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CHANNEL CATFISH POPULATION DYNAMICS, ABUNDANCE ESTIMATES, AND SHORT TERM TRENDS IN THE PLATTE RIVER, NEBRASKA

By

Aaron J. Blank

A THESIS

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Under the Supervision of Professor Mark A. Pegg

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CHANNEL CATFISH POPULATION DYNAMICS, ABUNDANCE ESTIMATES, AND SHORT TERM TRENDS IN THE PLATTE RIVER, NEBRASKA

Aaron J. Blank, M.S.

University of Nebraska, 2012

Adviser: Mark A. Pegg

Fishing for channel catfish (*Ictalurus punctatus*) is popular in Nebraska and channel catfish are the most sought after fish species in the Platte River. Anglers on the Platte River are also harvest oriented. Little is known about the effects anglers have on channel catfish population dynamics in the lower Platte River. The goal of this study was to determine if there were effects of angling on channel catfish at two high use fishing areas in the lower Platte River. My first objective was to evaluate differences in relative abundance, size structure, condition, age structure, growth, and mortality between two high use areas (near Fremont and Louisville, NE). I also used a robust design capture-mark-recapture study to estimate density and abundance of channel catfish > 200 mm within a 10-km stretch of the Platte River at each sampling site. The second objective was to assess the 5 year standardized monitoring data for spatial and temporal differences in relative abundance, size structure, condition, age structure, growth, and mortality across two river reaches and three river segments. Channel catfish at Fremont displayed lower size structure, slower growth, and were more abundant compared to channel catfish at Louisville. Population characteristics displayed considerable variation throughout the Platte River in the last five years.

However, channel catfish sampled between the Loup River Power Canal and the Elkhorn River confluence were more abundant, grew slower, and had a lower size structure compared to channel catfish above and below that segment. Key factors influencing differences in channel catfish population characteristics may be due to hydrology (e.g., flow modifications caused by the Loup River Power Canal, irrigation withdrawals, and precipitation amounts) and the resulting changes to other abiotic factors (e.g., water temperature extremes, ice flow), angler exploitation, predation, habitat characteristics, and tributary inflows.

Acknowledgments

This thesis is dedicated to my dad. Dad, thank you for all the time spent on the water, without that upbringing I would not be the man I am today! I would also like to say thank you to the rest of my family who has always been there for me. I would like to extend a huge thank you to my wife, Monica. Thank you for always being there for me, I could not have done this without you by my side. I also need to extend a huge thank you to Dan Blunk, thank you for all the time spent on the water, you have been a huge influence in my life!

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To my lab mates, thank you for the laughs, fishing and hunting trips, and the friendships. Marty Hamel, thank you for the guidance and more importantly thanks for always kicking my butt on the basketball floor! Jeremy “Wormy” Hammen, thank you for always letting me know if my jokes were funny or not, even though I know they always were. Mat Rugg, thanks for dragging me out of bed at 2 A.M. to hunt waterfowl; I will never forget the epic snow goose hunt. Nick Hoberg, thanks for always being there to lend a hand when I needed it. If you ever need a really good chase boat driver down the road, let me know.

Finally, I owe a huge debt of gratitude to my adviser, Mark Pegg. Thank you for your continued guidance, encouragement, and friendship. You have not only been a great mentor, but a true friend. Words cannot fully express how thankful I am for everything you have done for me in the past five years. I would not be where I am today without you!

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Chapter 1 – General Introduction

Introduction

Recreational fishing in the United States of America is a popular sport industry, consisting of 30 million anglers and generating $42 billion per year (USFWS 2007). The 2006 USFWS national survey specified that 45% of anglers fished rivers and streams, and that catfish were the third most sought after fish species (23%). Nebraska anglers alone spent $181,280,000 on fishing expeditions during their 2,913,000 days on the water in 2006 (USFWS 2007). We can therefore conclude that a catfish fishery contributes to local and state economies.

Fishing for channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictus olivaris* is popular in Nebraska. For example, more than 50% of Nebraska anglers in 1981 and 1982 (Zuerlein 1984) and 57% in 2002 (Hurley and Duppong-Hurley 2005) fished for catfish. Furthermore, 35% (69,000) of Nebraska anglers targeted catfish over all other species in 2006 (USFWS 2007). Similarly, river and stream fisheries play a substantial role in Nebraska angling activities. In 1982, 29% of fishing days were on Nebraska rivers and streams (Zuerlein 1984), even though much of the river and stream systems are encompassed by private land thus restricting access. The majority of fishing took place on the Platte River (35%) and the Missouri River (23%) (Zuerlein 1984).

Understanding catfish dynamics in any system is imperative to being able to effectively manage that catfish population. Several studies have investigated channel catfish population dynamics in the Platter River. From these studies, we have learned much about channel catfish habitat preferences (Peters et al. 1989, Holland and Peters

1994), growth rates (Holland and Peters 1992b, Barada 2009), size structure (Holland and Peters 1992b, Barada and Pegg 2011), survival (Holland and Peters 1992b, Barada 2009), and age structure (Holland and Peters 1992b, Barada 2009).

Complimentary to investigations of channel catfish population dynamics is the need to understand localized and regional effects of anglers on catfish populations. Holland and Peters (1994) found that channel catfish represented 67% of the catch in the lower Platte River by anglers in 1992, and 73% of the catch in 1993. A 2009 angler survey in the lower Platte concluded that 53% of anglers targeted catfish (Marty Hamel, UNL, unpublished data). Furthermore, Holland and Peters (1994) reported that catfish were the most harvested fish in the Platte River. Therefore, gaining a better understanding of angler harvest rates and how they influence catfish population dynamics on the Platte River is essential to better manage the system.

Catfish Population Characteristics

Management of any fish species is largely dependent on population characteristics such as condition, size structure, age, growth, mortality, abundance, and recruitment (Willis and Murphy 1996, Ney 1999, Van Den Avyle and Hayward 1999, Vokoun and Rabeni 1999). Each of the individual parameters listed above provide insight into management decisions, however, effective management encompasses all parameters to direct best management decisions.

Fish condition has become a standard practice in the management of fish populations as a measure of both individual and cohort (e.g., age or size group) wellness (Pope and Kruse 2007). Measures of fish condition are intended to provide insight of tissue energy reserves, with the expectation that a fish with better condition will demonstrate faster growth rates, greater reproductive potential, and higher survival than lesser conditioned fish (Pope and Kruse 2007). Condition indices such as Fulton's condition factor (Wootton 1990), relative condition factor (Le Cren 1951) and relative weight (W_r) (Wege and Anderson 1978) are widely used to asses condition based on the premise that a specific species at a given length should weigh as much as a standard or average for its length (Pope and Kruse 2007). The use of W_r as a condition index is a standard technique used in many state agencies (Blackwell et al. 2000). The use of W_r in catfishes has been gaining momentum due to the recent developments of standard weight (W_s) for channel catfish (Brown et al. 1995). Relative weights have recently been used to describe fish condition of channel catfish in Midwestern river systems (Doorenbos 1999, Barada and Pegg 2011). Barada and Pegg (2011) found differences in channel catfish W_r between river reach and length categories in the Platte River, NE.

Size structure is commonly used by fisheries managers to help identify problems such as inconsistent year-class strength, slow growth, or excessive mortality (Anderson and Neumann 1996). Size structure is primarily described by length-frequency distributions and stock density indices; however, size structure may misrepresent the true population because of size selectivity of the gear. Standardization of sampling methods can help to correct the biases associated with size selectivity of gears. Size structure of channel catfish has been well documented in midwestern lotic systems. Columbo et al. (2008) found differences in proportional size distribution (PSD) and length frequencies of channel catfish between sampling gears in the Wabash River.

Electrofishing displayed the largest PSD (68) and relative size distribution of preferred size fish (RSD-P) (5), whereas 25-mm hoop nets displayed the smallest PSD (14) and RSD-P (1) (Columbo et al. 2008). Holland and Peters (1992a) found channel catfish PSD to ranged from 4-11 in the lower Platte River. Recent work completed on the central and lower Platte River by Barada and Pegg (2011) showed differences in channel catfish PSD values longitudinally (10-50) as well as by gear (10-91).

Age determination without bias is critical to effective management and research (Isley and Grabowski 2007). Age data provides valuable information in estimation of mortality, year-class strength, as well as environmental effects on fish populations. Age determination of catfishes 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). Buckmeier et al. (2002) recommends using otoliths due to their accuracy and low variability, however, this method requires euthanasia and may not be practical in all situations. Pectoral spines have been used in previous studies on the Platte River (Holland and Peters 1992a, Barada and Pegg 2011) and have been documented to cause little or no mortality to the fish (Stevenson and Day 1987, Michaletz 2005). Hubert (1999) found that most channel catfish research has reported a mean maximum of age 8 with a wide range (3 – 22). Holland and Peters (1992b) and Barada (2009) used pectoral spines to determine ages of channel catfish in the Platte River, and found a maximum of age 18. However, the majority of fish were less than age 10, with age 2 and age 3 being the most abundant. Barada et al. (2011) determined that pectoral spines underestimated fish age 7 or older compared to otoliths; therefore, channel catfish ages found by Holland and Peters (1992b) and Barada (2009) and many others may be older than reported.

Growth is estimated when age data are coupled with size information. Growth provides fisheries managers with some indication of resource use and the effectiveness of their management strategies (Isely and Grabowski 2007). Hubert (1999) found variability in growth in channel catfish across their range. For example, mean lengths at age-3 ranged from 157-429-mm, age-6 ranged from 252-569-mm, and age-9 ranged from 305-726-mm. Relatively slow growth rates for channel catfish have been found in the Platte River by Holland and Peters (1992b) and Barada (2009). Holland and Peters (1992b) found age-3 mean lengths to be 202-mm, while Barada (2009) found age-3 mean lengths to be 221-mm.

Many factors can influence growth rates of catfishes. Durham et al. (2005) showed that growth may be correlated with length of growing season. Other factors that may be influencing growth are food availability, habitat features, and intra- and interspecific competition (Andrews and Stickney 1972, Quist and Guy 1998, Hubert 1999). Flow disturbances, such as the those found near the Loup River Power Canal, along with extreme water temperatures are hypothesized to cause slow growth of channel catfish in the lower Platte River (Holland and Peters 1992b, Barada 2009).

Mortality is the rate at which individuals are lost from a population (Miranda and Bettoli 2007). Estimated annual mortality rates from over 50 populations for channel catfish ranged from 13% to 88% (McCammon and LaFaunce 1961, Wahtola 1971, Mayhew 1972, Elrod 1974, Lorantas 1982, Hesse et al. 1982a, Gerhardt and Hubert 1991, Kubeny 1992, Newcomb 1989, Paragamian 1990, Hesse 1994, Pitlo 1997, Siegwarth and Johnson 1998). Peters et al. (1992) found channel catfish, collected by hoop nets in the Platte River, exhibited annual mortality in the range of 16% to 59%. Barada (2009) found that channel catfish exhibited a similar range in annual mortality (26%-44%).

The most common indices of relative abundance are computed from catch per unit effort (CPUE) data using samples from a fish stock (Fabrizio and Richards 1996, Hubert 1996, Ney 1999). Relative abundances of channel catfishes in the Platte River have been documented in the past where Peters et al. (1992) used baited hoop nets and found a wide range in CPUE (0.27 fish/net-night - 3.64 fish/net-night). Barada and Pegg (2011) also used baited hoop nets and found 25-mm hoop nets had the greatest mean CPUE (1.96 fish/net-night) while 38-mm nets had the lowest mean CPUE (0.61 fish/net-night). Barada and Pegg (2011) also found longitudinal differences in mean CPUE with highest CPUE's found in the middle reaches of their sampling sites.

Study Objectives

Angling is popular throughout the Platte River. However, a mail questionnaire, designed to document fishing pressure in the Platte River, by Holland and Peters (1994) documented there were areas in the Platte River that received greater pressure from anglers than others. Areas that received the greatest pressure in 1992 were Fremont (30%), Columbus tailrace (23%), and four locations (North Bend, Leshara, Two Rivers, and Louisville) which 20% of respondents fished. Fisheries that experience high angling pressure and harvest, in which I believe reaches of the lower Platte River may experience, may be at risk of over exploitation (Lester et al. 2003, Sullivan 2003, Wilberg et al. 2005). Recruitment overfishing as well as growth overfishing can lead to poor fish condition, size structure, recruitment, and growth (Longhurst 2002). Monitoring a fishery is one way to determine trends that may indicate the direction the fishery is going. Barada (2009) recommended long-term monitoring of the central and lower Platte River to determine trends and gain a better understanding of how the Platte River system functions on a yearly basis. Therefore, the goal of this study was to assess the channel catfish population dynamics in the Platte River. Specifically, I assessed standardized monitoring data for any spatial or temporal trends in channel catfish population characteristics as well as channel catfish population characteristics at two high use and high harvest fishing areas in the lower Platte River. My specific objectives were:

1. Determine differences in abundance, survival, condition, age structure, growth, and size structure of channel catfish between Louisville and Fremont.
2. Determine the estimated abundance and density of channel catfish at Louisville and Fremont.
3. Determine spatial and temporal differences in channel catfish relative abundance, size structure, condition, age structure, growth rates, and mortality in the central and lower Platte River.

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Chapter 2. Channel Catfish Population Characteristics at Two High Use Areas on the lower Platte River

Introduction

Recreational fishing in the United States is a popular sport industry, consisting of 30 million anglers and generating a total of $42 billion per year (USFWS 2007). The 2006 U.S. Fish and Wildlife Service (USFWS) national survey specified that 45% of anglers fished rivers and streams, and that catfish was the third most sought after fish group (23%). Nebraska anglers alone spent $181,280,000 on fishing expeditions during their 2,913,000 days on the water in 2006 (USFWS 2007). Fishing for channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictus olivaris* is popular in Nebraska. For example, more than 50% of Nebraska anglers in 1981 and 1982 (Zuerlein 1984) and 57% in 2002 (Hurley and Duppong-Hurley 2005) fished for catfish. Furthermore, 35% (69,000) of Nebraska anglers targeted catfish over all other species in 2006 (USFWS 2007). Similarly, river and stream fisheries play a substantial role in Nebraska angling activities. In 1982, 29% of fishing days were on Nebraska rivers and streams (Zuerlein 1984), even though much of the river and stream systems are encompassed by private land thus restricting access. The majority of fishing took place on the Platte River (35%) and the Missouri River (23%) (Zuerlein 1984). Therefore, we can conclude that the catfish fishery in Nebraska is an important component to local and state economies.

Understanding catfish dynamics in any system is imperative to being able to effectively manage that catfish population. Several studies have investigated channel catfish population dynamics in the Platte River. From these studies, we have learned much about habitat preferences (Peters et al. 1989, Holland and Peters 1994), growth rates (Holland and Peters 1992a, Barada 2009, Chapter 4), size structure (Holland and Peters 1992b, Barada and Pegg 2011, Chapter 4), survival (Holland and Peters 1992b, Barada 2009, Chapter 4), age structure (Holland and Peters 1992a, Barada 2009, Chapter 4), abundance (Holland and Peters 1992b, Barada and Pegg 2011, Chapter 4), and condition (Barada and Pegg 2011, Chapter 4). However, little has been done to understand the localized and regional effects of angling.

Anglers in the Platte River system, specifically the lower Platte River, tend to harvest most of their catch. Holland and Peters (1994) found that channel catfish were the most harvested fish species in the Platte River. Similarly, Parham et al. (2005) reported channel catfish as the most sought after species in the lower Platte River. Additionally, a 2009 creel survey found that anglers harvested 78% of the catfish they caught during April and May (Marty Hamel, UNL, Personal communication). Angling pressure is believed to be primarily focused around public access areas because much of the shoreline along the Platte River is privately owned (Zuerlein 1984). A mail survey, designed to document fishing pressure and harvest in the Platte River, (Holland and Peters 1994) determined that Louisville and Fremont were high pressure fishing areas. Twenty percent (20%) of the mail survey respondents fished the Louisville area in 1992, while 30% fished at Fremont (Holland and Peters 1994). Differences in fishing pressure were also documented around Louisville and Fremont. Areas above and below Louisville, South Bend (9%) and Cedar Creek (7%), displayed little fishing pressure; whereas, areas above and below Fremont, Cedar Lakes (17%) and Woodcliff (18%), demonstrated greater fishing pressure (Holland and Peters 1994). Holland and Peters (1994) also surveyed airboat usage, and found the Fremont area had the heaviest airboat traffic in the lower Platte River. Gaining a better understanding of the population characteristics of channel catfish in areas where angling is important is essential to better manage the system. Therefore my objective was to document differences in channel catfish abundance, condition, size structure, growth rates, age structure, and mortality rates between the two high pressure fishing areas at Fremont and Louisville, Nebraska.

Methods

Study Area

The Platte River, an alluvial, sand bottom, braided river, is formed at the confluence of the North and South Platte rivers. The river exhibits dynamic shifts in its bed as sand bars are consistently moving down the river which alters channel dimensions, and continually changes habitat quantity, quality and availability (Sidle et al. 1989, Simons 2000). Water availability, primarily influenced by high or low precipitation, hydropeaking, and irrigation withdrawals; compound the problems of habitat quantity, quality, and availability.

The lower Platte River, defined as the reach from the confluence of the Loup River near Columbus, NE to the confluence at the Missouri River near Plattsmouth, NE, is heavily influenced by the Loup River Power Canal and the Elkhorn River. Diel changes in discharge from the Loup River Power Canal can lead to rapid changes in depth, velocity, and habitat on a daily basis (Peters et al. 1989, Holland and Peters 1992b). The

Elkhorn River is one of the largest tributaries to the lower Platte River, which funnels water from northeast Nebraska into the lower Platte River. Due to the hydrological impacts of the Loup River Power Canal and Elkhorn River, I split the lower Platte River into two segments. Segment 1 is defined as the confluence of the Elkhorn River to the confluence of the Platte River with the Missouri River. Segment 2 is defined as the confluence of the Loup River Power Canal to the confluence of the Elkhorn River. I chose a 10 river kilometer (Rkm) sampling site from each segment (Figure 2.1). The sampling site in the segment 1 was between river kilometers (Rkm) 24-34, near Louisville, NE. The sampling site in segment 2 (Rkm 88-98), is located near the city of Fremont, NE.

Field Collections

Fish were collected using a suite of gears to encompass all size ranges of catfishes in the Platte River. Gears included baited hoop nets, high and low pulsed electrofishing. Sites were sampled by season until target sample sizes were met (Chapter 3). Seasons were defined as 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 0.6-m diameter 7-hoop, hoop nets with 25-mm mesh (7-hoop) and 0.5-m diameter 4-hoop, hoop nets with 25-mm mesh (4-hoop) baited with scrap cheese. Hoop nets were anchored at the cod end and an anchor lead was tied to the shoreline. Nets were deployed parallel to the shoreline in a variety of habitat types. Spring sampling consisted of 20 deployments of the 4-hoop, hoop nets to follow established standard sampling protocols (Chapter 4). Summer and fall sampling consisted of 10 gear deployments of each type of net daily until target tagging goals were reached for each season. Hoop net sets did not exceed 24 hours and catch per unit effort (CPUE) was expressed as fish/net-night.

Electrofishing was conducted using a cataraft (River King Catarafts, Port Ludlow, Washington) equipped with an MBS-2D Wisconsin box (ETS Electrofishing LLC, Madison, Wisconsin) powered by a 3500 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 (EFH; 4-8 A, 180-240 V, 60 pulses/s, 50% pulse width) and low frequency (EFL; 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 netting 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 individual's netted fish from the bow of the vessel. There were no time or distance limits to individual runs, however, start and stop times were recorded for individual runs; therefore, CPUE was expressed as fish per hour.

All captured fish were measured (total length), weighed (g), and returned to the water. Calcified structures, spine and/or otoliths, were taken from a subsample of fish at each site to provide information on age structure and growth rates. Pectoral spines were collected from a representative sample of five individuals from each 10-mm size group for channel catfish, and placed in coin envelopes immediately after removal.

Physical and chemical data were collected at each sampling occasion. Data were taken at the mid-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 (e.g., depth, pools, revetted banks, large woody debris) were also noted for each hoop net deployment or electrofishing run.

Laboratory Analysis

Spines were prepared using methods by Koch and Quist (2007). Spines were set in either 2.0 or 5.0ml centrifuge tubes, depending on spine size, and then filled with epoxy. Once hardened, the spines were cut into 0.8mm sections using either a Buehler *Isomet 1000* high precision saw or Buehler *low speed saw* (Buehler Inc., Lake Bluff, Illinois). Sections were placed on microscope slides and covered with Cytoseal in preparation for image capture (Richard-Allan Scientific, Kalamazoo, Michigan). Images were captured using a microscope (Olympus SZ61) and camera. Spine sections were viewed by two different readers to determine age.

Data Analysis

Catch per unit of effort was calculated for only taggable sized fish (≥ 200 mm) (Chapter 3). Differences in mean CPUE by site and year were analyzed using an analysis of variance (ANOVA) with Tukey's HSD multiple comparisons when significant differences were identified. Comparisons of CPUE by season were analyzed using a general linear modeling approach (GLM) with a least square means (LSM) statement. Catch data were $\log_{10}$ (CPUE+1) transformed to meet normality assumptions for parametric tests.

Size structure data were compared by site, gear, and years 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) described by Gabelhouse (1984). Proportional Size Distribution was calculated as:

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

Additional PSD indices (e.g., PSD-P) were calculated as:

$$\mathrm{PSD} - \mathrm{P} = \frac{\text{\# fish} \geq \text{minimum perferred length}}{\text{\# fish} \geq \text{minmum stock length}} * 100$$

Differences in PSD indices were statistically analyzed using chi squared (x^2) tests as recommended by Neumann and Allen (2007). Differences in length-frequency distributions of taggable sized fish (≥ 200-mm) were calculated using nonparametric Kolmogorov-Smirnov tests with a Bonferroni correction factor to maintain an overall α = 0.05.

Fish condition was analyzed using mean relative weight (W_r; Wege and Anderson 1978). The relative weight equation is as follows:

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

where W is the measured weight, and W_s is the standard weight for the species. Brown et al. (1995) reported a standard weight equation for channel catfish:

log10 (Ws) = -5.800 + 3.294*log10 (Total Length).

Comparisons of W_r were made using the mean for 50-mm length categories. Mean W_r differences by fish length and site were analyzed using ANOVA with Tukey's HSD multiple comparisons when significant differences were identified. Differences between sites were further broken down by $\log_{10}$-transformed length-weight linear regressions. Differences in length-weight regression slopes were tested using an analysis of covariance (ANCOVA) (Pope and Kruse 2007).

I estimated individual length at age information to assess growth using the Dahl-Lea method (FishBC, Doll and Lauer 2008) as:

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

where Li = length at annulus i, Lc = length at capture, Rc = spine radius at capture, and Ri = spine radius at annulus i. Differences in mean back-calculated lengths at age and mean annual growth increments between sites were analyzed using Tukey's studentized range (HSD) test when ANOVA results were significant. Growth rates were compared to the standard growth of channel catfish determined by Hubert (1999).

Fishery Analysis and Simulation Tools (FAST, Slipke and Maceina 2001) software was used to fit von Bertalanffy growth functions as:

$$L_t = L_\infty * (1 - e^{-k(t-t_o)})$$

where Lt = length at time t, L_∞ = theoretical maximum length, K = growth coefficient, and t_0 = time when length equals 0-mm. Age-length keys were built using Fish BC (Doll and Lauer 2008) which were used to estimate ages for fish that were not aged. Age-frequency distributions were then compared between sites and years using a Kolmogorov-Smirnov (KS) nonparametric test.

Weighted catch curves were created in program FAST (Slipke and Maceina 2001) and used to determine instantaneous mortality (Z) and annual mortality (A). Mortality parameters were estimated for each site in 2010 and 2011 using all gears. Differences in mortality estimates were made using an ANCOVA. All analyses were conducted using SAS (SAS Institute 2004) where significance was determined at $\alpha = 0.05$.

Results

A total 1,534 gear deployments captured 2,979 channel catfish at Louisville, whereas 1,027 gear deployments at Fremont captured 3,927 channel catfish (Table 2-1). Habitat characteristics were similar between sites for depth, temperature, dissolved oxygen, and turbidity (Table 2-2). However, mean conductivity was greater at Louisville (727 µS) compared to Fremont (580 µS) and mean discharge was greater at Louisville (282 m^3/sec) compared to Fremont (197 m^3/sec).

Relative Abundance

Annual mean hoop net catch per unit effort (CPUE) in 2010 was greater at Fremont for both 4-hoop (3.99 fish/net-night ≥ 200-mm) and 7-hoop (7.15 fish/net-night

≥ 200-mm) compared to Louisville (2.61 and 4.54 fish/net-night ≥ 200-mm) ($P < 0.05$; Figure 2-2). Catch per unit effort in 2011 was greater at Fremont for 4-hoop (3.81 fish/net-night ≥ 200-mm) compared to Louisville (1.42 fish/net-night ≥ 200-mm), however, no difference was noted between sites with 7-hoop nets (Figure 2-2).

Seasonal mean hoop net catch rates at Fremont during the summer and fall months were greater throughout both years ($P < 0.05$; Figure 2-3), but displayed no discernible trend during the spring. In spring 2010, greater catch rates were observed at Louisville (3.79 fish/net-night ≥ 200-mm) compared to Fremont (0.55 fish/net-night ≥ 200-mm), however, no differences were found between sites in 2011 or when 2010 and 2011 data were pooled (Figure 2-3).

Annual mean electrofishing CPUE in 2010 was greater for EFL at Fremont (6.98 fish/hour ≥ 200-mm) compared to Louisville (3.56 fish/hour ≥ 200-mm), although EFH showed no difference between sites (Figure 2-4). Electrofishing CPUE demonstrated high variability between seasons for both EFL and EFH with no apparent trends (Figure 2-5).

Size Structure

Differences in length-frequency distributions were found between years, gears, and sites (i.e., 2010 4-hoop at Louisville vs. 2010 4-hoop at Fremont) for all comparisons except 2011 4-hoop, hoop nets ($P < 0.01$; Figures 2-6 – 2-10). Length-frequency distributions were shifted towards small fish at Fremont and larger fish at Louisville. Mean length was also greater at Louisville for all gears and all years compared to Fremont ($P < 0.01$).

Differences in proportional size distribution (PSD) indices were also observed between sites (Table 2-3). Greater PSD was observed at Louisville for all gears in 2010, whereas in 2011 no differences were found ($P = 0.52$). Proportional size distribution values were significantly greater ($P < 0.01$) at Louisville for all gears when 2010 and 2011 data were pooled together. Proportional size distribution was greater ($P < 0.01$) at Louisville in 2010 compared to 2011. No annual differences were found at Fremont.

Condition

Channel catfish condition (W_r) varied by year and 50-mm length group (Figure 2-11). Smaller fish (≤ 200-mm) exhibited the largest mean W_r, followed by a decrease until around 350-mm, at which point condition improved as fish lengths increased (Figures 2-12, 2-13). Overall mean relative weights were greater in 2010 when compared to 2011 for both Louisville ($P < 0.0001$) and Fremont ($P < 0.0001$). Channel catfish between 300-450-mm had greater mean W_r in 2010 compared to 2011 at Louisville ($P < 0.0001$), while fish between 200-350-mm were greater in 2010 compared to 2011 at Fremont ($P < 0.0001$) (Figure 2-11). Few differences were found when comparing sites among years; however, Louisville had greater mean relative weights in 2011 for 150, 250, and 300-mm length categories ($P < 0.05$) (Figure 2-12). Length-weight relations showed no difference in incremental weight gain between sites in 2010 ($P > 0.05$; Figure 2-13), 2011 ($P > 0.05$; Figure 2-14), or combined years ($P > 0.05$; Figure 2-15).

Age Distribution

Channel catfish ages ranged from 0 to 14; however, age-3 and age-4 channel catfish were the most abundant at both Louisville and Fremont (Figure 2-16). No differences in age distribution were found between sites in 2010 ($P = 0.17$) or 2011 ($P = 0.46$) (Figure 2-16). However, differences were found within sites by year for both Louisville ($P < 0.01$) and Fremont ($P < 0.01$). Age distributions in 2010 had a greater proportion of older fish, while age frequencies in 2011 had a greater proportion of younger fish.

***Gro*wth**

No differences were found in back-calculated lengths between years for either site; therefore, all data for each site were pooled for statistical analyses. Growth rates varied between sites (Figures 2-17, 2-18). Asymptotic length was greater at Fremont (Figures 2-17, 2-18). The highest observed growth occurred in young fish at both locations. Channel catfish grew to 90-mm after one year, 167-mm after two years, and 243-mm after three years (Figure 2-19) at Louisville. Fremont showed a similar trend with fish reaching 88-mm, 158-mm, and 229-mm in the first three years (Figure 2-19). Louisville had greater mean back-calculated lengths for ages 2-6 ($P < 0.05$) (Figure 2-19). Mean back-calculated lengths were consistently above the 50th percentile of growth standards for the species, with the exception of age-3 fish at Fremont and age-9 fish at Louisville (Table 2-4). Younger fish were consistently in the 50th to 75th percentile at Louisville until age-6 and age-7 which were in the 75th-90th percentile (Table 2-4).

Mean annual incremental growth rates varied by site and age (Figure 2-20). There was a steady decrease in incremental growth as age increased for both Louisville and Fremont. Incremental growth rates were significantly greater for ages 2-4 at Louisville ($P < 0.05$); however, growth rates for all other years showed no difference between sites (Figure 2-20).

Mortality

Channel catfish recruited to the sampling gears at age-3 at both Fremont and Louisville. Lowest instantaneous (0.695) and annual mortality (50%) rates occurred at Louisville in 2010, while the largest estimates (0.812 and 56%) occurred at Fremont with 2010-2011 data combined (Table 2-4). Overall instantaneous and annual mortality rates did not differ between sites (ANCOVA, $P = 0.28$) (Figure 2-21).

Discussion

Channel catfish relative abundance in this study (2.61 – 7.15 fish/net-night ≥ 200-mm) was comparable to other Midwestern streams. Barada and Pegg (2011) used the same gear (4-hoop) as this study to evaluate relative abundance throughout the central and lower Platte River and reported an average of 2.3 fish/net-night. Hesse et al. (1979) used hoop nets of similar dimension (25-mm mesh, 1.47-m length, 0.6-m diameter) to determine relative abundance of channel catfish in the unchannelized Missouri River (0.2-2.3fish/net-night) and the Niobrara River (0.1-5.9 fish/net-night). Goble (2011) used the same nets (7-hoop) as my study to determine relative abundances of channel catfish throughout the Missouri River and reported an average of 4.42 fish/net-night. These comparisons suggest that channel catfish abundances in the lower Platte River are average compared to other systems in the region.

Angler exploitation is likely reducing size structure of channel catfish at Fremont. Fishing mortality is highly selective, and exploited stocks typically display greatly truncated size and age distributions that lack larger, older fish (Olson and Cunningham 1989, Beard and Kampa 1999, Conover and Munch 2002, Radomski 2003). Fishing pressure, and presumably fishing mortality, is greater at Fremont (Holland and Peters 1994). The majority of channel catfish collected at both Fremont and Louisville were less than age-5 and less than 400-mm in total length. Gerhardt and Hubert (1991) found channel catfish up to age-21, and fish over 400-mm were common in the unexploited Powder River system. Gerhardt and Hubert (1991) also found considerably lower annual mortality estimates (21%) on the Powder River system compared to Fremont (56%) and Louisville (53%). Size distribution, age distribution, and annual mortality data analyzed during this study, as well as past studies on the Platte River (Morris 1960, Holland and Peters 1992, Barada 2009), indicate that some exploitation is occurring at both Fremont and Louisville. However, coupling angler harvest (Morris 1960, Holland and Peters 1992, Barada 2009) with lower PSDs, and greater annual mortality I found at Fremont suggests higher exploitation at Fremont. Holland and Peters (1992b), and Barada (2009) found that tournament anglers near Fremont harvested channel catfish of quality size or greater in significantly higher proportion than their presence in the population. The long-term effect of this angler activity has likely resulted in a shift in size structure and other population characteristics to smaller sizes and higher mortality as I observed here. Continued pressure may continue to suppress the channel catfish size and age structure in the lower Platte River.

Growth and size structure were also negatively influenced by channel catfish abundance at Fremont. Density-dependent growth is commonly observed in fishes (Le Cren 1958, Backiel and Le Cren 1978, Walters and Post 1993). As fish density increases, growth is slowed as a result of increased intra-specific competition. Slowed growth rates have a direct impact on an individual's size at maturity and maximum length, with smaller maturation and maximum sizes occurring in slower growing fish (Bowen et al. 1991, Walters and Post 1993). I found consistent evidence of slower growth and reduced size structure at Fremont and throughout segment 2 (Chapter 4). Slowed growth and reduced size structure is likely negatively correlated with greater hoop net relative abundance estimates, as well as population estimates (Chapter 3). Furthermore, fish condition decreased in stock-quality sized fish, the most abundant size range in the Platte River. Decreased condition is likely a result of increased intra-specific competition and a lack of food availability. Angler exploitation may also be contributing to density-dependent growth. It is likely that channel catfish at Fremont are experiencing growth overfishing as indicated by high harvest rates (Holland and Peters 1994; Chapter 3), truncated size and age structure, and greater asymptotic length. Growth overfishing occurs in a stock when fishing mortality is high or fishing commences at too young of an age (Slipke et al. 2002). Pitlo (1997) found growth overfishing was occurring in the Upper Mississippi River while commercial harvest was still legal. Anglers at Fremont are harvesting channel catfish before they reach their maximum length causing a decrease in size and age structure. It is reasonable to think that channel catfish near Fremont may increase reproduction to counteract high angler harvest, which would increase fish density and further add to density-dependent growth issues.

Abiotic issues such as hydropeaking of the Loup River Power Canal may also be contributing to reduced growth and truncated size structure of channel catfish near Fremont. Previous studies (Barada and Pegg 2011, Holland and Peters 1992b) have hypothesized that the Loup River Power Canal has a negative impact on size structure, and growth of channel catfish. Water management in the canal for electricity causes extreme daily fluctuations in water elevation ($\pm$ 0.5 m) as well as changes in discharge ($\pm$ 100+ m^3/sec) across much of the lower Platte River (Barada and Pegg 2011, U.S. Geological Survey, unpublished data). Fluctuations in river discharge have been documented to cause harsh living environments (Hesse et al. 1982), limit community biomass and energy (Blinn et al. 1995), and decrease macroinvertebrate abundances (Gislason 1985, Blinn et al. 1995, Haxton and Findlay 2008). Additionally, Weisberg and Burton (1993) suggested that fish feeding rates and growth were greater during consistent availability of depth and flow conditions under minimum flow requirements compared to a widely fluctuating hydrograph. Therefore, channel catfish at Fremont are likely experiencing stressful habitat conditions, possibly leading to decreased growth and smaller size structure.

Growth and size structure at Louisville may be positively influenced by tributary inflows, namely from the Elkhorn River and Salt Creek. Positive effects of tributaries on river biota are widely known (Cushman 1985, Kiffney et al 2006, Pracheil et al. 2009). Kiffney et al. (2006) found that tributaries increased habitat complexity and productivity noting increases in nutrients, algal biomass, consumers, and predators. Furthermore, Cushman (1985) found that tributary inflows can moderate the variability of flow changes and provide a more natural flow regime to the main stem. The Elkhorn River is important to the lower Platte River because it is thought to dampen the effects of hydropeaking caused by the Loup River Power Canal (Barada 2009). The Elkhorn River also increases discharge in the Platte River, which may provide greater habitat complexity. More information is needed to assess the effects of tributaries (e.g., changes in nutrients, changes in invertebrate abundances) and the impacts they have on channel catfish population dynamics in the lower Platte River.

A few notable patterns existed within my two study sites. Channel catfish were larger, grew faster, and were less abundant at Louisville, whereas, channel catfish at Fremont were smaller, grew slower, and were more abundant. I highlighted angler exploitation and density-dependent growth mechanisms as the major factors influencing channel catfish size growth and size structure. Depending on the management goals of the Platte River, continued exploitation of larger, older channel catfish may be detrimental to the lower Platte River catfish fishery. For example, if the management goals are to solely provide anglers with edible sized fish, then management actions may not need to be taken. However, if management goals are to produce a specific number of quality sized fish (> 410-mm), then harvest restrictions may need to be implemented.

Gaining an understanding of catfish population dynamics in lotic systems like the Platte River provides many challenges. The complexities of determining the exact cause of channel catfish responses to both biotic and abiotic factors are many. Water availability, one of the most important aspects in a river (Poff et al. 1997) ,has largely not been an issue during my study. Further, I observed evidence anglers are having an effect on several of the population characteristics (e.g., high mortality through harvest, truncated size structure, etc.). It therefore seems reasonable that biotic and abiotic factors operate in conjunction with each other, but how those effects are expressed may occur on differing temporal scales. For example, it seems reasonable that anglers are important drivers in the structure of catfish populations during years when water availability is not an issue. Conversely, abiotic factors, like habitat quantity and quality, become the dominant driver of population structure when water availability issues are present. Further examination of the timing and influence both types of drivers have on channel catfish are warranted to gain better insight into how to manage and conserve channel catfish in systems like the Platte River.

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Table 2-1. Sampling effort (gear deployments) by site and season using 25-mm, 4-hoop, hoop nets (4-hoop), 25-mm, 7-hoop, hoop nets (7-hoop), low frequency pulsed-DC electrofishing (EFL) and high frequency pulsed-DC electrofishing (EFH) in the Platte River during 2010 and 2011.

2010												
	4-hoop			**7-hoop**			**EFL**			**EFH**		
Site	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Louisville	20	387	100	0	19	180	10	19	4	5	10	3
Fremont	20	218	80	0	0	117	2	22	8	2	5	5

2011												
	4-hoop			**7-hoop**			**EFL**			**EFH**		
Site	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Louisville	39	202	118	0	201	189	11	3	0	11	3	0
Fremont	78	138	90	0	133	109	0	0	0	0	0	0

Table 2-2. Mean values for habitat variables measured at each site during fish collections in the Platte River 2010 and 2011.

	Depth (m)				**Temperature (^{O}C)**				**Dissolved Oxygen (mg/L)**			
Site	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Louisville	1.19	0.01	0.5	>2.0	23.65	0.61	11.1	32.1	8.66	0.45	3.7	13
Fremont	1.2	0.01	0.4	>2.0	23.03	0.79	13.6	32.5	8.14	0.33	2.14	12.3

	Turbidity (NTU)				**Conductivity (μS)**				**Discharge (ft^3/sec)**			
Site	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Louisville	124.7	11.97	42	735	726.8	13.77	277	1080	9993	709.03	280	43600
Fremont	123.1	10.27	58	312	580.3	14.37	369	750	6950	527.24	2050	19900

Table 2-3. 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 gears in the Platte River during 2010 and 2011.

Year	Site	N	% Stock	PSD	PSD-P	PSD-M	PSD-T
2010	Louisville	1128	57	32	2	0	0
	Fremont	1647	57	16	2	1	0
2011	Louisville	1796	40	19	1	0	0
	Fremont	2282	36	17	1	0	0
Total	Louisville	2924	46	25	1	0	0
	Fremont	3929	44	17	1	1	0

Table 2-4. Mean back-calculated length at age for channel catfish collected at Louisville and Fremont (**Bold**) during 2010 and 2011 compared to standard growth percentiles for channel catfish across their geographic range. Percentiles provided by Hubert (1999). Superscripts following lengths delineate Louisville (^{L}) and Fremont (^{F}) channel catfish.

					Growth Percentile					
Age	**5th**	**10th**	**25th**		**50th**		**75th**		**90th**	**95th**
3	172	192	211	**228**^{F}	238	**244**^{L}	282		310	331
4	217	243	268		291	**293**^{F}, **315**^{L}	332		387	396
5	240	271	307		341	**353**^{F}, **374**^{L}	386		444	476
6	291	316	353		386	**409**^{F}	429	**432**^{L}	504	537
7	303	331	388		434	**447**^{F}	479	**480**^{L}	567	596
8	331	353	417		469	**486**^{L}, **492**^{F}	513		595	620
9	340	379	456	**500**^{L}	504	**530**^{F}	547		628	669

Table 2-5. Instantaneous mortality (Z), total annual mortality (AM) and theoretical maximum age (Max Age) of channel catfish collected with all gears in the Platte River during 2010, 2011 and both years combined.

