PERFORMANCE REPORT

Pallid Sturgeon Research and Recovery Efforts in the Upper Missouri River, MT

STATE: MONTANA

PERIOD COVERED: July 1, 2002 through June 30, 2003

PROJECT PERSONNEL: Bill Gardner
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OBJECTIVE:

1. **To determine habitat preference, movements, abundance, feeding and growth of wild pallid sturgeon in Recovery Management Area 1.**

2. **Conduct annual adult pallid sturgeon standardized netting to develop a baseline for future comparisons.**

3. **To assist with with collection of adult spawners for use in hatchery propagation efforts.**

4. **To assist with the release of hatchery-reared pallids and evaluate survival and recruitment over the years.**

5. **To coordinate and implement recovery efforts in conjunction with North Dakota, South Dakota, and the U.S. Fish and Wildlife Service.**

RESULTS:

A total of 732 hatchery-reared (HRJ) yearling pallids (1997 year class) were released into RPMA-1 during the summer, 1998. The pallid sturgeon augmentation plan called for annual stocking of juvenile pallids for 6 consecutive years, at which time the plan will be evaluated based on its effectiveness. Finally, after 3 years of no stocking, a second pallid sturgeon release was accomplished in 2002. A total of 2,063 yearling pallids (2001 year class) were stocked at 4 locations in the study area during the summer, 2002. This report deals with evaluating the success of these re-introductions and results of the pallid sturgeon effort during 2003.

It is important to evaluate the success of the pallid sturgeon augmentation program so that problems can be resolved early on in the program. Stocking densities, age of stocked fish, acclimation and growth of stocked fish, and location of release sites are all important aspects for evaluating survival and ultimately recruitment of the released HRJ pallid sturgeon.

The study area is a 168-mile reach of the Missouri River immediately upstream of Fort Peck Reservoir (Figure 1). Drift netting, setlining and angling were used to sample the HRJ pallids. Additionally, trawl sampling was conducted in the study area for assessing wild pallid and shovelnose sturgeon reproduction.

A total of 6 adult pallids, 24 HRJ 1997-year class pallid sturgeon (PLS-97) and 5 HRJ 2001-year class pallid sturgeon (PLS-01) were captured; 12 by netting, 4 by trawling, 2 by setlines and 17 by angling (Table 1). Table 2 is a list of the individual records for each pallid sturgeon. All of the pallid sturgeon were captured in the Robinson Bridge Section (RM 1902 - 1921), although sampling occurred throughout the entire study area.

Table 1
Effort by sampling method and number of pallid sturgeon captured in the Upper Missouri River Study Area, MT, during 2002-03.

	Effort	Adults	Juvenile-97	Juvenile-01	Total
Trammel net -	161 drifts	1	4	1	6
Spawning nets -	214 drifts	4	0	0	4
Trawl -	93 tows	0	0	4	4
Setlines -	25 sets	0	2	0	2
Angling -	---	0	17	0	17
		5	**23**	**5**	**33**

Juvenile pallid sturgeon netting survey:

Attempts were made to capture the HRJ pallid sturgeon by drifting small mesh trammel nets. A total of 1 adult, 4 PLS-97 and 1 PLS-01 pallids were captured by drift netting. Four of the 6 pallids were captured in channel cross-over habitat areas at depths of less than 6 ft. Additionally, a total of 1,056 fish, representing 17 species, were sampled while netting throughout the study area (Table 3). Shovelnose sturgeon (SNS), sauger, shorthead redhorse and goldeye dominated the catch comprising 44, 10, 9 and 7 percent of the fish sampled, respectively.

