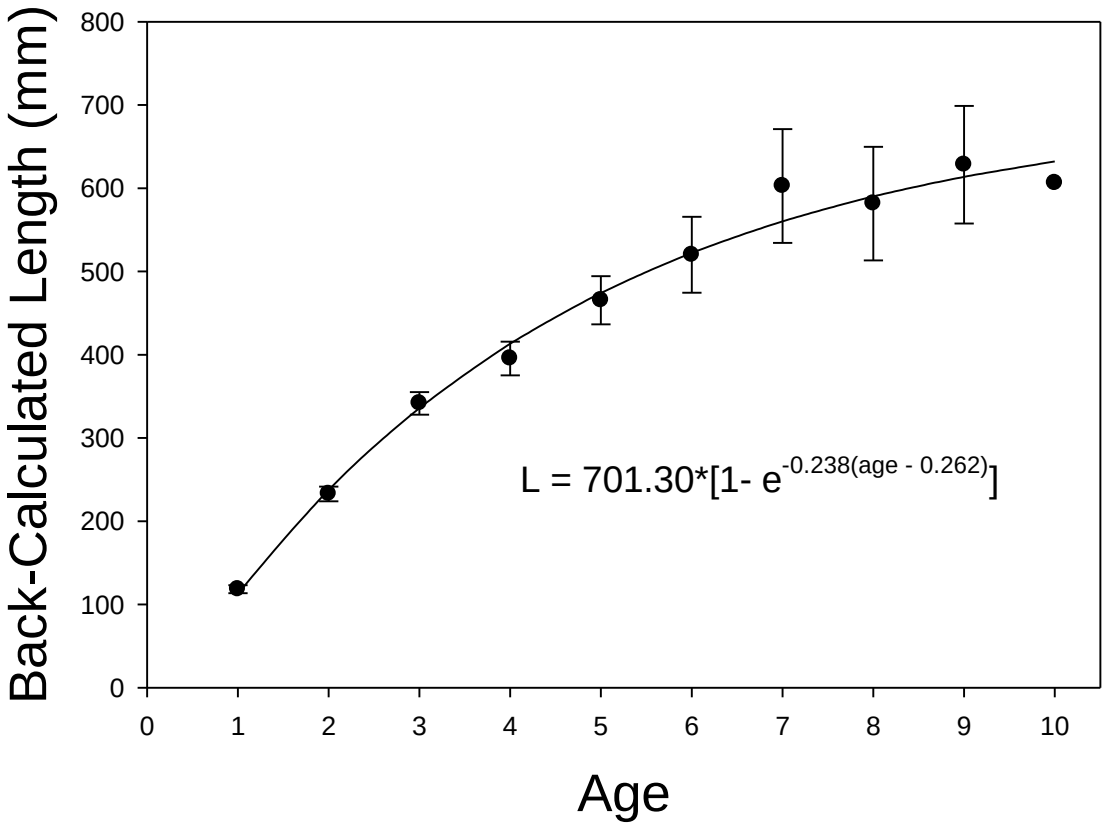

Figure 3-17. Mean back-calculated length at age and von Bertalanffy growth function of flathead catfish collected in the Platte River during 2007 and 2008.

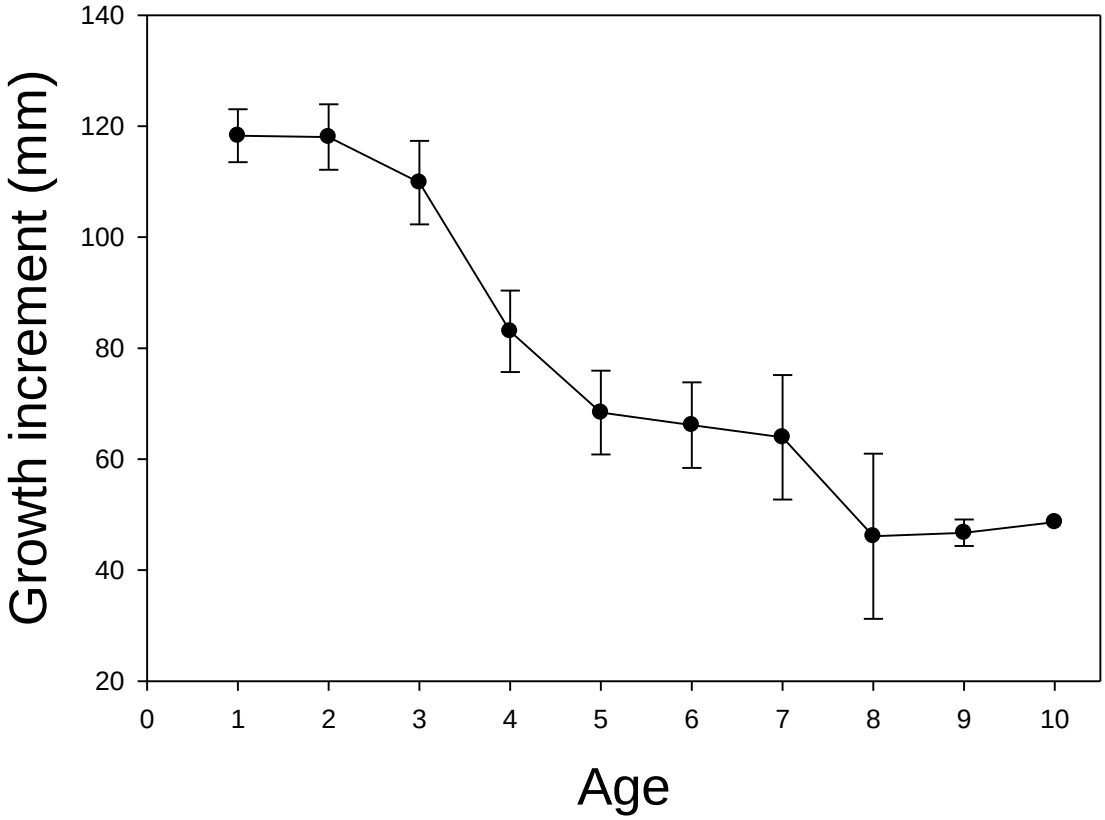

Figure 3-18. Mean annual growth increment of flathead catfish collected in the Platte River during 2007 and 2008.

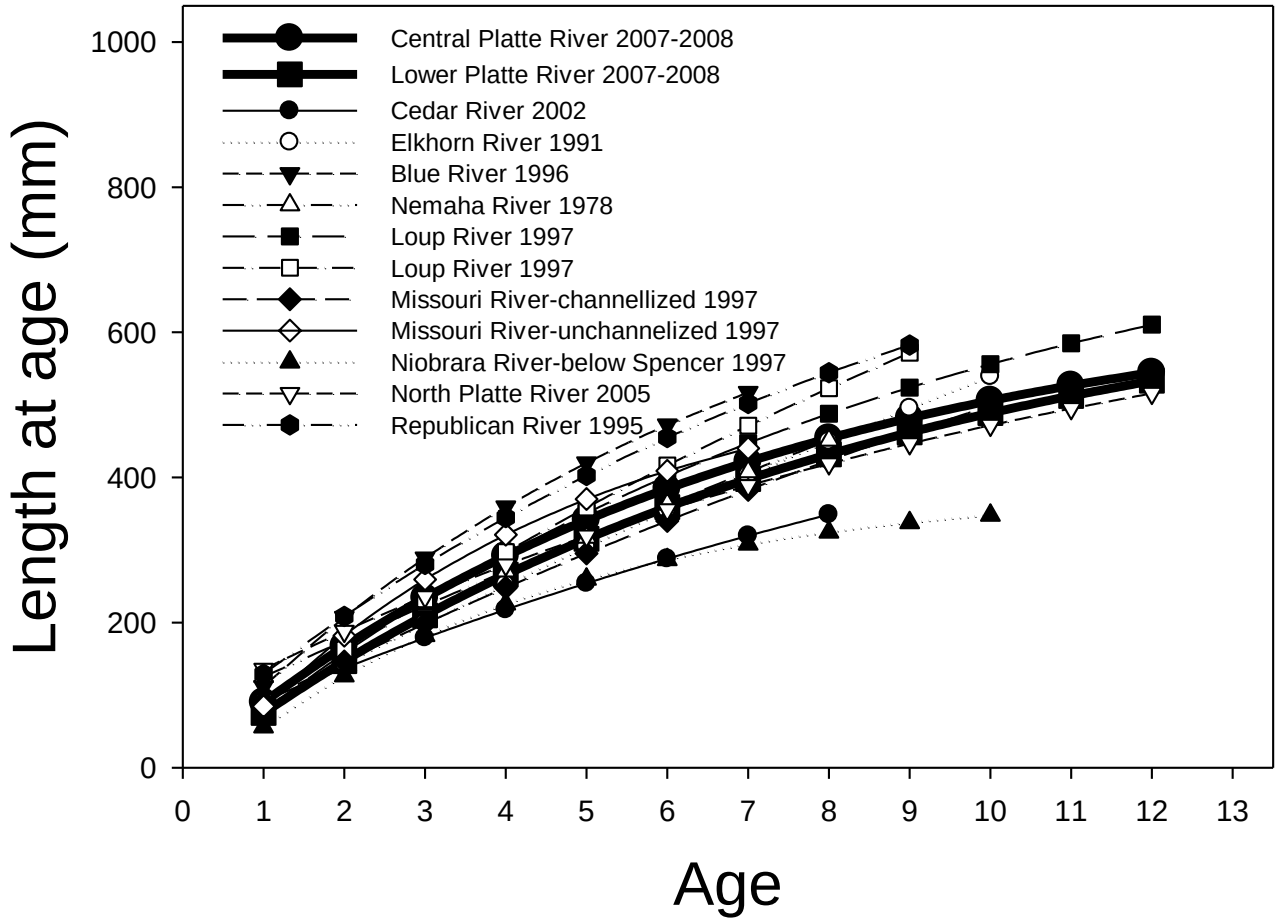

Figure 3-19. Central Platte River and lower Platte River channel catfish von Bertalanffy growth functions compared to other Nebraska rivers (data provided by Steve Schainost, Nebraska Game and Parks Commission).

