Three Year Summary Age and Growth Report

For

Sauger
(*Sander canadensis*)

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
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February 2008

Executive Summary

Pallid sturgeon *Scaphirhynchus albus* are native throughout the Missouri River and the middle and lower Mississippi River. Due to human influences, population levels of this species have greatly declined over the last century. To study this species in-depth, the U.S. Army Corps of Engineers (COE) developed the Pallid Sturgeon Population Assessment Program (PSPAP).

To meet the objectives of the PSPAP, eight species of fish were collected for age and growth analysis as a representative group of native Missouri River fishes. Age-growth information is important to fisheries management because this data can be used to answer many questions and problems that exist within a fishery. Length–at-age information can be used to show trends, either positive or negative, of the condition of a species. When a management strategy is implemented, this information can be used to determine the effectiveness of the plan.

These selected Missouri River fishes were processed by the following PSPAP agencies: Sand Shiner-*Notropis stramineus,* Sauger-*Sander canadensis*, Plains Minnow, Brassy Minnow and Western Silvery Minnow-*Hybognathus spp.* (Missouri Department of Conservation), Sicklefin Chub-*Macrhybopsis meeki,* Speckled Chub-*Macrhybopsis aestivalis, and* Sturgeon Chub-*Macrhybopsis gelida*, (U.S.Fish and Wildilfe Service-Columbia Fisheries Resource Office), Shovelnose Sturgeon-*Scaphirhynchus platorynchus*, (Nebraska Game and Parks Commission) and Blue Sucker-*Cycleptus elongatus* (South Dakota Game, Fish and Parks).

Age structures were collected from sauger March-July in 2004, October 2004-October 2005, and November 2005-October 2006. Sauger were captured using gill nets, trammel nets, otter trawls, beam trawls, bag seines, hoop nets, mini-fyke nets, and fishing poles. During 2004, 2005 and 2006, 1,650 sauger were collected from all river segments with age structures collected from 569 of these fish. Mean back calculated length at last annulus for the upper sampling universe was 171 mm at age 1, 261 mm at age 2, 311 mm at age 3, 347 mm at age 4, and 417 at age 5. Mean back-calculated length at last annulus for the lower sampling universe was 202 mm at age 1, 297 mm at age 2, 347 mm at age 3, 381 mm at age 4, 404 at age 5, 403 mm at age 6, and 459 mm at age 7. When comparing exact reader agreement among structures, otoliths (85.0%) had higher agreement than either scales (65.5%) or spines (62.8%).

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Introduction

Pallid sturgeon *Scaphirhynchus albus* are native throughout the Missouri River and the middle and lower Mississippi River. Due to human influences, population levels of this species have greatly declined over the last century. Contributions to losses include reduced water quality, habitat loss, barriers to migration and over-fishing. As a result Pallid Sturgeon were listed as endangered by the U.S. Fish & Wildlife Service in 1990 (Drobish 2007b).

The Pallid Sturgeon Recovery Plan (USFWS 1993) identified six priority pallid sturgeon recovery management areas (RPMAs), four of which lie within the Missouri River. Further, this document provided an outline that proposed to: 1) protect and restore pallid sturgeon populations, individuals, and their habitats; 2) conduct research necessary for survival and recovery of pallid sturgeon; 3) develop and implement a pallid sturgeon captive propagation program, and; 4) coordinate and implement conservation and recovery of sturgeon species (Drobish 2007b).

In 2000, the U. S. Fish and Wildlife Service (USFWS) issued the U. S. Army Corps of Engineers (COE) the <u>Biological Opinion on the Operation of the Missouri River Main System Reservoir system Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project and Operation of the Kansas River Reservoir System</u> (Bi-Op). This document recommended that the flow regime of the Missouri River mimic a more natural hydrograph, an increase in propagation and population augmentation efforts, and the development of a pallid sturgeon population assessment program (PSPAP). As the federal entity responsible for water management within the Missouri and Kansas River systems, the COE has an obligation under the Endangered Species Act to conserve the pallid sturgeon. To comply with the Bi-Op, the COE has proposed to operate Gavins Point Dam in a manner to create a more natural hydrograph, has funded hatchery improvements and expansions, has funded the PSPAP, and facilitated the development of the Pallid Sturgeon Population Assessment Team (Drobish 2007b).

The initial stocking of pallid sturgeon in 1994 consisted of approximately 7,000 fish from the 1992 year class that were stocked into RPMAs 4 (Missouri River below Gavins Point Dam) and 5 (middle Mississippi River). Subsequent stockings in 1997, 1998, 2000, and 2002 through 2005 in all six RPMAs have resulted in nearly 172,000 pallid sturgeon being stocked into the Missouri and Mississippi river systems (Drobish 2007b).

Implementation of the PSPAP began in 2001 when the USFWS-Columbia Fishery Resource Office (USFWS-CFRO) began monitoring under PSPAP guidelines and Nebraska Game and Parks Commission (NGPC) conducted an evaluation of benthic trawls. The COE hired a fishery biologist to coordinate the PSPAP in 2002 and the USFWS-CFRO and NGPC continued monitoring in segments 9, 13, and 14 in the lower Missouri River. Standardized sampling above Gavins Point Dam (segments 5 and 6) occurred for the first time in 2003 by the USFWS-Great Plains Fish and Wildlife Management Assistance Office. During 2004, monitoring continued in segments 5, 6, 8, 9, 13, and 14, and an independent science review was conducted to determine the ability of the PSPAP to address its objectives. Beginning with the 2005 fish community season, the Team added the USFWS-Missouri River Fish and Wildlife Management Assistance Office (segment 4), the South Dakota Department of Game Fish and Parks (segment 7), and the Missouri Department of Conservation (segments 10 and 11). In 2006, the team added the Montana Department of Fish, Wildlife, and Parks field crew to complete implementation of the PSPAP from segment 1 through 14 (Drobish 2007b).

The objectives of the PSPAP are as follows: 1) document annual results and long-term trends in pallid sturgeon population abundance and geographic distribution throughout the Missouri River System; 2) document annual results and long-term trends of habitat use of wild pallid sturgeon and hatchery stocked pallid sturgeon by season and life stage; 3) document population structure and dynamics of pallid sturgeon in the Missouri River System; 4) evaluate annual results and long-term trends in native target species population abundance and geographic distribution throughout the Missouri River system; 5) document annual results and long-term trends of habitat usage of the native target species by season and life stage; and 6) document annual results and long-term trends of all non-target species population abundance and geographic distribution throughout the Missouri River system, where sample size is greater than fifty individuals (Drobish 2007b).

To meet objective 5 of the PSPAP, age-growth and relative weight information was collected on a representative group of native Missouri River fishes. These target species were chosen based on possible prey and habitat relationships of pallid sturgeon and those listed as Missouri River species of concern (Berry and Young 2001).

Age-growth and relative weight information is important to fisheries management. These data can be used to answer many questions and problems that exist within a fishery. Length at age information can be used to show trends, either positive or negative, of the condition of a species. When a management strategy is implemented, this information can be used to determine the effectiveness of the plan (DeVries and Frie 1996).

The selected Missouri River fishes were processed by the following PSPAP agencies: Sand Shiner-*Notropis stramineus,* Sauger-*Sander canadensis*, Plains Minnow, Brassy Minnow and Western silvery Minnow-*Hybognathus spp.* (Missouri Department of Conservation), Sicklefin Chub-*Macrhybopsis meeki,* Speckled Chub-*Macrhybopsis aestivalis, and* Sturgeon Chub-*Macrhybopsis gelida,* (USFWS-Columbia Fisheries Resource Office), Shovelnose Sturgeon-*Scaphirhynchus platorynchus,* (Nebraska Game and Parks) and Blue Sucker-*Cycleptus elongatus* (South Dakota Game, Fish and Parks).

Study Area

The Missouri River was divided into segments for the PSPAP based on changes in physical attributes of the river (e.g., tributary influence, geology, turbidity, degrading or aggrading stream bed, etc.) (Figure 1). These segments were numbered 1 through 14 in a downstream direction and included all riverine portions of the Missouri River from Fort Peck Dam to the confluence (Table 1). Segments were also divided into an upper and lower sampling universe based on longitudinal difference as well as the length of the fish's growing season. Segments 1 through 4 make up the "upper sampling universe"; it is characterized by a meandering, often braided channel that lacks navigation structures. Segments 1 through 4 lie in RPMA 2 and includes the 203.5 river miles from Fort Peck Dam downstream to the headwaters of Lake Sakakawea, North Dakota.

Segments 5 through 14 make up the "lower sampling universe"; the lower sampling universe is characterized by having been highly engineered from its original state. Segments 5 and 6, lie in RPMA 3, and consist of 55 river miles from Fort Randall Dam, South Dakota, downstream to the headwaters of Lewis and Clark Lake, Nebraska-South Dakota. Segment 7 extends from Gavins Point Dam downstream 61 miles to Lower Ponca Bend, Nebraska-South Dakota, and is the only segment below Gavins Point Dam that is not channelized.

Segments 8 through 14 of the lower universe include the entire channelized portion (750 miles) of the Missouri River that extends from Lower Ponca Bend to the confluence with the Mississippi River. The Kansas River, from the Johnson County Weir (Kansas) to the mouth (15.4 miles), was given its own segment designation (segment 11) because this tributary was addressed by the 2000 Bi-Op as a high priority management area for pallid sturgeon (Caton et al. 2007).

Methods

All sampling was conducted in accordance with the guidelines established by the Pallid Sturgeon Assessment Team as outlined in the Missouri River Standard Operating Procedures for Sampling and Data Collection (Drobish 2007a) and Pallid Sturgeon Population Assessment Program ,(Drobish 2007b). Two distinct sampling seasons were established to assess sturgeon species and associated fish community. The sturgeon sampling season begins 1 November, or when water temperature drops below 12.8ºC, and continues until 30 June. Gear types used during this season include gill nets, trammel nets, otter trawls, and hoop nets. Fish community season runs from 1 July and continues through 31 October. Gear types used during the fish community season include trammel nets, benthic otter trawls, hoop nets, mini-fyke nets, push trawls, beam trawls, and bag seines.

Sampling Gears

Gill Nets - Standard gill nets (GN) were set primarily parallel with flow downstream from structures (rock dikes) and along the channel border. Gill nets were also set perpendicular to the bank depending on flow in sampling areas. Gill nets were anchored to rock dikes at the upstream end. Nets were also anchored on the downstream end to ensure complete extension of the net. A line and buoy were attached to the downstream end to mark the net and for retrieval. The standard gill nets (GN14 and GN41) were 30.5 m (100 ft.) in length, 2.4 m (8 ft.) deep, constructed from multifilament nylon mesh and contained four panels. Each panel was 7.6 m (25 ft.) with mesh size of 38.1 mm (1.5 in.; Panel 1), 50.8mm (2 in.; Panel 2), 76.2 mm (3.0 in.; Panel 3), and 101.6 mm (4.0 in.; Panel 4). Panels repeat (5 through 8) in double length nets with 38.1 mm, 50.8 mm, 76.2 mm, and 101.6 mm mesh sizes in panel 5, 6, 7, and 8 respectively. Sets made with 61 m (200 ft.) nets (GN18 and GN81) were counted as double effort (2 net nights). Set sites were selected randomly, and nets were set overnight for a maximum of 24 hours. All nets had a 13 mm braided polyfoam-core float line and a 7.1 mm diameter, 22.7 kg lead line (Kennedy et. al 2005).

Trammel Nets – Four different trammel nets (TN) were deployed off the bow of the boat to sample a variety of river habitats in water greater than 1.2m; these included TN, TN2, TN25, and TN50. The TN2 is 61 m (200 ft.) in length and was dead-set in water overnight. The TN and TN25 were 38.1 m (125 ft.) in length while the TN50 was 15.25 m (50 ft.) in length. Descriptions of net materials, mesh sizes of inner and outer walls, twine size, and floatline and lead line specifications are described in detail in Drobish (2007a). The TN, TN25, and TN 50 were drifted by throwing a buoy attached to a 10-m line and motoring in reverse perpendicular to the flow. A second buoy and line on the other end of the net remained on board and was held without tension as the net drifted downstream. Standard drifts ranged from a minimum distance of 75 m to a maximum distance of 300 m. Additional weight was added dependent on flow conditions (Kennedy et. al 2005).

Otter Trawl - Two different benthic otter trawls (OT) were used to sample a variety of river habitats with water greater than 1.2 m in depth: OT16 and OT01. The OT16 and OT01 had a 4.9 m (16 ft.) head-rope and a 0.9 m mouth height. The OT16 was 7.6 m long with size 110 mesh around the cod end. The OT01 was 7.2 m long with 4 mm mesh around the cod end. The towing warp consisted of 13 mm low-stretch nylon line with a 13.7-m bridle. Otter trawls were deployed from the stern or the bow of a jet boat while traveling in a downstream direction. A buoy and line were attached to the cod end of the trawls for retrieval if a snag was encountered. Standard trawl hauls ranged from a minimum distance of 75 m to a maximum distance of 300 m. Standard paired wooden otter doors (762 mm [30 in.] x 381 mm [15 in.]) were used on all otter trawls.

Beam Trawl - Beam trawls (BT) were deployed from the stern or the bow of a jet boat while traveling in a downstream direction. A buoy and line was attached to the crossbar of the trawl frame for retrieval if a snag was encountered. Standard beam trawl hauls ranged from a minimum distance of 75 m (25 m in pools) to a maximum distance of 300 m. Beam trawls were 2 m in width, 0.5 m in height, and 5.5 m in length. The trawl frame consisted of two D-shaped, sled-like runners held apart by a beam to which the net was attached.

Bag Seine - Bag seines (BS) were used to sample water less than 1.2 m using three seine haul configurations: quarter arc, half arc, and rectangular. Seining with any method could be conducted in an upstream or downstream direction. Standard seine hauls covered a minimum of 50 m^2 of river bottom. Bag seines were constructed from 6.4 mm ace mesh, were 9.1 m (30 ft.) in length and 1.8 m (6 ft.) in depth. Bag dimensions were 1.8 m x 1.8 m x 1.8 m. Seines were attached at each end to 1.8 m x 51 mm brails (Kennedy et al. 2005).

Hoop Net - Hoop nets (HN) were used to sample water greater than 1.2 m and areas with strong currents. Nets were tied to an anchor or to the bank and marked with a float attached to the first hoop. Nets were generally set in the afternoon and left overnight with a maximum soak time of 24 hours. Hoop nets had a 1.3 m (4 ft.) diameter with 38 mm (1.5 in.) mesh, consisting of seven hoops that contained two throats. Float line length was double the water depth with a diameter of 6 mm (0.25 in.). The lead line was 9.23 m (30 ft.) in length and had a diameter of 10 mm (0.38 in.).

Mini-fyke Net - Mini-fyke nets (MF) were set in shallow, slack water areas with the lead extending perpendicular to the river bank or sand bar. In areas with moderate flow, nets were positioned at a slight downstream angle with weights attached to the upstream side of the cab to prevent the net from overturning. The perpendicular distance measured from the midpoint of the cab to the bank was recorded. Nets were generally set in the afternoon and left overnight with a maximum soak time of 24 hours. Mini-fyke nets were constructed from 3-mm ace or delta mesh with two rectangular frames 1.2 m wide and 0.6 m high to form the cab. The body of the net was constructed with two 0.6 m steel hoops, with a single, 51-mm throat. The lead was 4.5-m in length and 0.6 m high (Kennedy et al. 2005).

Fishing Pole - Fishing poles (FP) were used to sample a variety of habitats from both the bank and an anchored boat. Spinning rods were used to fish the bottom using a hook baited with a worm.

Data Collection and Analysis

Sauger structures were received by the MDC from each field office for age and growth analysis. Scales were prepared by pressing them into acetate slides or by placing them directly between two glass slides. Acetate slides were prepared by placing a minimum of five scales, ridge-side up, between two acetate strips and running them through a roller press. The slides were then separated, scales were removed, and the slide with the scale impression was viewed for age determination. This traditional method was initially used because it made the best image for viewing on a microfiche reader. In June 2006, MDC acquired equipment to digitally capture and analyze images. Eventually, the preparation method changed to placing a minimum of five scales face up on a glass slide and taping another glass slide on top to view the scales directly, instead of viewing a scale impression. Assessing age using the actual scale instead of an impression produced a better image for our digital equipment and was more time efficient.

Sauger dorsal spines were prepared by placing the spines in a small tubular mold and filling the mold with a clear two-part epoxy resin. The spines encased in the hardened resin were removed from the mold, and secured in the saw chuck of a Beuhler low-speed Isomet saw at a 90 degree angle to a 0.0012” wafering blade. Three cross sections were cut from the proximal end of the spines with the first cut of 0.55 mm, the second 0.60 mm, and the third 0.65 mm. These three cross sections were affixed to a glass slide using Cytoseal™ 280 mounting medium, and the slides were labeled with a unique code that included: field station code, segment number, unique id, and fish number.

Sauger otoliths were prepared by cracking them along the dorso-ventral axis through the nucleus. The cracked otolith halves were sanded across the nucleus with 600 - 1200 grit wet/dry sandpaper. These otoliths were mounted one of two ways: permanently mounted to a glass slide with thermoplastic cement, or temporarily mounted in clay or cardboard to be viewed with a fiberoptic light source.

Images from all prepared structures were digitally captured using a Paxcam 3 digital microscope camera mounted on an Olympus SZ61TR stereo microscope using Sigmascan 5 software. Structures were recorded at the highest magnification possible that allowed the entire structure to be viewed on the monitor (magnification ranged from 15.8X to 106.2X).

Captured images were named with all pertinent information in the title, including field office, river segment, unique ID, collection season year, fish identification number, and structure type. They were then saved to the appropriate computer file folder according to collection season year, species, and segment number.

Two readers independently analyzed each scale, recording annuli number and location. Ages were compared, and any difference in age was discussed, until a concert agreement was reached. Sigmascan was used to measure the cumulative distance (in pixels) first from the focus to each annuli, then from the focus to the outer edge. Annuli in scales were determined to be the outermost border of closely spaced circuli before growth resumes in the spring causing circuli to be spaced further apart and be more defined (DeVries and Frie 1996). Annuli in dorsal spines are the light colored rings on a dark background, while otolith annuli are dark bands on a light background (Kocovsky and Carline 2000). Virtual annuli were assigned to the outer edge of the structure when fish were collected after January 1 but before actual annulus formation in spring (DeVries and Frie 1996).

Annuli formation in walleye occurs between mid April to early June (Carlander 1969) depending on latitude, with northern fish forming annuli later than those located in a more southern region. We assumed this information to be applicable to sauger since they are a closely related species. Collecting sauger from July to March eliminates the concern of collecting age structures when annuli are forming.

The Fraser-Lee method was used to determine back calculated length at age for sauger (DeVries and Frie 1996). For this model a species specific y-intercept is required. A literature search yielded a y-intercept for *Sander spp*. of 55 mm (Carlander 1982). All age data were entered into a Microsoft Excel spreadsheet. Statistical analysis was preformed using SAS 9.1 and Excel. Data were tested for normality (Kurtosis) and processed using a parametric ANOVA, Tukey multiple comparison test, linear regression, and t-test. SigmaPlot 9.0 was used to construct figures.

Table 1. Description of each segment of the Missouri River with its corresponding river miles.

