Three Year Summary Age and Growth Report

For

Blue Sucker

Pallid Sturgeon Population Assessment Project and Associated Fish Community Monitoring for the Missouri River

Prepared for the U.S. Army Corps of Engineers – Northwest Division
By:

Steve LaBay, Jason Kral and Sam Stukel

South Dakota Department of Game, Fish and Parks
Wildlife Division
31247-436th Ave.
Yankton, SD 57078

Executive Summary

The age and growth of the Missouri river blue sucker population was described in this report for three growth years: 2004, 2005 and 2006. Blue suckers < 650 mm in total length and < 8 years old were used in the age-specific analysis of growth parameters. Parameters used to characterize growth in this study were, length-at-capture, condition, and first full increment width. These three growth parameters used to test for spatial differences and temporal among segments for all three growth years. Mean back-calculated lengths at age were also compared among segments to detect for spatial differences. Significant differences and longitudinal trends were examined in relation to the physical variables of flow and temperature. The specific objectives for this report were to 1) determine if mean length at capture, condition, and last full increment width of annual growth differs significantly among river segments and among growth years 2004, 2005 and 2006, 2) compare back-calculated lengths at age among segments and 3) determine if mean length-at-capture differs between the upper and lower Missouri river. Samples from 1,095 fish were collected from 2004 through 2006. Few structures were collected from above Gavin's point dam (n = 8). The age-specific analysis contained 544 of the 1,095 structured collected. Segments 9, 14 and 14 were tested in the 2004 age-specific analysis. Segments 7, 9, 10, 13 and 14 were tested in the 2005 analysis and segments 7, 8, 9, 10, 13 and 14 were tested in the 2006 analysis. Segments 7 and 8 showed significant differences in *Wr*, median lengths at capture, and mean back-calculated lengths from segments further downstream (9-14) which were more alike. All growth parameters with the exception of the first full increment analysis showed

increases in values from the North to the South. This was likely due to the effects of Gavin's point dam in withholding nutrients and sediments and warmer water temperatures in segments further downstream. No correlations with the growth parameters and discharge could be made, however, aging revealed that 18 age-0 blue suckers were captured in segment 8 in 2006 and this could be linked to high flow event that took place in April. Few age 1 and 2 fish were capture in all three years, however, this was not due to recruitment failure but to behavioral bias. Additionally, aging of the fish > 559 m and > 7 years old showed that no age classes were missing between ages 0-11 in 2006 and 0-15 in 2005. This data suggests that the Missouri river blue suckers could be recruiting to older ages below Gavin's point dam regularly.

TABLE OF CONTENTS

Introduction.....1

Study Area 3

Methods.....8

Results.....28

Discussion.....82

Acknowledgments.....89

References.....89

LIST OF TABLES

Table 1. Segment information for the Missouri River. 4

Table 2. Starting and ending date by growth year when pectoral fin rays of blue sucker were collected. 27

Table 3. Starting and ending date by growth year when scales of blue sucker were collected. 27

Table 4. Total number of aging structures collected for age and growth analysis. 33

Table 5. Mean back-calculated total length-at-last annulus (+/- 2 SE) of blue suckers ages 0-7 and < 650 mm collected in each segment during 2004. 36

Table 6. Mean back-calculated total length-at-last annulus (+/- 2 SE) of blue suckers ages 0-7 and < 650 mm collected in each segment during 2005. 37

Table 7. Mean back-calculated total length-at-last annulus (+/- 2 SE) of blue suckers ages 0-7 and < 650 mm collected in each segment during 2006. 38

Table 8. Median length-at-capture comparisons of blue suckers < 650 mm among segments for 2004. Numbers below the median are the inter-quartile range, followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median length at capture among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons(α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. 43

Table 9. Median-length-at-capture comparisons of blue suckers < 650 mm among segments for 2005. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Astericks indicate ages where median length at capture among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's Multiple comparisons(α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant 44

Table 10. Median length-at-capture comparisons of blue sucker < 650 mm among segments for 2006. Numbers below the median are the inter-quartile range followed by the samplesize. Dashes indicate an insufficient *n* to calculate a range. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was significant. Different letters indicate significance differences. Similar letters indicate no significant differences. 45

Table 11. Median *Wr* at age comparisons of blue suckers ages 0-7 < 650 mm among segments for 2004. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median Wr at age was compared among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using scales.
.....46

Table 12. Median *Wr* at age comparisons of blue suckers ages 0-7 < 650 mm among segments for 2005. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median *Wr* at age was compared among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.
.....47

Table 13. Median *Wr* at age comparisons of blue suckers ages 0-7 < 650 mm among segments for 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median *Wr* at age was compared among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.
.....48

Table 14. Median first full increment (mm) at age comparisons of blue suckers ages 0-7 and < 650 mm between segments for 2004. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where first full increment at age was compared among segments. Medians were compared using Mann-Whitney U tests (α = 0.05). Ages were determined using scales.
..... 49

Table 15. Median first full increment (mm) at age comparisons of blue suckers ages 0-7 and < 650 mm among segments for 2005. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median first full increment at age was compared among segments. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences.

Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.

.....50

Table 16. Median first full increment (mm) at age comparisons of blue suckers ages 0-7 and < 650 mm among segments for 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median first full increment at age was compared among segments. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.
.....51

Table 17. Median total length (pooled from segments 9-14) at capture comparisons of blue suckers < 650 mm for fish ages 0-7 between 2005 and 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median length at capture among segments was compared. Medians were compared using Mann-Whitney U tests (α = 0.05). Ages were determined using fin rays ages. Discharge is mean annual discharge in m3/s from segment 14.
..... 52

Table 18. Median *Wr* (pooled ages 0-7 by segment) comparisons of blue sucker < 650 mm among sample years 2004-2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range, therefore, its corresponding median was not tested. Asterisks indicate segments where pooled median Wr was compared among segments. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significant differences. Similar letters indicate no significant difference. Discharge values are mean annual discharge values in m3/s.
.....53

Table 19. Median first full increment (mm) (pooled from segments 9-14) comparisons of blue suckers ages 0-7 and < 650 mm between 2005 and 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median first full increment was compared between years. Medians were compared using Mann-Whitney U tests (α = 0.05). Ages were determined using fin rays ages. Discharge is mean annual discharge in m3/s from segment 14.
.....54

Table 20. Age/length key for segment 9 during 2004. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 55

Table 21. Age/length key for segment 13 during 2004. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 57

Table 22. Age/length key for segment 14 during 2004. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 59

Table 23. Age/length key for segments 7 during 2005. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 61

Table 24. Age/length key for segment 9 during 2005. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 63

Table 25. Age/length key for segment 10 during 2005. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 65

Table 26. Age/length key for segment 13 during 2005. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 67

Table 27. Age/length key for segment 14 during 2005. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 69

Table 28. Age/length key for segment 7 during 2006. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment. 71

Table 29. Age/length key for segment 8 during 2006. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment.
.....73

Table 30. Age/length key for segment 9 during 2006. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment.
.....75

Table 31. Age/length key for segment 10 during 2006. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment.
.....77

Table 32. Age/length key for segment 13 during 2006. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment.
.....79

Table 33. Age/length key for segment 14 during 2006. Numbers in the boxes represent the probability that a known length individual is a certain age based on aging data from each segment.
.....81

Appendix 1. Mean length at capture summary statistics of fish collected > 650 mm in 2005 and 2006.
..... 93

LIST OF FIGURES

Figure 1. Map of the Missouri River basin with locations of major tributaries and urban areas. Study segments are numbered, labeled and delimited by red dots. 15

Figure 2. Mean daily discharge and mean daily water temperature for segment 1 of the Missouri River during 2006. 16

Figure 3. Mean daily discharge and mean daily water temperature for segment 2 of the Missouri River during 2006. 17

Figure 4. Mean daily discharge and mean daily water temperature for segment 3 of the Missouri River during 2006. 18

Figure 5. Mean daily discharge and mean daily water temperature for segment 4 of the Missouri River during 2005 and 2006. 19

Figure 6. Mean daily discharge and mean daily water temperature for segment 5/6 of the Missouri River during 2003 through 2006. 20

Figure 7. Mean daily discharge and mean daily water temperature for segment 7 of the Missouri River during 2005 and 2006. 21

Figure 8. Mean daily discharge and mean daily water temperature for segment 8 of the Missouri River during 2003 through 2006. 22

Figure 9. Mean daily discharge and mean daily water temperature for segment 9 of the Missouri River during 2003 through 2006. 23

Figure 10. Mean daily discharge and mean daily water temperature for segment 10 of the Missouri River during 2005 and 2006. 24

Figure 11. Mean daily discharge and mean daily water temperature for segment 13 of the Missouri River during 2003 through 2006. 25

Figure 12. Mean daily discharge and mean daily water temperature for segment 14 of the Missouri River during 2003 through 2006. 26

Figure 13. Mean back-calculated total length-at-last annulus of blue sucker < 650 mm and < 8 years old that were collected for age and growth analysis from segments 9, 13 and 14 of the Missouri River during 2004.. 39

Figure 14. Mean back-calculated total length-at-last annulus of blue suckers < 650 mm and < 8 years old that were collected for age and growth analysis from segments 7, 9, 10, 13 and 14 of the Missouri River during 2005.. 40

Figure 15. Mean back-calculated total length-at-last annulus of blue sucker < 650 mm and < 8 years old that were collected for age and growth analysis from segments 7, 8, 9, 11, 13 and 14 of the Missouri River during 2006. 41

Figure 16. Comparison of mean back-calculated length-at-last annulus for the upper sampling universe versus the lower sampling universe in 2005. Age determinations were made using scales 42

Figure 17. Illustration of fin ray methodology and measurements 13

Introduction

The pallid sturgeon *Scaphirynchus albus* was listed as an endangered species in 1993. The biological opinion issued by the United States Fish and Wildlife Service in 2000 declared that this was due to do anthropogenic modification to the environment causing a myriad of habitat degradation problems such as blocked of fish passage, destroyed spawning habitat, reduced food availability, altered water temperature, decreased turbidity, and disrupted natural flows. As a response for recovery of the species, the United States Corps of Engineers formed a workgroup composed of several state and federal agencies which became known as the pallid sturgeon population assessment program (PSPAP).

The PSPAP is a monitoring program that is designed to detect changes in the native river fish community and fish habitat preferences over time with an emphasis on the pallid sturgeon (Drobish 2007). The program selected 14 river segments to monitor annually based on a variety of various physical and hydrological characteristics. The team chose 9 other target species in which specific biological information is collected such as weight, condition, and age. These species include the sand shiner *Notropis stramineus*, sicklefin chub *Macrhybopsis meeki*, sauger S*ander canadensi*, shovelnose sturgeon *Scaphirhynchus platorynchus*, plains minnow *Hybognathus placitus*, western silvery minnow *Hybognathus argyritis*, speckled chub *Macrhybopsis aestivalis*, sturgeon chub *Macrhybopsis gelida*, and blue sucker *Cycleptus elongatus*. These species were assigned among the pallid sturgeon population assessment offices for the purpose of characterizing the age and growth of their delegated species. Each office was to characterize the growth of their assigned species for all river segments. The United States Fish and Wildlife Service in Columbia were contracted with the analysis for sicklefin chub, speckled chub and sturgeon chub, South Dakota

Department of Game, Fish and Parks with blue sucker, Nebraska Game and Parks Commission with shovelnose sturgeon, and Missouri Department of Conservation with sand shiner, sauger, plains minnow and western silvery minnow. This report focuses on the age and growth characteristics of blue sucker in the Missouri River.

Blue sucker are of particular interest in that they could be used as a surrogate species to pallid sturgeon for implying similarities in biological trends between the two species (Quist et al. 2004). Both species are native large river fishes that prefer large, deep, swift sections of rivers (Morey and Berry 2003); (Bramblett and White 2001). Additionally, blue sucker have shown population declines throughout the range of the species (Elstad and Werden 1993), in concert with pallid sturgeon populations (Dryer and Sandoval 1993), suggesting that these two species are biological indicators of the declining ecological heath of the Missouri River.

Fish growth can be an excellent indicator of physical, chemical, or biological conditions in the environment. Fish growth is typically measured as length, weight, condition, or size structure. Quantification of such growth data is a common way for fisheries biologist to evaluate the effectiveness of management practices (Van Den Avyle and Hayward 1999) such as alterations to flow management. In this report, the overall goal was to characterize growth of the blue sucker in relation to temperature and flow. Our specific objectives in this report are to 1) determine if mean length-at-capture, condition, and last full increment of annual growth differs significantly among 12 of the 14 river segments and among sample years 2004, 2005 and 2006, 2) compare back-calculated lengths at age among segments and 3) determine if mean length-at-capture differs between the upper and lower Missouri River.

Study Area

The Missouri River flows 3,768 km from its origin near Three Forks, Montana where the Jefferson, Madison and Gallatin rivers meet then flows in a South-East direction to its mouth at St. Louis, Missouri (Figure 1). The Missouri river is also the longest river in the continental United States, with a watershed that drains nearly a sixth of the nation and is second only to the Mississippi River in annual discharge.

Segment 1 of the Missouri River began at Fort Peck Dam runs downstream to its confluence with the Milk River. This segment constitutes a small section (6%) of the riverine portion of the Missouri River that extends from Fort Peck to the headwaters of Lake Sekakawea. This reach of the Missouri River is characterized by an unnatural hydrograph, thermograph, sediment dynamics, and fish community due to the influence of the dam (Bramblett and White, 2001). Immediately below the dam area, geography is characterized by deep and wide cuts that are remnants from dam construction. The reservoir has reduced turbidity in the river below Fort Peck Dam when compared to its natural state (Galat et al. 2005). See Haddix et al. (2007a) for a more detailed description of segment 1.

Segment 2 of began at the confluence of the Missouri and Milk Rivers and ended downriver downriver 59 river miles to Wolf Point, Montana (Drobish, 2007). This segment is highly influenced by the operation of Fort Peck Dam in ways physically and has similar hydrology as segment 1. This segment is considered a transitional segment, exhibiting characteristics of both cold hypolimnetic water releases and warmer sediment packed waters due to the influence of the Milk and Redwater Rivers in the area (Haddix et al. 2007b). The geology in segment 2 is unique, consisting of mostly bearpaw shale formation. The upstream

reaches are characterized by mostly gravel substrate, then transitioning to mostly sand. Fish distributions change throughout the segment with turbidity, temperature, and substrate (Haddix et al. 2007b).

Segment 3 of the Missouri River Pallid Sturgeon Population Assessment Program encompasses 119 river miles from Wolf Point, MT to the confluence of the Missouri and Yellowstone Rivers in North Dakota. The river completely transitioned from a clear, cold river with cobble substrate to a warm and turbid river more like its natural state (Galat et al. 2005) in this segment. The aggrading streambed is flanked by stream deposited sediment of the Fort Union Formation (NRIS, 2007). Segment 3 is not as flow regulated as the upstream segments due to high precipitation events and upstream tributary inputs. Five tributaries influence this section of river including: the Milk, Redwater, Poplar and Big rivers, Muddy Creek, and Prairie Elk Creek. These sediment packed tributaries flush their warmer turbid waters into the Missouri River increasing flows and sediment load, which in turn enables sandbar and island formation (Wilson et al. 2007). Sand bar and island formation occur more frequently than in segment 2 due to the tributary inputs. The species composition is vastly different from the uppermost segment just below Fort Peck Dam. Additionally, the presence of exotic fish species is decreased and the number of native fish is increased (Gardner and Stewart 1987).

Segment 4 was defined as that area of the Missouri River from the Yellowstone River Confluence (RM 1582) downstream to the headwaters of Lake Sakakawea (RM 1574) (Figure 1a). The amount of riverine habitat available for sampling in segment 4 is entirely dependent on reservoir levels. For example, in 2005 and 2006 the river reached below rivermile 1535. At full pool, the reservoir will extend as far up as rivermile 1574; however,

the normal reach of river is around rivermile 1550. Although the Yellowstone River is not part of the segment, it does provide a significant amount of influence on this reach of the Missouri River. Seasonal flows, sediment load, and natural temperature fluctuations provide a resemblance of the historic conditions that existed prior to development of the Missouri under the Pick Sloan plan (Wilson et al. 2007).

Segments 5 and 6 were combined and treated as one single unit in this report due to similarities. The head waters of Lewis and Clark Lake (river kilometer [rkm] 1327, river mile [rm] 825) defined the downstream end of segment 6. Lewis and Clark Lake extends to Fort Randall Dam (rkm 1416, rm 880) which also defined the upper end of segment 5 (Shuman et al. 2007). The confluence of the Niobrara river at rm 845 divided these two segments. Segments 5 and 6 combine to form a riverine section of Lewis and Clark Lake extends approximately 89 rkm from Fort Randall Dam to Springfield, South Dakota (Figures 1a). Maximum depth is about 12 m and channel width ranges from 45-90 m (Shuman et al. 2007). The section exhibits many natural characteristics including: sandbars, sandbar pools, side channels, backwater areas, islands, old growth riparian forest and year round flows. Flow and temperature has been changed due to the Fort Randall Dam. Water levels fluctuate substantially daily and with season. Daily water levels are subject to fluctuations of almost 1 m. Lowest daily flows generally occur at 0600 hours with peak flows occurring between 1200 to 1900 hours in support of power generation demands (Engineers 1994).