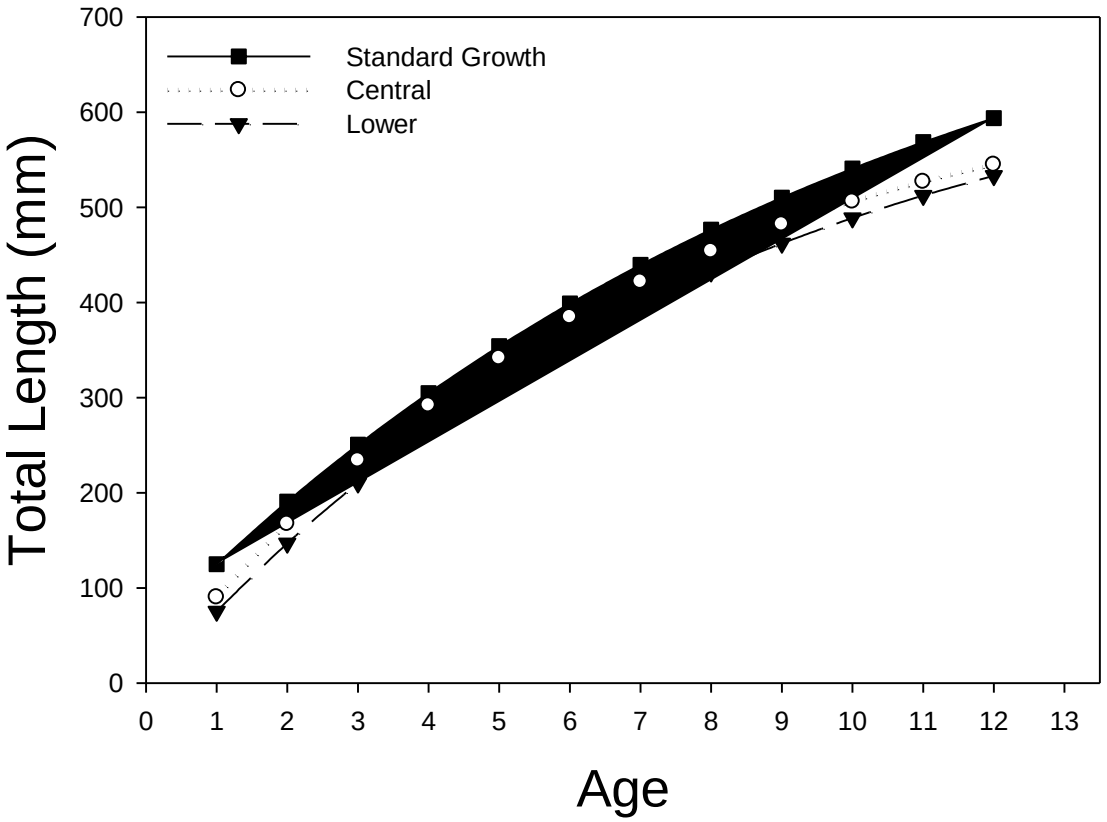

Figure 3-20. Central Platte River and lower Platte River channel catfish von Bertalanffy growth functions compared to the standard channel catfish growth function (standard von Bertalanffy growth function provided by Jackson et al. 2008).

CHAPTER 4 - FUTURE RESEARCH AND MANAGEMENT RECOMMENDATIONS

Catfish angling is popular throughout the United States, especially in the Midwest and Nebraska (Arterburn et al 2002, Hurley and Duppong Hurley 2007, USFWS 2007). Furthermore, channel catfish are the most sought after (Holland and Peters 1994) and likely the most important fish species driving the Platte River fishery. However, current research on channel catfish populations in the Platte River is lacking, resulting in minimal information to base management decisions. Therefore, my objective was to determine the current status of catfish populations in the central and lower Platte River. Specifically, I evaluated channel catfish and flathead catfish population characteristics identifying factors potentially influencing abundance, size structure, condition, growth and mortality.

The current Platte River channel catfish population appears to be comparable in demographics to many Midwestern river populations (Hesse et al. 1979a, Gerhardt and Hubert 1991, Quist and Guy 1998, Colombo 2007). However, spatial patterns in channel catfish population characteristics exist throughout the Platte River. In general, highest channel catfish relative abundances were observed in the lower Platte River but these populations exhibited smaller size structures, lower condition, slower growth and higher mortality compared to central Platte River channel catfish populations. I highlighted prey availability, habitat characteristics, flow manipulations, tributary inflows and angler exploitation, among others, as factors potentially influencing channel catfish populations along the Platte River. My findings provide new insights and sound information on

channel catfish populations in the Platte River that will guide management of this valuable resource.

Several research needs emerged through my study. Specific investigations concerning prey availability, food habits, recruitment and recreational fishing pressure would be beneficial in identifying direct factors influencing catfish populations. Additionally, studies evaluating direct effects of flow manipulations and tributaries on channel catfish populations would further our understanding of the dynamic Platte River system.

Management Recommendations

Species-specific management targeting channel catfish is minimal in Nebraska, especially in lotic systems. This trend is not uncommon throughout the United States (Michaletz and Dillard 1999). Currently, no special regulations have been implemented for channel catfish in the Platte River. Rather, catfish angling in the Platte River follows statewide regulations of no length limit and a 10-fish bag limit (NGPC 2009). Before management actions are implemented, managers must identify goals and objectives for the Platte River fishery. Depending on objectives, different management strategies will likely be adopted. With this in mind, I recommend the following management considerations:

1 – Understanding angler attitudes and expectations is vital in shaping objectives of a fishery (Barber and Taylor 1990, Knuth and McMullin 1996). Therefore, assessing these views along the Platte River should be a primary focus. Angler surveys targeting these questions would give managers an idea of what anglers are currently experiencing

and their desires for the fishery. Critical information concerning catch per unit effort and exploitation rates can also be obtained from such surveys (Malvestuto 1996). Human dimensions data combined with population assessments can provide managers with sufficient information to formulate attainable goals for the fishery.

2 – Platte River channel catfish population characteristics have been assessed at two snapshots in time, once during the early 1990's (Holland and Peters 1992a, Holland and Peters 1992b, Holland and Peters 1994) and most recently during the present study. Valuable information has been gained from these studies. However, high annual variability is a concern and may cause difficulty in identifying temporal change. Therefore, I recommend continued monitoring of catfish populations along the Platte River. Standard sampling procedures should be adopted to ensure comparability of data in order to detect change. Based on analyses of gear-specific catch rates and size structures I recommend spring sampling using 25-mm hoop nets (HN_{25}) and high-frequency pulsed DC electrofishing (EF_{60}), supplemented by angler tournament collections. Annual sampling by these methods will provide sufficient information for overall population assessment and contribute to a long term dataset. Accordingly, this information will be useful for assessing temporal change and gaining further insights on factors influencing abundance, size structure, condition, growth and mortality of catfish populations in the Platte River.

3 – Demands for limited water supplies continue to increase throughout the Platte River basin (NRC 2005, USDOI 2006). These water demands, including municipal use, irrigation, hydropower and recreation, have contributed to the highly altered flow regime the Platte River experiences today. The central Platte River often exhibits very low flows

during the summer (Sinokrot and Gulliver 2000, USGS unpublished data). Consequently, low precipitation coupled with water diversions can greatly reduce aquatic habitat in the central Platte River. The lower Platte River is also affected by water demands. My findings provide some evidence that flow manipulations, especially directly downstream of the Loup River Power Canal, may be influencing channel catfish populations in the lower Platte River. Maintaining in-stream flows is one way to diminish effects of the fluctuating flow regime in the lower Platte River and ensure suitable fish habitat in the central Platte River. However, these actions may only provide minimal mitigation. Water management aimed at representing a natural flow regime is optimal. Therefore, it is important for researchers and resource managers to contribute in the development of water-management plans that aim to protect aquatic resources in the Platte River.

4 – Channel catfish populations have displayed great interconnectivity between tributaries and main-stem rivers (Hesse et al. 1979a, Hesse et al. 1979b, Hesse et al. 1982, Dames et al. 1989, Newcomb 1989, Smith and Hubert 1989, Pellet et al. 1998, Peters et al. 1992). The Platte River has been identified as an important tributary to the Missouri River (Hesse et al. 1982, Newcomb 1989). Conversely, relatively little is known about the tributaries of the Platte River (i.e., Elkhorn River and Loup River). The Elkhorn River is likely an important component of the Platte River system as it provides a natural flow regime to the lower Platte River. Additionally, the Loup River and tributaries to the central Platte River may be important refuge areas for channel catfish and other fish species during low flow periods. Understanding the interconnectivity and the role these rivers play in the life history of Platte River channel catfish is important.

Catfish population monitoring in the Missouri River is currently being conducted (Mestl and Porter 2009) and continues to be a research priority. However, research on Platte River tributaries is limited. Collaboration between Platte River and Missouri River catfish researchers, including data analyses and identification of new information needs, could provide additional insight into the interdependence between these river systems and further identify factors influencing channel catfish population dynamics. Additionally, research focused on the Elkhorn River, Loup River, and other possibly influential tributaries (including canals) would further develop our understanding of catfish populations throughout the Platte River system.

5 – The lower Platte River has been documented to support a recreational fishery for channel catfish (Holland and Peters 1994) and current populations appear to be similar to previous studies. Conversely, little is known about fishing pressure in the central Platte River where the channel catfish population exhibits a larger size structure, higher condition and faster growth compared to the lower Platte River. Most river recreationists and individuals I spoke with during my study were surprised catfish research was being conducted in the central Platte River, mainly because they assumed no catfish inhabited this area of the river due to intermittent flows. Although catfish may be popular to anglers in this region, I believe the potential of a channel catfish fishery in the central Platte River has been overlooked. The Nebraska Game and Parks Commission (NGPC) have put forth great efforts in their plan to recruit, develop and retain anglers in Nebraska (NGPC 2008). Given the goals of NGPC and the status of Platte River catfish populations, I recommend promoting the central Platte River and lower Platte River as viable options for catfish anglers. Most catfish anglers fish from

shore (Burlingame and Guy 1999, Schramm et al. 1999, Arteburn et al. 2002) but fishing access is difficult, often limited to bridge crossings or boat ramps along the lower Platte River. Therefore, efforts should be made to acquire more public access points throughout the Platte River. Some consequences may come with promoting a fishery. I described catfish populations in the central Platte River to be relatively unexploited due to low mortality rates. However, populations in the lower Platte River experience some fishing pressure resulting in higher mortality. Consequently, increased fishing pressure throughout the Platte River may result in overexploitation of the fishery. Although overexploitation may be a concern, previous recommendations to 1) assess fishing exploitation through angler surveys and 2) continue population monitoring to evaluate temporal change, would provide managers basic information to make confident decisions for the fishery.

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APPENDIX A. EVALUATION OF TROTLINES TO CATCH CHANNEL CATFISH AND FLATHEAD CATFISH IN THE PLATTE RIVER, NEBRASKA

Introduction

Numerous sampling gears have been used to assess catfish population demographics. However, most sampling methods have some size selectivity and inherent biases (Hesse et al. 1982, Holland and Peters 1992a, Tillma et al. 1997, Gale et al. 1999, Sullivan and Gale 1999, Shoup et al. 2003, Colombo et al. 2008). Therefore, multiple gear sampling regimes are often implemented to dampen these effects (Vokoun and Rabeni 1999, Colombo et al. 2008). Hoop netting and electrofishing were methods used during previous Platte River catfish studies (Holland and Peters 1992a, Holland and Peters 1992b, Peters et al. 1992, Holland and Peters 1994). However, these methods tended to sample smaller channel catfish. Previous studies also supplemented standard methods with angler tournament data to gain information on large catfish, but this method didn't allow for spatial analysis compared to standard sampling.