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
11	Lower Kansas River, Johnson County Weir to mouth	15.4	0	15.4
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

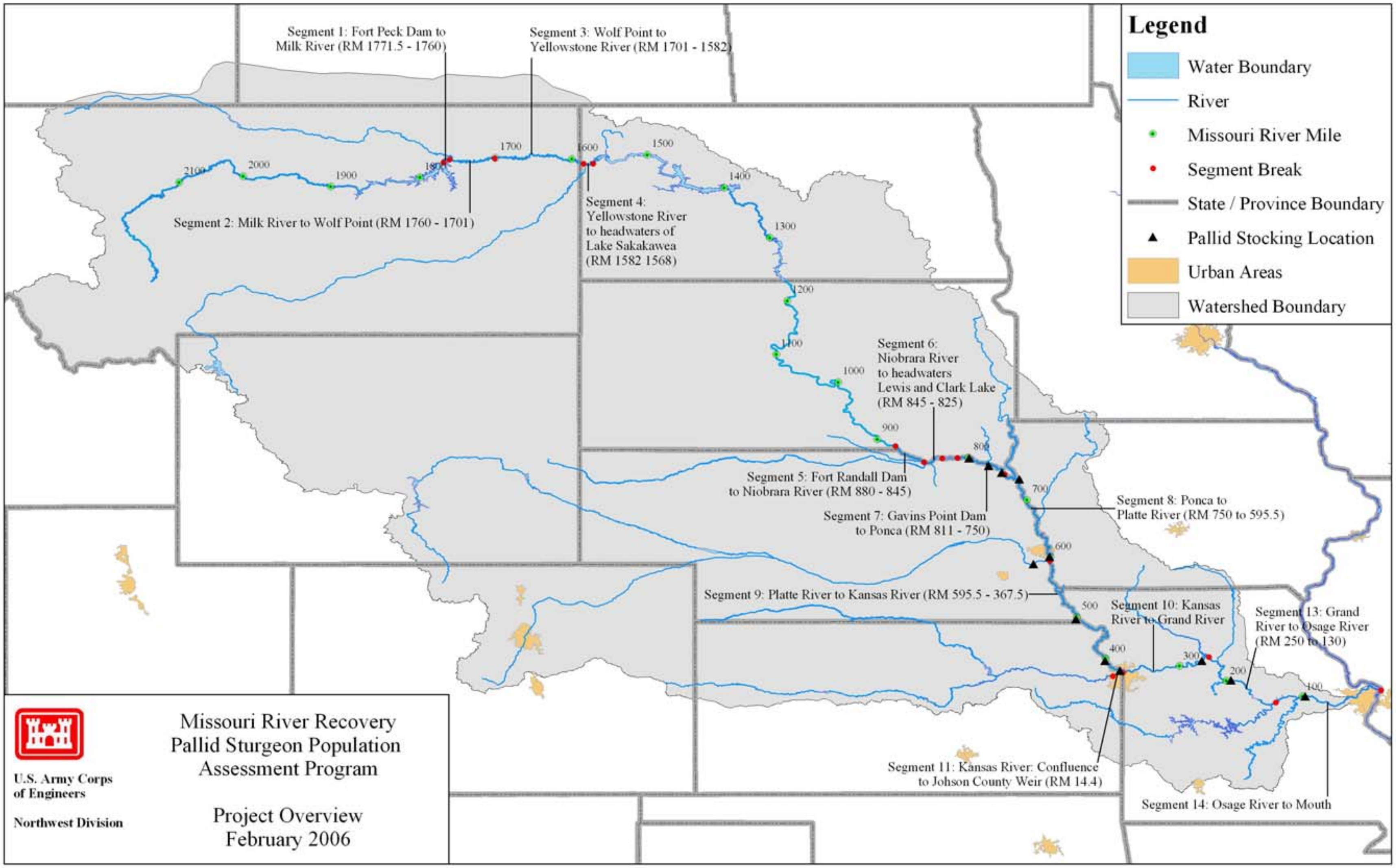

Figure 1. Map of the Missouri River basin.

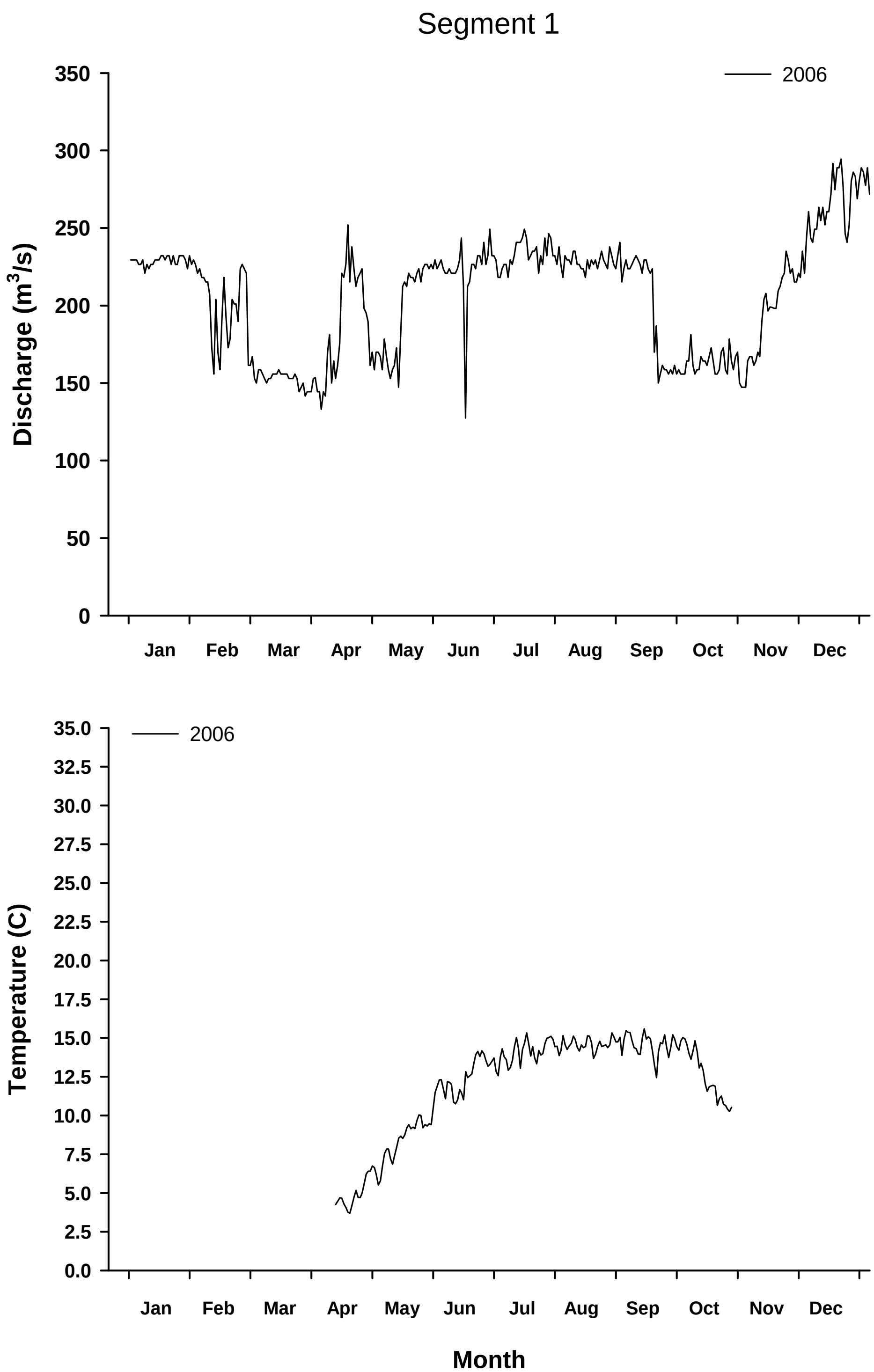

Figure 2. Mean daily discharge and mean daily water temperature for segment 1 of the Missouri River during 2006

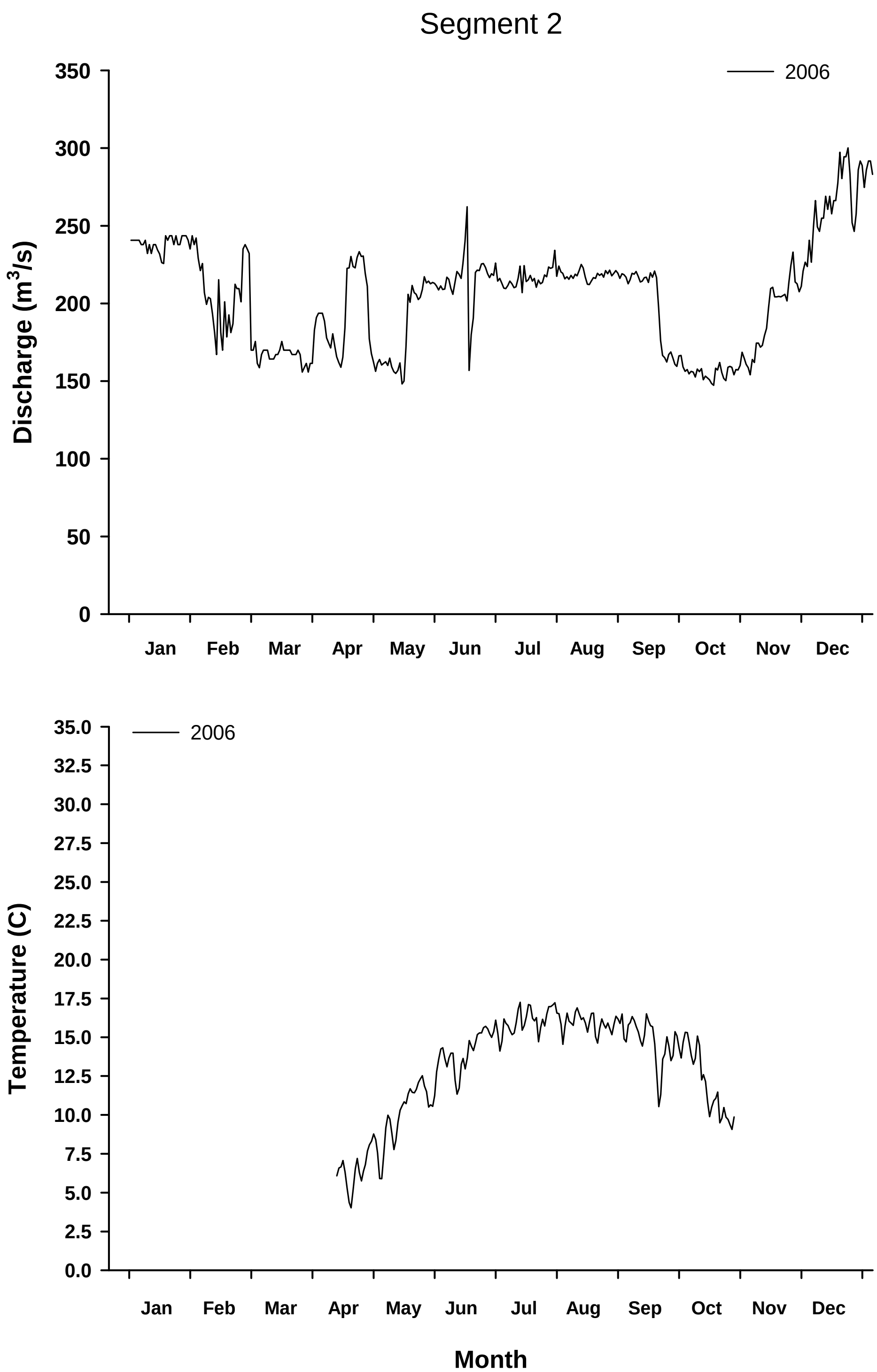

Figure 3. Mean daily discharge and mean daily water temperature for segment 2 of the Missouri River during 2006

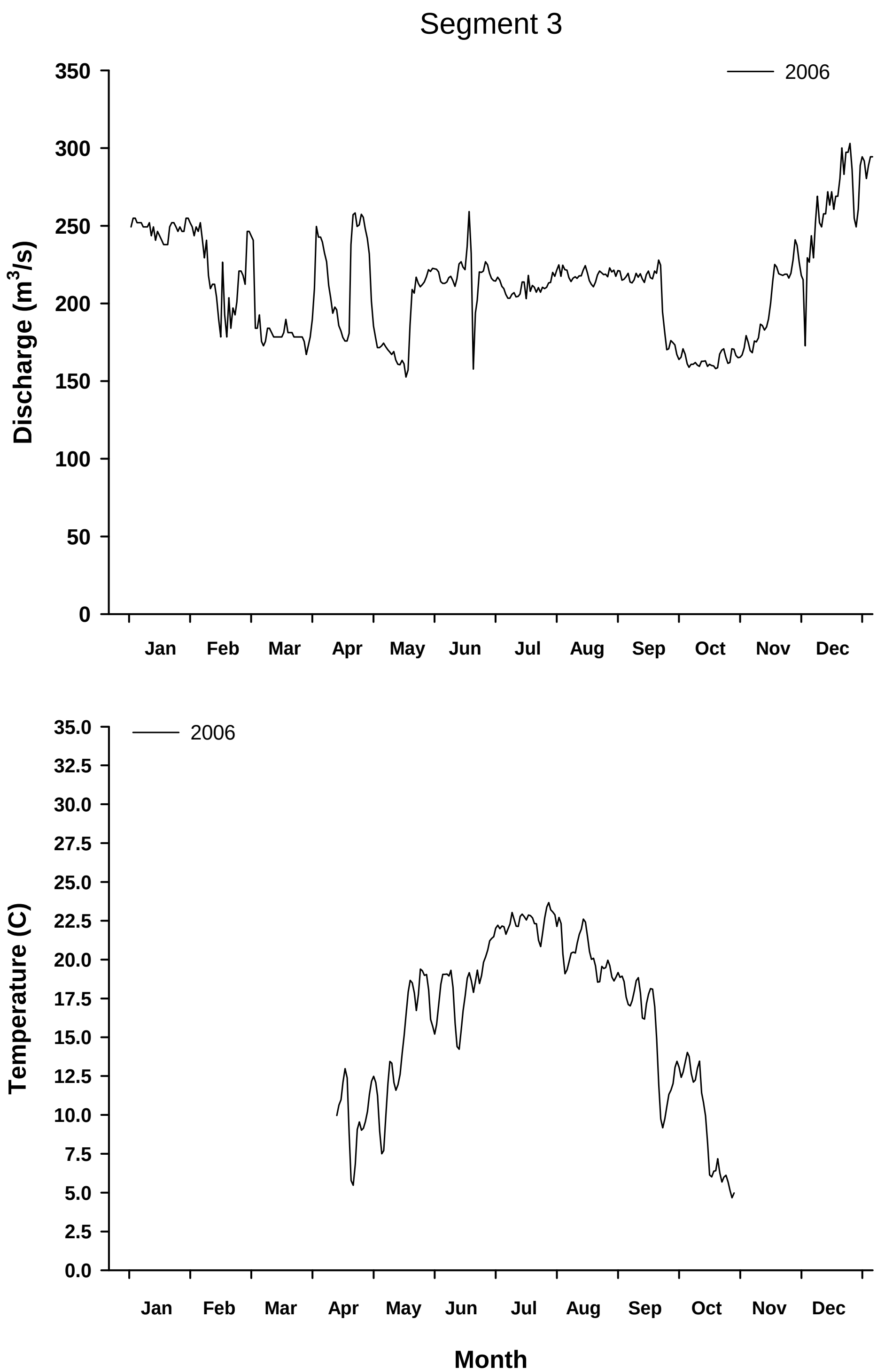

Figure 4. Mean daily discharge and mean daily water temperature for segment 3 of the Missouri River during 2006

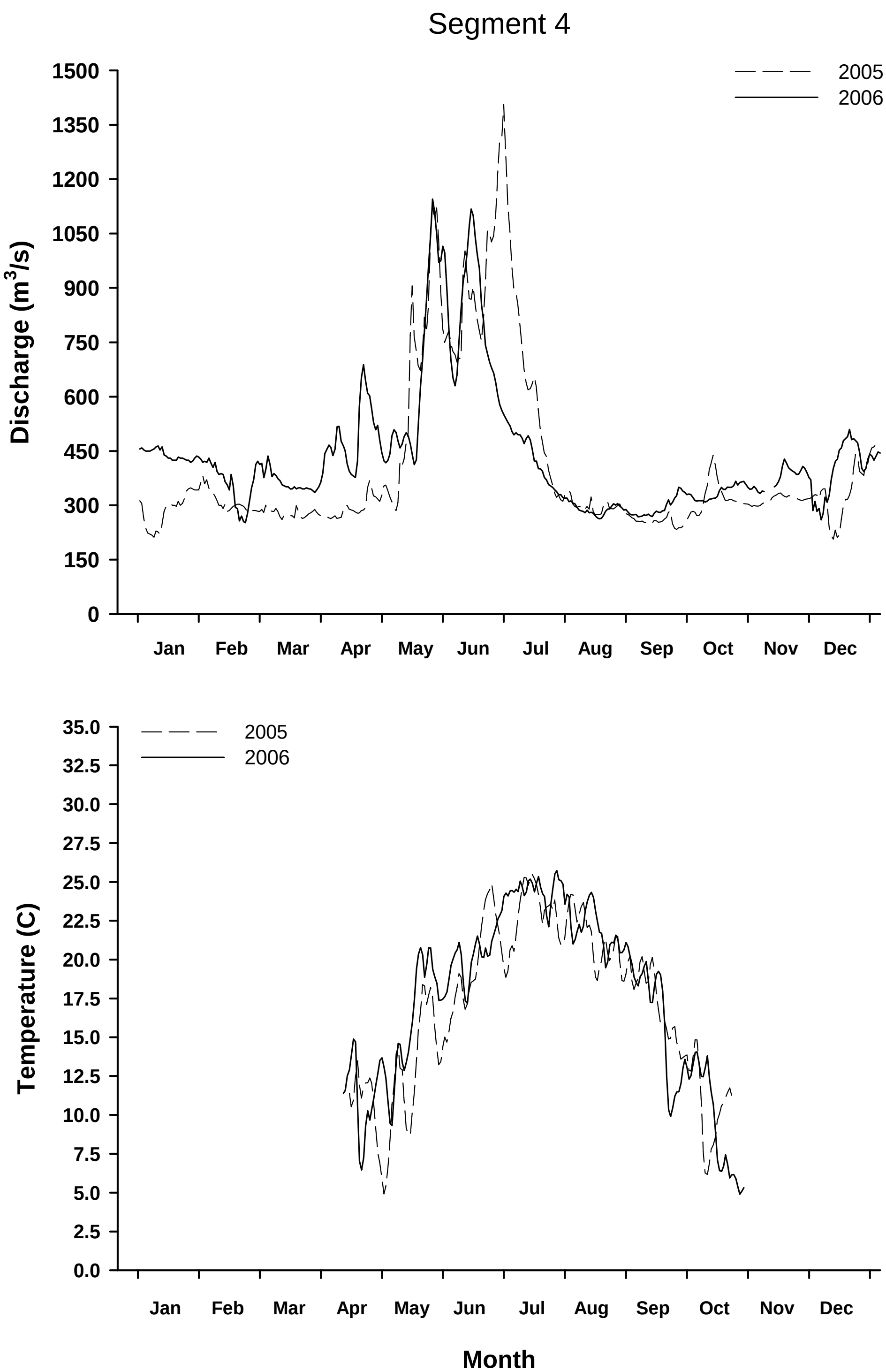

Figure 5. Mean daily discharge and mean daily water temperature for segment 4 of the Missouri River during 2005 and 2006.

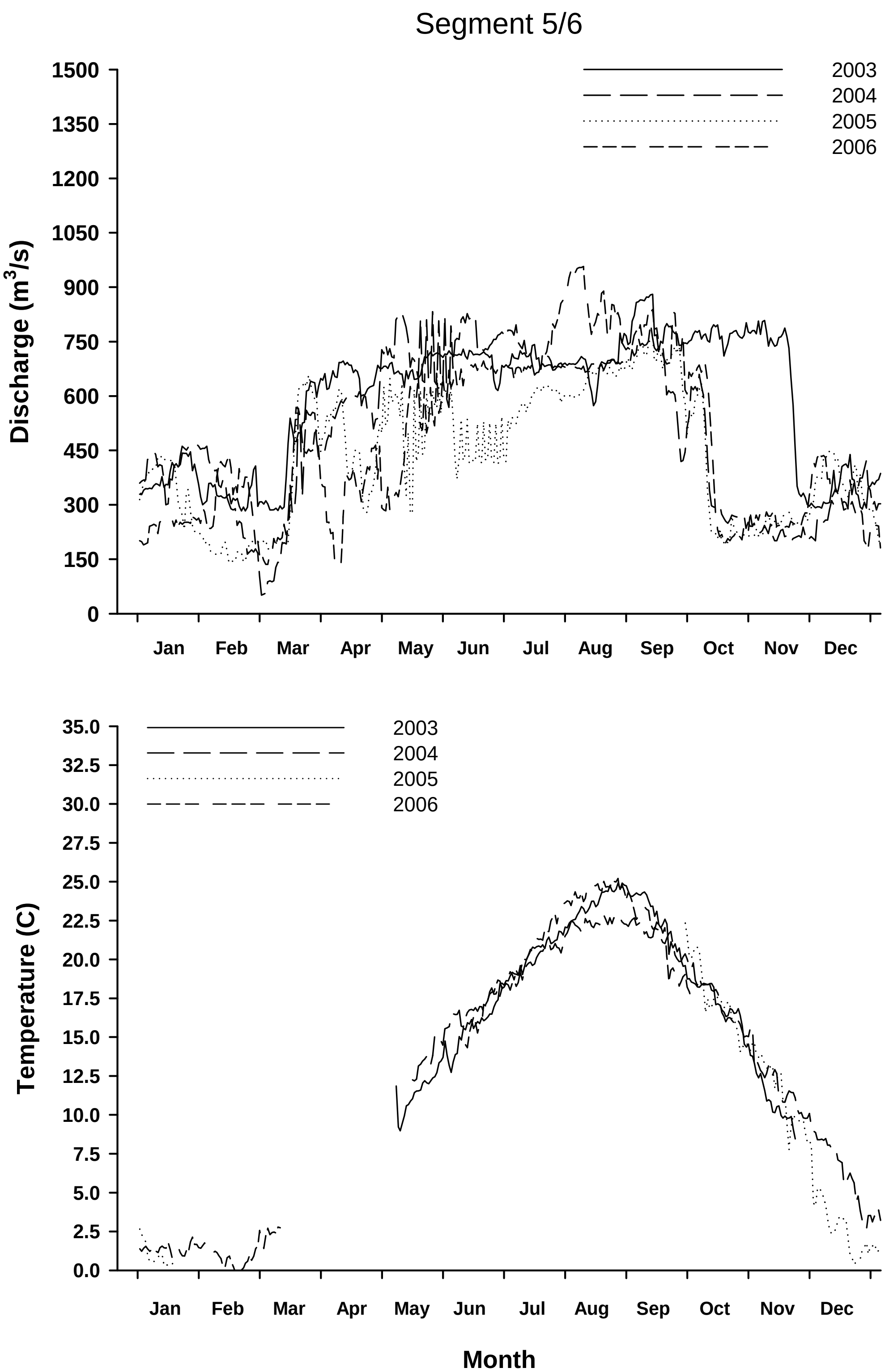

Figure 6. Mean daily discharge and mean daily water temperature for segment 5/6 of the Missouri River during 2003 through 2006.