Segment 7 is located between Gavins Point Dam and Ponca State Park (miles 811 to 752). The segment comprises the lower (59-mile) reach of Missouri National Recreational River. Common habitats include sandbars, backwaters, secondary channels, and wooded islands. Bank stabilization is sporadic, allowing some erosion to occur. Controlled releases

from Gavins Point influence the morphology and ecology of segment. The dam blocks natural sediment transport causing incision and decreased turbidity. The U.S. Army Corps of Engineers uses the dam to provide stable releases to downstream areas, thus allowing for reliable navigation and water supplies. Discharge from Gavins Point Dam typically peaks late summer at about 30,000 cfs and declines to near 12,000 cfs during the winter (http://www.nwdmr.usace.army.mil/rcc/reports/pdfs/aopfinal2005.pdf). Daily variations are not as significant as those in segments 5 and 6. Much of the river in segment 7 is less than 2 m deep (Stukel et al. 2007). River width varies from over 1,400 m to less than 300 m. The James (mile 798) and Vermillion (mile 772) rivers are major tributaries contributing to flows and turbidity (Stukel et al. 2007).

Segment 8 was defined as the Lower Ponca Bend downstream to the Platte River (RM 750-595.5) and is characterized by a degrading stream bed, channelization, higher turbidities and flow fluctuations (Drobish 2007). For a more detailed description of habitats within segment 8 see (Hamel and Steffensen 2007).

Segment 9 was defined as the confluence with the Platte River downstream to the confluence of the Kansas River (RM 595.5-367.5). This segment is characterized as having major tributary influence, a degrading and aggrading stream bed, and several restoration projects (Drobish 2007). For a more detailed description of habitats within segment 9 see Steffensen and Hamel (2007).

Segment 10 was defined as beginning at the confluence of the Kansas River (RM 367.5) and ending at the confluence of the Grand River (RM 250.0). In segment 10, the USACE maintains a 9-foot-deep river channel for navigation traffic. Also, bank revetment exists along the outside bends of the river and various dike structures have been constructed

to create a self-cleaning navigation channel. Structures in this segment included kicker dikes, L-dikes, wing dikes and rootless dikes, some of which have been notched or otherwise modified to increase habitat diversity (Caton et al. 2007). There are few islands and side channels in this segment, but expansive sand bars exist in some areas and are often exposed depending on river stage (Caton et al. 2007). A few side channels and islands exist here, however, larger islands are found infrequently. Sometimes, they are only exposed by fluctuating river stages.

Segment 13 was defined as the confluence of the Grand River to the confluence with the Osage River (RM 250-130). This stretch is characterized by major tributary influence, a floodplain, a more natural hydrograph, and restoration projects (Drobish 2007). Much effort in this segment has been given to dyke modification and developing new dyke structures that allow erosion or deposition, creating fish habitat (Plauck et al. 2007).

Segment 14 was defined as the confluence of the Osage River downstream to the mouth of the Missouri (RM 130-0). It is characterized by major tributary influence and restoration projects (Drobish 2007). Dyke modification and the development of new dyke structures are also common in this segment. Also, there are some remnant historical habitats that exist at different water stages (Utrup et al. 2007).

For this report, the upper Missouri river i.e. “upper sampling universe” was defined as segments 1-6 and the lower Missouri river i.e. “lower sampling universe” was defined as segments 7-14.

Methods

Field Collections

Segments 9, 13 and 14 were sampled in 2004. In 2005, segments 4, 5, 6, 7, 9, 10, 13 and 14 were sampled. In 2006, segments all 12 segments were sampled.

Sampling was conducted in a standardized fashion within the Pallid Sturgeon Population Assessment Team guidelines. The sample year was split into two distinct seasons termed "sturgeon season" and "fish community season". Sturgeon season started in mid October when water temperatures dropped below 12.8ºC. Fish community season began on July 1 and ended on Oct 31. These two seasons overlap and together they constitute one sample year. Protocol was to collect aging structures for blue sucker from July 1 to October 31. Field crews were instructed to recorded total length to the nearest mm. Weights were recorded to the nearest g. See Drobish (2007) for a more detailed description of gears used and deployment methods. Also, see Table 2 that indicates the dates and locations when sampling took place for each segment and year.

Fish were tallied in 10mm length groups ranging from 150 mm to 899 mm, which was the span of length ranges for which blue suckers that were collected. Ten to 15 scales were taken from the area between the lateral line and the dorsal fin from each fish. Scales were collected only in 2004. The scales were placed into a coin envelope for storage and later processing. In 2005, a structure comparison was conducted comparing scale and ray age determination methodologies, finding that the pectoral fin ray was a significantly more precise (coefficient of variation = 20 %; p= .007; LaBay, unpublished data) structure to use than scales, and thereafter was used as the standard structure for aging blue suckers by the PSPAP. As a result, age data derived from ray methodology was used for the 2005 sample

year and in subsequent years. Also, a length minimum and maximum was establish on 27 March, 2006 and thereafter, aging structures were taken only on blue suckers >100 mm and <650 mm. The maximum was implemented due to a loss in precision of aging larger fishes at older ages (LaBay, unpublished data) and for better time management for field crews. The minimum was implemented due to the difficulty in obtaining weight measurements for smaller fish.

The left pectoral fin ray was collected by cutting a 2.5 cm section of the first anterior ray off of the fin with a pair of garden shears. The cut started approximately 5 mm above the insertion of the ray, and then continued distally approximately 2.5 cm. The rays were then stored in a coin envelope and dried for later processing.

Structure Preparations

A minimum of 10 scales per fish were pressed onto acetate slides (.5 mm thick). Rays were boiled in water for approximately 3 min, and then the upper lobe of the first ray was separated from the lower lobe and brushed free of fleshy materials. The upper lobe of the first ray was then embedded in epoxy and then cut into three sections approximately .5 mm to 1 mm thick with a low speed saw. Three sections were cut starting from the base of the ray, with successive cuts being made posterior towards the tip of the mold. Sections were then mounted to a glass slide for viewing purposes.

Aging and Measuring Procedures

Each fish was aged once by two independent readers (two determinations were made for each fish). Reader agreement rates between the two readers and the two structures were

then compared by calculating the proportion of fish on which they agreed. Later, the two readers read the structures together to assign ages for the fish in which they originally disagreed. This served as a calibration tool to eliminate the effects of individual reader biases and to provide more precise ages. This reading was termed a "consensus age" and was the age assigned to fish when the two readers were originally in disagreement. Structure measurements were not made until readers reached a consensus age for a fish.

Scales were viewed under transmitted light a through a binocular microscope with 3.15-20 magnification. Criteria for determining annuli on scales followed DeVries and Frie (1996) by the identification of incomplete circuli and "cutting over". Readers were instructed to make a final age determination for a fish when they found three scales per slide that agreed as to prevent within-fish age bias and contamination from other fish scales. A digital picture was taken of the most discernable scale from each fish using a digital camera at a magnification of 3.15. Distances between scale annuli were measured vertically starting from the center of the focus, to each annulus, and to the edge of the scale using Sigma Scan Pro v. 5.0 software (Systat software, Inc., Point Richmond, CA) (figure ?). If the acetate slide did not lay flat or was warped, then the slide was pressed between two glass slides before the image was captured.

Rays were viewed under reflected light and a black background with magnification ranging from 6.5 to 40. A ray annulus was defined as the transition between the darker opaque zone and the lighter hyaline zone on the ray. Readers were allowed to view all three ray sections and then make their age determination. Digital images were taken of the most discernable ray section at a magnification of 20 and then measurements were made using Sigma Scan software. Ray radii and distances between ray annuli were measured vertically

on the elongated half of the upper ray lobe starting from the edge of the ray focus to each of the annuli and to the edge of the ray (figure ?). Increment widths between annuli were measured in actual mm (vs. back-calculated increment distances) from digital images taken at the magnifications specified for scale and ray methodology. Pixel distances were converted to mm at a ratio of 1mm = 34.9 pixels for the 3.15 magnification and 1 mm = 194.66 pixels for the 20 magnification.

A growth year for this report was defined as starting on July 1 and ending on 30 April the following year (table ??). We placed fish birthday on 1 July. Fish that were caught June through April generally had large growth areas beyond the last identified annulus. (Rupprecht and Jahn 1980) also noted that for blue sucker in the Illinois portion of the Mississippi River that a large proportion of the blue sucker that they had collected after May had formed an annulus near the edge of their scales. Any growth past the last identified annulus in fish collected from 1 July through 30 April was considered as the current sample year.

Statistical Analysis

To detect spatial differences, median length at capture, median first full increment width, and median relative weight (*Wr*) (Marty Hamel, Nebraska Game and Parks Commission, under review) at ages 0-7 of fishes < 650 mm was tested among segments for each growth year using Kruskal-Wallis tests based on an α level of 0.05, followed by Dunn's multiple comparisons tests when a test was found to be significant. Spatial differences in *Wr* were also tested for by pooling ages 0-7. For the spatial analysis, an age was tested when at least three or more segments had an *n* of 3 or greater

To detect temporal differences, length at capture and first full increment width data was pooled among segments 9-14 for 2005 and 2006. Median length at capture and median first full increment width using data derived from ray aging methodology at ages 0-7 of fishes <650 mm was then tested between growth years 2005 and 2006 using Mann-Whitney U-tests based on an α level of 0.05. *Wr* data for fish ages 0-7 was pooled for each segment and then tested among growth years 2004, 2005 and 2006 using Kruskal-Wallis (α level of 0.05) for each segment. For the temporal *Wr* analysis, an year was tested when at least all three years had an *n* of 3 or greater.

For the upper versus lower sampling universe comparison, median length at age of fishes 0-7 <650 was compared for ages 0-7 for the 2006 growth year. Length data for segments 1-4 was pooled, comprising the upper universe and data for segments 7-14 were pooled, comprising the lower universe. The two samples were compared with a Mann-Whitney U-test at an α level of 0.05.

Mean back-calculated length-at-last-annulus was also compared in tables and graphically to detect spatial differences among segments and years. The direct proportion method of back calculating fish lengths was used;

$$L_i = [\ S_i / S_c\ ] \times L_c$$

where, L_i = back-calculated length of the fish at the *i*th increment, L_c = length of the fish at capture, S_i = the structure radius at the ith increment, and S_c = the structure radius.

Figure 13. Diagram illustrating the method and direction in which measurements on fin rays were made.

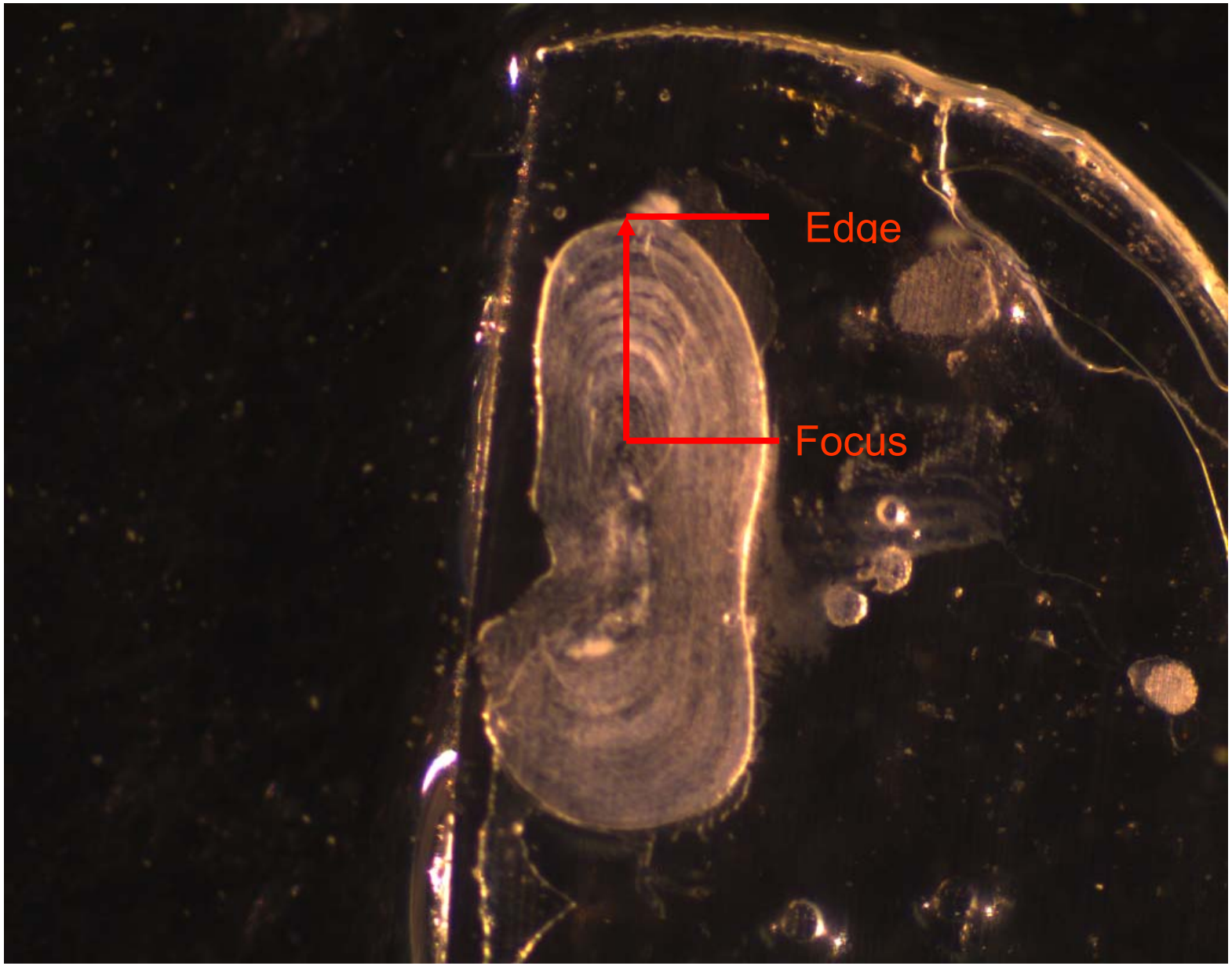

Table 1. Segment information for the Missouri River.

Segment Number	Segment Description	Upper River Mile	Lower River Mile	Length (mi)
1	Fort Peck Dam to the confluence of the Milk River	1771.5	1760.0	11.5
2	Confluence of the Milk River to Wolf Point	1760.0	1701.0	59.0
3	Wolf Point to the confluence of the Yellowstone River	1701.0	1582.0	119.0
4	Confluence of the Yellowstone River to the headwaters of Lake Sakakawea	1582.0	1568.0	14.0
5	Fort Randall Dam to the confluence of the Niobrara River	880.0	845.0	35.0
6	Confluence of the Niobrara River to the headwaters of Lewis and Clark Lake	845.0	825.0	20.0
7	Gavins Point Dam to Lower Ponca Bend	811.0	750.0	61.0
8	Lower Ponca Bend to the confluence of the Platte River	750.0	595.0	155.0
9	Confluence of the Platte River to the confluence of the Kansas River	595.0	367.5	227.5
10	Confluence of the Kansas River to the confluence of the Grand River	367.5	250.0	117.5
13	Confluence of the Grand River to the confluence of the Osage River	250.0	130.0	120.0
14	Confluence of the Osage River to the confluence with the Mississippi River	130.0	0.0	130.0

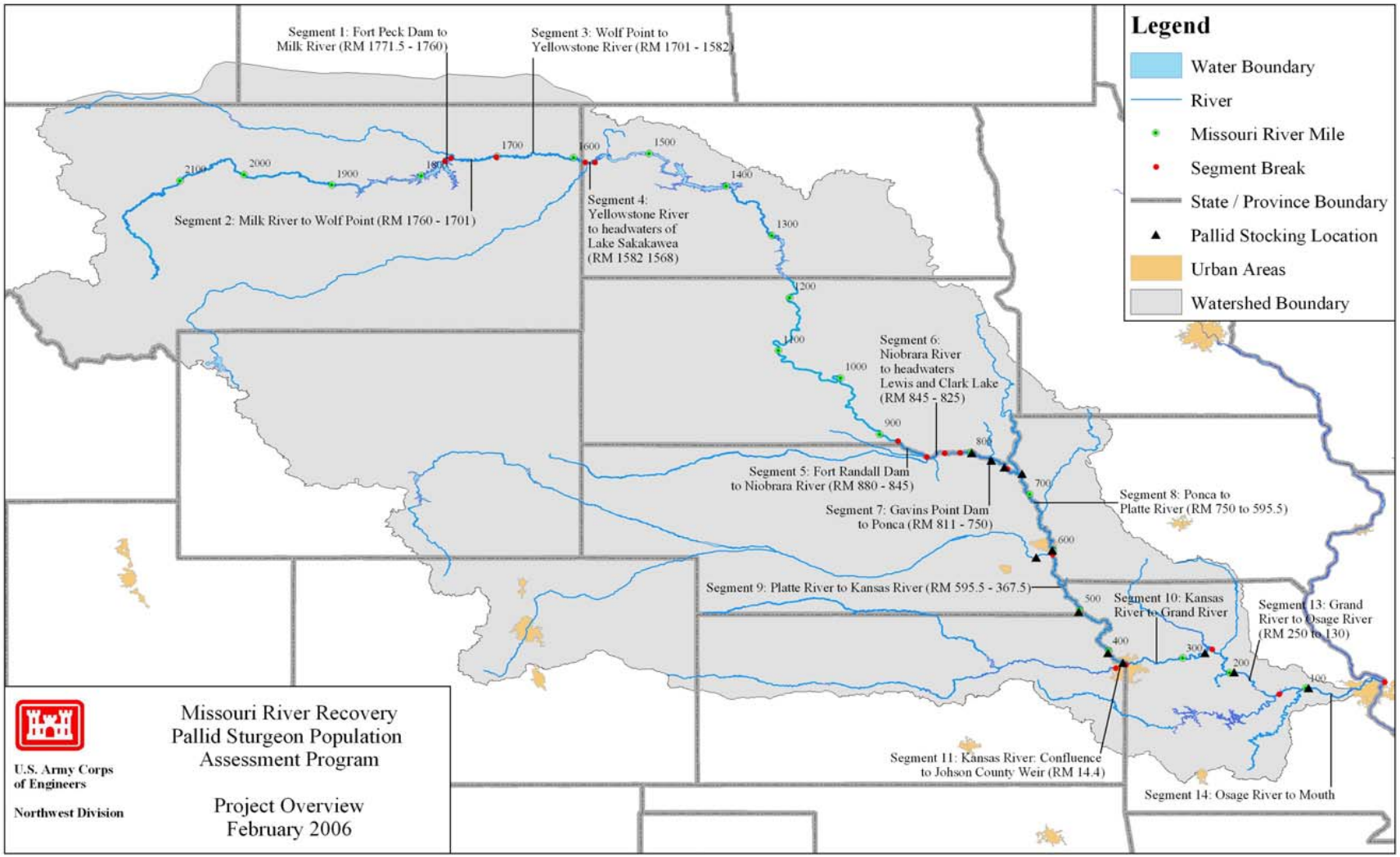

Figure 1. Map of the Missouri River basin with locations of major tributaries and urban areas. Study segments are numbered, labeled and delimited by red dots.