Set lines and trotlines are well known to collect the largest catfish in a population (Santucci et al. 1999, Stauffer and Koenen 1999, Vokoun and Rabeni 1999, Arterburn and Berry 2002). Therefore, trotlines were incorporated into a sampling regime aiming to capture large catfish not sampled with other standard gears. Preliminary gear analysis was necessary in order to prioritize sampling effort for overall study objectives. Therefore, the objective of this analysis was to determine the relative efficiency of trotlines, specifically evaluating whether trotlines were a suitable gear to obtain and monitor catfish population dynamics in the Platte River.

Methods

Field Collections

A suite of gears were used to assess the overall catfish population in the Platte River during 2007. Standard gears included cheese-baited hoop nets, trotlines and an electrofisher. Sampling was conducted seasonally (spring, summer, fall) at ten fixed sites along the Platte River ranging from Elm Creek (river kilometer [rkm] 370) to Plattsmouth, Nebraska (rkm 1; Figure A-1). Winter assessment was not conducted due to ice flow. Adverse flows and other logistical constraints also prevented sampling intermittently throughout the year.

I used 25-mm mesh hoop nets (HN_{25}) and 38-mm mesh hoop nets (HN_{38}) in an attempt to capture different size ranges of catfish. Hoop nets were 1.3-m in length, equipped with four 0.5-m diameter fiberglass hoops with two square throats. Nylon bait bags, 3-mm mesh, were filled with scrap cheese and placed inside the cod end of the hoop nets. Hoop nets were set parallel with the river current in pools and runs along bank and in-stream habitat where available. Anchors were attached to the net and placed 1-m upstream. Anchors were also secured to the bank (i.e., tree limb, rock, etc.) to further restrict net displacement. Effort per sampling trip consisted of 10 deployments of each hoop net size deployed in the afternoon and retrieved the next morning.

Trotlines (TL) were constructed following Arterburn and Berry (2002) where 10 droppers, placed 1.2 m apart, were equipped with 3/0 O'Shaughnessy hooks. Trotlines, 13.2-m total length, were alternately baited with cutbait (i.e., gizzard shad) and live bait (i.e., native minnows). Trotlines were also set parallel with the river current in similar habitat as hoop nets (pools, runs, in-stream structure). Two anchors, one on each end of

the line, were used to restrict movement and ensure bottom contact. A 3-m long lead rope was also attached to the upstream anchor and secured to the bank. Effort per sampling trip consisted of 10 trotlines set in the afternoon and retrieved the next morning.

Electrofishing was conducted using a cataraft (River King Catarafts, Port Ludlow, Washington) equipped with a MBS-2D Wiscosnsin box (ETS Electrofisihng LLC, Madison, Wisconsin) powered by a 5500 W/240 V generator to provide pulsed-DC current. Anode poles, equipped with steel cable droppers, were attached to the front pontoons of the cataraft. A cathode array was positioned at the mid-section of the cataraft where cable droppers hung between the pontoons to contact water. High frequency pulsed-DC settings (EF_{60}; 4-8 A, 180-240 V, 60 pulses/s, 50% pulse width) were used during sampling. Electrofishing was conducted in a downstream fashion sampling bank habitat and any available in-stream structure. Shallow areas were sampled by walking and pulling the cataraft unit like a tote barge electrofisher, while two netters walked alongside the electrode droppers capturing fish. The cataraft was used similar to a boat electrofisher in non-wadeable sections of the river where the operator controlled the cataraft from within using a tiller motor and individuals netted fish from the bow of the vessel. A minimal amount of high frequency pulsed-DC electrofishing was conducted due to equipment failures and time constraints.

Information from area fishing club tournaments was also collected to supplement standard sampling. Angler tournaments provided an excellent opportunity to gain valuable information about the fishery from the viewpoint of local anglers and allowed collection of quality information from harvested fish. Tournaments also allowed data collection on fish size ranges not commonly captured with standard sampling. The

Fremont Airboat Club hosts a catfish outing each spring over Memorial Day weekend where anglers use setlines to capture catfish. Angler tournament setlines (SL) generally had 1-2 hooks baited with live fathead minnows and were fished overnight.

Data analyses

I compared catch data for each gear analyzing size structure and relative gear efficiency. Population size structure was compared between gears using Proportional Size Distribution indices (PSD; Anderson and Neumann 1996, Guy et al. 2007), based on length categories (stock, 280-mm; quality, 410-mm; preferred 610-mm; memorable, 710-mm; trophy, 910-mm) described by Gabelhouse (1984). Proportional Size Distribution was calculated as:

$$\text{PSD} = \frac{\#\,\text{fish} \geq \text{minimum quality length}}{\#\,\text{fish} \geq \text{minimum stock length}} * 100$$

Additional Proportional Size Distribution indices (i.e., PSD-P) were calculated as:

$$\text{PSD-P} = \frac{\#\,\text{fish} \geq \text{minimum preferred length}}{\#\,\text{fish} \geq \text{minimum stock length}} * 100$$

Differences in size structure indices were statistically analyzed using chi-square (χ^2) tests and differences in length-frequency distributions were compared using Kolmogorov-Smirnov (KS) nonparametric tests (Neumann and Allen 2007). A Bonferonni correction for the P-values was applied for multiple comparisons to adjust for experimentwise error rate (i.e., $\alpha = 0.05/3 = 0.017$ for three comparisons).

Relative gear efficiencies were compared using gear-specific catch rates in terms of catch per unit effort (CPUE) and catch per personnel time (CPPT). Proportion of sets that captured zero catfish was also used to evaluate relative gear efficiency. Only HN_{25},

HN_{38} and TL data were used for relative gear efficiency analysis due to incomparable units and lack of effort for other methods. Hoop nets and trotlines were fished overnight; therefore CPUE was calculated as fish/net-night or fish/trotline-night. Exact processing time for each sampling gear was not documented. Therefore, personnel time was estimated for each gear by subtracting time between gear deployments and CPPT was calculated as fish/minute. Catch data were $\log_{10}$ (CPUE + 1) transformed to meet normality assumptions for parametric tests and gear catch rates were compared using a one-way analysis of variance (ANOVA). Multiple comparisons were made using Tukey's studentized range (HSD) test when ANOVA results were significant. Statistical analyses were conducted using SAS (SAS Institute 2004) where significance was determined at $\alpha = 0.05$.

Results

A total of 541 gear deployments were made during the 2007 sampling season. Most sampling was conducted with TL (N = 173), HN_{25} (N = 169) and HN_{38} (N = 165). However, only 32 electrofishing runs were conducted during 2007.

A total of 594 channel catfish ranging from 53 to 970-mm were collected during 2007. Mean length of channel catfish was 290-mm. Only 22 flathead catfish were collected ranging from 66 to 579-mm with a mean length of 374-mm. Size distribution and gear efficiency analysis focused on channel catfish due to low catches of flathead catfish.

Most channel catfish were captured using HN_{25} (N=371). Fish collected with HN_{25} ranged from 80 to 570-mm with a mean length of 272-mm. However, the majority

(68%) of catfish sampled with HN_{25} fell within a narrow size range (200-300-mm; Figure A-2). Fewer channel catfish were collected with HN_{38} (N=85) with a mean length of 295-m. However, HN_{38} collected a very similar size range of channel catfish (72-586-mm) compared to HN_{25} (Figure A-2). Channel catfish collected by EF_{60} had the smallest mean length (191-mm) but provided the widest size range (53-709-mm; Figure A-2). Only 21 channel catfish were captured using TL, but collections consisted of larger individuals (mean length = 413-mm). However, the size range of fish collected by TL was very narrow (267-567-mm) and the largest fish were not collected by this method (Figure A-2). Angler tournament set lines (SL) also collected large channel catfish (mean length = 554-mm) with sizes ranging from 316 to 970-mm (Figure A-2).

Kolmogorov-Smirnov test results indicate all gears sampled different size distributions of channel catfish ($P < 0.01$). However, similar and overlapping size ranges were documented for different gear types. Size structure indices also varied by gear type as PSD ranged from 13-88 with a PSD of 36 using all gears (Table A-1). The highest PSD was observed for SL and was greater compared to all other gears ($P < 0.01$). However, EF_{60} and HN_{38} had similar PSD values ($P = 0.75$) but were higher compared to HN_{25} ($P < 0.01$). The only standard sampling method to capture preferred size channel catfish was EF_{60}. However, preferred, memorable and trophy size channel catfish were collected using SL (Table A-1).

Overall, HN_{25} had the highest catch rates with a mean CPUE of 2.46 fish/net-night (Figure A-3). Conversely, TL catch rates were significantly lower compared to HN_{25} and HN_{38} ($P < 0.05$). Personnel time also differed between gears as TL took almost twice as long to setup, bait and run compared to HN_{25} and HN_{38} (Figure A-4). Low catch

rates coupled with greater personnel time resulted in extremely low CPPT for trotlines (Figure A-5). Furthermore, CPPT was 30 times greater for HN_{25} and 8 times greater for HN_{38} compared to TL.

A considerable amount of gear deployments captured zero channel catfish. Trotlines had the highest percentage of sets capturing zero catfish (88%). However, hoop nets were more likely to catch at least one channel catfish with 71% of HN_{38} and 55% of HN_{25} sets resulting in zero catches.

Discussion

Most catfish studies incorporate multiple sampling methods to lessen individual gear bias and size selectivity effects (Vokoun and Rabeni 1999, Santucci et al. 1999, Brown 2007, Colombo et al. 2008). Biases and selectivity of common catfish sampling methods were observed during my study. Differences in size ranges, size distributions, size structure indices and relative efficiencies (i.e., CPUE, CPPT) were observed between gears.

All sampling methods captured different size distributions of channel catfish. However, size ranges of fish captured with multiple gears overlapped one another. The size range of catfish captured by TL (267-567-mm) fell within all other standard sampling gear size ranges and SL provided most information on large catfish.

Size distributions were compared using length-frequency histograms and size structure indices. However, sample sizes were not always sufficient for each sampling gear. Vokoun et al. (2001) suggest the use of 300-400 individuals when constructing length-frequency histograms while 375-1,200 fish were suggested by Miranda (2007).

Minimum sample sizes have also been suggested for PSD comparisons. Recommended sample sizes range from 100 (Anderson and Neumann 1996) to 408 stock-sized fish depending on analyses (Miranda 1993). Most sampling gears used during 2007 failed to collect specified sample sizes. However, some sampling gears collected fish numbers closer to recommendations than others. The number of catfish captured by trotlines (N=21) was extremely low when compared to suggested sample sizes. Consequently, precision of size structure and size distribution assessments of TL captured fish may be low and comparisons can only be made with little confidence.

Trotlines had the lowest relative gear efficiencies based on CPUE and CPPT analyses. Furthermore, CPPT for TL was 30 times lower compared to HN_{25} and nearly 90% of TL deployments captured zero channel catfish. This indicates an incredible amount of effort was put forth with very little return.

Evidence suggests that trotlines have not provided sufficient numbers of fish for statistical analysis. Overall evaluations of size distribution, size structure and relative gear efficiency have very little power with such low sample sizes. Longitudinal comparisons (i.e. site, river reach) are impractical due to sample sizes as low as one or two fish per site. Trotlines required a tremendous amount of time and effort but little information was gained from this method compared to other standard gears. Therefore, trotlines were eliminated as a standard sampling gear during 2008.