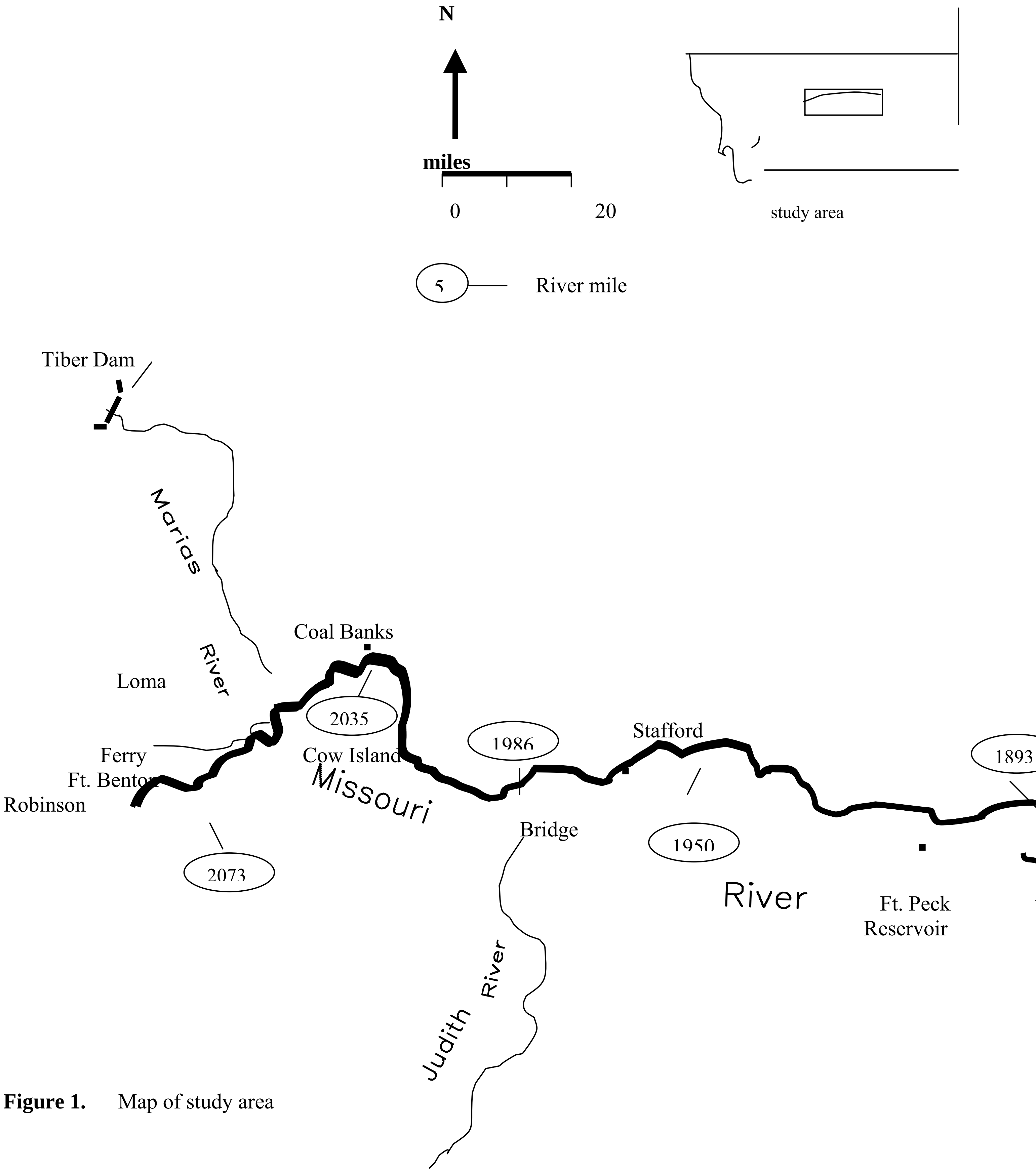

Figure 1. Map of study area

Table 2. A list of hatchery-reared pallid sturgeon captured in the Upper Missouri River, MT, 2002-03.

#	PIT Number	Color	Recap date	Recap Rivermile	Release Rivermile	Recap Meth.	FL (in)	TL (lb)
1	414D675574	Green	8/20/02	1921.2	2051.2	Hk & Line	18.8	0.75
2	411D0A3152	Yellow	8/23/02	1915.8	Lost PIT	Hk & Line	20.1	0.93
3	414D58501E	Red	8/23/02	1921.2	2051.2	Hk & Line	20.6	1.11
4	4359544666	Grn/Bl	8/26/02	1904.5	1920.6	Trawl	10.5	
5	434D707260	Pnk/Bl	8/26/02	1904.5	1920.6	Trawl	11.6	
6	435E311B3F	Brn/Bl	8/26/02	1903.0	1920.6	Trawl	9.6	
7	435F205A79	Brn/Bl	8/26/02	1903.0	1920.6	Trawl	9.8	
8	411D094840	Green	8/27/02	1918.2	Lost PIT	Hk & Line	17.5	0.61
9	411D175D57	Yellow	8/27/02	1901.5	Lost PIT	Hk & Line	18.2	0.66
10	414D44475A	Orange	8/28/02	1920.5	1984.3	Hk & Line	18.2	0.75
11	414D610D5E	Red	9/24/02	1916.4	1984.3	Trammel	20.9	1.1
12	435D141E1A	Purp/Bl	9/24/02	1916.4	1920.6	Trammel	12.0	
13	G-01433	Wild	9/24/02	1916.2	1909	Trammel	50.3	29.5
14	411D2E771E	Yellow	9/25/02	1911.0	Lost PIT	Trammel	19.2	0.78
15	414D45357E	Red	4/08/03	1915.5	1921.2	Set line	20.3	0.92
16	414D54266F	Red	4/09/03	1905.6	1921.2	Trammel	20.7	1.00
17	4526652B17	Green	4/09/03	1917.2	Lost PIT	Set line	19.3	1.28
18	45292A661D	Yellow	4/09/03	1901.0	Lost PIT	Hk & line	19.4	1.11
19	414D3A5536	Green	4/09/03	1917.8	2051.2	Hk & line	17.3	0.65
20	41095B0556	Yellow	4/09/03	1902.7	2051.2	Hk & line	19.7	0.87
21	414D3A365B	Orange	4/10/03	1912.7	1984.3	Hk & line	18.1	0.75
22	414D54611B	Orange	5/29/03	1917.1	1921.2	Hk & line	19.9	0.92
23	45294F0A55	Yellow	5/30/03	1921.0	Lost PIT	Trammel	19.4	0.80
24	414D621E44	Green	6/05/03	1913.2	1984.3	Hk & line	20.2	1.10
25	45252B7F44	Green	6/05/03	1913.2	New PIT	Hk & line	19.8	0.91

Table 2. Continued.

#	PIT Number	Color	Recap date	Recap Rivermile	Release Rivermile	Recap Meth.	FL (in)	TL (lb)
26	414D6010C69	Blue	6/09/03	1915.7	1984.3	Hk & line	22.2	1.24
27	414D490E09	Green	6/10/03	1907.0	1921.2	Hk & line	19.3	0.95
28	414D556218	Orange	6/18/03	1915.6	1984.3	Hk & line	21.8	1.24
29	452A3D6110	Green	6/18/03	1915.6	Lost PIT	Hk & line	22.0	1.4
30	452A4E1F15	Wild	5/28/03	1916.0	New fish	Spawn net	50.4	33.0
31	452738076E	Wild	6/06/03	1916.3	New fish	Spawn net	57.0	37.4
32	411D0E2C5F	Wild	6/09/03	1916.0	1916	Spawn net	56.0	36.0
33	1F4A4B5973	Wild	6/13/03	1916.0	1916.0	Spawn net	49.5	28.0

Table 3. Average catch rates (no./drift) of fish sampled while drifting trammel nets in the Upper Missouri River, MT, April-October, 2002-03.