	2010		**2011**		**2010-2011**	
	Louisville	Fremont	Louisville	Fremont	Louisville	Fremont
Z	0.695	0.712	0.794	0.795	0.745	0.812
AM	50%	51%	55%	55%	53%	56%
Max Age	12.1	12.5	11.3	11.6	12.6	12.4

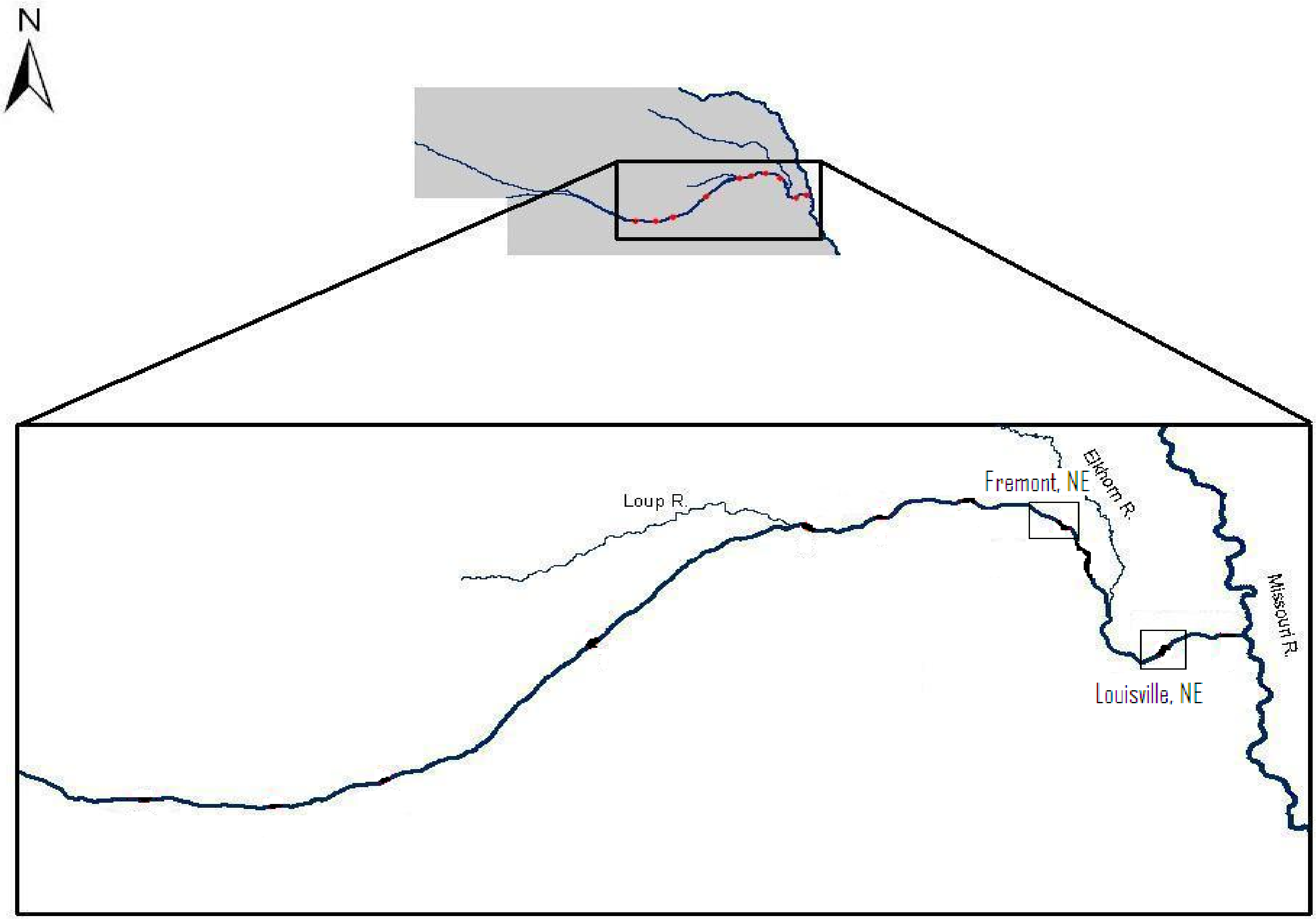

Figure 2-1. Study area including sampling locations at Louisville and Fremont in the Platte River, Nebraska.

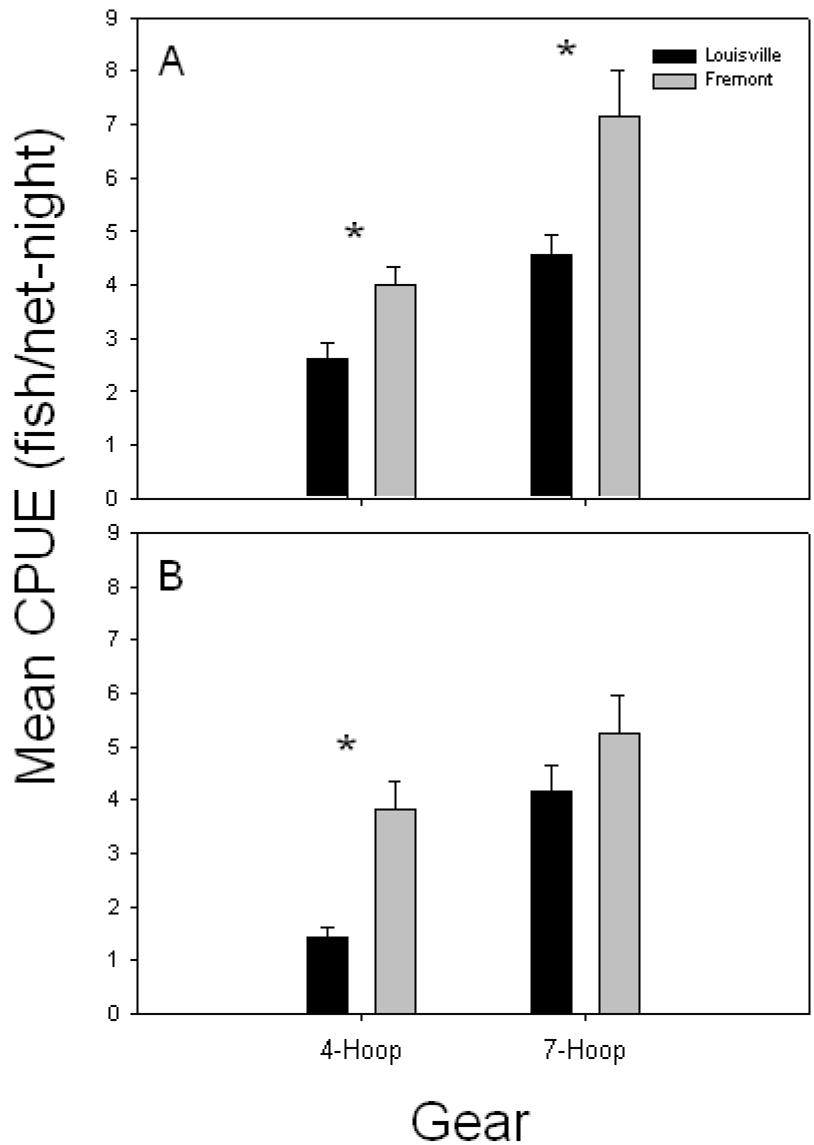

Figure 2-2. Mean catch per unit effort (CPUE) of channel catfish ≥ 200-mm collected with 25-mm, 4-hoop, hoop nets (4-Hoop) and 25-mm, 7-hoop, hoop nets (7-Hoop) at Louisville and Fremont in 2010 (A) and 2011 (B). Error bars represent 1 SE. Asterisks above plots indicate differences in CPUE between sites.

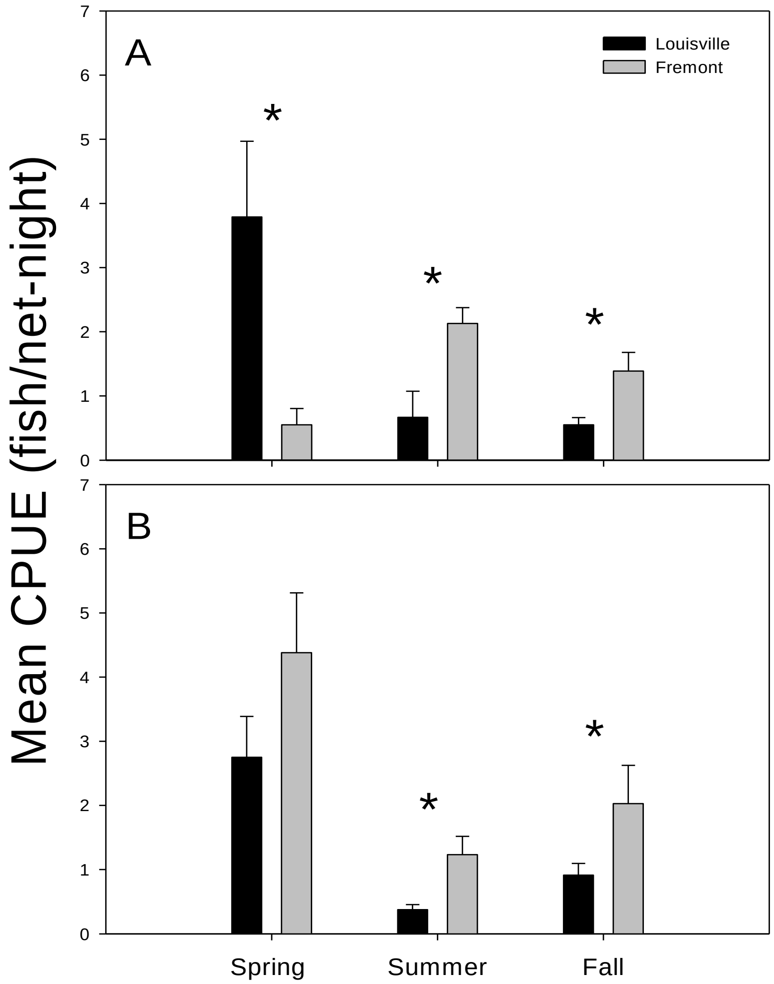

Figure 2-3. Seasonal mean catch per unit effort (CPUE) of channel catfish ≥ 200-mm collected with 25-mm, 4-hoop, hoop nets at Louisville and Fremont in 2010 (A) and 2011 (B). Error bars represent 1 SE. Asterisks above plots indicate differences in CPUE between sites.

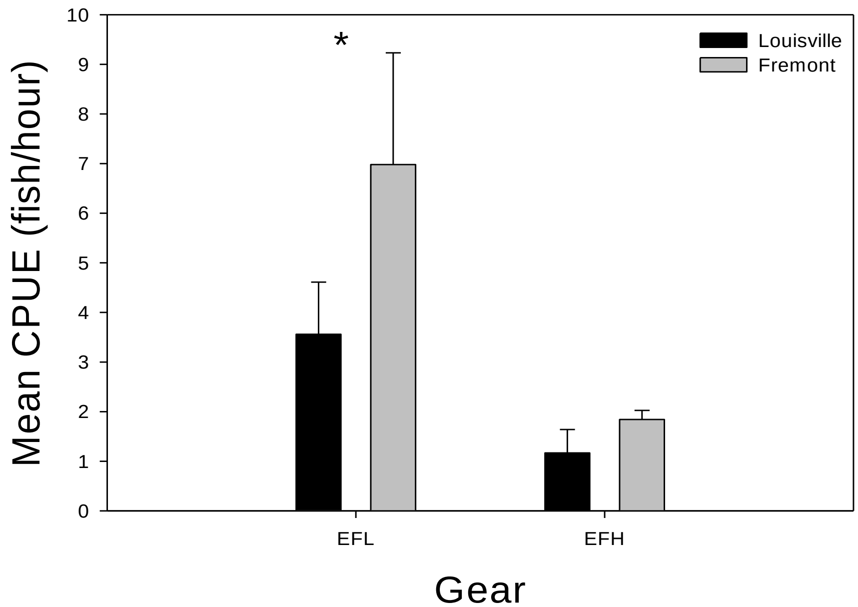

Figure 2-4. Mean catch per unit effort (CPUE) of channel catfish ≥ 200-mm collected with low pulsed-DC electrofishing (EFL) and high pulsed-DC electrofishing (EFH) at Louisville and Fremont in 2010. Error bars represent 1 SE. Asterisks above plots indicate differences in CPUE between sites.

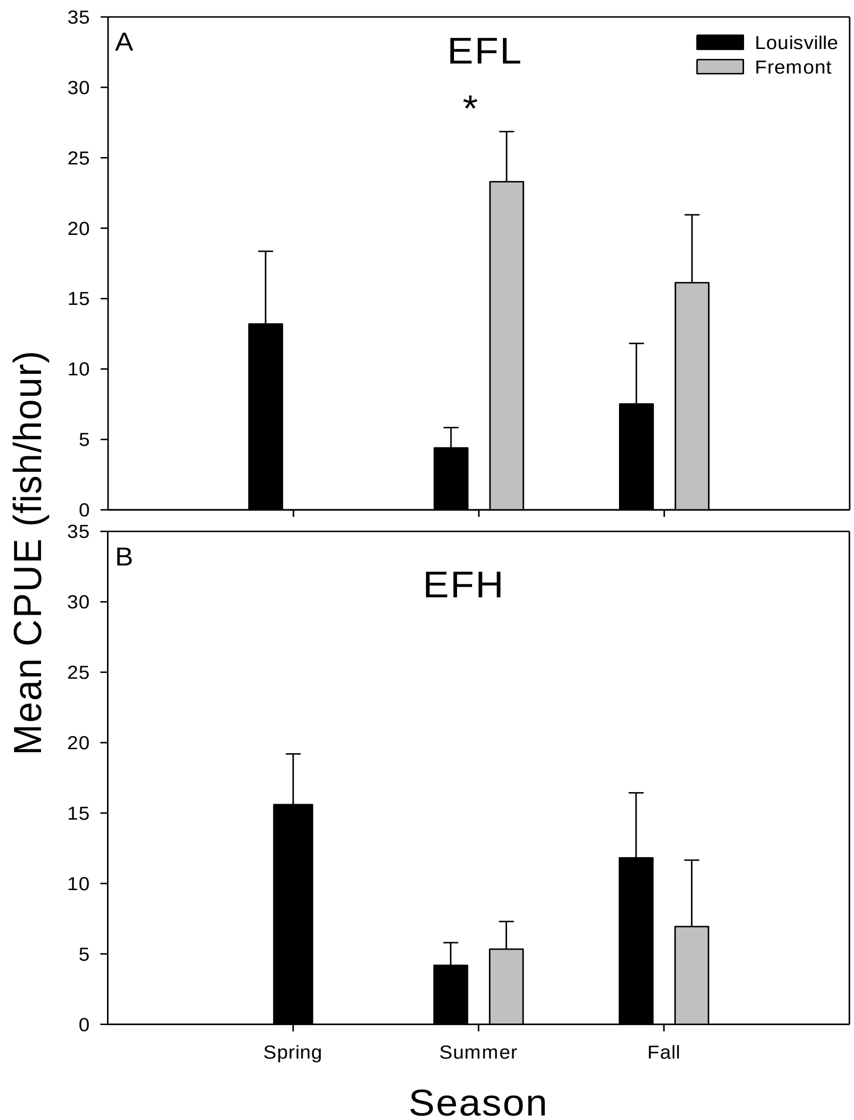

Figure 2-5. Seasonal mean catch per unit effort (CPUE) of channel catfish ≥ 200-mm collected with low pulsed-DC electrofishing (EFL; A) and high pulsed-DC electrofishing (EFH; B) at Louisville and Fremont in 2010. Error bars represent 1 SE. Asterisks above plots indicate differences in CPUE between sites.

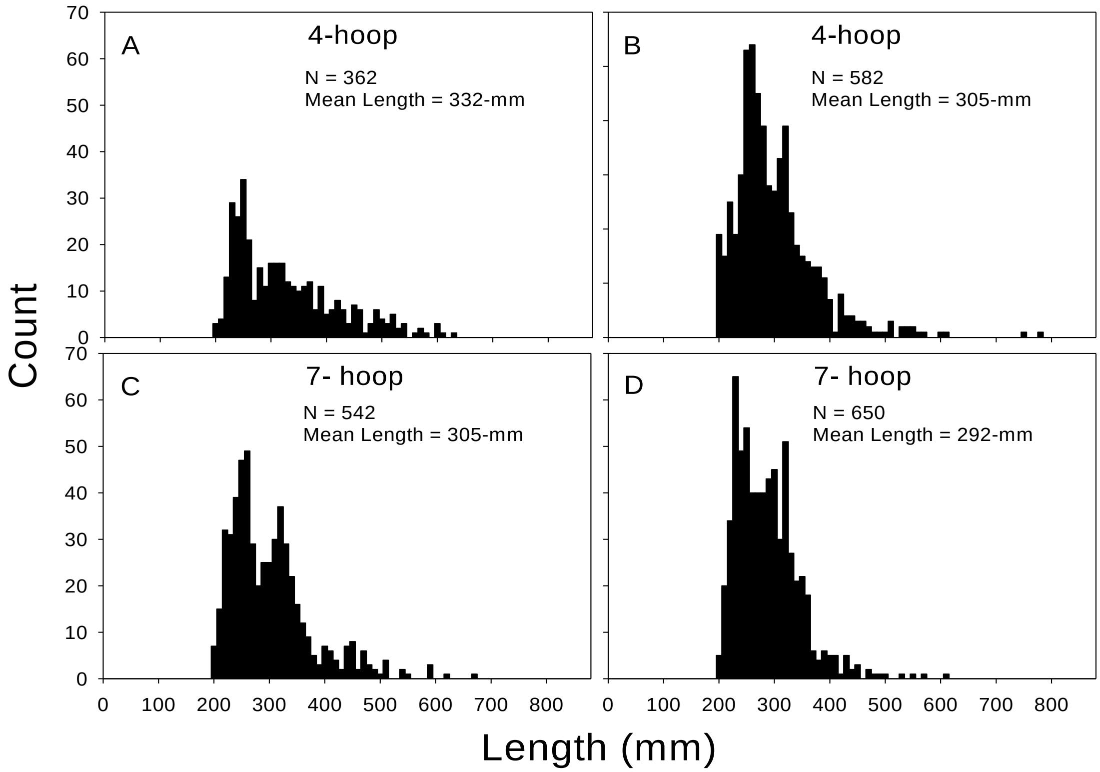

Figure 2-6. Length-frequency distributions of channel catfish ≥ 200-mm collected in 2010 at Louisville with 25-mm, 4-hoop, hoop nets (4-Hoop; A), at Fremont with 25-mm, 4-hoop, hoop nets (4-Hoop; B), at Louisville with 25-mm, 7-hoop, hoop nets (7-Hoop; C), and at Fremont with 25-mm, 7-hoop, hoop nets (7-Hoop; D).

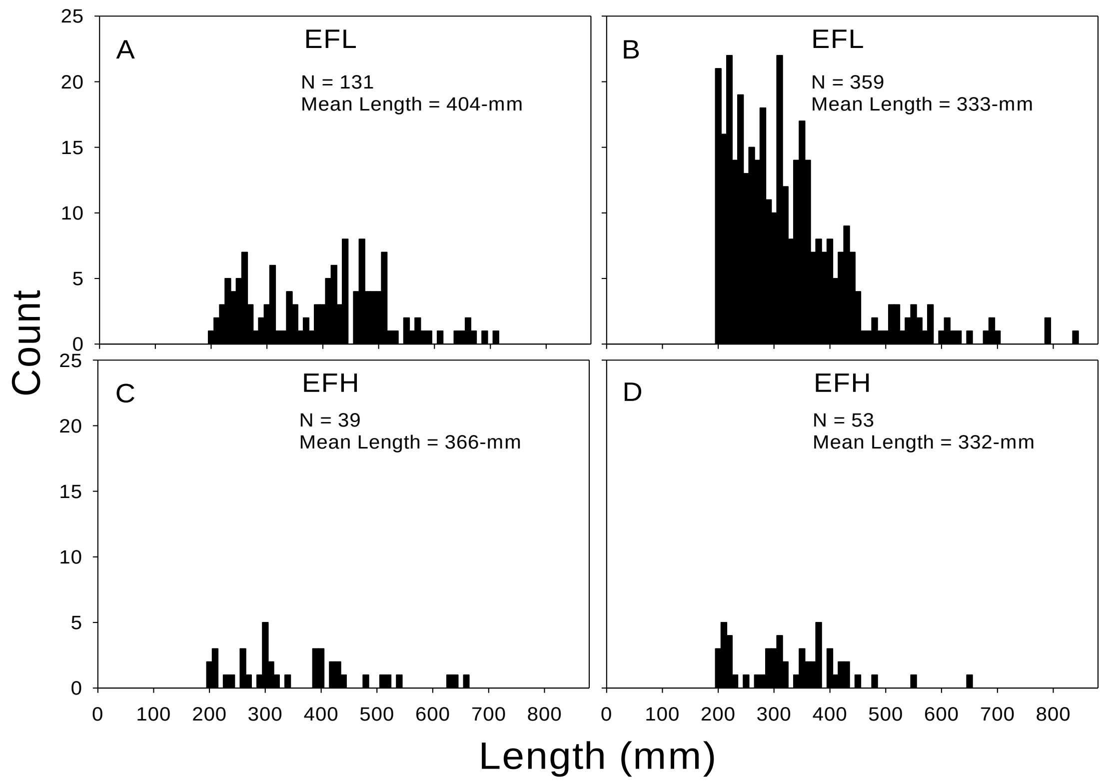

Figure 2-7. Length-frequency distributions of channel catfish ≥ 200-mm collected in 2010 at Louisville with low pulsed-DC electorfishing (EFL; A), at Fremont with low pulsed-DC electorfishing (EFL; B), at Louisville with high pulsed-DC electrofishing (EFH; C), and at Fremont with high pulsed-DC electrofishing (EFH; D).

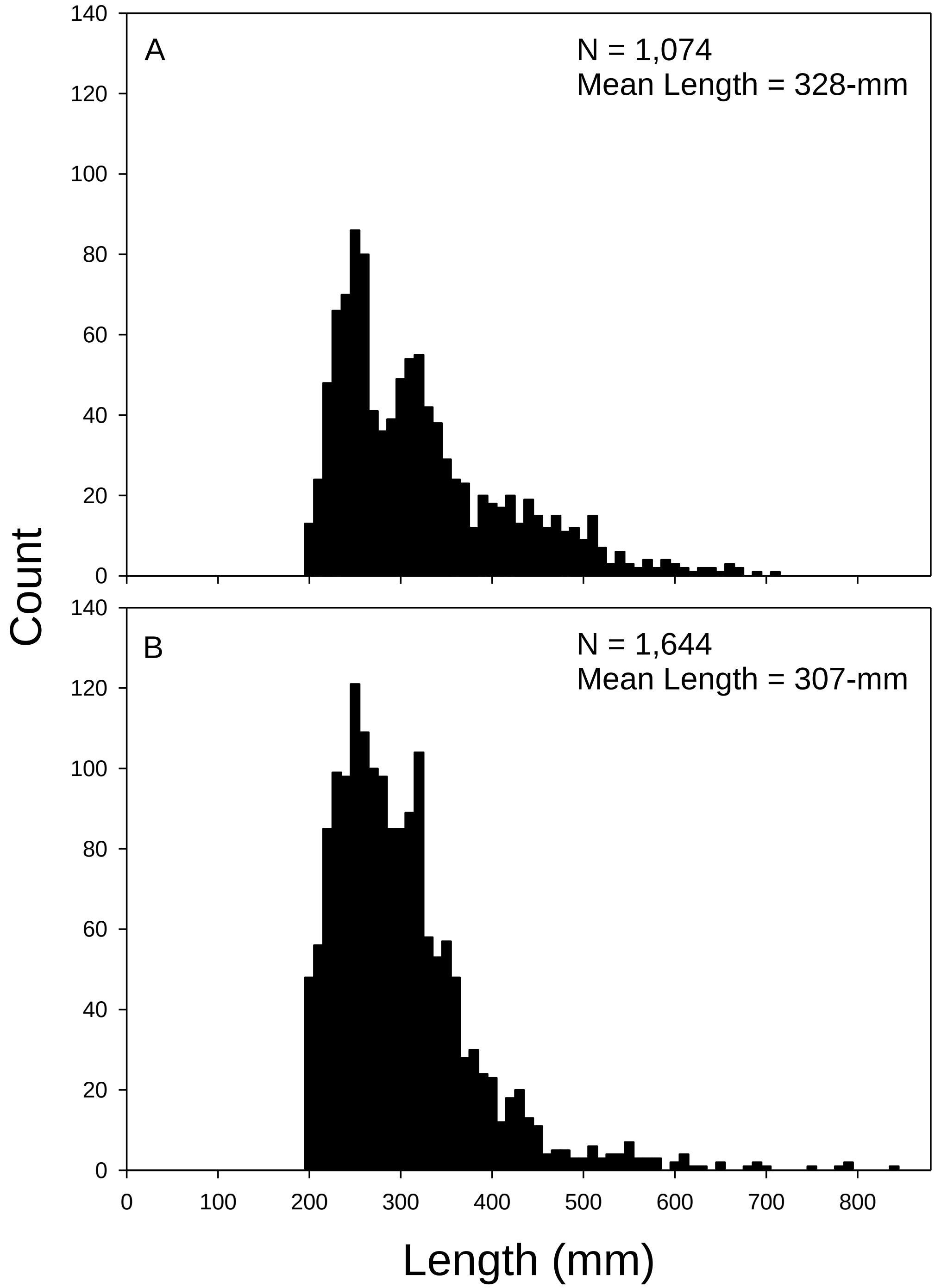

Figure 2-8. Length-frequency distributions of channel catfish ≥ 200-mm collected with all sampling gears in 2010 at Louisville (A) and Fremont (B).

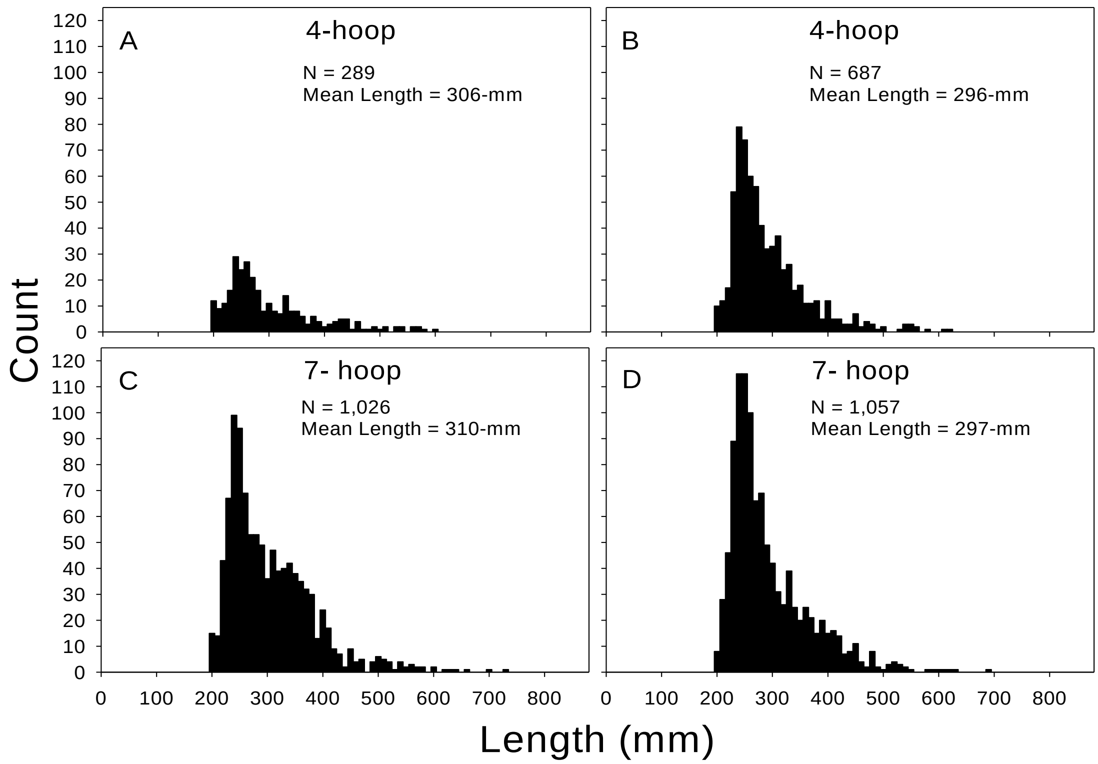

Figure 2-9. Length-frequency distributions of channel catfish ≥ 200-mm collected in 2011 at Louisville with 25-mm, 4-hoop, hoop nets (4-Hoop; A), at Fremont with 25-mm, 4-hoop, hoop nets (4-Hoop; B), at Louisville with 25-mm, 7-hoop, hoop nets (7-Hoop; C), and at Fremont with 25-mm, 7-hoop, hoop nets (7-Hoop; D).

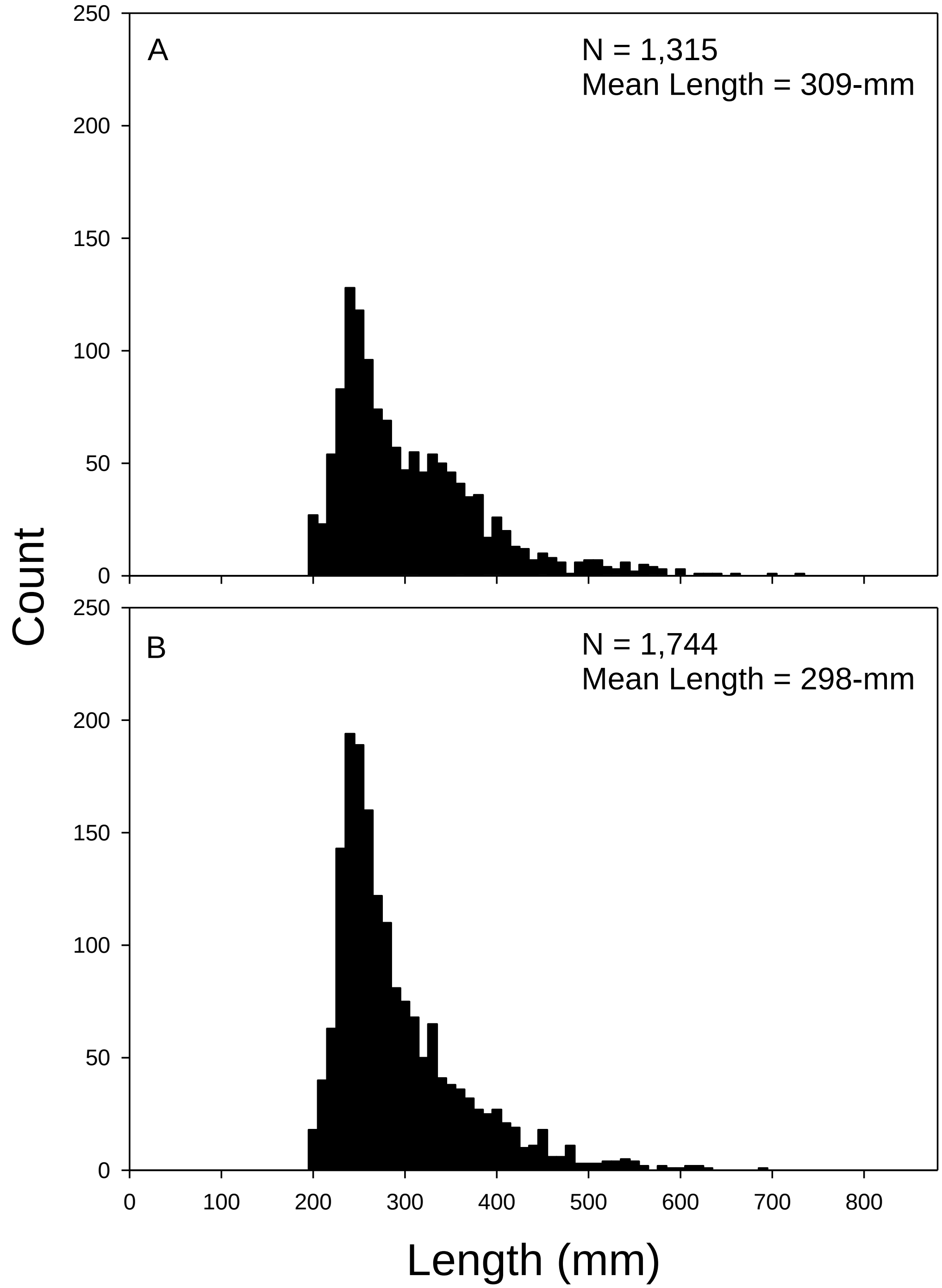

Figure 2-10. Length-frequency distributions of channel catfish ≥ 200-mm collected with all sampling gears in 2011 at Louisville (A) and Fremont (B).

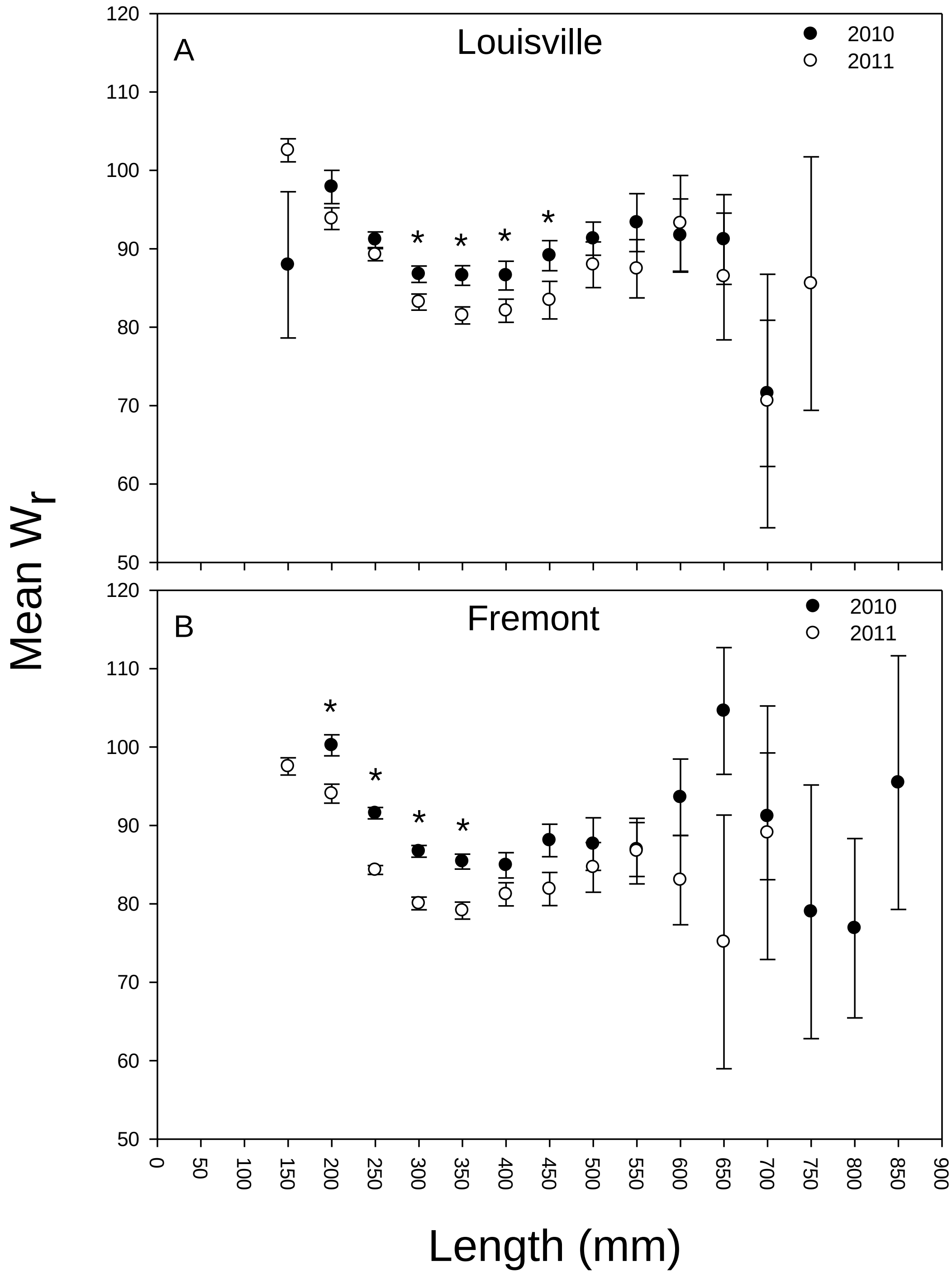

Figure 2-11. Mean relative weight (W_r) of channel catfish by 50-mm length groups collected with all sampling gears in 2010 and 2011 at Louisville (A) and Fremont (B). Error bars represent 1 SE. Asterisks indicate differences in mean relative weight between years.

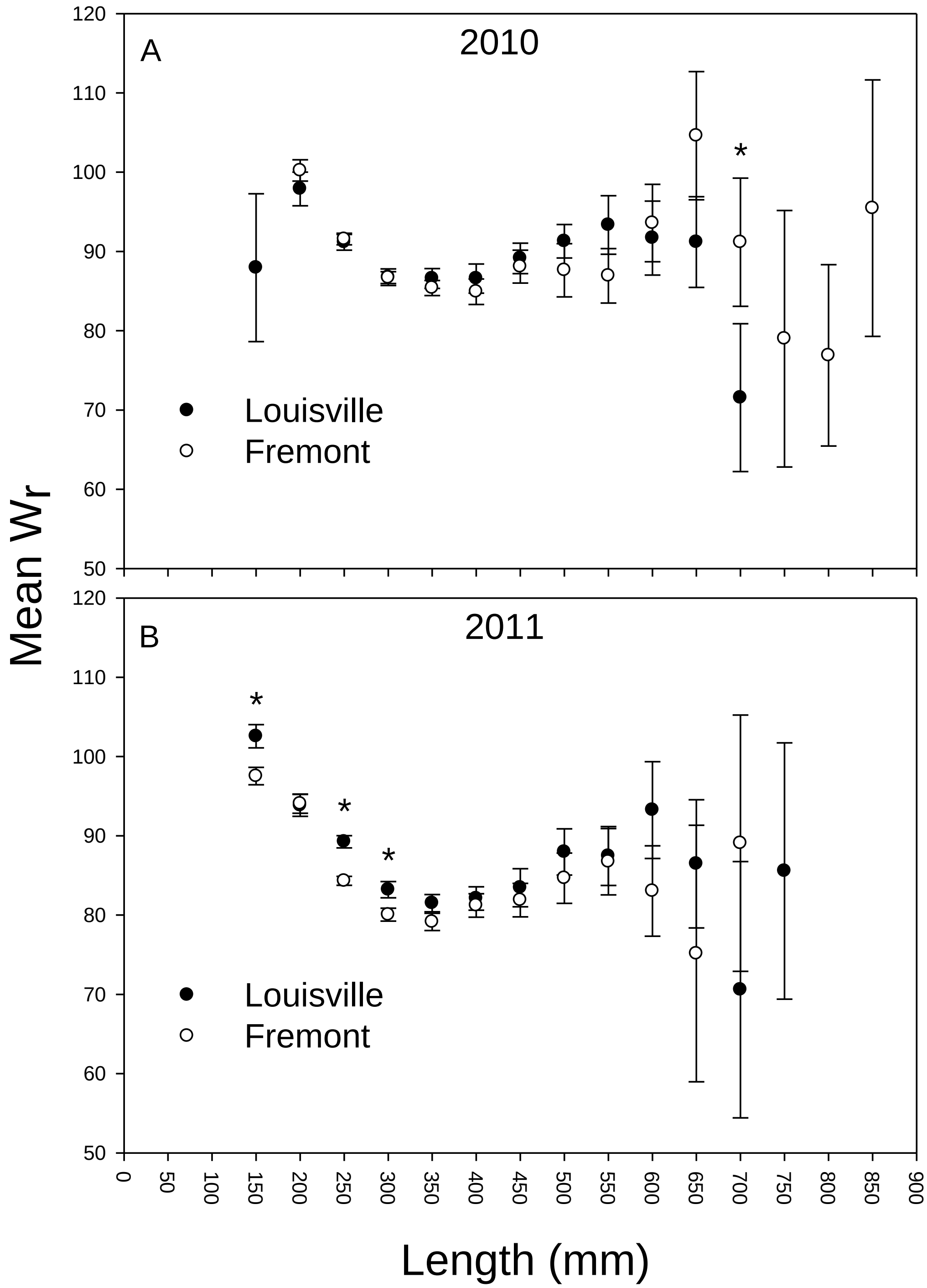

Figure 2-12. Mean relative weight (W_r) of channel catfish by 50-mm length groups collected with all sampling gears in 2010 (A) and 2011 (B) at Louisville and Fremont. Error bars represent 1 SE. Asterisks indicate differences in mean relative weight between sites.