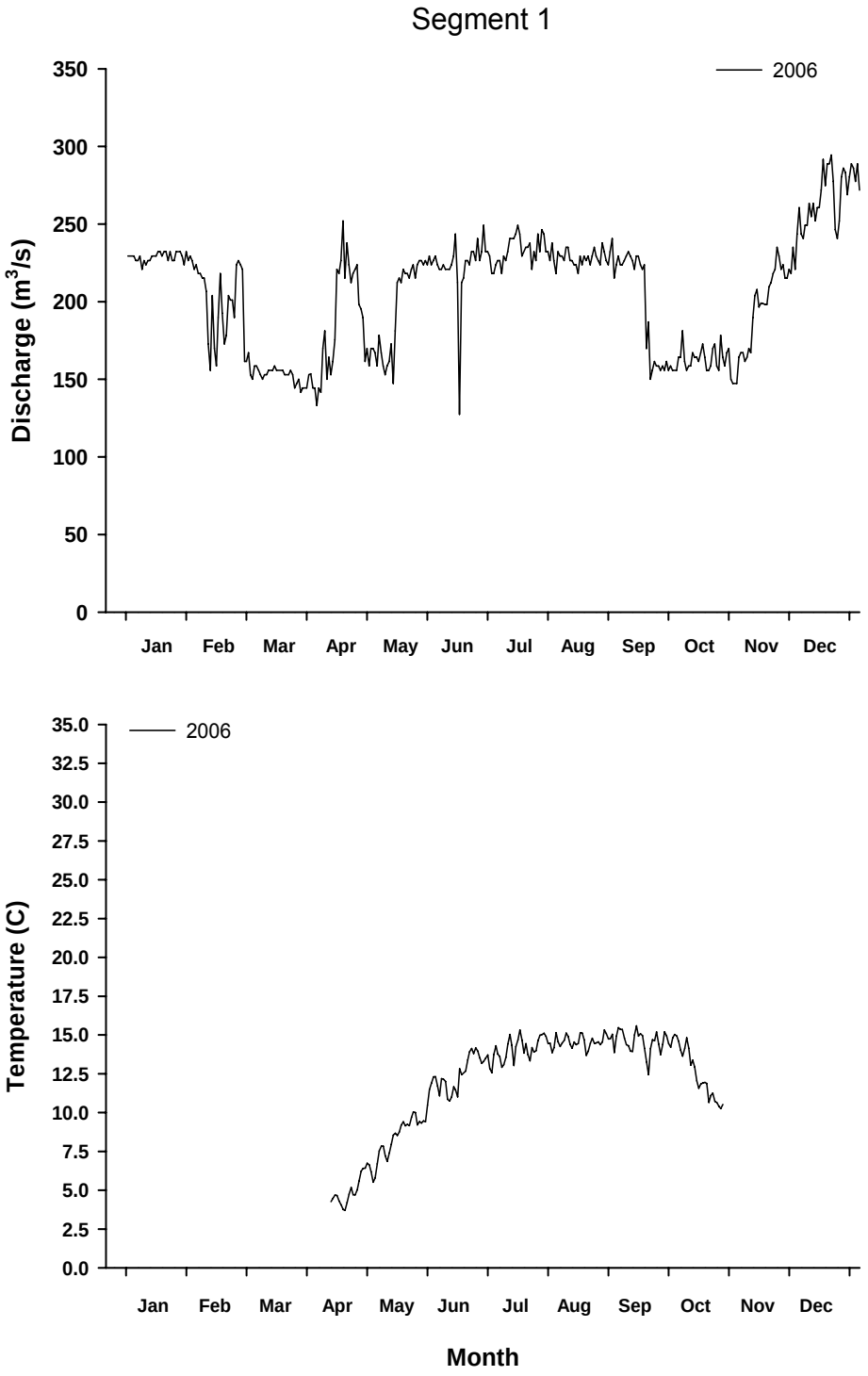

Figure 2. Mean daily discharge and mean daily water temperature for segment 1 of the Missouri River during 2006

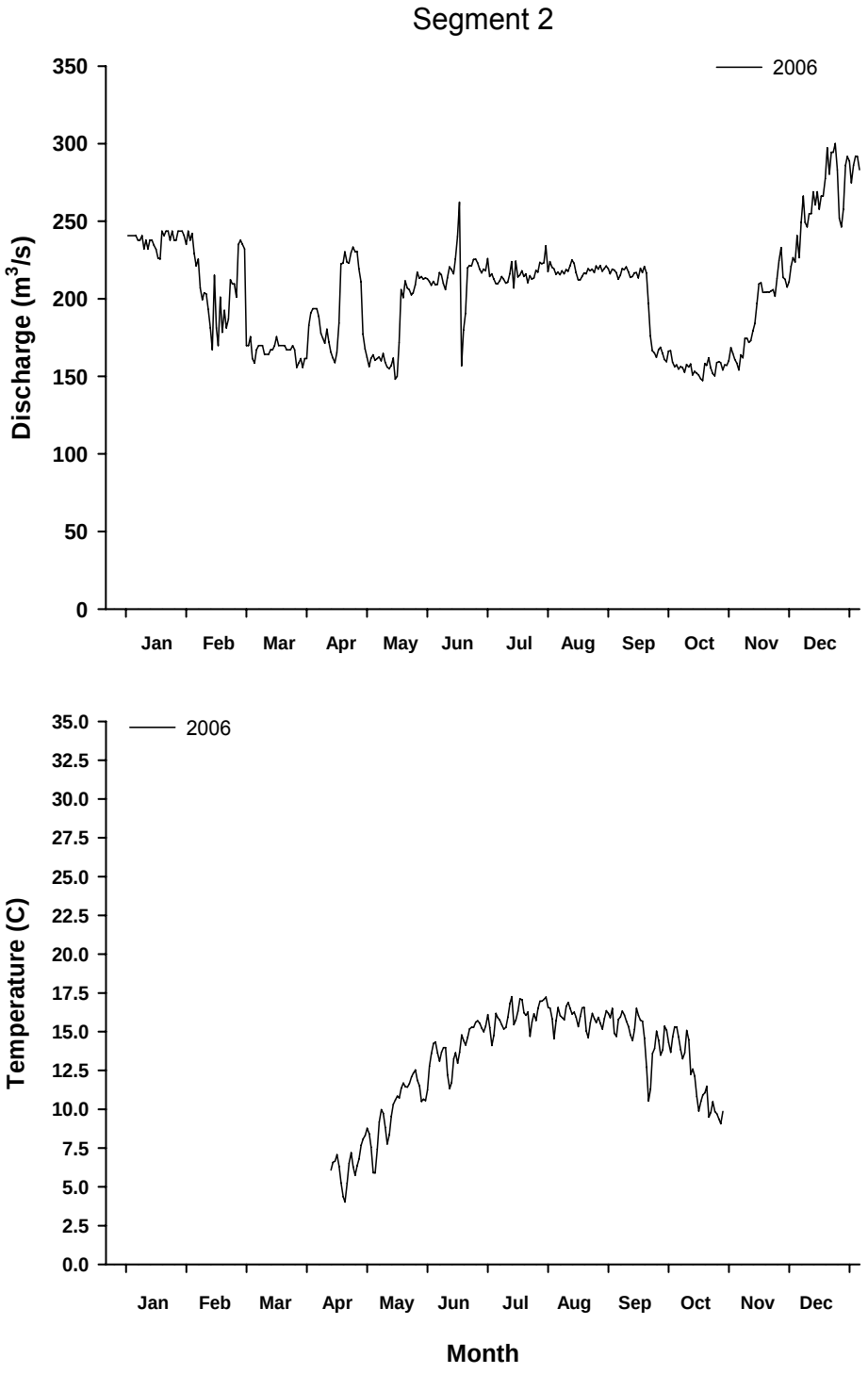

Figure 3. Mean daily discharge and mean daily water temperature for segment 2 of the Missouri River during 2006

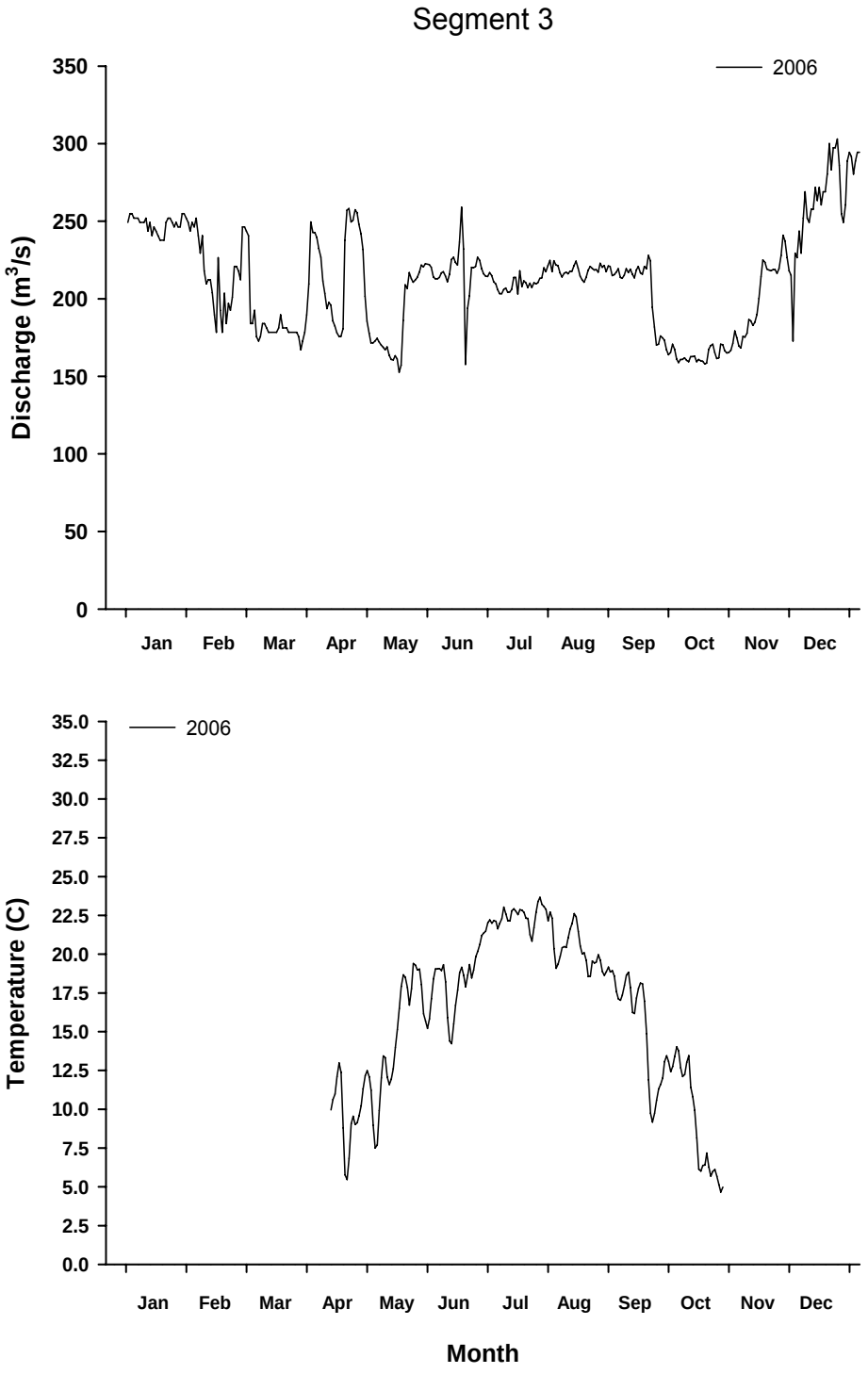

Figure 4. Mean daily discharge and mean daily water temperature for segment 3 of the Missouri River during 2006

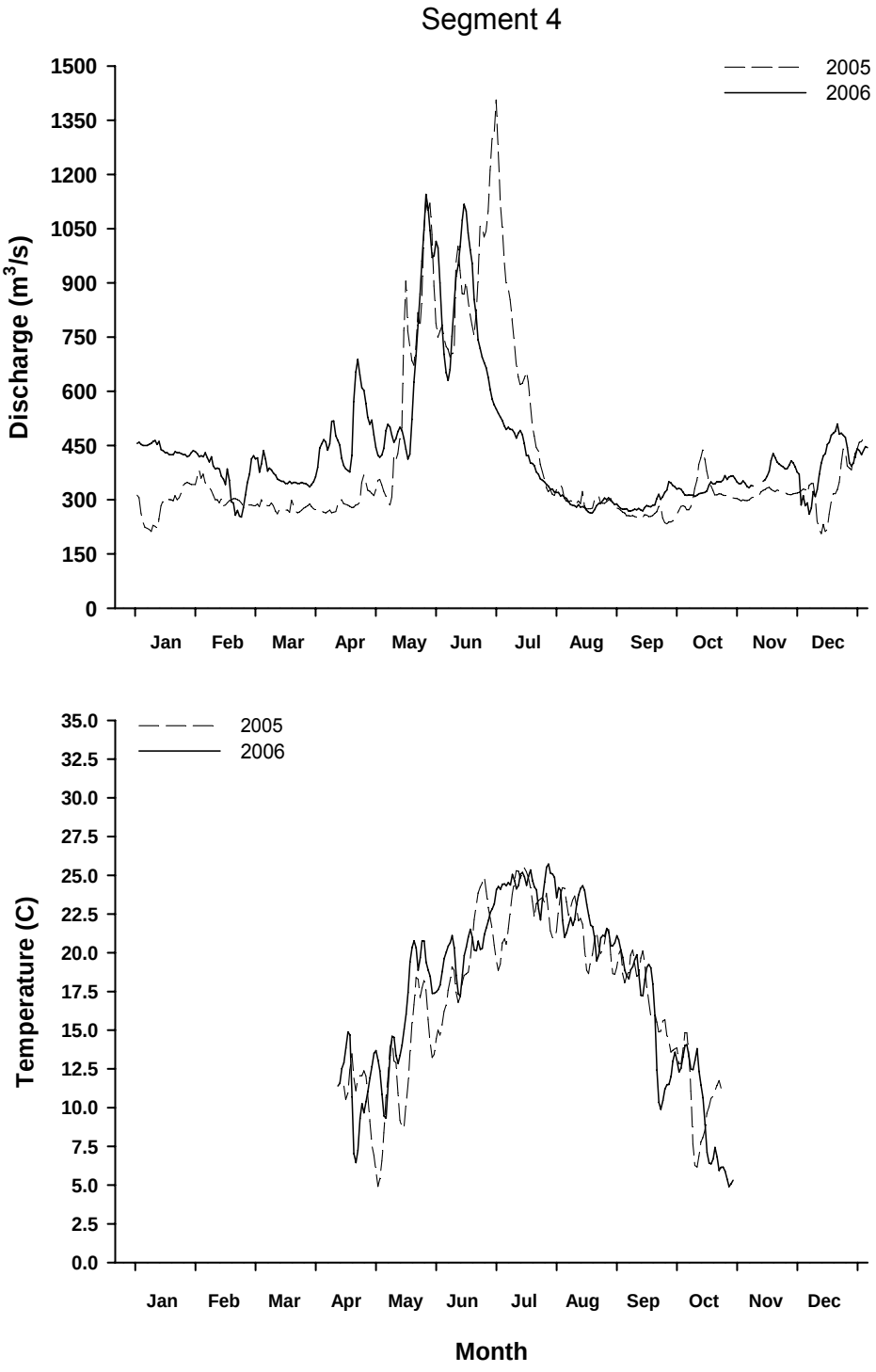

Figure 5. Mean daily discharge and mean daily water temperature for segment 4 of the Missouri River during 2005 and 2006.