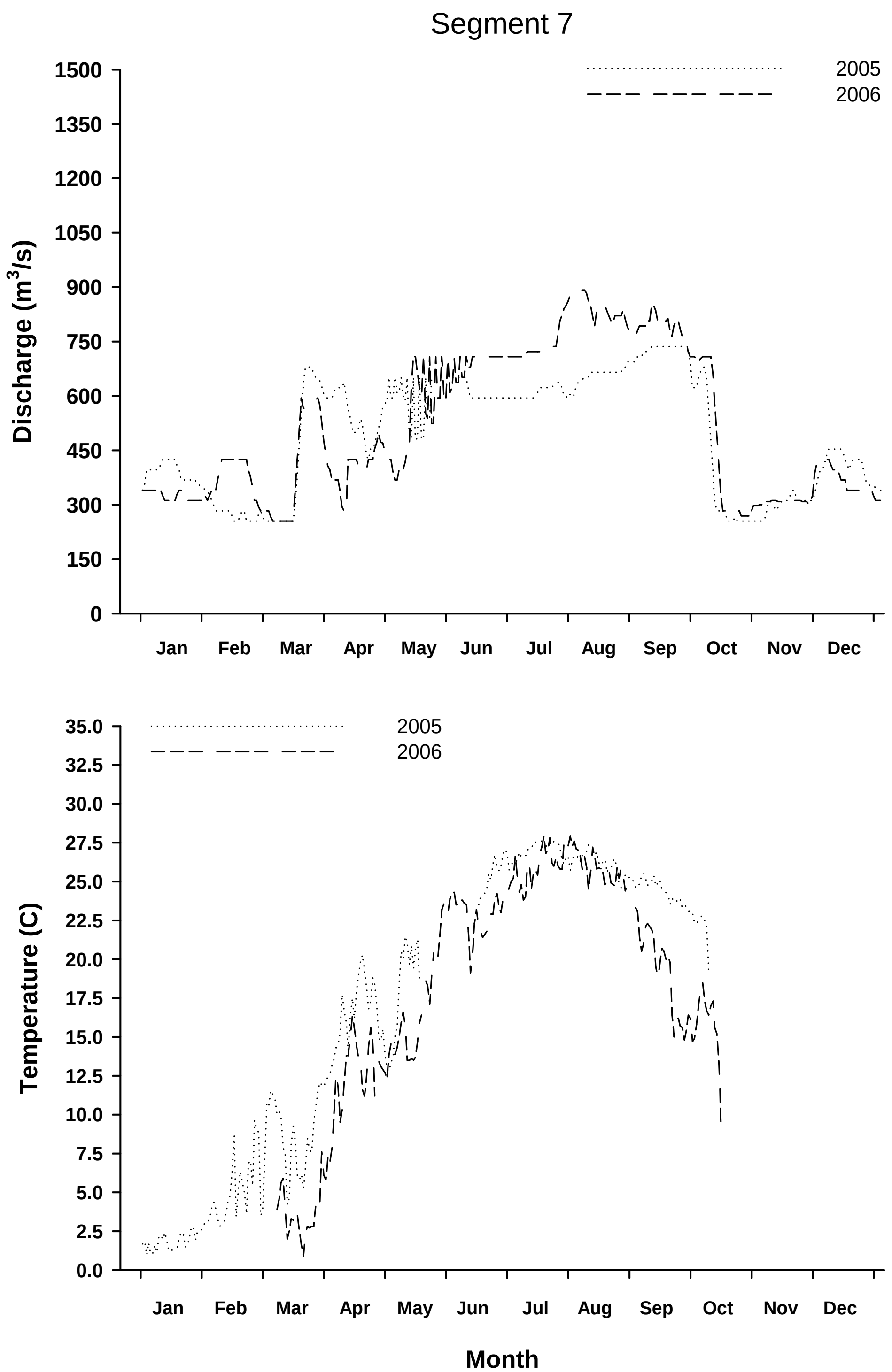

Figure 7. Mean daily discharge and mean daily water temperature for segment 7 of the Missouri River during 2005 and 2006.

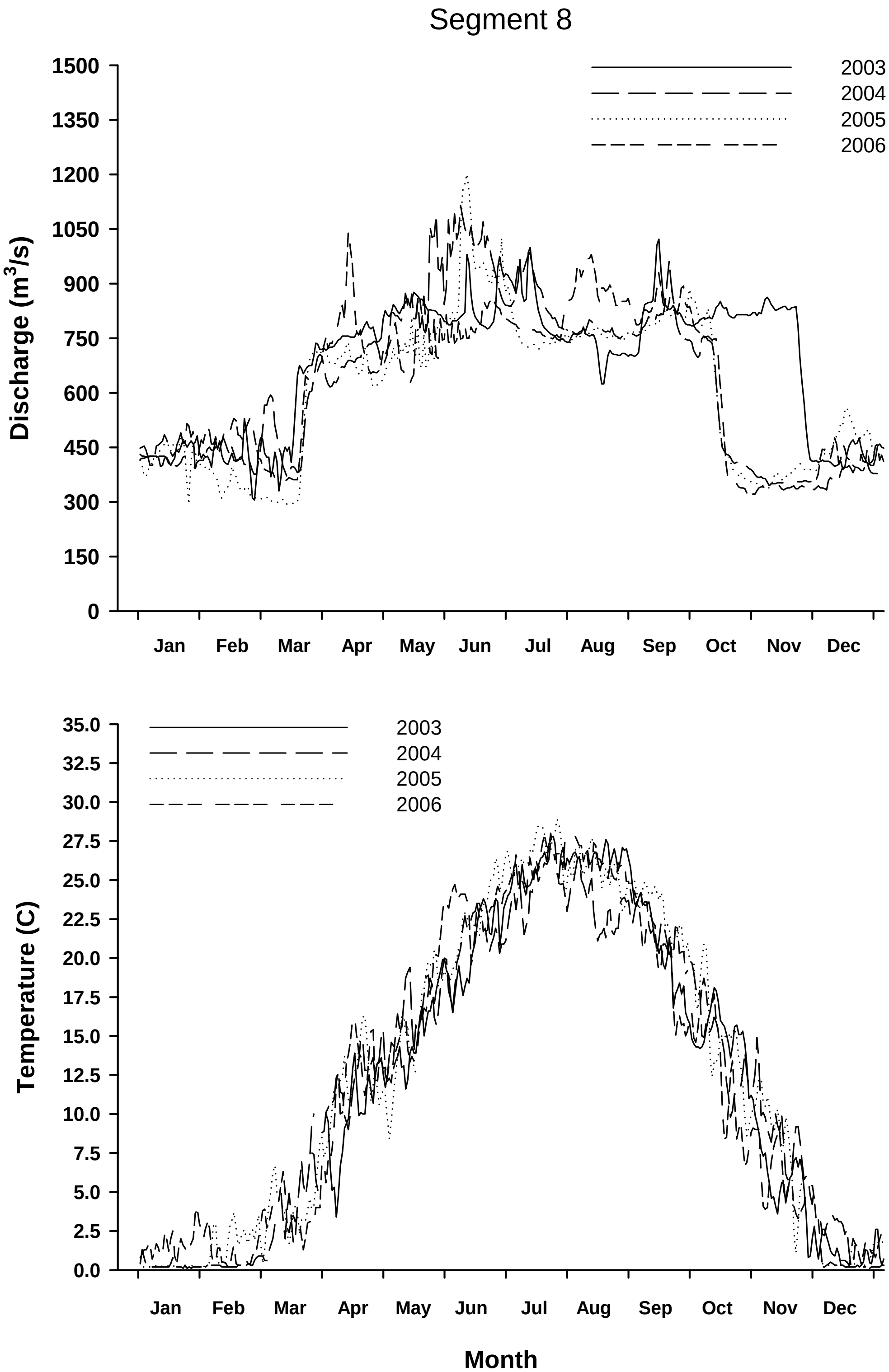

Figure 8. Mean daily discharge and mean daily water temperature for segment 8 of the Missouri River during 2003 through 2006.

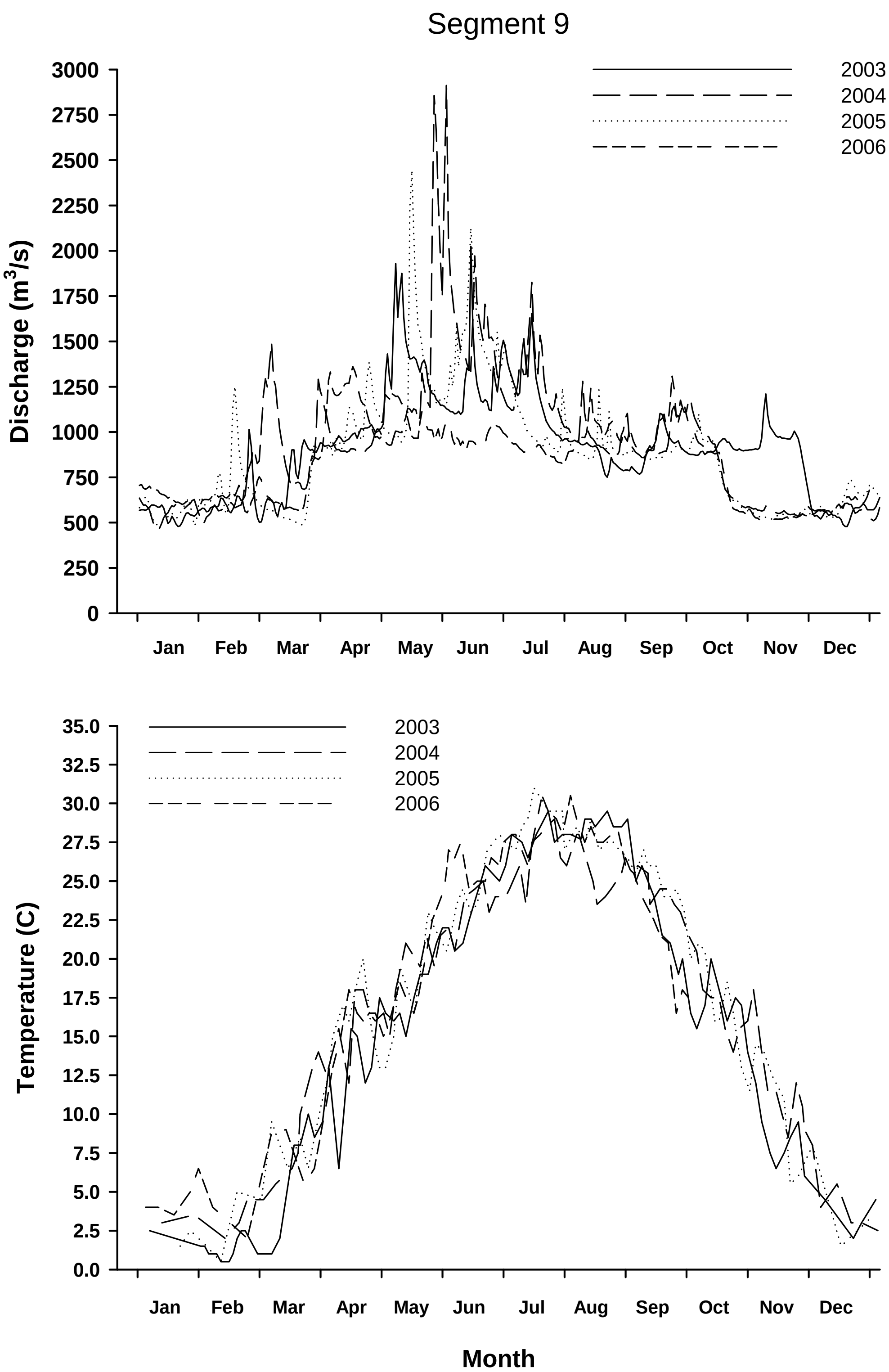

Figure 9. Mean daily discharge and mean daily water temperature for segment 9 of the Missouri River during 2003 through 2006.

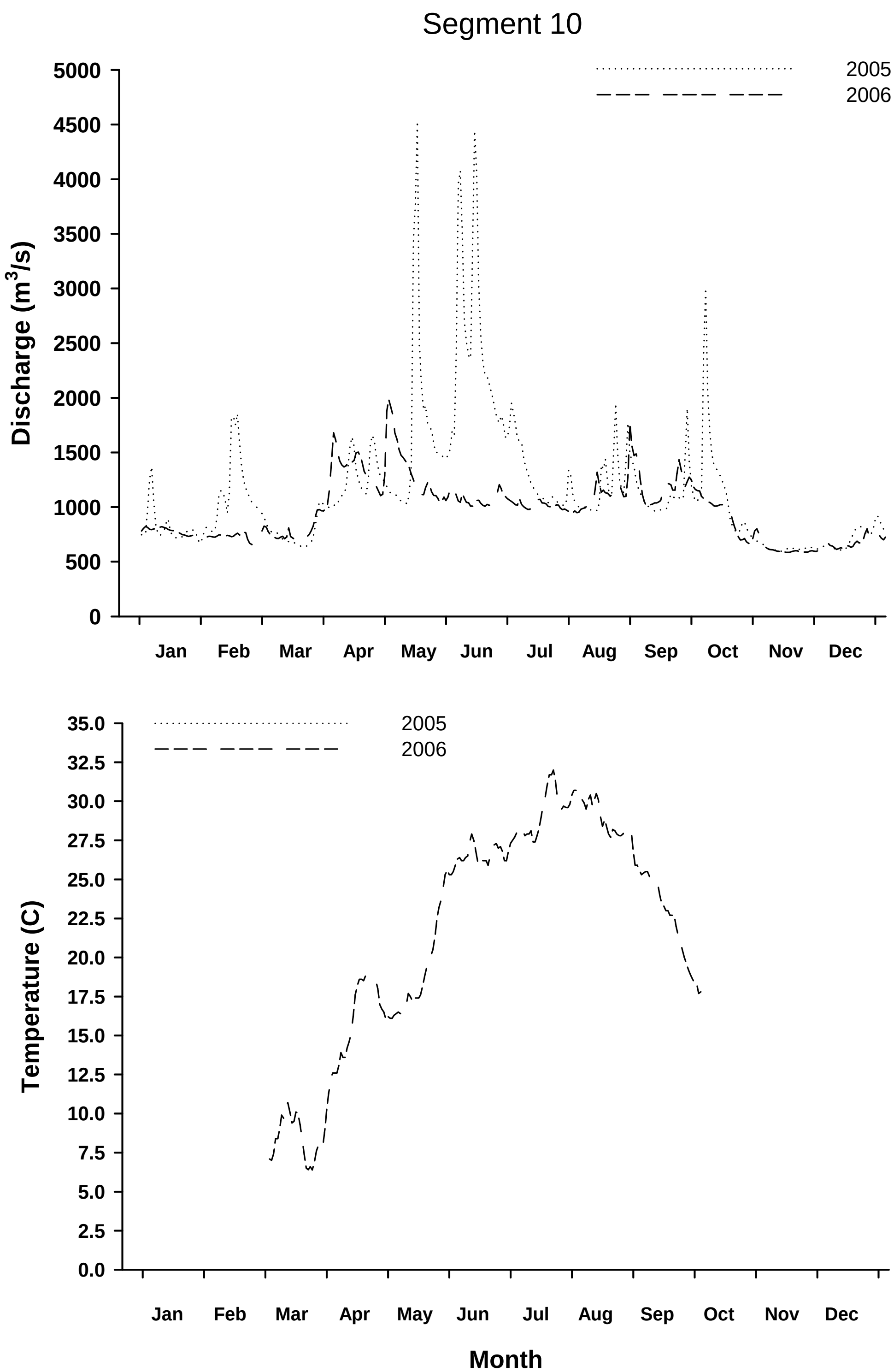

Figure 10. Mean daily discharge and mean daily water temperature for segment 10 of the Missouri River during 2005 and 2006.

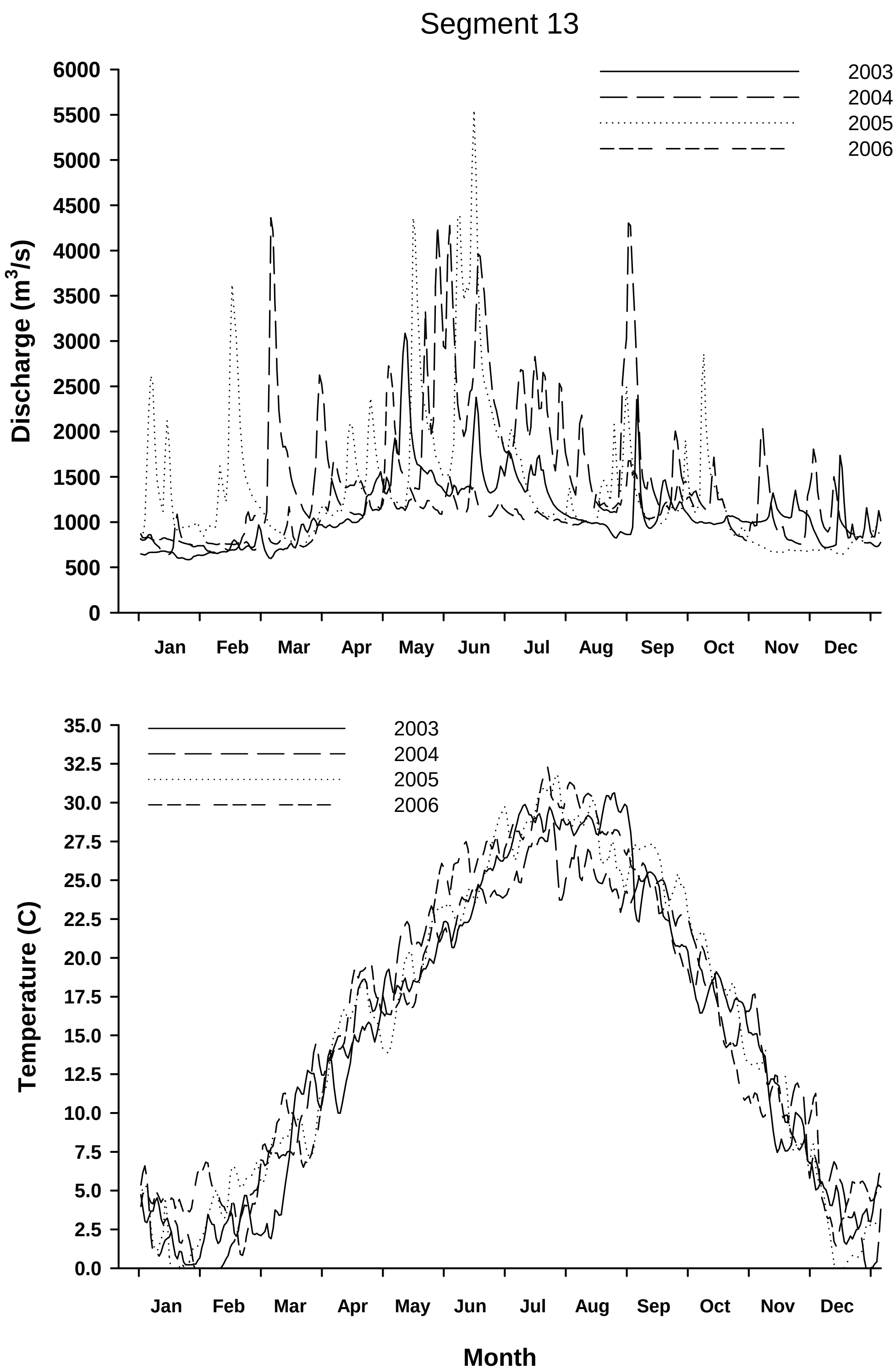

Figure 11. Mean daily discharge and mean daily water temperature for segment 13 of the Missouri River during 2003 through 2006.