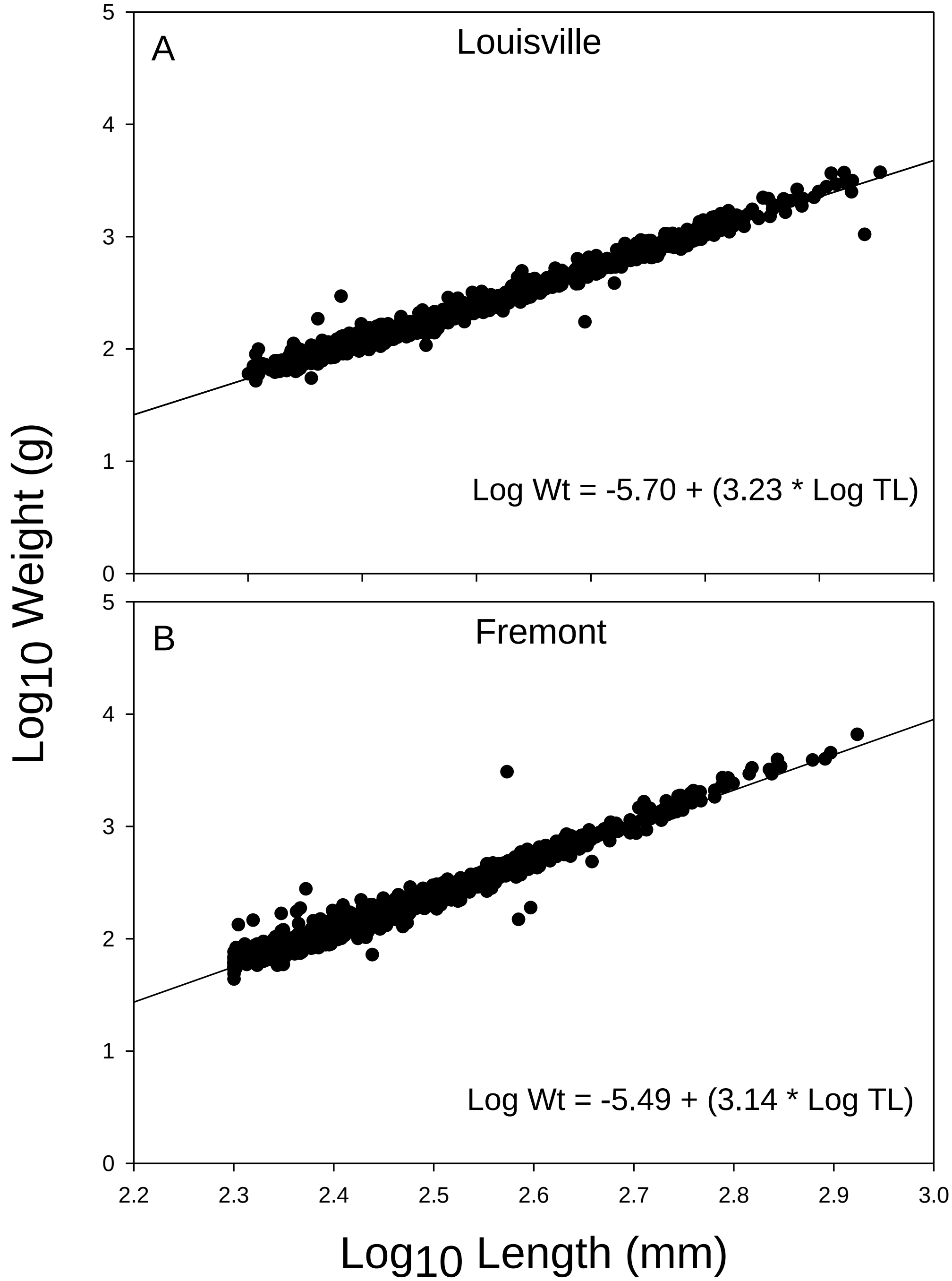

Figure 2-13. Log_{10}-transformed length-weight relation of channel catfish collected with all sampling gears in 2010 at Louisville (A) and Fremont (B).

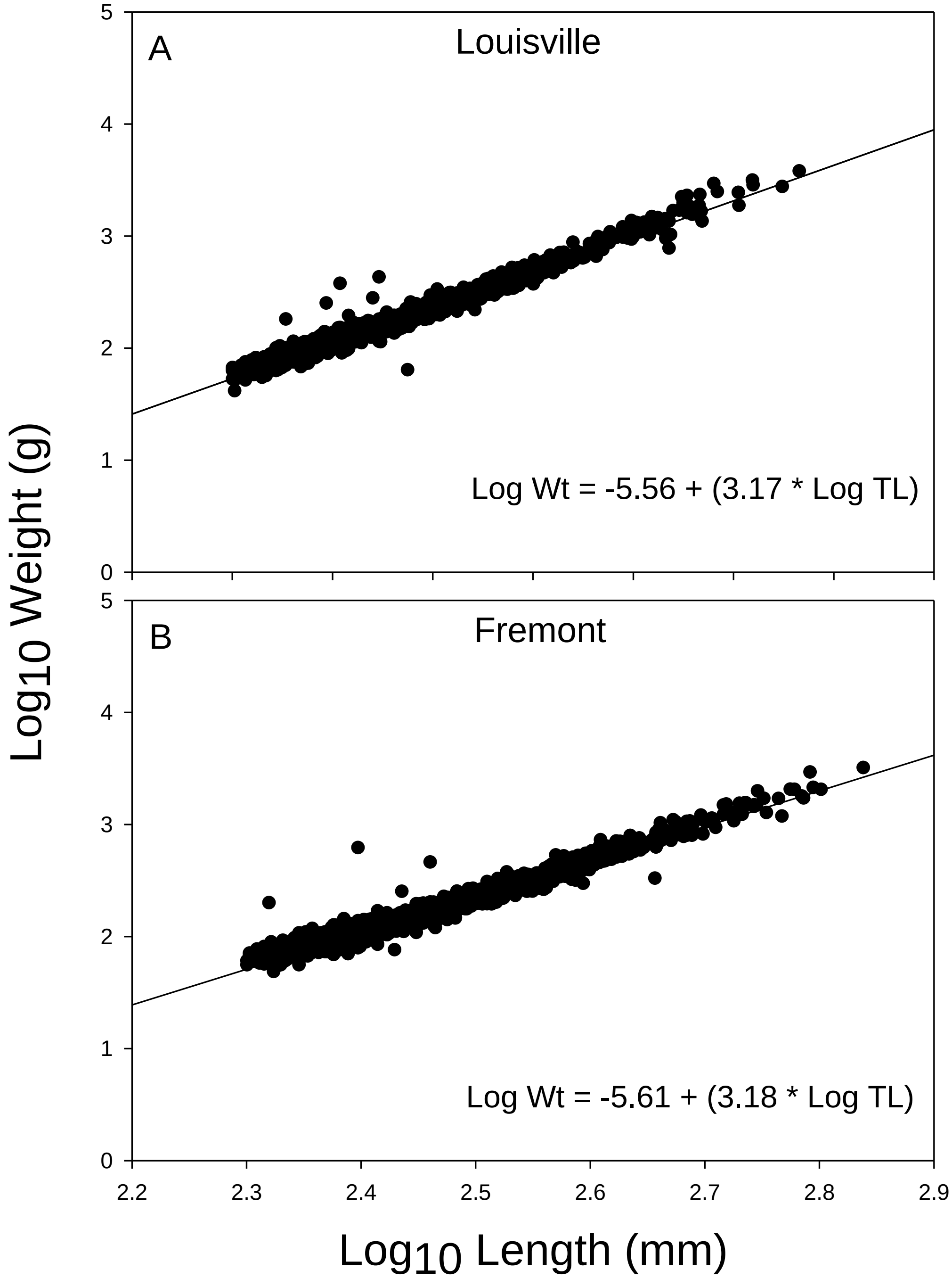

Figure 2-14. Log_{10}-transformed length-weight relation of channel catfish collected with all sampling gears in 2011 at Louisville (A) and Fremont (B).

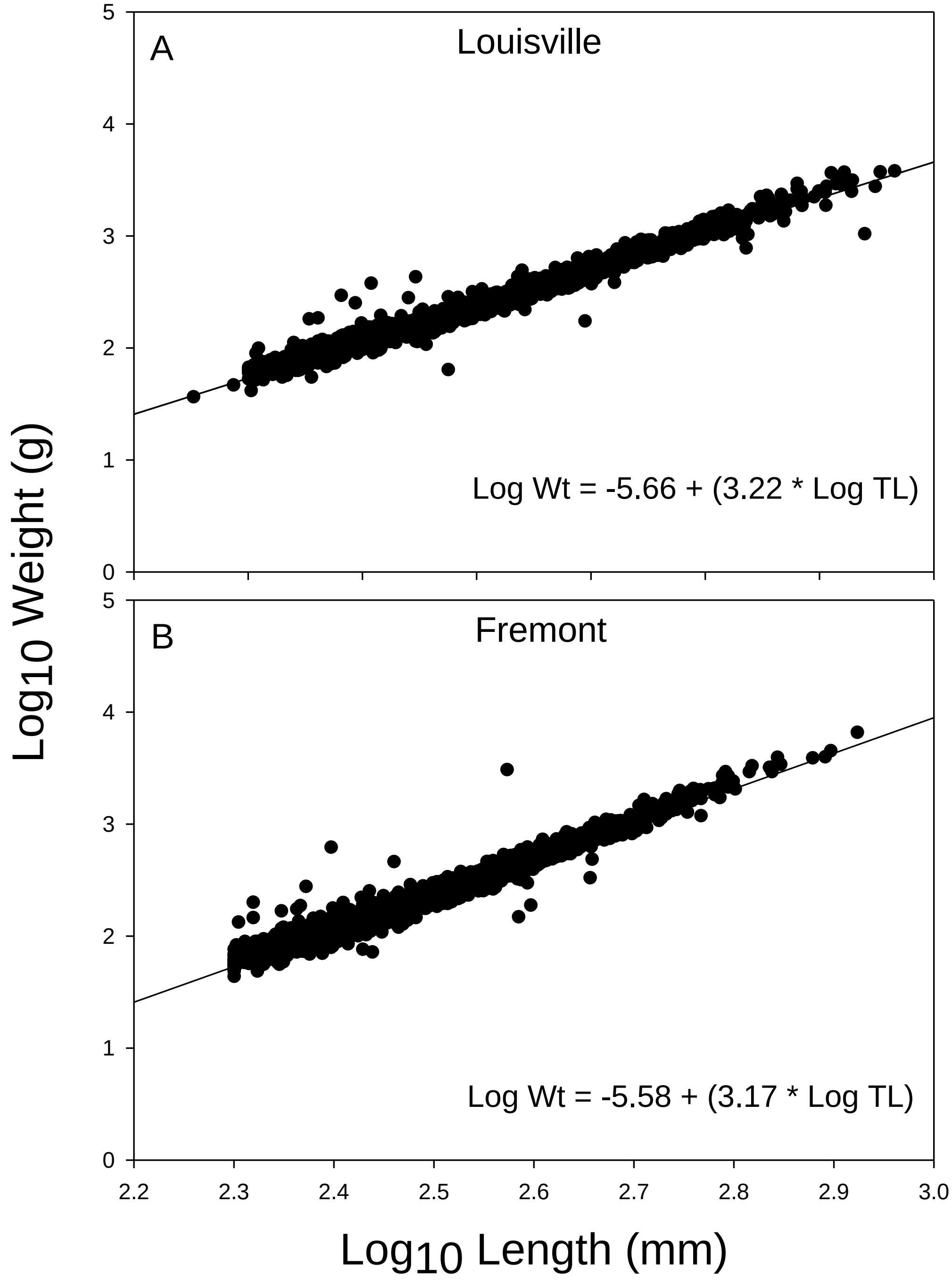

Figure 2-15. Log_{10}-transformed length-weight relation of channel catfish collected with all sampling gears in 2010 and 2011 at Louisville (A) and Fremont (B).

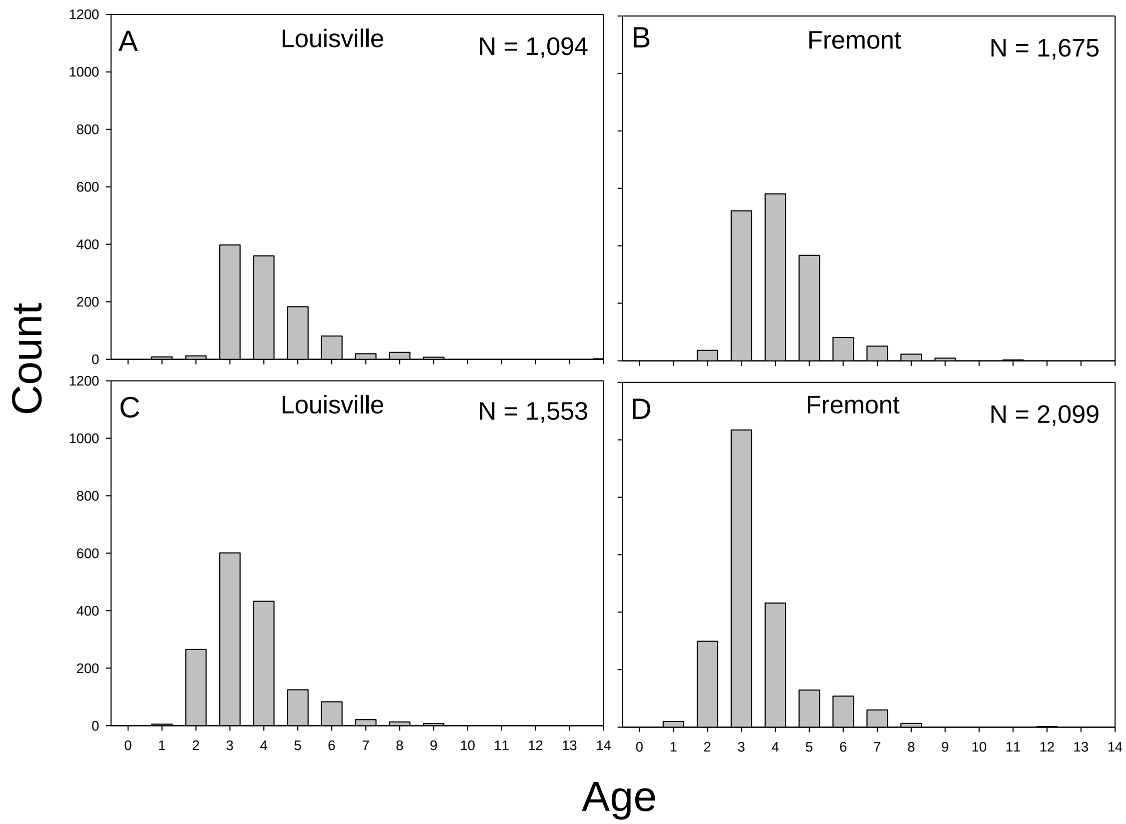

Figure 2-16. Age distributions of channel catfish collected with all sampling gears 2010 at Louisville (A) and Fremont (B), and in 2011 at Louisville (C) and Fremont (D).

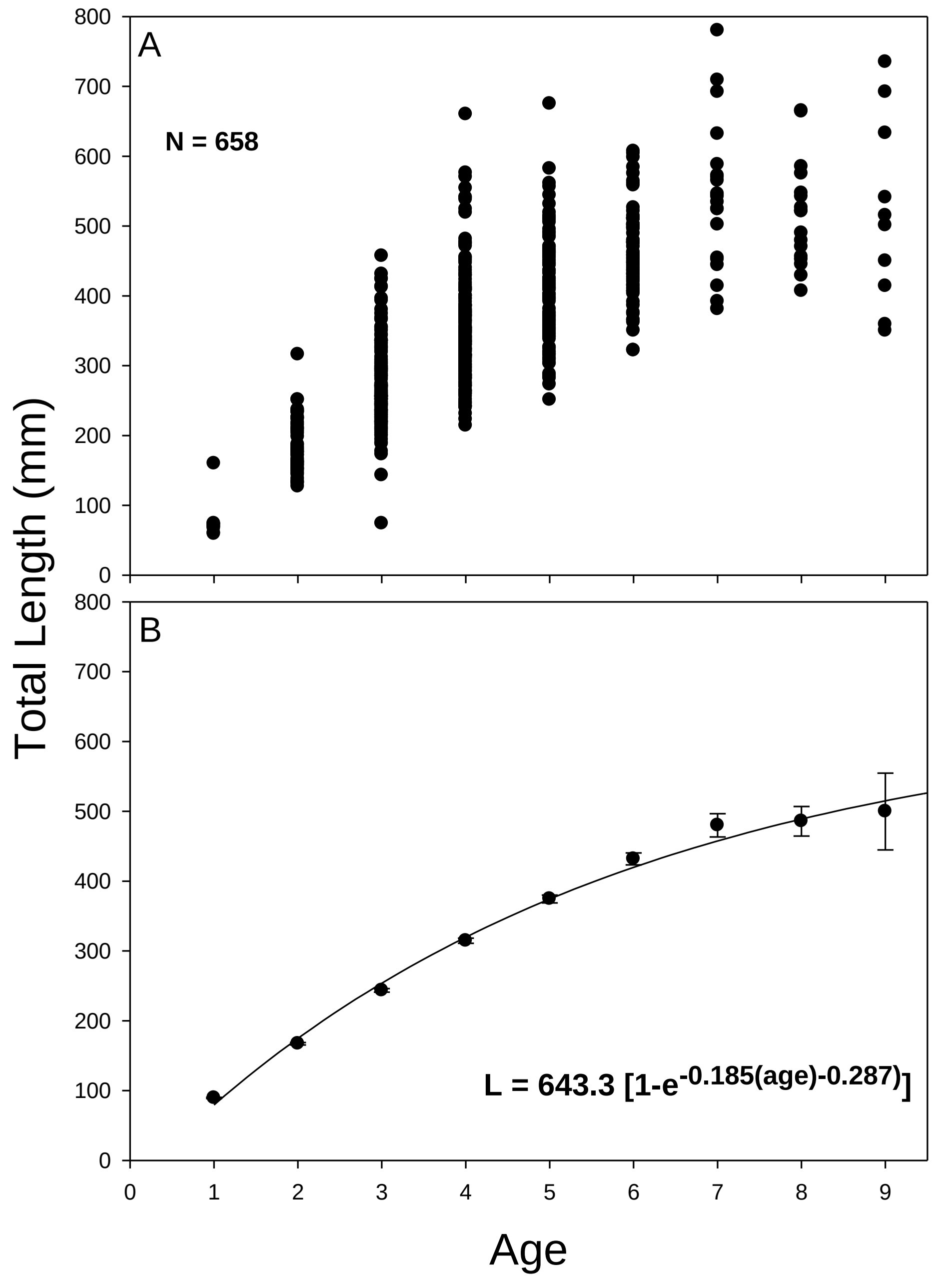

Figure 2-17. Individual length at capture (A), mean length at capture and von Bertalanffy growth function (B) of channel catfish collected with all sampling gears at Louisville during 2010 and 2011. Error bars represent 1 SE.

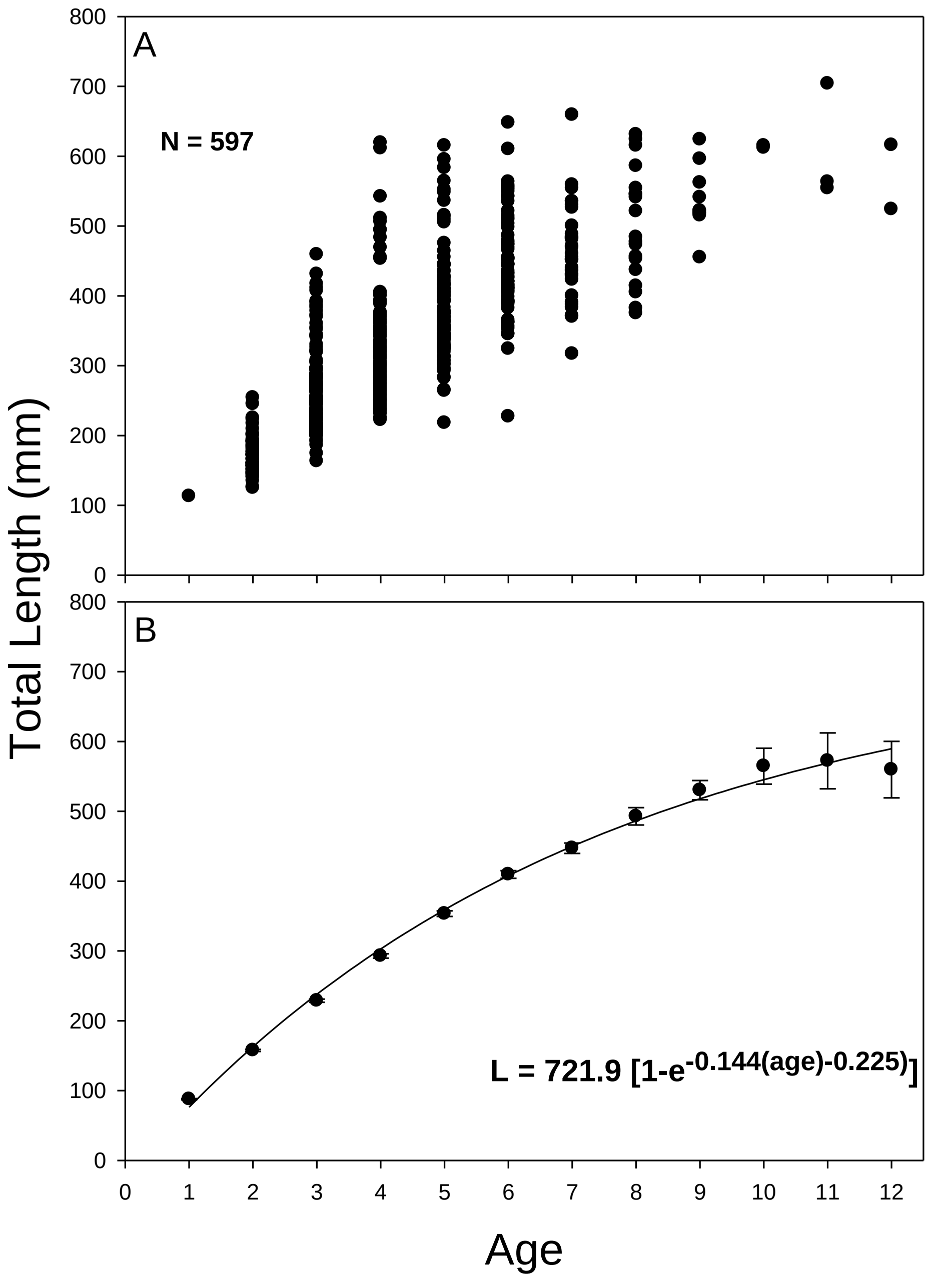

Figure 2-18. Individual length at capture (A), mean length at capture and von Bertalanffy growth function (B) of channel catfish collected with all sampling gears at Fremont during 2010 and 2011. Error bars represent 1 SE.

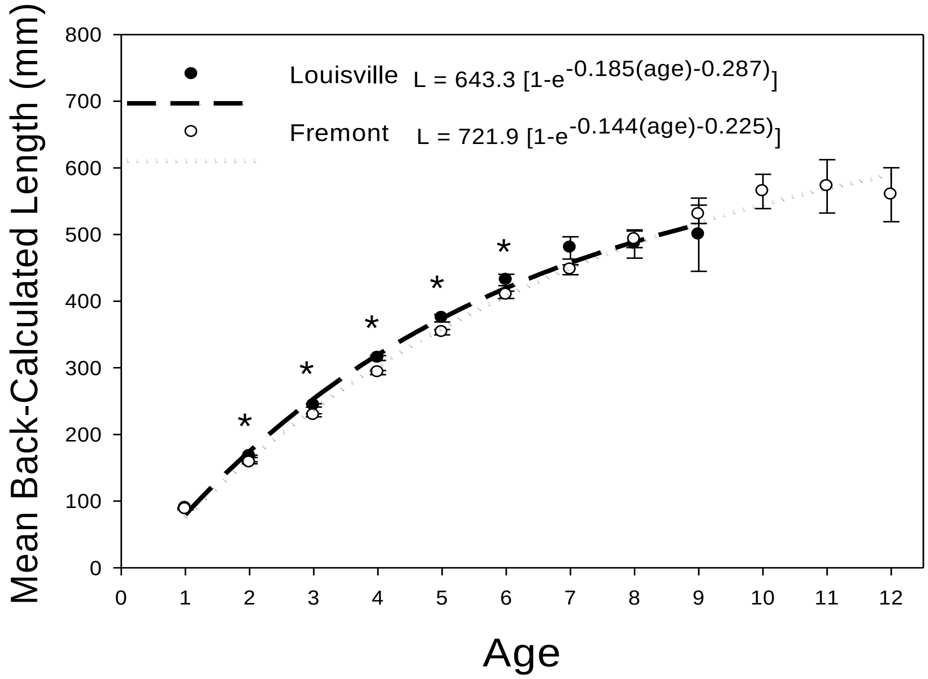

Figure 2-19. Mean back-calculated length at age and von Bertalanffy growth functions of channel catfish collected with all sampling gears at Louisville and Fremont during 2010 and 2011. Error bars represent 1 SE. Asterisks indicate differences in mean back-calculated length at age between the Louisville and Fremont.

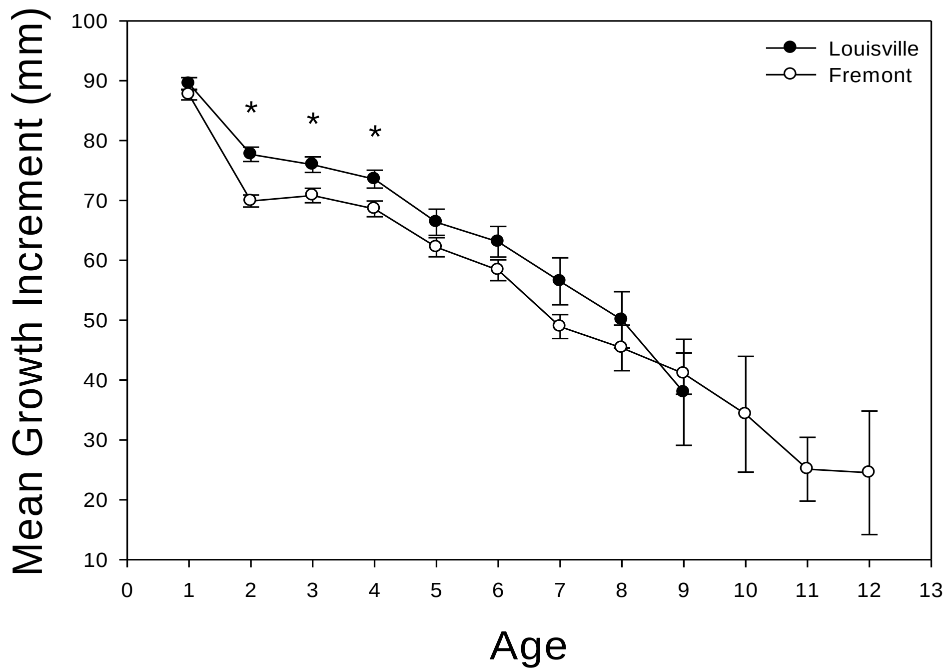

Figure 2-20. Annual Mean annual growth increment of channel catfish collected with all sampling gears at Louisville and Fremont River during 2010 and 2011. Asterisks indicate differences in mean annual growth increments between sites.

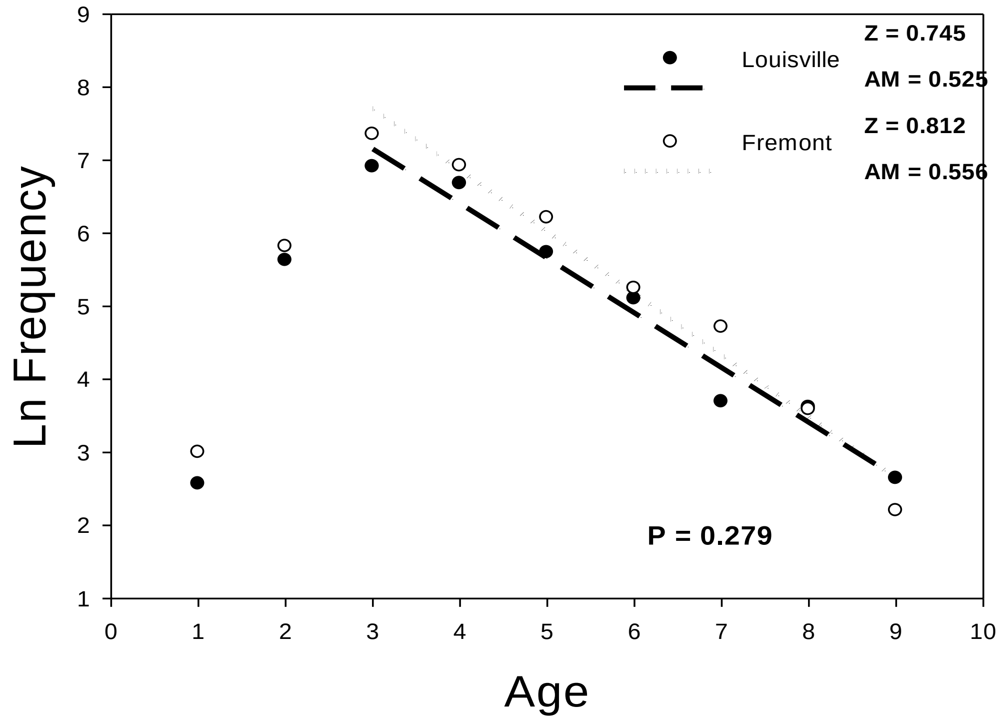

Figure 2-21. Weighted regression catch curves for channel catfish collected from all sampling gears at Louisville and Fremont during 2010 and 2011. P-value is reported for ANCOVA testing for difference in regression line slope (instantaneous mortality, Z).

Chapter 3. Mark-recapture population size estimates and movements of channel catfish at two high use areas in the lower Platte River, Nebraska.

Introduction

Mark-recapture studies have been used as a general sampling and analysis method to assess population status and trends in many biological populations (Burnham et al. 1994). Numerous mark-recapture studies have been conducted to gain a better understanding of fish dynamics and movement (Newcomb 1989, Gerhardt and Hubert 1991, Muoneke 1994, Billman and Crowl 2007, Barada 2009, Steffensen et al., 2012). Muoneke (1994) used a mark-recapture design to asses a heavily exploited white bass population in Texas. The author looked at angler harvest by seasonal time frames, and found that white bass are much more susceptible to angling during the spring spawn. Steffensen et al. (2012) estimated population size and temporary emigration parameters of pallid sturgeon in the Missouri River. Catfish studies have also been conducted using mark-recapture. Gerhardt and Hubert (1991) implemented a mark-recapture study using anchor tags to gain a better understanding of channel catfish fishing mortality in the Powder River system in Montana and Wyoming. Newcomb (1989) used a tagging approach to study overwintering habitats of catfish in the Missouri River. Barada (2009) also used a mark-recapture study in an enclosed side channel in the Platte River to asses gear selectivity and bias. Information gained from these studies have helped biologists better estimate population sizes, mortality rates, and facilitate setting harvest limits based on population estimates through time.

Current fish management strategies are largely based on relative abundance data. Relative abundance is assumed to be related to absolute abundance (*N*) in a specific area (A) by means of a coefficient of constant catchability (*q*) resulting in the general relation between catch per unit effort (CPUE) and abundance represented as:

$$CPUE = q(N/A).$$

However, several studies have shown that *q* is often sensitive to changes in fish distributions (Paloheimo and Dickie 1964), fish density (Ricker 1975, Hilborn and Walters 1992), and environmental factors (Hubert and Fabrizio 2007). Thus, measures of CPUE may not truly reflect differences in abundance as much as they reflect differences related to other factors such as distributions, density, and environmental factors. Thus, the use of mark-recapture approaches could provide insights into the CPUE=N relation, estimates of absolute abundance (N), and angler harvest and movement patterns of channel catfish needed for accurate management decisions. No absolute abundance estimates have been conducted on the Platte River. Therefore, my objectives were to 1) estimate absolute abundance of channel catfish at two high use areas in the lower Platte River, and 2) examine movement patterns (e.g., immigration and emigration) of channel catfish in the high use areas.

Methods

Study Area

The Platte River, an alluvial, sand bottom, braided river, is formed at the confluence of the North and South Platte rivers. The river exhibits dynamic shifts in its bed as sand bars are consistently moving down the river altering channel dimensions, and continually changing habitat quantity, quality and availability (Sidle et al. 1989, Simons 2000). Fluctuations in water availability, primarily influenced by high or low precipitation, irrigation withdrawals, and flow manipulations of the Loup River Power Canal, play a key role in determining habitat quantity, quality, and availability in the lower Platte River.

I chose two sampling sites in the lower Platte River, which are known to be high use fishing areas (Holland and Peters 1994) (Figure 3 - 1). The “Fremont” sampling site was between river kilometer (RKM) 88-98, near Fremont, Nebraska. The Platte River near Fremont is used heavily by anglers. A mail survey designed to document fishing pressure and harvest in the lower Platte River by Holland and Peters (1994) showed that 30% of respondents fished the Fremont area in 1992. Areas directly up-river and down-river of Fremont also documented heavy fishing pressure. Nearly 18% of respondents fished the Woodcliff area, while 17% fished the Cedar Lakes area. Holland and Peters (1994) also surveyed anglers and airboat usage, and found the Fremont had the most airboat traffic in the lower Platte River.

The “Louisville” sampling site was between RKM 24-34 which is located near Louisville. A mail survey by Holland and Peters (1994) showed that 20% of respondents fished the Louisville area in 1992. However, drastically lower fishing pressure was documented directly up-river and down-river of the Louisville area. Only 9% of respondents fished the South Bend area, while 7% stated they fished the Cedar Creek area. Both sites are located near large metropolitan areas (i.e., Omaha and Lincoln) which provide the majority (52%) of anglers who fish the lower Platte River.

Field Collections

Hoop nets, 0.6-m diameter, 7-hoop 25-mm mesh (7-hoop) and 0.5-m diameter 4-hoop, 25-mm mesh (4-hoop) baited with scrap cheese and electrofishing were used to collect channel catfish at both sites. Hoop nets were anchored at the cod end and an anchor lead was tied to the shoreline. Nets were deployed parallel to the shoreline in a variety of habitat types. Spring sampling (March – May) consisted of 20 deployments of the 4-hoop, hoop nets to follow standard sampling protocol (Chapter 4). Summer (June – September) and fall (October – November) sampling consisted of 10 gear deployments per day of each type of net. Hoop net sets did not exceed 24 hours.

Electrofishing was conducted using a cataraft (River King Catarafts, Port Ludlow, Washington) equipped with an MBS-2D Wiscosnsin box (ETS Electrofishing LLC, Madison, Wisconsin) powered by a 3500 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 (EFH; 4-8 A, 180-240 V, 60 pulses/s, 50% pulse width) and low frequency (EFL; 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 netting 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 individual's netted fish from the bow of the vessel.

All captured fish were measured (total length), weighed, and returned to the water. Channel catfish that were of taggable size (≥ 200-mm) received and adipose clip, to account for tag loss, and were tagged by implanting a FD-94 T-bar anchor tag (Floy mfg.) between the dorsal pterygiophores on the fish's left side. All tags had a unique identifier number, as well as a phone number for anglers to report tagged fish.

Data Analysis

Population estimates were derived using a Robust design (Kendall et al. 1997) in program MARK (White and Burnham 1999) which provides estimates of population size, survival, capture and recapture rates, and temporary emigration rates. The robust design is a unique combination of mark-recapture population methods that includes abundance (assumes closed population) and Jolly-Seber (assumes open population) analysis methods. Robust sampling designs include primary sampling periods (Jolly-Seber) with repeated secondary sampling periods (closed) that occur during a short time interval within the primary periods. Therefore, there are a variety of assumptions that must be met for both the closed capture and Jolly-Seber methods. These assumptions are (1) the population is assumed closed to additions and deletions for all secondary sampling sessions within a primary period, (2) temporary emigration is assumed to be either completely random, Markovian, or based on a temporary response to first capture, and (3) survival rates are assumed to be the same for all animals in the population, regardless of availability for capture (Cooch and White 2010).

Fish collections were rotated weekly by site (i.e., one week sampling at Fremont, followed by one week sampling at Louisville). To meet closure assumptions I used a week of sampling as primary periods (open population) broken down by days as secondary periods (closed population). Angler recaptured fish that were caught within the sampling site during a primary session were added into that primary session. Angler recaptured fish that were not caught during primary sessions, usually weekends, were added to the nearest primary session by date caught. Tag loss was estimated by calculating the percentage of channel catfish recaptured without a tag present, however, population estimates did not account for tag loss.

I created individual capture histories for each tagged fish collected at each site as described by Cooch and White (2010). All secondary periods (dates sampled) were included in encounter histories. A specific capture history may look something like:

1000000010000001

where each number represents a sampling day. The first "1" represents the day the fish was first captured, and the second and third "1" would be days that the fish was recaptured. Primary sessions were then added into the capture history to format the data like:

1000 0000 1000 0001

Primary sessions were grouped by week; therefore, the first "1000" would represent four days of data collection (e.g., sampling was conducted on Tuesday, Wednesday, Thursday, and Friday of a given week of sampling).

I knew *a priori* that our annual sample sizes could limit the number of parameters estimable, and the robust design is parameter-rich (Kendall et al. 1997). Therefore, I kept annual survival (*S*) and emigration parameters (γ' and γ'') time-constant to ensure that sample sizes were large enough to estimate all parameters. I was able to incorporate some temporal variation by allowing capture (*p*), recapture (*c*), and population size (*N*) to vary by primary session. Models included/allowed for scenarios of equal or unequal capture and recapture probabilities (i.e., $p_{.} = c_{.}$ or $p. \neq c_{.}$), as well as varying estimates of N by combined years (N.) or separate years (N^{yearly}). Population estimates were determined as the number of channel catfish ≥200-mm in the effective sampling area (e.g., defined as the area from which fish could have been captured by our methods).

