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Comparison of Age and Growth of Shovelnose Sturgeon in the Missouri and Yellowstone Rivers

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Abstract.—During the spring and summer 1991–1995, sampling was conducted on the Missouri River in North Dakota and on the Yellowstone River in Montana to compare the age and growth of shovelnose sturgeon *Scaphirhynchus platorynchus* in differently altered river segments. The study area consisted of two distinct river segments, the Yellowstone River near Intake, Montana (Williston–Yellowstone segment), a quasi-natural segment, and the Missouri River near Bismarck, North Dakota (Bismarck segment), a flow-regulated, altered segment. A total of 710 fish were aged by assessing pectoral fin sections, 565 from the Williston–Yellowstone segment and 145 from the Bismarck segment. Shovelnose sturgeon from the Yellowstone–Williston segment grew significantly faster and reached a larger size than shovelnose sturgeon from the Bismarck segment. The closure of Garrison Dam upstream of the Bismarck segment in December 1953 resulted in cooler summer water temperatures, less flow variation, and greater water clarity in the Bismarck segment. These habitat changes, coupled with a decrease in productivity in the Bismarck segment, may explain much of the difference in growth observed between the two segments.

Shovelnose sturgeon *Scaphirhynchus platorynchus* are distributed throughout the Mississippi and Missouri River basins (Lee 1978), typically inhabiting large, turbid rivers with high current velocities (Carlson et al. 1985). In Montana and North Dakota, the species is distributed throughout the lower Yellowstone River and in the Missouri River above and below Fort Peck Dam (Holton 1990). It is also found above and below Garrison Dam in North Dakota (Hendrickson and Lee 2000). The smallest of North America's sturgeon species, shovelnose sturgeon rarely exceed a length of 1 m or a weight of 3 kg throughout most of its range (Zweiacker 1967; Pflieger 1975), although specimens from the upper Missouri can reach 5 kg (D. L. Scarnecchia, unpublished).

Shovelnose sturgeon prefer a substrate of sand and small gravel (Pflieger 1975; Modde and Schmulbach 1977) and feed primarily on larvae of aquatic insects, worms, and crustaceans (Hoopes 1960; Modde and Schmulbach 1977; Hurley and Nickum 1984). Members of this long-lived species can exceed age 30 (Scarnecchia, unpublished). Age at maturity varies with geographic location and growth rate. On the upper Mississippi River, males mature at age 5 and females at age 7 (Hurley and Nickum 1984). Males and females show strong sexual size dimorphism, the females growing larger and maturing later.

Over the past several decades, the abundance of the shovelnose sturgeon has declined in portions of its range. Pflieger (1975), Hurley and Nickum (1984), and others have implicated overharvesting and especially degradation of natural main-stem river habitats as major causes of decline. During the last century, sturgeon habitat has been lost over much of the Missouri River's 3,768 km length. The construction of six main-stem dams from 1937 to 1963 reduced the amount of free-flowing water by two-thirds (Hesse 1987; Hesse et al. 1989; Werdon 1993). Important habitat changes have included the replacement of riverine habitat with reservoir

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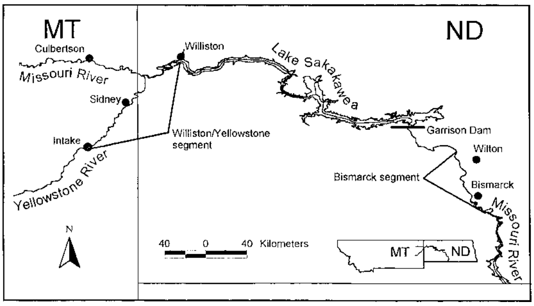

FIGURE 1.—Map of the lower Yellowstone River and Lake Sakakawea, Montana and North Dakota.

habitat, alterations of the natural hydrograph, altered river temperatures, and decreases in the river's turbidity. Many remaining riverine reaches of the Missouri River now consist of a single, narrow, deep, swift-flowing channel (Hesse et al. 1989; Hesse and Mestl 1993). Reductions in the variability of discharge and the overall peak discharge have eliminated the flood pulse of spring and early summer (Hesse and Mestl 1993; Galat and Rasmussen 1995). Moreover, each reservoir serves as a sediment sink, limiting the downstream movement of the river's suspended load (Hesse and Mestl 1993) and reducing the river's turbidity (Hesse 1987). The dams themselves restrict fish movement, creating fragmented and disjunct populations.

These habitat changes have had substantial effects on much of the Missouri River fish community, especially fishes such as shovelnose sturgeon that inhabit primarily main-channel habitats (Curtis et al. 1997). Many of the specific effects are poorly understood but manifested as the decline or disappearance of a species from a river segment.