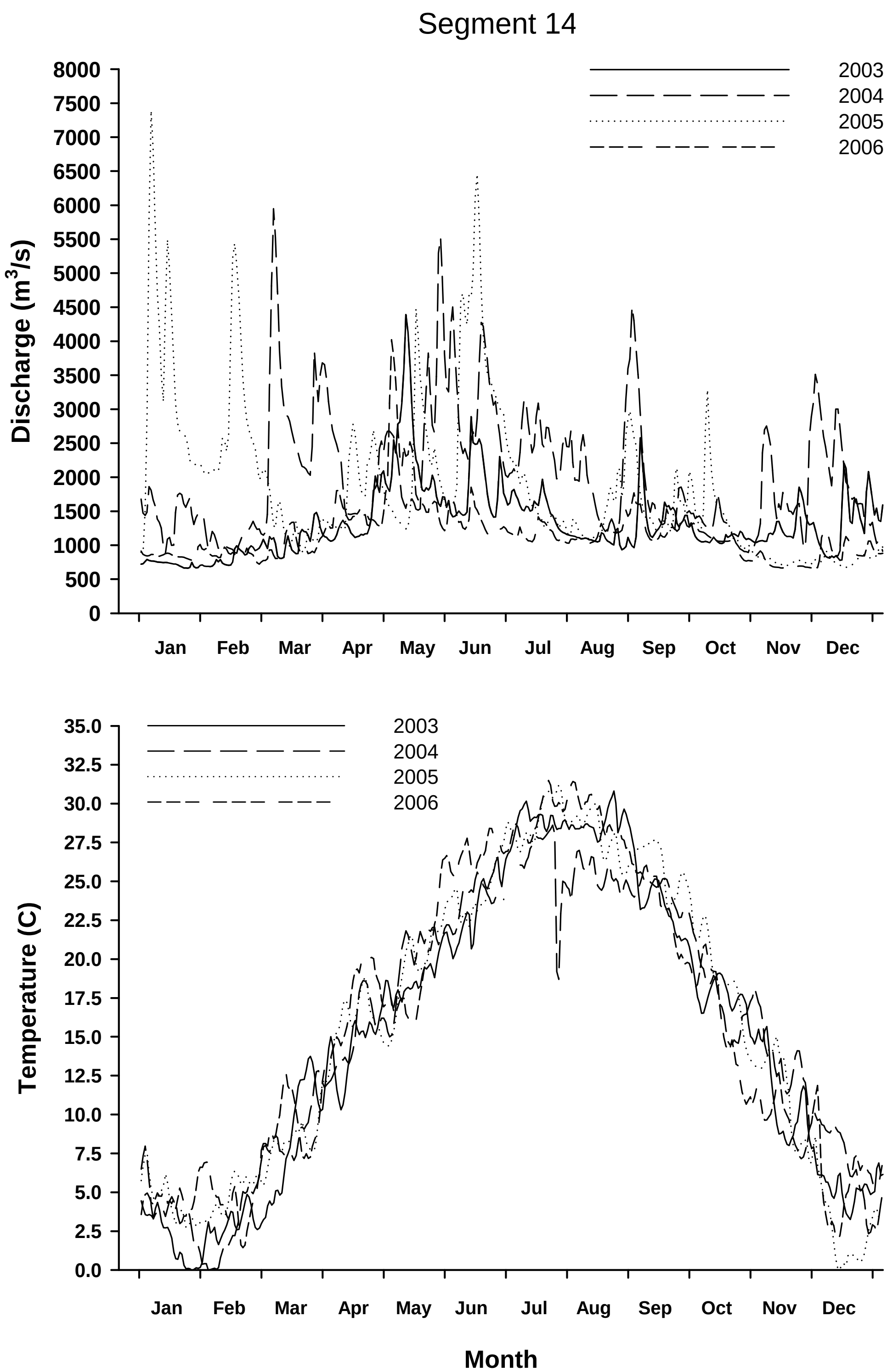

Figure 12. Mean daily discharge and mean daily water temperature for segment 14 of the Missouri River during 2003 through 2006.

Table 2. Specific dates for each year when aging structures of sauger were removed.

Year	**Starting Date**	**Ending Date**	**Segments**
2004	March 2004	July 2004	9
2005	October 2004	October 2005	4, 5, 6, 7, 8, 9, 10, 13 and 14
2006	October 2005	October 2006	2, 3, 4, 5, 6, 7, 8, 9, 10,11, 13 and 14

Results

During 2004, 2005 and 2006, 1,650 sauger were captured from all river segments (Appendix A), and aging structures were collected on 569 of these fish (Table 3). Mean back calculated lengths at age for 2005 were 181 mm, 278 mm, 340 mm, 397 mm , 451 mm, 468 mm at age 1, 2, 3, 4, 5 and 6, respectively (Table 6; Figure 15). Mean back calculated lengths at age for 2006 were 188 mm, 281 mm, 332 mm, 368 mm, 391 mm and 354 mm at age 1, 2, 3, 4, 5, and 6, respectively (Table 7; Figure 16).

The average back-calculated length of sauger for the lower universe was greater than the upper universe at any given age (Figure 18). The similarity of the length-at-capture to the mean back-calculated lengths supports the use of 55 mm as the y-intercept, and should give a good approximation of annulus formation at a given age (Appendix B).

Sauger data were tested for normality using the Kurtosis test. A parametric ANOVA with a Tukey post-hoc test showed that differences existed among segments for mean length at age based on length at capture during both 2005 (Table 10) and 2006 (Table 11). However, there was considerable variability in mean length at age among segments during both years, and no discernable trends were evident (Tables 10 and 11). When comparing mean length at capture, the upper sampling universe had significantly lower mean lengths at all ages compared with the lower universe across all ages (Table 12).

Length frequencies by segment for each year show that the sauger population in the Missouri River has a bi-modal distribution. (Appendix C). A weak size class occurs within a range of 150mm to about 270mm. This distribution is noticeable in each sampling universe and for each segment individually.

Age frequencies of sauger were compared among segments for each year. Age frequencies for 2004 were 10% age 4, 37% age 5, 37% age 6, and 16% age 7. Age frequencies for 2005 were 35% age 0, 10% age 1, 20% age 2, 20% age 3, 10% age 4, 4% age 5, and 1% age 6. Age frequencies for 2006 were 13% age 0, 11% age 1, 27% age 2, 27% age 3, 12% age 4, 8% age 5, and 3% age 6 (Appendix D).

Table 3. Total number of aging structures collected for age and growth analysis.

Length	Total	2004	2005								2006										
		9	**4**	**5&6**	**7**	**8**	**9**	**10**	**13**	**14**	**2**	**3**	**4**	**5&6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
10	0																				
20	0																				
30	0																				
40	0																				
50	0																				
60	0																				
70	0																				
80	3		3																		
90	6		5										1								
100	26		10		2		1						10				2				1
110	30		15		1		1						11				2				
120	19		12	1	1		1						4								
130	15		14											1							
140	6		2		1								1	2							
150	6		1	1	1					1		1									1
160	5			1								1		1							2
170	5			2												1					1
180	4		1		1							1	1								
190	6			1			1						2							1	1
200	6		1									2	2								1
210	3											2									1
220	6		2	1								1	2								
230	4		1									1	2								
240	11		1	2							1	3	2	1						1	
250	6		1	1								2		1						1	
260	9		2	2					2		2		1								
270	8				1				3		1	1				1			1		
280	17		6	2					2		1	2		1		1				2	
290	21		4	2	1				2		2	2	1	2		1	1			1	2
300	33		6	1	2				2		6	8	1	3			1		1	1	1
310	28	1	4	1					1	1	5	6	1	4				1			3

320	24		2	1	1	2		1	4		3	4		2			1		2	1
330	32		5				1		2	1	2	3	1	3		1	5	2	3	3
340	40		2				1		5	3	3	4	1	1	1	1	2	4	6	6
350	20		1	2			1				1	1	2	1			5	1	4	1
360	23	3	1	4	1				1					2	1		2	2	4	2
370	21	2	3	2	1				2	1	1	1		1	1		3		2	1
380	13	1	1	1			1		2						1		3			3
390	16	1	2	1					1	1				1	1		2		5	1
400	15	1	1	2	1	1			2	1				1			2	2		1
410	13	2	1				1						1		2	1	2		3	
420	9	1	1				1		1	2							1	2		
430	13	1	1		1				3								4	1	1	1
440	10	1	1							1							3	2	1	1
450	11	2	1					1						2			3	1	1	
460	1																			1
470	5	2		1					1							1				
480	6	1	1							1							1	1		1
490	2																1		1	
500	3								1								1		1	
510	2									1									1	
520	1																1			
530	2			1												1				
540	1						1													
550	0																			
560	0																			
570	1						1													
580	0																			
590	0																			
600	2					1														
610	0																			
620	0																			
630	0																			
640	0																			
650	0																			

Table 4. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sauger collected in each segment during 2003. A mean total length-at-age of all segments combined is also provided for each age class.

Age	Segments												Mean
	1	2	3	4	5 & 6	7	8	9	10	11	13	14	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

No data for 2003

Table 5. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sauger collected in each segment during 2004. A mean total length-at-age is not applicable because structures were only collected in segment 9 during 2004.

Age	**Segments**												**Mean**
	1	**2**	**3**	**4**	**5 & 6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	
1								201 (0.27)					
2								290 (0.21)					
3								350 (0.25)					
4								385 (0.23)					
5								409 (0.19)					
6								424 (0.12)					
7								459 (0.10)					
8													
9													
10													

Table 6. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sauger collected in each segment during 2005. A mean total length-at-age of all segments combined is also provided for each age class.

Age	**Segments**												**Mean**
	1	**2**	**3**	**4**	**5 & 6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	
1				171 (0.40)	170 (0.47)	179 (0.23)	200 (0.09)	204 (0.16)	187 (0.09)		189 (0.41)	225 (0.17)	181 (0.70)
2				255 (0.33)	290 (0.20)	270 (0.11)	285 (0.06)	314 (0.11)	285 (0.05)		282 (0.30)	323 (0.12)	278 (0.48)
3				315 (0.23)	362 (0.10)	323 (0.11)	406 (0.02)	376 (0.08)	346 (0.04)		339 (0.25)	370 (0.16)	340 (0.35)
4				375 (0.09)	490 (0.00)	376 (0.16)	459 (0.02)	436 (0.06)	432 (0.00)		377 (0.14)	411 (0.21)	397 (0.19)
5							589 (0.00)	471 (0.03)			430 (0.13)	434 (0.18)	451 (0.11)
6											468 (0.06)		468 (0.06)
7													
8													
9													
10													

Table 7. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sauger collected in each segment during 2006. A mean total length-at-age of all segments combined is also provided for each age class.

Age	**Segments**												**Mean**
	1	**2**	**3**	**4**	**5 & 6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	
1		172 (0.48)	157 (0.59)	169 (0.25)	188 (0.24)	178 (0.29)	186 (0.14)	209 (0.39)	220 (0.32)	239 (0.00)	216 (0.25)	178 (0.30)	188 (0.79)
2		260 (0.36)	243 (0.44)	225 (0.15)	283 (0.23)	287 (0.10)	286 (0.08)	315 (0.32)	326 (0.24)	281 (0.00)	320 (0.20)	249 (0.21)	281 (0.57)
3		296 (0.36)	297 (0.53)	307 (0.22)	343 (0.13)	314 (0.66)	370 (0.06)	368 (0.26)	377 (0.17)		349 (0.12)	299 (0.18)	332 (0.45)
4		335 (0.15)	323 (0.20)	328 (0.16)	376 (0.07)	342 (0.00)	406 (0.05)	403 (0.17)	416 (0.09)		393 (0.06)	335 (0.18)	368 (0.27)
5				394 (0.00)	425 (0.12)		513 (0.00)	422 (0.09)	460 (0.07)		424 (0.04)	344 (0.18)	391 (0.16)
6												354 (0.16)	354 (0.16)
7													
8													
9													
10													

Figure 13. No data for 2003.

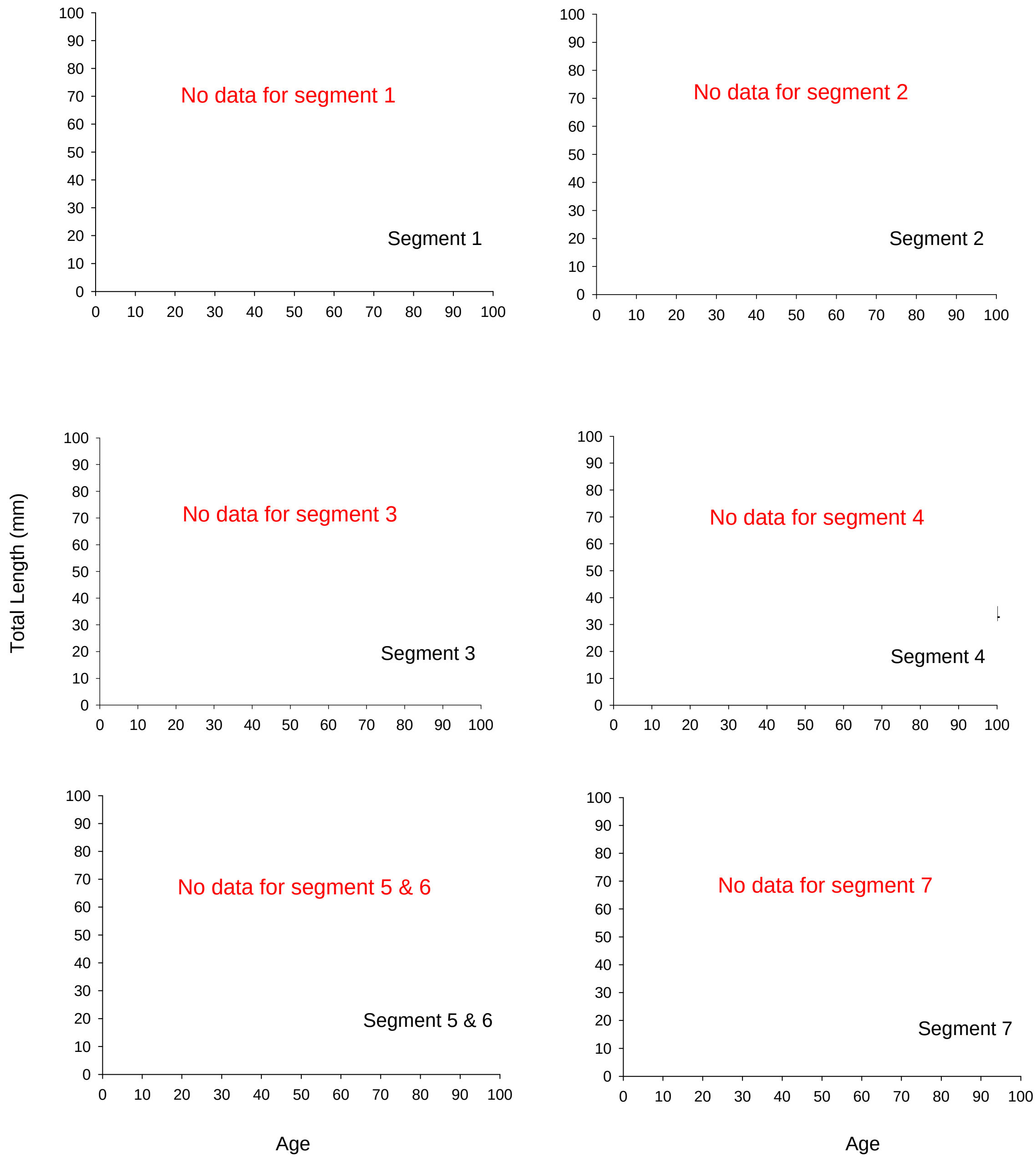

Figure 14. Mean back-calculated total length-at-last annulus curves of sauger that were collected for age and growth analysis from segments 1, 2, 3, 4, 5 & 6, 7, 8, 9, 10, 11, 13, and 14 of the Missouri River during 2004.

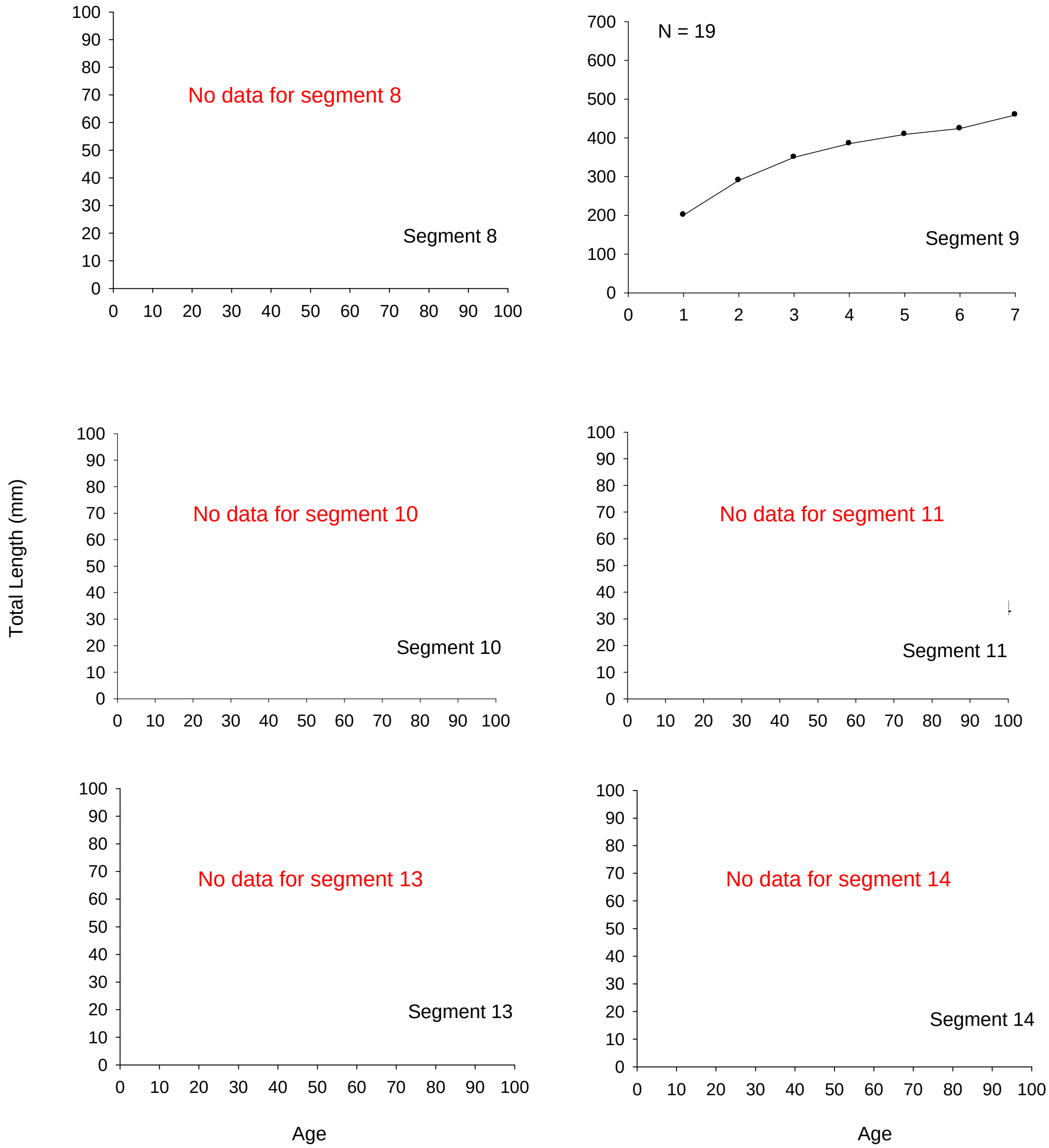

Figure 14. Continued.

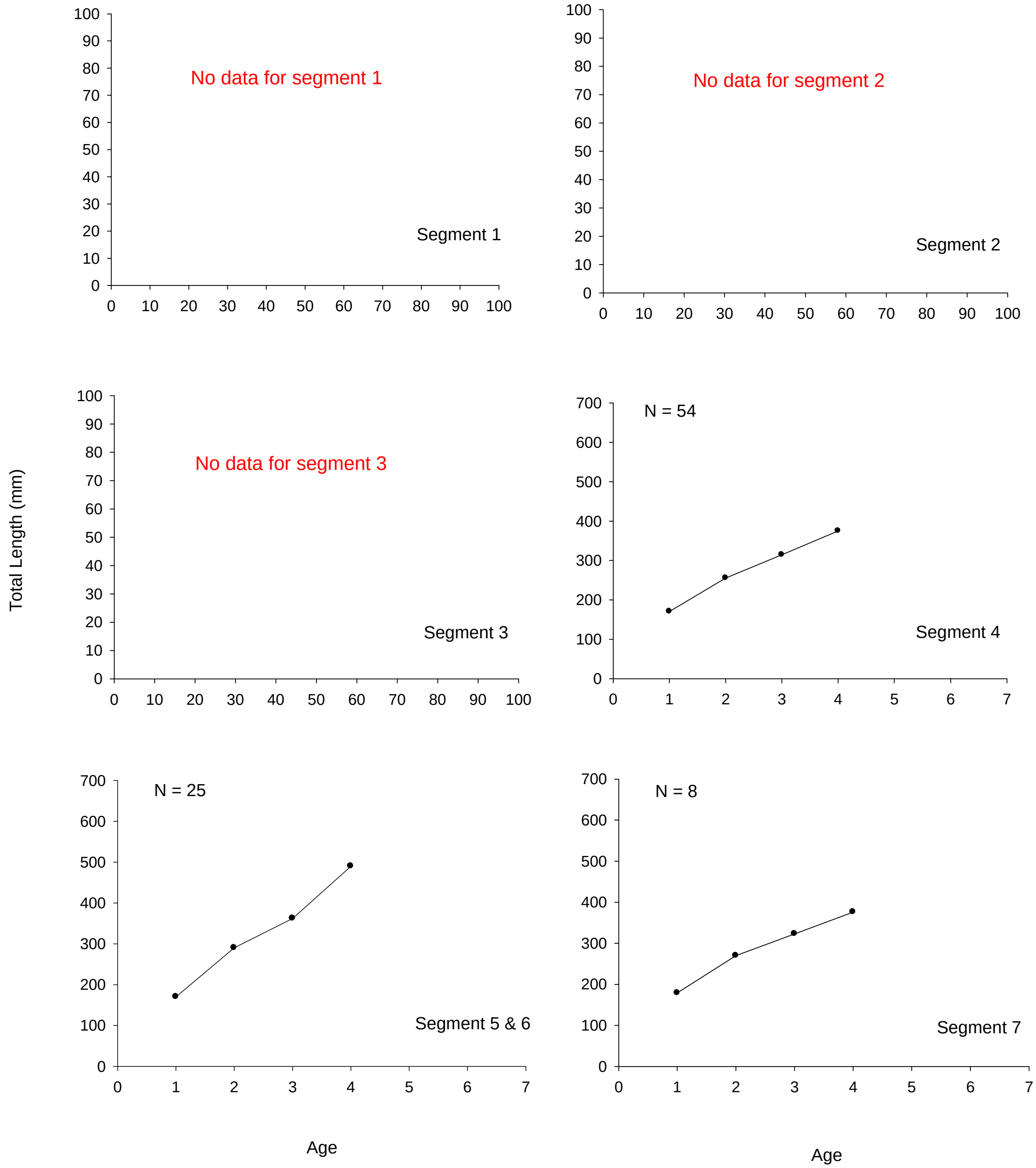

Figure 15. Mean back-calculated total length-at-last annulus curves of sauger that were collected for age and growth analysis from segments 1, 2, 3, 4, 5 & 6, 7, 8, 9, 10, 11, 13, and 14 of the Missouri River during 2005.