	Ft. Benton	Loma	Judith L.	Robinson	Total #
Bigmouth Buffalo				tr	1
Blue sucker			0.1	tr	3
Carp		0.2	0.1	0.2	27
Channel catfish		0.1		0.1	8
Flathead chub				tr	2
Freshwater drum		0.1		tr	4
Goldeye	6.0	2.4	0.4	0.3	71
Longnose sucker	3.0	0.4	0.6	tr	12
Northern pike				tr	1
Paddlefish				0.1	16
Pallid sturgeon				0.1	6
River carpsucker		0.4		0.5	49
Sauger		0.7	0.3	0.9	108
Shorthead redhorse	3.0	1.9	1.5	0.5	91
Shovelnose sturgeon	19.0	17.2	1.5	2.2	468
Smallmouth buffalo			0.2	0.2	21
Walleye				0.2	19
Total # fish	29	234	79	714	1,056
Total # drifts	1	10	14	136	161
Average depth (ft.)	4.5	5.6	6.6	5.4	
Average distance (yd.)	350	282	146	233	
Avg. duration (min.)	7	6.1	6.8	6.6	

Benthic trawling:

The main purpose for trawling was to evaluate pallid and shovelnose sturgeon spawning success. A total of 299 fish, representing 14 species, were sampled while trawling during August in the Judith Landing and Robinson Bridge sections (Table 4). The average physical conditions measured for the 93 tows were: Column water velocity = 2.2fps (1.3-2.8); Depth = 7.6ft (3-18); Channel location/macro-habitat = 55% channel cross-over area (CHXO), 20% inside bend area (ISB), 18% outside bend area (OSB), 1% side channel-connected (SCC), and 6% at tributary mouth (TRM). Most of the trawling occurred in the lower 36 miles of the study area between RM-1921 and RM-1885 where it is thought most of the age-0 SNS usually reside. Sicklefin chub, stonecat, channel catfish and sturgeon chub dominated the catch comprising 37, 21, 17 and 10 percent of the fish sampled, respectively.

Four hatchery reared PLS-01 were sampled trawling, all caught in deep water areas (>9 ft). Based on PIT tag numbers, these pallids were originally stocked in the general vicinity, one month prior to the date of capture. It appears that trawling is fairly effective for sampling hatchery reared yearling pallids. Only 1 age-0 SNS were sampled this year compared to 2 in 2001 (Gardner 2002). During the first year of intensive trawling (1995) a total of 28 age-0 SNS were sampled in about 100 tows (Gardner 1996) indicating this method was effective at sampling age-0 SNS when they are more numerous. Based on the low catches of age-0 SNS this year and previous years, it appears there has been poor SNS spawning success at least during the past 3 years.

Other sampling methods:

Setline fishing and angling enables us to effectively sample difficult places to net that could be important habitat areas for juvenile pallid sturgeon. Setlining is a more passive sampling technique than angling and easier to standardized, so that a fairly unbiased measure of abundance can be applied for this method. Only a minor effort, using these techniques, were initiated in 2003 because the main purpose was to evaluate the effectiveness of these unconventional methods. The setline sampling effort was light, consisting of only 25 sets over five days, however, two HR PLS-97 were captured (Table 5).

Additionally, a total of 64 fish, comprised of nine other species were sampled using the set lines. Angling was the most productive method used for capturing pallid sturgeon, particularly the PLS-97 group. Seventeen hatchery PLS-97, comprising about 50% of all pallids caught during this one-year period, were sampled while angling for approximately 100 angler hours spread out over 25 days (Table 1). Circle hooks, size 2 and 4 were used for both angling and setlines instead of the more common "J"-type hook, to prevent the pallids from swallowing the hook.

Fall pallid sturgeon standardized baseline survey:

A total of 4 pallid sturgeon were sampled while conducting the fall survey in the 16-mile Robinson Bridge trend area (Table 6). The one adult, wild, pallid sturgeon that was netted was initially captured in 1991 and subsequently captured 2 more times over the years. Three juvenile hatchery pallids, 2 PLS-97 and 1PLS-01 were also netted during the survey. This baseline survey has been completed 5 times since 1996; Table 6 summarizes these survey results.

Table 4. Average catch rates (average number/tow) of fish sampled by trawling in the Middle Missouri River, MT, 2002.

	Judith L.	**Robinson**	**Total #**
Brook stickleback		tr	1
Burbot y		tr	2
Channel catfish		tr	4
Channel catfish y		0.5	46
Flathead chub	1.0	0.1	12
Flathead chub y		0.1	9
Goldeye y		tr	1
Hybognathus spp		0.1	10
Longnose dace	0.2		3
Longnose sucker y		tr	1
Pallid sturgeon		tr	4
Shorthead redhorse y		tr	2
Shovelnose sturgeon y		tr	1
Sicklefin chub	0.7	1.2	110
Stonecat		0.3	40
Stonecat y	1.0	0.1	23
Sturgeon chub		0.2	17
Sturgeon chub y		0.1	13
# Tows	12	81	93
Avg. Depth (ft)	5.1	7.9	7.6
Avg. Col. Velocity (fps)	2.2	2.2	2.2
Macro-habitat type (%)			
CHXO	33	58	
ISB	8	22	
OSB	8	19	
SCC	8		
TRM	42		

Y = age-0 fish

Table 5. Average catch rates (average number/set) of fish sampled by set lines in the Middle Missouri River, MT, 2003.

	C. P. U. E. - Judith L.	C. P. U. E. - Robinson	Total # Fish
Carp	0.1	0.1	2
Channel catfish	0.6	0.1	6
Flathead chub	0.6	0.6	15
Goldeye	0.9	1.1	26
Pallid sturgeon		0.1	2
Sauger	0.3	0.1	4
Shorthead redhorse	0.4	0.2	6
Shovelnose		0.1	1
Stonecat	0.1	0.1	2
Walleye	0.3		2
Total # Fish	23	43	66
# Sets	7	18	25

Table 6. Sampling statistics recorded for the pallid sturgeon standardized sampling program in the Upper Missouri River, MT, 1996-2002.