Information on age and growth of a long-lived species, such as shovelnose sturgeon, can reveal the effect of habitat changes over decades. The objective of this paper is to compare growth rates of shovelnose sturgeon inhabiting two distinct segments of the Missouri River Basin—a slightly altered habitat and a highly altered habitat.

Study Area

The study area included the Yellowstone River near Intake, Montana, and in the Missouri River near Bismarck, North Dakota (Figure 1). The Yellowstone and Missouri rivers are particularly useful for comparing growth rates of shovelnose sturgeon between quasi-natural and highly altered river segments. The lower Yellowstone River has no large main-stem dams, a near natural hydrograph, high turbidity, and habitat conditions characteristic of a slightly altered large river system (White and Bramblett 1993). The Missouri River has a similar habitat from its confluence with the Yellowstone River downstream to the headwaters of Lake Sakakawea. This entire area (hereafter called the Williston–Yellowstone segment) is inhabited by sturgeon that are able to move freely within the area. In contrast, the Missouri River in North Dakota downstream of Garrison Dam (hereafter called the Bismarck segment) is characterized as highly altered and has a highly regulated hydrograph, reduced turbidity, and cool water from hypolimnetic releases. These changes have occurred since the dam was closed in December 1953. The Bismarck segment has also undergone more bank stabilization and other habitat modifications than the Williston–Yellowstone segment. Garrison Dam effectively isolates the two populations of sturgeon. Habitat conditions for sturgeon, which were presumably similar in these reaches before regulation and permitted unimpeded movements of sturgeon, thenceforth differed greatly above and below the dam.

Methods

Shovelnose sturgeon were captured from the Williston-Yellowstone and Bismarck segments by using gill nets and trammel nets during the spring and summer. Gill nets were 30.5 m long by 1.8 m deep, with 7.6 cm mesh. Trammel nets were 45.7 m long × 1.8 m deep, with 5.1-cm inner and 30.5-cm outer mesh. In addition, fish were sampled from the Williston–Yellowstone segment during spring creel censuses. A total of 736 shovelnose sturgeon were sampled from the two segments: 580 fish from the Williston–Yellowstone segment and 156 fish from the Bismarck segment. Fish were sampled from the Williston–Yellowstone segment in 1991, 1992, 1993, 1995, and 1996 and from the Bismarck segment in 1995 (Table 1). Each shovelnose sturgeon was measured for fork length and weighed. Gender was determined for most of the creeled fish.

The first ray of the left pectoral fin was removed for age analysis. Collins and Smith (1996) reported that the complete removal of the first pectoral fin ray was nondeleterious in both shortnose sturgeon *Acipenser brevirostrum* and Atlantic sturgeon *A. oxyrinchus*. Our method was less invasive in that we removed only a portion of the pectoral fin ray. The rays were clipped at the point of attachment and again distally about 2.5 cm from this point.

TABLE 1.—Summary of the number of pectoral fin rays collected, aged, and removed from analysis because of age discrepancies.

Year	Collected	Removed	Aged
Williston–Yellowstone			
1991	104	2	102
1992	241	10	231
1993	87	1	86
1995	53	0	53
1996	95	2	93
Bismarck			
1995	156	11	145
Total	736	26	710

Each ray was cleaned and cut by using a procedure similar to that outlined by Brennan and Cailliet (1989). From near the proximal end of each ray, two 0.635-mm-thick sections were cut by using a Buehler Isomet low-speed saw with a diamond-edged blade. Sections were mounted on slides with clear fingernail polish. The image of each section was displayed onto a computer monitor with a microscope camera. The aging characteristics of the fin rays were assessed with the aide of BioSonics Optical Pattern Recognition System (OPRS; BioSonics 1987). The OPRS recognized differentially illuminated portions of the image. Opaque bands were assumed to have formed during the summer, translucent bands (annuli) during the winter. One pair of opaque and translucent bands constituted 1 year's growth. Annuli were counted from the center of ossification (focus) anteriorly along the longest axis to the distal edge of each section (Rossiter et al. 1995). This method of aging sturgeon has been validated for Atlantic sturgeon (Secor et al. 1997), lake sturgeon *A. fulvescens* (Rossiter et al. 1995; LeBreton and Beamish 2000), and white sturgeon *A. transmontanus* (Brennan and Cailliet 1991; Tracy and Wall 1994). All work was done without specific knowledge of the length, weight, origin, or gender of the fish. Two technicians interpreted each fin ray independently. If there was a discrepancy between the two annuli counts, then the fin ray was reexamined by each technician. If the discrepancy was not resolved after the second examination, then the fin ray was reexamined with both technicians present. If the discrepancy was not resolved after the third examination, then the fin ray was removed from the sample. This procedure resulted in removal of 26 fish from the samples (15 from the Williston–Yellowstone segment and 11 from the Bismarck segment).