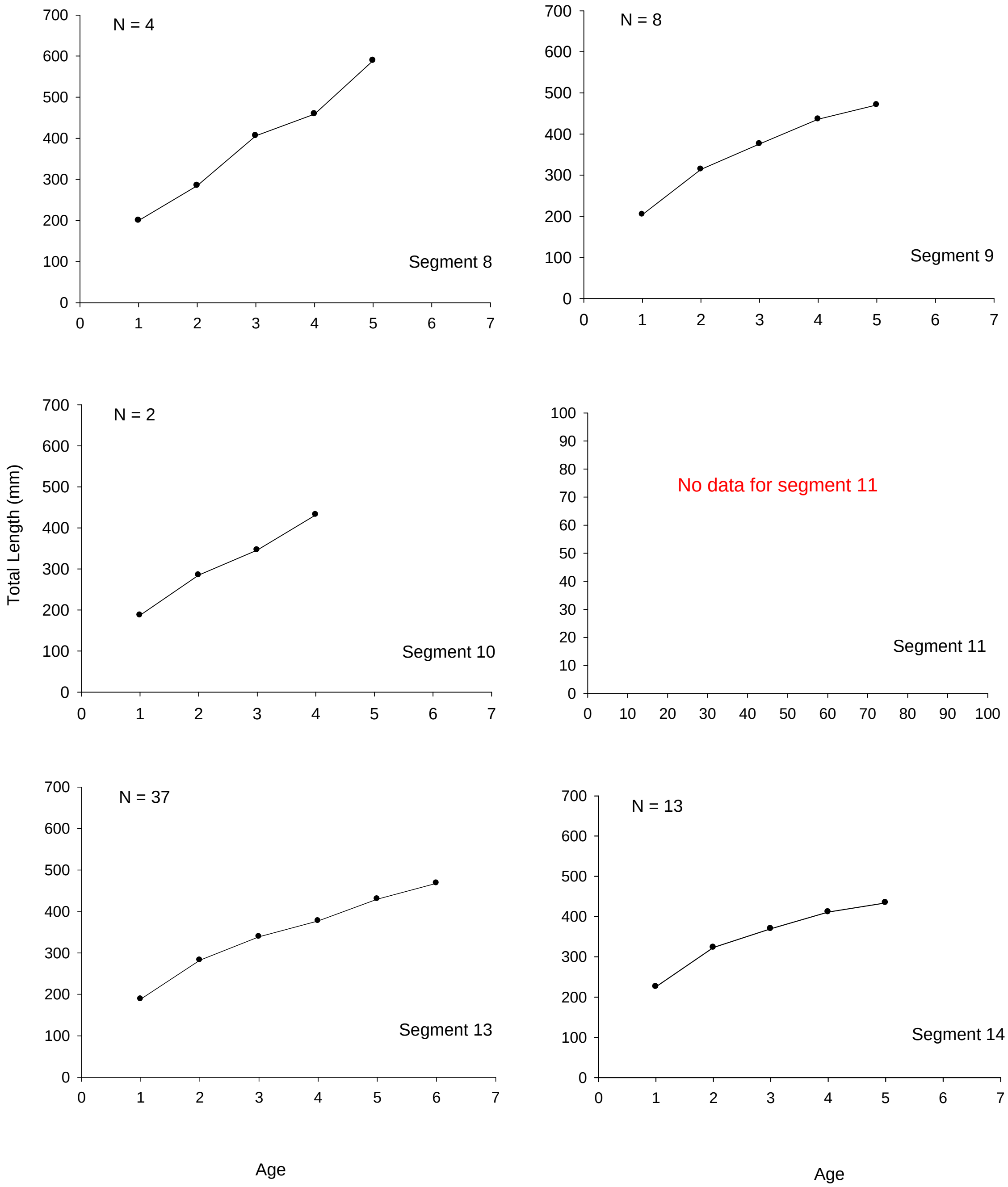

Figure 15. Continued.

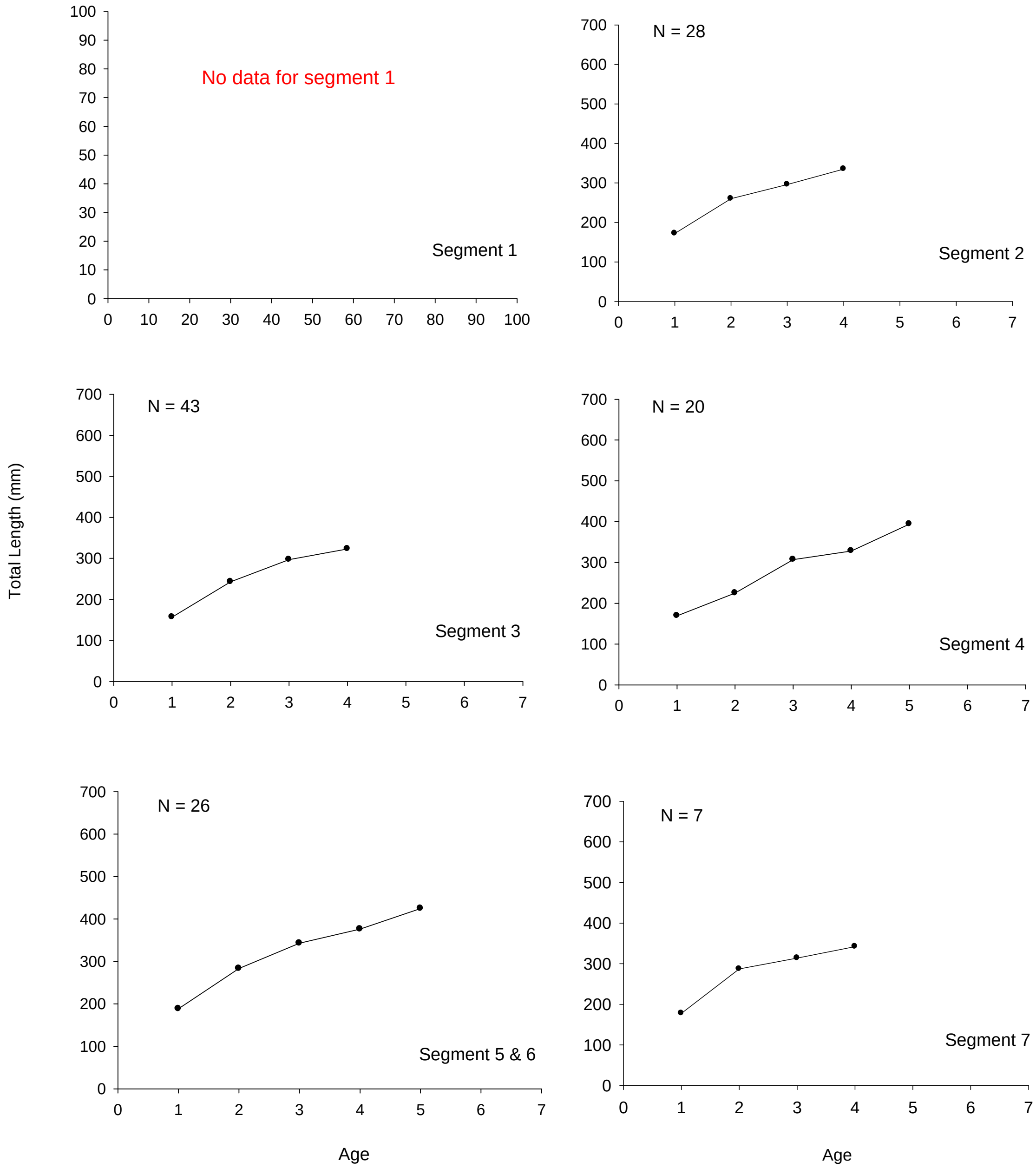

Figure 16. Mean back-calculated total length-at-last annulus curves of sauger that were collected for age and growth analysis from segments 1, 2, 3, 4, 5 & 6, 7, 8, 9, 10, 11, 13, and 14 of the Missouri River during 2006.

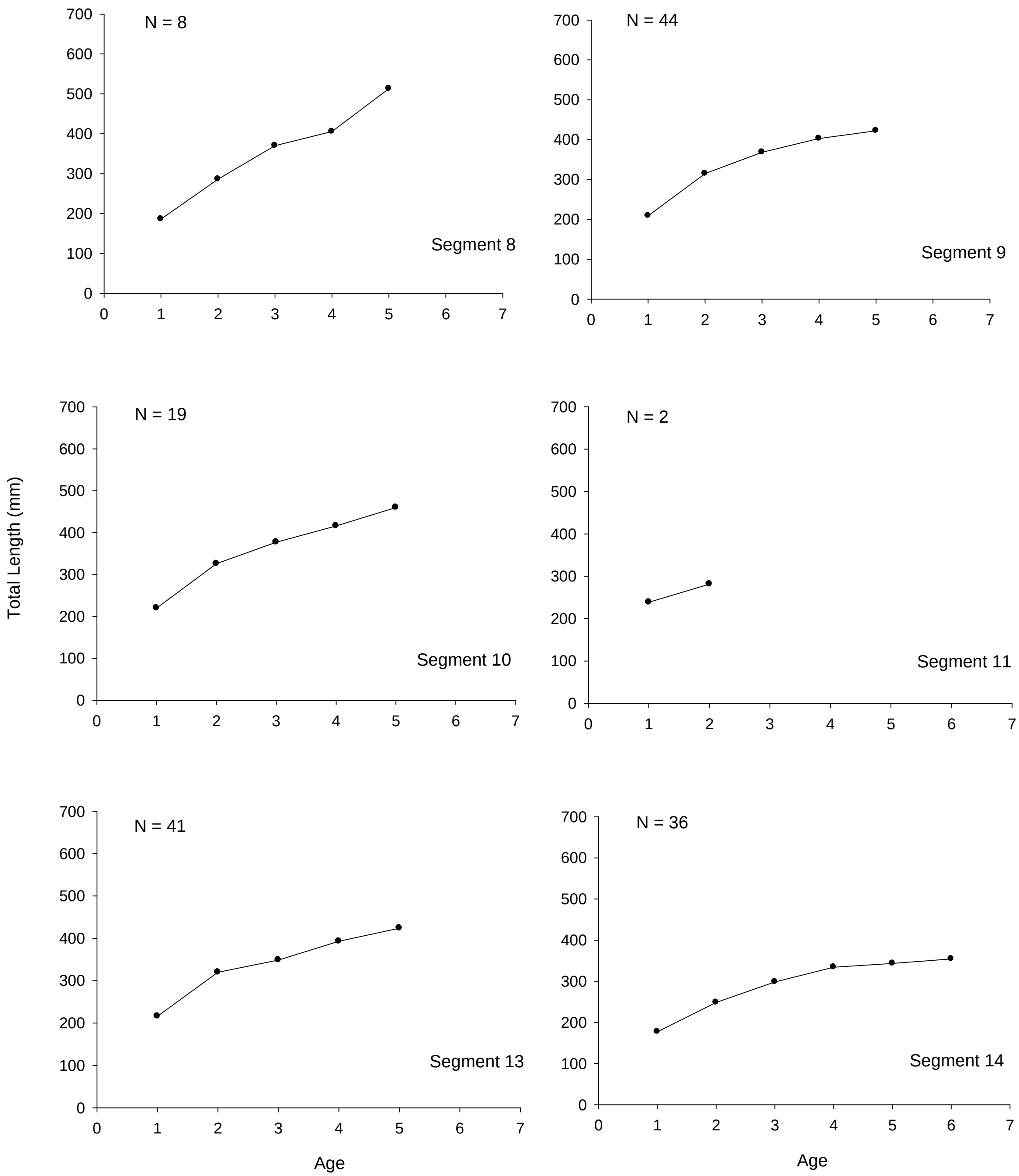

Figure 16. Continued.

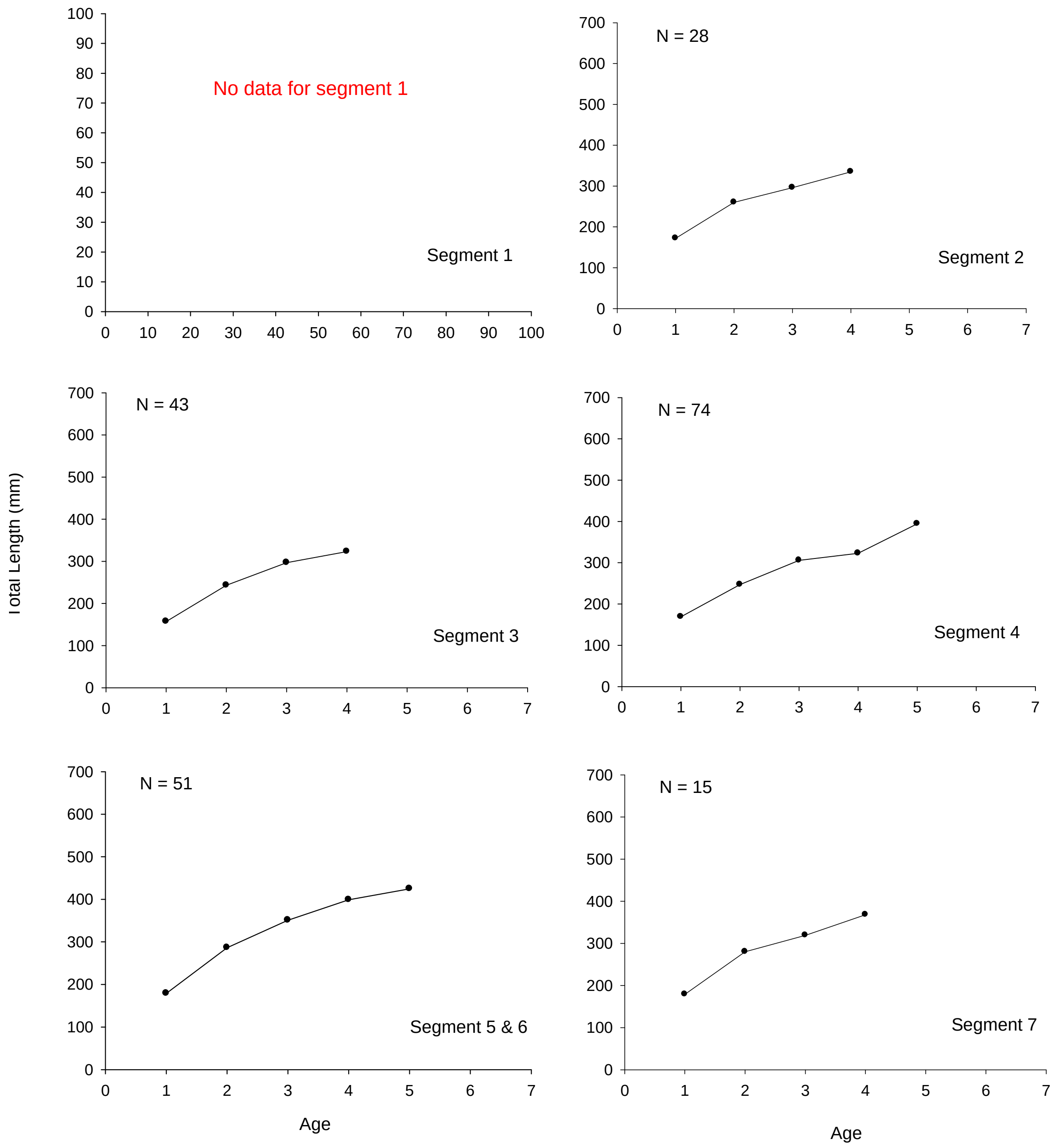

Figure 17. Mean back-calculated total length-at-last annulus curves of sauger that were collected for age and growth analysis from segments 1, 2, 3, 4, 5 & 6, 7, 8, 9, 10, 11, 13, and 14 of the Missouri River for all years combined.

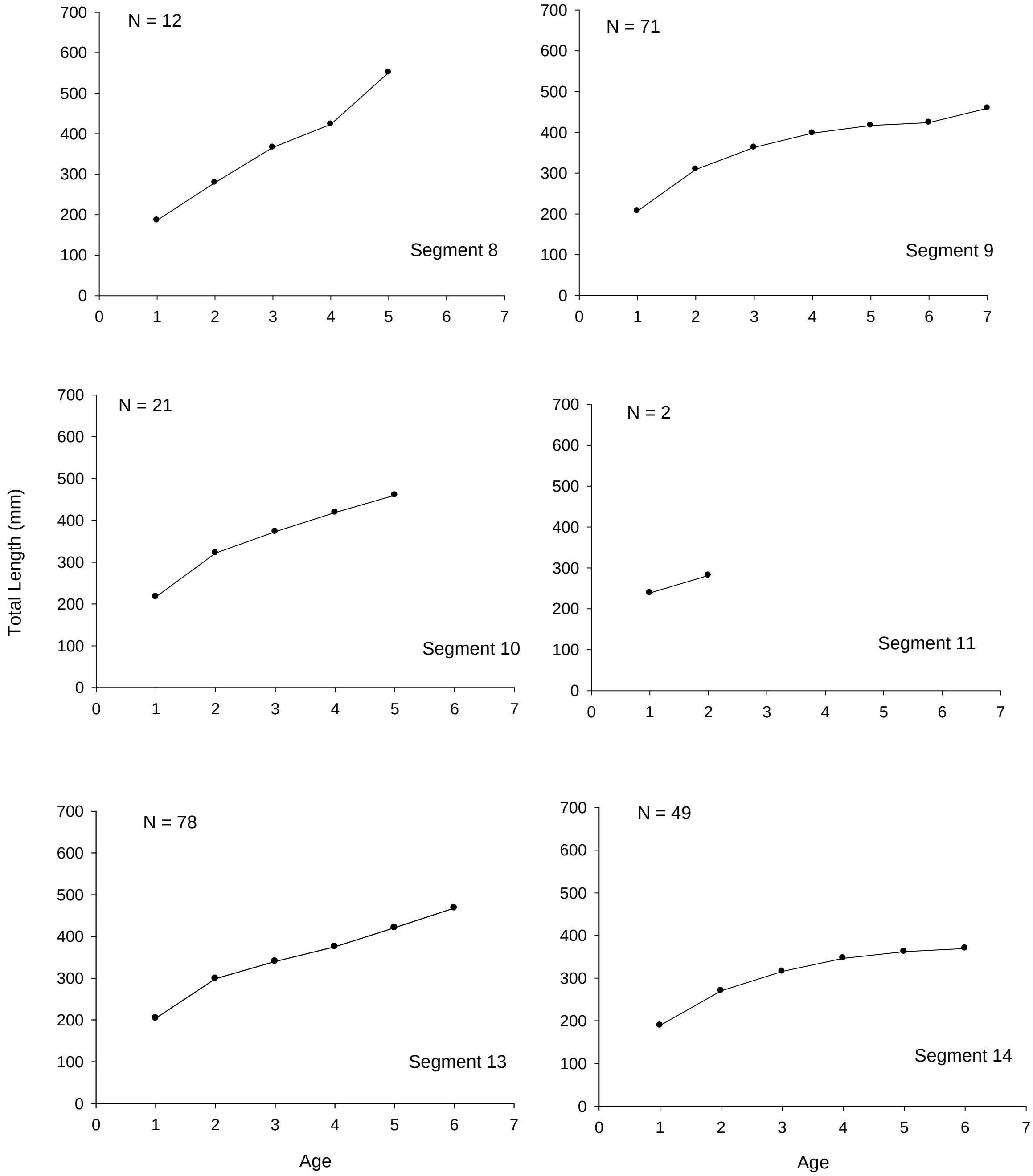

Figure 17. Continued.