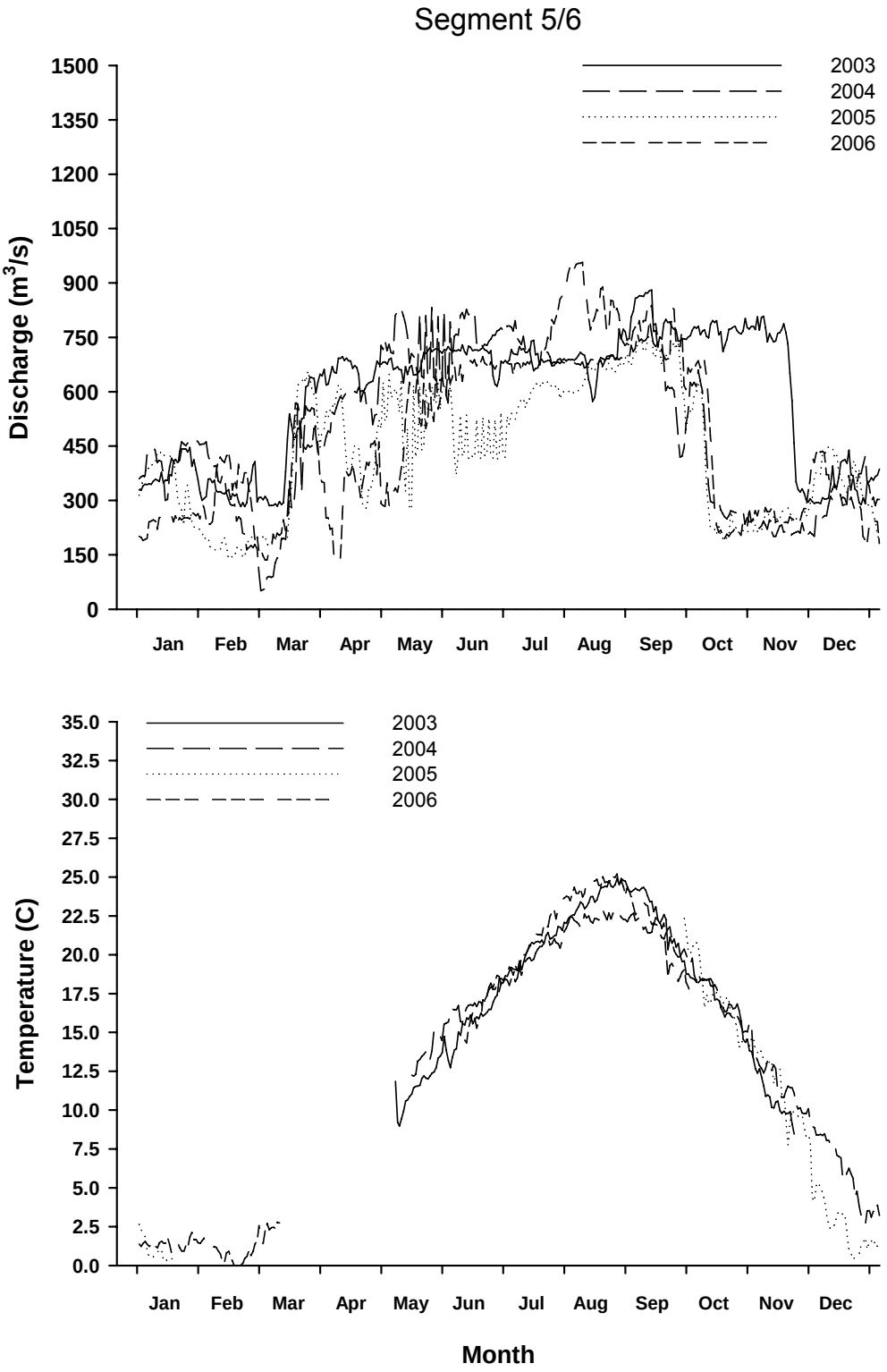

Figure 6. Mean daily discharge and mean daily water temperature for segment 5/6 of the Missouri River during 2003 through 2006.

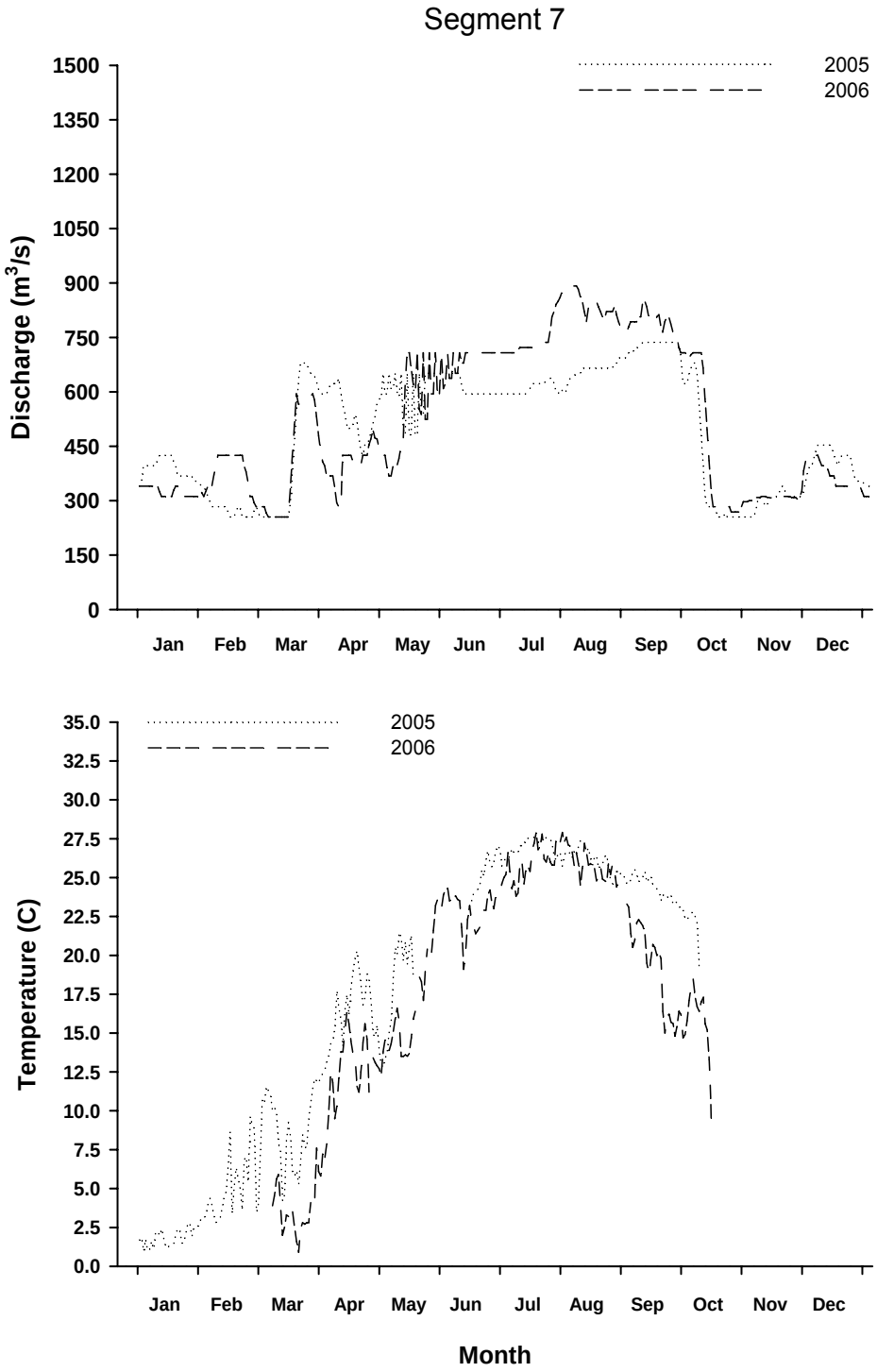

Figure 7. Mean daily discharge and mean daily water temperature for segment 7 of the Missouri River during 2005 and 2006.

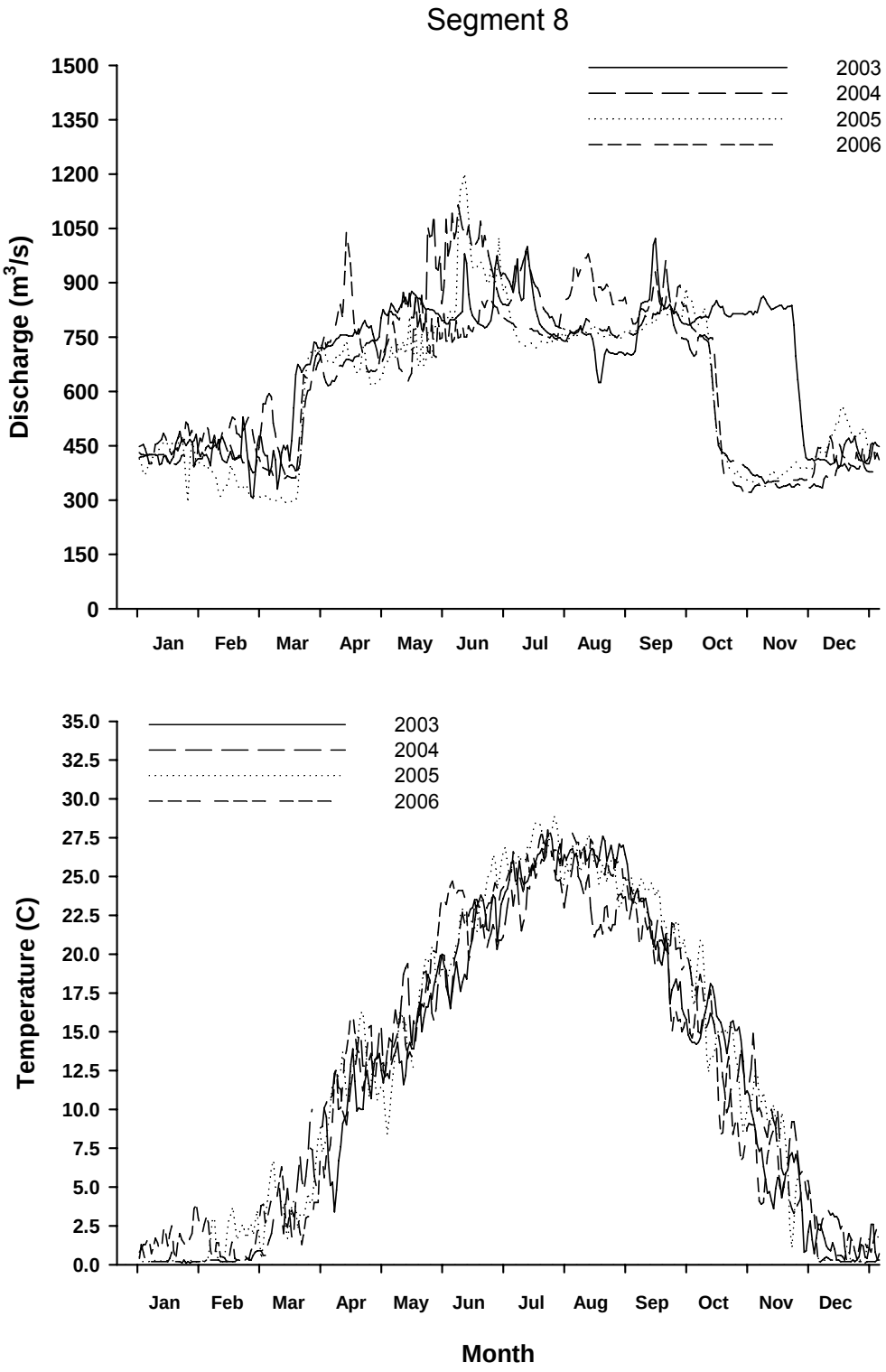

Figure 8. Mean daily discharge and mean daily water temperature for segment 8 of the Missouri River during 2003 through 2006.

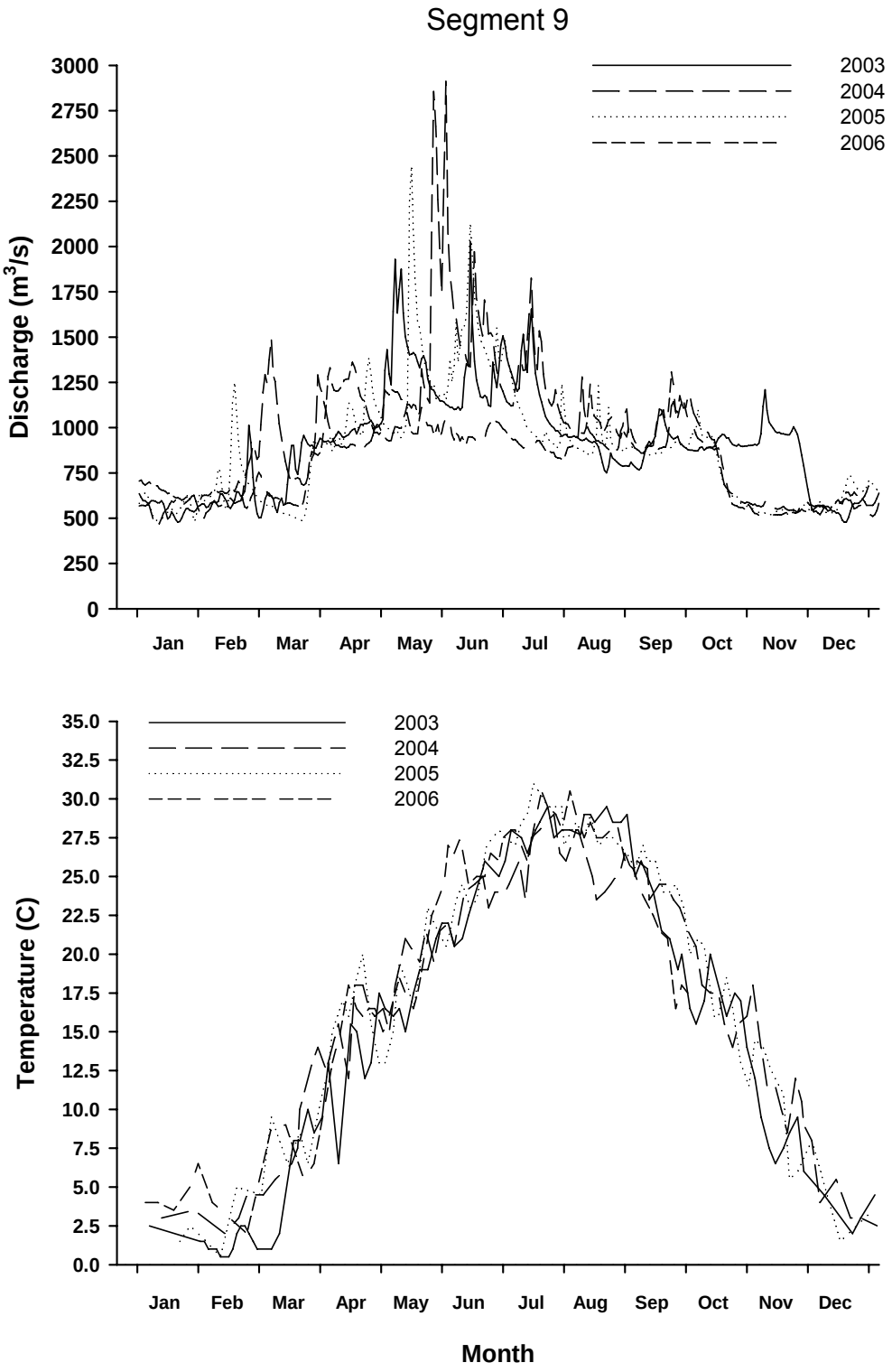

Figure 9. Mean daily discharge and mean daily water temperature for segment 9 of the Missouri River during 2003 through 2006.

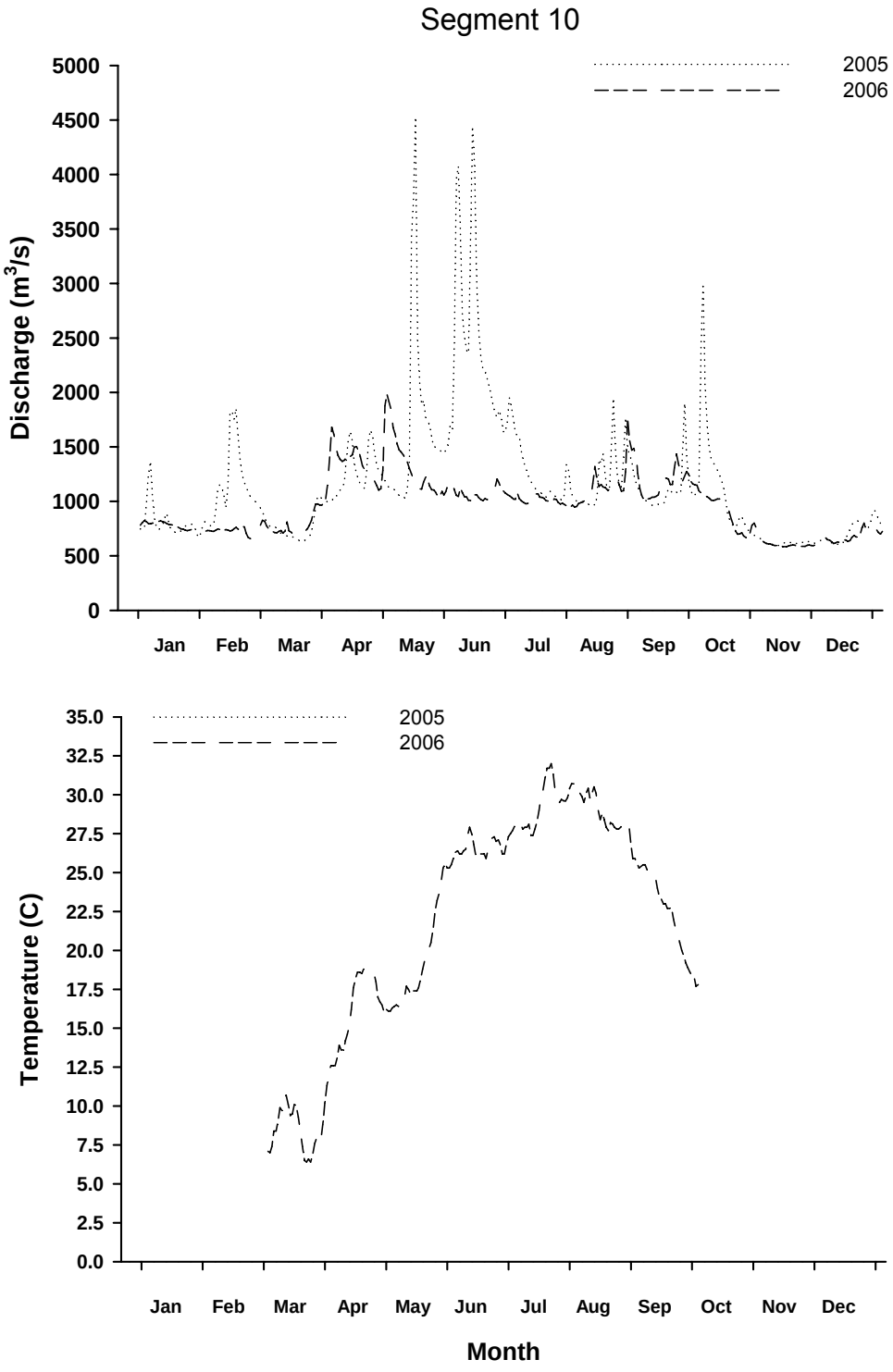

Figure 10. Mean daily discharge and mean daily water temperature for segment 10 of the Missouri River during 2005 and 2006.