Eliminating TL provided time for additional sampling with standard gears and assessment of other research questions. Previously, sampling gear time requirements only allowed for gear deployment and retrieval on separate days. Eliminating TL allowed for gear retrieval and deployment on the same day, saving a considerable amount

of time. Consequently, extra time allowed for additional electrofishing, including low frequency pulsed-DC electrofishing (EF_{15}), and more effort focusing on gear evaluation experiments (Appendix C).

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Table A-1. Size structure indices, including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P), memorable (PSD-M) and trophy (PSD-T) channel catfish collected with 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}), trotlines (TL), high frequency pulsed-DC electrofishing (EF_{60}) and setlines (SL) in the Platte River during 2007.

Gear	N	% stock	PSD	PSD-P	PSD-M	PSD-T
HN_{25}	371	38	13	0	0	0
HN_{38}	85	51	51	0	0	0
TL	21	95	50	0	0	0
EF_{60}	75	17	46	31	0	0
SL	42	100	88	21	7	2
ALL	594	48	36	5	1	0

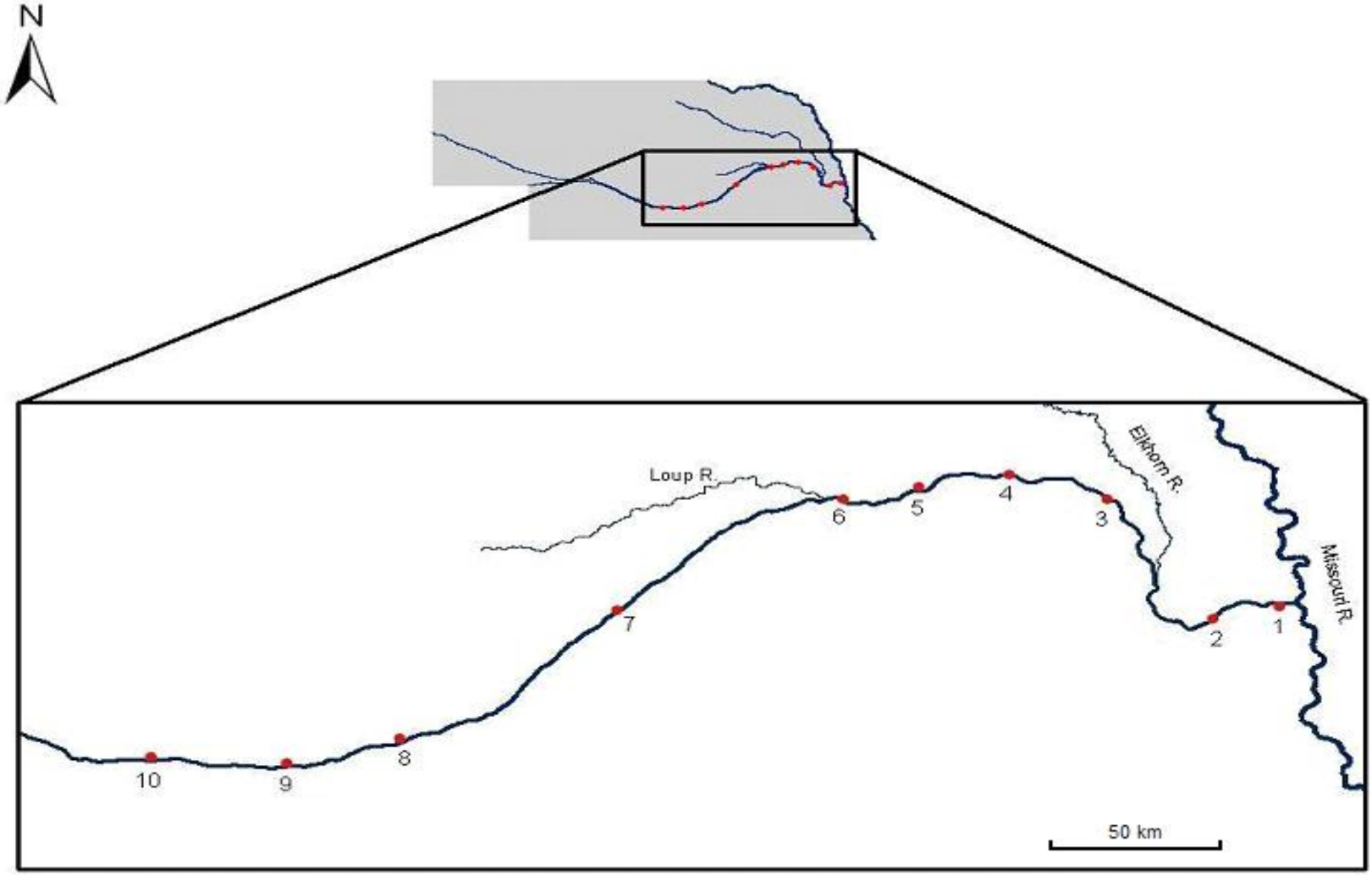

Figure A-1. Study area including sampling locations in the central (Sites 7-10) and lower (Site 1-6) Platte River, Nebraska.

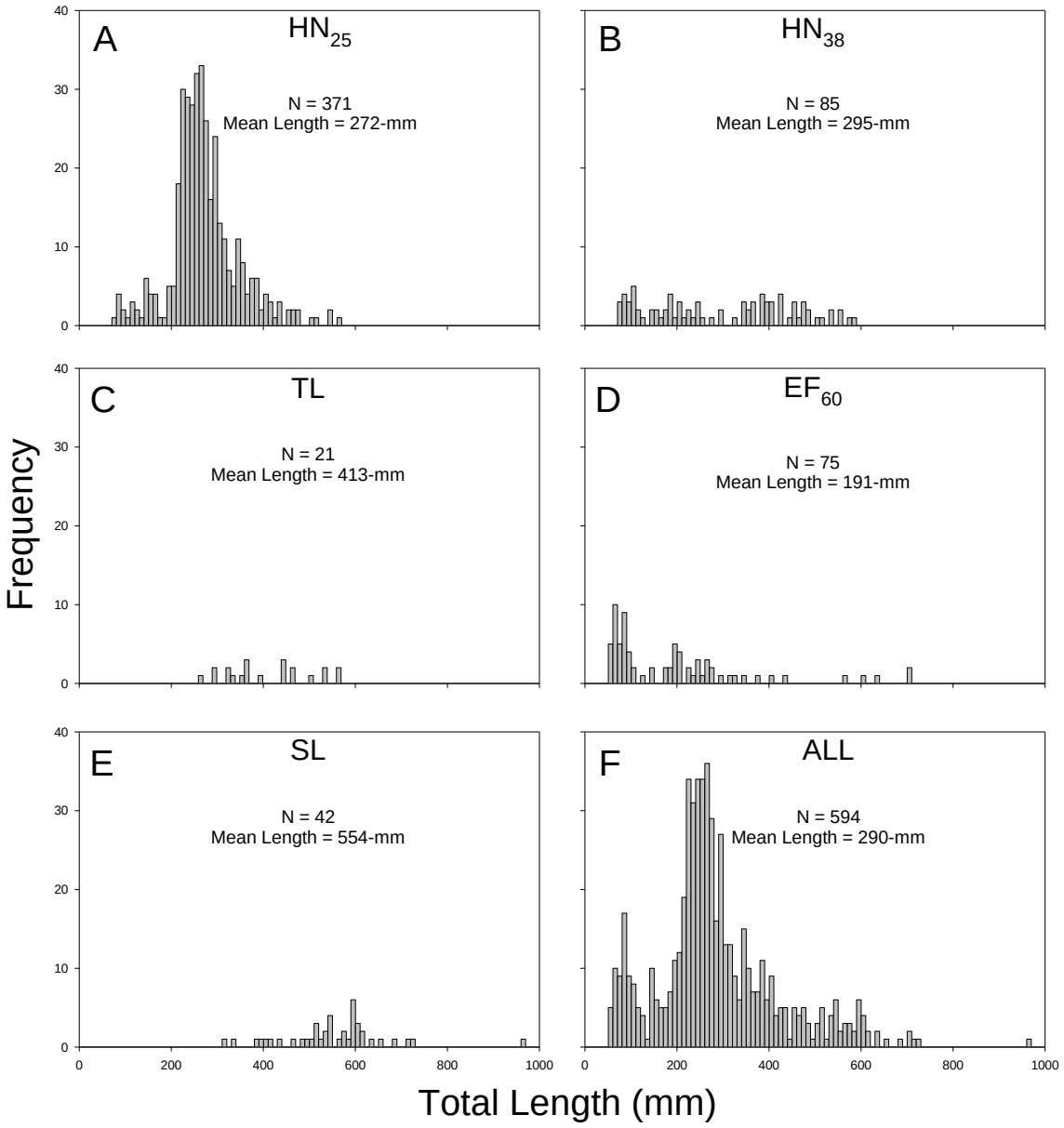

Figure A-2. Length-frequency distributions of channel catfish collected with 25-mm hoop nets (HN_{25}; A), 38-mm hoop nets (HN_{38}; B), trotlines (TL; C), high frequency pulsed-DC electrofishing (EF_{60}; D), angler tournament set lines (SL; E) and all gears combined (ALL; F) in the Platte River during 2007.

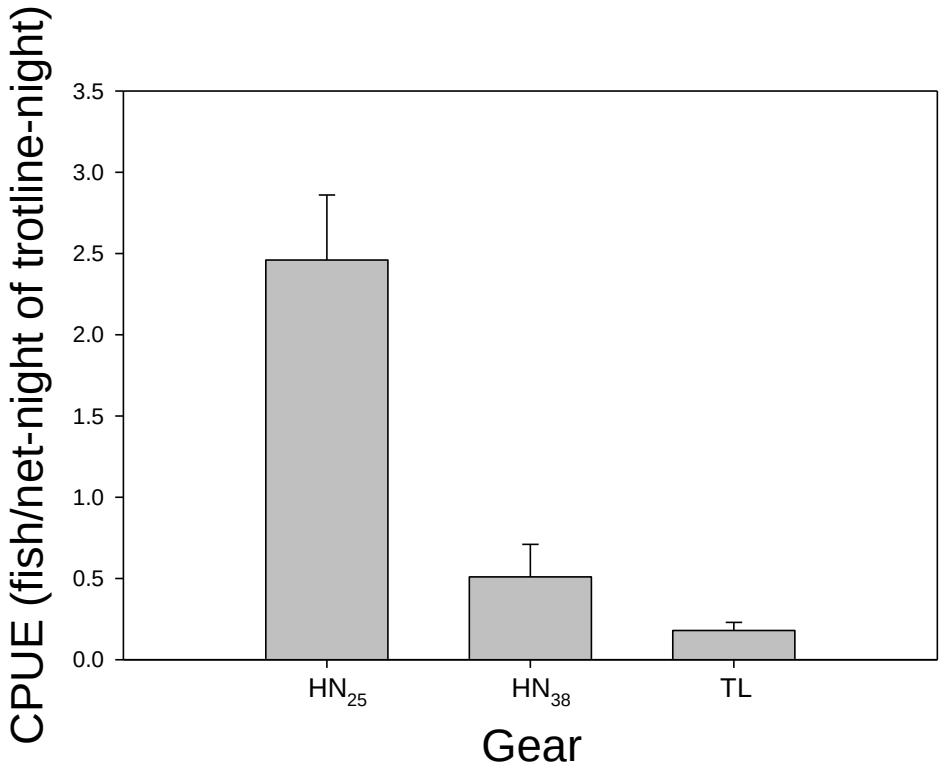

Figure A-3. Mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}) and trotlines (TL) in the Platte River during 2007.