The major advantage of the robust design is its capability to estimate temporary emigration rates by two parameters: γ' and γ''. Kendall et al. (1997) defined the parameter γ' to be the probability an individual that is away from the study area remains away from the study area in the next time period, given the individual survives to the next time period (essentially, the probability that an animal that has emigrated away from the study area during time *t* does not immigrate back in time *t + 1*; immigration rate could be defined as 1 - γ', and γ'' to be the probability that an animal within the study area in time *t* emigrates from the study area in the next time period, given that it survives (essentially, a temporary emigration rate). Three different scenarios of γ' and γ'' ($\gamma' = \gamma''$, $\gamma' \neq \gamma''$, and $\gamma' = \gamma'' = 0$) were used. The first scenario, $\gamma' = \gamma''$, refers to random emigration (Kendall et al. 1997), in which the probability that an individual was away from the study area was the same, regardless of its position the previous time period. The second, $\gamma' \neq \gamma''$, or Markovian emigration (Kendall et al. 1997), refers to the probability of an individual being away from the study area could depend on its position (at the study area or away) the previous time period. Lastly, $\gamma' = \gamma'' = 0$, or "no emigration", specifically describes a scenario in which no emigration occurred.

Model selection is underpinned by a philosophical view that understanding can best be approached by simultaneously weighing evidence for multiple working hypotheses (Hilborn and Mangel 1997, Burnham and Anderson 2002). I used Akaike's information criterion (AIC) to compare all possible models (Burnham and Anderson 2002), and conducted analyses with the robust-design module of program MARK (White and Burnham 1999). I report AIC scores with a second-order correction for small sample sizes (AIC_c), which asymptotically become equal to AIC scores as sample size increases. Top models for both Louisville and Fremont were selected based on lowest AIC_c scores.

The robust design provides estimates of population size (*N*) for the effective sampling range (defined as the area from which fish could have been captured by our methods). However, an estimate of the sample reach population (the area in which fish could immigrate to and emigrate from—in our case the 10-rkm stretch of the Platte River at each sampling site) were obtainable because the estimates of temporary emigration (γ' and γ'') allow a larger inference that allows further estimates of density in my sample areas. Density estimates were calculated using population estimates from the sample reach population. Area was determined by calculating the length (10-km) by mean width (0.3-km at Fremont, 0.4-km at Louisville) of each river reach.

Movement of individuals was evaluated using angler returned tags. Distance traveled was estimated by centerline measures along the thalweg of the Platte or other river with the path tool in Google Earth. Distance estimates are conservative given the error associated with the ruler tool in Google Earth as well as not knowing the exact position where each fish was caught or where the fish had been between observations.

Results

A total of 3,206 channel catfish were tagged at Fremont (Tables 3-1), and 2,253 channel catfish were tagged at Louisville (Table 3-1). Recapture rates were highest for Louisville (5.19%) compared to Fremont (3.65%) (Table 3-2). Total recapture rate during sampling was greater (3.59%) than angler return rates (1.56%) (Table 3-2). Anglers harvested 63% of the channel catfish they caught and tag loss was approximately 20%.

Abundance Estimates

Top models were the same for both sites: $(\text{Ø}.)\ (\gamma'.) \neq (\gamma''.)\ (p_t)=(c_t)\ (n^{(yearly)})$ (Tables 3-3; 3-4), in which capture and recapture rates were equal and varied by primary session, population estimates varied by year, and emigration parameters were not equal. Daily survival estimates were greater at Fremont (0.9981, 49% annual) compared to Louisville (0.9944, 13% annual). Temporary emigration estimates of *γ″* were greater at Fremont (0.905) compared to Louisville (0.784); however, estimates of *γ′* were nearly equal between sites (0.9998 at Louisville, 0.9995 at Fremont). Capture and recapture probabilities had a range of (0.0011 – 0.0067) at Louisville and (0.0016 – 0.0086) at Fremont. Population estimates in the effective sampling range Louisville were 8,281 (SE

= 1,486) in 2010 and 11,620 (SE = 2,016) in 2011, and estimates for Fremont were 24,261 (SE = 4,707) in 2010 and 14,359 (SE = 2,283) in 2011. Top models for both sites showed little or no immigration was taking place; therefore, conservative sample reach population estimates for each site were attained by extrapolating emigration parameter estimates (*y*'') to my 10-km study areas. Emigration parameter estimates at Louisville were 0.78; thus, I was only effectively sampling around 22% of the sample reach population. Fremont emigration parameter estimates were 0.90, meaning I was effectively sampling around 10% of the sample reach population. Sample reach population estimates for the 10-km river stretch at Louisville were 37,641 in 2010 and 52,818 in 2011, and estimates for Fremont were 242,610 in 2010 and 142,359 in 2011. Channel catfish density estimates at Louisville were 75 fish > 200-mm/ha in 2010, 106 fish > 200-mm/ha in 2011. Channel catfish density estimates at Fremont were 606 fish > 200-mm/ha in 2010, 356 fish > 200-mm/ha in 2011.

Movement

The majority of recaptured fish tagged at Louisville (86%) and Fremont (84%) were recaptured within the 10-km sampling area; however, some channel catfish did move out of their respective sample areas (Figure 3-2). Twenty three channel catfish were caught or moved through the Missouri River, of which 17 (74%) were tagged at Louisville (Table 3-5; 3-6; Figure 3-2)). Furthest distance traveled was approximately 436 km. This specific channel catfish was tagged at Fremont, moved into the Missouri River, and was caught below Gavins Point Dam (Table 3-5). Four channel catfish, two from each tagging site, were caught at or near the Big Sioux River confluence with the

Missouri River (Table 3-9). Furthermore, one of the two fish tagged at Fremont traveled at least 316 km in 77 days, moving a minimum average of 4.1 km per day (Table 3-5).

Channel catfish were also found in tributaries of the Platte and Missouri Rivers (Table 3-6; Figure 3-2). Two channel catfish were caught in the James River, a tributary of the Missouri River, near Yankton, SD (Table 3-6). Five channel catfish moved into the Elkhorn River or into Bell Creek, a tributary to the Elkhorn River; whereas, Wahoo Creek, a tributary of Salt Creek, had one fish recaptured in it (Table 3-6). Three channel catfish were also captured outside the 10-km sampling areas in sandpit lakes along the Platte River, which are only connected to the river during high water events.

Discussion

Otis et al. (1978) stated the assumption of a closed population is "never completely true in a natural biological population." However, the assumption of closure "can be met at least approximately" with proper study designs. I attempted to minimize any bias associated with violations of the closure assumption by using a robust design. The robust design is uniquely suited to help meet closure assumptions during short intervals (secondary periods), and still account for fish movements throughout reaches of the Platte River using emigration parameters. Furthermore, the emigration parameters in the robust design allowed me to estimate true abundance and density at each of my sampling sites.

Channel catfish densities from this study (75-106 channel catfish ≥ 200-mm/ha at Louisville, 356-606 channel catfish ≥200-mm/ha at Fremont) are generally greater than other densities reported in the midwest and Canada. Haxton and Punt (2004) found channel catfish densities ranged from 4-32 fish/ha throughout six locations in the Ottawa River. Parrett et al. (1999) found channel catfish densities ranged from 11-202 fish/ha in Ohio impoundments. However, it should be pointed out that density estimates by Haxton and Punt (2004) and Parrett et al. (1999) did not implement minimum length as in this study, so comparative density estimates may actually be smaller. Density estimates have also been calculated in the Missouri River. Goble (2011) estimated channel catfish density at 194 fish ≥ 200-mm/ha near Decatur, NE. Furthermore, Newcomb (1989) found densities ranged from 7-60 channel catfish ≥ 250-mm/ha at three sites in the Missouri River. Goble (2011) hypothesized that the increase in channel catfish abundance in the Missouri River between his and Newcomb's studies may be due to differences in minimum tagging length (200-mm vs. 250-mm), or the closing of the commercial fishery in 1992.

Channel catfish density estimates in the Platte River may be greater than other densities reported because different population estimators were used. Newcomb (1989), Haxton and Punt (2004), and Goble (2011) used the closed capture methods (Schnabel or Closed capture methods in program MARK) to estimate population size in river systems, which assumes no emigration or immigration, and does not account for fish outside the effective sampling ranges of the gears used. Conversely, the robust model used in this study accounts for emigration and immigration parameters, and allows for estimates of the sample reach population (the area in which fish could immigrate to and emigrate from). Density estimates from this study are likely greater because they are based on sampling reach population estimates rather than at a specific site.

More information is needed to fully evaluate the relative abundance relation to true abundance. However, my initial results suggest that there is a relation between the two, in which relative abundance data reflects relative changes to comparisons of N through time and across sites. Population estimates decreased at Fremont between 2010 and 2011. Hoop net (7-hoop) CPUE data displayed a similar trend of decreasing abundance at Fremont between 2010 and 2011 (Chapter 2). Furthermore, Hoop net (7-hoop) CPUE data and population estimates found greater abundance at Fremont in 2010, while in 2011 no differences were found (Chapter 2).

Estimates of y' and y'' were larger than expected and may have been large due to hoop nets only sampling a relatively small portion of the 10-km study area each sampling day. There is a large area of river that channel catfish may inhabit but would not encounter the hoop nets on any given day. The same holds true for estimates of y'', fish may not have needed to move far to be considered out of our effective sampling range, and therefore temporarily emigrated. Future research is needed to determine what the effective sampling range of baited hoop nets is in lotic systems. If the effective sampling range was determined, it would allow for more insight into estimates of y' and y''. Another hypothesis to explain high emigration rates lies in gear efficiency. Porath et al. (2011) determined hoop net escapement rates for channel catfish ranged from 4-13% at low densities (6 fish/net) and 14% at high density (60 fish/net). Mean hoop net CPUE for both sites was around 4 fish/net (Chapter 2); however, high catch rates (>30 fish/net) were not uncommon at Fremont. Escapement rates may be influencing emigration rates at both sites. For example, if channel catfish were escaping from the nets, the model assumes them to be absent, and therefore, temporarily emigrated.

I expected some channel catfish movements throughout the Platte River because channel catfish are known to be a mobile species in streams (Funk 1957; Trautman 1957, Bunnell 1988, Dames et al. 1989, Chapman et al. 1992, Pellet et al. 1998). However, I documented movements of 21 channel catfish to the Missouri River (Table 3-5), and nine channel catfish into tributaries of the Platte River or to the Missouri River (Table 3-6). The extent and distances of this movement was not expected, but provides some evidence that river connectivity may be important to channel catfish in the Platte River and Missouri River. Conversely, most fish did not move large distances. Some fish were recaptured within the same site they were tagged at over a year later. Dames et al. (1989) found similar movement patterns in channel catfish movement in Perche Creek, a tributary of the Missouri River. Dames et al. (1989) determined that resident populations of channel catfish were in Perche Creek and the Missouri River, as well as transient populations that moved between the two river systems. Recapture data from my study suggests that resident and transient populations may exist in the lower Platte River and Missouri River as well; however, further research is needed to confirm this hypothesis.

Mark-recapture studies have been used, and will continue to be used to gain more knowledge of population dynamics for a variety of aquatic and terrestrial biota. One major advantage of mark-recapture study designs is the ability to analyze data with a variety of methods. I chose to use a robust design because it was uniquely suited to not only analyze population estimates, but also to gain a better understanding of emigration and immigration rates in the lower Platte River. Results from my study provide the initial groundwork to further understand true abundance of channel catfish in the lower Platte River, and also add to our understanding of river networks and their connectivity. These results will assist managers in making important decisions, not only within the Platte River, but also its tributaries and the Missouri River.

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Table 3-1. Total number of channel catfish tagged in the spring, summer, fall, and all seasons in the Platte River near Fremont and Louisville in 2010, 2011, and combined years.

		2010		
Site	Spring	Summer	Fall	All Seasons
Fremont	142	685	783	1610
Louisville	116	349	606	1071
		2011		
Site	Spring	Summer	Fall	All Seasons
Fremont	317	605	674	1596
Louisville	144	368	670	1182
		2010-2011		
Site	Spring	Summer	Fall	All Seasons
Fremont	459	1290	1457	3206
Louisville	260	717	1276	2253
Totals	719	2007	2733	5459

Table 3-2. Total number of channel catfish recaptured in the spring, summer, fall, and all seasons and recapture method in the Platte River near Fremont and Louisville in 2010, 2011, and combined years.

2010 Recapture Totals					**Recapture Methods**	
Site	Spring	Summer	Fall	All Seasons	Sampling	Angler
Fremont	1	8	29	38	33	5
Louisville	1	4	33	38	35	3
2011 Recapture Totals					**Recapture Methods**	
Site	Spring	Summer	Fall	All Seasons	Sampling	Angler
Fremont	22	63	38	123	84	39
Louisville	11	21	47	79	43	36
2010-2011 Recapture Totals					**Recapture Methods**	
Site	Spring	Summer	Fall	All Seasons	Sampling	Angler
Fremont	23	71	67	161	117	44
Louisville	12	25	80	117	78	39
Totals	35	96	147	278	195	83

Table 3-3. Comparison of competing models used to describe channel catfish population estimates near Fremont, NE in the lower Platte River from 2010 to 2011. Models include survival (Ø), temporary emigration (γ'and *y''*), capture probability (*p*), recapture probability (*c*), and population size (*N*). Superscripts include "yearly" (channel catfish population estimates were allowed to vary by year). Subscripts include "*t*" (the parameter was allowed to vary by time—i.e., year or primary event), and "." (the parameter was constant across time). Models are ranked by corrected Akaike's information criterion (AIC*c*; the first row shows the highest-ranking model), where *k* is the number of parameters, ΔAIC*c* is the difference between a model's AIC*c* value and that of the highest-ranked model, and WAIC*c* is the Akaike weight (sum of all weights = 1.00).

Model	AICc	ΔAICc	WAICc	*k*
Ø. (γ'.) ≠ (γ".) $(p_t)=(c_t)$ (N^{yearly})	-22243.6346	0.00000	0.88009	19
Ø.(γ'.) ≠ (γ".) $(p_t)=(c_t)$ (N.)	-22239.6307	4.00390	0.11887	18
Ø. (γ'.) ≠ (γ".) $(p_t)≠(c_t)$ $N^{(yearly)}$	-22228.8723	14.76230	0.00055	33
Ø. (γ'=0) (γ"=0) $(p_t)=(c_t)$ (N^{yearly})	-22227.3267	16.30790	0.00025	17
Ø. (γ'= γ")$(p_t)=(c_t)$ (N^{yearly})	-22226.4377	17.19690	0.00016	18
Ø. (γ'.) ≠ (γ".) $(p_t)≠(c_t)$ (N.)	-22224.9172	18.71740	0.00008	32
Ø. (γ'=0) (γ"=0) $(p_t)≠(c_t)$ (N^{yearly})	-22216.1959	27.43870	0.00000	31
Ø. (γ'= γ") $(p_t)=(c_t)$ (N.)	-22215.4467	28.18790	0.00000	17
Ø. (γ'= γ") $(p_t)≠(c_t)$ (N^{yearly})	-22214.1682	29.46640	0.00000	32
Ø. (γ'=0) (γ"=0) $(p_t)=(c_t)$ (N.)	-22213.6245	30.01010	0.00000	16
Ø. (γ'=0) (γ"=0) $(p_t)≠(c_t)$ (N.)	-22203.0025	40.63210	0.00000	30
Ø. (γ'= γ") $(p_t)≠(c_t)$ (N.)	-22201.9709	41.66370	0.00000	31

Table 3-4. Comparison of competing models used to describe channel catfish population estimates near Louisville, NE in the lower Platte River from 2010 to 2011. Models include survival (Ø), temporary emigration (γ'and *y''*), capture probability (*p*), recapture probability (*c*), and population size (*N*). Superscripts include "yearly" (channel catfish population estimates were allowed to vary by year). Subscripts include "*t*" (the parameter was allowed to vary by time—i.e., year or primary event), and "." (the parameter was constant across time). Models are ranked by corrected Akaike's information criterion (AIC*c*; the first row shows the highest-ranking model), where *k* is the number of parameters, ΔAIC*c* is the difference between a model's AIC*c* value and that of the highest-ranked model, and WAIC*c* is the Akaike weight (sum of all weights = 1.00).

Model	AICc	ΔAICc	WAICc	*k*
Ø. (γ'.) ≠ (γ".) $(p_t)=(c_t)$ (N^{yearly})	-12899.967	0.00000	0.74485	24
Ø. (γ'.) ≠ (γ".) $(p_t)≠(c_t)$ (N.)	-12897.107	2.86000	0.17825	42
Ø. (γ'.) ≠ (γ".) $(p_t)≠(c_t)$ $N^{(yearly)}$	-12895.287	4.68030	0.07174	43
Ø. (γ'=0) (γ"=0) $(p_t)≠(c_t)$ (N^{yearly})	-12888.202	11.76510	0.00208	41
Ø. (γ'= γ") $(p_t)≠(c_t)$ (N^{yearly})	-12888.202	11.76510	0.00208	41
Ø. (γ'=0) (γ"=0) $(p_t)≠(c_t)$ (N.)	-12885.042	14.92490	0.00043	40
Ø. (γ'= γ") $(p_t)≠(c_t)$ (N.)	-12885.042	14.92490	0.00043	40
Ø. (γ'= γ") $(p_t)=(c_t)$ (N.)	-12880.515	19.45240	0.00004	22
Ø.(γ'.) ≠ (γ".) $(p_t)=(c_t)$ (N.)	-12880.487	19.48040	0.00004	22
Ø. (γ'=0) (γ"=0) $(p_t)=(c_t)$ (N^{yearly})	-12880.461	19.50640	0.00004	22
Ø. (γ'= γ")$(p_t)=(c_t)$ (N^{yearly})	-12878.739	21.22850	0.00002	23
Ø. (γ'=0) (γ"=0) $(p_t)≠(c_t)$ (N^{yearly})	63618.871	76518.83890	0.00000	20

Table 3-5. Observed movements of channel catfish tagged in the Platte River and recaptured by anglers in the Missouri River during 2010-2011.

Date Tagged	Date Recaptured	Days at Large	Tagged at Site	Recaptured at Site	Km Traveled	Km/Day
9/14/10	5/20/12	614	Fremont	Missouri River near Gavins Point Dam	436	0.71
10/12/10	9/18/11	341	Louisville	Missouri River (RM 787)	335	0.98
10/26/10	5/17/12	569	Louisville	Missouri River near Wynot, NE	331	0.58
7/7/10	3/29/12	631	Fremont	Big Sioux Confluence with Missouri River	316	0.50
10/25/10	9/1/11	311	Fremont	Big Sioux Confluence with Missouri River	316	1.02
7/18/11	10/3/11	77	Fremont	Big Sioux Confluence with Missouri River	316	4.10
11/3/10	5/31/11	209	Louisville	Missouri River near Ponca State Park	282	1.35
10/26/10	10/15/11	354	Fremont	Missouri River (RM 709)	276	0.78
11/2/10	9/4/11	306	Louisville	Big Sioux Confluence with Missouri River	250	0.82
11/1/10	10/5/11	338	Louisville	Big Sioux Confluence with Missouri River	250	0.74
3/21/11	8/18/11	150	Louisville	Floyd River Confluence with Missouri River	245	1.63
8/17/10	9/4/11	383	Louisville	Missouri River near Sargeant Bluff	236	0.62
11/2/10	11/6/11	369	Louisville	Missouri River (RM 660.5)	131	0.36
8/18/10	3/29/12	589	Louisville	Missouri River near Mondamin, IA	130	0.22
9/21/11	4/15/12	207	Louisville	Missouri River near Blair, NE	111	0.54
9/29/10	4/11/12	560	Fremont	Platte River Confluence with Missouri River	92	0.16
10/19/11	3/25/12	158	Louisville	Missouri River (RM 568)	69	0.44
8/18/10	3/29/12	589	Louisville	Missouri River near Lake Manawa	46	0.08
9/19/11	4/12/12	206	Louisville	Missouri River near Plattsmouth Boat Ramp	32	0.16
5/25/10	5/30/10	5	Louisville	Platte River Confluence with Missouri River	26	5.20
5/25/10	11/3/10	162	Louisville	Platte River Confluence with Missouri River	26	0.16

Table 3-6. Observed movements of channel catfish tagged in the Platte River and recaptured by anglers in tributaries of the Platte River and Missouri River during 2010-2011.

Date Tagged	Date Recaptured	Days at Large	Tagged at Site	Recaptured at Site	Km Traveled	Km/Day
10/28/10	9/30/11	337	Louisville	James River, SD	390	1.16
10/28/10	5/17/12	567	Louisville	James River, SD	354	0.62
10/24/11	6/7/12	227	Louisville	Elkhorn River near Wisner, NE	184	0.81
10/26/10	8/1/11	279	Fremont	Bell Creek, North of Arlington, NE	104	0.37
8/5/10	6/19/11	318	Fremont	Wahoo Creek, near Ithaca, NE	88	0.28
9/30/10	6/11/11	254	Fremont	Bell Creek Confluence with Elkhorn River	87	0.34
8/4/10	4/2/11	241	Fremont	Elkhorn River near Q St. Bridge	52	0.22
11/2/10	4/2/11	151	Louisville	Papio Creek Confluence with Missouri River	29	0.19
10/24/11	5/19/12	208	Louisville	Elkhorn River, 2 miles North of Confluence	28	0.13

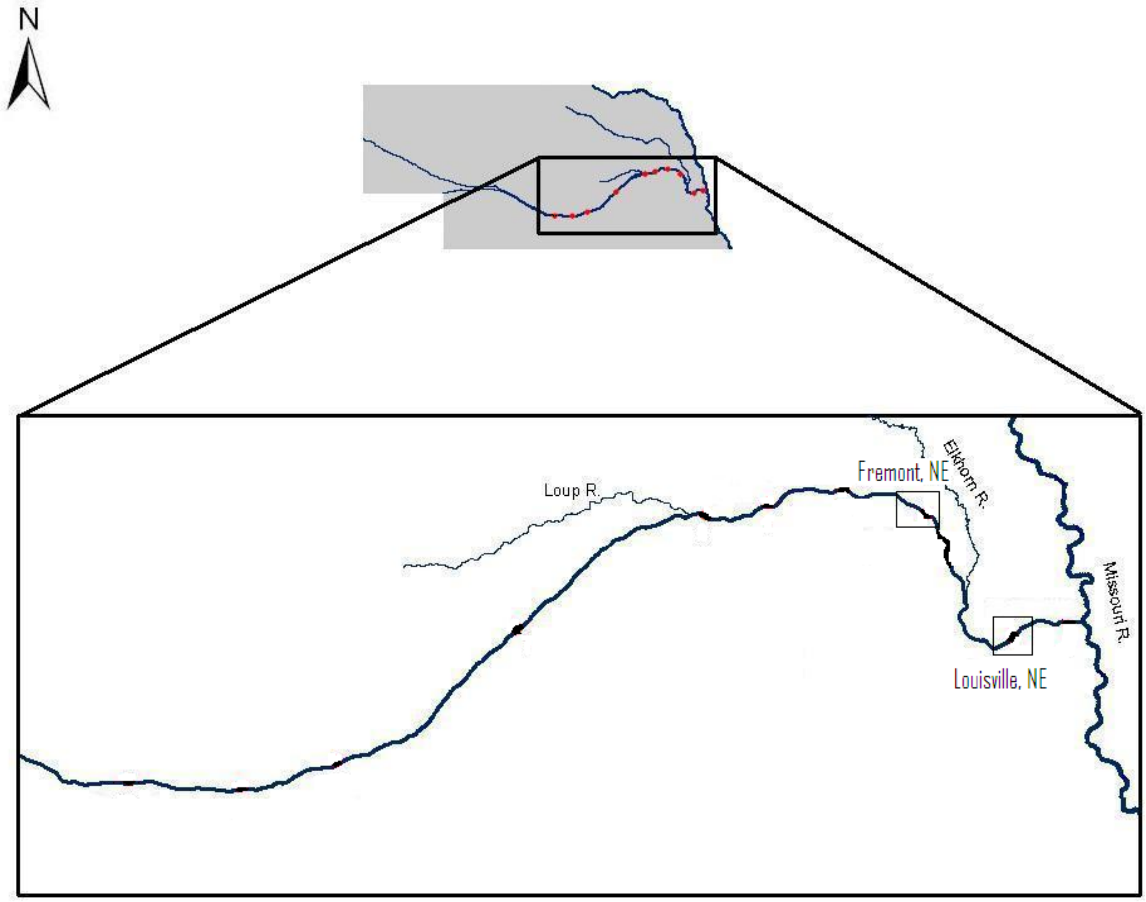

Figure 3-1. Sampling sites located at Fremont and Louisville, Nebraska

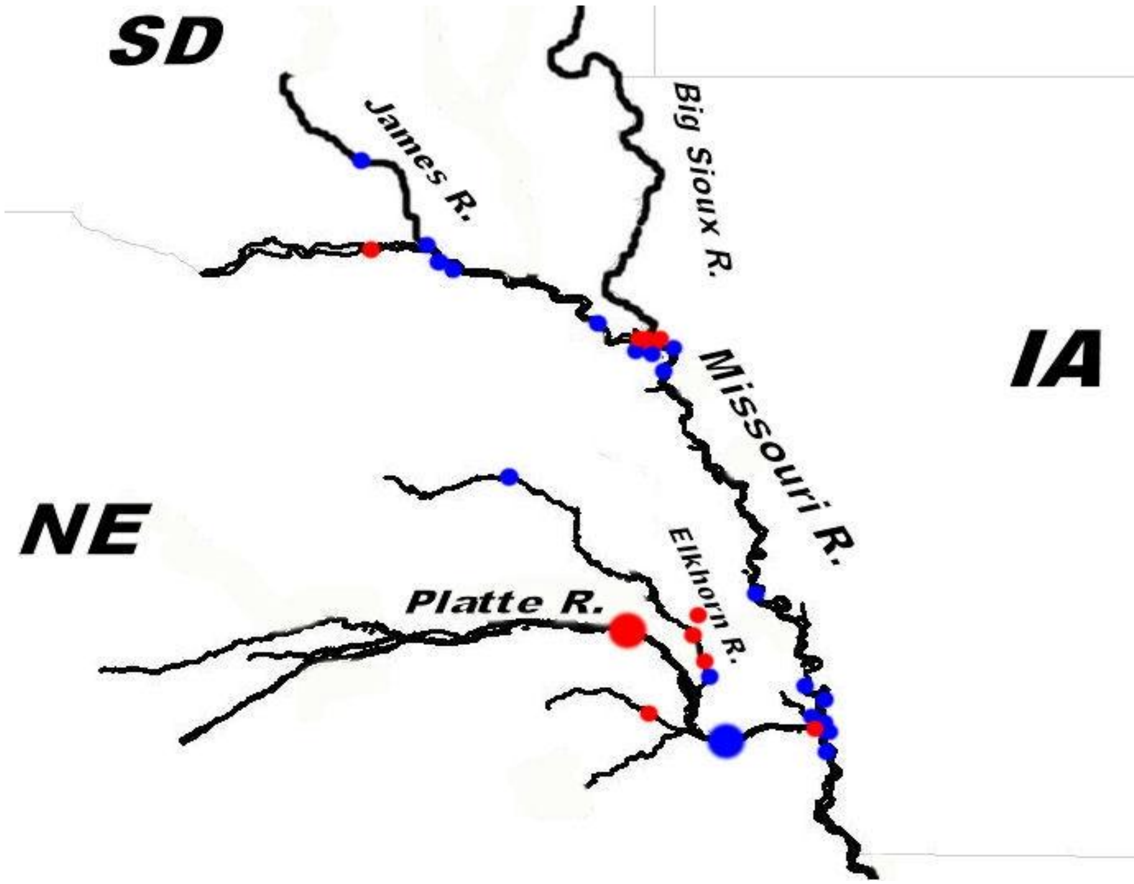

Figure 3-2. Observed movements of channel catfish tagged at Louisville (blue circles) and Fremont (red circles).

Chapter 4. Channel catfish population trends within years of the central and lower Platte River, Nebraska.

Introduction

Understanding catfish population dynamics in any system is imperative to being able to effectively manage that catfish population. Several studies have investigated channel catfish population dynamics in the Platter River. From these studies, we have learned much about habitat preferences (Peters et al. 1989), growth rates (Holland and Peters 1992b, Barada 2009), size structure (Holland and Peters 1992a, Barada and Pegg 2011), survival (Holland and Peters 1992b, Barada 2009), age structure (Holland and Peters 1992b, Barada 2009), relative abundance (Holland and Peters 1992a, Barada and Pegg 2011), and condition (Barada and Pegg 2011).

Monitoring is crucial to managing fish populations, and the basic need for long-term data is widely acknowledged (Likens 1992, Thomas 1999). This is particularly true given the need for understanding how the environment or management practices change fish communities, stocks, populations, or other units of interest to achieve specific goals and objectives (Noble et al. 2007). Short-term studies can provide a great deal of insight as to what is happening to fish communities, stocks, or populations at a specific point in time; however, those insights may not accurately represent the fishery. Conversely, long-term monitoring studies are designed to provide a periodic update on the status of the fishery, detect major changes, and establish trends.

Recent short-term research by Barada (2009) and Barada and Pegg (2011) found considerable differences between river reaches (e.g., central and lower Platte River) in relative abundances, condition, size structure, growth rates, and mortality. Growth rates were variable throughout the river, however, slower growth rates were observed in the lower Platte River compared to the central Platte River. Size structure, relative abundance, and condition also differed between reaches, with larger, healthier, but fewer fish coming from the central Platte compared to the lower Platte. Mortality rates also varied between reaches; the central Platte River exhibited an instantaneous mortality rate of 0.312, while in the lower Platte River mortality rate was 0.596. Fish ages ranged from 0-13 with the majority of fish in the 2 to 3 year old range. Barada (2009) and Barada and Pegg (2011) also found differences within the lower Platte River reach. Channel catfish displayed greater relative abundance, slower growth, lower mean relative weights (W_r), and decreased size structure above the Elkhorn River confluence compared to below it. Barada (2009) recommended continued monitoring of the Platte River to gain a better understanding of the system. The goal of this study was to evaluate monitoring data that has continued from 2007-present. My objective was to document spatial or temporal differences in channel catfish relative abundance, size structure, condition, age structure, growth rates, and mortality in the central and lower Platte River. Specifically, I tested for differences within years in relative abundance, size structure, condition, age structure, growth rates, and mortality at two spatial scales (e.g., river reach, and river segment).

Methods

Study Area

The lower reach of the Platte River, defined as the reach from the confluence of the Loup River near Columbus to the confluence at the Missouri River near Plattsmouth, is an alluvial, sand bottom, braided river. Differences in discharge and available habitat exist within the lower reach; therefore, I split the lower reach into two segments. Segment 2, defined as the Loup River confluence to the Elkhorn River confluence, is dramatically affected by hydropeaking of the Loup River Power Canal. The canal creates drastic downstream diel changes in water depth, current velocity and cover availability to meet electricity demands (Holland and Peters 1989, Holland and Peters 1992b). Segment 1, defined as the Elkhorn River confluence to the confluence at the Missouri River, has greater discharge with habitat more suitable for juvenile and adult catfish compared to segment 2 (Holland and Peters 1994). Discharge and habitat availability is greater in segment 1 because the Elkhorn River funnels the majority of Northeast Nebraska's water into the segment leading to high flow events as well as mitigating some of the hydropeaking effects of the Loup River Power Canal.

The central reach, or segment 3, of the Platte River, defined as the Platte River near Elm Creek, Nebraska to the Loup River confluence, is characterized by lower discharge and well vegetated islands. Shoreline and island vegetation, primarily *Phragmites australis*, have altered the system by preventing erosion resulting in deeper narrower river channels. Water availability, primarily influenced by high or low precipitation and irrigation withdrawals, is also a key determinate in habitat quantity, quality, and availability in the central reach.

Field Collections

I used data from Barada and Pegg (2011) and additional fieldwork following similar methods to assess a five-year dataset in the central and lower Platte River. I used the fixed sampling sites identified by Barada and Pegg (2011) that include, from west to east: 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), 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 1). Each site was defined by the river kilometer location as the center point of a ± 0.8-km site (1.6-km total) to ensure that fish collection could be completed.

Sites were sampled with baited hoop nets in addition to high and low pulsed electrofishing every spring (March-May), summer (June-August), and fall (September-November) in 2007, 2008, and 2009. Barada (2009) recommended continued monitoring of the central and lower Platte River using spring hoop net, and electrofishing data. Therefore, 2010 and 2011 data was collected only in the spring. However, adverse flows and other logistical constraints prevented sampling intermittently throughout the study period.

Hoop nets were 0.5-m diameter 4-hoop, hoop nets with 25-mm mesh (4-hoop) baited with scrap cheese. Hoop nets were anchored at the cod, and 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. Sampling included 15 sets/site in 2007 and 2008; however, due to monitoring protocol recommended by Barada (2009), sampling included 20 sets/site in 2009, 2010, and 2011. Hoop nets were set for no longer than 24 hour sets; therefore, catch per unit effort (CPUE) will be expressed fish/net-night.

Electrofishing was conducted using a cataraft (River King Catarafts, Port Ludlow, Washington) equipped with a MBS-2D Wisconsin box (ETS Electrofishing LLC, Madison, Wisconsin) powered by a 3500 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 (EFH; 4-8 A, 180-240 V, 60 pulses/s, 50% pulse width) and low frequency (EFL; 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. Electrofishing was limited to five, ten-minute runs per site for both high and low pulsed throughout all years. Catch data were extrapolated to one hour; therefore, all CPUE will be expressed fish/hour.

All captured fish were measured (total length; mm), weighed (g), and returned to the water. Pectoral spines were taken from a subsample of channel catfish at each site to provide information on growth rates. Pectoral spines were collected from a representative sample of five individuals from each 10-mm size group. Spines were placed in coin envelopes immediately after removal. Length, weight, species code, date, unique identifier, and fish numbers were recorded on each envelope.

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.

Laboratory Analysis

Spines were prepared using methods by Koch and Quist (2007). Spines were set in either 2.0 or 5.0ml centrifuge tubes, depending on spine size, and then filled with epoxy. Once hardened, the spines were cut into 0.8mm sections using either a Buehler

Isomet 1000 high precision saw or Buehler *low speed saw* (Buehler Inc., Lake Bluff, Illinois). Sections were placed on microscope slides and covered with Cytoseal (Richard-Allan Scientific, Kalamazoo, Michigan). Images of each section were captured using an Olympus SZ61 microscope and camera. Spine sections were viewed by two different readers (same two readers throughout the study) to determine age.

Data Analysis

I evaluated population characteristics across two spatial scales: 1) river reach and 2) river segment. These scales were chosen because of differences in population dynamics, hydrology, and habitat differences found between the central and lower Platte River, and within the lower Platte River by Barada (2009) and Barada and Pegg (2011). Comparisons between the two spatial scales were calculated for CPUE, size structure, condition, age structure, growth, and mortality estimates. Catch per unit effort analyses are based on spring catch rates only. Longitudinal differences in mean CPUE were analyzed using an analysis of variance (ANOVA). Catch data were $\log_{10}$ (CPUE+1) transformed to meet normality assumptions for parametric tests.

Length frequency histograms were created using spring 4-hoop data from 2008-2011. Electrofishing data were excluded because all sites were not equally sampled during the spring. Data from 2007 were excluded due to low sample sizes. Proportional Size Distribution (PSD) analysis was performed using data from 4-hoop, EFL, and EFH samples from 2007- 2011 to ensure large enough sample sizes for analysis. Data collected in 2007-2009 include spring, summer, and fall samples; while data collected in

2010 and 2011 include only spring samples. I used PSD indices (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) described by Gabelhouse (1984) to compare size distributions between reaches. Proportional Size Distribution was calculated as:

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

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

$$\mathrm{PSD} - \mathrm{P} = \frac{\#\ \text{fish} \geq \text{minimum perferred length}}{\#\ \text{fish} \geq \text{minmum stock length}} *100.$$

Differences in PSD indices were statistically analyzed using chi squared (x^2) tests as recommended by Neumann and Allen (2007). Differences in length-frequency distributions of two groups were calculated using nonparametric Kolmogorov-Smirnov tests with a Bonferroni correction factor to maintain an overall α = 0.05. Differences in length-frequency distributrions of multiple groups were calculated using nonparametric Kuskal-Wallis tests.

Channel catfish condition analysis was conducted using data collected with 4-hoop, EFL, and EFH samples in the spring of 2008, 2009, 2010, and 2011. Data from 2007 were excluded due to low sample size. Fish condition was analyzed using mean relative weight (Wr; Wege and Anderson 1978). The relative weight equation is as follows:

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

where W_r is relative weight, W is the measured weight, and W_s is the standard weight for the species. Brown et al.(1995) provide the standard weight equation for channel catfish:

$$\log10 (Ws) = -5.800 + 3.294*\log10 (\text{Total Length}).$$

Comparison of W_r were made using length categories; sub-stock size (S-S), stock size (S-Q), quality size (Q-P), and preferred size (P-M). Mean W_r differences by fish length and site were analyzed using ANOVA with Tukey's HSD multiple comparisons when significant differences were identified.

Channel catfish age distribution, growth rates, and mortality estimate analyses were conducted using data from 4-hoop, EFL, and EFH samples from 2007- 2011. Data collected in 2007-2009 include spring, summer, and fall samples, while data collected in 2010 and 2011 include only spring samples. Back-calculations were calculated using FishBC 3.0 software (FishBC, Doll and Lauer 2008). 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 at age and mean annual growth increments between sites were analyzed using Tukey's studentized range (HSD) test when ANOVA results were significant.

Fishery Analysis and Simulation Tools (FAST, Slipke and Maceina 2001) software was used to fit von Bertalanffy growth functions as:

$$L_t = L_\infty * (1 - e^{-k(t-t_o)})$$

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 built using Fish BC (Doll and Lauer 2008) to estimate ages for fish that were not aged. Age-frequency distributions were compared between sites and years using a Kolmogorov-Smirnov (KS) nonparametric test.

Weighted catch curves were created in program FAST (Slipke and Maceina 2001) to determine instantaneous mortality (Z), and annual mortality (A). Mortality parameters were estimated for each reach and segment for all years. Data collected in 2007-2009 include spring, summer, and fall samples, while data collected in 2010 and 2011 include only spring samples. Differences in mortality estimates were found using an ANCOVA. All analyses were conducted using SAS (SAS Institute 2004) where significance was determined at $\alpha = 0.05$.

Results

River Reach

Habitat Characteristics

Habitat characteristics varied spatially and temporally across the Platte River. Temperature ranged from 4.8 – 32.2 ^{o}C in the lower reach and 7.2 – 28 ^{o}C in the central reach (Table 4-1). Dissolved oxygen ranged from 3.5 – 13.2 mg/L in the lower reach and 3.4 – 10.7 mg/L in the central reach (Table 4-1). Mean turbidity levels were greater in the lower reach (168.3 NTU) compared to the central reach (51.3 NTU; $P < 0.01$; Table 4-

1). Conductivity was greater in the central reach (934.9 µS) compared to the lower reach (504.1 µS; $P < 0.01$; Table 4-1).

Relative Abundance

Channel catfish spring 4-hoop CPUE displayed sporadic catch rates (0 – 17.2 fish/net-night); however, a few trends seem to be present (Figures 4-2, 4-3). Comparisons of channel catfish relative abundance between reaches of the Platte River displayed greater hoop net catch rates in the lower reaches in 2008, 2009, and 2011; no difference was found between reaches in 2010 (Figure 4-4). The central and lower reaches of the Platte River showed little difference in catch rates for both EFL and EFH; however, greater catch rates were observed in the lower reach for EFL in 2010 (Figures 4-5, 4-6).

Size Structure

Channel catfish total length (TL) ranged from 50 to 540-mm in 2008, 52 to 550-mm in 2009, 71 to 635-mm in 2010, and 78 to 704-mm in 2011 (Figures 4-7 – 4-10). Greatest annual mean and median lengths were found in the central reach in 2011 (mean = 353-mm, median = 342-mm), while lowest annual mean and median lengths were found in the lower reach (mean = 160-mm, median = 154-mm).

Length-frequency distribution comparisons between the central and lower reaches were different ($P < 0.01$) in 2008 and 2011 where lengths were shifted towards smaller fish in the lower reach (Figures 4-7, 4-10). However, no differences were found between reaches in 2009 or 2010 (Figures 4-8, 4-9). The central reach had a greater PSD compared to the lower reach in 2007 ($P < 0.02$) and 2011 ($P < 0.01$) (Table 4-2).