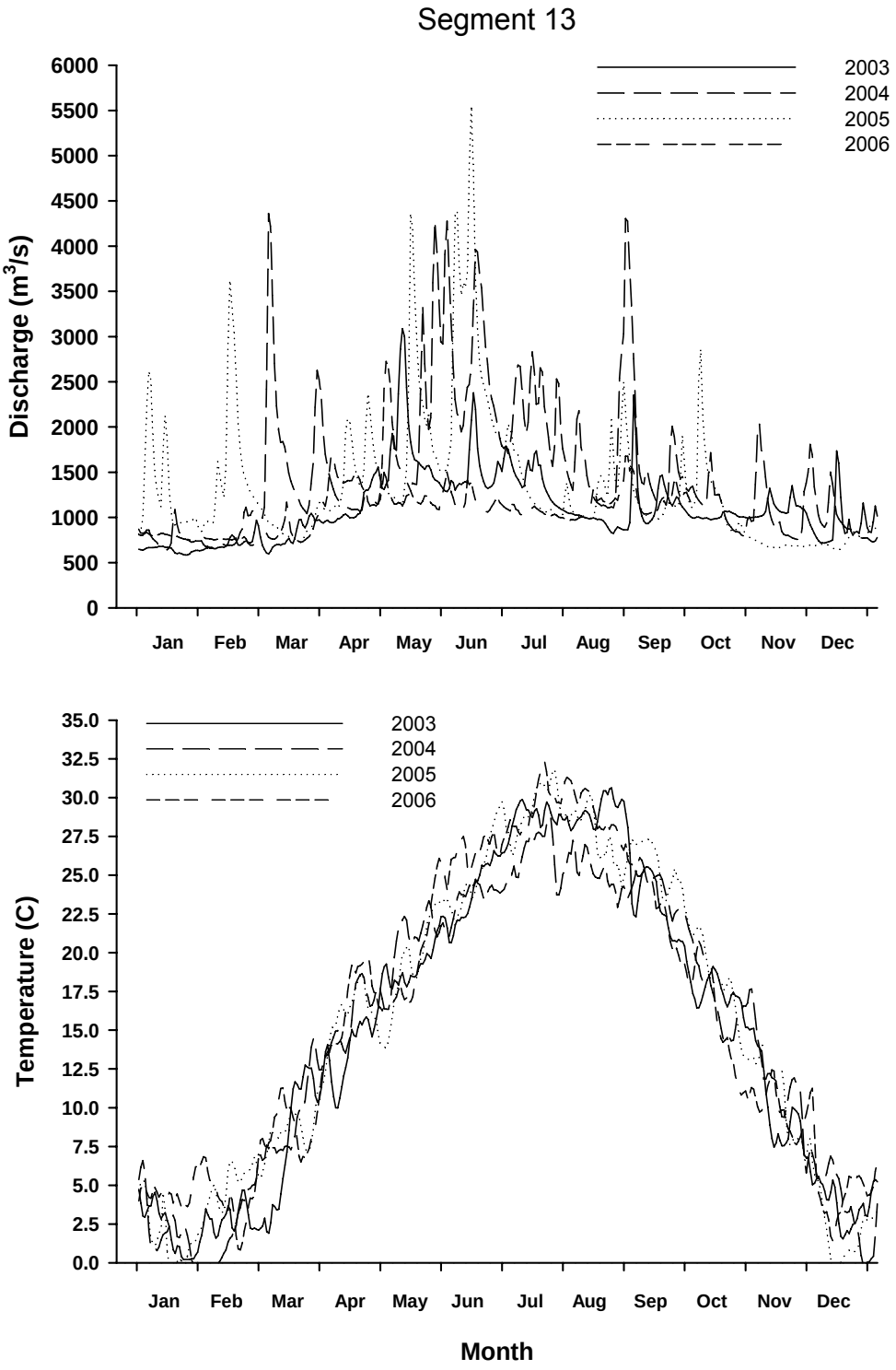

Figure 11. Mean daily discharge and mean daily water temperature for segment 13 of the Missouri River during 2003 through 2006.

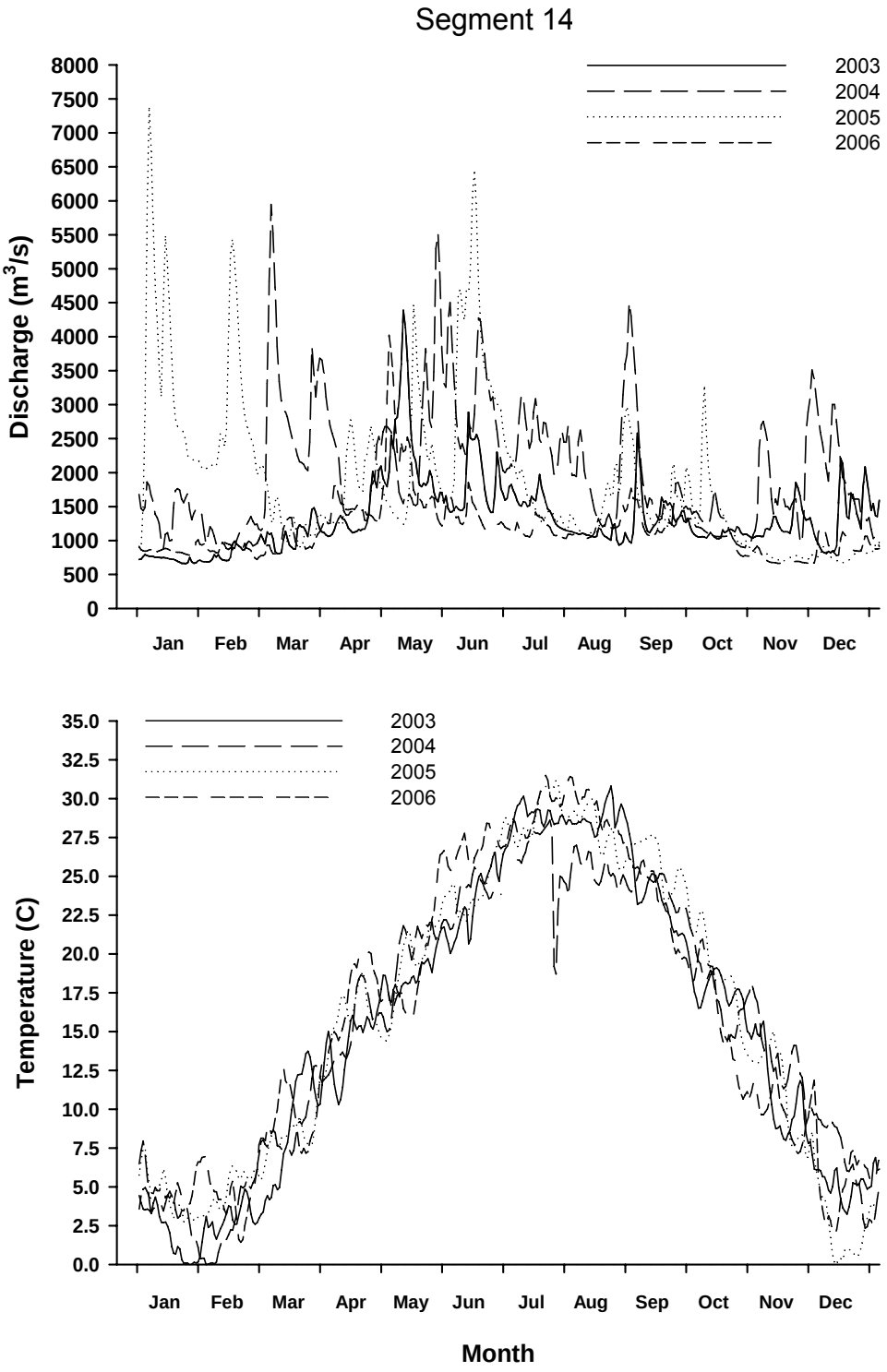

Figure 12. Mean daily discharge and mean daily water temperature for segment 14 of the Missouri River during 2003 through 2006.

Table 2. Starting and ending date by year and segment where blue sucker pectoral fin rays were collected.

Year	Starting Date	Ending Date	Segments
2005	July 2005	April 2006	7, 9, 10, 13, and 14
2006	July 2006	April 2007	2, 3, 7, 8, 9, 10, 13, and 14

Table 3. Starting and ending date by year and segment where scales where collected were
collected.

Year	Starting Date	Ending Date	Segments
2004	July 2004	March 2005	9 and 13
2005	July 2005	April 2006	4, 5, 6, 8, 9, 13, and 14

Results

General structure collection results

Age structures were collected from 1,095 blue suckers from 2004-2006. Scales from 296 blue suckers were collected in 2004. In 2005, structures from 516 fish were collected, of which 301 were rays and 215 were scales. In 2006, structures from 283 fish were collected all of which were rays. 551 of the total 1,095 structures collected from 2004-2006 were from fish greater than 599 mm and/or greater than 7 years old, or were from 2005 scale collections. None of the structures collected in the upper universe were from fish < 650 mm or younger than age 8. However, scales from 2 fish were collected in segment 4 in 2005 for the upper universe and this was graphically compared to scale collections made in the lower universe in 2005 (Figure 15).

Age specific results

Because of the low sample sizes from segments 5 and 6 and from the upper universe for all three years, fish from segments 2-6 were excluded from the spatial and temporal analysis. In addition to fish from the upper universe, any fish not < 650 mm and/or greater than 7 years old were excluded from the spatial and temporal analysis so that accurate comparisons could be made. Information on fish excluded from the analysis was recorded in appendix (1). Samples used in the spatial and temporal analysis were from segments 9, 13 and 14 in 2004. (Table 33). In 2005, samples were from segments 7, 9, 10, 13 and 14 (Table 33). In 2006, samples were from segments 7, 8, 9, 10, 13 and 14 (Table 33).

In 2004, 5 gear types collected aging structures from blue suckers < 650 mm and/or less than 8 years old, including: gill nets (n = 49), hoop nets (n = 48), small trammel nets (n

= 36), 16 ft. otter trawls (*n* = 11) and large trammel nets (*n* = 2). In 2005, the gear types successful in obtaining aging structures for this analysis were gill nets (*n*= 69), small trammel nets (*n* = 54), 16 ft. otter trawls (*n* = 36), and small mesh otter trawls (*n* = 1). In 2006, gear types that collected aging structures included: small mesh otter trawls (*n* = 29), 16 ft. otter trawls (*n* = 77), and small trammel nets (*n* = 133).

Aging resulted in 28 age-0 blue suckers in 2006, ranging in size from 153-409 mm in total length. Most of the age-0 blue suckers caught in 2006 were found in segment 8 (*n* = 18), followed by segment 9 (*n* =4), 14 (*n* = 4) and 1 each ere caught in segments 7, 10, and 13. The 16 ft. otter trawls and small trammel nets caught the most age-0 blue suckers (11 each), followed by small mesh trawls (*n* = 6). In 2005, 2 age-0 blue suckers were captured in segment 9 and 1 was captured in segment 7. They ranged in size from 152-461 mm. No age-0 blue suckers were captured in 2004.

Few age-1 and age-2 blue suckers were obtained in this study. Aging resulted in sample sizes of 2, 4 and 15 age-1 blue suckers collected from growth years 2004-2006, respectively. Age-2 blue suckers resulted in sample sizes of 10, 5, and 11 from growth years 2004-2006, respectively.

Length at Capture Spatial Analysis

Low sample sizes precluded analysis to test for spatial differences among segments 9, 13 and 14 for the 2004 growth year at all ages (Table 8). However, segment 9 had lower median length-at-capture at ages 2, 3 and 4 than segment 13.

Ages 3, 4, 5 and 6 were tested for median length-at-capture in segments that had an *n* greater than 2 for the 2005 growth year (Table 10). No significant difference was found in any age.

All ages, except ages 2 and 3, were tested for spatial differences for the 2006 growth year. Median-length-at-capture of age 7 blue sucker was significantly lower in segment 7 than in segments 8 and 9. No other significant differences were found, however median length at capture was lowest in segment 7 at ages 1, 4 and 6.

Mean back-calculated lengths at last annulus spatial analysis

For the 2004 growth year, mean back-calculated lengths at last annulus were compared in a tabular fashion among segments 9, 13, and 14 for ages 1-5. Segment 14 had the lowest mean back-calculated lengths at all 5 ages. Segment 13 had the highest mean back-calculated length at last annulus for ages 1-4 (Table 5).

For the 2005 growth year , Segment 7 had the lowest mean back-calculated length at last annulus than all other segments at ages 1-5. Segment 9 had the highest mean back-calculated length at all ages, except at ages 2 and 3 (Table 6).

Similarly, for the 2006 growth year, segment 7 also had the lowest mean back-calculated length at last annulus at ages 1-5. Segment 9 had the highest mean back-calculated length at ages 3-7 (Table 7).

Wr spatial analysis

Low sample sizes precluded age specific analysis for the 2004 growth year. However, *Wr* pooled for ages 0-7 was compared among segments. No significant differences

were found, however, segment 9 had a lower median value than segments 13 and 14, which were more similar (Table 11).

Wr at ages 3, 5 and pooled ages were tested for differences among segments in 2005 (Table 12). Segment 7 had a significantly lower *Wr* at age 5 than segments 9 and 14. Median Pooled *Wr* was significantly lower in segment 7 than in segments 9 and 10. Additionally, median *Wr* values were lowest in segment 7 at ages 3-7.

For the 2006 growth year, ages 1, 4, 5, 6, and 7 had adequate *n* to test medians among segments (Table 13). Median *Wr* was significantly lower at ages 4, 5, 7 and pooled ages in segments 7 and 8 than in segment 9. Segments 7 and 8 were not significantly different from each other at all individual ages tested. Additionally, segments 7 or 8 had lower median Wr values at all ages than the further downstream segments. A clear trend in median *Wr* decreasing longitudinally by segment was identified at all ages tested and in the pooled ages test in 2006.

First full increment width spatial analysis

Low samples sizes did not allow for testing of median first full increment for the 2004 growth year. No clear trends in first full increment width were identifiable among segments (Table 14).

Median first full increment at ages 3, 5 and 6 were tested for significant differences for the 2005 growth year. No significant differences were found and no trends in median values were identified.

For the 2006 growth year, ages 1, 4, 5, 6 and 7 were tested for significant differences. No differences were found and no clear trends were identified.

Temporal analysis

Because of the spatial differences in *Wr*, median length at capture, and mean back-calculated lengths detected between the upstream segments (7 and 8) compared to downstream segments (9-14), data for segments 9-14 was pooled together by each age for the temporal comparisons of length at capture and first full increment width. For the *Wr* temporal comparisons, data was pooled among ages 0-7 by each segment.

Length at capture temporal analysis

Ages 1, 3, 4, 5, 6 and 7 were tested for differences in median length at capture (Table 52). No significant differences were found between sample years 2005 and 2006, however, higher median length at capture values were recorded in 5 of the 6 ages that were tested for the 2006 growth year.

Wr temporal analysis

Segments 9, 13 and 14 were tested for differences in median *Wr* among growth years 2004, 2005, and 2006 (Table 18). No significant differences were found, however, median *Wr* values were highest in 2006 for 2 of the 3 segments tested.

Median First Full increment temporal analysis

All ages, except age 2, were tested for differences in median first full increment between growth years 2005 and 2006 (Table 19). No significant differences were found and no consistent trends in first full increment width were identified.

Table 4. Total number of aging structures collected during 2004-2006 from blue suckers ages 0-7 and < 650 mm age blue suckers in 2004 and pectoral fin rays were used in 2005 and 2006.