	1996	**1997**	**1999**	**2000**	**2001**	**2002**
Pallid Strugeon:						
Number sampled	3	1	1	3	4	4
Avg. Wt. (lb)	38.0	40.6	0.33*	0.61*	0.60*	7.90*
Number/drift	0.06	0.02	0.02	0.06	0.08	0.08
Shovelnose Sturgeon:						
Number sampled	225	131	153	392	274	128
Avg Wt. (lb)	3.15	3.17	3.30	3.42	3.40	3.70
Number/drift	4.5	2.6	3.1	7.8	5.5	2.6
Average drift duration (min)	6.3	6.5	6.7	7.1	7.2	7.0
Average drift distance (yd)	239	294	239	222	281	259
Average depth @ drift site (ft)	7.1	8.3	7.1	6.0	4.7	5.4

Juveniles present in sampl

Pallid sturgeon sightings, July1, 2002 to June 30, 2003:

Angler reports of pallid sturgeon sightings were recorded by MSU graduate students, FWP creel clerk, game wardens and the pallid sturgeon crew. All sighting reports were scrutinized for identification and accuracy because of the taxonomic similarities between pallid and the commonly caught shovelnose sturgeon. Only pallid sturgeon sightings that included observations of colored elastomere marks on the ventral rostrum, presence of a transmitter, actual measurements of inner and outer barbel lengths (OBL $\geq$ 2X IBL), body length measurements (TL > 48 inches) or weight (>16 lbs.) were accepted as valid sightings.

Angler reports:

Number caught while snagging for paddlefish	= 1 (adult)
Number caught while bait fishing	= 0

Pallid crew sampling:

Number caught in 6x10 gillnets	= 4 (adults)
Number caught in trammel nets	= 6 (1 adult, 4 PLS-97, 1 PLS-01)
Number caught by trawling	= 4 (all PLS-01)
Number caught by gill netting	= 2 (all PLS-97; Ft. Peck R)
Number caught by angling	= 17 (all PLS-97)
Number caught by set lines	= 2 (all PLS-97)

Only 1 confirmed angler caught and released pallid was reported this year; this adult was caught while snagging for paddlefish. This spring the usual paddlefish creel was not conducted and is probably a factor for the lower number of sightings by the public. Several pallid sturgeon were observed by fisheries crews this year and probably is the results of more effort, presence of more hatchery pallids and improved sampling efficiencies at catching hatchery pallids.

Propagation assistance:

Preserving a representation of the Upper Missouri River pallid sturgeon gene pool is an important goal for recovery. To that end, a pilot effort was initiated in 2000 to test the feasibility of collecting sperm from wild male pallids in this area and ship the fresh milt to Garrison National Fish Hatchery (GNFH) for use in their pallid sturgeon propagation program and cryopreserve representative sperm samples. Results from the initial effort proved worthwhile and collection of pallid sperm from the wild population was incorporated into my work plan.

River flow conditions during June, 2003 were somewhat normal, with discharges ranging from about 9,000 to 16,000 cfs during June. However, these higher June flows made netting for adult pallid sturgeon considerably more difficult than it had been during the low run-off years. Four males were captured and examined for spawning readiness. A list the pallid sturgeon captured and their sizes and tag numbers are presented in Table 7. All of the male pallids were sexually mature and held in a 16 ft diameter tank for staging. Propagation in the study area did not occur again this year because a female pallid was not captured. Sperm samples from all the male pallid sturgeon were shipped to GNFH and cryopreserved for use in the future propagation effort.

Table 7. A list of pallid sturgeon spawners captureded during spring 2003, Upper Missouri River, MT.

PIT #	DATE	FL (in)	WT (lb)	Rivermile	Sex	Recap
452A4E1F15	May 28	50.5	33.0	1916.0	M	No
452738076E	June 6	57.0	37.4	1916.3	M	No
1F4A4B5973	June 13	49.5	28.0	1916.0	M	Yes
411D0E2C5F	June 9	56.0	36.0	1916.0	M	Yes

Shovelnose Sturgeon Irido Virus assistance:

The Shovelnose Sturgeon Irido Virus (SSIV) was first discovered in a group of yearling shovelnose sturgeon at Gavins Point National Fish Hatchery during December, 1998. It was unknown where the virus originated, although most investigators suspect it may have originated from wild sturgeon brought into the hatchery. Because of the uncertainty of the virus origin, the viruses virulence and concern for wild sturgeon populations in Montana, FWP suspended all pallid sturgeon stocking (from outside sources) in RMA-1, beginning in 1999, until more information becomes available. This partial suspension of stocking pallid sturgeon in RMA-1, now in its 5th year, has severely limited recovery efforts in the area. Not only has this suspension reduced numbers of pallids released , but also, has reduced the number of families (genetic variability) that can be stocked. RMA-1 is loosing its value as a secondary brood stock reserve. Therefore, it is important to increase our knowledge on SSIV and re-evaluate the stocking restriction in this area relative to SSIV concerns. The USFWS Fish Health Lab, Bozeman, MT, initiated SSIV sampling of wild sturgeon in 1999 and this effort, along with the FWP health biologists, continues to collect samples each year. Tissue samples were collected from 50 shovelnose sturgeon from the Upper Missouri River, during 2003. These samples were fixed in a preservative and sent to the lab for histological analysis. Results from this sampling is still pending, although previous years collections have never tested positive for SSIV.