Lengths at age were used to estimate von Bertalanffy growth curves. Growth curves were estimated separately for each river segment. In addition, growth curves were estimated separately by gender for creeled fish from the Williston–Yellowstone segment. The von Bertalanffy growth equation is $L(t) = L_\infty[1 - e^{-K(t-t_0)}]$ where L_∞ represents the length of an infinitely old fish; K represents a curvature parameter, or how fast the fish reach L_∞; and t_0 is an initial condition parameter. Maximum likelihood estimates were obtained for the von Bertalanffy equation parameters by using Proc NLP in SAS/OR software (SAS Institute 1987).

Von Bertalanffy growth curves were compared to test the null hypothesis that shovelnose sturgeon growth rates were not significantly different between fish inhabiting the Williston–Yellowstone and Bismarck segments. A likelihood ratio test (Kimura 1980; Hyndes and Potter 1996) was used to test for differences between river segments using the asymptotic chi-square distribution of the test statistic to obtain P-values. Similarly, a likelihood ratio test was used to test for differences between genders for creeled fish from the Williston-Yellowstone segment.

Results

Fish creeled from the Williston–Yellowstone segment ranged from 1 to 39 years in age (Figure 2A) and from 269 to 956 mm in fork length (FL; Figure 3A). Fish netted from the Williston–Yellowstone segment ranged from 1 to 43 years old (Figure 2B) and from 202 to 996 mm FL (Figure 3B). Fish netted from the Bismarck segment ranged from 5 to 37 years old (Figure 2C) and from 350 to 680 mm FL (Figure 3C).

Within the Williston–Yellowstone segment, females grew significantly faster than males (Figure 4). The likelihood ratio test for difference between genders had a test statistic value of 169.7 on 3 df, yielding a P-value far less than 0.0001. An age-15 female averaged 772 mm FL, compared with only 669 mm for a male. After age 15, female growth in length was negligible, whereas males continued to grow.

Mean fork length differed between fish creeled and netted within the Williston–Yellowstone segment (t-test, $P < 0.05$). Creeled fish averaged 100 mm FL longer than netted fish. In addition, the distribution of fork lengths sampled by anglers was narrower than the distribution sampled by netting. Also, the sex ratio of creeled fish strongly favored females. Because of the differences observed in mean fork lengths, range of fork lengths, and sex