Furthermore, PSD-P was also greater in the central reach in 2007 ($P < 0.02$) and 2008 ($P < 0.03$) compared to the lower reach (Table 4-2).

Condition

No differences were observed in mean W_r of sub-stock (S-S), stock (S-Q), quality (Q-P), and preferred (P-M) length fish between the central and lower reaches throughout the four years (Figure 4-11). Mean W_r was low (< 90) for the majority of length categories in all years (Figure 4-11). Comparisons of W_r suggest S-S channel catfish had the highest relative weight compared to all other length categories. Furthermore, channel catfish W_r decreased as fish reached S-Q size and generally increased as fish got larger.

Age Distribution

Age-2, age-3, and age-4 channel catfish were most abundant in the Platte River while very few age-8 and older fish were collected (Figures 4-12 – 4-16). Age distributions differed between the central and lower reaches in 2007 ($P = 0.03$), 2010 ($P < 0.01$), and 2011 ($P = 0.03$); age distributions were skewed towards younger fish in the lower reach (Figures 4-12, 4-15, 4-16).

Growth

Growth rates varied greatly throughout years, and reaches as indicated by mean back-calculated lengths (Figures 4-17 – 4-19). Mean back calculated lengths at age were greater in the central reach compared to the lower reach for age-1 channel catfish in 2007 and 2008, ages 2, 3, and 4 in 2007, 2008, 2009, and 2011, age-5 in 2007, 2008, and

2011, and age-6 in 2007, 2008, and 2010 (Figures 4-17 – 4-19). However, no differences were observed between age-7 and older fish.

Mortality

Channel catfish were considered fully recruited to hoop nets at age-3, and electrofishing at age-2. Estimates of instantaneous mortality (Z), total annual mortality (AM), and theoretical maximum age varied by year, and reach (Tables 4-3; Figures 4-20 – 4-22). Greatest annual mortality was observed in the central reach in 2009 (75%; Table 4-3), while lowest annual mortality was also observed in the central reach in 2007 (33%; Table 4-3). Mortality rate estimates were greater in the central reach compared to the lower reach in 2009 (ANCOVA, $P = 0.02$) (Figure 4-21), whereas, mortality rate estimates were greater in the lower reach in 2011 (ANCOVA, $P = 0.02$) (Figure 4-22).

River Segment

Habitat Characteristics

Mean temperature and dissolved oxygen varied by river segment; however, no differences were found between segments (Table 4-1). Mean turbidity levels were greater in segment 1 (174.4 NTU; $P < 0.01$) and segment 2 (164.5 NTU; $P < 0.01$) compared to segment 3 (51.3 NTU; Table 4-1). Conductivity was greater in segment 3 (934.9 µS) compared to segment 1 (618.7 µS; $P < 0.01$) and segment 2 (439 µS; $P < 0.01$; Table 4-1).

Relative Abundance

Channel catfish hoop net CPUE estimates in segment 2 and segment 1 were greater than segment 3 in 2008, 2009, and 2011 (Figure 4-23). Segment 2 had a greater hoop net CPUE compared to segment 1 in 2008 while no differences were found between the two in 2009, 2010, or 2011 (Figure 4-23).

A comparison of electrofishing CPUE between segment s 1, 2, and 3 displayed few differences in catch rates. However, relative abundance estimates were greater in segment 3 and segment 2 compared to segment 1 in 2009 for both EFL and EFH (Figures 4-24, 4-25). Relative abundance was also greatest in segment 2 in 2010 for EFL (Figure 4-24).

Size Structure

Length-frequency distribution comparisons between segment s 1, 2, and 3 also displayed differences between years. In 2008, length-frequency distributions differed between all comparisons (segment 1 vs. segment 2, $P < 0.01$; segment 1 vs. segment 3, $P < 0.01$; segment 2 vs. segment 3, $P < 0.01$). Segment 3 was shifted towards large fish and segment 1 was shifted towards small fish (Figure 4-26). In 2009, both segment 3 ($P < 0.02$) and segment 2 ($P < 0.01$) were again shifted towards larger fish than segment 1 (Figure 4-27). In 2010, no differences in length-frequency distributions were found (Figure 4-28). Finally, in 2011, length-frequency distributions differed between all segments (segment 3 vs. segment 2, $P < 0.01$; segment 3 vs. segment 1, $P < 0.01$; segment 2 vs. segment 1, $P = 0.01$) (Figure 4-29). Segment 3 was shifted towards large fish while segment 1 was shifted towards small fish.

Segment 3 had greater PSD than segment 2 in 2008 (P = 0.005), and PSD-P was greater in segment 3 compared to segment 2 in 2008 (P = 0.004) (Table 4-4). Segment 3 had a higher PSD compared to both segment 2 and segment 1 of the Platte River in 2011 (Table 4-4).

Condition

Few differences were observed in mean W_r of sub-stock (S-S), stock (S-Q), quality (Q-P), and preferred (P-M) length fish were observed between river segments; however, low mean W_r weights (< 90) were observed in the majority of length categories. Only one comparison was significantly different (2009 segment 3 S-S) from other segments (Figure 4-30).

Age Distribution

Age distributions in segment 2 differed from both the central (P = 0.002) and segment 1 (P < 0.01) in 2007 (Figure 4-31). In 2008, segment 2 differed from segment 1 (P = 0.003) (Figure 4-32). In 2009, differences were found between segment 3 and segment 1 (P < 0.01), segment 3 and segment 2 (P < 0.04), and segment 2 and segment 1 (P < 0.01) (Figure 4-33). Age distributions differed between central and segment 1 (P = 0.008) as well as central and segment 2 (P < 0.01) in 2010 (Figure 4-34). Finally, in 2011, differences were found between central and segment 1 (P = 0.04), central and segment 2 (P < 0.01), and segment 2 and segment 1 (P < 0.01) (Figure 4-35).

Growth

Growth rates varied greatly throughout year and segments as indicated by the mean back-calculated lengths at age (Figures 4-36 – 4-38). Channel catfish in segment 3 displayed faster growth for ages 2 to 5 compared to segment 2 in 2007, 2008, and 2009; Figures 4-33, 4-34). Von Bertalanffy growth equations indicate variable growth between years in all segments (Figures 4-36 – 4-38).

Mortality

Channel catfish were considered fully recruited to hoop nets at age-3, and electrofishing at age-2. Estimates of instantaneous mortality (Z), total annual mortality (AM), and theoretical maximum age varied by year and segment (Table 4-5; Figures 4-39 – 4-41). Greatest annual mortality was observed in segment 3 in 2009 (75%; Table 4-5), while lowest annual mortality was also observed in segment 3 in 2007 (33%; Table 4-5). Mortality rate estimates were greater in segment 3 compared to segment 2 (ANCOVA, P = 0.01), and segment 1 (ANCOVA, P = 0.01) segment in 2009 (ANCOVA, P = 0.02) (Figure 4-40). Mortality rates in segment 2 were also greater than segment 3 in 2011 (ANCOVA; P = 0.04) (Figure 4-41).

Discussion

One of the fundamental concepts of biology is that no population can increase without limit and, consequently, that population growth generally is believed to be negatively density-dependent. Density-dependent growth is commonly observed in fishes (Le Cren 1958, Backiel and Le Cren 1978, Walters and Post 1993). As fish density increases, growth is slowed as a result of increased intra-specific competition. Slowed growth rates have a direct impact on an individual's size at maturity and maximum length, with smaller maturation and maximum sizes occurring in slower growing fish (Bowen et al. 1991, Walters and Post 1993). I believe greater channel catfish densities and greater fishing pressure (Holland and Peters 1994) are slowing growth and decreasing size structure in the lower reach, specifically in segment 2. Growth rates were consistently slower in the lower reach throughout the study period, and greater relative abundance estimates were found in the lower reach in 2008, 2009, and 2011. Furthermore, channel catfish densities have been found to be as high as 606 channel catfish ≥ 200-mm/ha in areas of segment 2 (Chapter 3). Density-dependent growth is also believed to be the cause of slower growth and lowered sized structure at Fremont, Nebraska (Chapter 2). The central reach of the Platte River, however, may be experiencing faster growth and larger size structure due to decreased fish density.

Although it appears that density-dependent mechanisms are driving differences in channel catfish growth and size structure, other biotic and abiotic factors may also be contributing to those differences. Barada (2009) and Holland and Peters (1992b) hypothesized catfish in the lower Platte, specifically sites in segment 2, may be experiencing stressful habitat conditions because of varying discharges and low food availability caused by water manipulations from the Loup River Power Canal. Fluctuations in river discharge have been documented to cause harsh living environments (Hesse et al. 1982, Travnichek and Maceina 1994), limit community biomass and energy (Blinn et al. 1995), and decrease macroinvertebrate abundances (Gislason 1985, Blinn et al. 1995, Haxton and Findlay 2008, Braaten and Guy 1995). Additionally, Weisberg and Burton (1993) suggested that fish fed and grew more under consistent availability of depth and flow conditions compared to a widely fluctuating hydrograph. Evidence of slower growth and lower PSD in segment 2 of the Platte River may be caused by fluctuations in discharge from the Loup River Power Canal. The central reach also displays fluctuations in discharge due to the Johnson 2 return (J2) in the tri-county canal system. However, J2 fluctuations in discharge are generally not as great as the Loup River Power Canal, are shorter in duration, and the effects of those fluctuations are not noticed as far down river as with the Loup River Power Canal. Channel catfish in segment 3 demonstrate faster growth, and greater PSD compared to segment 2. Furthermore, segment 1 also displays faster growth and greater PSD compared segment 2. Barada (2009) hypothesized the inflow from the Elkhorn River tributary allowed for a more favorable environment for channel catfish in segment 1 of the Platte River. Cushman (1985) found that tributary inflows can moderate the variability of flow changes and provide a more natural flow regime to the main stem. Tributaries have also been documented to increase habitat complexity and productivity (Kiffney et al. 2006, Pracheil et al. 2009). Consistent evidence of slower growth rates and lower PSD at sites near the Loup River Power Canal, and faster growth and greater PSD further away from the canal provide some evidence that water manipulations from the Loup River Power Canal may be negatively influencing growth and size structure of channel catfish in segment 2 of the Platte River system.

Variations in water temperature in a given year may also be affecting growth. Holland and Peters (1992) stated high water temperatures during most of the summer in shallow rivers like the Platte that have little available cover may expose catfish to long periods of metabolic stress. Kilambi et al. (1971) and Andrews and Stickney (1972) found that growth is presumably reduced in the summer when water temperatures exceed the optimum temperature (30^{o}-32^{o}C) for growth of channel catfish. Data collected during this study (Chapter 2) confirm that the Platte River often exceeds 30^{o}C during the summer months. Diel temperature fluctuations may also be contributing to slower growth, particularly when water temperatures are near 20^{o}C. Channel catfish growth is slow at less than 21^{o}C (Andrews and Stickney 1972) and there is no growth below 18^{o}C (Starostka and Nelson 1974). Therefore, daily temperature fluctuations of 7^{o}-10^{o}C, which are common in the lower Platte River, may be negatively influencing growth when water temperatures are near 20^{o}C.

Temperature extremes in the Platte River during winter months may also play a significant role in channel catfish mortality. Little is known about channel catfish mortality during winter months in the Platte River. However, ice related fish mortality may be caused by areas of the water column freezing solid, collapsing ice shelves and snowbanks, frazil ice suffocating fish, or rapid de-watering of rivers after ice jams are broken up (Shumway and Springer 1992, Brown et al. 1994). More research needs to be done to assess over-winter habitat availability as well as over-wintering mortality in the Platte River.

Abiotic factors such as fluctuations in discharge and temperature likely have a greater impact on channel catfish population dynamics during low precipitation years. It is crucial to point out that the five years sampled during this study were average or above average precipitation years. Little is known about how drought affects channel catfish in the Platte River; however, effects of the current drought, which began in 2012, have already been noticed. Fish kills have been reported throughout the central and lower Platte River and are believed to be caused by low discharge and extremely high water temperatures. Matthews (1998) found that fishes may become stranded as water levels drop, and increased water temperatures may become lethal. Future impacts of the current drought on channel catfish populations will likely decrease abundance and recruitment. Cowx et al. (1984) found that drought greatly reduced recruitment of Atlantic salmon *Salmo salar* in a Welsh river. Continued monitoring of catfish population dynamics is needed in the Platte River as other climate phenomena, like drought, change the dynamics of the system.

Biotic processes such as inter and intra-specific competition and predation may also be contributing to differences in channel catfish population dynamics. Morris et al. (1971) reported that channel catfish and small flathead catfish, made a significant portion of adult flathead catfish diets in the channelized Missouri River. Goble (2011) theorized that lower abundances of channel catfish in some portions of the Missouri River along the Nebraska border could be caused by an increased abundance of flathead catfish. I found greater flathead relative abundances in segment 1 of the Platte River (Chapter 2) which may be contributing to lesser channel catfish abundance in this segment. Furthermore, greater abundances of sight feeding predators, mainly largemouth bass *Micropterus salmoides*, were observed in the less turbid central reach (N = 229) compared to the more turbid lower reach (N = 45). Abrahams and Kattenfeld (1997) found the impact of predation risk on fathead minnows *Pimephales promelas* by sight feeding fish such as yellow perch *Perca flavescens*, is reduced in turbid aquatic systems. Krummrich and Heidinger (1973) found that largemouth bass consumed small catfish (< 6 inches). Therefore, it seems reasonable that small channel catfish may be at a higher risk of predation by sight feeding predators in the central reach.

Channel catfish population dynamics in the Platte River vary both spatially and temporally. Greater relative abundances, slower growth, and lowest size structure were generally observed in the lower reach, specifically in segment 2; whereas, lower relative abundances, faster growth, and greatest size structure were found in the central reach. Density-dependent mechanisms are the main influence shaping population dynamics when water is readily available, as displayed during this study period. Other abiotic factors, including fluctuations in discharge from the Loup River Power Canal and the current water temperature regime, are likely playing a role in shaping population dynamics when water is readily available. However, when water availability is an issue, abiotic factors play major role is shaping channel catfish population dynamics throughout the Platte River.

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Table 4-1. Mean values for habitat variables measured at each reach and segment during fish collections in the Platte River from 2007-2011.

	Temp (^oC)			Dissolved Oxygen (mg/L)			Turbidity (NTU)			Conductivity (µS)		
Reach	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Lower	19.4	4.8	32.2	8.4	3.5	13.2	168.3	21	1806	504.1	272	955
Central	17.8	7.2	28	7.7	3.4	10.7	51.3	6	225	934.9	649	1073
Segment	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Segment 1	19.6	10.6	28.6	8.8	4.6	13.2	174.4	40	697	618.7	378	955
Segment 2	19.3	4.8	32.2	8.1	3.5	11.9	164.5	21	1806	439	272	804
Segment 3	17.8	7.2	28	7.7	3.4	10.7	51.3	6	225	934.9	649	1073

Table 4-2. Size structure indices including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P) channel catfish collected using all gears in the central and lower reaches of the Platte River during 2007-2011. Different letters beside PSD and PSD-P values indicate differences between reaches.

Year	Reach	N	% Stock	PSD	PSD-P
2007	Central	126	39	49[A]	6[A]
	Lower	432	39	19[B]	0[B]
2008	Central	268	37	35[A]	6[A]
	Lower	1068	23	24[A]	2[B]
2009	Central	308	33	21[A]	2[A]
	Lower	1090	28	22[A]	1[A]
2010	Central	198	21	12[A]	2[A]
	Lower	333	26	24[A]	7[A]
2011	Central	170	52	45[A]	1[A]
	Lower	1307	34	9[B]	0[A]

Table 4-3. Instantaneous mortality (Z), total annual mortality (AM) and theoretical maximum age (Max Age) of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River during 2007-2011.

	Central	**Lower**
2007		
Z	0.405	0.541
AM	33%	42%
Max Age	11	12
2008		
Z	0.682	0.619
AM	49%	46%
Max Age	9	12
2009		
Z	1.407	0.575
AM	75%	44%
Max Age	7	13
2010		
Z	0.649	0.659
AM	48%	48%
Max Age	10	10
2011		
Z	0.734	0.972
AM	52%	62%
Max Age	9	10

Table 4-4. Size structure indices including Proportional Size Distribution (PSD) and PSD of preferred (PSD-P) channel catfish collected using all gears in segment 3, segment 2, and segment 1 of the Platte River during 2007-2011. Different letters beside PSD and PSD-P values indicate differences between reaches.

Year	Reach	N	% Stock	PSD	PSD-P
	Segment 3	126	39	49^{A}	6^{A}
2007	Segment 2	357	41	17^{B}	0^{B}
	Segment 1	75	31	30^{AB}	0^{AB}
	Segment 3	268	37	35^{A}	6^{A}
2008	Segment 2	930	23	20^{B}	2^{A}
	Segment 1	138	23	44^{A}	0^{A}
	Segment 3	308	33	21^{AB}	2^{A}
2009	Segment 2	896	30	19^{B}	1^{A}
	Segment 1	194	18	41^{A}	0^{A}
	Segment 3	198	21	12^{A}	2^{A}
2010	Segment 2	242	24	26^{A}	7^{A}
	Segment 1	91	32	21^{A}	7^{A}
	Segment 3	170	52	45^{A}	1^{A}
2011	Segment 2	1162	35	9^{B}	0^{A}
	Segment 1	145	23	9^{B}	0^{A}

Table 4-5. Instantaneous mortality (Z), total annual mortality (AM) and theoretical maximum age (Max Age) of channel catfish collected with all standard sampling gears in segment 3, segment 2, and segment 1 reaches of the Platte River during 2007-2011.

	Segment 3	Segment 2	Segment 1
2007			
Z	0.405	0.417	0.473
AM	33%	34%	38%
Max Age	11	14	10
2008			
Z	0.682	0.621	0.77
AM	49%	46%	54%
Max Age	9	11	7
2009			
Z	1.407	0.606	0.507
AM	75%	46%	40%
Max Age	7	12	10
2010			
Z	0.649	0.523	0.757
AM	48%	41%	53%
Max Age	10	11	7
2011			
Z	0.734	0.926	N/A
AM	52%	60%	N/A
Max Age	9	10	N/A

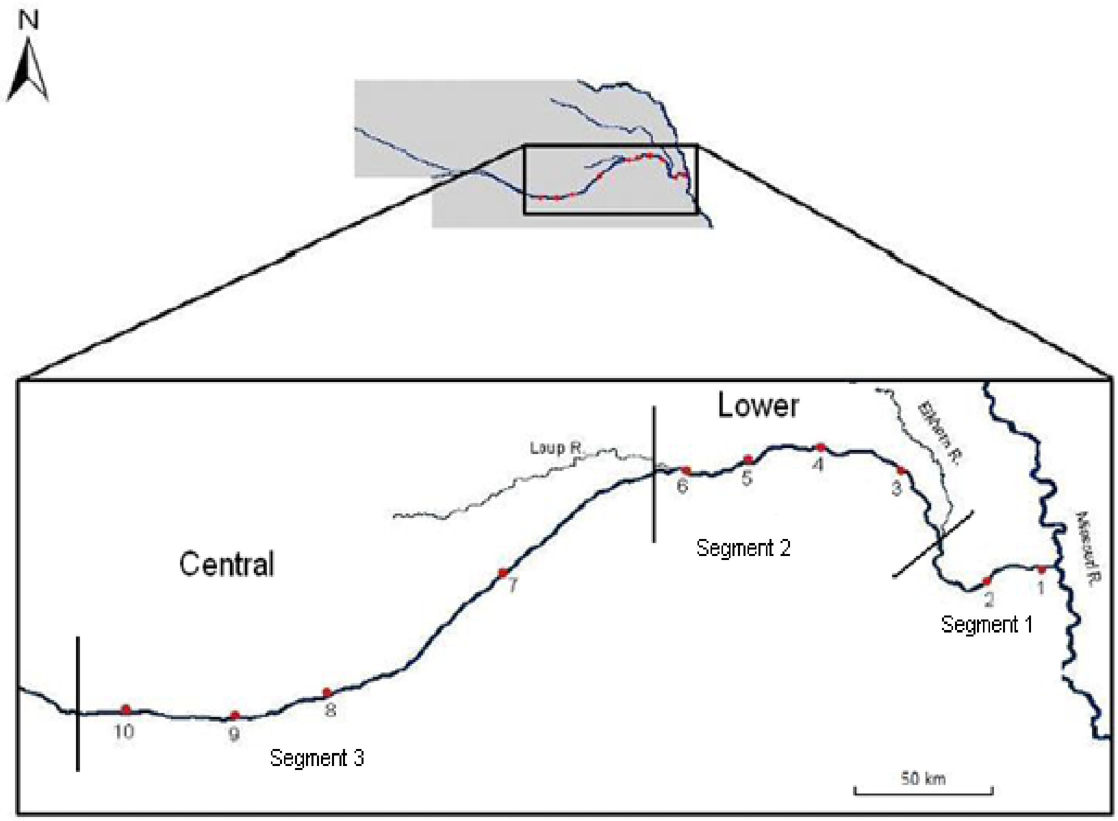

Figure 4-1. Study area including sampling locations in the central (Sites 7-10) and lower reach (Sites 1-6), segment 3(Sites 7-10), segment 2 (Sites 3-6), and segment 1 (Sites 1-2) of the Platte River, Nebraska

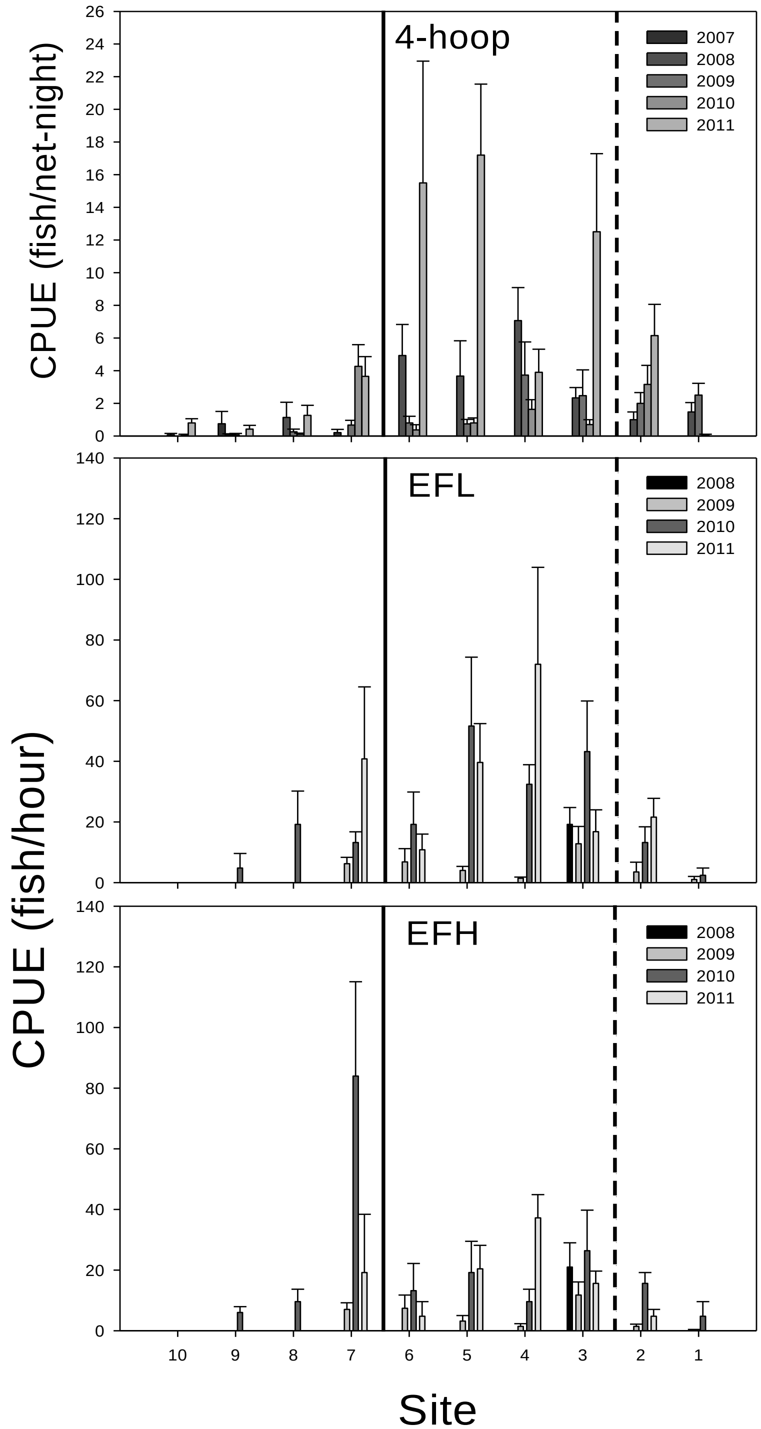

Figure 4-2. Mean catch per unit effort (CPUE) by site of channel catfish collected with 25-mm hoop nets (4-hoop), low frequency pulsed-DC electrofishing (EFL) and high frequency pulsed-DC electrofishing (EFH) in the Platte River during 2007-2011. Error bars represent 1 SE. Solid vertical lines differentiate between the central and lower river reaches. Dashed vertical lines differentiate between the segment 2 and segment 1.

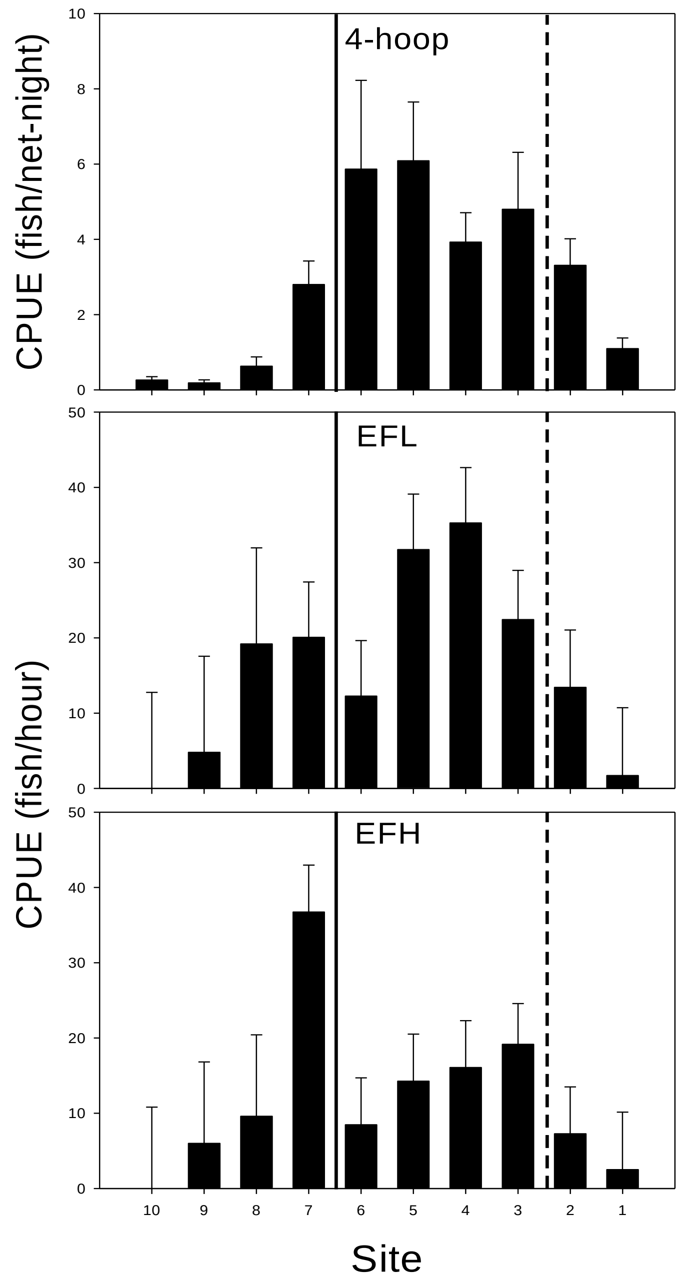

Figure 4-3. Mean catch per unit effort (CPUE) averaged for each site of channel catfish collected with 25-mm hoop nets (4-hoop), low frequency pulsed-DC electrofishing (EFL) and high frequency pulsed-DC electrofishing (EFH) in the Platte River during 2007-2011. Error bars represent 1 SE. Solid vertical lines differentiate between the central and lower river reaches. Dashed vertical lines differentiate between the segment 2 and segment 1.

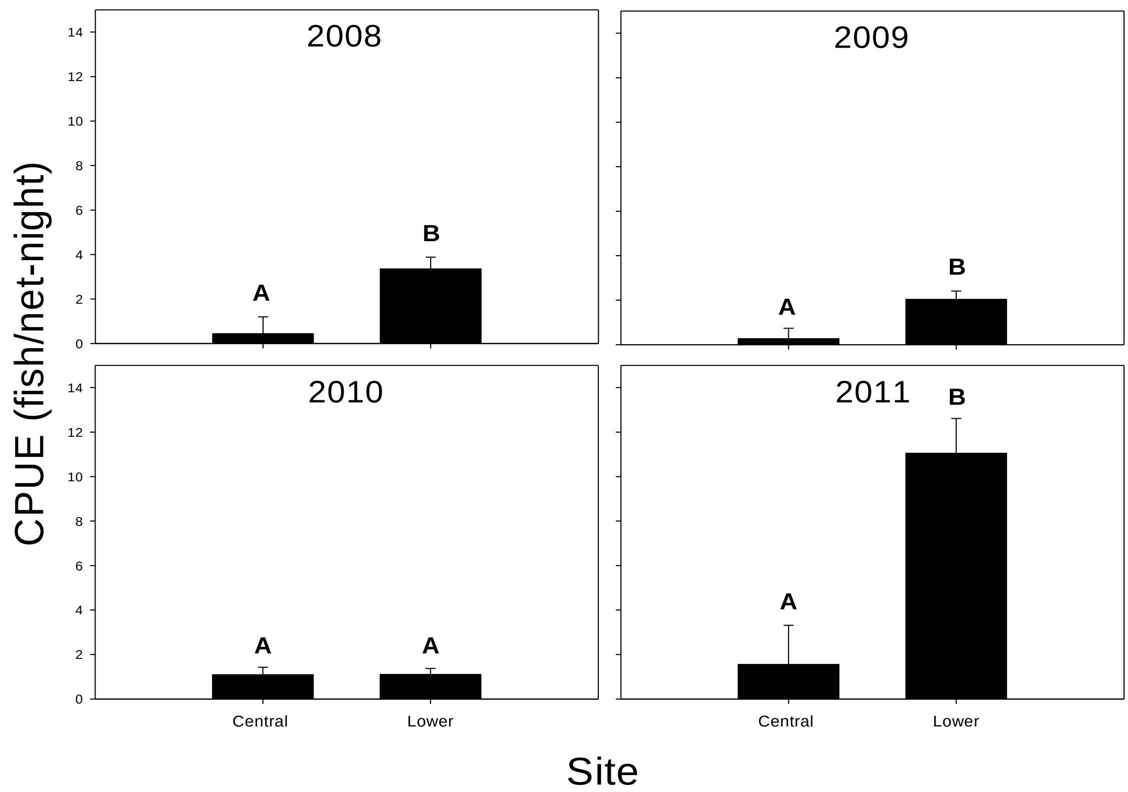

Figure 4-4. Mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (4-hoop) in the central and lower reaches of the Platte River during 2008-2011. Error bars represent 1 SE. Different letters above plots indicate differences in CPUE between reaches.

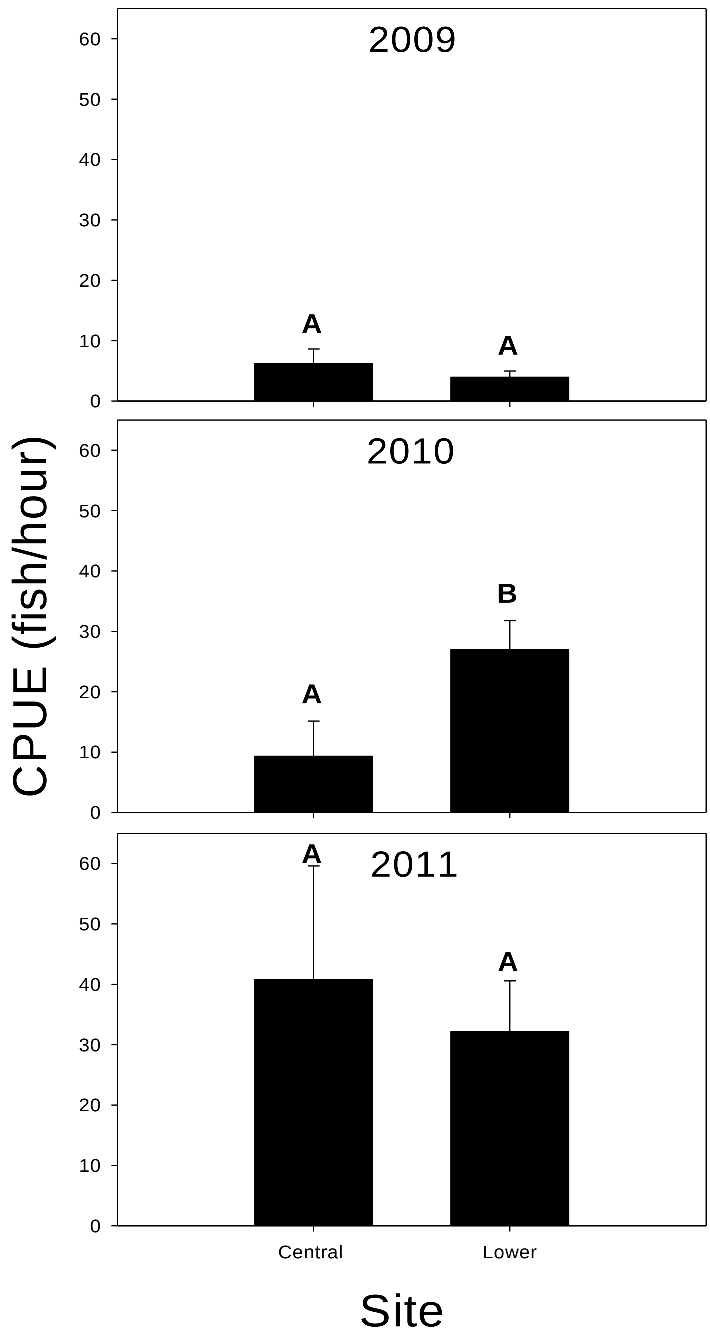

Figure 4-5. Mean catch per unit effort (CPUE) of channel catfish collected with low pulsed-DC electrofishing (EFL) in the central and lower reaches of the Platte River during 2009-2011. Error bars represent 1 SE. Different letters above plots indicate differences in CPUE between reaches.

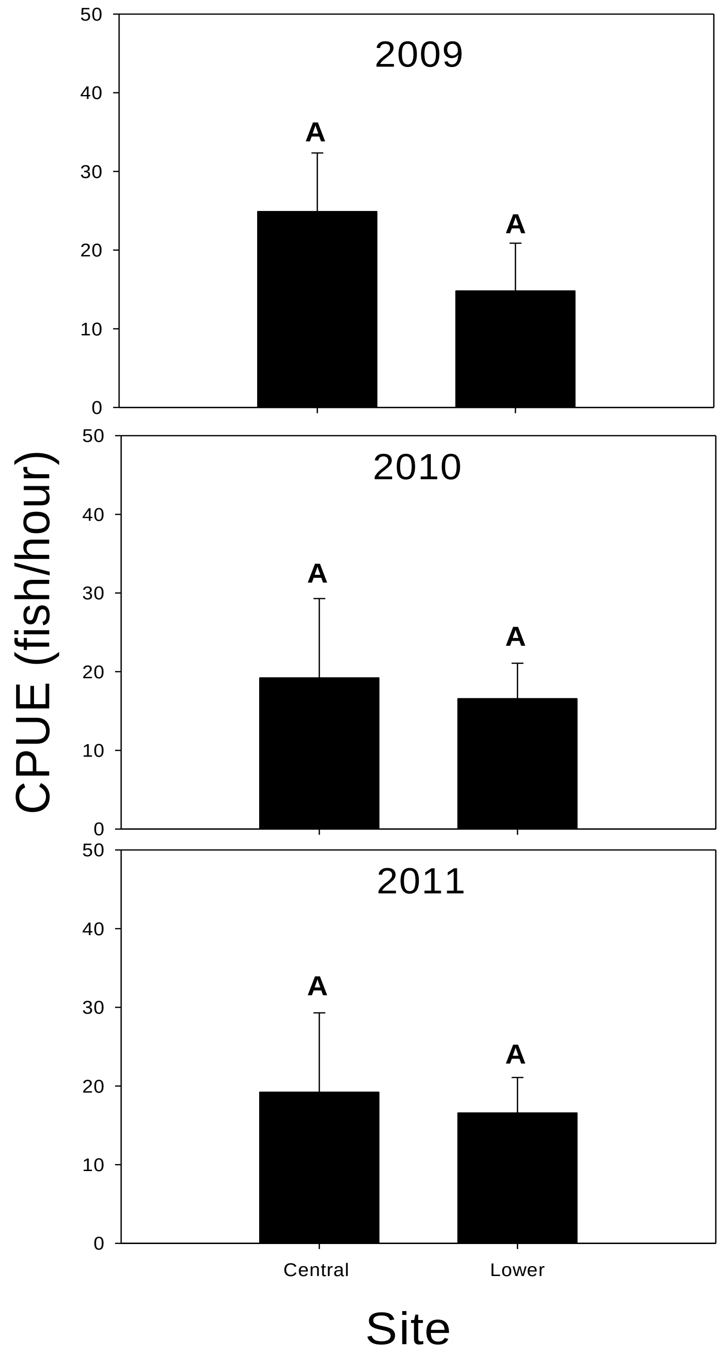

Figure 4-6. Mean catch per unit effort (CPUE) of channel catfish collected with high pulsed-DC electrofishing (EFH) in the central and lower reaches of the Platte River during 2009-2011. Error bars represent 1 SE. Different letters above plots indicate differences in CPUE between reaches.