Length	Overall	2004				2005									
	Total	9	13	14	Total	7	9	10	13	14	Total	7	8	9	10
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	2	0	0	0	0	1	0	0	0	0	1	0	1	0	0
160	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
170	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
180	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
190	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0
200	3	0	0	0	0	0	0	0	0	0	0	0	2	1	0
210	2	0	0	0	0	0	0	0	0	0	0	0	1	1	0
220	4	0	0	0	0	0	0	0	0	0	0	0	2	1	0
230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
240	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
260	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0
270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
280	2	0	0	0	0	0	1	0	0	0	1	0	1	0	0
290	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
310	4	0	0	0	0	0	0	0	0	0	0	0	4	0	0
320	2	1	0	0	1	0	0	0	0	0	0	1	0	0	0
330	2	0	0	0	0	0	0	0	0	0	0	0	1	1	0

Table 4. Continued

Length	Overall	2004				2005						2006						
	Total	9	13	14	Total	7	9	10	13	14	Total	7	8	9	10	13	14	Total
340	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
360	3	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	2
370	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
380	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
390	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
400	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
410	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
420	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
430	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
440	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
450	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
460	3	0	0	0	0	1	1	0	0	0	2	0	1	0	0	0	0	1
470	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
480	3	0	1	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1
490	14	6	2	0	8	3	1	0	0	0	4	1	1	0	0	0	0	2
500	7	1	1	0	2	3	0	1	0	0	4	0	1	0	0	0	0	1
510	13	4	1	0	5	4	0	0	0	1	5	0	1	2	0	0	0	3
520	16	1	3	0	4	4	1	0	0	1	6	2	3	1	0	0	0	6
530	23	2	1	1	4	10	0	0	1	1	12	4	2	1	0	0	0	7
540	25	4	0	0	4	11	0	1	0	4	16	4	1	0	0	0	0	5
550	28	5	0	0	5	7	3	0	0	0	10	3	7	2	0	0	1	13
560	37	8	1	0	9	10	1	1	0	1	13	3	7	3	0	0	2	15
570	32	7	1	1	9	6	1	1	0	2	10	1	9	1	0	0	2	13
580	33	7	0	1	8	6	2	0	1	0	9	2	7	4	0	2	1	16

Table 4. Continued

Length	Overall	2004				2005						2006						
	Total	9	13	14	Total	7	9	10	13	14	Total	7	8	9	10	13	14	Total
590	40	10	1	0	11	8	1	0	0	2	11	1	9	8	0	0	0	18
600	46	12	1	0	13	10	2	1	0	0	13	6	9	4	0	1	0	20
610	45	9	2	1	12	5	1	0	0	1	7	6	11	7	0	1	1	26
620	43	10	5	0	15	4	2	0	0	1	7	2	6	11	0	1	1	21
630	48	12	3	0	15	4	3	1	2	0	10	4	8	9	0	0	2	23
640	47	15	1	1	17	6	5	2	0	1	14	3	9	4	0	0	0	16
Total	544	117	24	5	146	104	27	8	4	16	159	44	112	62	1	6	14	239

Table 5. Mean back-calculated total length-at-last annulus (+/- 2 standard errors) of blue sucker ages 0-7 and < 650 mm collected in segments 9, 13 and 14 in 2004. Ages were derived from scale readings.

	Segments		
Age	**9**	**13**	**14**
1	172 (6.9)	189 (22.4)	161 (39.1)
2	324 (11.9)	356 (35.0)	287 (71.3)
3	441 (11.8)	464 (33.7)	324 (65.0)
4	519 (9.8)	530 (34.6)	414 (73.2)
5	563 (10.3)	555 (53.1)	469 (62.9)
6	570 (24.2)	589	525 (37.5)
7	582 (69.4)		587

Table 6. Mean back-calculated total length-at-last annulus (+/- 2 standard errors) of blue sucker ages 0-7 and < 650 mm collected in segments 7, 9, 10, 13 and 14 during 2005. Ages were derived from fin ray readings.

	Segments				
Age	**7**	**9**	**10**	**13**	**14**
1	165 (11.3)	204 (24.1)	189 (31.4)	187 (48.9)	203 (37.1)
2	279 (14.5)	321 (28.2)	301 (47.4)	326 (47.4)	325 (43.3)
3	371 (14.6)	408 (30.7)	409 (55.3)	402 (55.3)	420 (45.2)
4	427 (14.3)	466 (30.5)	459 (57.8)	458 (57.8)	451 (43.1)
5	461 (14.5)	510 (30.0)	465 (43.3)	490 (43.3)	481 (43.4)
6	489 (14.7)	542 (33.2)	504 (44.6)	484 (44.6)	494 (48.1)
7	514 (15.5)	547 (40.1)	516 (56.0)	531 (56.0)	500 (16.2)

Table 7. Mean back-calculated total length-at-last annulus (+/- 2 standard errors) of blue sucker ages 0-7 and < 650 mm collected in segments 7, 8, 9, 13 and 14 during 2006. Ages were derived from fin ray readings.

	Segments				
Age	**7**	**8**	**9**	**13**	**14**
1	176 (23.6)	183 (14.6)	209 (20.5)	203 (37.6)	242 (68.3)
2	272 (24.8)	300 (15.5)	319 (17.5)	320 (40.8)	278 (61.8)
3	352 (21.0)	386 (15.6)	419 (18.3)	412 (50.8)	357 (54.5)
4	417 (23.2)	453 (16.0)	481 (16.9)	468 (61.8)	433 (53.3)
5	470 (24.5)	494 (15.3)	520 (15.5)	489 (65.4)	489 (54.3)
6	490 (23.8)	513 (16.7)	551 (11.5)	486 (65.8)	499 (67.9)
7	521 (21.2)	537 (19.1)	580 (9.2)	532 (44.7)	514 (60.7)

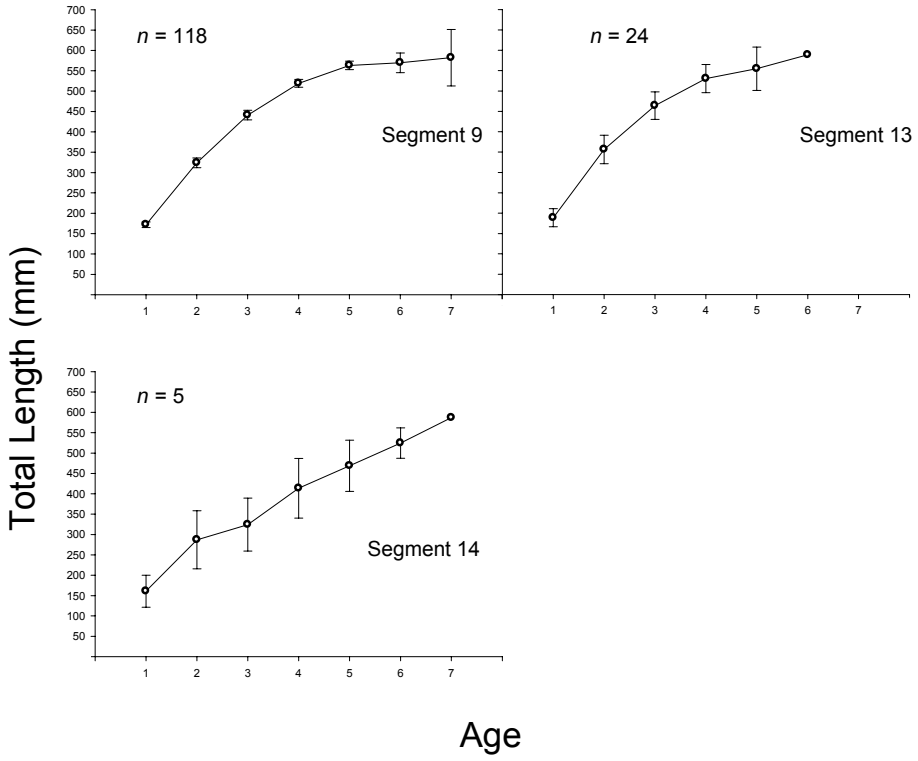

Figure 13. Mean back-calculated fork length-at-last annulus of blue suckers < 560 mm and < 8 years old collected from segments 9, 13 and 14 during 2004.

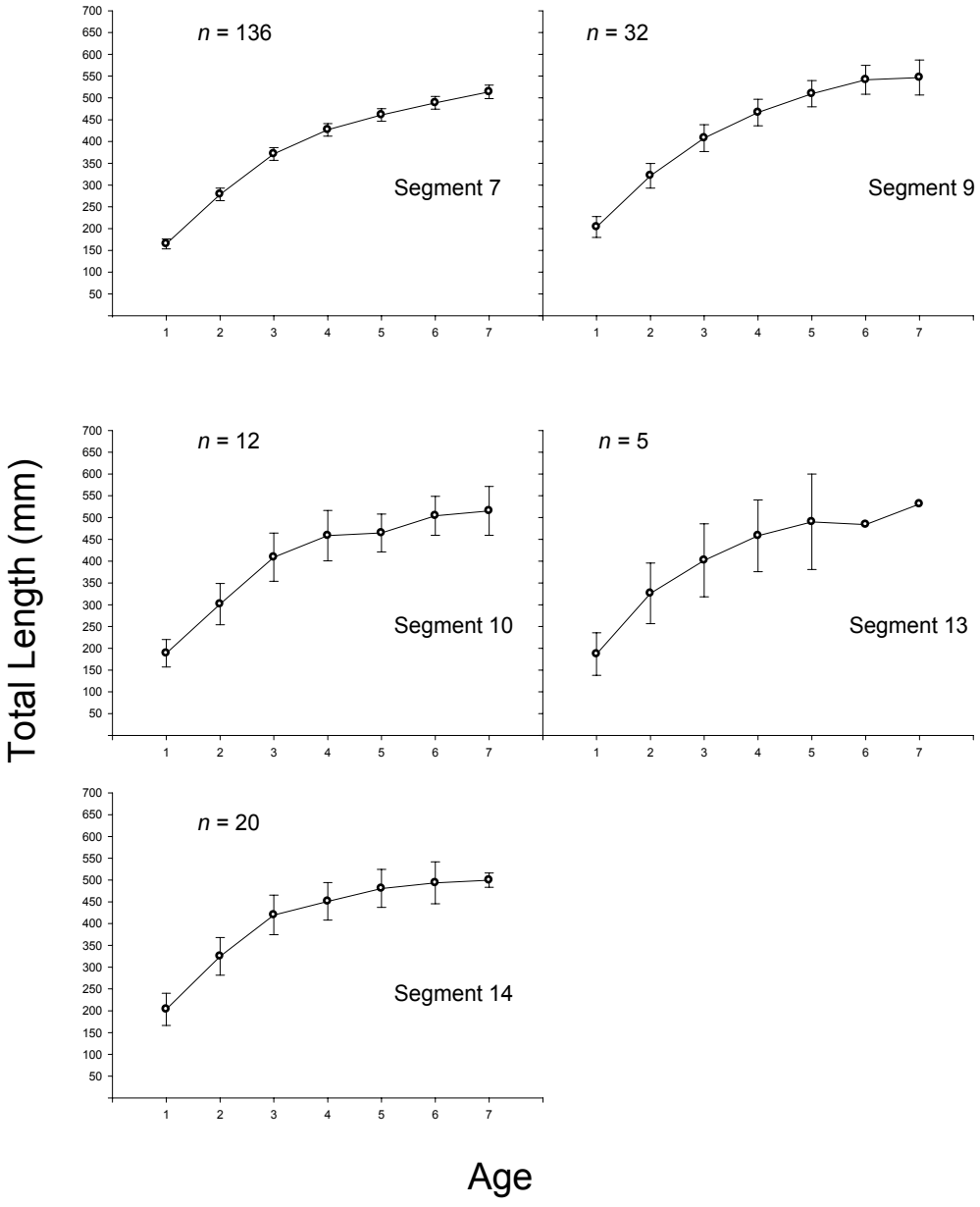

Figure 14. Mean back-calculated fork length-at-last annulus of blue suckers < 560 mm and < 8 years old collected from segments 7, 9, 10, 13 and 14 during 2005.

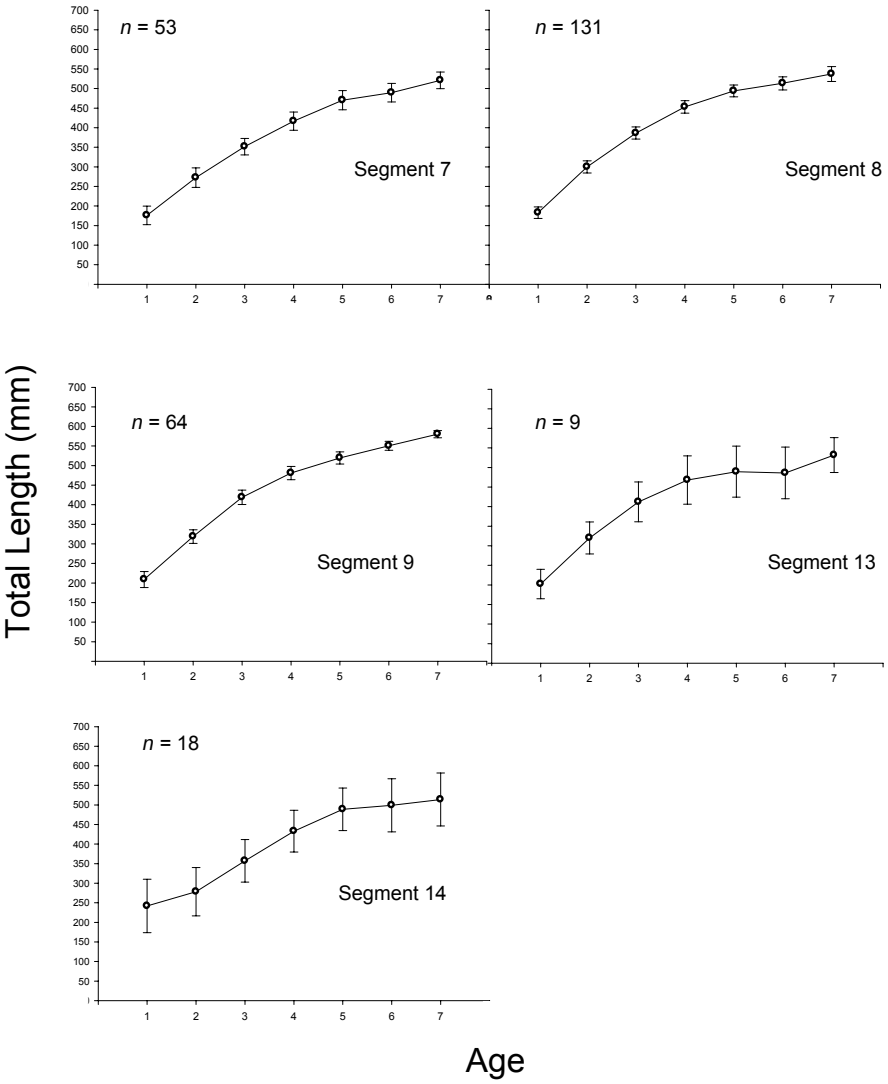

Figure 15. Mean back-calculated fork length-at-last annulus of blue suckers < 560 mm and < 8 years old collected from segments 7, 8, 9, 13 and 14 during 2006.

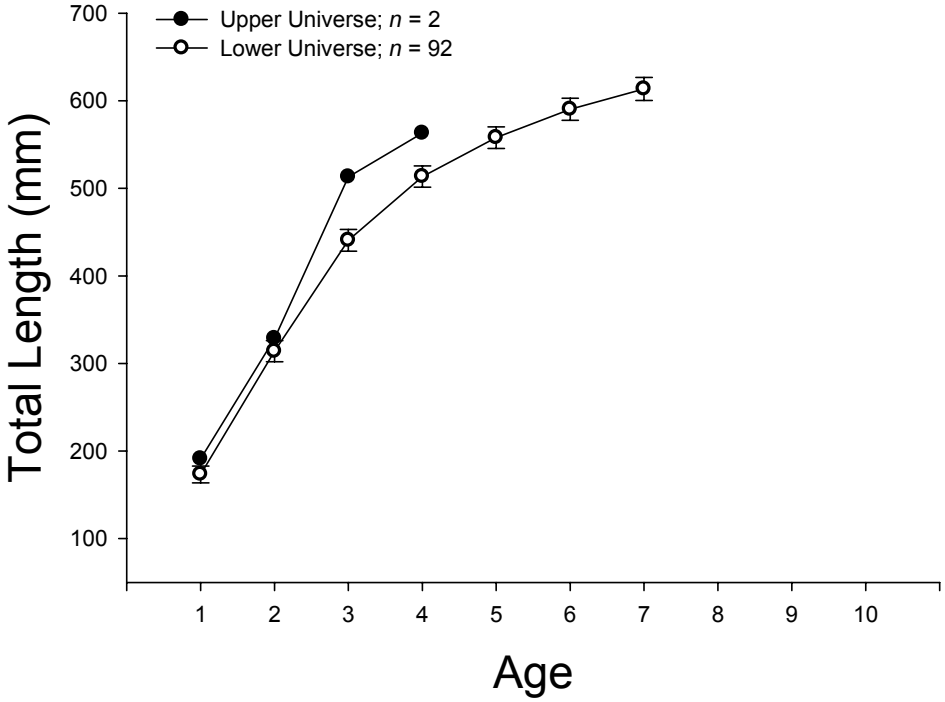

Figure 16. Upper universe vs. lower universe mean back-calculated fork length-at-last annulus of blue suckers captured in 2005. Age determinations were made using scales.

Table 8. Median length at capture comparisons of blue suckers < 650 mm among segments for 2004. Numbers below the median are the inter-quartile range, followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median length at capture among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons(α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference.

	Segment		
Age	9	13	14
0			
1	296 −, 2		
2	490 62, 5	505 41, 4	529 −, 1
3	553 60, 23	573 95, 10	
4	605 58, 35	614 103, 7	569 −, 1
5	611 37, 41	619 −, 2	
6	630 9, 57	622 −, 1	587 −, 2
7	634 −, 2		634 −, 1

Table 9. Median length at capture comparisons of blue suckers < 650 mm among segments for 2005. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median length at capture among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference.

	Segment				
Age	7	9	10	13	14
0	153	349			
	−, 1	−, 2			
1	540	462			459
	−, 1	−, 1			−, 2
2	530	481			
	165, 3	−, 2			
3*	562	558	560		551
	64, 16	122, 5	70, 3		108, 6
4*	552	606	623	553	582
	39, 23	34, 3	33, 3	−, 2	60, 3
5*	587	576		624	552
	67, 24	87, 5		−, 1	103, 3
6*	567	621	585		535
	78, 17	46, 6	−, 2		81, 3
7	588	635		622	
	60, 19	57, 3		−, 1	

Table 10. Median length at capture comparisons of blue sucker < 650 mm among segments for 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was significant. Different letters indicate significance differences. Similar letters indicate no significant differences.