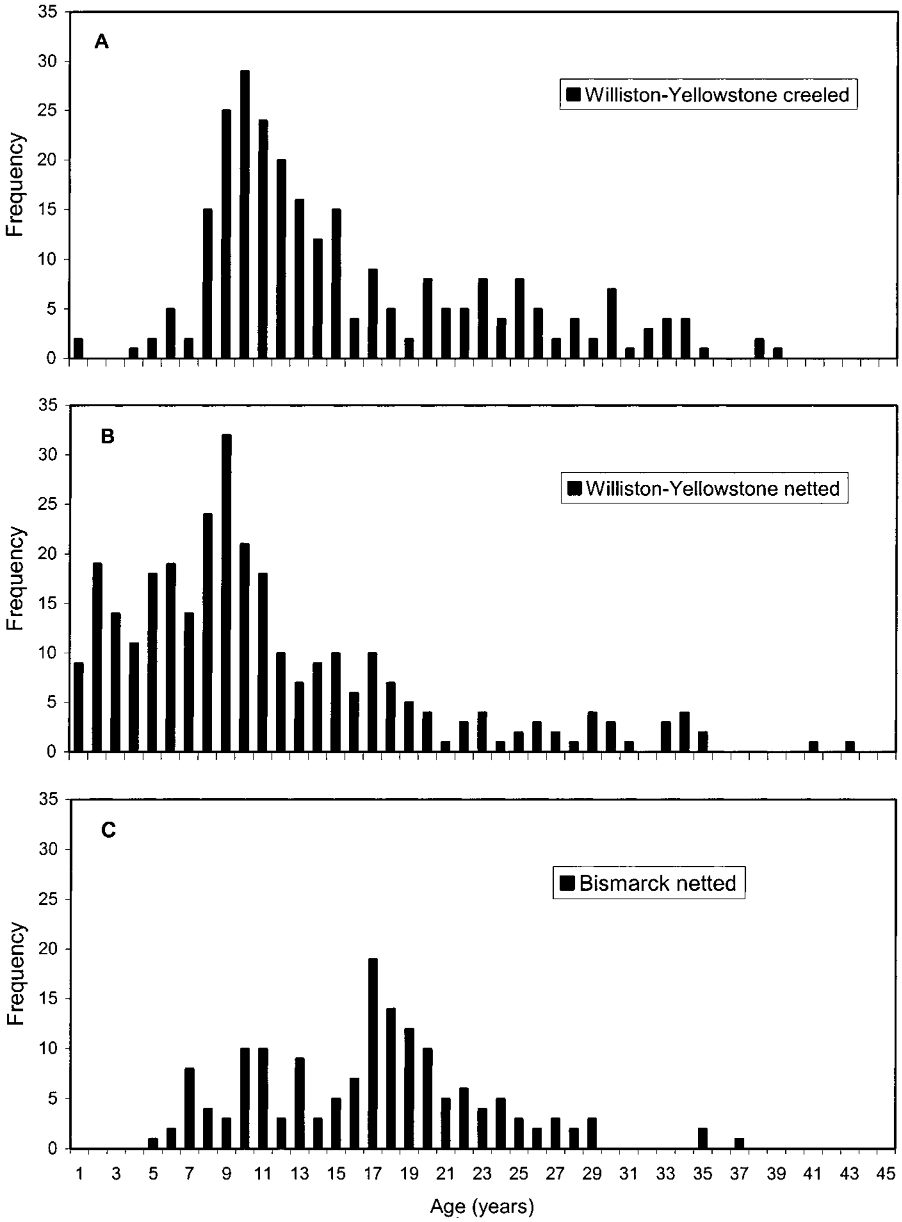

FIGURE 2.—Age-frequency distributions for (**A**) creel-sampled shovelnose sturgeon from the Williston–Yellowstone segment, (**B**) netted shovelnose sturgeon from the Williston–Yellowstone segment, and (**C**) netted shovelnose sturgeon from the Bismarck segment.

ratio, creeled fish within the Williston–Yellowstone were not combined with netted fish within that segment when comparing growth rate differences between segments. Therefore, the subsequent analysis was based on 303 fish of unknown sex netted from the Williston–Yellowstone segment and 145 fish of unknown sex netted from the Bismarck segment.

For netted fish, shovelnose sturgeon in the Williston–Yellowstone segment grew significantly faster than fish in the Bismarck segment (Figure 5). Therefore, the null hypothesis that shovelnose sturgeon had equal growth rates between segments was rejected. The likelihood ratio test for difference between river segments had a test statistic value of 638.8 on 3 degrees of freedom, yielding