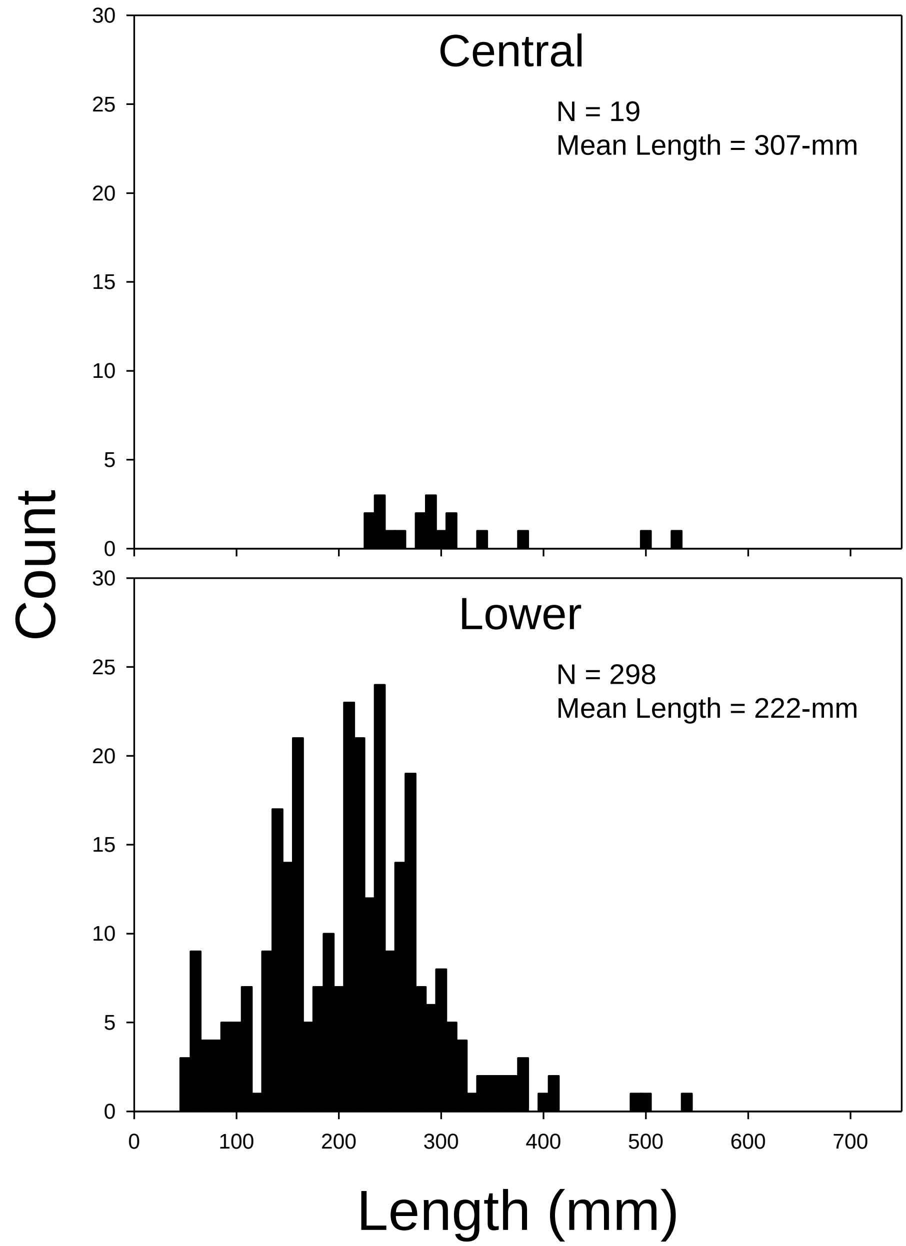

Figure 4-7. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in the central and lower reaches of the Platte River in the spring of 2008.

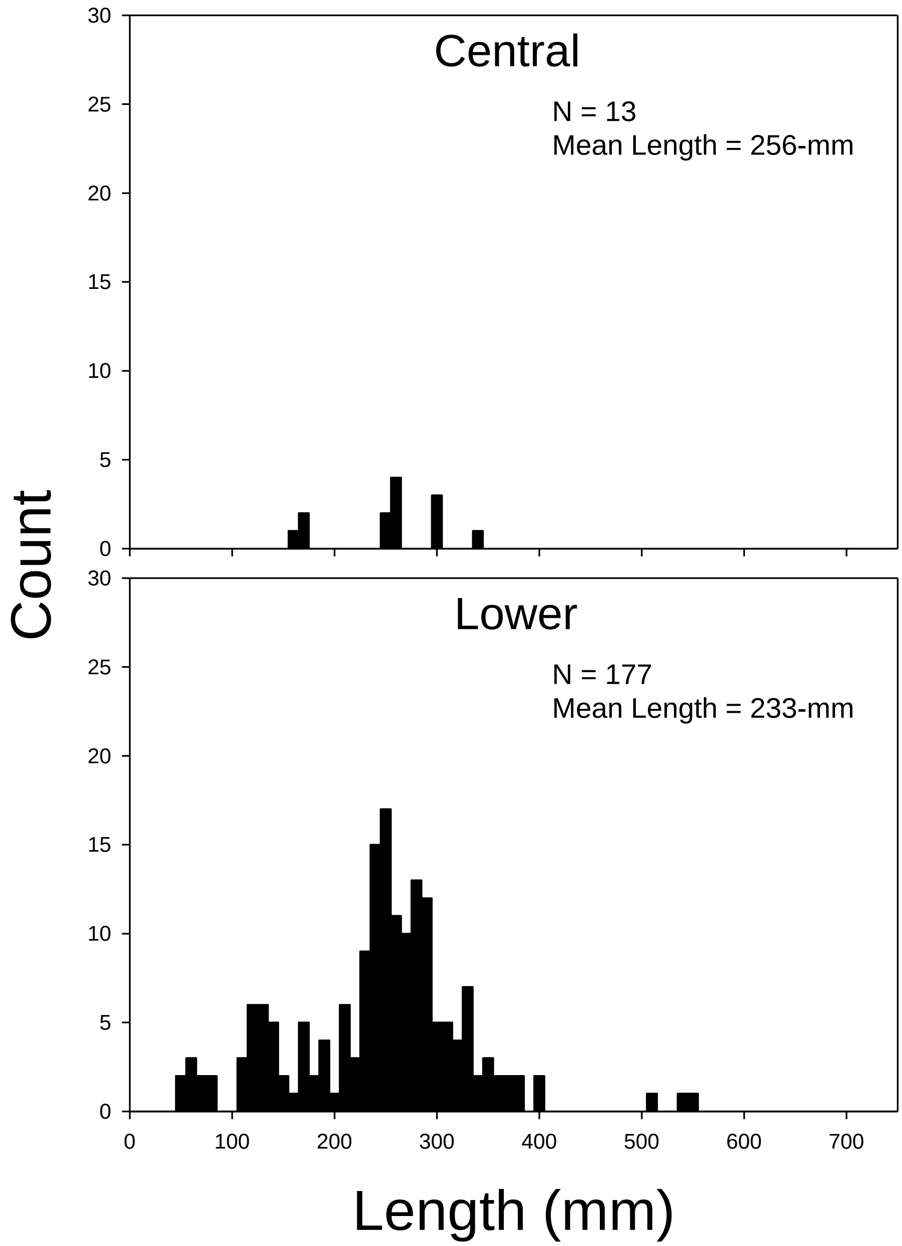

Figure 4-8. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in the central and lower reaches of the Platte River in the spring of 2009.

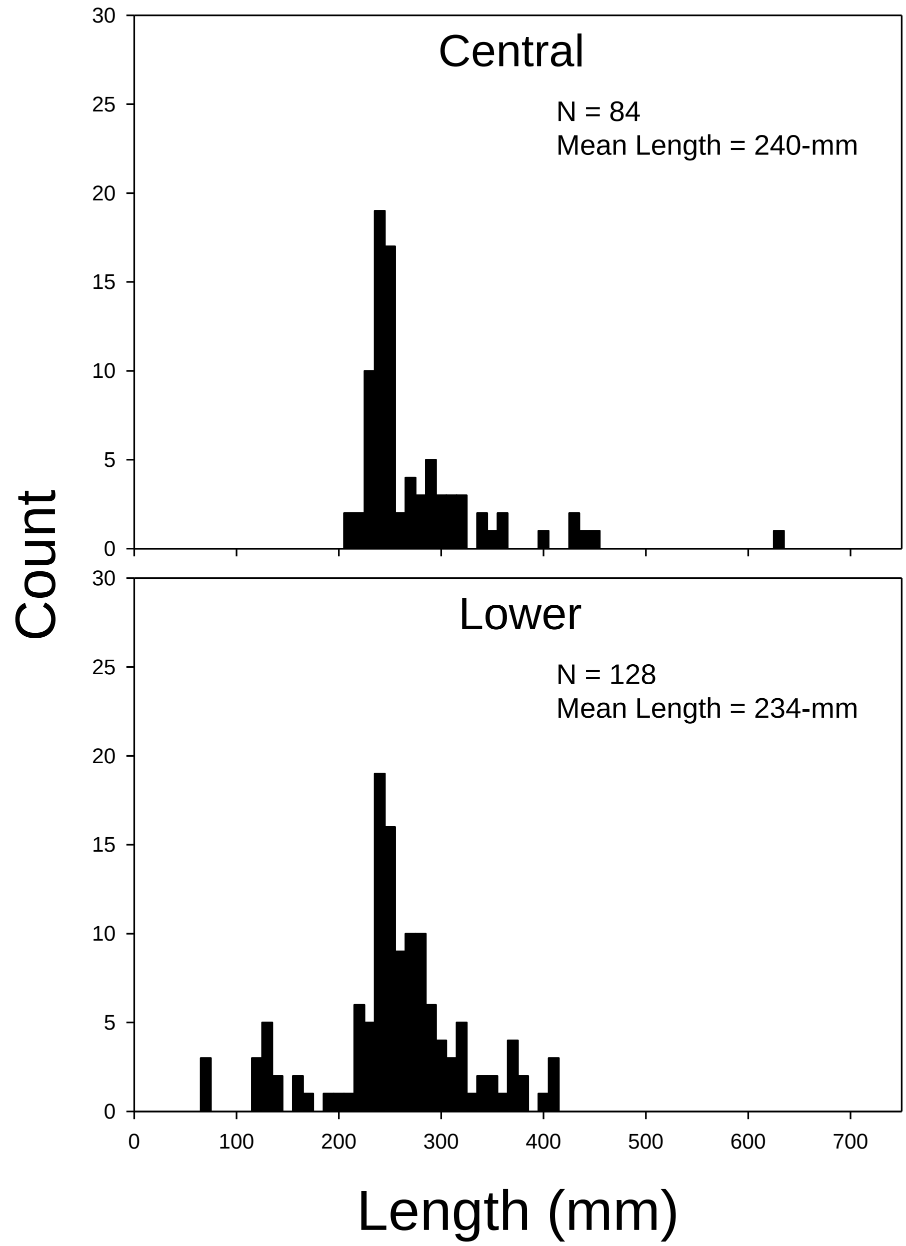

Figure 4-9. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in the central and lower reaches of the Platte River in the spring of 2010.

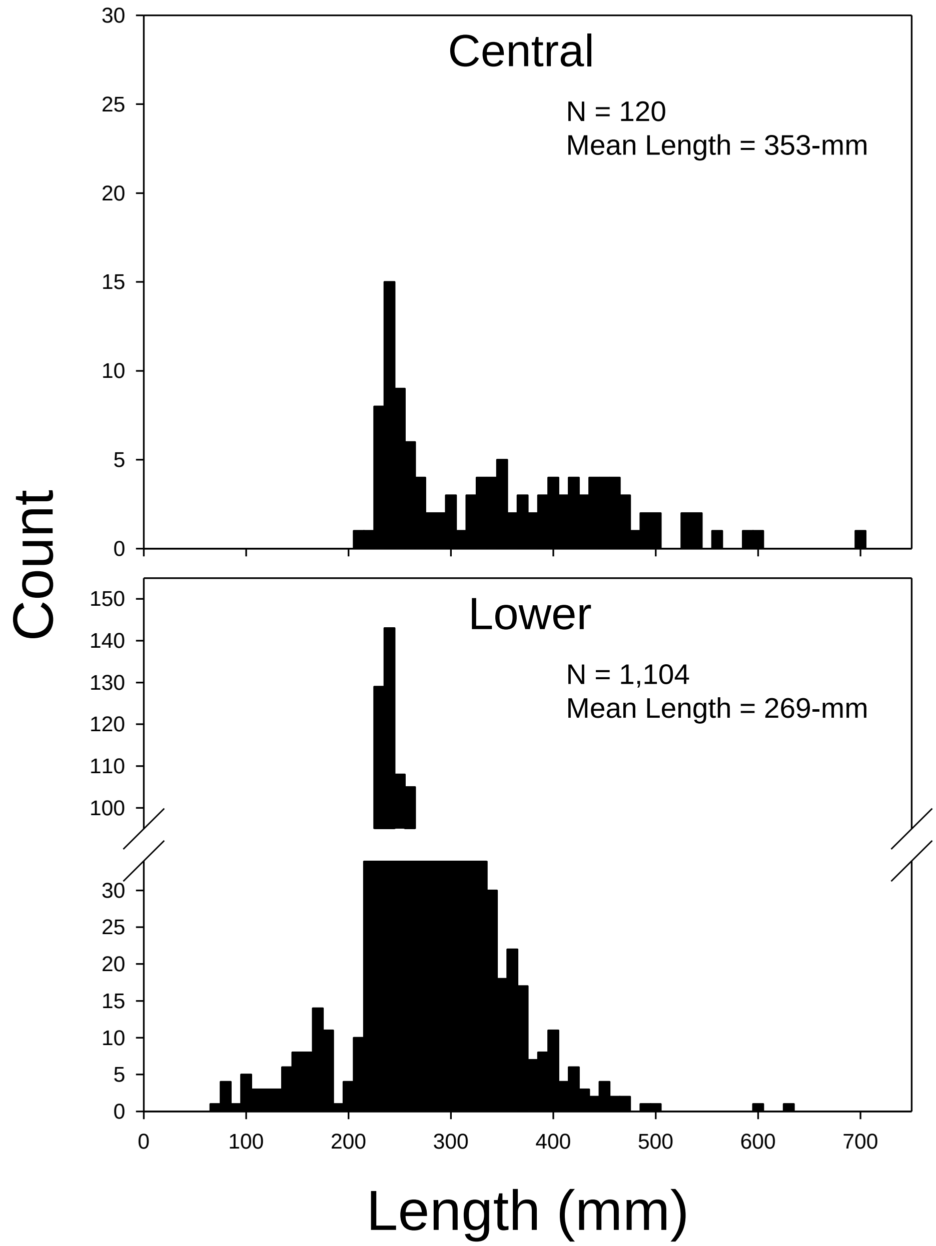

Figure 4-10. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in the central and lower reaches of the Platte River in the spring of 2011.

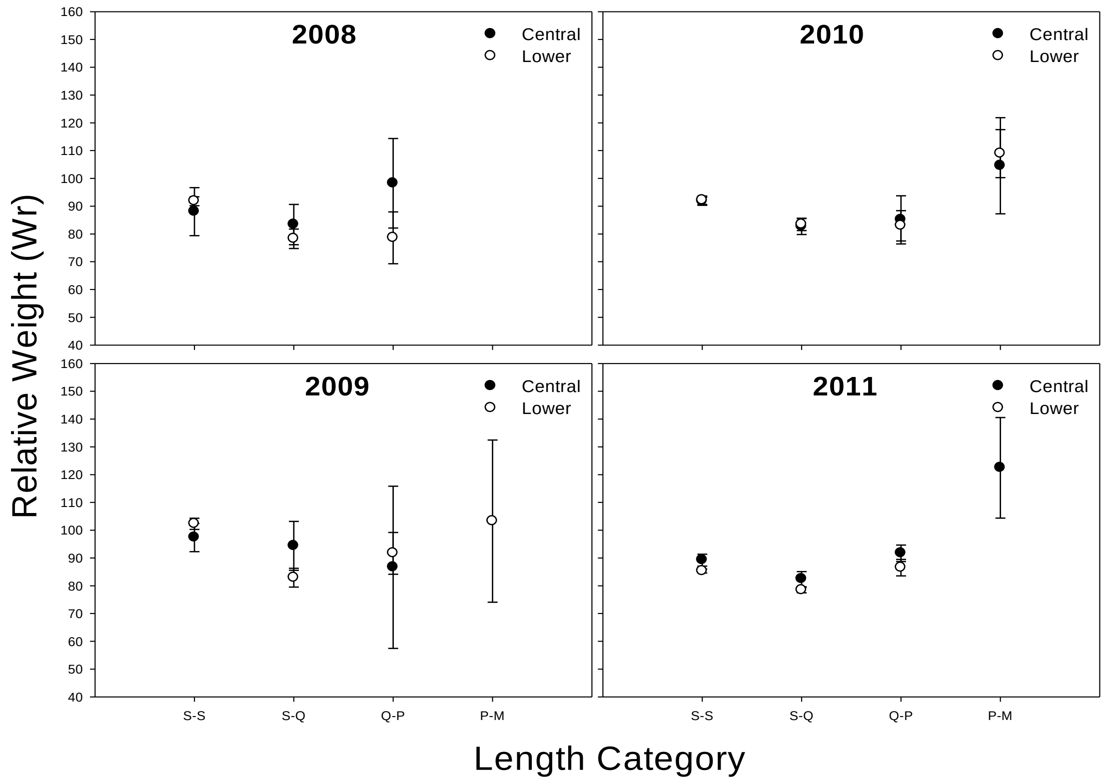

Figure 4-11. Mean relative weight (Wr) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P) and preferred-memorable (P-M) channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River during 2008-2011. Error bars represent 1 SE.

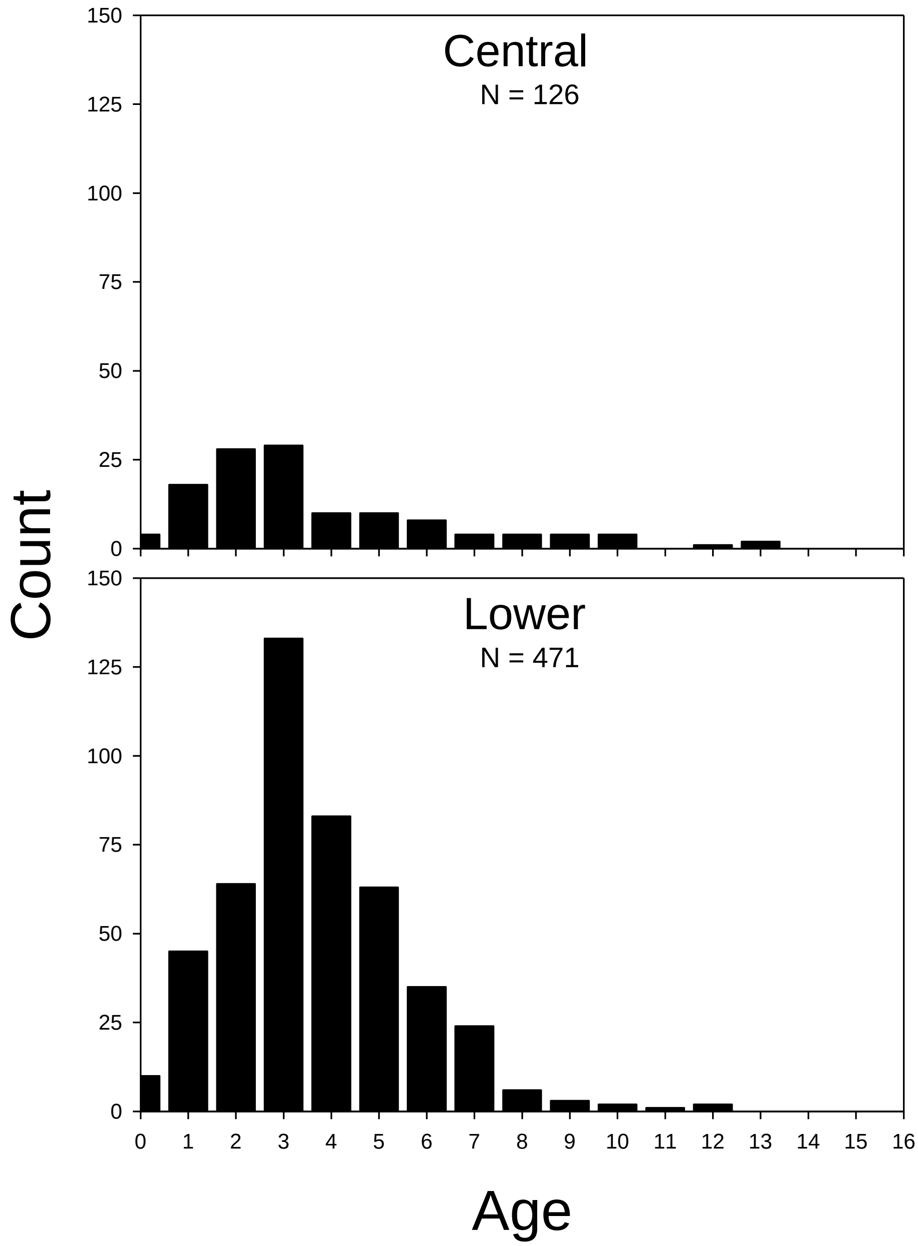

Figure 4-12. Age-frequency distributions of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River in 2007.

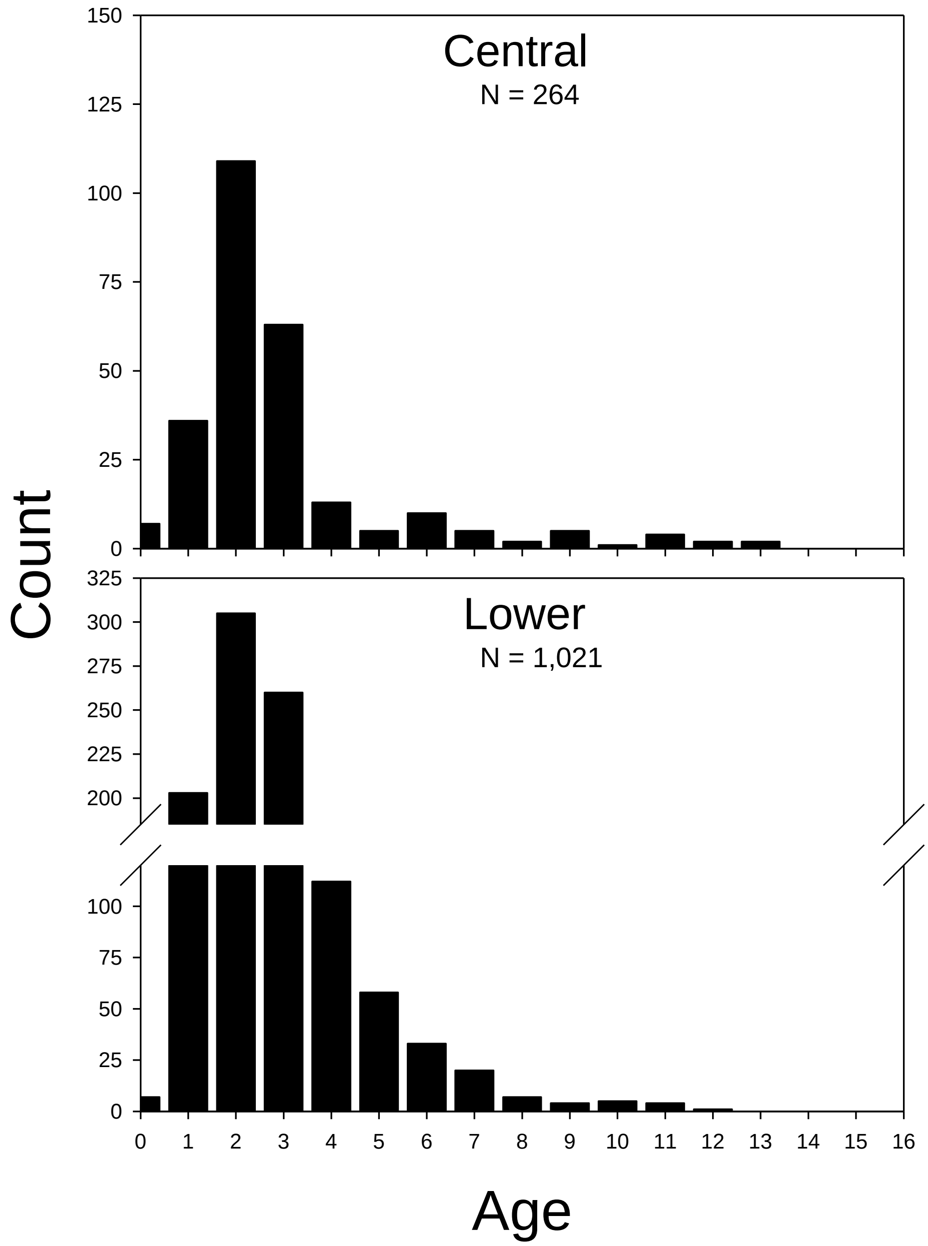

Figure 4-13. Age-frequency distributions of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River in 2008.

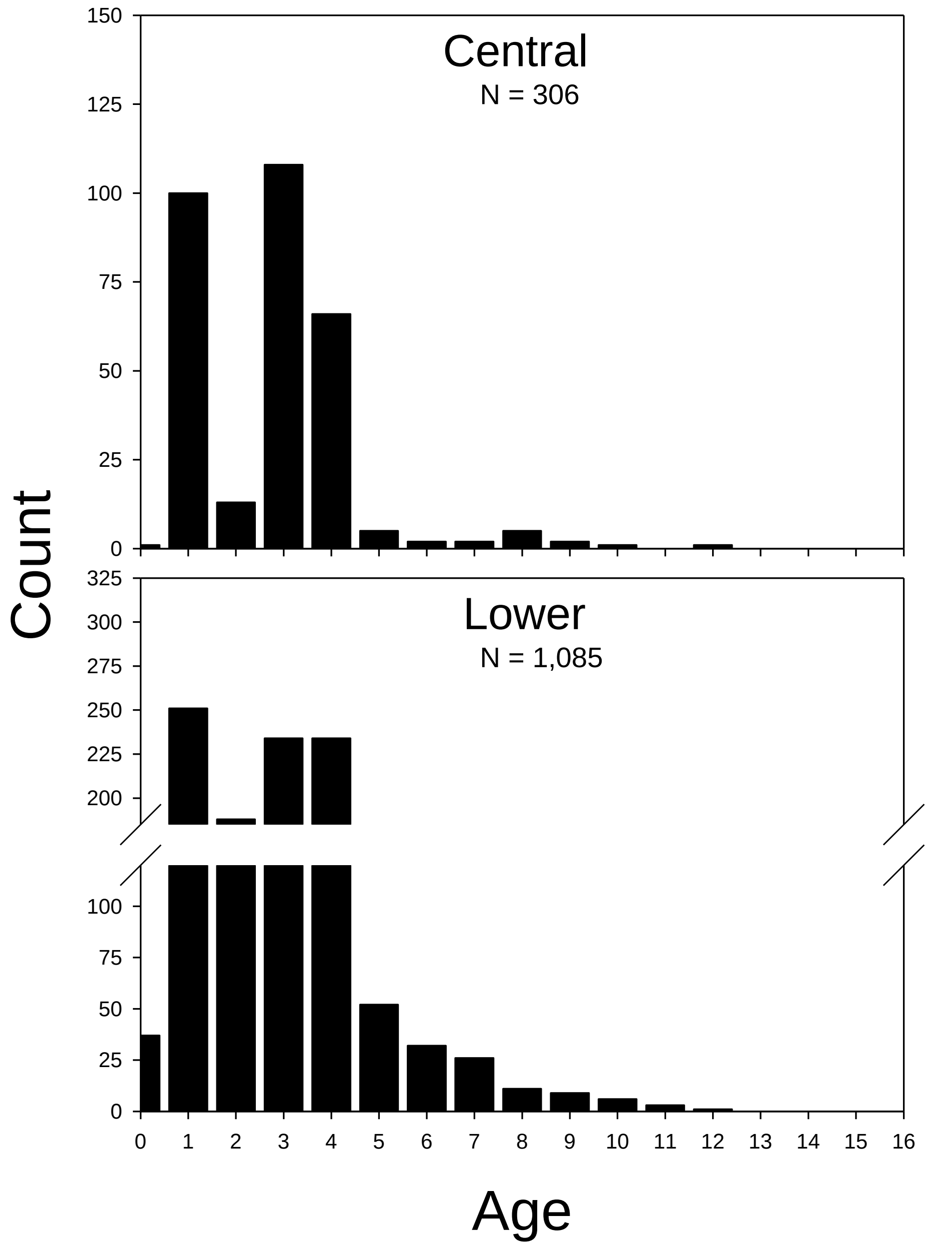

Figure 4-14. Age-frequency distributions of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River in 2009.

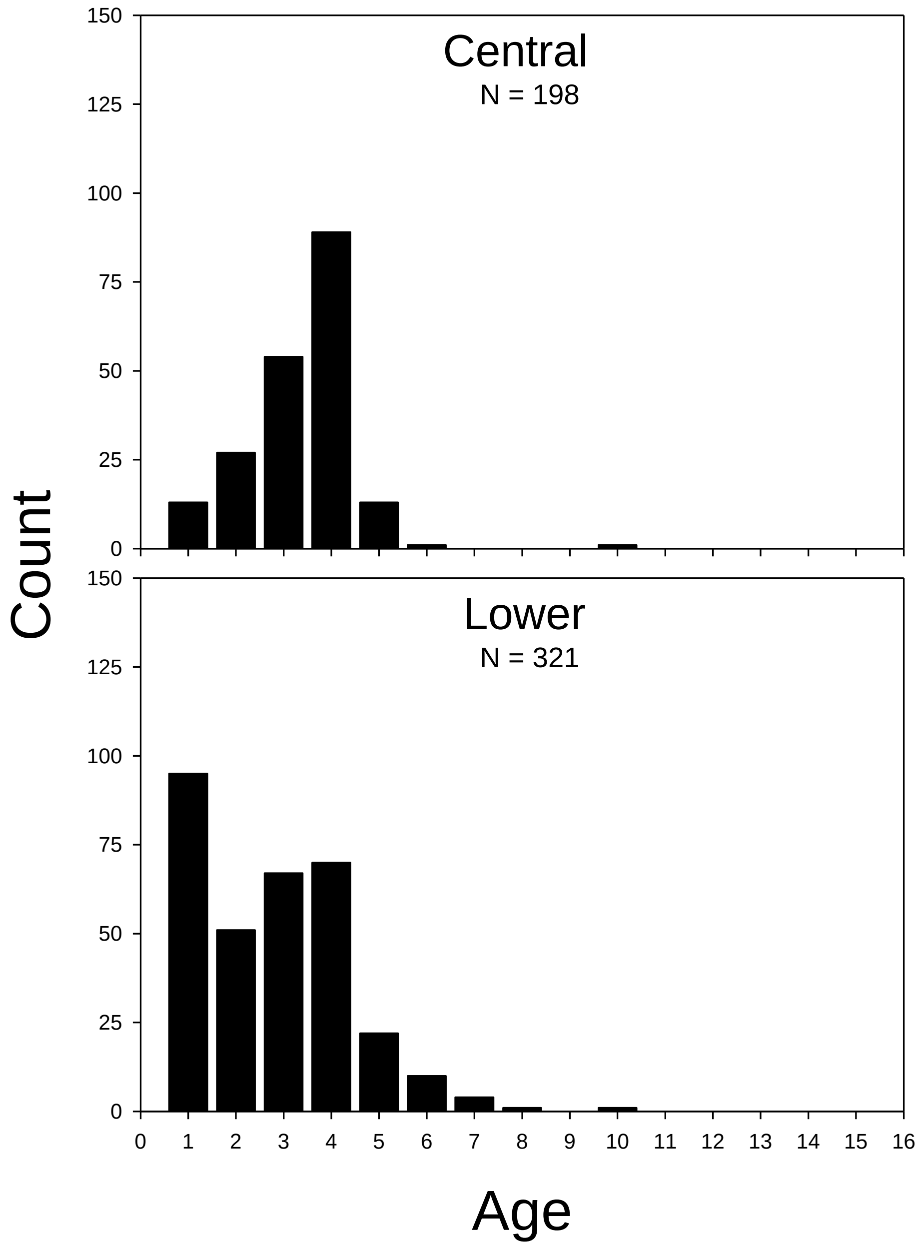

Figure 4-15. Age-frequency distributions of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River in the spring of 2010.

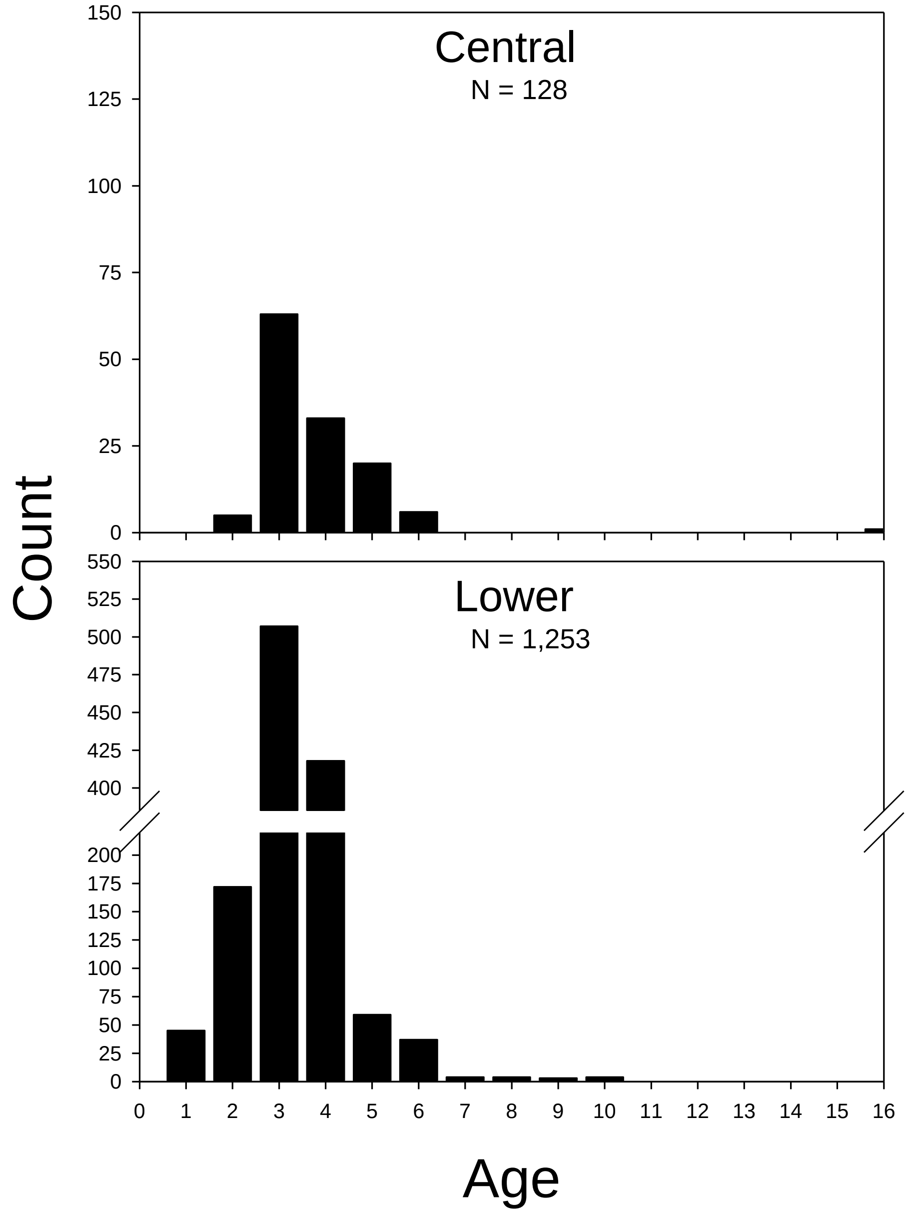

Figure 4-16. Age-frequency distributions of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River in the spring of 2011.

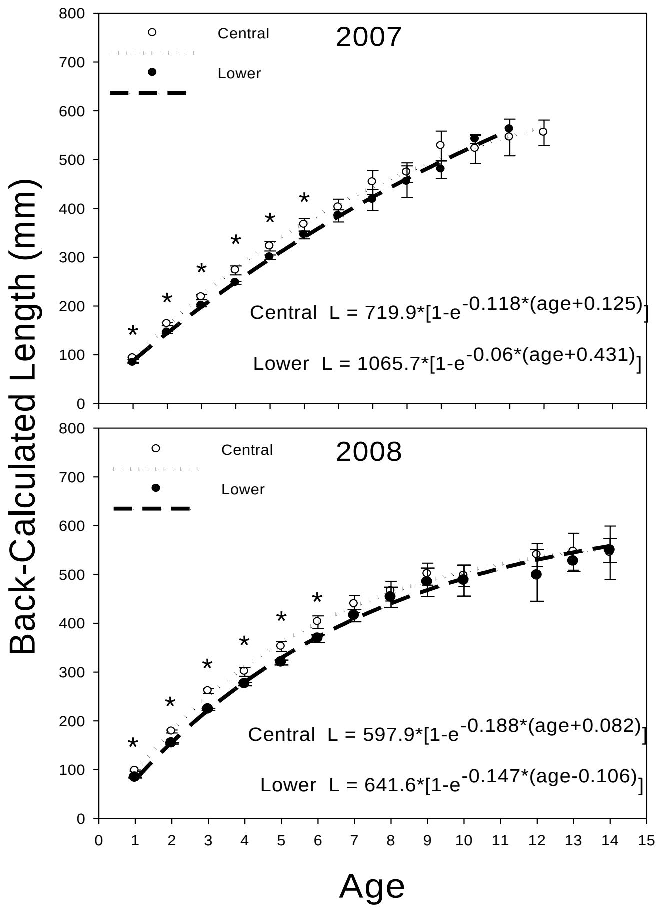

Figure 4-17. Von Bertalanffy growth function of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River during 2007 and 2008. Error bars represent 1 SE. An (*) indicates differences in mean back-calculated length at each age.

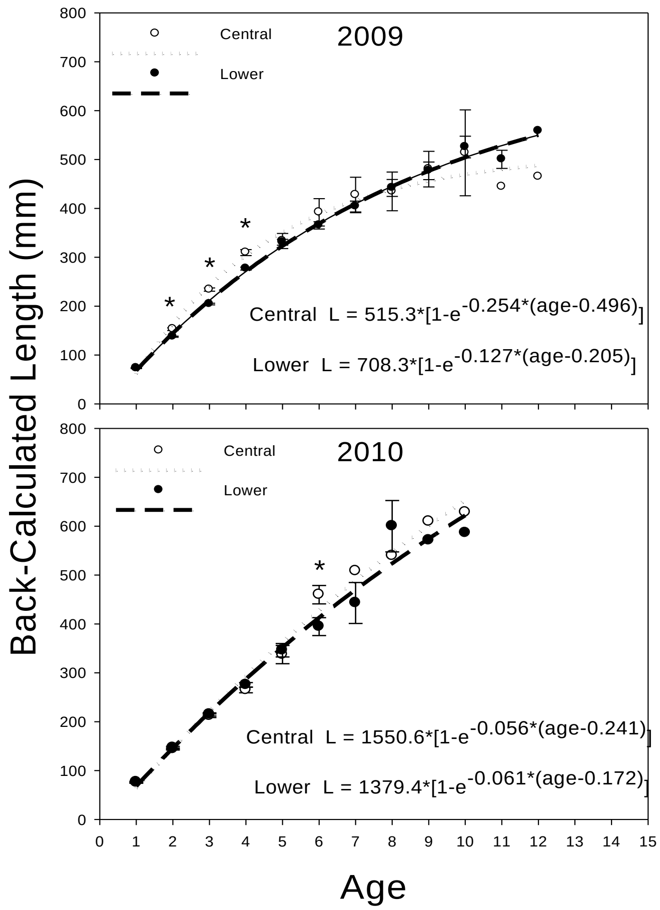

Figure 4-18. Von Bertalanffy growth function of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River during 2009 and 2010. Error bars represent 1 SE. An (*) indicates differences in mean back-calculated length at each age.

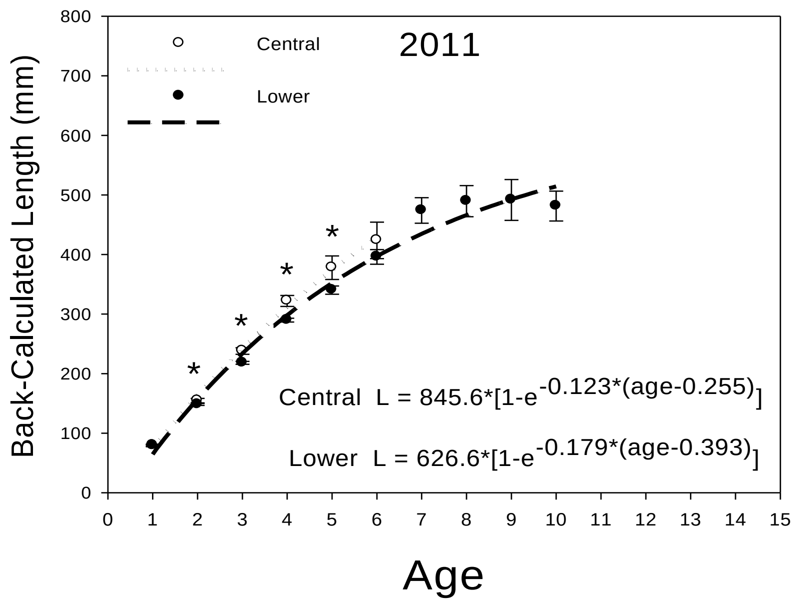

Figure 4-19. Von Bertalanffy growth function of channel catfish collected with all standard sampling gears in the central and lower reaches of the Platte River during 2011. Error bars represent 1 SE. An (*) indicates differences in mean back-calculated length at each age.