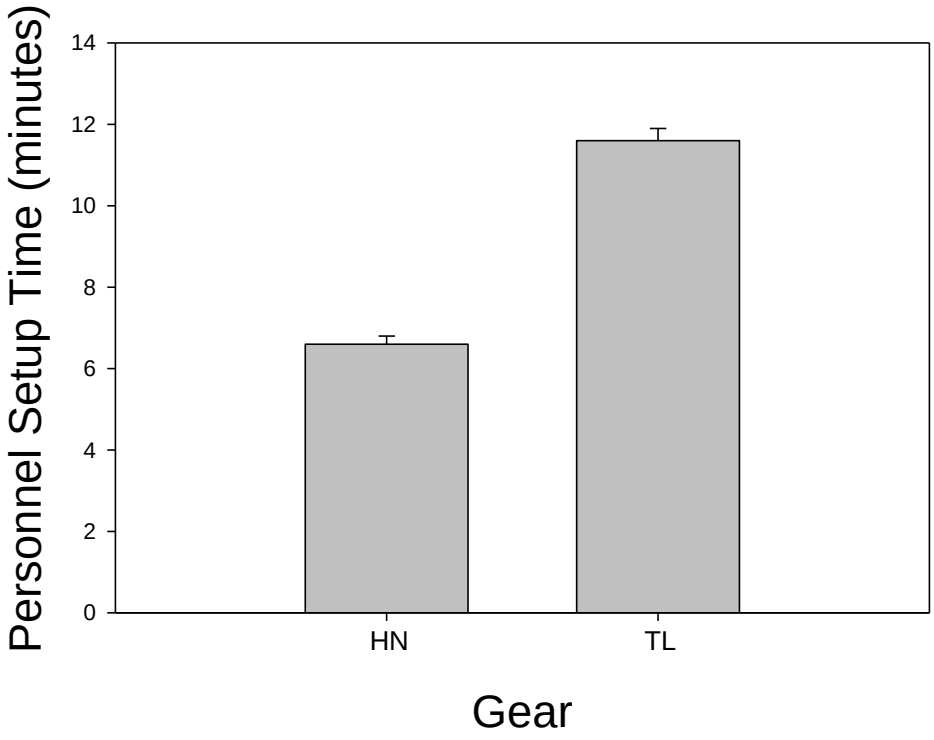

Figure A-4. Mean personnel setup time for hoop nets (HN) and trotlines (TL) deployed in the Platte River during 2007.

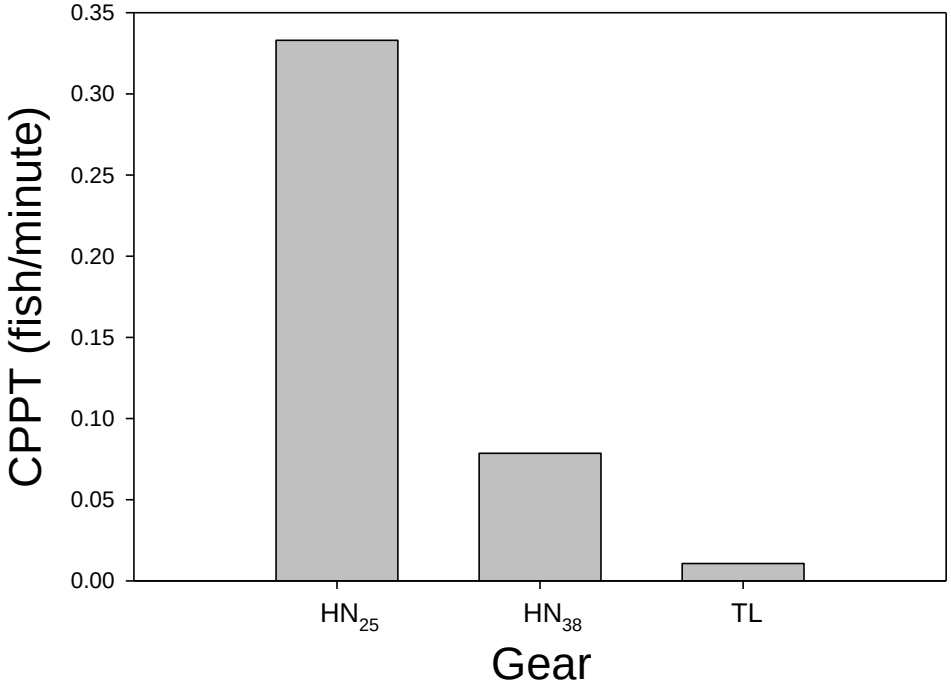

Figure A-5. Catch per personnel time (CPPT) of channel catfish collected with 25-mm hoop nets (HN_{25}), 38-mm hoop nets (HN_{38}) and trotlines (TL) in the Platte River during 2007.

APPENDIX B. ENCLOSURE EXPERIMENTS TO EVALUATE CATFISH GEAR EFFICIENCY IN A LOTIC SYSTEM

Introduction

Catfish angling is popular throughout North America (Arterburn et al. 2002, USFWS 2007). However, most resource agencies do not intensively manage catfish populations (Michaletz and Dillard 1999). Collecting sound information regarding population characteristics precludes implementing intensive management plans for a fishery. A major reason for minimal management of catfish populations is the concern surrounding unknown bias and selectivity of common catfish sampling techniques (Michaletz and Dillard 1999, Brown 2007).

Numerous methods have been used to sample catfishes throughout their range. Different strategies, gears and methods are often required to fulfill specific information needs. Therefore, evaluating fishing gears and their bias is an important aspect of population assessments for fisheries managers. Comparisons of relative efficiencies between catfish sampling gears have helped researchers refine what methods work best to achieve certain management goals (Jacobs and Swink 1982, Johnson 1987, Perry and Williams 1987, Bonar et al. 1995, Pugh and Schramm 1998, Santucci et al. 1999, Stauffer and Koenen 1999, Sullivan and Gale 1999, Vokoun and Rabeni 1999), but there remains a large gap in validating the accuracy and precision of these gears (Brown 2007).

Studies have documented size selectivity of numerous catfish sampling gears (Hesse et al. 1982a, Holland and Peters 1992, Tillma et al. 1997, Gale et al. 1999, Sullivan and Gale 1999, Shoup et al. 2003, Colombo et al. 2008). Additionally, season (Gerhardt and Hubert 1989), bait (Pierce et al. 1981, Perry and Williams 1987, Arterburn

and Berry 2002), water temperature (Quinn 1986, Justus 1994, Grussing et al. 1999) and habitat characteristics (Arterburn and Berry 2002) have been documented to affect relative gear efficiencies. However, true evaluation of gear efficiencies and size bias with known population information, especially in lotic systems, has not been performed. Most gear comparison studies only compare relative abundance estimates among gears rather than evaluating inherent collection biases associated with each gear. Not knowing the catch biases associated with gears precludes making conclusions that variability in catch is due to factors including year-class strength, environmental responses or management actions. Specific information on the precision and accuracy of sampling efforts is often in question, leading to statements in the literature that continually propose the need for new research on gear efficiency characteristics (Michaletz and Dillard 1999, Brown 2007, Colombo et al. 2008). Therefore, the objective of my study was to assess gear bias and selectivity of commonly used catfish collection techniques, specifically evaluating hoop net and electrofishing efficiencies in a lotic system.

Methods

Study Area

A side channel of the lower Platte River, near Leshara, NE, was identified as a prime location for experiments due to accessibility, habitat representation, and ability to hold block nets effectively (Figure B-1). Therefore, enclosures were constructed by placing large block nets at each end of the side channel. Block nets, mesh size 25-mm, equipped with chain leadline were secured to the bank and substrate using 2.4-m steel fence posts. Multiple enclosures were constructed during the study ranging from 2.6-5.1

hectares (ha). Block nets were subject to siltation and frequently filled with debris; therefore a significant amount of time and effort was expended on daily net maintenance.

Experiment Collections

Gear evaluation experiments were conducted during a 2 week low-flow period in August, 2008. Channel catfish were collected from nearby areas of the Platte River using high frequency pulsed-DC electrofishing (EF_{60}) and rod and reel (RR) angling. All captured catfish were measured for total length (TL; mm) and mass (g). Each catfish was also marked, using a unique fin clip for each experiment, and distributed evenly throughout the enclosure at one of three locations (upstream reach, middle reach, and downstream reach). Fish were allowed to acclimate as the blocked area was left undisturbed for 24 hours after experimental fish release. Following the acclimation period, 25-mm hoop nets (HN_{25}) and 38-mm hoop nets (HN_{38}) were alternately deployed in available habitat (~ 50-m spacing) within the enclosure. Hoop nets (collectively; HN) were deployed in the afternoon and retrieved the next morning. Immediately following HN retrieval, EF_{60} runs were conducted throughout the entire enclosure. All fish captured by HN_{25}, HN_{38} and EF_{60} were measured for TL and mass and examined for fin clip presence (recaptured fish) or absence (new fish).

Data Analyses

Length-frequency histograms were constructed for experimental catfish (known population). Additionally, separate length-frequency histograms were constructed for recaptured catfish populations from HN and EF_{60} collections. Summary data (i.e., mean

length, median length) were also calculated for experimental and recaptured fish. Data analysis was limited due to low recapture rates. Kolmogorov-Smirnov (KS) tests were performed to analyze length-frequency distribution similarities between recaptured and experimental fish populations. Gear efficiencies were also calculated as a percent of fish recaptured from the experimental fish population.

Results

Three trials were conducted using different enclosure sizes and experimental fish populations. New fish were captured for each trial; therefore, experimental channel catfish were only used once per trial. A total of 62 experimental channel catfish were released in a 5.1 ha enclosure for the 1st trial (12.2 fish/ha). No experimental fish were recaptured during HN or EF_{60} collections within the enclosure. However, 27 new channel catfish were captured during sampling efforts. Block nets were moved to decrease enclosure size for the 2nd trial. A total of 121 experimental channel catfish were placed in the 3.5 ha enclosure for Trial # 2 (35 fish/ha). Again, no experimental fish were recaptured during HN or EF_{60} sampling efforts. A total of 13 new catfish were captured during this trial. Block nets were moved again to further reduce enclosure size for the 3rd trial.

Trial # 3 finally yielded marginal results. Therefore, more details are provided for the experiment. The 2.6 hectare enclosure used during trial # 3 was stocked with 146 experimental channel catfish (56 fish/ha). Experimental catfish mean length was 245-mm and ranged from 112 to 546-mm (Figure B-2). Hoop nets recaptured six catfish (4%) with a range of 157-520-mm and mean length of 333-mm (Figure B-2). Electrofishing

runs recaptured five catfish (3%) ranging from 140 to 284-mm with a mean length of 218-mm (Figure B-2). Results of KS tests indicate length-frequency distributions from HN and EF_{60} recaptured fish were different than the experimental population ($P < 0.01$).