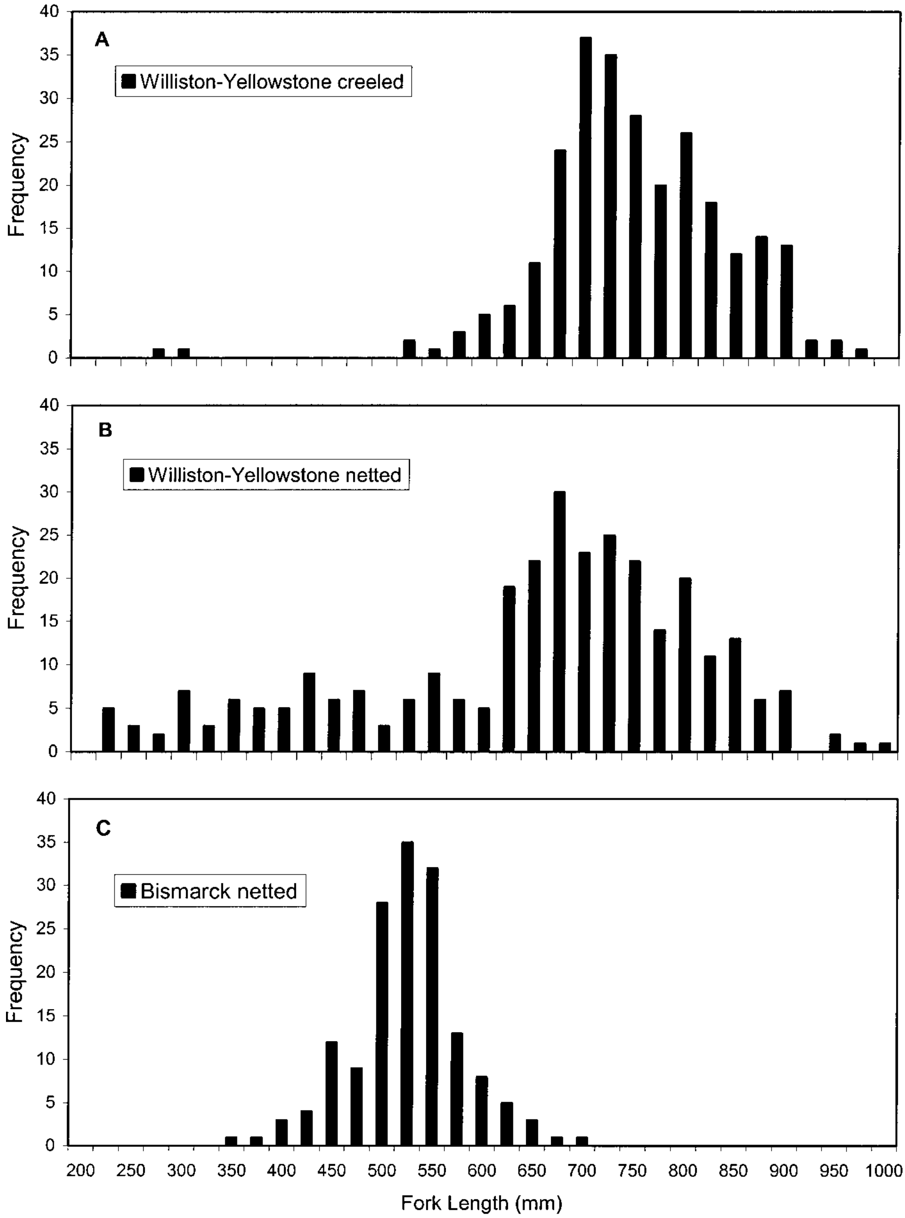

FIGURE 3.—Length-frequency distributions for (**A**) creel-sampled shovelnose sturgeon from the Williston–Yellowstone segment, (**B**) netted shovelnose sturgeon from the Williston–Yellowstone segment, and (**C**) netted shovelnose sturgeon from the Bismarck segment.

a P-value far less than 0.0001. The fork length of an age-10 fish in the Williston–Yellowstone segment averaged 689 mm, compared with only 457 mm in the Bismarck segment. After age 10, differences in growth rate between the two segments were less pronounced, but fish in the Bismarck segment remained smaller than in the Williston–Yellowstone segment.

Discussion

The mean lengths at age of shovelnose sturgeon vary greatly with geographical location (Figure 6). The mean lengths at age of shovelnose sturgeon from the slightly altered Williston–Yellowstone segment are similar to those reported for shovelnose sturgeon in the Missouri River, Montana, above the confluence of the Yellowstone River

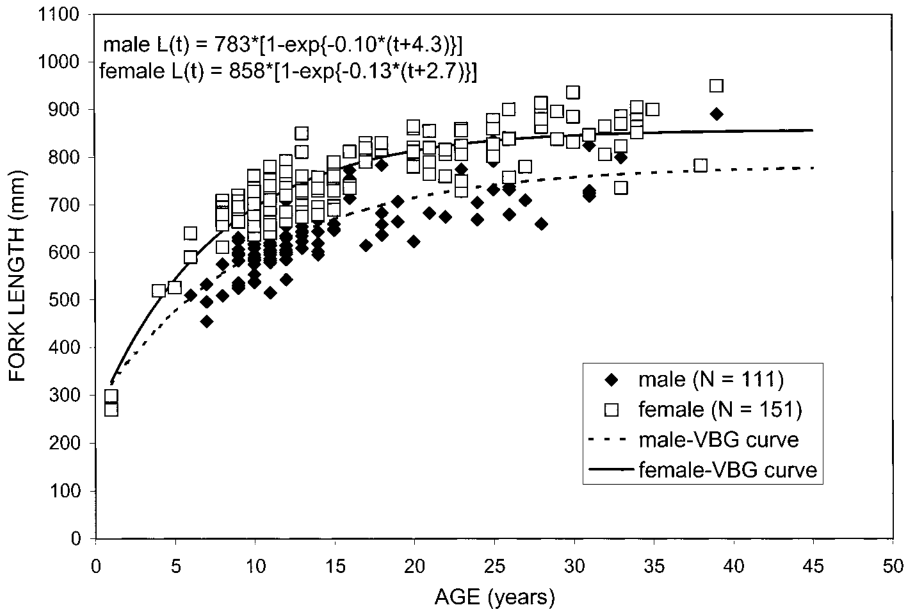

FIGURE 4.—Von Bertalanffy growth (VBG) curves of male and female shovelnose sturgeon from the Williston–Yellowstone segment.

(Gardner and Stewart 1987). Similarly, the mean lengths at age of shovelnose sturgeon from the highly altered Bismarck segment are similar to those reported for shovelnose sturgeon in the Missouri River, South Dakota, below Gavins Point Dam, Nebraska (Zweiacker 1967).