Evaluation of pallid sturgeon reintroduction and other observations:

The second release of hatchery pallid sturgeon into RMA-1 since the program began in 1998 was completed July 23 and 24, 2002. These pallids were from the local Upper Missouri River stock comprised of 5 families (1 female mated with 5 males). The reason for the 4 year delay between releases was because of SSIV concerns expressed from FWP. A total of 418 pallids were released in the Missouri River at Marias River confluence (RM-2051), 375 at Coal Banks Landing (RM-2031), 375 at Judith Landing (RM-1984) and 895 at Robinson Bridge area (RM-1921); 2,063 in all. The reason for greater numbers released at Robinson was because 476 PLS-01 were designated for research purposes (age validation, radio telemetry and anatomical condition), and therefore, compensate for any effects or losses associated with studying these fish. The PIT tags of the individual pallids were recorded and released at specified release sites so that we could evaluate survival success for a particular release location. The pallids were received in good condition, although a portion had some evidence of pectoral fin deformity as a result of undetermined nutrient/mineral deficiencies in their hatchery diet. The PLS-01 averaged 9.2 inches fork length (range = 6.5 - 16.0) and weighed an average of 0.11 lb (9.0 fish/lb). At the time of release river flow was about 5,000 cfs, slightly below average for this time of year and water temperatures ranged 70 -75 F.

Attempts were made to sample as many juvenile pallids as possible for evaluation of growth, movement patterns, habitat selection and abundance estimates. All release site areas were sampled, although a greater amount of effort was directed in the Robinson Bridge area. A total of 28 hatchery juvenile pallids were captured during the period July1, 2002 and June 30, 2003. Of this total, PIT tags were found in only 68% of the juvenile pallids. Only 5 PLS-01 out of the 2,063 released were subsequently captured; all in the summer/fall, 2002. Based on PIT tag readings, all 5 fish were originally released in the Robinson Bridge area.

Most of the hatchery pallids that were captured were from the PLS-97 group, stocked in 1998. These fish were age-5 during 2002 and age-6 during 2003. All PLS-97 were captured in the Robinson Bridge area although only 29% were initially stocked in the area. Clearly, most of the pallids captured in the Robinson Bridge area were from the upriver release sites; 43% of the PLS-97 originated from Judith Landing and 29% from Marias River Confluence. Past information on the PLS-97 group shows the same trend where 63% of the pallids captured at the Robinson Bridge were originally released at the upriver sites (Gardner 2001 & 2002).

A total of 38 PLS-97's have been captured and measured over the past 6 years. Table 3 shows the average fork length for these pallids, although sample size is generally low. Over the last 2 years the PLS-97 group has been growing at the rate of 1.2 inches per year. There has not been a PLS-97 recaptured for a second time in the past 5 years of sampling, indicating a fairly high density and, therefore, indicating a high survival rate of the PLS-97's in RMA-1. A very rough estimate will be made next year using years 3-5 as the marking run and year-6 as the recovery run. Based on the survival rate estimates from the Stocking Plan (Upper Basin Pallid Sturgeon Workgroup, 2003) there should be a population of 74 PLS-97 pallids in RMA-1 after year-6.

It has long been recognized that re-establishing normal high spring flows in tributary streams is important for pallid sturgeon spawning migrations (Dryer and Sandvol, 1993). Gardner (1990) presented historic information regarding pallid sturgeon use at the confluence of the Marias River during a high flow event. Although the Marias River is dammed, it remains the largest tributary to the Upper Missouri River upstream of the Yellowstone. Because of this importance, FWP has been encouraging BOR to provide a spring pulse out of Tiber Dam when conditions are favorable. During 2002 conditions were favorable for a spring pulse and the BOR was able to provide a large spring discharge into the lower Marias River. High flows lasted for several weeks and peaked at 5,300 cfs on June 20. This was the greatest flow in the Lower Marias River since 1975 and was well over the estimated bankfull flow of 3,936 cfs. We didn't observe any pallid sturgeon at the Marias River confluence area, but were not too surprised due to the difficulty sampling under high flow conditions and the extremely low numbers of adult pallid sturgeon. High spring flow releases from Tiber Dam should be provided every 3-5 years when conditions are favorable.

An unusual mini-flood event occurred in the study area that seemed to have an interesting effect on the hatchery pallid sturgeon. Heavy rains in the area produced high river flows that were double of the preceding weeks flow (from 4,840 to 11,400 cfs). High flows lasted only about 5 days, however, we observed that 3 of 4 PLS-01 that were radio tagged drifted downstream 30-40 miles into the delta area of Fort Peck Reservoir. We did observe that 2 of the 3 radio pallids returned back upriver once the high flows subsided. Mike Ruggles, FWP reservoir biologist, reported other observations that further suggest pallid sturgeon drifted into the reservoir as a result of the sudden high flows were reported by. Ruggles captured and released two hatchery pallid sturgeon, PLS-97, (along with several wild shovelnose sturgeon) a few days after the high river flow event while conducting his annual netting surveys at the upper end of the reservoir. Very few, if any, sturgeon are usually sampled in the Fort Peck Reservoir wide netting surveys.

Table 3. Average sizes of the 1997- year class pallid sturgeon captured over the years since being released in 1998. Upper Missouri River, MT, 1998-2003.

	------ Average Fork-length (in.) at Age-class -----					
	1yr	**2yr**	**3yr**	**4yr**	**5yr**	**6yr**
Pallid juvenile-97 -	11.5	15.3	18.2	17.3	18.8	19.5
Number measured -	3	3	5	7	9	11

RECOMMENDATIONS

1. Continue with the intensive drift netting for HRJ pallid sturgeon. The success of the 1998 pallid release remains unknown and recapturing these fish will give better information on acclimation, survival and desirable release locations. Additional sampling methods such as angling and setlines should be added to the sampling program and a measure of effort should be devised so that these methods can provide an accurate, quantifiable catch rate index.

2. The fall pallid sturgeon abundance survey should be continued on an annual basis as funding allows. The HRJ pallid sturgeon should be approaching a size where they are more effectively sampled and this effort will more accurately describe their abundance in the area.

3. The Upper Missouri River pallid sturgeon gene pool needs to be preserved. Efforts to collect sperm from ripe males and eggs from females should continue as conditions allow. The fresh sperm should be either used during the current propagation year or stored in cryopreservation.