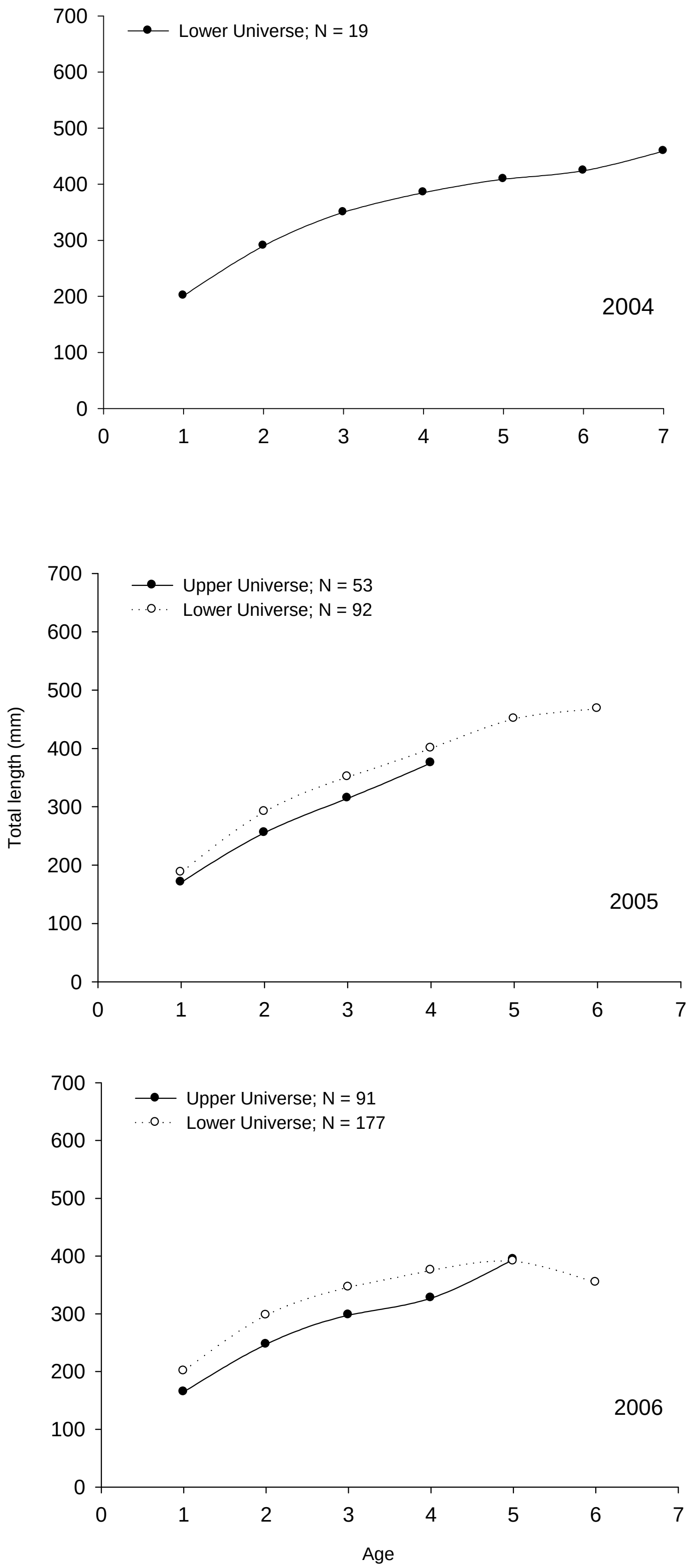

Figure 18. Mean back-calculated total length-at-last annulus curves of sauger that were collected for age and growth analysis from the upper and lower universe of the Missouri River for 2004, 2005, and 2006.

Table 8. Mean length-at-capture comparisons of sauger between segments for 2003. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

	Segment											
Age	**1**	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0												
1												
2												
3												
4												
5												
6												
7												
8												

No data for 2003

Table 9. Mean length-at-capture comparisons of sauger between segments for 2004. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

	Segment											
Age	**1**	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0												
1												
2												
3												
4												
5												
6												
7												
8												

Insufficient data for 2004

Table 10. Mean length-at-capture comparisons of sauger between segments for 2005. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

Age	**Segment**											
	1	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0*				118 a (4.1, 61)	157 b (19.1, 5)	148 b (39.3, 8)		134 ab (39.7, 4)				150 ab (-, 1)
1*				251 a (45.2, 8)	256 a (19.2, 10)	311 a (11.6, 3)					280 a (-, 1)	
2*				315 ab (24.5, 22)	346 ab (21.2, 11)		325 ab (2.0, 2)	359 ab (-, 1)			289 a (22.4, 6)	388 b (94.9, 3)
3*				346 ab (19.7, 19)	396 a (35.7, 6)	329 ab (75.5, 2)		342 ab (7.8, 2)	321 ab (-, 1)		334 b (18.1, 10)	384 ab (46.3, 4)
4*				404 a (47.4, 4)	535 a (-, 1)	405 a (30.6, 3)	405 a (-, 1)	452 a (93.3, 3)	452 a (-, 1)		356 a (39.7, 9)	
5*							608 a (-, 1)	492 ab (158.8, 2)			418 b (31.0, 5)	434 ab (21.6, 2)
6											468 (70.6, 2)	
7												
8												

Table 11. Mean length-at-capture comparisons of sauger between segments for 2006. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

	Segment											
Age	**1**	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0*			168 a (17.0, 3)	112 b (3.9, 27)	145 c (11.7, 4)		172 ac (-, 1)	110 b (6.4, 4)			195 a (-, 1)	104 b (-, 1)
1*		261 ab (-, 1)	233 bc (20.0, 6)	228 ac (22.5, 10)	283 ac (28.2, 5)						334 a (33.2, 9)	182 b (27.6, 4)
2*		302 ab (15.5, 13)	270 b (21.4, 12)	254 b (42.8, 5)	322 abc (12.2, 11)	400 d (14.5, 4)	299 abc (41.3, 3)	358 ad (43.5, 5)	355 ad (33.4, 4)	307 bd (-,1)	364 cd (22.1, 20)	276 ab (77.6, 4)
3*		316 a (12.6, 11)	318 a (7.9, 19)	344 ab (13.8, 3)	353 ab (31.0, 6)	353 ab (24.5, 2)		381 b (22.7, 20)	381 b (29.0, 10)		380 b (26.4, 5)	330 ab (57.6, 6)
4*		343 a (32.2, 3)	334 a (19.7, 6)	341 a (-, 1)	316 a (-, 1)	376 a (-, 1)	407 a (79.3, 3)	411 a (29.1, 10)	404 a (61.4, 3)		368 a (45.1, 2)	390 a (53.0, 6)
5*				419 a (-, 1)	439 a (34.0, 3)		530 a (-, 1)	439 a (52.0, 6)	460 a (57.8, 2)		426 a (91.1, 5)	365 a (41.6, 6)
6												354 (24.9, 9)
7												
8												

Table 12. Mean length-at-capture comparisons of sauger between the upper and lower sampling universe. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Sampling universe comparisons were analyzed with a t-test. Sharing a letter indicate no significant differences while different letters indicate significance differences (alpha = 0.05).

Age	**Sampling Universe**	
	Upper	**Lower**
0*	118 a (3.6, 91)	143 b (13.9, 29)
1*	238 a (17.5, 25)	279 b (20.5, 32)
2*	295 a (13.9, 52)	342 b (11.7, 75)
3*	329 a (9.0, 52)	366 b (11.2, 74)
4*	356 a (22.7, 14)	396 b (17.4, 46)
5	419 (-, 1)	427 (21.6, 40)
6		389 (27.0, 18)
7		459 (40.5, 3)
8		

Table 13. Age/length key for segment 1. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
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									
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

No data for segment 1

Table 14. Age/length key for segment 2. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	**Age**								**N**
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
80									
90									
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240			100						1
250									
260		50	50						2
270			100						1
280				100					1
290			50	50					2
300			50	50					6
310			60	40					5
320			33	33	33				3
330			50		50				2
340				100					3
350			100						1
360									
370					100				1
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

Table 15. Age/length key for segment 3. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
100									
110									
120									
130									
140									
150	100								1
160	100								1
170									
180	100								1
190									
200		100							2
210			100						2
220			100						1
230		100							1
240		33	67						3
250		100							2
260									
270			100						1
280			50	50					2
290			50	50					2
300			25	63	13				8
310			33	50	17				6
320				100					4
330				67	33				3
340				50	50				4
350				100					1
360									
370					100				1
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

Table 16. Age/length key for segment 4. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80	100								3
90	100								6
100	100								19
110	100								26
120	100								16
130	100								14
140	100								3
150	100								1
160									
170									
180		100							2
190		100							2
200		67	33						3
210									
220		75	25						4
230		33	67						3
240		100							3
250		100							1
260		33	67						3
270									
280		17	67	17					6
290			80	20					5
300		14	57	29					7
310			80	20					5
320				100					2
330				83	17				6
340			33	33	33				3
350			33	67					3
360				100					1
370				100					3
380				100					1
390		50	50						2
400					100				1
410				50		50			2
420					100				1
430			100						1
440					100				1
450				100					1
460									
470									
480			100						1
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

Table 17. Age/length key for segments 5 & 6. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
100									
110									
120	100								1
130	100								1
140	100								2
150	100								1
160	100								2
170	100								2
180									
190		100							1
200									
210									
220		100							1
230									
240		100							3
250		100							2
260		100							2
270									
280		33	33	33					3
290		75	25						4
300			100						4
310		40	40		20				5
320			100						3
330			67	33					3
340			100						1
350			33	67					3
360			67	33					6
370			67	33					3
380				100					1
390				100					2
400			33	33		33			3
410									
420									
430									
440									
450						100			2
460									
470				100					1
480									
490									
500									
510									
520									
530					100				1
540									
550									
560									
570									
580									
590									
600									

Table 18. Age/length key for segment 7. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
100	100								2
110	100								1
120	100								1
130									
140	100								1
150	100								1
160									
170									
180	100								1
190									
200									
210									
220									
230									
240									
250									
260									
270	100								1
280									
290				100					1
300		100							2
310									
320		100							1
330									
340				100					1
350									
360				100					2
370					100				2
380			100						1
390			100						1
400					100				1
410			100						2
420									
430					100				1
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

Table 19. Age/length key for segment 8. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
100									
110									
120									
130									
140									
150									
160									
170	100								1
180									
190									
200									
210									
220									
230									
240									
250									
260									
270			100						1
280			100						1
290				100					1
300									
310									
320			100						2
330					100				1
340			100						1
350									
360									
370									
380									
390									
400					100				1
410					100				1
420									
430									
440									
450									
460									
470					100				1
480									
490									
500									
510									
520									
530						100			1
540									
550									
560									
570									
580									
590									
600						100			1

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

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
100	100								3
110	100								3
120	100								1
130									
140									
150									
160									
170									
180									
190	100								1
200									
210									
220									
230									
240									
250									
260									
270									
280									
290				100					1
300			100						1
310							100		1
320				100					1
330			17	67		17			6
340				100					3
350			33	50	17				6
360			20	20	20	20	20		5
370				20	60	20			5
380				20	60	20			5
390				67		33			3
400			33		33		33		3
410				20		60		20	5
420				33	33		33		3
430			40		20	20	20		5
440				25	25	50			4
450				40	20	20	20		5
460									
470							50	50	2
480						50		50	2
490				100					1
500					100				1
510									
520						100			1
530									
540					100				1
550									
560									
570						100			1
580									
590									
600									

Table 21. Age/length key for segment 10. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									
300									
310				100					1
320				100					1
330			100						2
340			25	50	25				4
350				100					1
360				100					2
370									
380									
390									
400			50	50					2
410									
420				50	50				2
430						100			1
440				50	50				2
450				50	50				2
460									
470									
480						100			1
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

Table 22. Age/length key for segment 11. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	3	4	5	6	7	N
80									
90									
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270			100						1
280									
290									
300			100						1
310									
320									
330									
340									
350									
360									
370									
380									
390									
400									
410									
420									
430									
440									
450									
460									
470									
480									
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

Table 23. Age/length key for segment 13. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	**Age**								**N**
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
80									
90									
100									
110									
120									
130									
140									
150									
160									
170									
180									
190	100								1
200									
210									
220									
230									
240		100							1
250		100							1
260			50		50				2
270			100						3
280		25	25	25		25			4
290			33	33	33				3
300			67		33				3
310					100				1
320			33	50	17				6
330		20	40	20	20				5
340		18	18	36	9	18			11
350		25	50	25					4
360		40	40		20				5
370			50	50					4
380					50	50			2
390		17	17	33	33				6
400						100			2
410			67	33					3
420					100				1
430			25		25	25	25		4
440			100						1
450			100						1
460									
470						100			1
480									
490						100			1
500						50	50		2
510						100			1
520									
530									
540									
550									
560									
570									
580									
590									
600									

Table 24. Age/length key for segment 14. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age								N
	0	1	2	3	4	5	6	7	
80									
90									
100	100								1
110									
120									
130									
140									
150	50	50							2
160		50	50						2
170		100							1
180									
190		100							1
200				100					1
210		100							1
220									
230									
240									
250									
260									
270									
280									
290			50	50					2
300			100						1
310				25		50	25		4
320							100		1
330			25		25	25	25		4
340			33	11	22		33		9
350				100					1
360				50	50				2
370					50		50		2
380				33		33	33		3
390				100					2
400				50		50			2
410									
420				50		50			2
430							100		1
440						100			2
450									
460					100				1
470									
480			50		50				2
490									
500									
510							100		1
520									
530									
540									
550									
560									
570									
580									
590									
600									

Additional Analysis

There was not sufficient data to accurately construct catch curves for each segment with the age length keys from this report. Data from each segment were combined to make an age length key for the upper (Appendix E) and lower sampling universe (Appendix F) to assign an age to all sauger sampled. Annual mortality rates of sauger were higher in the upper universe than in the lower universe. The oldest age assigned in the upper and lower universe was 5, and 7, respectively. Average annual mortality for the upper universe and lower universe was 81% and 37%, respectively (Appendix G).

To compare age-assessment structures (i.e., spines, scales, and otoliths) collected from the same fish, age bias graphs were constructed (Kocovsky and Carline 2000). Comparison between scale age and mean spine age showed that spines were aged older than scales for fish aged 3 and younger; for fish over age 3, the trend was reversed (Appendix H). Otoliths were directly compared to scales and spines due to the low number of otoliths collected. Comparison between scale age and otolith age showed general agreement between age estimations. When comparing otoliths to spines, spine age was found to be higher on average than otolith age (Appendix I).

Structure age estimations were done independently by two readers. Reader agreement was tested to determine the accuracy and precision of assigned ages. Scales, spines, and otoliths were used to compare agreement. Exact reader agreement of scales and spines was similar to each other with reader agreement of otoliths being much higher (Appendix J).

Discussion

Sauger structures were not obtained from the entire population. In the beginning of the PSPAP, standard operating procedures stated that structures were to be obtained from fish 350 mm or less because of the inaccuracy of aging older fish using scales and spines. From the total number of sauger captured, structures were collected from 44% of the fish that were under 350 mm, compared to only 24% of the fish collected over 350mm (ten fish per 10 mm length groups). Structures from sauger over 350 mm were collected in some segments, but had no set number to be obtained, resulting in unequal representation of older fish. We believe this has skewed some of our data for this report. Our reader agreement for the two structures supports the notion that older fish are difficult to age using scales and spines. Otoliths had a high reader agreement because of the clarity of annuli and fish could be aged more accurately, especially for fish over 350 mm.

Length frequency histograms of sauger showed a bi-modal distribution (Appendix C). This is perhaps attributed to sampling gear bias. Out of the 287 sauger less than 150 mm that were captured, 99% were caught in mini-fyke nets and otter trawls. Out of 1,177 fish greater than 270 mm that were captured, 85% were caught in gill and trammel nets. The size range of sauger between 150 mm and 270 mm is not being captured effectively by the PSPAP sampling gear. To rule out the possibility of weak year classes, this size range was evaluated for each year by segment. If the bimodal distribution was attributed to a weak year class, it would shift across the length classes over the three years. The weak size class remained in the same range (150-270 mm) for each sampling year, indicating gear bias against this size group of sauger.

Length at capture for all age groups of sauger between each sampling universe showed fish in the upper universe were significantly smaller than sauger in the lower universe. This could be a result of prey structure between the two universes. Braaten and Guy 2002 found that some fish species, including sauger, exhibit declined growth rates in higher latitudes. This decline was found to be in relation to gizzard shad abundance.

The abnormal distribution in the length frequency is also displayed when looking at age frequency. Age 1 sauger for each year was a weaker class than age 0 and age 2 fish. According to our age length keys, age 1 sauger fall into the range of 150mm to 270mm. Collecting structures from sauger throughout the entire year would provide us an opportunity to obtain enough data to fill our recommended ten fish per 10mm length groups for this weak size/age class throughout the basin.

The oldest fish aged in the upper universe was age 5, in the lower universe it was age 7. This could also be accounted for the inaccuracy to age fish older than 5 with scales and/or spines. Kocovsky and Carline (2000) found that scales and spines from walleye became more difficult to read over the age of 4 for females and age 3 for males. They stated that spines and scales exhibit slow growth following sexual maturity, when annuli begin forming close together. For this reason, the use of otoliths was recommended. With 85% reader agreement compared to approximately 64% for spines and scales, otoliths should be collected throughout all length classes in an attempt to more accurately age sauger.

The low number of older fish in the upper universe is also shown by the high mortality rates compared to the lower universe. This is partly due to the length restrictions of 350 mm. This restriction biased our age length key, which was used to calculate mortality, by assigning lower ages to larger fish. This provides more data supporting removal of the 350 mm restriction.

Acknowledgments

Funding for PSPAP was provided by the United States Army Corps of Engineers. We would like to thank Mark Drobish for his input and coordination of the program. Appreciation is extended to Yan Hong for database management expertise and summarization. Thanks also to Angela Waits, Carol Lutes, Jenny Mosley and Joyce Baker for data entry and field assistance. Assistance with the development of the template for this age and growth report is by Kirk Steffensen. Primary field assistance and data collection were provided by all field crews of the PSPAP. Age and growth preparation/analysis was provided by David Garrett, Caleb Lucas, Erin Gilmore, and Patty Herman. Additional field assistance and data collection were provided by personnel from the Missouri Department of Conservation (MDC) Fisheries, Protection, and Outreach and Education Divisions. A special thanks to the Chillicothe and St. Joseph MDC office Administrative Services and to Resource Science Division central office personnel for their ongoing support to this field station.

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Appendices

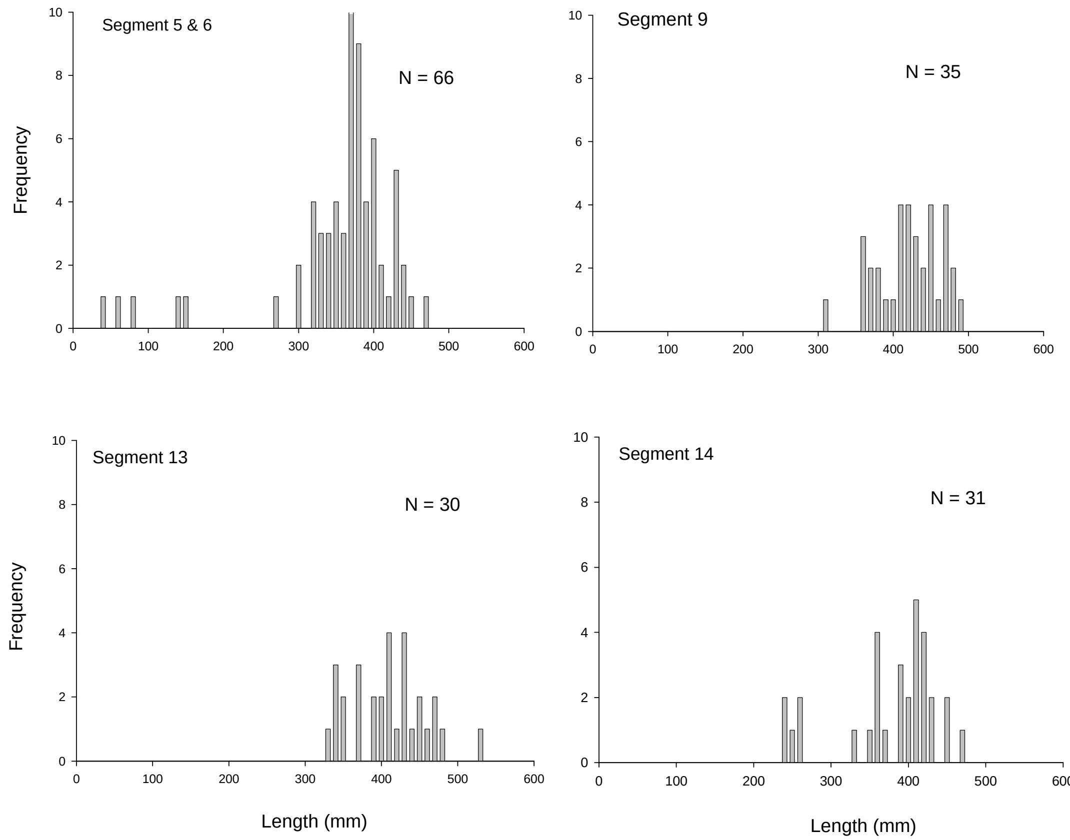
Appendix A. Total number of sauger sampled in the Missouri River for each segment during 2004, 2005, and 2006.