Our length distribution results are consistent with those of Elstad et al. (1992), who reported that shovelnose sturgeon netted in the Williston–Yellowstone segment attained a greater length (maximum FL, 910 mm) than the largest fish netted in the Bismarck segment (maximum FL, 710 mm).

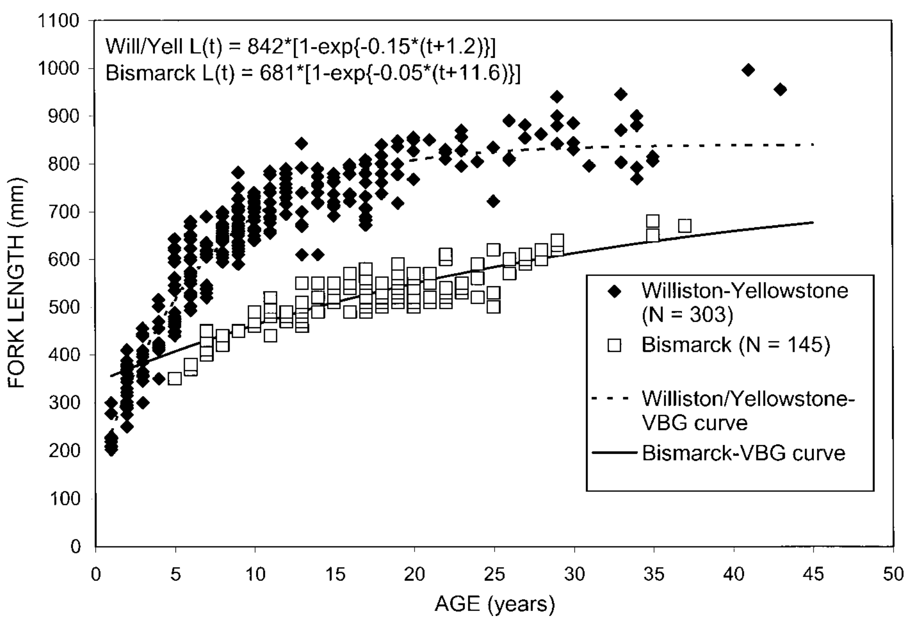

FIGURE 5.—Von Bertalanffy growth curves of shovelnose sturgeon from the Williston–Yellowstone and Bismarck segments.

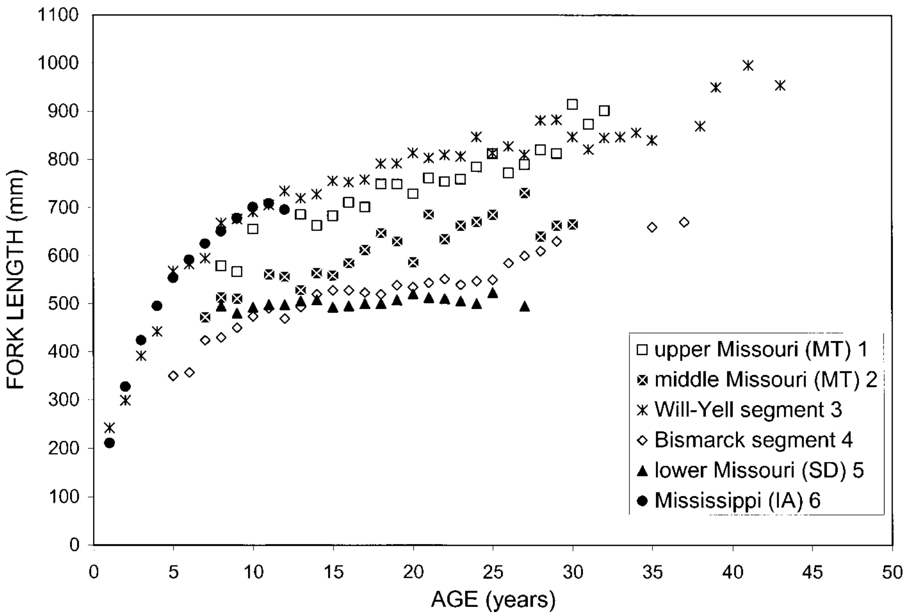

FIGURE 6.—Mean lengths at age for different shovelnose sturgeon populations in the Missouri and Mississippi rivers: 1, Missouri River above Fort Peck Reservoir, Montana (from Berg 1981); 2, Missouri River above the confluence with the Yellowstone River, Montana (from Gardner and Stewart 1987); 3, Williston–Yellowstone segment of the Missouri and Yellowstone rivers; 4, Bismarck segment of the Missouri River; 5, Missouri River above Vermillion, South Dakota (from Zweiacker 1967); and 6, Pool 13 of the Mississippi River, Iowa (from Helms 1974).