Discussion

I observed very low capture efficiencies for HN (4%) and EF_{60} (3%) used in a lotic system with known populations of catfish. No studies have attempted to quantify true gear efficiencies in lotic systems, therefore comparisons are virtually nonexistent. However, these efficiencies are higher compared to trotlines, slat traps, gill nets, electrofishing and angler catch (< 1.2 %) evaluated in a small Illinois Lake with known channel catfish populations (Santucci et al. 1999). Extremely low capture efficiencies suggest increased sampling effort may be needed to collect sufficient numbers of fish for population assessment.

It appears HN collect larger channel catfish compared to the known population and EF_{60} selects for smaller catfish. Although no evaluations of gear size selectivity have been validated for lotic systems my findings contradict numerous studies evaluating relative selectivity. Colombo et al. (2008) found AC electrofishing to sample larger channel catfish compared to 25-mm hoop nets in a Midwestern river. Additionally, Nelson and Little (1986) documented smaller catfish in hoop net collections compared to electrofishing. However, my results were similar to Vokoun and Rabeni (2001) who found electrofishing to collect smaller channel catfish compared to hoop nets and bank poles. My conclusions were made from few recaptured fish. Therefore, caution should be taken when interpreting the results of this study.

Enclosure size and experimental fish population appear to influence recapture rates. Therefore, experimental fish densities may have been too low to obtain sufficient recaptures for analysis. Very few catfish population estimates have been made for lotic systems. However, Hesse et al. (1982b) estimated channel catfish populations for reaches of the unchannelized Missouri River and Niobrara River ranging from 356 to 1,015 fish/km. I further extrapolated these numbers to estimate fish density by area using rough estimates of channel width, resulting in densities of 14 to 20 catfish/ha. These estimates are comparable to fish densities used during experimental trials of this study. Additionally, Haxton and Punt (2004) estimated channel catfish abundances in the Ottawa River ranging from 8.2 to 31.7 fish/ha. These findings indicate fish densities used during enclosure experiments were comparable to other rivers and were likely adequate for experimental analysis in the Platte River

Conducting experiments in a natural environment proved to be very difficult and it is obvious why similar investigations have not been conducted. Although analysis was limited due to low recapture rates, new insights were obtained to facilitate future investigations. I recommend taking the opposite approach compared to my study, starting with a small enclosure with high fish densities. Additionally, organizing collaborative efforts involving abundant manpower would greatly increase chances for success. Quantifying gear efficiencies in lotic systems can be done. I am optimistic this is the first step in obtaining this valuable information that has been forever elusive to fisheries managers.

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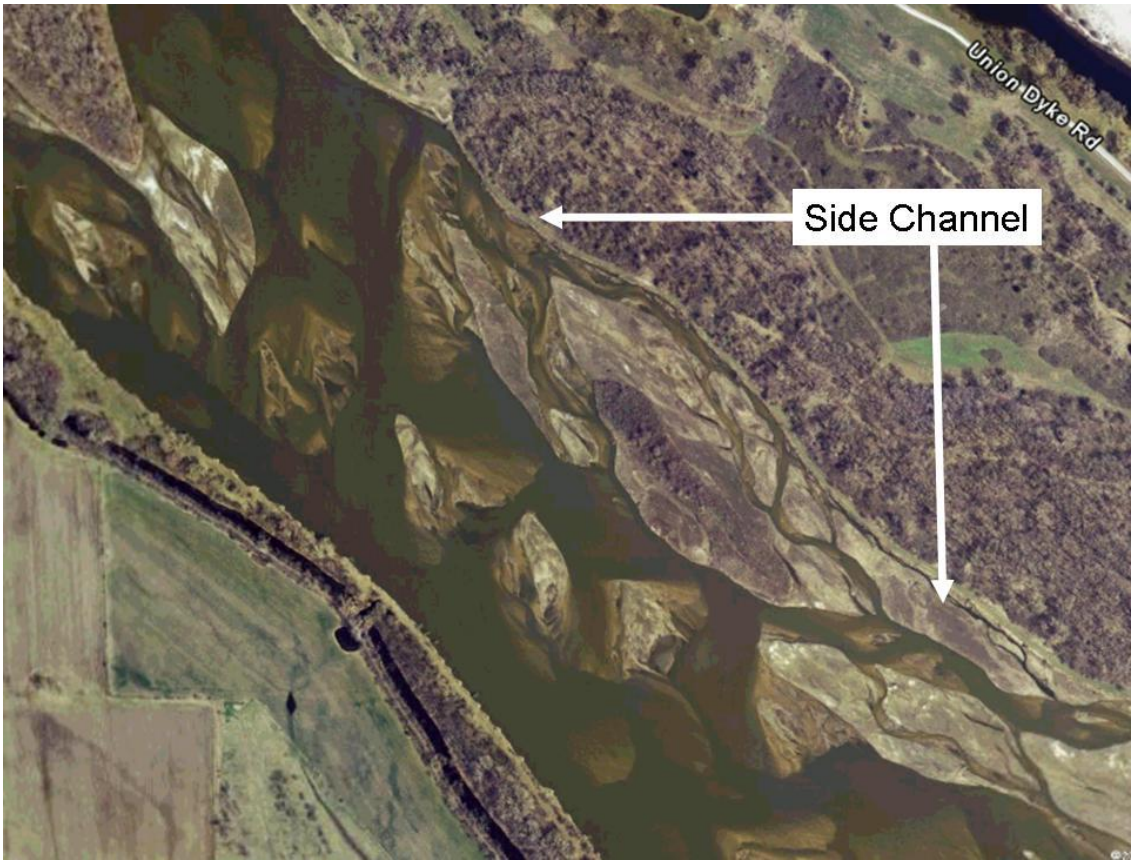

Figure B-1. Side channel of the lower Platte River used for enclosure experiments during 2008.

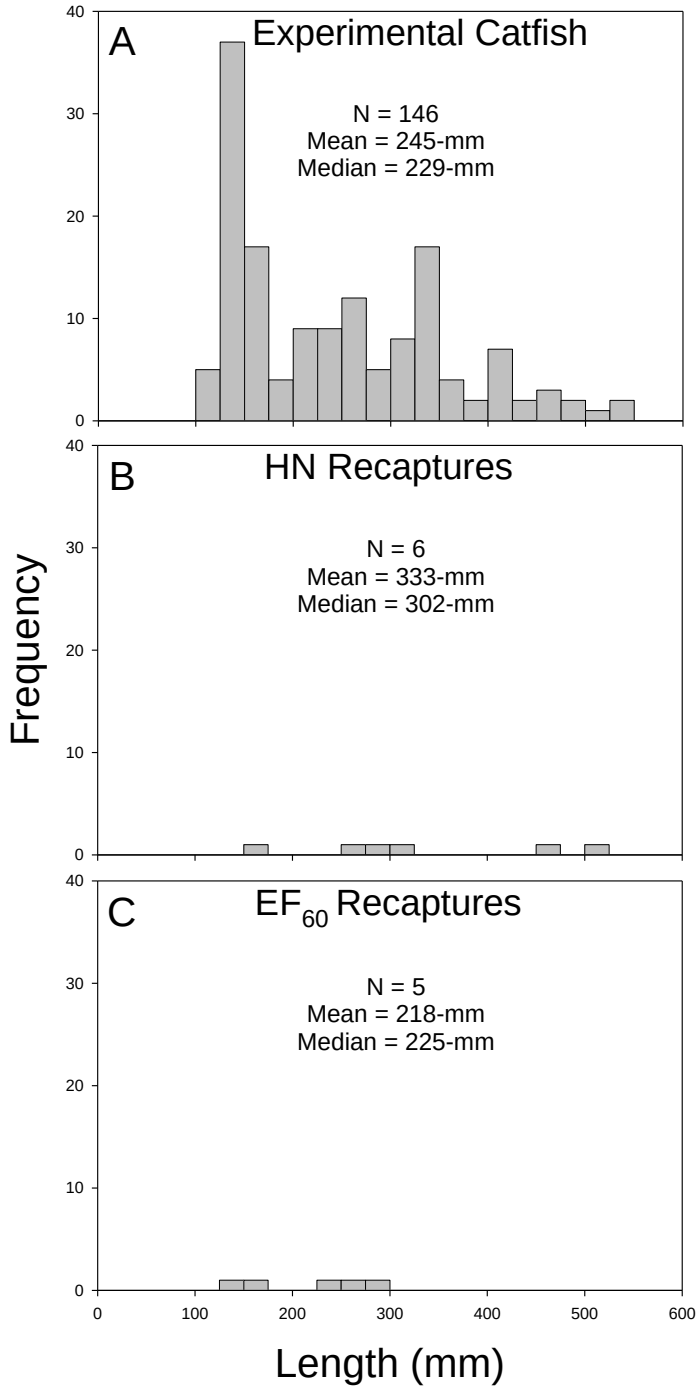

Figure B-2. Length-frequency distributions of experimental (A), hoop net (HN) recaptured (B) and high frequency pulsed-DC electrofishing (EF_{60}) recaptured (C) channel catfish from enclosure experiments in a Platte River side channel during 2008.

APPENDIX C. BIAS AND PRECISION OF OTOLITHS AND PECTORAL SPINES USED FOR CHANNEL CATFISH AGE ESTIMATION

Introduction

Age data are often used to estimate growth characteristics, age distribution and mortality of fish populations (Devries and Frie 1996). Therefore, accurate age estimates are essential when assessing fish population dynamics to guide resource management. Numerous hard parts have historically been used to determine catfish ages including vertebrae (Appelgat and Smith 1951, Marzolf 1955), dorsal fin spines (Layher 1981), pectoral fin spines (Mayhew 1969, Prentice and Whiteside 1975, Holland and Peters 1992, Shephard and Jackson 2006) and otoliths (Crumpton et al. 1987, Nash and Irwin 1999, Buckmeier et al. 2002). Pectoral fin spines and otoliths appear to be structures most commonly utilized today. Otolith removal requires fish to be euthanized. However, pectoral spine removal causes little if any mortality (Stevenson and Day 1987, Michaletz 2005) and is preferred when euthanizing fish is undesirable.

Evaluating different age estimation techniques is important to ensure accuracy and precision of specific age structures. However, few channel catfish age structure investigations have been conducted and results from these studies are conflicting. Prentice and Whiteside (1975) validated basal recess (BR) pectoral spine cross-sections for age-1 to age-4 channel catfish, observing no trends in under- or over-aging compared to known-age fish. Crumpton et al. (1987) compared age estimates from otoliths to BR, midspine (MS) and articulating process (AP) pectoral spine cross-sections. Results indicated identical age estimates among all spine sections (age-2 to age-7). However, otoliths were deemed unacceptable for channel catfish age estimation. More recently,

Buckmeier et al. (2002) used known age (age-1 to age-4) channel catfish to measure accuracy and validate age estimations for pectoral spines and otoliths. They found pectoral spine (AP sections and a new 'cut spine' method) age estimates were more variable and tended to over-estimate fish ages compared to otoliths. Ultimately, otoliths were recommended for channel catfish age estimation because of their accuracy and low variability (Buckmeier et al. 2002).