	2004	2005	2006	Totals
Segment 1			1	1
Segment 2			84	84
Segment 3			125	125
Segment 4		171	183	354
Segments 5 & 6	66	114	116	296
Segment 7		44	17	61
Segment 8		44	119	163
Segment 9	35	52	146	233
Segment 10		3	26	29
Segment 11			4	4
Segment 13	30	68	61	159
Segment 14	31	44	66	141
Totals	162	540	948	**1650**

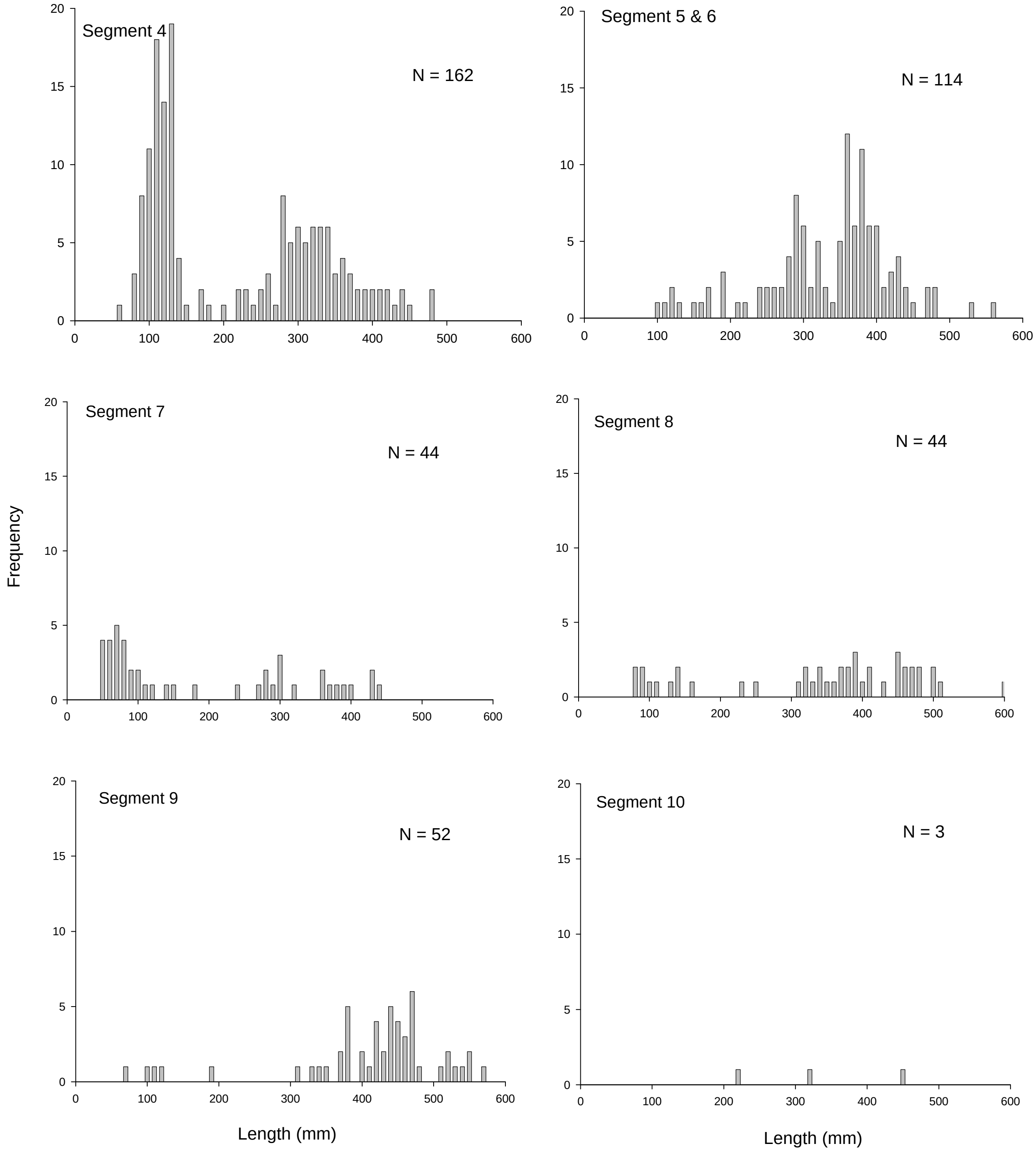
Appendix B. Length-at-capture and back-calculated length comparisons between the upper and lower sampling universe for sauger for all years combined.

Age	Mean total length at capture		Mean back calculated total length	
	Upper	Lower	Upper	Lower
0	118	143	-	-
1	238	279	167	197
2	295	342	250	295
3	329	366	303	348
4	356	396	340	384
5	419	427	394	408
6		389		398
7		459		459

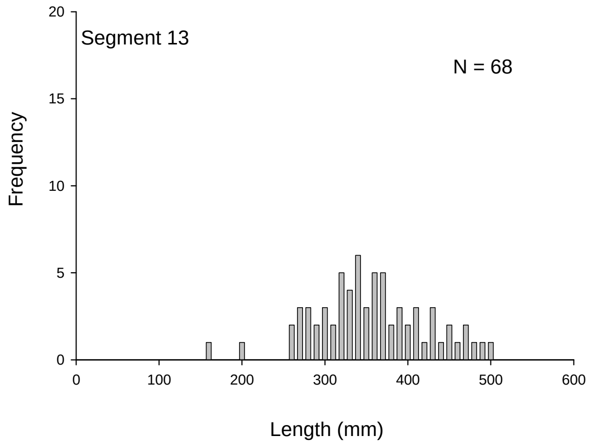
Appendix C. Length frequency of all sauger sampled in the Missouri River for 2004, 2005, and 2006.

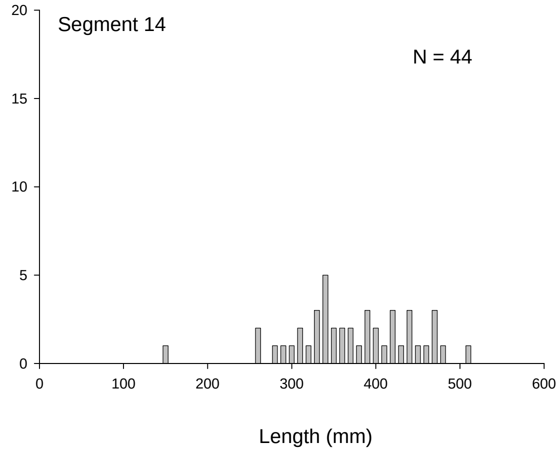


Appendix C1 - Length Frequency of all sauger collected from segments 5 & 6, 9, 13, and 14 of the Missouri River during 2004.

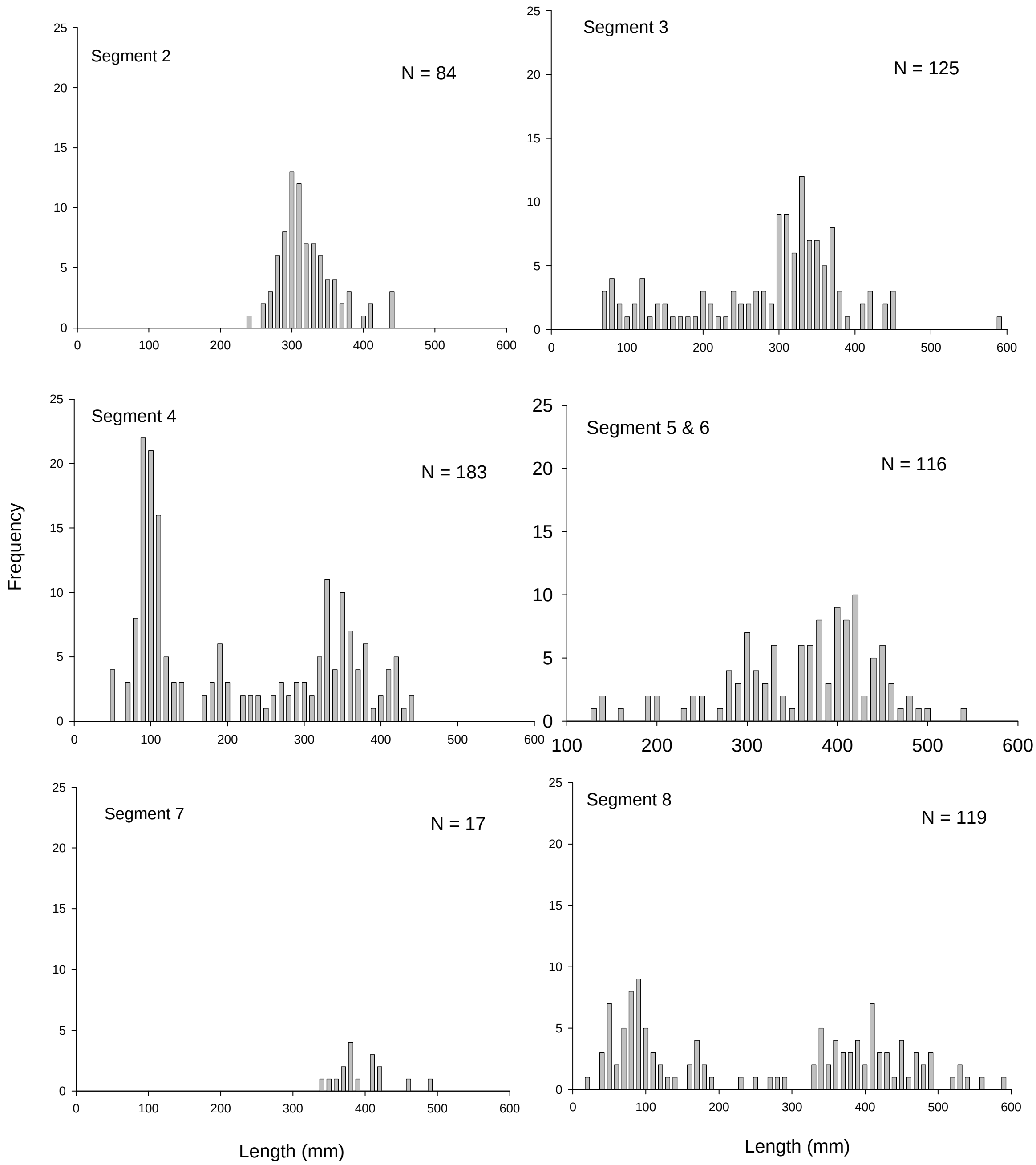


Appendix C2 - Length Frequency of all sauger collected from segments 4, 5 & 6, 7, 8, 9, 10, 13, and 14 of the Missouri River during 2005.

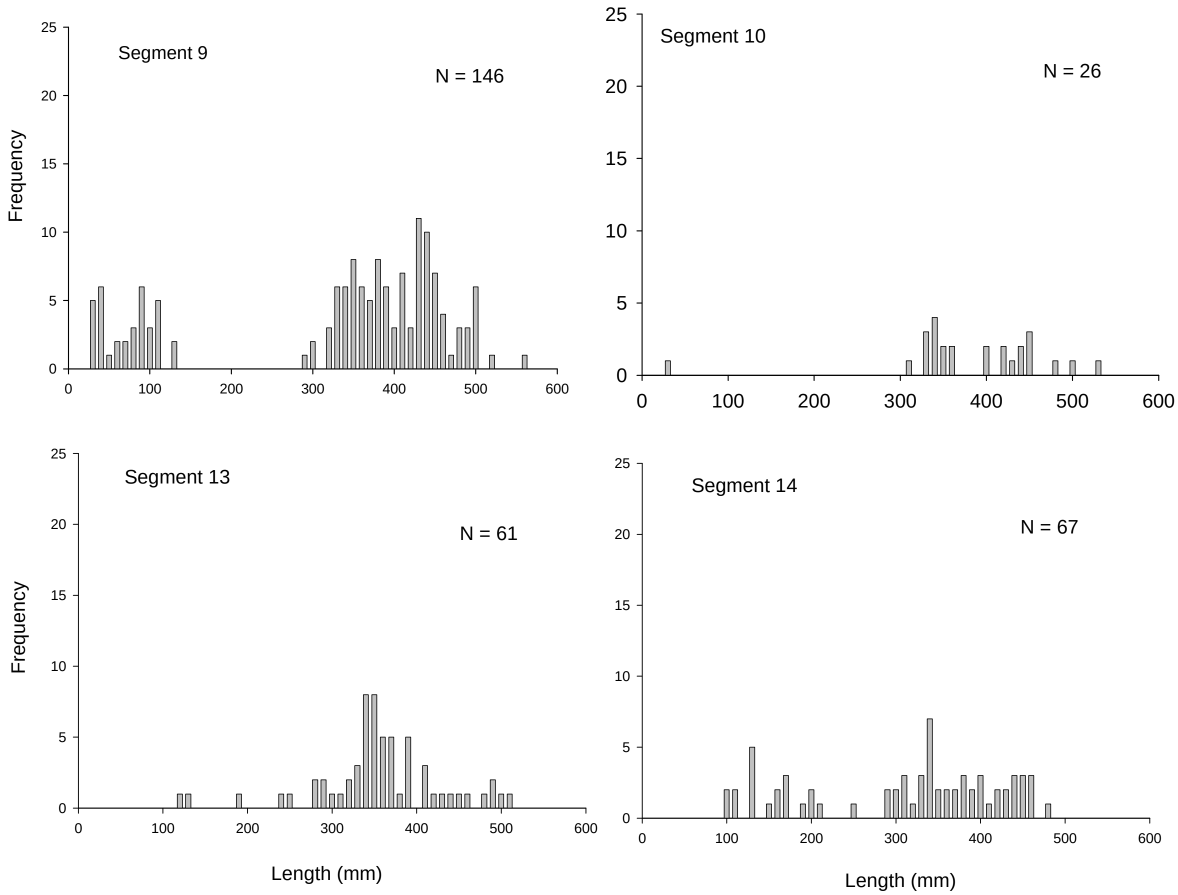




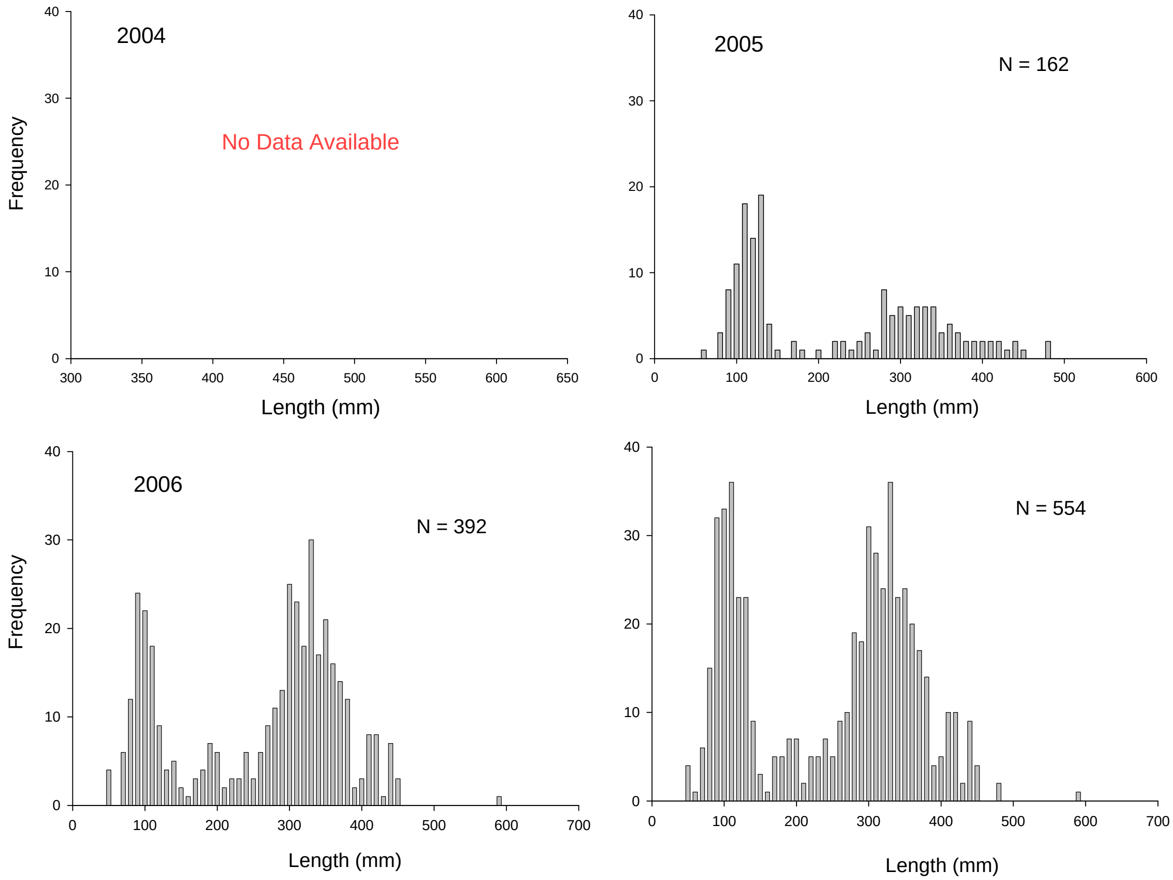
Appendix C2. Continued.



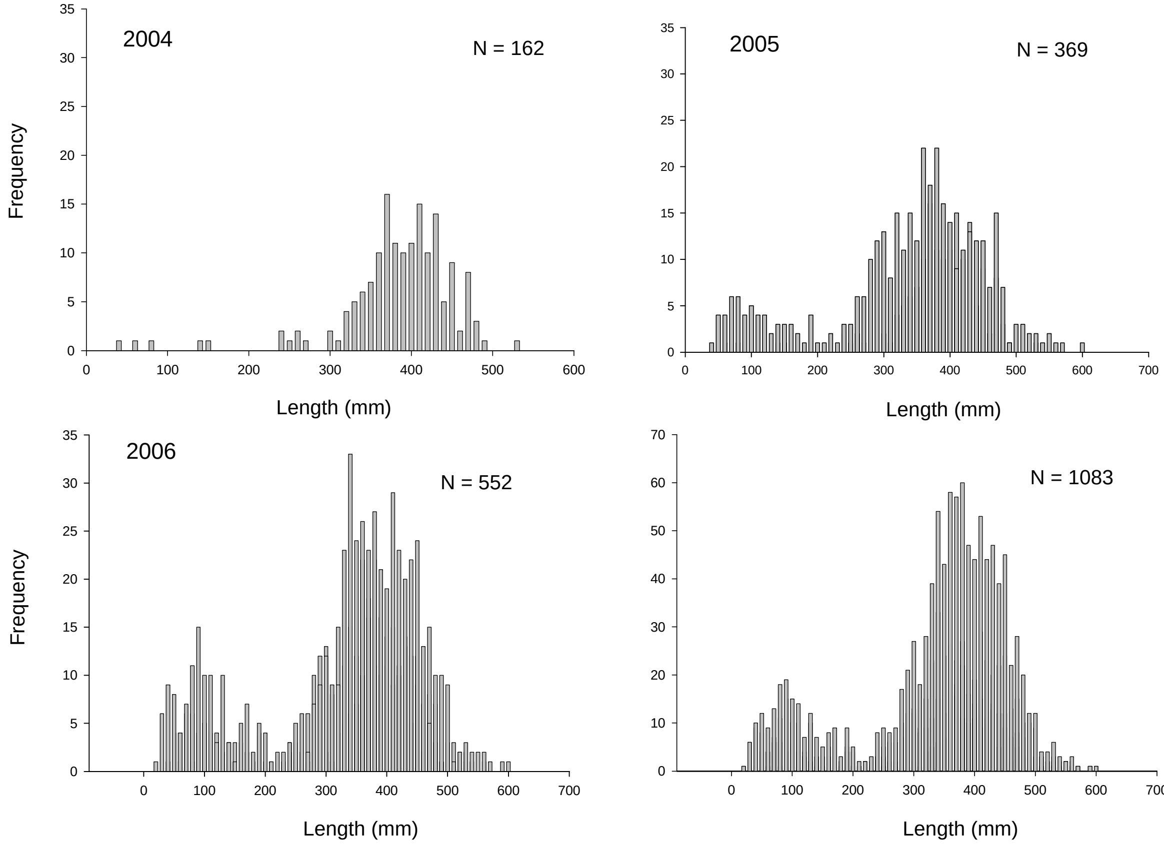
Appendix C3 - Length Frequency of all sauger collected from segments 2, 3, 4, 5 & 6, 7, 8, 9, 10, 13, and 14 of the Missouri River during 2006.