	Segment					
Age	7	8	9	10	13	14
0*	190	256	221	240	212	256
	−, 1	123, 18	108, 4	−, 1	−, 1	27, 3
1*	551	611	562			553
	279, 3	330, 4	77, 3			112, 5
2	559	539	538			
	93, 3	67, 6	−, 2			
3	548	587	585		593	
	−, 2	78, 9	86, 12		−, 1	
4*	584	585	617		589	622
	98, 4	54, 19	9, 27		−, 2	−, 1
5*	613	597	623		598	588
	88, 14	41, 29	43, 12		−, 2	54, 4
6*	601	606	610			621
	89, 7	65, 17	20, 10			−, 1
7*	586 y	624 z	610 z			
	47, 10	44, 10	20, 10			

Table 11. Median *Wr* at age comparisons of blue suckers ages 0-7 < 650 mm among segments for 2004. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median Wr at age was compared among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.

	Segment		
Age	9	13	14
0			
1	89 −, 2		
2	84 10.0, 5	92 17.9, 4	93 −, 1
3	89 13.4, 23	98 20.5, 10	
4	96 16.4, 35	111 28.8, 7	97 −, 1
5	95 13.9, 41	105 −, 2	
6	97 16.9, 9	106 −, 1	105 −, 1
7	101 −, 2		117 −, 1
Pooled Ages*	94 14.3, 117	100 19.9, 24	101 19.8, 4

Table 12. Median *Wr* at age comparisons of blue suckers ages 0-7 < 650 mm among segments for 2005. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median *Wr* at age was compared among segments was compared. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.

	Segment									
Age	7		9		10		13		14	
0	115		101						99	
	−, 1		−, 2						5.7, 3	
1	77		89						112	
	−, 1		−, 1						21.2, 5	
2	77		107							
	18.4, 3		−, 2							
3*	83		93		106					
	11.5, 16		23.3, 5		16.7, 3					
4	88		100		114		94		112	
	27.3, 23		−, 2		53.1, 3		−, 2		−, 1	
5*	87.8	y	113	z					100	z
	13.6, 24		27.4, 5						13.7, 4	
6	92		107		107				93	
	17.8, 17		23.9, 6		−, 2				−, 1	
7	91		106				92			
	13.5, 19		14.7, 3				−, 1			
Pooled Ages*	89	y	105	z	109	z	92	zy	99	zy
	16.0, 104		18.4, 26		10.4, 8		21.9, 3		17.2, 15	

Table 13. Median *Wr* at age comparisons of blue suckers ages 0-7 and < 650 mm among segments for 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median *Wr* at age was compared among segments. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.

	Segment					
Age	7	8	9	10	13	14
0*	115	81	112	87	99	99
	−, 1	15.5, 17	27.7, 4	−, 1	−, 1	5.7, 3
1*	78	81	95			112
	10.2, 3	40.9, 4				21.2, 5
2	83	87	100			
	12.9, 3	15.9, 6				
3	80	83	92		100	
	−, 2	7.1, 9	15.6, 12		−, 1	
4*	79 y	87 y	95 z		98	112
	7.8, 4	5.9, 19	8.3, 9		−, 2	−, 1
5*	77 y	81 y	92 z		103	100 z
	14.1, 13	10.1, 28	9.6, 12		−, 2	13.8, 4
6*	76 y	86 zy	93 z			93
	11.4, 7	5.3, 17	12.6, 10			−, 1
7*	80 y	83 y	92 z			
	12.2, 10	16.0, 10	10.8, 10			
Pooled Ages*	77 x	84 y	93 z	87	101 z	102 z
	9.6, 43	9.1, 110	10.6, 61	−, 1	6.0, 6	18.2, 14

Table 14. Median first full increment (mm) at age comparisons of blue suckers ages 0-7 and < 650 mm between segments for 2004. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where first full increment at age was compared among segments. Medians were compared using Mann-Whitney U tests (α = 0.05). Ages were determined using scales.

	Segment		
Age	9	13	14
1	1.662		
	−, 2		
2	2.292	2.006	2.292
	1.49, 5	1.031, 4	−, 1
3	1.146	0.318	
	0.745, 23	0.731, 10	
4	0.917	1.204	1.375
	0.459, 35	1.547, 7	−, 1
5	0.688	0.573	
	0.315, 41	−, 2	
6	0.516	1.032	0.689
	0.287, 9	−, 1	−, 2
7	0.344		1.143
	−, 2		−, 1

Table 15. Median first full increment (mm) at age comparisons of blue suckers ages 0-7 and < 650 mm among segments for 2005. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median first full increment at age was compared among segments. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.

	Segment				
Age	7	9	10	13	14
1	0.503	0.185			0.36
	−, 1	−, 1			−, 2
2	0.113	0.072			
	0.062, 3	−, 2			
3*	0.123	0.093	0.164		0.206
	0.067, 16	0.031, 5	0.144, 3		0.211, 6
4	0.103	0.082	0.113	0.118	0.154
	0.042, 23	0.103, 3	0.082, 3	−, 2	0.051, 3
5*	0.093	0.082		0.134	0.082
	0.049, 24	0.056, 5		−, 1	0.052, 3
6*	0.113	0.093	0.113		0.103
	0.067, 17	0.072, 6	−, 2		0.113, 3
7	0.093	0.072		0.144	
	0.051, 19	0.031, 3		−, 1	

Table 16. Median first full increment (mm) at age comparisons of blue suckers ages 0-7 and < 650 mm among segments for 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient *n* to calculate a range. Asterisks indicate ages where median first full increment at age was compared among segments. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significance differences. Similar letters indicate no significant difference. Ages were determined using pectoral fin rays.

	Segment					
Age	7	8	9	10	13	14
1*	0.360	0.452	0.277			0.277
	0.216, 3	0.347, 4	0.226, 3			0.247, 5
2	0.072	0.308	0.118			
	0.267, 3	0.334, 6	−, 2			
3	0.159	0.206	0.149		0.360	
	−, 2	0.072, 9	0.108, 12		−, 1	
4*	0.103	0.113	0.092		0.093	0.062
	0.069, 4	0.072, 19	0.072, 9		−, 2	−, 1
5*	0.098	0.103	0.118		0.077	0.113
	0.054, 14	0.077, 29	0.062, 12		−, 2	0.059, 4
6*	0.154	0.093	0.082			0.123
	0.092, 7	0.036, 17	0.039, 10			−, 1
7*	0.092	0.103	0.082			
	0.054, 10	0.031, 10	0.044, 10			

Table 17. Median total length (pooled from segments 9-14) at capture comparisons of blue suckers < 650 mm for fish ages 0-7 between 2005 and 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median length at capture among segments was compared. Medians were compared using Mann-Whitney U tests (α = 0.05). Ages were determined using fin rays ages. Discharge is mean annual discharge in m3/s from segment 14.

	Year		
Age	2005	2006	Significance
	Annual Discharge		
	1904	1156	
	Median Total Length at Capture		
0	349	240	
	−, 2	54.5, 9	
1*	462	558	n. s.
	212.0, 3	15.6, 8	
2	481		
	−, 1		
3*	559	585	n. s.
	103.0, 14	78.0, 13	
4*	596	610	n. s.
	45.0, 11	24.0, 12	
5*	576	613	n. s.
	89.0, 9	58.5, 18	
6*	613	611	n. s.
	92.0, 11	24.0, 11	
7*	629	632	n. s.
	46.0, 4	20.0, 10	

Table 18. Median *Wr* (pooled ages 0-7 by segment) comparisons of blue sucker < 650 mm among sample years 2004-2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range, therefore, its corresponding median was not tested. Asterisks indicate segments where pooled median Wr was compared among segments. Medians were compared using Kruskal-Wallis tests (α = 0.05) followed by Dunn's multiple comparisons (α = 0.05) if the test was found significant. Different letters indicate significant differences. Similar letters indicate no significant difference. Discharge values are mean annual discharge values in m3/s.

	Sample Year					
Segment	2004	Discharge	2005	Discharge	2006	Discharge
7			89 16.0, 104	493	77 9.6, 43	517
8					84 9.1, 110	619
9*	94 14.3, 117	930	105 18.4, 26	872	93 10.6, 61	830
10			109 10.4, 8	1178	87 −, 1	962
13*	100 19.9, 24	1503	92 21.9, 3	1380	101 6.0, 6	1098
14*	101 19.8, 4	2051	99 17.2, 15	1904	102 18.2, 14	1156

Table 19. Median first full increment (mm) (pooled from segments 9-14) comparisons of blue suckers ages 0-7 and < 650 mm between 2005 and 2006. Numbers below the median are the inter-quartile range followed by the sample size. Dashes indicate an insufficient n to calculate a range. Asterisks indicate ages where median first full increment was compared between years. Medians were compared using Mann-Whitney U tests (α = 0.05). Ages were determined using fin rays ages. Discharge is mean annual discharge in m3/s from segment 14.

	Year		
Age	2005	2006	Significance
	Annual Discharge		
	1904	1156	
	Median First Full Increment		
1*	0.360	0.277	n. s.
	0.175, 3	0.200, 8	
2	0.072	0.118	
	−, 2	−, 2	
3*	0.113	0.154	n. s.
	0.134, 14	0.119, 13	
4*	0.123	0.087	n. s.
	0.093, 11	0.064, 12	
5*	0.082	0.108	n. s.
	0.057, 9	0.062, 18	
6*	0.103	0.092	n. s.
	0.062, 11	0.062, 11	
7*	0.077	0.082	n. s.
	0.072, 4	0.044, 10	

Table 20. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 9 during 2004. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using scales.

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260	1(1)		100						
270									
280									
290									
300									
310									
320	1(1)		100						
330									
340									
350									
360									
370									

Table 20. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440	1(2)			100					
450	1(2)			100					
460									
470									
480									
490	2(2) 3(3) 1(4)			33.33	50	16.67			
500	1(3)				100				
510	1(2) 3(3)			25	75				
520	1(5)						100		
530	1(3) 1(4)				50	50			
540	2(3) 2(4)				50	50			
550	3(3) 1(4) 1(5)				60	20	20		
560	3(3) 3(4) 1(5) 1(6)				37.5	37.5	12.5	12.5	
570	3(3) 2(4) 2(5)				42.86	28.57	28.57		
580	1(3) 3(4) 2(5) 1(6)				14.29	42.86	28.57	14.29	
590	1(3) 2(4) 5(5) 2(6)				10	20	50	20	
600	1(3) 5(4) 6(5)				8.33	41.67	50		
610	3(4) 6(5)					33.33	66.67		
620	3(4) 6(5) 1(7)					30	60		10
630	1(3) 6(4) 3(5) 2(6)				8.33	50	25	16.67	
640	3(4) 8(5) 3(6) 1(7)					18.75	50	18.75	6.25
Total	117								

Table 21. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 13 during 2004. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using scales.

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 21. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470	1(2)			100					
480	1(4)					100			
490	1(2) 1(3)			50	50				
500	1(3)				100				
510	2(2) 1(3)			66.67	33.33				
520	1(4)					100			
530									
540									
550	1(3)				100				
560	1(3)				100				
570									
580	1(3)				100				
590	1(3)				100				
600	1(3) 1(4)				50	50			
610	1(3) 2(4) 1(5)				25	50	25		
620	1(3) 1(4) 1(5) 1(6)				25	25	25	25	
630	1(4)					100			
640									
Total	24								

Table 22. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 14 during 2004. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age							
		0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 22. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520	1(2)			100					
530									
540									
550									
560	1(4)					100			
570	1(6)							100	
580									
590									
600	1(6)							100	
610									
620									
630	1(7)								100
640									
Total	5								

Table 23. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 7 during 2005. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age							
		0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150	1(0)	100							
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 23. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460	1(2)			100					
470									
480	1(3)				100				
490	2(3) 1(4)				66.67	33.33			
500	1(4) 2(5)					33.33	66.67		
510	1(4) 2(5) 1(6)					25	50	25	
520	1(3) 1(4) 1(6) 1(7)				25	25		25	25
530	1(2) 1(3) 2(4) 2(5) 3(6) 1(7)			10	10	20	20	30	10
540	1(1) 2(3) 5(4) 1(5) 2(7)		9.09		18.18	45.45	9.09		18.18
550	3(4) 1(5) 2(6) 1(7)					42.86	14.29	28.57	14.29
560	3(3) 2(4) 3(6) 2(7)				30	20		30	20
570	1(3) 2(4) 2(5) 1(7)				16.67	33.33	33.33		16.67
580	3(5) 1(6) 2(7)						50	16.67	33.33
590	2(3) 1(4) 3(5) 1(6) 1(7)				25	12.5	37.5	12.5	12.5
600	1(3) 1(4) 5(5) 1(6) 2(7)				10	10	50	10	20
610	1(4) 2(5) 2(7)					20	40		40
620	1(3) 1(5) 1(6) 1(7)				25		25	25	25
630	1(2) 1(4) 1(6) 1(7)			25		25		25	25
640	1(3) 1(4) 2(6) 2(7)				16.67	16.67		33.33	33.33
Total	104								

Table 24. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 9 during 2005. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age							
		0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280	1(0)	100							
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 24. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400	1(0)	100							
410	1(2)			100					
420									
430									
440									
450									
460	1(1)		100						
470									
480									
490	1(3)				100				
500									
510									
520	1(3)				100				
530									
540									
550	1(2) 1(3) 1(5)			33.33	33.33		33.33		
560	1(5)						100		
570	1(5)						100		
580	1(6) 1(7)							50	50
590	1(4)					100			
600	1(4) 1(6)					50		50	
610	1(6)							100	
620	1(3) 1(6)				50			50	
630	1(3) 1(4) 1(7)				33.33	33.33			33.33
640	2(5) 2(6) 1(7)						40	40	20
Total	24								

Table 25. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 10 during 2005. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age							
		0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 25. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490	1(3)				100				
500									
510									
520									
530	1(6)							100	
540									
550									
560	2(3)				100				
570									
580									
590	1(4)					100			
600									
610									
620	1(4)					100			
630	1(4) 1(6)					50		50	
640									
Total	8								

Table 26. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 13 during 2005. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age							
		0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 26. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520	1(4)					100			
530									
540									
550									
560									
570	1(4)					100			
580									
590									
600									
610									
620	1(5) 1(7)						50		50
630									
640									
Total	4								

Table 27. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 14 during 2005. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350	1(1)		100						
360									
370									

Table 27. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500	1(3)				100				
510	1(3)				100				
520	1(4)					100			
530	1(5) 2(6)						33.33	66.67	
540	1(3)				100				
550	1(5)						100		
560	1(1) 1(3)		50		50				
570									
580	2(4)					100			
590									
600									
610	1(3) 1(6)				50			50	
620									
630	1(5)						100		
640	1(3)				100				
Total	17								

Table 28. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 7 during 2006. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using scales.

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190	1(0)	100							
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320	1(1)		100						
330									
340									
350									
360									
370									

Table 28. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490	1(4)					100			
500									
510									
520	1(5) 1(7)						50		50
530	1(3) 1(5) 1(6) 1(7)				25		25	25	25
540	1(2) 3(5)			25			75		
550	1(1) 1(2) 1(6)		33.33	33.33				33.33	
560	1(3) 1(4) 1(7)				33.33	33.33			33.33
570	1(7)								100
580	2(7)								100
590	1(7)								100
600	1(1) 1(4) 1(5) 2(6) 1(7)		16.67			16.67	16.67	33.33	16.67
610	1(4) 4(5) 1(7)					16.67	66.67		16.67
620	1(6) 1(7)							50	50
630	1(2) 2(5) 1(6)			25			50	25	
640	2(5) 1(6)						66.67	33.33	
Total	44								

Table 29. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 8 during 2006. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150	1(0)	100							
160	1(0)	100							
170	1(0)	100							
180	1(0)	100							
190	1(0)	100							
200	2(0)	100							
210	1(0)	100							
220	1(0) 1(1)	50	50						
230									
240									
250									
260									
270									
280	1(0)	100							
290	1(0)	100							
300									
310	4(0)	100							
320									
330	1(0)	100							
340									
350									
360	1(0)	100							
370									

Table 29. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420	1(3)				100				
430									
440									
450									
460	1(0)	100							
470									
480	1(2)			100					
490	1(5)						100		
500	1(3)				100				
510	1(2)			100					
520	1(2) 1(4) 1(6)			33.33		33.33		33.33	
530	1(4) 1(6)					50		50	
540	1(3)				100				
550	1(2) 1(4) 2(5) 3(6)			14.29		14.29	28.57	42.86	
560	1(2) 5(4) 1(5)			14.29		71.43	14.29		
570	1(3) 1(4) 4(5) 2(6) 1(7)				11.11	11.11	44.44	22.22	11.11
580	1(1) 1(2) 1(3) 1(4) 2(5) 1(7)		14.29	14.29	14.29	14.29	28.57		14.29
590	1(3) 2(4) 5(5) 1(6)				11.11	22.22	55.56	11.11	
600	3(3) 2(4) 1(5) 2(6) 1(7)				33.33	22.22	11.11	22.22	11.11
610	2(4) 7(5) 1(6) 1(7)					18.18	63.64	9.09	9.09
620	1(4) 3(6) 2(7)					16.67		50	33.33
630	1(1) 1(4) 5(5) 1(6)		12.5			12.5	62.5	12.5	
640	1(1) 1(4) 1(5) 2(6) 4(7)		11.11			11.11	11.11	22.22	44.44
Total	112								

Table 30. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 9 during 2006. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200	1(0)	100							
210	1(0)	100							
220	1(0)	100							
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330	1(3)				100				
340	1(0)	100							
350									
360									
370									

Table 30. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510	1(2) 1(3)			50	50				
520	1(3)				100				
530	1(3)				100				
540									
550	1(1) 1(5)		50				50		
560	1(1) 1(2) 1(5)		33.33	33.33			33.33		
570	1(3)				100				
580	2(3) 2(6)				50			50	
590	2(3) 2(4) 2(5) 2(6)				25	25	25	25	
600	2(4) 1(6) 1(7)					50		25	25
610	2(4) 1(5) 3(6) 1(7)					28.57	14.29	42.86	14.29
620	1(1) 2(3) 1(4) 2(5) 2(6) 3(7)		9.09		18.18	9.09	18.18	18.18	27.27
630	1(3) 2(4) 3(5) 3(7)				11.11	22.22	33.33		33.33
640	2(5) 2(7)						50		50
Total	62								

Table 31. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 10 during 2006. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age							
		0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240	1(0)	100							
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 31. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									
610									
620									
630									
640									
Total	1								

Table 32. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 13 during 2006. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age							
		0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210	1(0)	100							
220									
230									
240									
250									
260									
270									
280									
290									
300									
310									
320									
330									
340									
350									
360									
370									

Table 32. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550									
560									
570	1(4)					100			
580	1(5)						100		
590	1(3)				100				
600	1(4)					100			
610	1(5)						100		
620									
630									
640									
Total	6								

Table 33. Age length key for blue suckers ages 0-7 and < 650 mm caught in segment 14 during 2006. Numbers in the boxes represent the probability (%) that a known length individual is a certain age data. Age determinations were made using fin rays.