They found that the length distribution in the Williston–Yellowstone segment (range, 320–910 mm FL) also included smaller, presumably younger, fish (320–500 mm), whereas these fish were absent in the narrower length distribution (500–710 mm) of the Bismarck segment. They attributed the narrower distribution in the Bismarck segment to slower growth and the inadequate reproduction and recruitment of small fish. Our results indicated that although fish in the Bismarck segment were shorter than in the Williston–Yellowstone segment, they were not younger but simply grew more slowly (Figure 3).

Habitat changes in the Bismarck segment may explain much of the difference in growth observed between the two segments. After the closure of Garrison Dam in December 1953, the Bismarck segment underwent major changes in water temperature (Figure 7A), hydrograph (Figure 7B), and water clarity (Figure 7C). Hypolimnetic releases from Lake Sakakawea resulted in lower temperatures in the Bismarck segment. As of 1996, mean monthly water temperature in the Missouri River at Bismarck during the peak growing season (June–August) averaged about 7°C colder (14°C versus 21°C) than in the Yellowstone River at Sidney, Montana. The effect of temperature on fish growth is well documented. Gershanovich (1983) observed a twofold increase in metabolism for sheap sturgeon *A. nudiventris* over a temperature increase of 12°C (from 12°C to 24°C). Cech et al. (1984) showed that growth of age-1 white sturgeon was greater at 20°C than at 15°C. Lutes et al. (1990) showed that growth was greater at 18.4°C than at 14.7°C for white sturgeon larvae. Furthermore, Fortin et al. (1996) showed a positive relationship between mean annual air temperature and total length in different populations of lake sturgeon. An increase of 1°C resulted in an average increase of 40 mm for a lake sturgeon between ages 23 and 27. In addition, Nilo et al. (1997) found significant ($P < 0.05$) positive correlation between warmer water and year-class strength in lake sturgeon.

Another important habitat change associated with Garrison Dam was the alteration of the Bismarck segment's hydrograph. Shovelnose sturgeon feed primarily on aquatic invertebrates (Modde 1971; Helms 1974; Modde and Schmulbach 1977), and altered river discharge affects their growth in-