4. Continue sampling for age-0 pallid and shovelnose sturgeon with the trawl. Trawling has provided a considerable amount of information on shovelnose spawning success and the distribution and abundance of several unique fish species such as the sicklefin and sturgeon chubs

5. Annual releases of hatchery pallid sturgeon are essential for developing a pallid population with a genetically diverse and sound age structure. This is not happening in RMA-1 because of the difficulty with propagation and a severely restrictive ban on releasing hatchery pallids in the area due to SSIV concerns. These potential fish that were not stocked due to the ban were invaluable because of the impending threat of extinction in the area. A more reasonable disease management plan needs to be devised for the pallid sturgeon culture facilities so that releases of pallid sturgeon will occur on a regular basis in RMA-1.

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2003 Pallid Sturgeon Research and Recovery Efforts in the Upper Missouri River, MT.

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December, 2003

1. A total of 40 pallid sturgeon were captured this year (8 adults (*comprised of 5 recaptures and 3 new fish*); 29 juvenile-1997 and 3 juvenile-2001) **(Table 1).**

2. Attempted on-site spawning in June again (3rd year) and captured only 4 male pallids for on-site propagation. Therefore, we ended up only sending sperm from 3 males for cryopreservation at Garrison National Fish Hatchery (GNFH).

3. Assisted MSU with the habitat and food habits study by capturing several PS-97 for radio implants and diet studies.

4. We did not do a pallid sturgeon release this year because of FWP restrictions as it relates to SSIV concerns.

5. Completed our 7th pallid sturgeon baseline abundance survey. The purpose of the survey is to monitor changes in the pallid population using a standardized approach so comparisons can be made for evaluating treatments directed at improving the pallid sturgeon population. The sampling area is the same 16 miles of river where I believe most of the adult live. Our effort consists of drifting 50, 2" trammel nets in a prescribed manner at randomly selected sites during late-September. This effort in 2003 captured a total of 6 pallids (*1 juvenile-01, 4 juvenile-97, and 1 wild adult*) **(Table 2).**

6. The main interest of the pallid work in the study area has been directed at evaluation of the release of ~750 juvenile pallids, now 6 years-old (PS-97). What habitat conditions do they prefer, are they surviving and are they in a healthy condition, what are the best strategies for stocking pallids in the study area.

   - Are the PS-97 surviving at an acceptable rate? Since 1999 (1 yr after release) we sampled 57* different PS-97. Intuitively, I would say, yes, the PS-97s have good survival in RMA-1. Probability of recapture appears to be low… (1/29= 3%). So this indicates they are there but are difficult to get.

     Hope to do a Peterson mark/recapture type estimate next year. We will capture 30+ PS-97's and call it a recovery run. Using 2003 as a marking run (N=29) and using PITS for "marks" we should be able to get a rough abundance estimate.

   - Are the PS-97's exhibiting good condition and growth ? The pallids grew an average of 1.3 inches over the year **(Table 3)**. At this rate they will be 50 inches (full grown) in about 22 more years. 59 % were over 1.0 lb. MSU sampled one specimen that was 3.32 lb. This was a 1998 radio fish and was 0.84 lb @ release (8/18/98); therefore it grew ~0.50 lbs/yr.

   - Stocking strategies continued to be evaluated. We released the PLS-97 at a three sites to evaluate what location is best for survival. Records from 33 PS-97 are summarized in **Table 4**. The up-river sites are represented by 66% of the recaps, which suggests that releasing fish in these areas has been a successful strategy. This observation is particularly significant considering the fact that ~ 70% of our sampling effort is directed at the lower area where we have sampled only 33% of the PS-97.

- Evaluation of our tagging system. We have been witnessing a higher than normal rate of tagging loss for PIT tags. Following is a summary of tag loss by year:
- 1998 screened 3 and all had PITs; 100%
- 1999 screened 3 and all had PITs; 100%
- 2000 screened 4 and 3 had PITs; 75%
- 2001 screened 9 and 4 had PITs; 44%
- 2002 screened 9 and 4 had PITs; 44%
- 2003 screened 27 and 19 had PIT's; 70%

The elastomere tags are all holding good and tag but visibility is starting to get compromised by thickening skin tissue.

- This is year-2 since we released the PS-01's. Its still to early to tell what survival rate is but we have observed some disturbing pectoral fin deformities. Of the 3 PS-01 recaps sampled this year, two had severe pectoral fin curl while the third appeared to have minor deformity. Matt Toner with BTC (where the fish were reared) reported that this batch had rated 14.4% very good; 43.7% good; 29.8% moderate; 10.6% poor and 1.5% worse case condition when released.

- Several state species of special concern (SSC) were sampled in the study area this year. Totals of 230 sicklefin chub and 143 sturgeon chub were captured while trawling. **Included in this total are, 20+ sturgeon chub were sampled in the Coal Banks area; a first-time recording for this species at this upriver location.** Other SSC sampled this year were paddlefish (~50), sauger (~2000), and blue sucker (~30). Only 2 age-0 shovelnose were sampled in our 135 trawl tows.

Table 1. Effort by sampling method and number of pallid sturgeon captured in the Upper Missouri River Study Area, MT, during 2003.

	Effort	Adults	Juvenile-97	Juvenile-01	Total
Trammel net -	132 drifts	5	14	3	22
Spawning nets -	213 drifts	3	0	0	3
Trawl -	135 tows	0	0	0	0
Set lines -	353 hrs	0	2	0	2
Angling -	31 hrs.	0	13	0	13
		8	29	3	40

Table 2. Sampling statistics recorded for the pallid sturgeon standardized sampling program in the Upper Missouri River, 1996-2003.