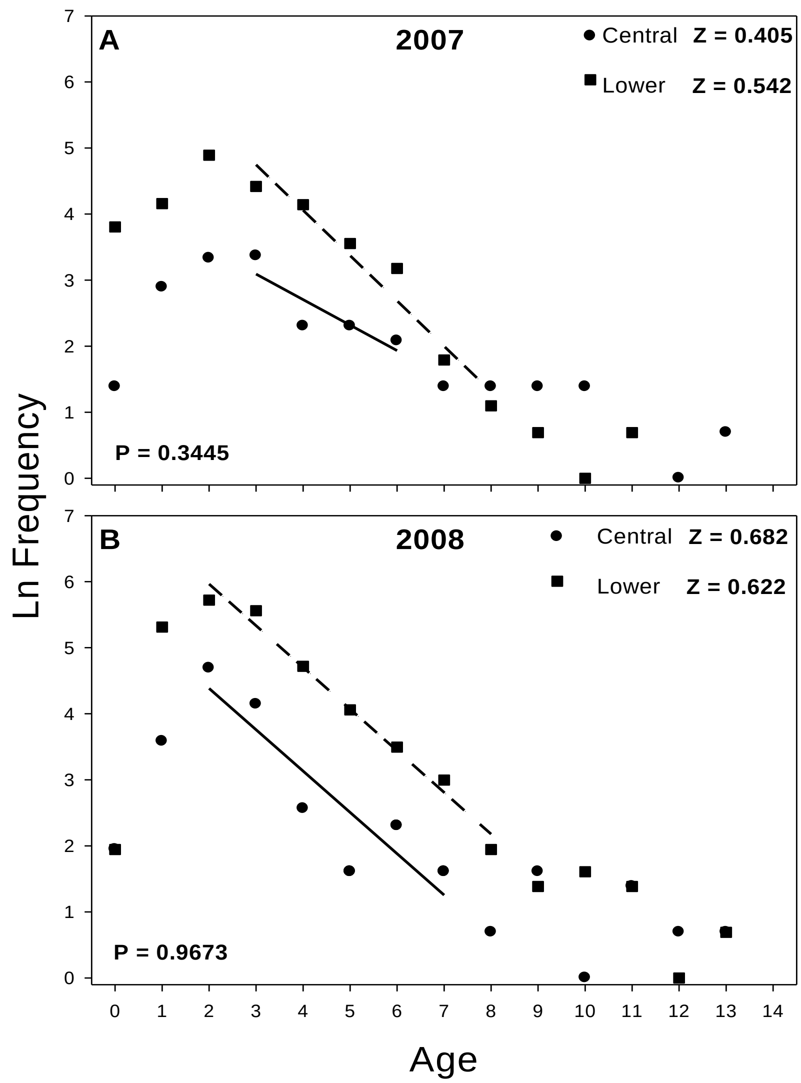

Figure 4-20. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the central and lower reaches of the Platte River during 2007 and 2008. P-values are reported for ANCOVA testing differences in regression line slopes (instantaneous mortality, Z).

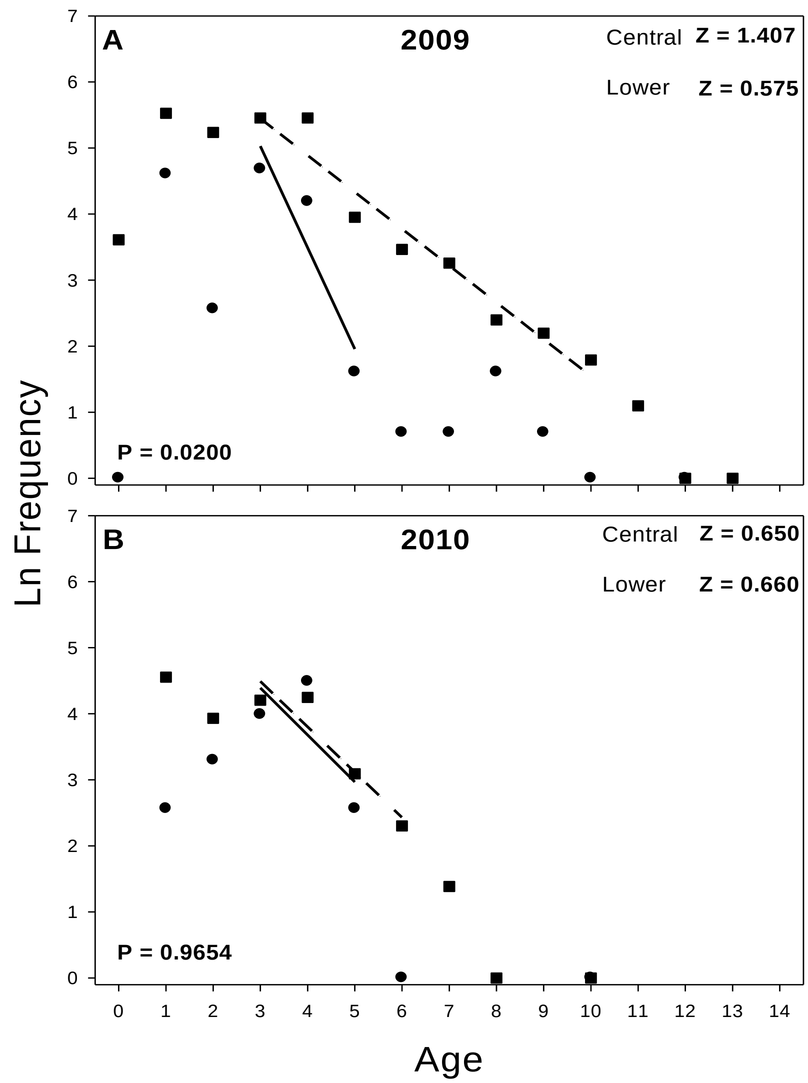

Figure 4-21. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the central and lower reaches of the Platte River during 2009 and 2010. P-values are reported for ANCOVA testing differences in regression line slopes (instantaneous mortality, Z).

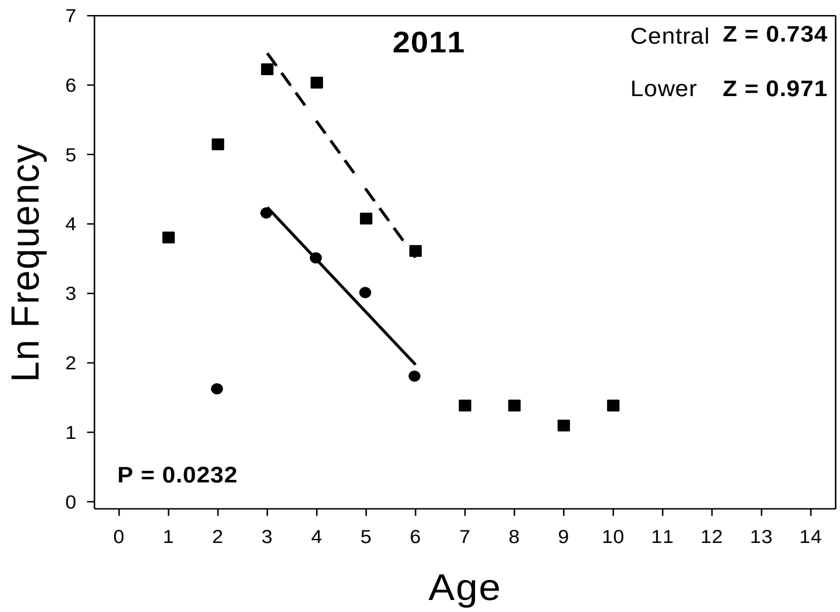

Figure 4-22. Weighted regression catch curves for channel catfish collected from all standard sampling gears in the central and lower reaches of the Platte River during 2011. P-values are reported for ANCOVA testing differences in regression line slopes (instantaneous mortality, Z).

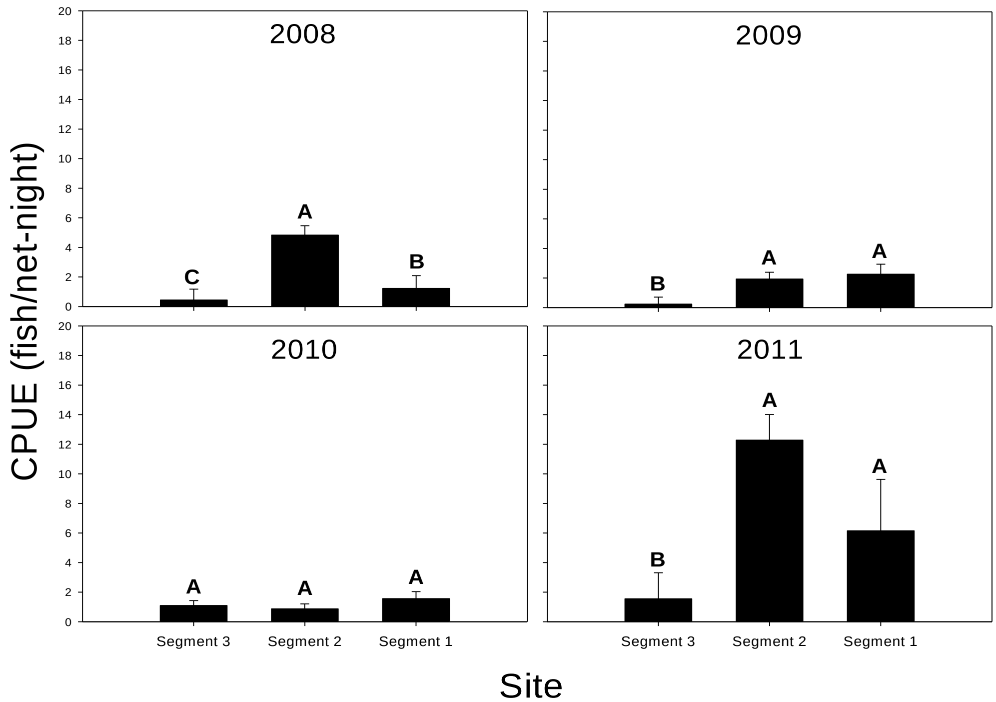

Figure 4-23. Mean catch per unit effort (CPUE) of channel catfish collected with 25-mm hoop nets (4-hoop) in segment 3, segment 2, and segment 1 of the Platte River during 2008-2011. Error bars represent 1 SE. Different letters above plots indicate differences in CPUE between segments.

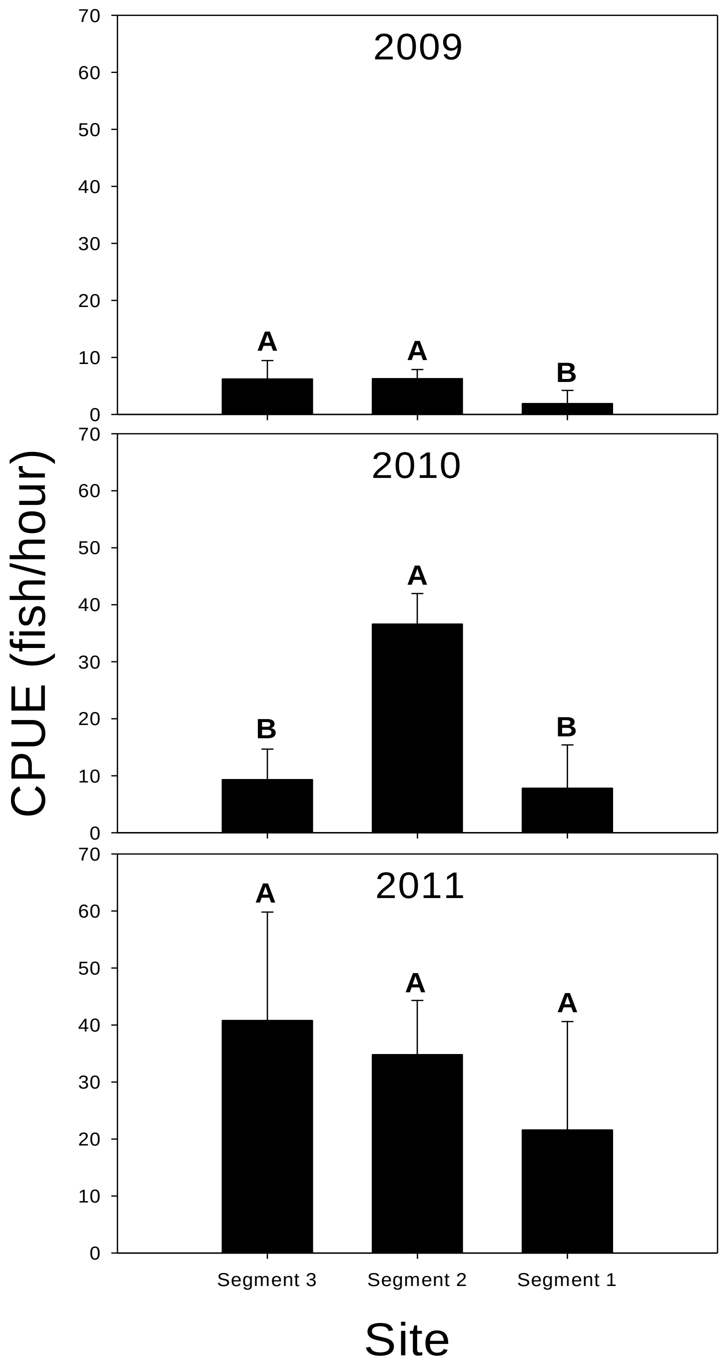

Figure 4-24. Mean catch per unit effort (CPUE) of channel catfish collected with low pulsed-DC electrofishing (EFL) in segment 3, segment 2, and segment 1 of the Platte River during 2009-2011. Error bars represent 1 SE. Different letters above plots indicate differences in CPUE between segments.

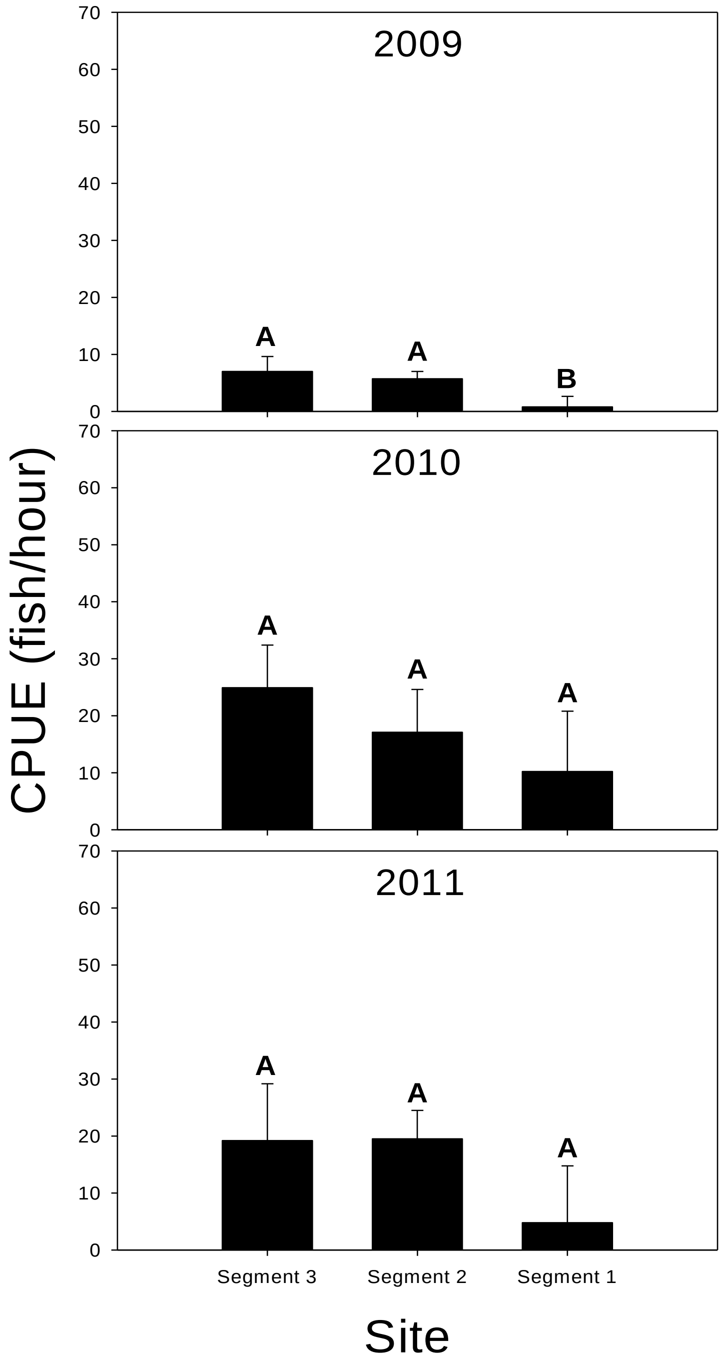

Figure 4-25. Mean catch per unit effort (CPUE) of channel catfish collected with high pulsed-DC electrofishing (EFH) in segment 3, segment 2, and segment 1 of the Platte River during 2009-2011. Error bars represent 1 SE. Different letters above plots indicate differences in CPUE between segments.

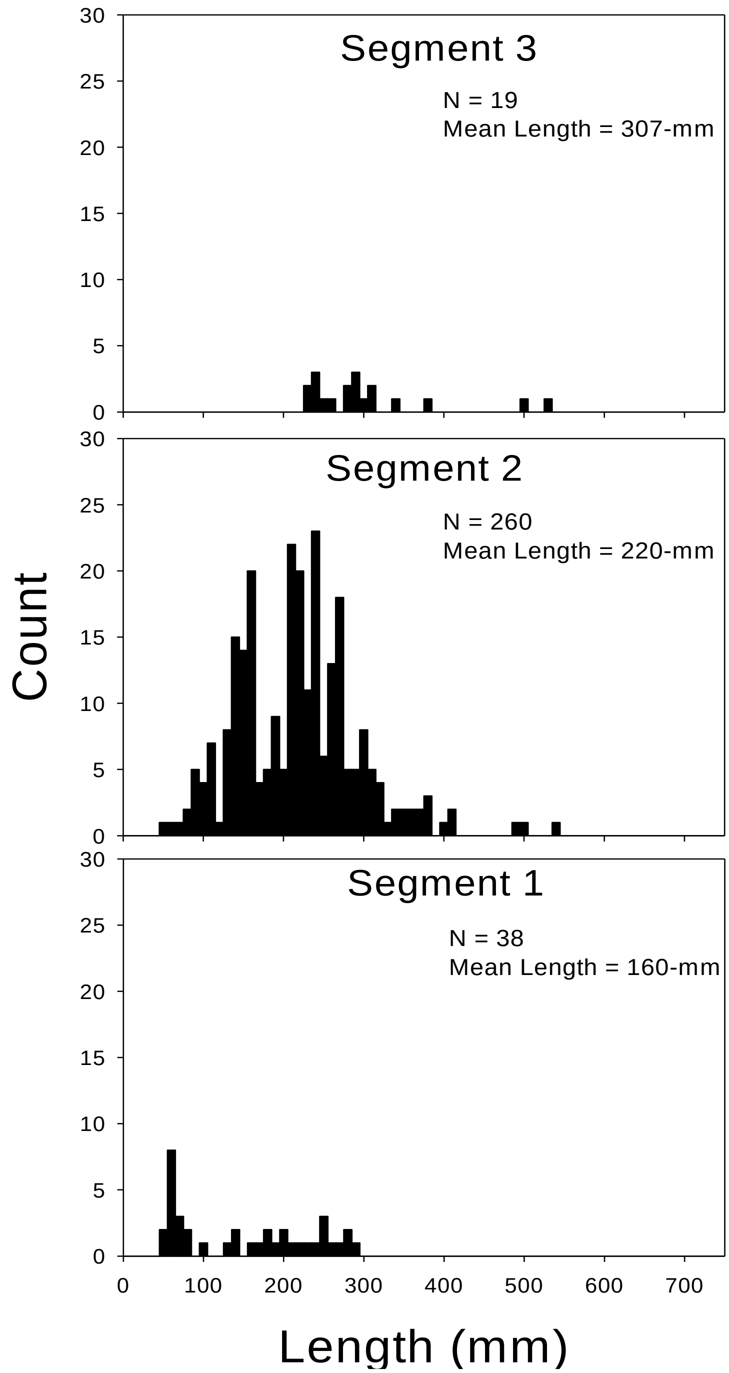

Figure 4-26. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in segment 3, segment 2, and segment 1 of the Platte River in the spring of 2008.

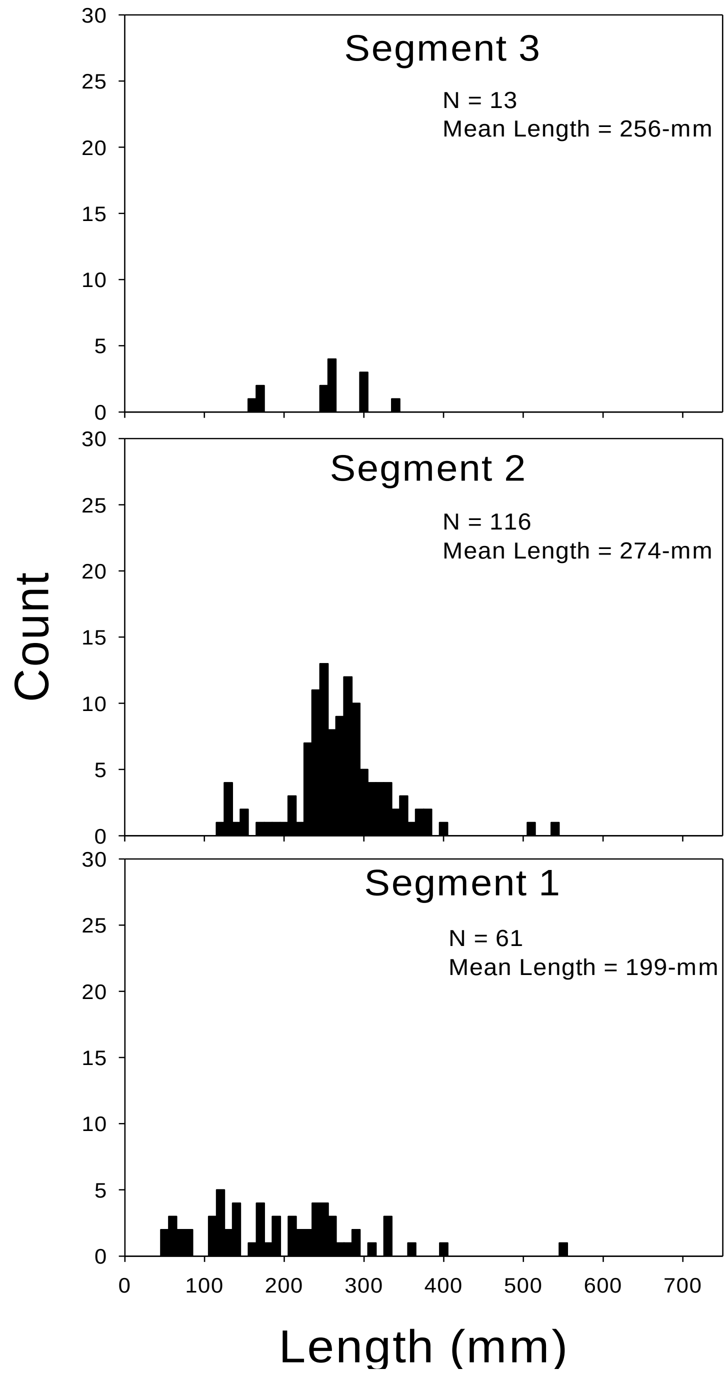

Figure 4-27. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in segment 3, segment 2, and segment 1 of the Platte River in the spring of 2009.

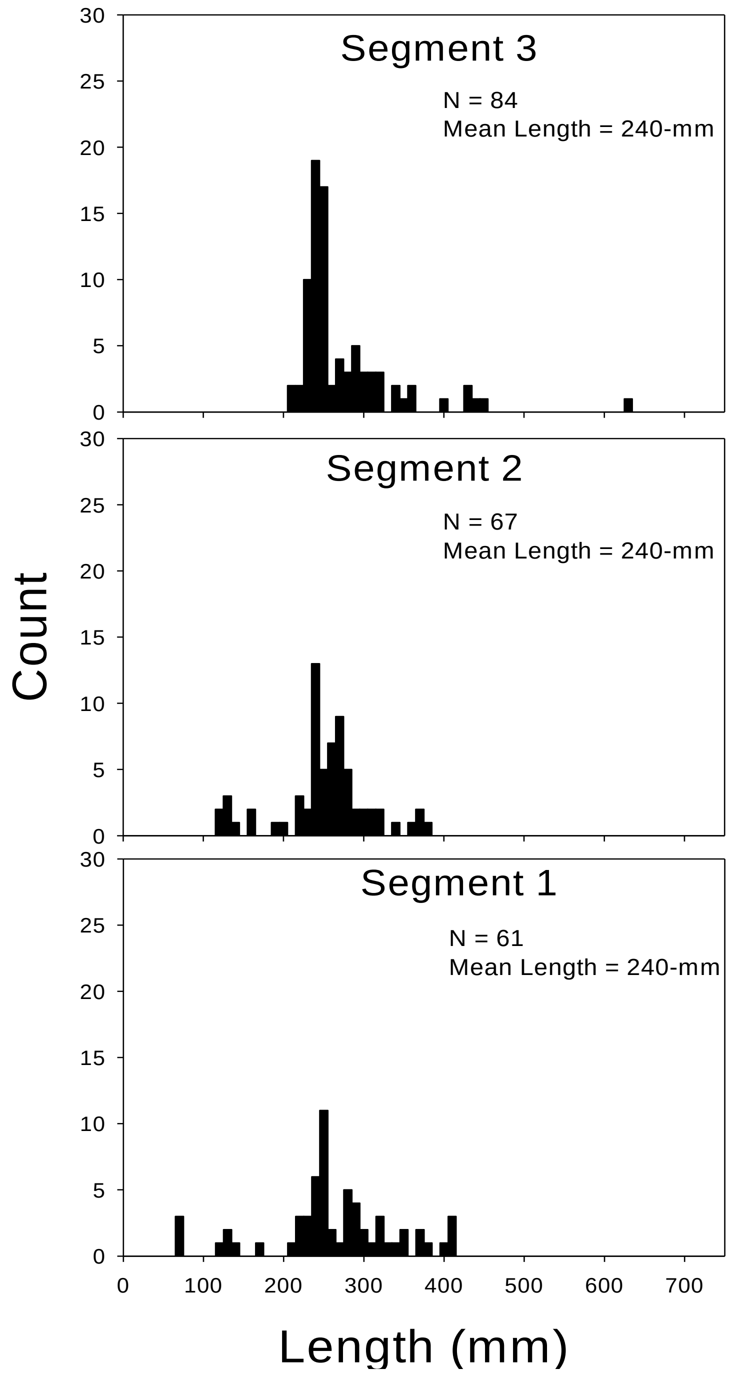

Figure 4-28. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in segment 3, segment 2, and segment 1 of the Platte River in the spring of 2010.

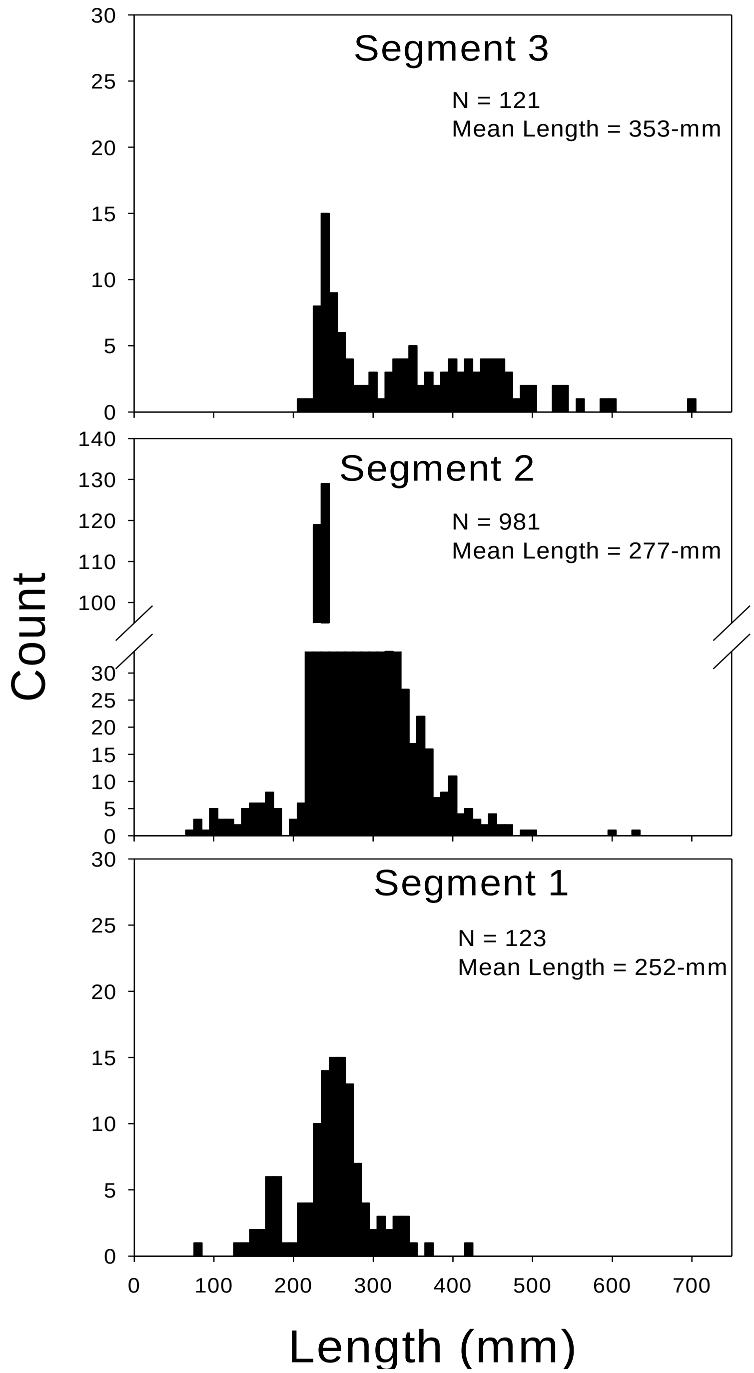

Figure 4-29. Length-frequency distributions of channel catfish collected with hoop nets (4-hoop) in segment 3, segment 2, and segment 1 of the Platte River in the spring of 2011.

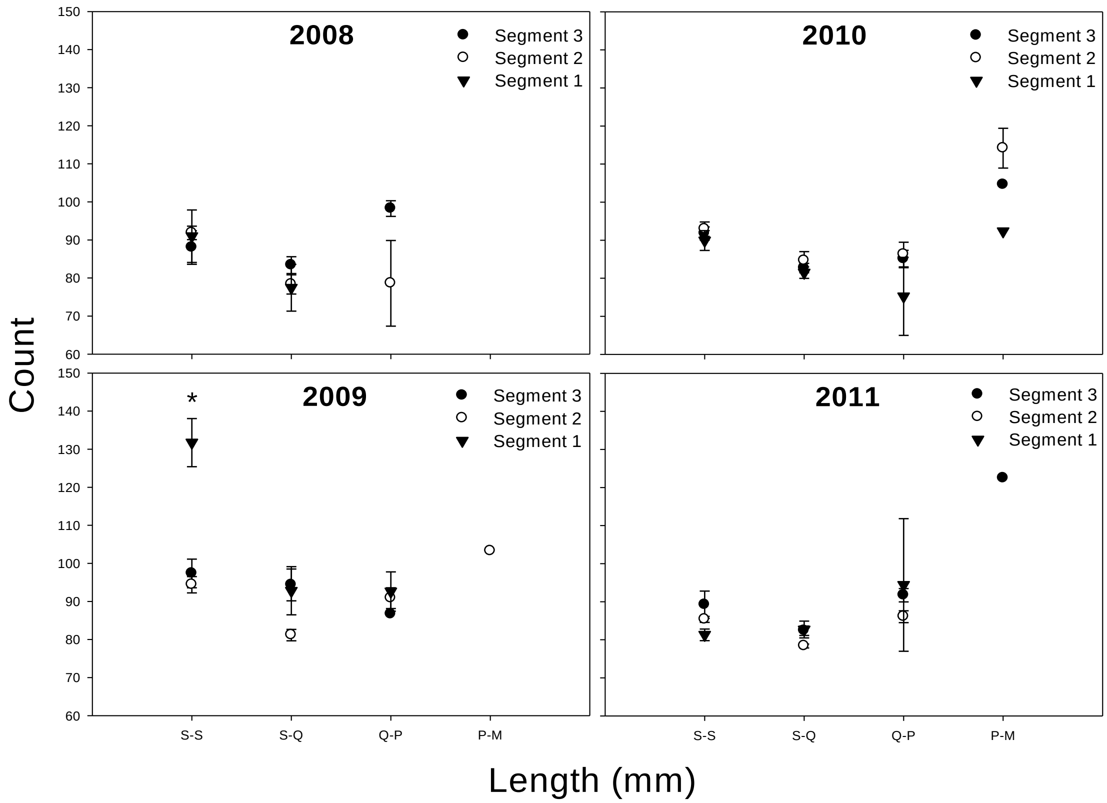

Figure 4-30. Mean relative weight (Wr) of sub-stock (S-S), stock-quality (S-Q), quality-preferred (Q-P) and preferred-memorable (P-M) channel catfish collected with all standard sampling gears in segment 3, segment 2, and segment 1 of the Platte River during 2008-2011. Error bars represent 1 SE. An (*) indicates differences in mean relative weight between segments.

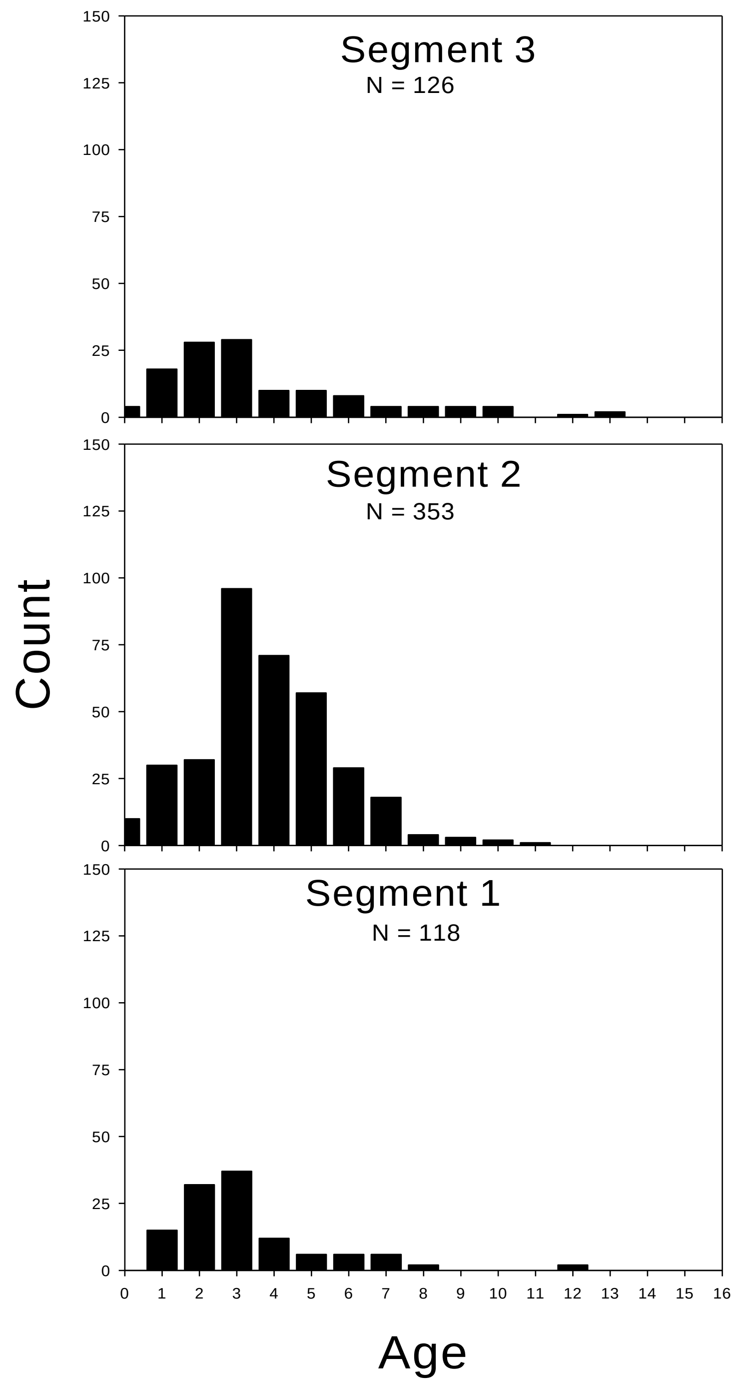

Figure 4-31. Age-frequency distributions of channel catfish collected with all standard sampling gears in segment 3, segment 2 and, segment 1 of the Platte River in 2007.

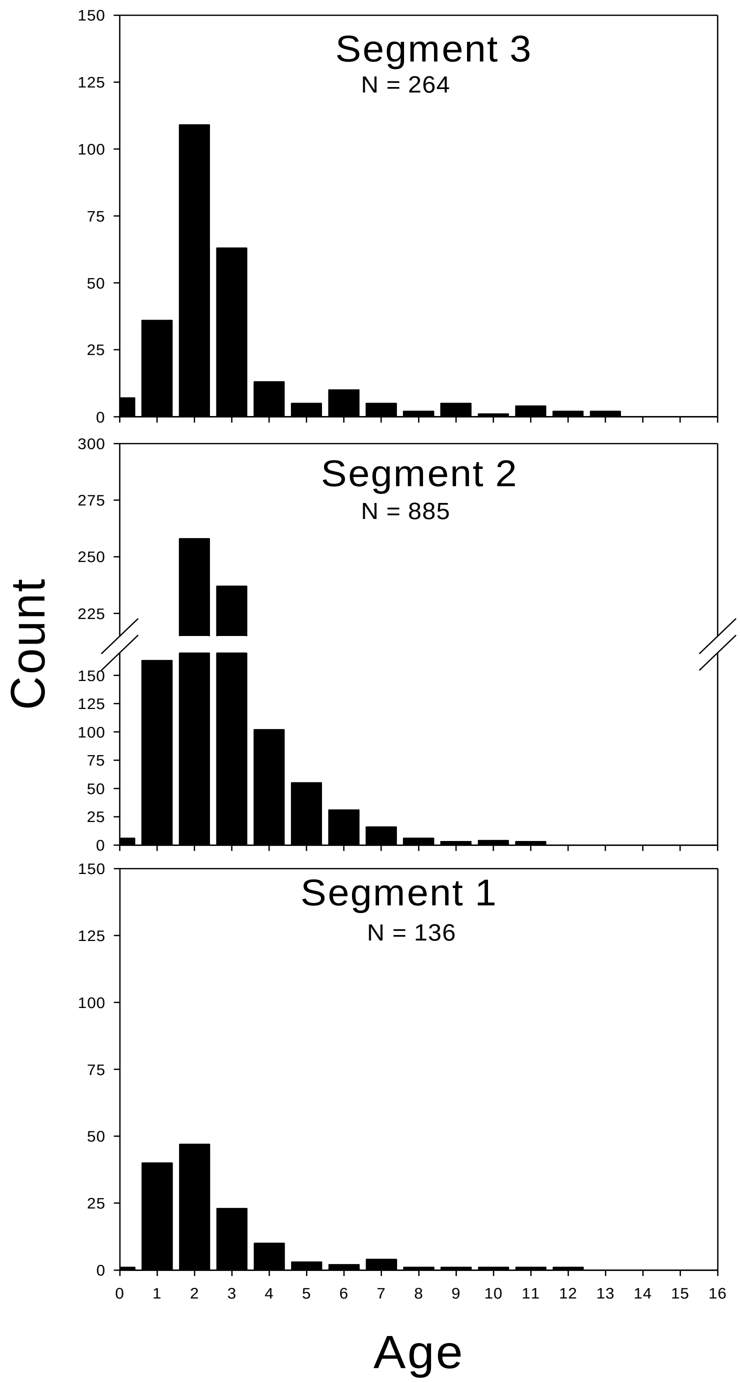

Figure 4-32. Age-frequency distributions of channel catfish collected with all standard sampling gears in segment 3, segment 2 and, segment 1 of the Platte River in 2008.