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250	2(0)	100							
260									
270									
280	1(0)	100							
290									
300									
310									
320									
330									
340									
350	1(1)		100						
360									
370									

Table 33. Continued

Length Category	N(Age)	Age 0	1	2	3	4	5	6	7
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550	2(1) 1(5)		66.67				33.33		
560	2(1)		100						
570	1(5)						100		
580									
590									
600	1(5)						100		
610	1(5)						100		
620	1(4) 1(6)					50		50	
630									
640									
Total	14								

Discussion

Factors limiting interpretations

Factors potentially limiting the interpretation of spatial and temporal comparisons for this report may include: lack of statistical independence among segments due to fish migration, and variation due to low sample sizes at some ages. Blue suckers are known to make substantial upstream movements in the Fall starting in mid-October, sometimes traveling as far as 320 km upstream (Been Neely, personal communication). Therefore, in treating each segment as an individual replicate, there is a possibility of migrating fish skewing the results of the spatial analysis towards the spawning population, when resident populations of blue suckers could possibly show more pronounced differences in growth among segments. Evidence of migration influence was shown in 2006 because spatial differences were found in segments 7 and 8 and 100 % of the ray collections were obtained before 15 October, compared to 67 % in 2005, and 61 % in 2004 where no spatial differences in length at capture were detected. Variation due to lower sample sizes probably had the most influence in the interpretation of this analysis. Segments 10, 13 and 14 had sample sizes lower than 25 all three years, therefore data was missing for many of the age specific analysis except for segments- those segments were not well represented in the length-at-capture and first full increment spatial analysis

Interesting observations

Of particular interest in this study was the finding of 28 age-0 blue suckers captured in 2006. 18 of these were captured in segment 8, just below the Big Sioux River (Kirk Steffensen, personal communication). Additionally, the mean daily discharge graph (Figure

8), showed values increasing steadily to a peak near 1050 m^3/s with a steadily decreasing end throughout the month of April. The 2006 April peak was much higher than other years in which it did not exceed 800 m^3/s. This suggests that a spawning event may have occurred in 2006. Since spawning blue suckers have been found in the Big Sioux River in early May (Dieterman and Berry 1995), it is likely that this pulse may have triggered fish to spawn in April.

Another interesting note was that relatively few age-1 and age-2 blue suckers were found in this study. For example, in 2005, only 4 age-1 blue suckers and 5 age-2 blue suckers were captured, compared to 34 age-4 fish and 33 age-5 fish captured that same year. Ages 3-7 all had sample sizes greater than 23 in 2005 and 2006. There has long been discussion in blue sucker literature as to whether or not missing age classes of younger aged fish are due to gear ineffectiveness of capturing younger fish that may be behaviorally using habitats too difficult to sample at early ages, or if the lack of fish caught at younger ages means that the fishery failed to recruit to younger ages (Beal 1967; Eitzmann et al. 2007; Morey and Berry 2003). This study supports the position of gear inefficiencies to capture fish at younger age classes rather than the fishery failing to recruit. Ages 3-7 were well represented in the spatial and temporal analysis in all three years . Additionally, no missing age classes were reported from ages 1-9 in 2004, ages 0-15 in 2005, and ages 0-11 in 2006, when the fish greater than 7 years old are included into the analysis (Appendix 1). This suggests that consistent recruitment has been occurring in the Missouri River, however, this statement is highly dependent on the accuracy of the aging method and the skill level of the age readers. Also, catch-per-unit-effort of fish by size, or age by gear type, was not taken into account in this study.

Spatial analysis

The spatial analysis was successful in demonstrating a clear longitudinal trend of spatial differences in length-at-capture, back-calculated lengths, and *Wr* among segments with values of those parameters all increasing downstream by segment. Median lengths at capture was lower for segments 7 and 8 at most ages than all other segments in 2006, with a significant difference found at age 7. Mean back-calculated lengths were lowest in segment 7 in 2005, and also in 2006, at ages 1-5 both years. Segment 8 had the second lowest mean-back calculated lengths at ages 1 and 2 in 2006 as well. The *Wr* spatial analysis was most effective in demonstrating longitudinal trends. In 2004 and 2006, *Wr* increased downstream at each segment sampled, at all ages that had an $n > 3$, and in the pooled ages analysis for both years. Significant differences with this trend were found in 2006 in the spatial analysis, where segments 7 and 8 were significantly different from all other segments at ages 4, 5, 7 and in the pooled ages analysis. These findings suggest that the 2 uppermost segments tested in this analysis (Segments 7 and 8) are distinctly different in regards to blue sucker length and condition growth parameters. Braaten and Guy (2002) found mean K to increase longitudinally from north to south in river carpsucker *Carpoides carpio*, and sauger, and additionally found mean back-calculated lengths to increase longitudinally from the north to the south for freshwater drums $\geq$ age 4 and saugers (ages 1-5). Similarly, Pierce et al. (2003) found sauger *Wr* to have an increasing trend from upstream to downstream throughout the Missouri river. These findings agree with the results that were seen in this study with blue sucker mean back-calculated lengths, and *Wr* increasing downstream in

2006. Braaten and Guy (2002) attributed their longitudinal differences due to thermal regime changes with latitudinal influences. This is the most plausible mechanism to explain the spatial differences in growth rates observed in this study as well. Also, maximum mean daily water temperatures were similar for segments 7 and 8 in 2006 near 27.5 ºC, whereas segments 9-14 were more similar with maximum mean daily water temperatures near 32.5 (Figures 7-12).

Another possible explanation of the reduced growth rates and condition in segments 7 and 8 could be due the influences from Gavin's Point Dam. Decreased turbidities and nutrient retention caused by the dam could have caused the decrease in *Wr* as far down as segment 8. The first 30 km downstream from the dam are free of any major tributary major that may provide inputs into the main stem of the Missouri river that are more characteristic of a natural free flowing river, such as higher turbidities. Pierce et al. (2003) also showed condition of shovelnose sturgeon to be affected by the presence of dams as lower *Wr* values were recorded from fish below Ft. Peck Lake, Lake Sakakawea, and Lewis and Clark Lake compared to *Wr* values of shovelnose sturgeon collected in each of the lake headwaters. This would explain the lower *Wr* values for Segments 7 and 8 found in this study as well. The effects of Gavin's Point Dam on *Wr* appear to lessen downstream of segment 8, where segments 9-14 were more similar.

The differences in *Wr*, mean back-calculated lengths, mean lengths-at-capture could also be due to increased intraspecific competition for food resources or habitat in segments and 7 and 8. Segments 7 and 8 comprised 65% of the age structure collections in the 2006 growth year. A review of small trammel net catch-per-unit-effort of blue suckers caught during the 2006 FC season showed segment 8 had higher catch rates (1.1 fish/100 m) than all

other segments. Segment 9 was second highest (.75 fish/100 m), followed by segment 13 (.13 fish/100 m), 14 (.10 fish/100m) and 10 (.022 fish/100 m) (Caton et al. 2007; Hamel and Steffensen 2007; Plauck et al. 2007; Steffensen and Hamel 2007; Utrup et al. 2007). This implies that although conditions may not be optimal for growth in the upstream segments, they may contain more preferable habitat for blue suckers. Since catch rates were found to be generally higher in the segments further upstream in 2006, blue suckers could be selecting for more preferable habitat in segments 7 and 8 and thus the potential exists for increased intraspecific competition for food resources. Moss et al. (1983) found that juvenile blue suckers significantly preferred large cobble and bedrock in controlled settings. Field studies have also observed that blue suckers are selective towards swift moving water over hard substrates (Eitzmann et al. 2005). Laustrup et al. (2007) identified a high frequency of occurrence of large natural particulate deposits within the first 16 mi of segment 7. Additionally, they identified high densities of bedrock exposures in the upstream portions of segment 8. These areas may be important for blue sucker habitat use and areas for competition to occur if they are limiting habitats.

The age specific analysis of the first full increment did not detect any spatial or temporal differences or trends in any of the growth years. This could be due to difficulties in detecting annuli consistently. However, methods will be implemented in future plans to improve annuli clarity using the pectoral fin ray method such as sanding and polishing or using a reference set of structures that are of known age fish that can be used as a calibration tool for each of age readers. This growth parameter will continue to be assessed in the future as increment growth can better demonstrate the effects of management actions on a yearly basis than mean length at capture (Porath and Hurley 2005).

Temporal analysis

Median length at capture was higher in 2006 at most ages. However, mean annual discharge was lower in 2006 than they were in 2005. This was the opposite of what was expected of higher median length at capture in years when discharge was higher. This suggests that fish growth in the Missouri River below Gavin's Point Dam is probably more closely related to temperature parameters. Also, in the *Wr* temporal analysis, higher *Wr* values were obtained in segments 13 in 2006, when flow were lower in 2006 than they were in 2005 (Table 18). Again, this was opposite of what we expected. Because we were not able to correlate the growth parameters tested in this report with increases in discharge, does not mean that discharge is not having effects on blue sucker populations. Discharge may be very crucial to trigger native river fish to migrate and then spawn, as was seen with the capture of 18 age-0 blue sucker captured in segment 18 in 2006 in this study being traced to high discharge in April. We recommend continuing to correlate all 3 growth parameters tested in this report with flow as well as use other temperature variables such as degree days or the number of days over the lower limit temperature range of growth for the species.

Other future recommendations

We recommend investigating the use of new methods to improve the clarity of annual rings using the ring using fin ray such as sanding and polishing for future reports. Additionally, we would like to use a reference set of pectoral fin rays from known age blue

suckers to train new readers and to keep the current readers between each other. Also, back-calculations of fish lengths at previous ages were preformed without using a y-intercept, which does not account for asymptotic growth. No fish less than 140 mm were collected in this study. Smaller fish collections are needed to develop a proper y-intercept value. We will continue to research an accurate y-intercept to use for future reports.

Acknowledgments

We would like to thank the United States Army Corps of Engineers for funding this growth evaluation. Also, we would like to thank Kevin Buhl and the Columbia Environmental Research Center for providing laboratory space for processing all 1,045 aging structures. We would also like to thank those who extended a hand out to help process aging structures: Ron Gunderson (USGS), Ron Grandi, and Nathan Locker.

References

Beal, C. D. 1967. Life history information on the blue sucker, Cycleptus elongatus (LeSueur), in the Missouri River. University of South Dakota, Vermillion.

Braaten, P. J., and C. S. Guy. 2002. Life history attibutes of fishes along the lattiudinal gradient of the Missouri River. Transactions of the American Fisheries Society 131:931-945.

Bramblett, R. G., and R. G. White. 2001. Habitat Use and Movements of Pallid and Shovelnose Sturgeon in the Yellowstone and Missouri Rivers in Montana and North Dakota. Transactions of the American Fisheries Society 130:1006-1025.

Caton, D. J., P. T. Horner, and V. H. Travnichek. 2007. 2006 annual report. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri

River: segment 10. Report of Missouri Department of Conservation to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

DeVries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483-512 *in* B. R. Murphy, and D. W. Willis, editors. Fisheries techniques, volume 2nd. American Fisheries Society, Bethesda, Maryland

Dieterman, D., and C. R. Berry. 1995. The distribution and relative abundance of fishes in the Big Sioux River, South Dakota. Department of Game, Fish and Parks, Pierre.

Drobish, M. 2007. Pallid sturgeon Population Assessment Program. United States Army Corps of Engineers, Omaha District, Yankton, South Dakota.

Dryer, M. P., and A. J. Sandoval. 1993. Recovery plan for the pallid sturgeon (*Scaphirhynchus albus*). United States Fish and Wildlife Servcie, Bismark, North Dakota.

Eitzmann, J. L., A. S. Makinster, and C. P. Paukert. 2005. Kansas Department of Wildlife and Parks wildlife surveys and research: assessment of streams on public lands study: population dynamics of blue suckers in the Kansas river. Report of Kansas Cooperative Fish and Wildlife Research Unit to Kansas Department of Wildlife and Parks Environmental Services Section, Pratt, KS.

Eitzmann, J. L., A. S. Makinster, and C. P. Paukert. 2007. Distribution and growth of the blue sucker in a Great Plains river, USA. Fisheries Management and Ecology 14:255-262.

Elstad, S. A., and S. J. Werden. 1993. Draft status report on blue sucker (Cycleptus elongatus), a cadidate endangered or threatened species. United States Fish and Wildlife Service, Bismark, ND.

Engineers, U. S. A. C. o. 1994. Missouri River master water control manual review and update study, alternative evaluation report, volume 1. United States Army Corps of Engineers, Missouri River Division, Omaha, Nebraska.

Galat, D. L., C. R. Berry, E. J. Peters, and R. G. White. 2005. Missouri River. Pages 427-480 *in* A. C. Benke, and C. E. Cushing, editors. Rivers of North America. Elsevier, Oxford.

Gardner, W. M., and P. A. Stewart. 1987. The fishery of the Lower Missouri River Job I-b. Montana Fish, Wildlife and Parks., Helena, Montana.

Haddix, T., L. Holte, and C. Sampson. 2007a. Pallid sturgeon population assessment and associated fish monitoring for the Missouri River: segment 1. Report of Montana Fish, Wildlife, and Parks Department to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Haddix, T., L. Holte, and C. Sampson. 2007b. Pallid sturgeon population assessment and associated fish monitoring for the Missouri River: segment 2. Report of Montana Fish, Wildlife, and Parks Department to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Hamel, M., and K. Steffensen. 2007. 2006 annual report. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segment 8. Report of Nebraska Game and Parks Commission to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Laustrup, M. S., R. B. Jacobson, and D. G. Simpkins. 2007. Distribution of potential spawning habitat for sturgeon in the Lower Missouri River: . U.S. Geological Survey Open-File Report 2007-1192, 26 p.

Morey, N. M., and C. R. Berry. 2003. Biological characteristics of the blue sucker in the James River and Big Sioux River, South Dakota. Journal of Freshwater Ecology 18(1):33-41.

Moss, R. E., J. W. Scanlan, and C. S. Anderson. 1983. Observations on the natural history of the blue sucker. American Midland Naturalist 109(1):15-22.

Pierce, C. L., C. S. Guy, P. J. Braaten, and M. A. Pegg. 2003. Fish growth, mortality, recruitment, condition, and size structure. Volume 4. Population structure and habitat use of benthic fishes along the Missouri and lower Yellowstone rivers. U. S. Geological Survery, Cooperative Reaserch Units, Iowa State University, Science Hall II, Ames, Iowa 50011.

Plauck, A., N. Utrup, W. Doyle, P. Herman, and T. Hill. 2007. 2006 annual report. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segment 13. Report of United States Fish and Willife Service to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Porath, M. T., and K. L. Hurley. 2005. Effects of waterbody type and management actions on bluegill growth rates. North American Journal of Fisheries Management 25:1041-1050.

Rupprecht, R. J., and L. A. Jahn. 1980. Biological notes on blue suckers in the Mississippi River. Transactions of the American Fisheries Society 109:323-326.

Shuman, D. A., G. A. Wanner, R. A. Klumb, and W. J. Stancill. 2007. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segments 5 and 6. Report of United States Fish and Wildlife Service to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Steffensen, K., and M. Hamel. 2007. 2006 annual report. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segment 9. Report of Nebraska Game and Parks Commission to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Stukel, S. M., J. G. Kral, and S. R. LaBay. 2007. 2006 annual report. Pallid sturgeon population assessment project and associated fish community monitoring for the Missouri River: segment 07. Report of South Dakota Department of Game, Fish and Parks to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Utrup, N., A. Plauck, W. Doyle, P. Herman, and T. Hill. 2007. 2006 annual report. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segment 14. Report of United States Fish and Wildlife Service to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Van Den Avyle, M. J., and R. S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127-166 *in* C. C. Kohler, and W. A. Hubert, editors. Inland Fisheries Management in North America, Second edition. American Fisheries Society, Bethesda, MD.

Wilson, R., Z. Sadness, E. Nelson, and S. Krentz. 2007. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segment 4. Report of United States Fish and Wildlife Service to United States Army Corps of Engineers, Northwest Division, Omaha, NE.

Appendix 1. Mean length at capture summary statistics for blue sucker > 650 mm collected in 2004 and 2005.

2005			
Age	*n*	Mean Length	SE
1	1	664	*
3	2	716	41.5
4	5	739	12.9
5	11	686	6.5
6	11	705	9.6
7	10	710	14.3
8	11	696	10.5
9	11	721	12.9
10	15	727	8.5
11	5	755	25.3
12	3	717	31.5
13	5	738	22.7
14	3	752	38.5
15	1	812	*
17	2	769	11.5

2006			
Age	*n*	Mean Length	SE
2	1	692	*
5	1	748	*
6	1	655	*
7	2	692.5	29.5
8	1	655	*
9	1	675	*