Valuable information has been gained from these channel catfish structure comparisons. However, contrasting results from individual studies have complicated overall conclusions. Additionally, all studies have been narrow in nature, being conducted in southern latitudes, using young fish (age-1 to age-7) collected from lentic habitats. Little is known about the accuracy and precision of hard-part age estimates obtained from channel catfish in more northerly lotic environments. Addressing issues concerning aging structures is beneficial to fisheries managers aiming to collect sound population dynamics information. Therefore, my objective was to evaluate common hard structures used for channel catfish age estimation, specifically estimating reader bias and precision of pectoral spines and otoliths from riverine channel catfish populations.

Methods

Field Collections

Channel catfish were collected using hoop nets, electrofishing and trotlines in the Platte River, Nebraska during 2007 and 2008. All captured catfish were measured for total length (TL; mm) and mass (g). Pectoral spines were removed from a subsample of channel catfish for age and growth analysis. Additional fish were collected from angler

tournaments. Angler caught catfish were measured for TL and mass at the angler check-in and tagged with individually numbered floy tags (Floy Tag Inc., Seattle, Washington) before being cleaned by fisherman. Heads (floy tags intact) of filleted catfish were then kept on ice and transported back to the laboratory for spine and otolith extraction.

Laboratory Preparation

Pectoral spines used for age determination were cleaned and dried in the lab before sectioning. Spines were prepared using methods from Koch and Quist (2007) where the spine was embedded in epoxy to reduce damage and facilitate manipulation during sectioning. Three to four cross-sections, 0.7-mm thick, were cut at the distal end of the basal process of each spine (Sneed 1951, Crumpton et al. 1987) using a Buehler IsoMet low-speed saw (Buehler Inc., Lake Bluff, Illinois). Cross-sections were mounted on glass slides using Cytoseal mounting medium (Richard-Allan Scientific, Kalamazoo, Michigan) and photographed using a high resolution digital camera. Digital images were then imported into image analysis software (FishBC, Doll and Lauer 2008) for manual aging. All fish were aged independently by the same two readers throughout the study. Disagreements in age estimates were resolved with a concert reading.

Otoliths were processed following methods from Buckmeier et al. (2002). Otoliths were first browned on a hot plate to increase readablility of annular marks. Otoliths were then mounted on microscope slides using Crystalbond adhesive (Buehler Inc., Lake Bluff, Illinois) with the rounded anterior edge upright and the pointed posterior edge in contact with the slide. Wetted sand paper (400-grit) was used to grind 1/3-1/2 of the mounted otoliths to reveal the nucleus. Finer sandpaper (600-grit) was then used to

polish the otolith surface further enhancing annuli appearance. Polished otoliths were examined under a dissecting microscope using side illumination. Fish ages were assigned similar to pectoral spine readings as all fish were aged independently by the same two readers throughout the study. Disagreements were resolved with a concert reading.

Data Analyses

Between-reader (Reader 1 vs. Reader 2) and between-structure (pectoral spine vs. otolith) precision and bias were analyzed. Individual reader ages were used for between-reader analysis; whereas, reader consensus ages were used for between-structure comparisons. The presence of bias confounds the interpretation of most measures of precision (Campana et al. 1995). Therefore, analyses initially addressed the possibility of systematic differences. Scatter plots were first constructed and simple linear regression analysis was used to identify relative under- and/or over-estimation. Visual observations of these plots do not always typify the amount of bias present because coincident points are not shown. Additionally, age-estimation bias does not always follow a linear pattern. Therefore, I also constructed age-bias plots with 95% confidence intervals to further analyze systematic differences. Age-bias plots are more sensitive to nonlinear bias across all age-classes (Campana et al. 1995). Age-bias plots depict the mean age assigned by one reader for all fish assigned a given age by a second reader (Stolarski and Hartman 2008). Therefore, specific age-class bias can be indicated by visual observations of plot deviance from a 1:1 equivalence line. Percent exact agreement (PA-0), percent agreement within 1 year (PA-1) and percent agreement within 2 years (PA-2) were used

to measure precision for between-reader and between-structure comparisons. All otoliths were aged over the same time period. However, pectoral spines were aged after each year of collection (i.e., 2007, 2008). Readers had some experience aging fish species using different hard parts. However, neither reader had experience aging channel catfish using pectoral spines. Therefore, I also analyzed pectoral spine precision and bias in terms of reader experience by year.

Results

A total of 2,234 channel catfish age structures were collected and aged during 2007 and 2008. The majority of structures used for age estimations were pectoral spines (N = 1,932). However, sufficient numbers of channel catfish otoliths (N = 302) were obtained from angler tournament catches (Table C-1). Paired samples of pectoral spines and otoliths were collected from 279 channel catfish for age structure comparisons. Estimated channel catfish ages ranged from age-0 to age-14.

Observations of scatter plot regressions indicate some between-reader bias for 2007 pectoral spine aged channel catfish (Figure C-1). However, little bias was observed for 2008 samples. Additionally, channel catfish aged with otoliths appear to display no age-estimation bias with a regression slope very close to 1 (b = 0.993; Figure C-1). Age-bias plots further indicate between-reader bias for 2007 aged pectoral spines where Reader 2 slightly under-estimated age-3 and older fish relative to the estimates of Reader 1 (Figure C-2). Further observations of age-bias plots indicate less reader bias for 2008 pectoral spines and almost no bias for otolith age-estimations (Figure C-2). Exact percent agreement (P-0) between readers was much lower for pectoral spines aged during 2007

(46%) compared to 2008 (67%). However, improved reader precision for 2008 pectoral spines was still considerably lower compared to otoliths (85%). Percent agreement within 1 year (PA-1) was greater than 90% for each structure during both years (Table C-1). Additionally, all otolith age estimations were within 2 years (PA-2 = 100%).

Bias between pectoral spines and otoliths was observed from scatter plot regressions (Figure C-3). It appears pectoral spines consistently under-age channel catfish relative to otolith age estimates. Observations of age-bias plots reveal between-structure bias for specific age-classes of channel catfish (Figure C-3). Pectoral spine and otolith age estimates are similar for age-4 and age-5 channel catfish. However, pectoral spines over-estimate fish age-3 and under-estimate age-6 and older fish in relation to otolith age estimates. It is important to note that only slight under-estimations are observed for age-6 to age-10 channel catfish with much greater bias for age-11 and older fish. Between-structure precision appears to be low with only 42% exact reader agreement. However, precision dramatically increases for PA-1 and PA-2 (Table C-1)

Discussion

Otoliths extracted from channel catfish in a lotic environment displayed high precision and little bias in age estimation. It appears precision and bias of age estimates from pectoral spines are positively influenced by increased reader experience. Pectoral spines aged by experienced readers (2008) had lower between-reader bias, similar to otolith age estimates. However, precision of these estimates were lower than otoliths. Additionally, age-specific bias was observed for pectoral spines in relation to otoliths, especially for age-11 and older channel catfish.

My findings of little bias and high precision for otolith age estimates support results from Buckmeier et al. (2002). However, high precision should not be mistaken for high accuracy. In fact, inaccurate age readings can be highly reproducible (Campana 2001). Nonetheless, high precision of age estimates obtained from valid structures provides some confidence in accuracy.

Experienced readers provided more precise and less biased pectoral spine age estimates for channel catfish. Similar reader experience trends have been observed with otolith and scale age determinations for black crappie and white crappie (Ross et al. 2005). Therefore, experienced readers should be used for age estimation whenever possible. In any case, quality control should be conducted periodically during age and growth investigations (Campana 2001).

Pectoral spines over-estimate young (age-3) channel catfish age in relation to otolith age estimates. Over-aging of younger channel catfish was also observed by Buckmeier et al. (2002) who suggested annular marks composed of multiple rings led to over-estimation. Holland and Peters (1992) also observed ‘false annuli’ on pectoral spine cross sections of channel catfish collected from the Platte River. Therefore, over-estimation of younger fish was likely due to interpreting false marks as true annuli.

Pectoral spines under-estimate older channel catfish compared to otoliths. Under-estimation of age for older channel catfish has not been documented. However, Nash and Irwin (1999) found pectoral spines under-estimated adult flathead catfish age compared to otoliths. Under-estimations of age using pectoral spines likely occurs due to expansion of the central lumen (Muncy 1959, Nash and Irwin 1999) and/or merging of outer annuli (Devries and Frie 1996), especially with older slow growing individuals.

Pectoral spine age estimations for age-6 to age-11 channel catfish only under-estimated fish age slightly (~ 1-year) compared to otoliths. This may suggest the central lumen has expanded just past the first annulus in age-6 to age-11 channel catfish. However, higher variability in age estimates of age-11 and older fish suggest the lumen has expanded to encompass 2 or more annuli and/or annuli are merging near the edge of the spine.

Understanding population characteristics of channel catfish populations is important for monitoring and implementing management activities. The use of pectoral spines has been the sole method for obtaining channel catfish age estimates in Nebraska rivers (Hesse et al. 1982, Holland and Peters 1992, Holland and Peters 1994, Mestl and Porter 2009, personal communication, S. Schainost, NGPC). However, bias and precision of pectoral spine age estimates can be problematic, especially with older fish. Otoliths have been validated as an accurate structure to age channel catfish (Buckmeier et al. 2002) and my findings indicate otolith age estimates are non-bias and highly precise up to age-14 channel catfish. However, more research is needed regarding structure-specific processing times, increased harvest effects on populations of interest, and public acceptance of this method, before otoliths can be recommended as the “best” structure for age determination.

Most channel catfish populations are dominated by younger fish with few individuals exceeding age-8 (Hubert 1999). Therefore, it may be possible to obtain accurate age estimates using pectoral spines alone. Sacrificing a limited number of fish from a population for otolith age reference could also improve pectoral spine age estimates (Buckmeier et al. 2002, Campana 2001). However, caution should always be taken when using age-structures that have not been validated.

Further research is needed to validate age structures for older (< age-4) channel catfish. In addition to age validation, identifying the timing of annulus formation is an important consideration. Additionally, investigations conducted in more northerly latitudes using fish from lotic habitats would be beneficial in understanding bias, precision and accuracy associated with age structures throughout the habitat and geographic range of channel catfish.

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Table C-1. Between-reader and between-structure percent exact agreement (PA-0), percent agreement within 1 year (PA-1), and percent agreement within 2 years (PA-2) in age estimates assigned by two readers for pectoral spines and otoliths of channel catfish from the Platte River, Nebraska.