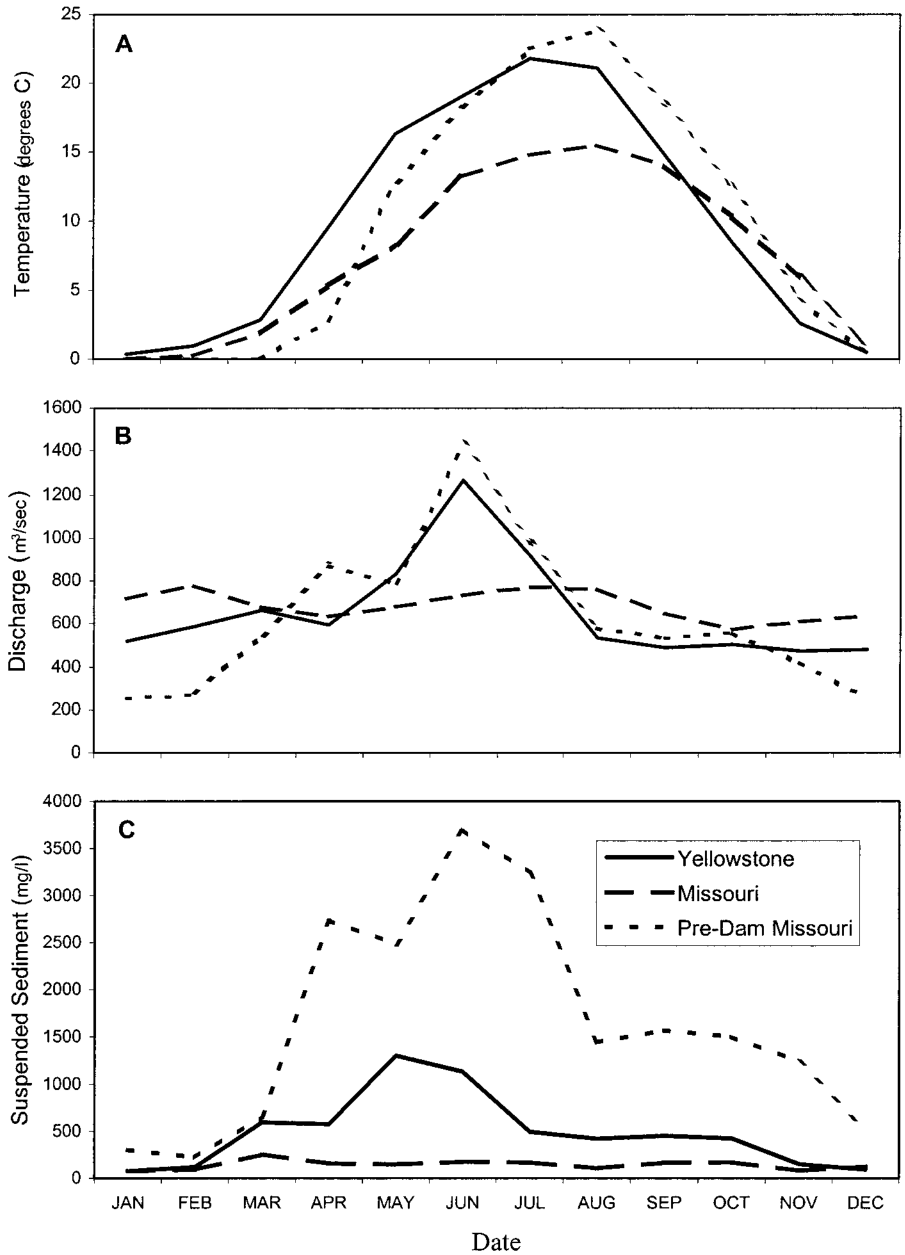

FIGURE 7.—(**A**) Mean monthly water temperature for the Yellowstone River at Sidney, Montana, from 1971 to 1996; for the Missouri River at Bismarck, North Dakota, from 1971 to 1996 (USGS 1998); and for the Missouri River at Bismarck from 1947 to 1953 (predam; data provided by the Bismarck wastewater treatment plant, Bismarck, North Dakota). (**B**) Mean monthly discharge for the Yellowstone River at Sidney, Montana; for the Missouri River at Bismarck, North Dakota, from 1971 to 1996; and for the Missouri River at Bismarck from 1928 to 1953 (predam; USGS 1998). (**C**) Mean monthly suspended sediment for the Yellowstone River at Sidney, Montana, from 1971 to 1996; for the Missouri River at Bismarck, North Dakota, from 1971 to 1996; and for the Missouri River at Bismarck from 1946 to 1953 (predam; USGS 1998).

directly through effects on food supply. Irvine (1985) showed that artificial flow perturbations decreased benthic invertebrate densities. Increased channelization and reduction in backwater areas have led to decreased benthic invertebrate densities in the Missouri River (Hesse and Mestl 1993). During periods of low water, invertebrates concentrate in backwater sloughs in high concentrations. Modde and Schmulbach (1977), studying shovelnose sturgeon from the Missouri River below Gavins Point Dam, Nebraska, suggested that increased water velocities mobilize shovelnose sturgeon prey species, thereby resulting in decreased concentration of food. Furthermore, they found shovelnose sturgeon had lower condition factors during periods of high discharge. In contrast, Megargle and White (1997) found no evidence of discharge affecting shovelnose sturgeon prey items above Fort Peck Reservoir, Montana. Their study area had a natural hydrograph with a relatively large shovelnose sturgeon population that grew to a large size (as much as 3.7 kg).

The lower growth rates observed in the Bismarck segment could have several effects on the population. Slow growth increases the time smaller sturgeon are vulnerable to predation. In addition, marked delays in maturation may occur, especially in a late-maturing species such as shovelnose sturgeon (Hurley and Nickum 1984). Slower growth results in lower production from the population. Moreover, the lack of young shovelnose sturgeon (year-classes 1–4) in the samples collected from the Bismarck segment suggests low recruitment and reproduction. In contrast, the habitat conditions in the Williston-Yellowstone segment serve as a good model for shovelnose sturgeon management. Shovelnose sturgeon from this segment showed faster growth rates and an abundance of diverse year-classes and supported a successful recreational fishery in Montana. Reproduction and recruitment of this population is also occurring; age-1 and age-2 fish have been incidentally caught at Intake, Montana, by paddlefish *Polyodon spathula* snaggers every year since the early 1990s (Scarnecchia, unpublished).

Further information is needed to clarify the effects of habitat alteration on shovelnose sturgeon growth. Techniques need to be refined to capture age-0 and age-1 shovelnose sturgeon more effectively. Specific dietary differences of sturgeon between the two segments of river environment need to be described. In addition, differences in prey selectivity as well as prey availability need to be identified in these segments as well as throughout the Missouri River. Finally, the relationship between habitat characteristics and forage abundance needs to be determined. Information in these areas will help to clarify the mechanism through which shovelnose sturgeon growth differs between the two river segments.

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