	1996	1997	1999	2000	2001	2002	2003
No. pallids sampled	3	1	1	3	4	4	6
Avg. Wt. (lb)	38.0	40.6	0.3*	0.6	0.6	7.9	5.6
No. pallids/drift	0.06	0.02	0.02	0.06	0.08	0.08	0.12
No. shovelnose sampled	225	131	153	392	274	128	239
Avg Wt. (lb)	3.1	3.1	3.3	3.4	3.4	3.7	3.1
No. shovelnose/drift	4.5	2.6	3.1	7.8	5.5	2.6	4.8
Average drift duration (min)	6.3	6.5	6.7	7.1	7.2	7.0	7.0
Average drift distance (yd)	239	294	239	222	281	259	284
Average depth @ drift site (ft)	7.1	8.3	7.1	6.0	4.7	5.4	5.2

Table 3. Size statistics for hatchery-reared pallids released into the Upper Missouri River, MT, during 1998 and 2002.

	------ Age -----					
	1yr	**2yr**	**3yr**	**4yr**	**5yr**	**6yr**
Year	1998	1999	2000	2001	2002	2003
Pallid juvenile-97						
• Avg. Fork Leng.	11.5	15.3	17.7	17.1	19.4	20.7
• FL Range	(10.4-13.2)	(13.3-17.8)	(16.3-20.4)	(15.5-18.5)	(17.5-20.9)	(17.3-29.8)
• Avg. Weight	0.18	0.42	0.72	0.58	0.82	1.12
• WT Range	(0.12-0.27)	(0.26-0.68)	(0.0.46-1.06)	(0.43-0.80)	(0.61-1.10)	(0.65-3.32)
• N Sampled	3	3	5	9	11	29

	------ Age -----	
	1yr	**2yr**
Pallid juvenile-01		
• Avg. Fork Leng.	10.7	13.5
• FL Range	(9.6-11.6)	(11.6-16.1)
• Avg. Weight	---	0.28
• WT Range	----	(0.20-0.44)
• N Sampled	5	3

Table 4. Relocations of PIT-tagged PS-97 in the Upper Missouri River, 1999-03. Release site vs. subsequent relocation. (N=33)

-------- RELOCATIONS --------

	Loma	**Coal Bnk**	**Judith L**	**Robinson**
Loma		**1**	**1**	**8**
Judith L		**1**		**11**
Robinson				**11**

HABITAT USE, FOOD HABITS, AND GROWTH OF HATCHERY-REARED JUVENILE PALLID STURGEON AND JUVENILE SHOVELNOSE STURGEON IN THE MISSOURI RIVER ABOVE FORT PECK RESREVOIR, MONTANA

Annual Report for 2003

by

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May 2004

In 1998, 736 age-1 hatchery-reared juvenile pallid sturgeon (HRJPS) were stocked into the Missouri River above Fort Peck Reservoir (Recovery Priority Area 1 of the Pallid Sturgeon Recovery Plan). In addition, approximately 2,300 age-1 HRJPS were stocked into this area in 2002. Evaluation of these HRJPS is necessary to determine their performance in a natural lotic environment. Stocking pallid sturgeon that cannot adapt to their natural lotic environment would be an inefficient way to recover the species. Therefore, we are evaluating the habitat use, movements, growth, and food habits of 1997 year class HRJPS, 2001 year class HRJPS, and indigenous juvenile shovelnose sturgeon (JSNS) in Recovery Priority Area 1. Although similar in many aspects, pallid and shovelnose sturgeon are two distinct species, and differences in ecology should exist. Therefore, a large amount of resource overlap between the two species may indicate limiting habitat for HRJPS. Alternatively, observed differences in habitat use, movements, and food habits may help define the needs of HRJPS relative to JSNS.

Methods:

In the summer of 2003, we implanted radio transmitters in 10 HRJPS from the 1997 year class, 1 HRJPS from the 2001 year class, and 13 JSNS captured from Recovery Priority Area 1 (Table 1). In addition, five hatchery surplus 2001 year class HRJPS from the Bozeman Fish Technology Center were implanted with transmitters and released in 2003 (Table 1). At each fish location, river mile was recorded and abiotic habitat variables were measured (e.g., temperature, velocity, substrate, macrohabitat, and presence of islands and alluvial bars within 350 m). Cross section profiles were recorded at each fish location by driving the boat from one riverbank to the other along a transect. Longitudinal profiles were also recorded while driving the boat from 50 m downstream to 50 m upstream of each fish location. Depth was recorded in 5 m increments in all profiles. These data were useful in determining maximum depth, relative depth, and distance to thalweg of each fish location. In addition, diet information was obtained from all captured HRJPS and JSNS using a gastric lavage. We also obtained growth data on HRJPS and JSNS by recapturing them before their transmitter battery power expired. Fish were recaptured by deploying a trammel net 75 m upstream and retrieving it 45 m downstream of a fish after it was located.

Results:

Two radio-tagged surplus 2001 year class HRJPS, 9 1997 year class HRJPS, and 12 JSNS were relocated. Most JSNS moved further upstream than HRJPS (Table 2). The two surplus 2001 year class HRJPS were each located once. Hatchery-reared juvenile pallid sturgeon 40.761 was located at river mile 1892.0, and HRJPS 40.681 was located at river mile 1904.5 less than one day after their release at river mile 1916.5.

Differences in use of macrohabitat between HRJPS and JSNS were observed in June and July; however, more similarities were apparent in August (Figure 1). Relative depth of HRJPS increased from June-August in cross section profiles, but was similar in longitudinal profiles (Figure 2). Relative depth data for JSNS have not been analyzed.

Diet information was obtained from 16 HRJPS (2 from the 2001 year class and 14 from the 1997 year class) and 64 JSNS. Stomach contents were obtained from eight of the HRJPS (1 from the 2001 year class and 7 from the 1997 year class). Fish made up 82% of the wet weight of HRJPS (Figure 3). Other diet items found in HRJPS stomachs included Chironomidae, Ephemeroptera, Trichoptera, detritus, and plant material (Figure 3). Diet data for JSNS have not been analyzed, however, no fish were found in the diet.

Growth data was obtained from three JSNS and three HRJPS. Hatchery-reared juvenile pallid sturgeon lost a considerable amount of weight after transmitter implantation, while growth varied among JSNS. Note that JSNS generally weighed more than HRJPS when implanted with transmitters (Table 3).