	Agreement between readers			**Agreement between structures**
	Pectoral Spines		**Otoliths**	
	2007	**2008**	**2007-2008**	
N	521	1411	302	279
PA-0 (%)	46	67	85	42
PA-1 (%)	91	97	99	84
PA-2 (%)	97	99	100	94

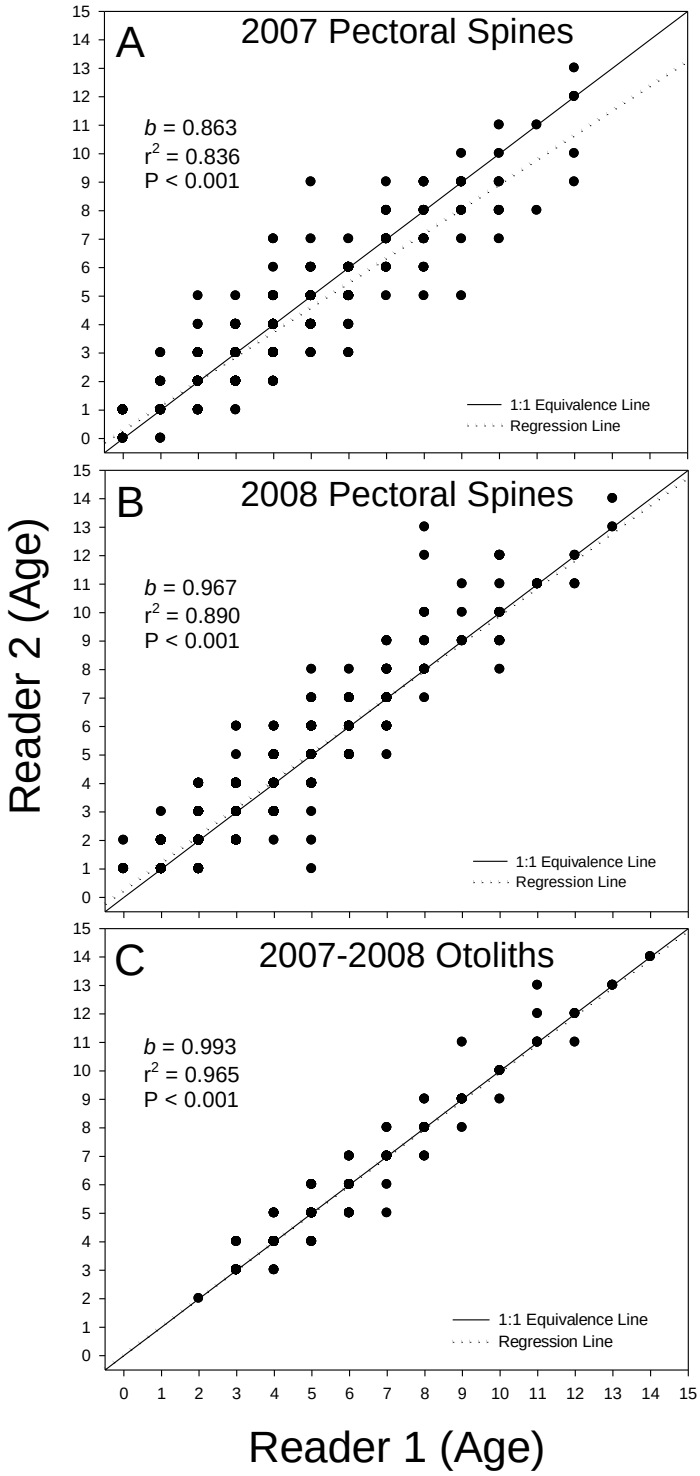

Figure C-1. Scatter plot regression of channel catfish age estimates assigned by two readers for 2007 pectoral spines (A), 2008 pectoral spines (B), and 2007-2008 otoliths (C) compared to a 1:1 equivalence line (*b* = regression slope).

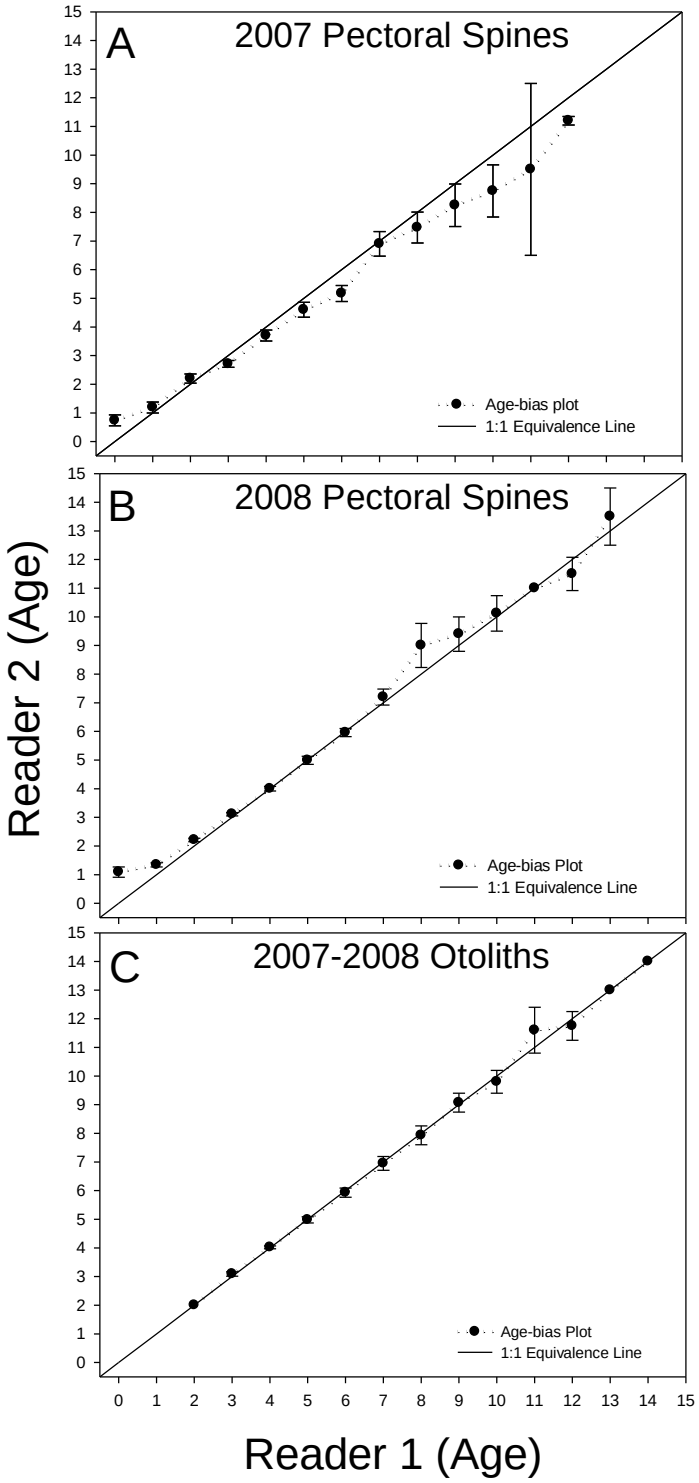

Figure C-2. Age-bias plots with 95% confidence intervals for channel catfish age estimates assigned by two readers for 2007 pectoral spines (A), 2008 pectoral spines (B), and 2007-2008 otoliths (C) compared to a 1:1 equivalence line.

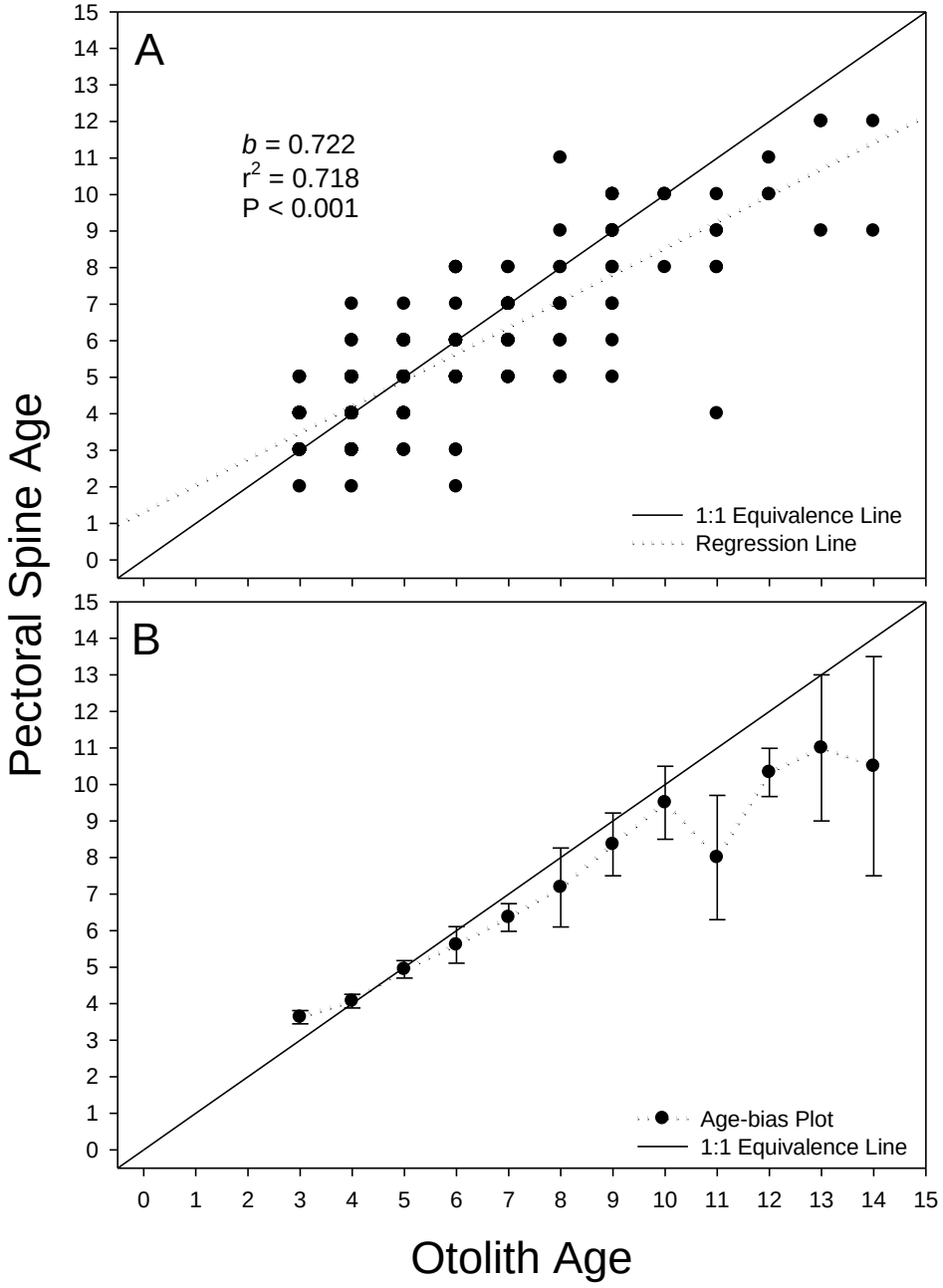

Figure C-3. Scatter plot regression (A) and age-bias plots with 95% confidence intervals (B) of channel catfish age estimates assigned for otoliths and pectoral spines compared to a 1:1 equivalence line (*b* = regression slope).