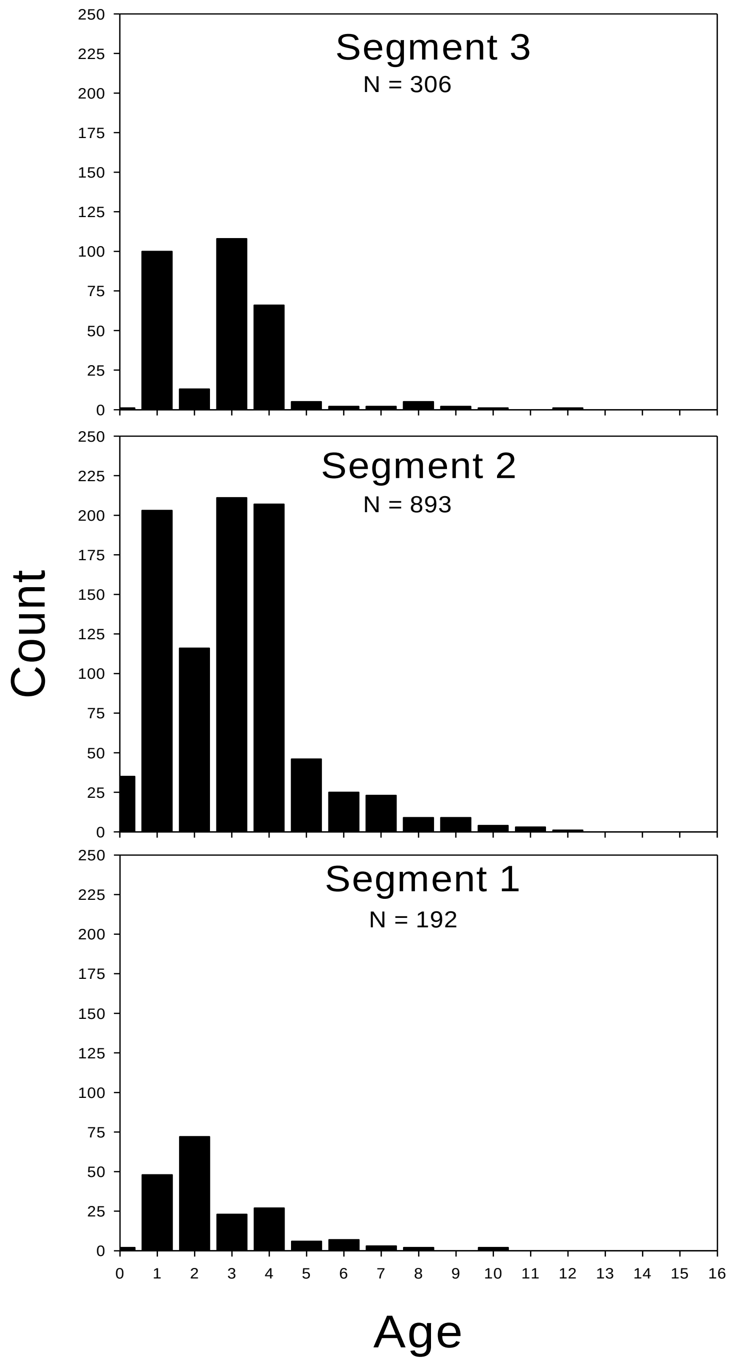

Figure 4-33. Age-frequency distributions of channel catfish collected with all standard sampling gears in segment 3, segment 2 and, segment 1 of the Platte River in 2009.

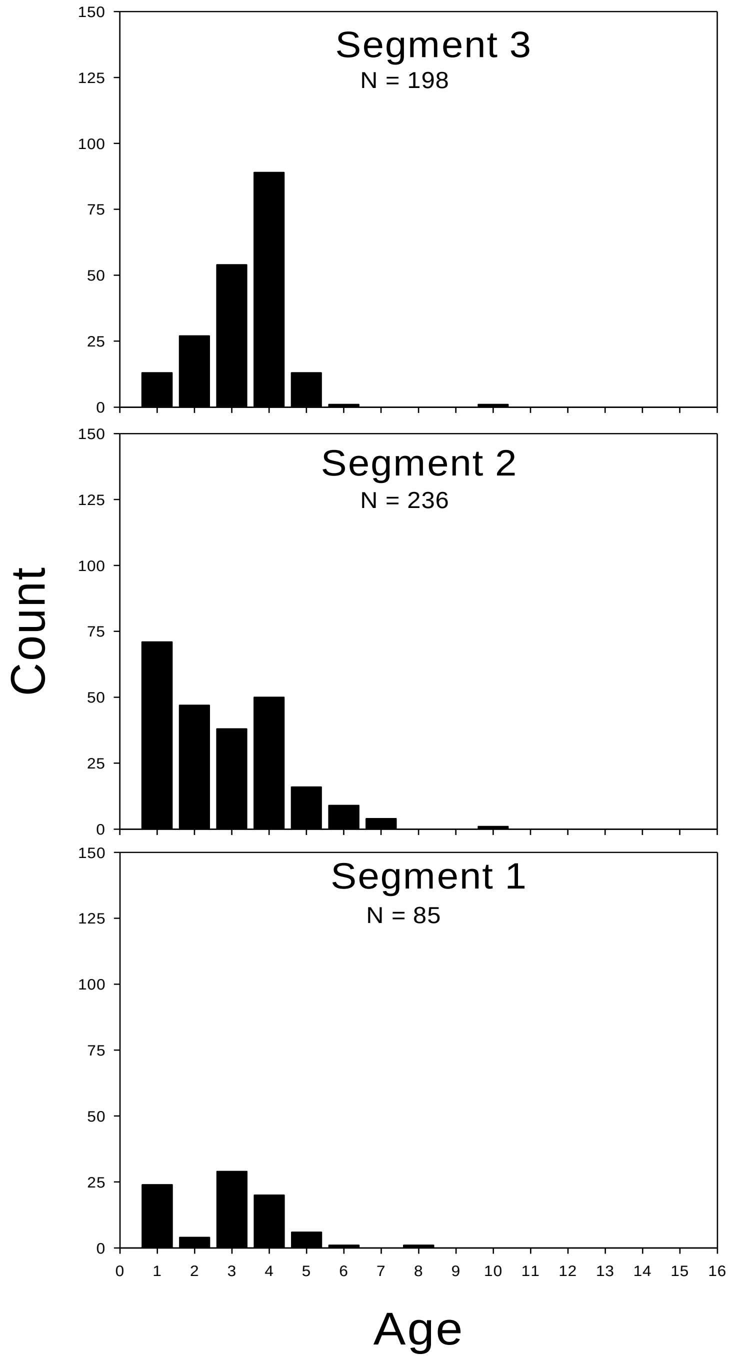

Figure 4-34. Age-frequency distributions of channel catfish collected with all standard sampling gears in segment 3, segment 2 and, segment 1 of the Platte River in the spring of 2010.

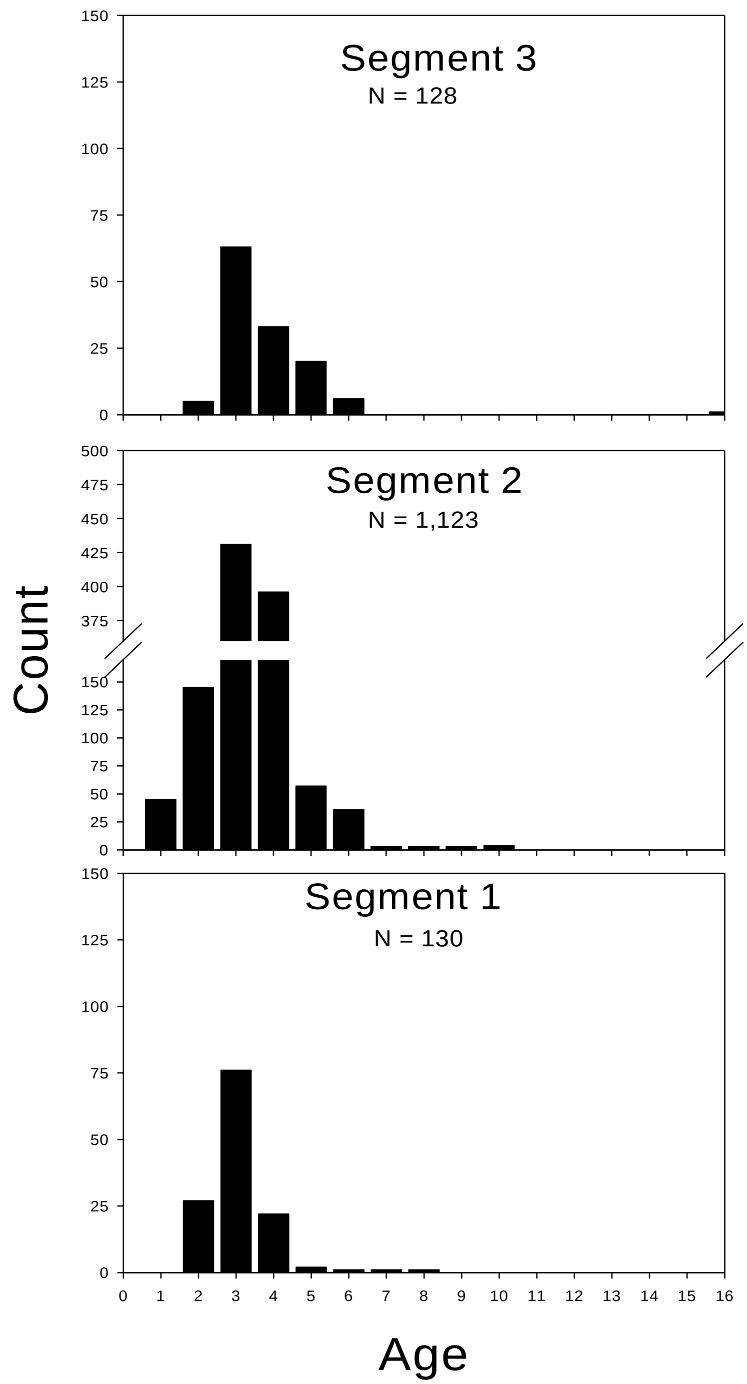

Figure 4-35. Age-frequency distributions of channel catfish collected with all standard sampling gears in segment 3, segment 2 and, segment 1 of the Platte River in the spring of 2011.

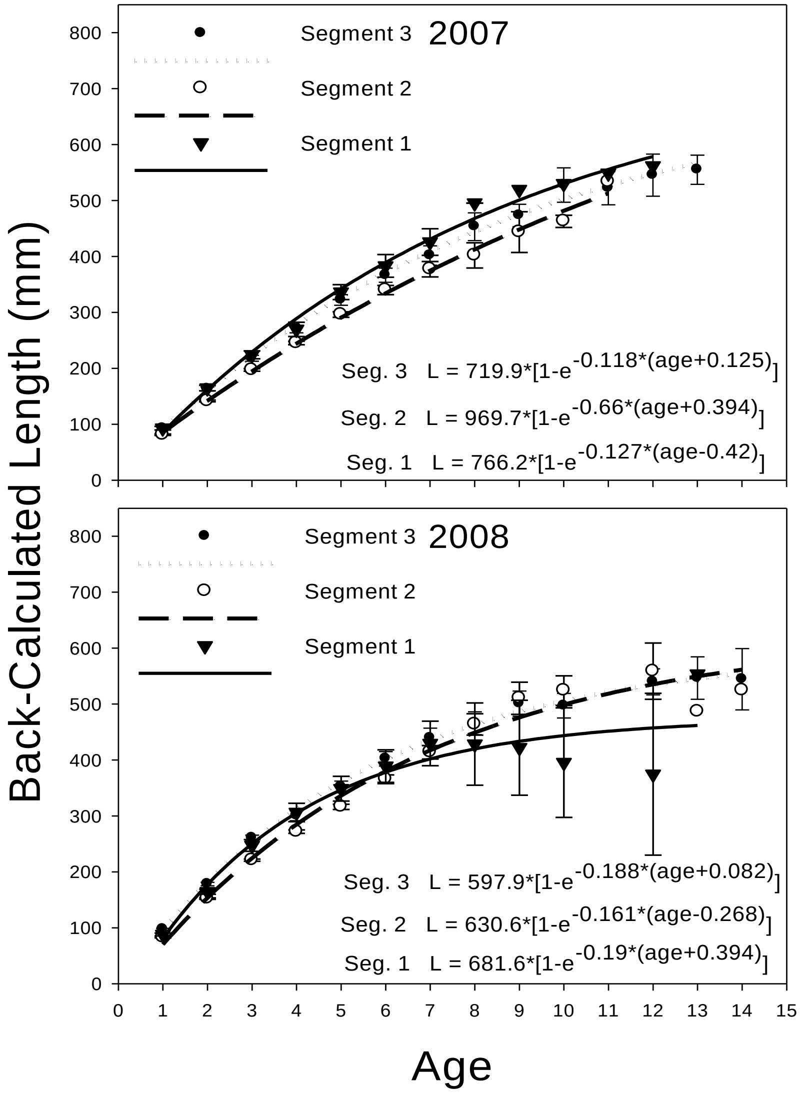

Figure 4-36. Von Bertalanffy growth function of channel catfish collected with all standard sampling gears in segment 3, segment 2, and segment 1 of the Platte River during 2007 and 2008. Error bars represent 1 SE.

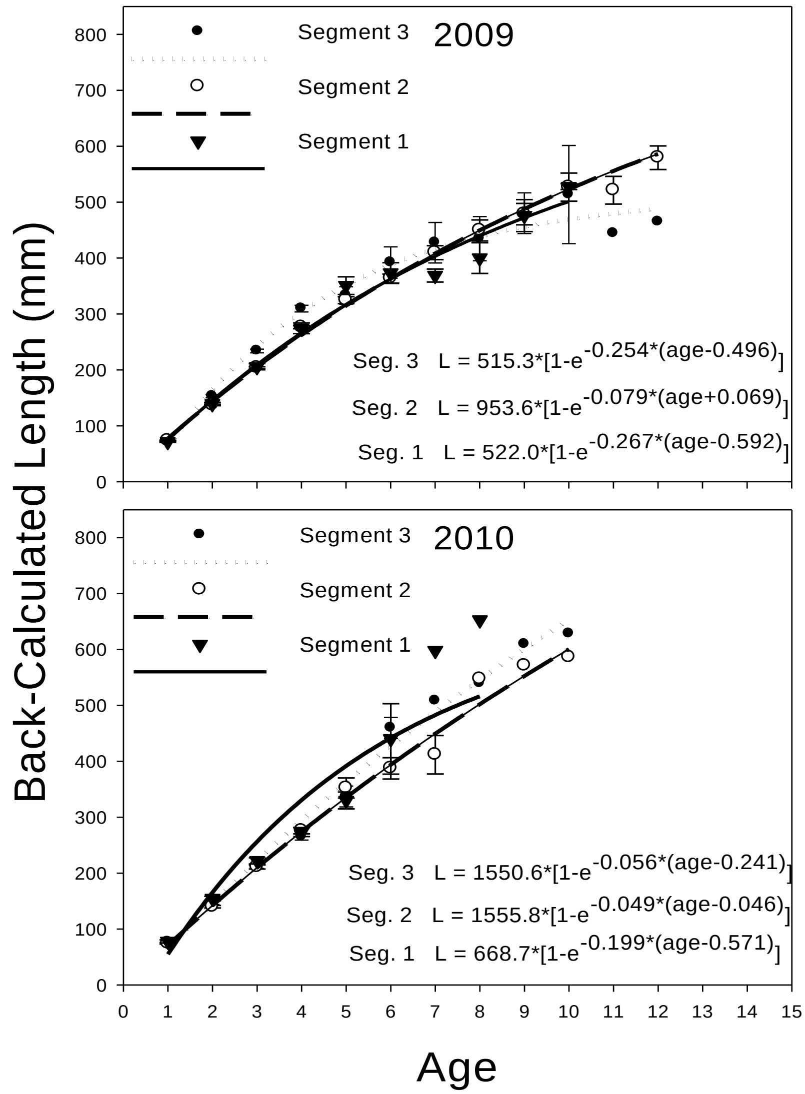

Figure 4-37. Von Bertalanffy growth function of channel catfish collected with all standard sampling gears in segment 3, segment 2, and segment 1 of the Platte River during 2009 and 2010. Error bars represent 1 SE.

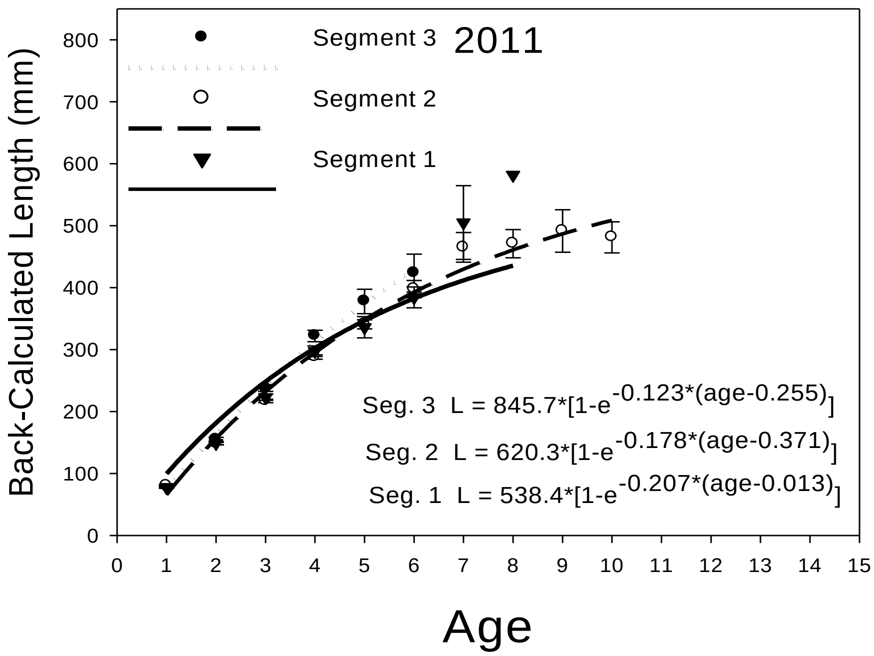

Figure 4-38. Von Bertalanffy growth function of channel catfish collected with all standard sampling gears in segment 3, segment 2, and segment 1 of the Platte River during 2011. Error bars represent 1 SE.

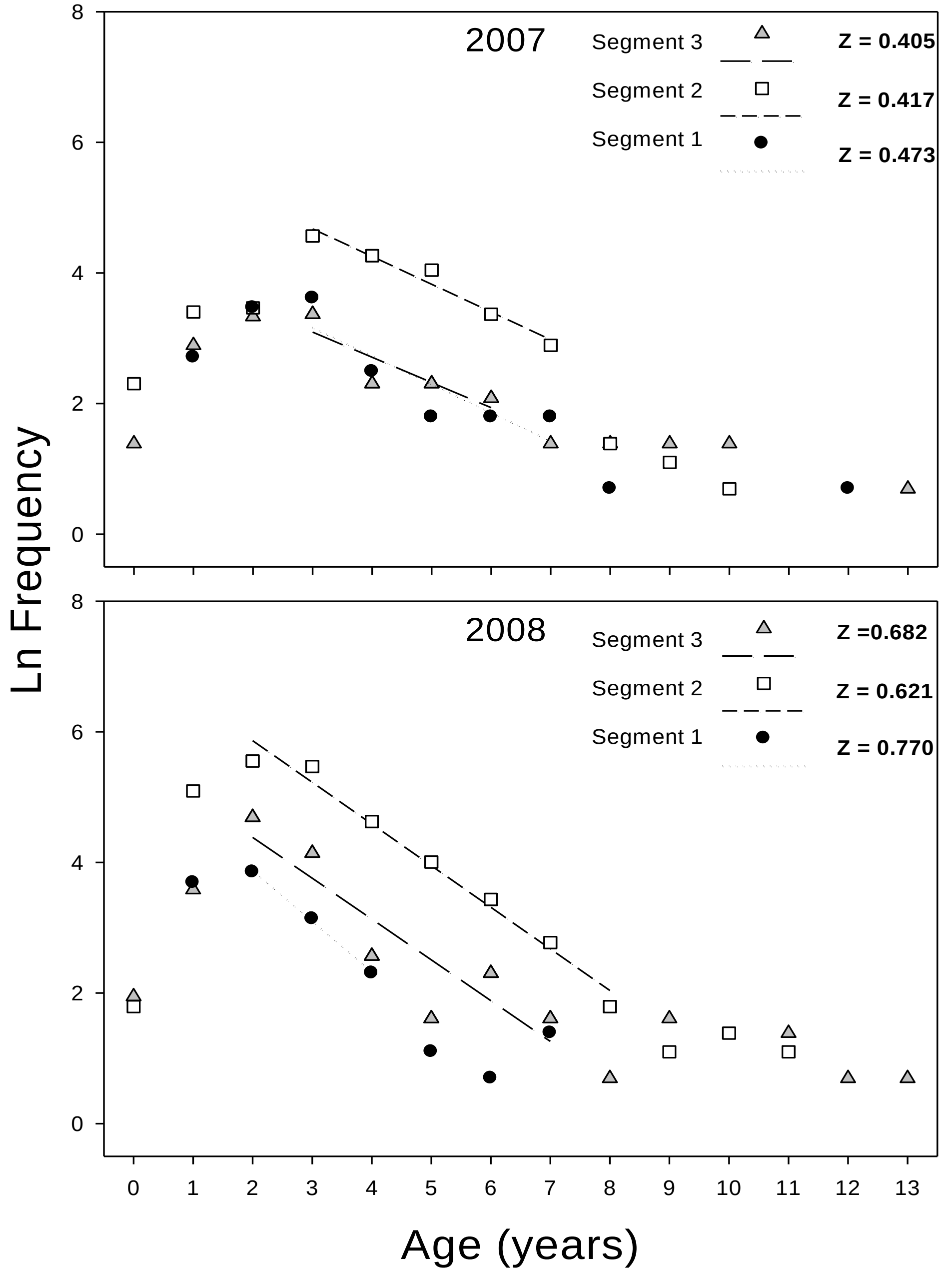

Figure 4-39. Weighted regression catch curves for channel catfish collected from all standard sampling gears in segment 3, segment 2, and segment 1 of the Platte River during 2007 and 2008.

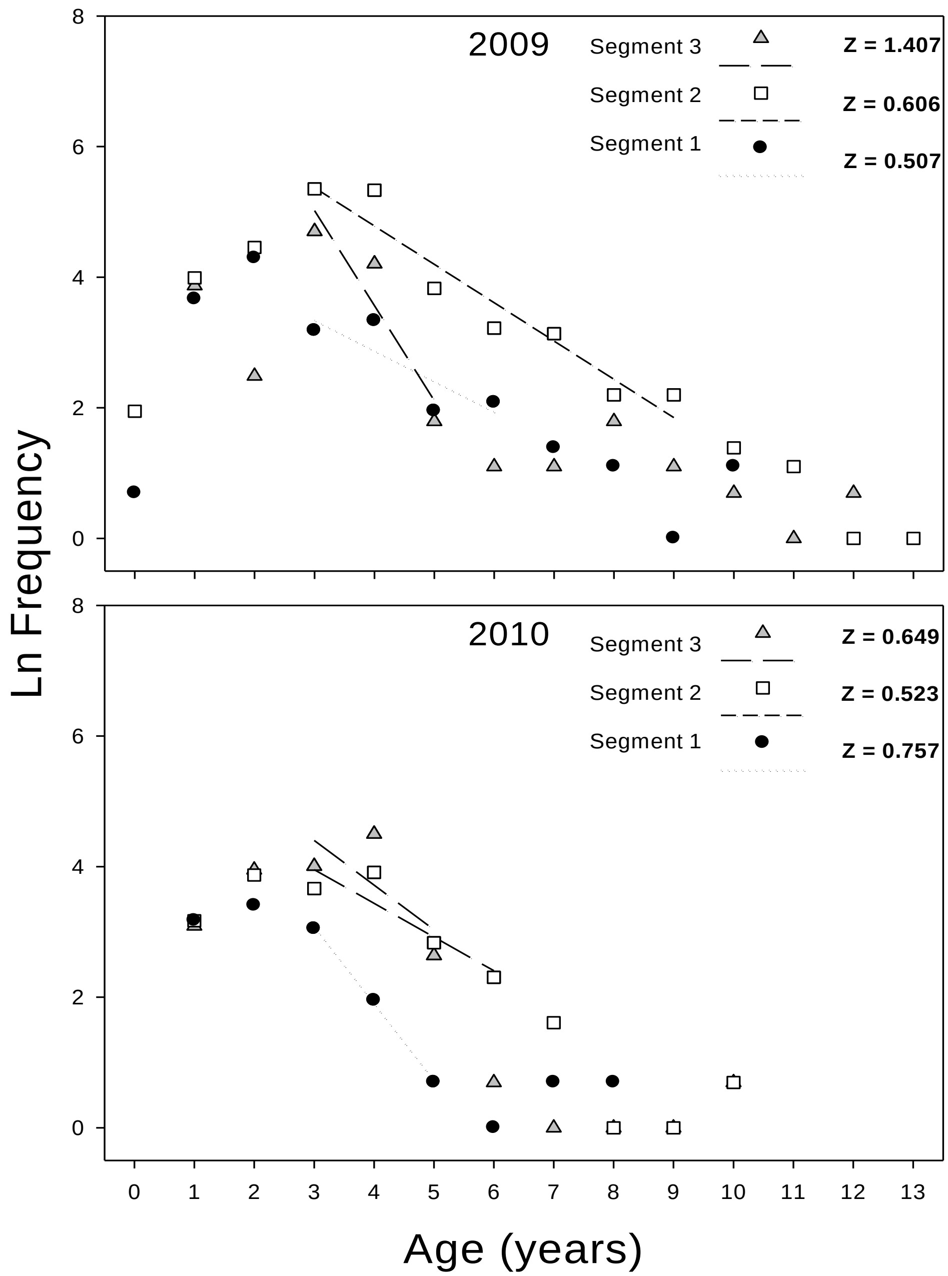

Figure 4-40. Weighted regression catch curves for channel catfish collected from all standard sampling gears in segment 3, segment, and segment 1 of the Platte River during 2009 and 2010.

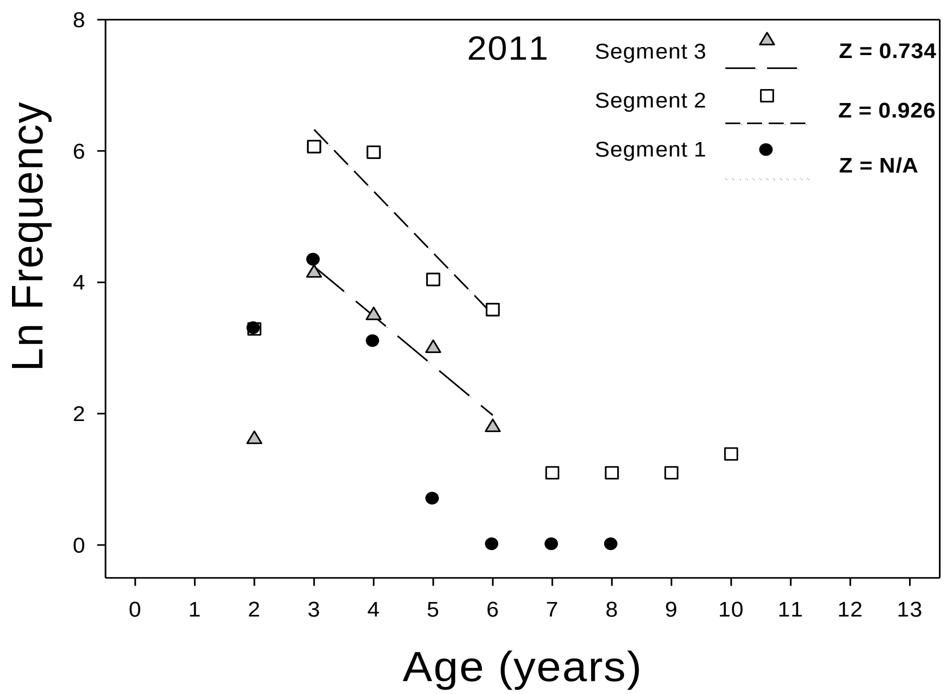

Figure 4-41. Weighted regression catch curves for channel catfish collected from all standard sampling gears in segment 3, segment 2 and segment 1 of the Platte River during 2011.

Chapter 5. Future Research and Management Recommendations.

The Platte River is an important resource for catfish anglers in Nebraska. For example, more than 50% of Nebraska anglers in 1981 and 1982 (Zuerlein 1984), and 57% in 2002 fished for channel catfish (Hurley and Duppong-Hurley 2005). In 1982, 29% of fishing days were on Nebraska rivers and streams (Zuerlein 1984), even though much of the river and stream systems are encompassed by private land. The majority of fishing took place on the Platte River (35%) and the Missouri River (23%) (Zuerlein 1984). However, water manipulations, namely by irrigation withdrawals and the Loup River Power Canal, are believed to be causing a harsh living environment for channel catfish in the Platte River (Holland and Peters 1992, Barada 2009).

The goal of my study was to evaluate channel catfish dynamics in the Platte River with special attention paid to two known areas of relatively high angling pressure. My specific objectives were:

1. Determine differences in abundance, survival, condition, age structure, growth, and size structure of channel catfish between Louisville and Fremont (Chapter 2).
    - Greater catch rates at Fremont
    - Greater size structure and growth rates at Louisville
    - Angler effort is greater at Fremont
    - Angler exploitation is likely reducing size structure at Fremont
    - Density-dependent mechanisms are likely slowing growth and reducing size structure at Fremont

- Water manipulations by the Loup River Power Canal may also be slowing growth at Fremont

2. Determine the estimated abundance and density of channel catfish at Louisville and Fremont (Chapter 3).

   - Abundance estimates in the effective sampling range for Louisville were 8,281 (SE = 1,486) in 2010 and 11,620 (SE = 2,016) in 2011
   - Absolute abundance and density estimates in the 10-km stretch near Louisville were 37,641 (75 fish > 200-mm/ha) in 2010 and 52,818 (106 fish > 200-mm/ha)
   - Abundance estimates in the effective sampling range for Fremont were 24,261 (SE = 4,707) in 2010 and 14,359 (SE = 2,283) in 2011.
   - Absolute abundance and density estimates in the 10-km stretch near Fremont were 242,610 (606 fish > 200-mm/ha) in 2010 and 142,359 (356 fish > 200-mm/ha)

3. Determine spatial and temporal differences in channel catfish relative abundance, size structure, condition, age structure, growth rates, and mortality in the central and lower Platte River (Chapter 4).

   - Lower size structure, slower growth, and greater relative abundances in segment 2 compared to segment 3 and segment 1.
   - Angler exploitation and density dependent mechanisms are having a negative impact on growth and size structure in the lower Platte River.

- Flow manipulations from irrigation withdrawals and hydropeaking from the Loup River Power Canal may be having a negative influence on channel catfish.

Channel catfish population dynamics appear to be comparable to other areas in the midwest (Hesse et al. 1979, Gerhardt and Hubert 1991, Quist and Guy 1998, Colombo 2007, Goble 2011). Recruitment appears to be sufficient throughout the Platte River given the amount of age-2 and age-3 fish sampled each year. However, differences in abundance, growth rates, and size structure were documented in different segments of the Platte River. Greater fishing pressure and lower size structure at Fremont provided evidence that angler are having an impact on lowering size structure. However, the biggest threat to channel catfish may be the water management regimes currently in place. The Platte River is currently used to provide water to a variety of shareholders (i.e., farmers, power companies, fish and wildlife). In years of good or above average flows, like the ones we observed during this 5-year study, water was readily available to provide for all shareholders; thus, channel catfish, and likely most fish species benefitted. However, as we are approaching drought in the midwest, water availability, and therefore water rights, become much more important. I believe it is critical to maintain instream flow rights for fish and wildlife for future generations.

My evaluation of the above objectives led to the following recommendations for future research and management.

Research Recommendations

1. Knowledge of habitats used by fishes throughout their life history is essential for effective management and conservation of fish populations, especially for riverine species that may move considerable distances for spawning, forage, or refuge (Fausch et al. 2002). Furthermore, Hanski and Gilpin (1997) indicated that understanding fish movement and dispersal patterns are particularly important for understanding metapopulation dynamics and determining the most appropriate spatial scales for managing fisheries. My study provides evidence that channel catfish are capable of moving to, and using, a variety of river systems in Nebraska and other surrounding states. However, we do not understand what role (e.g., origin, rearing, adult life, etc.) the Platte River plays in the life histories of channel catfish. Therefore, I recommend conducting trace element and stable isotopic compositions on channel catfish otoliths and pectoral spines to assess important areas in channel catfish life histories. Stable isotopic compositions of otoliths can serve as natural markers of different environments inhabited by channel catfish throughout their life histories. Numerous studies have demonstrated this for individual fishes in the middle Mississippi and Illinois rivers, their tributaries, and floodplain lakes (Whitledge 2009, Zeigler 2009, Zeigler and Whitledge 2010). Information gained from trace element and stable isotope compositions will help managers determine the

relative importance of different environments as recruitment sources for catfish populations and characterize movement and dispersal patterns, particularly during early life stages.

2. With the onset of drought in 2012, falling water levels have reduced the amount of habitat available for most aquatic biota, leading to exposing marginal areas (Stanley et al. 1997), breaking surface water contact between the stream and its riparian zone, and reducing the hydraulic heterogeneity of flow (Lake 2003). Little is known about the effects of drought on channel catfish in the Platte River. Droughts can have direct and indirect impacts on stream biota. Direct impacts are those caused by loss of water and flow, and habitat reduction and reconfiguration, whereas indirect impacts are those associated with changes in phenomena such as interspecific interactions, especially predation and competition, and the nature of food resources (Lake 2003). For example, Matthews (1998) found that fishes may become stranded as water levels drop, and increased water temperatures may become lethal. Recent data collection efforts on the Platte River (e.g., 2007 – 2011) have occurred during average or above average precipitation years. Therefore, it is imperative to understand the effects of drought on Platte River biota. It is not unreasonable to think that 2012 may be a dryer precipitation cycle than has recently been observed. Fish kills have already been reported in the central and lower Platte River; additional strain will likely result in a continuation of fish kills. Therefore, I recommend standard sampling protocols as determined by Barada (2009) continue within

drought years to further understand the impacts droughts have on stream biota. Sampling during drought conditions will help managers understand not only the physical changes in fish (i.e., reduced W_r, slower growth), but also how fish react to increased stress caused by abiotic factors (i.e., extreme temperatures, low discharge). Additional data should be collected post-drought to determine long-term responses.

3. Little is known about the role tributaries play in the lower Platte River. However, positive effects of tributaries are known (Kiffney et al. 2006, Cushman 1985, Pracheil 2009). Channel catfish have moved between tributaries and main-stem rivers in other systems (Hesse et al. 1979; Bunnell 1988; Dames et al 1989; Newcomb 1989; Chapman 1995). Results from my thesis made it clear that some channel catfish were moving to tributaries of the Platte River. For example, five fish were captured in the Elkhorn River. However, little is known about channel catfish in the Elkhorn River. Therefore, I recommend sampling in the Elkhorn River to help managers and researchers gain a better understanding of channel catfish population dynamics (i.e., relative abundance, size structure, condition, etc.) within that river system. The Elkhorn River may also provide important refuge for channel catfish during low water years. The Elkhorn River is groundwater fed so discharge, and possibly water temperature, is affected less than the Platte River discharge during low precipitation years.
4. Much has been hypothesized about the potential stress extreme environmental conditions like those found in the Platte River have on catfish. Holland and

Peters (1992b) and Barada (2009) hypothesized catfish in the lower Platte may be experiencing stressful conditions because of varying discharges and water temperatures caused by water manipulations from the Loup River Power Canal that limit suitable habitat. Barada and Pegg (2011) found channel catfish to have lower mean relative weights, and slower growth near the Loup River Power Canal. However, there are no concrete data that those findings are linked to stress levels in channel catfish. Plasma cortisol has been measured as an indicator of stress using commercially available radioimmunoassay (RIA) kits on plasma samples from channel catfish (Klinger et al. 1983, Ainsworth et al. 1985). Therefore, I recommend blood samples be taken from channel catfish to measure plasma cortisol levels. Blood samples should be taken from a variety of sizes, as well as from all ten standard sampling sites. This will help managers gain insight on how stress levels are affected by channel catfish size, longitudinal location, season, water temperature, and discharge.

5. Fishing for channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictus olivaris* has been, and continues to be a popular activity in Nebraska. The Platte River is a unique river system in the midwest and attracts a variety of anglers. Understanding angler attitudes and expectations is vital in shaping objectives of a fishery (Barber and Taylor 1990, Knuth and McMullin 1996). Angler dynamics, attitudes, and expectations may have changed since the last creel survey in 1992-1993; therefore, I recommend a creel survey, mail survey, or a combination of the two be done on the lower Platte River. Understanding angler attitudes,

expectations, and harvest will help managers set goals for the Platte River fishery and validate/refute conclusions found here in terms of angler effects. Coupling goals with the population estimates from this study should provide managers sufficient data to formulate attainable management and conservation goals for the Platte River fishery.

6. In addition to #5 above, is the need to assess the potential impacts anglers are having on channel catfish population dynamics. This study provided some initial insights on the impacts of angler exploitation by studying population characteristics at two high use areas in the Platte River. I found that greater angler exploitation at Fremont is negatively influencing channel catfish growth and size structure. Sustained angler exploitation of channel catfish at Fremont will likely result in a continuation of decreased growth and size structure. Continued research, however, is needed to assess the impacts in other areas of the Platte River.

Management Recommendations

1. The Nebraska Game and Parks Commission (NGPC) have made it a priority to recruit, develop, and retain anglers (NGPC 2008). Channel catfish are relatively easy to catch, and readily available in the Platte River. Population estimates at two high use areas in the lower Platte River indicate a large quantity of channel catfish over 200-mm. Also, the central Platte River has continually had larger and faster growing channel catfish compared to the lower Platte River suggesting a valuable fishery could be promoted in this reach. However, much of the Platte

River is privately owned (Zuerlien 1984) making fishing access difficult, often limited to bridge crossings or boat ramps in the Platte River. Therefore, efforts to acquire more river access throughout the Platte River would be beneficial.

2. In 2010, the NGPC changed the bag limit on channel catfish from 10 to 5 fish per day. Results from my study indicate that the Platte River can sustain a 10 fish per day bag limit. Population estimates from two high use areas indicate a large quantity of channel catfish over 200-mm. I believe the anglers are causing little, if any additive mortality. I recommend replacing the 5 fish per day bag limit with a 10 fish per day.
3. Conversely to #2 above, the population may be able to sustain the current or higher harvest rate, but the cost looks is a reduction in size structure. Size structure at Fremont and Louisville displayed a large amount of small channel catfish (< 400-mm), and very few larger fish suggesting areas of the Platte River may be experiencing a cropping effect on larger individuals by anglers. One way to prevent the cropping effect on larger fish would be to implement a "one over" regulation. This may focus angling pressure on smaller channel catfish, which are readily available in the Platte River.

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