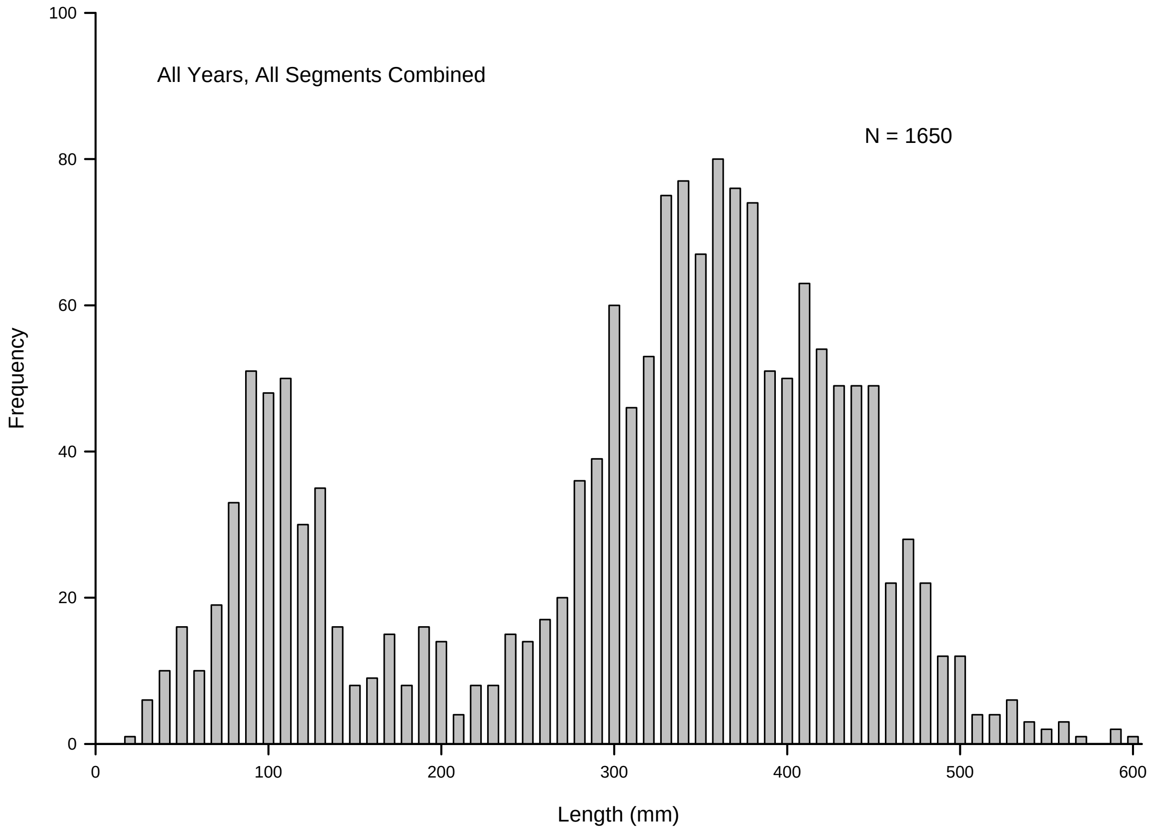
Appendix C3. Continued.



Appendix C4 - Length Frequency of all sauger collected from the upper universe of the Missouri River during 2004, 2005, 2006, and all years combined.



Appendix C5 - Length Frequency of all sauger collected from the lower universe of the Missouri River during 2004, 2005, 2006, and all years combined.



Appendix C6 - Length Frequency of all sauger collected from the Missouri River for all years combined.

Appendix D. Age frequency tables for sauger that were collected for age and growth analysis for each segment of the Missouri River during 2004, 2005, and 2006.

2004								
Segment	Age							
	0	1	2	3	4	5	6	7
9	-	-	-	-	2	7	7	3
Total	0	0	0	0	2	7	7	3
Percentage	-	-	-	-	10%	37%	37%	16%

2005								
Segment	Age							
	0	1	2	3	4	5	6	7
4	61	8	22	19	4	-	-	-
5 & 6	5	10	11	6	1	-	-	-
7	8	3	-	2	3	-	-	-
8	-	-	2	-	1	1	-	-
9	4	-	1	2	3	2	-	-
10	-	-	-	1	1	-	-	-
13	-	1	6	10	9	5	2	-
14	1	-	3	4	-	2	-	-
Total	79	22	45	44	22	10	2	0
Percentage	35%	10%	20%	20%	10%	4%	1%	-

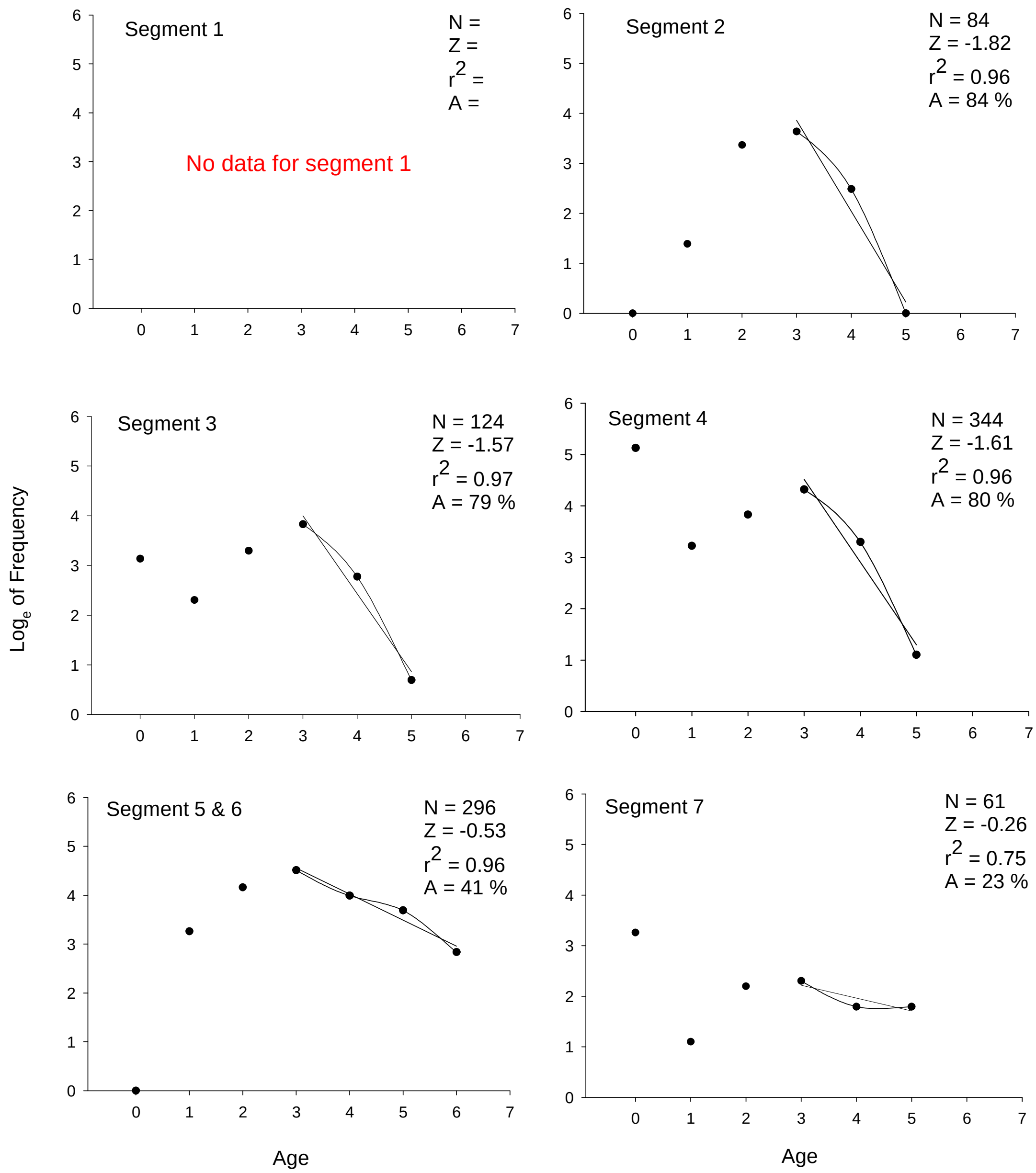
2006								
Segment	Age							
	0	1	2	3	4	5	6	7
2	-	1	13	11	3	-	-	-
3	3	6	12	19	6	-	-	-
4	27	10	5	3	1	1	-	-
5 & 6	4	5	11	6	1	3	-	-
7	-	-	4	2	1	-	-	-
8	1	-	3	-	3	1	-	-
9	4	-	5	20	10	6	-	-
10	-	-	4	10	3	2	-	-
11	-	-	1	-	-	-	-	-
13	1	9	20	5	2	5	-	-
14	1	4	4	6	6	6	9	-
Total	41	35	82	82	36	24	9	0
Percentage	13%	11%	27%	27%	12%	8%	3%	-

Appendix E. Age/length key for upper universe. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data.

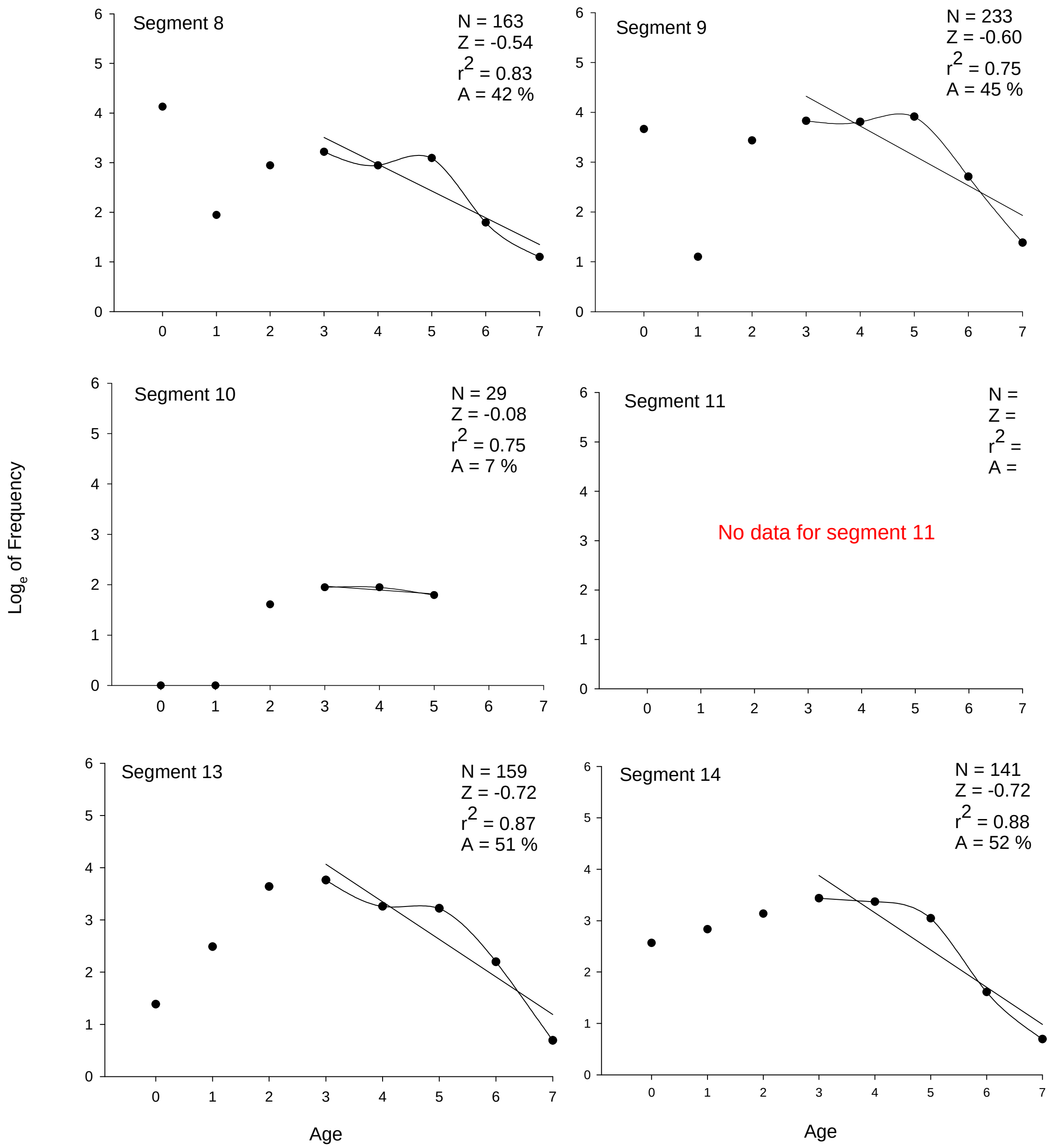
Length Category	Age								N
	0	1	2	3	4	5	6	7	
80	100								3
90	100								6
100	100								19
110	100								26
120	100								16
130	100								14
140	100								3
150	100								2
160	100								1
170									
180	33	67							3
190		100							2
200		80	20						5
210			100						2
220		60	40						5
230		50	50						4
240		57	43						7
250		100							3
260		40	60						5
270			100						2
280		11	56	33					9
290			67	33					9
300		5	43	48	5				21
310			56	38	6				16
320			11	78	11				9
330			9	64	27				11
340			10	60	30				10
350			40	60					5
360				100					1
370				60	40				5
380				100					1
390		50	50						2
400					100				1
410				50		50			2
420					100				1
430			100						1
440					100				1
450				100					1
460									
470									
480			100						1
490									
500									
510									
520									
530									
540									
550									
560									
570									
580									
590									
600									

Appendix F. Age/length key for lower universe. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data.

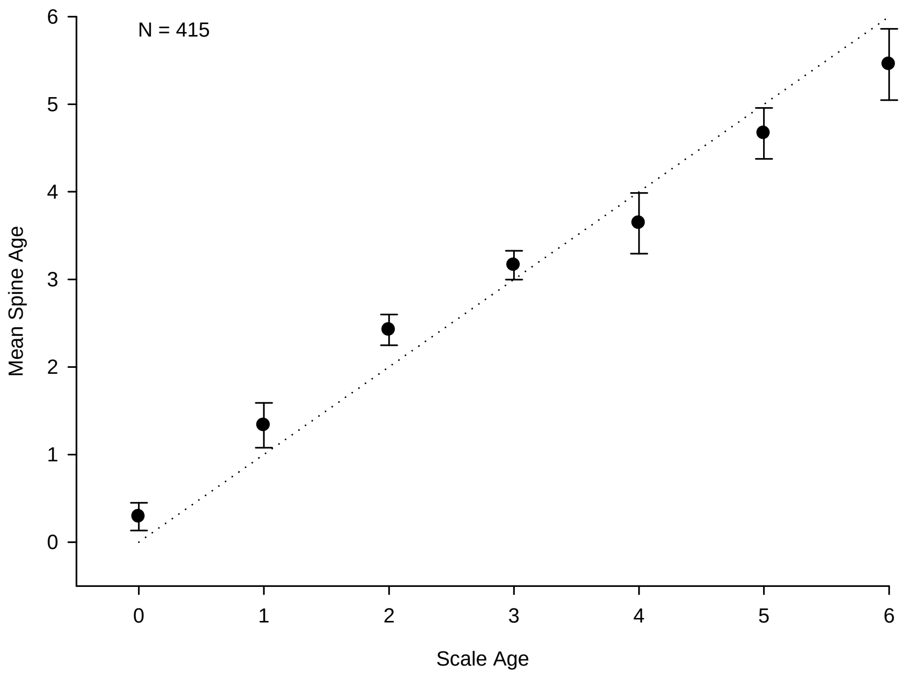
Length Category	**Age**								**N**
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
80									
90									
100	100								6
110	100								4
120	100								3
130	100								1
140	100								3
150	75	25							4
160	50	25	25						4
170	75	25							4
180	100								1
190	50	50							4
200				100					1
210		100							1
220		100							1
230									
240		100							4
250		100							3
260		50	25		25				4
270	17		83						6
280		25	38	25		13			8
290		25	25	42	8				12
300		17	75		8				12
310		17	17	17	17	17	17		12
320		7	47	33	7		7		15
330		5	38	29	14	10	5		21
340		7	27	37	13	7	10		30
350		7	33	53	7				15
360		9	32	36	14	5	5		22
370			25	25	38	6	6		16
380			8	25	33	25	8		12
390		7	14	57	14	7			14
400			21	21	21	29	7		14
410			36	18	9	27		9	11
420				38	38	13	13		8
430			25		25	25	25		12
440			11	22	22	44			9
450			10	30	20	30	10		10
460					100				1
470				20	20	20	20	20	5
480			20		20	40		20	5
490				50		50			2
500					33	33	33		3
510						50	50		2
520						100			1
530					50	50			2
540					100				1
550									
560									
570						100			1
580									
590									
600						100			1



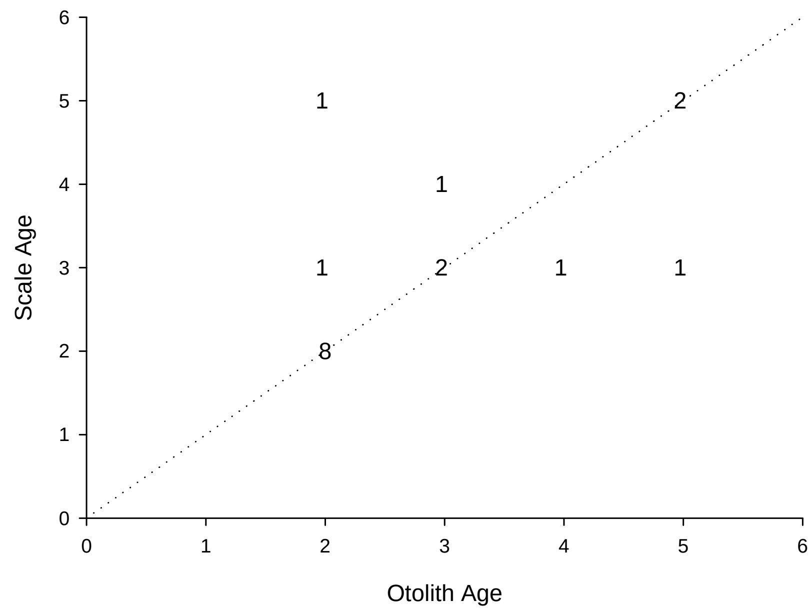
Appendix G. Catch curve for sauger that were collected in segments 1, 2, 3, 4, 5 & 6, 7, 8, 9, 10, 11, 13, and 14 of the Missouri River for all years and gears combined. Z represents the instantaneous mortality rate and A is The estimate of interval mortality rate.

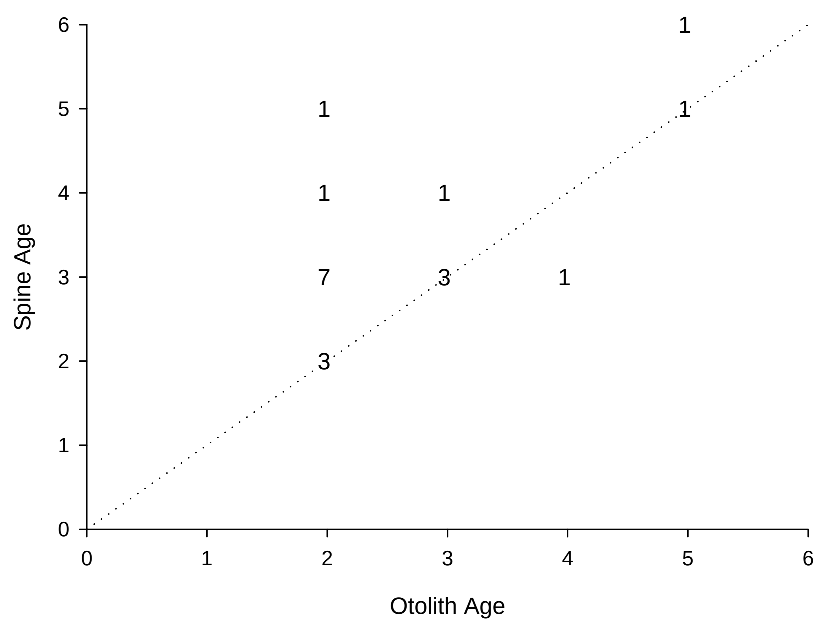


Appendix G. Continued.



Appendix H. Age bias graph for all aged sauger comparing average ages assigned from spines with ages assigned to scales. Vertical bars are 95% confidence limits. The diagonal line represents agreement between spine age and scale age.





Appendix I. Age bias graphs for all aged sauger comparing ages assigned to scales and spines to ages assigned to otoliths. Numbers on the graph represent the frequency of fish at a data point. The diagonal line represents exact agreement between age assignments.

Appendix J. Reader agreement for sauger between structures in the Missouri River for all years combined.

Structure	N	Percent Agreement			
		Exact	(+/- 1 year)	(+/- 2 year)	(+/- 3 year)
Scale	581	65.5	94.2	99.4	100
Spine	474	62.8	95.6	99.8	100
Otolith	20	85.0	100		