Plans for 2004:

Habitat use, food habits, and growth data will be collected using methods similar to those in 2003; however, some modifications will be made to the sampling plan. Seven gram transmitters will be used in 2004 instead of the 2.5 g transmitters that were used in 2003. The 7 g transmitters have an approximately one-year battery life, whereas the 2.5-g transmitters had a maximum battery life of approximately 75 days. The increased battery life of the 7 g transmitters will allow transmitters to be implanted as early as April, so that more habitat use data may be collected in May and June. In May and June of 2003, the majority of the field work was devoted to sampling for juvenile sturgeon for transmitter implantation, and less effort was devoted to measuring habitat variables at fish locations due to lack of radio-tagged fish. The increased battery life of the 7-g transmitters will also allow for the same fish to be tracked throughout the entire field season.

More time will also be devoted to studying the food habits of HRJPS and JSNS in 2004. Every third HRJPS and JSNS implanted with a transmitter will be recaptured every two weeks to obtain stomach contents. In addition, abundance of potential prey fish (e.g., fish of the family Cyprinidae and all juvenile fish $\leq$ 12 cm) will be estimated at HRJPS and JSNS locations during the spring (May-June), summer (July-August), and autumn (September-October) by sampling at fish locations using a benthic trawl. Description of potential prey fish will only be conducted at locations of fish designated for recapture so that natural behavior of other radio-tagged fish is not altered due to sampling.

Table 1. – Length and weight by species and year class for HRJPS and JSNS from the Missouri River above Fort Peck Reservoir implanted with transmitters during the summer of 2003.

Species	Year Class	Frequency	Date Tagged	Length (mm)	Weight (g)
Pallid	2001 (hatchery surplus)	40.681	2-Jun-03	476	320
		40.731	2-Jun-03	470	320
		40.741	29-May-03	487	366
		40.751	29-May-03	441	280
		40.761	2-Jun-03	514	430
	Mean (SE)			478 (12)	343 (26)
	2001 (wild caught)	40.611	6-Aug-03	295	90
	1997	40.051	14-Aug-03	557	552
		40.061	5-Jun-03	512	462
		40.091	19-Jun-03	491	484
		40.101	3-Jul-03	549	538
		40.141	10-Jun-03	493	450
		40.601	10-Jul-03	522	462
		40.691	5-Jun-03	503	396
		40.811	9-Jun-03	554	504
		40.820	29-May-03	491	355
		40.830	29-May-03	506	419
	Mean (SE)			518 (8)	462 (19)
Shovelnose		40.021	15-May-03	321	128
		40.071	5-Jun-03	570	682
		40.110	3-Jul-03	567	768
		40.121	3-Jul-03	528	810
		40.131	3-Jul-03	568	836
		40.631	7-Aug-03	432	251
		40.641	7-Aug-03	555	697
		40.651	8-Aug-03	537	865
		40.661	4-Jun-03	398	208
		40.671	5-Jun-03	561	708
		40.771	31-Jul-03	508	428
		40.782	29-May-03	560	812
		40.791	20-Jun-03	535	732
	Mean (SE)			511 (22)	610 (72)

Table 2. – Movement data by river mile for individual HRJPS and JSNS from the Missouri River above Fort Peck Reservoir implanted with transmitters during the summer of 2003.

Species	Frequency	N	Mean	SE	Min.	Max.	Range	CV
1997 Pallid	40.051	6	1907.6	0.2	1907.2	1908.5	1.3	0.0
	40.061	19	1912.0	0.4	1907.1	1916.7	9.6	0.1
	40.091	13	1905.9	1.6	1899.3	1917.6	18.3	0.3
	40.141	14	1908.0	0.2	1906.5	1909.0	2.5	0.0
	40.601	15	1912.8	0.8	1909.2	1919.6	10.4	0.2
	40.691	8	1912.8	0.1	1912.3	1913.1	0.8	0.0
	40.811	5	1918.3	0.2	1918.0	1919.0	1.0	0.0
	40.820	8	1913.9	1.0	1910.9	1920.2	9.3	0.2
	40.830	6	1917.0	0.4	1915.8	1917.9	2.1	0.0
Shovelnose	40.021	11	1925.0	0.8	1921.5	1928.0	6.5	0.1
	40.071	4	1932.8	3.3	1925.0	1939.7	14.7	0.3
	40.110	6	1925.6	1.0	1922.2	1928.5	6.3	0.1
	40.121	15	1919.2	0.4	1916.6	1921.0	4.4	0.1
	40.631	9	1911.5	0.1	1911.0	1911.8	0.8	0.0
	40.641	8	1904.4	0.2	1903.8	1905.4	1.6	0.0
	40.651	2	1929.3	1.1	1928.2	1930.4	2.2	0.1
	40.661	6	1944.7	3.7	1935.1	1956.0	20.9	0.4
	40.671	15	1913.2	0.8	1910.8	1919.1	8.4	0.2
	40.771	3	1898.3	5.9	1888.8	1909.2	20.4	0.5
	40.782	19	1923.1	0.3	1921.5	1925.1	3.6	0.1
	40.791	14	1925.1	0.2	1923.5	1926.4	2.9	0.0

Table 3. – Absolute growth rate for recaptured HRJPS and JSNS from the Missouri River above Fort Peck Reservoir implanted with transmitters during the summer of 2003.

			Absolute growth rate	
Species	Frequency	Days	Length (mm/day)	Weight (g/day)
Shovelnose	40.671	63	-0.095	-0.175
Shovelnose	40.782	77	0.039	0.104
Shovelnose	40.791	64	-0.047	0.375
		Mean	-0.034	0.101
1997 Pallid	40.141	65	0.308	-0.077
1997 Pallid	40.061	71	0.000	-0.310
1997 Pallid	40.091	70	0.100	-1.890
		Mean	0.136	-0.759

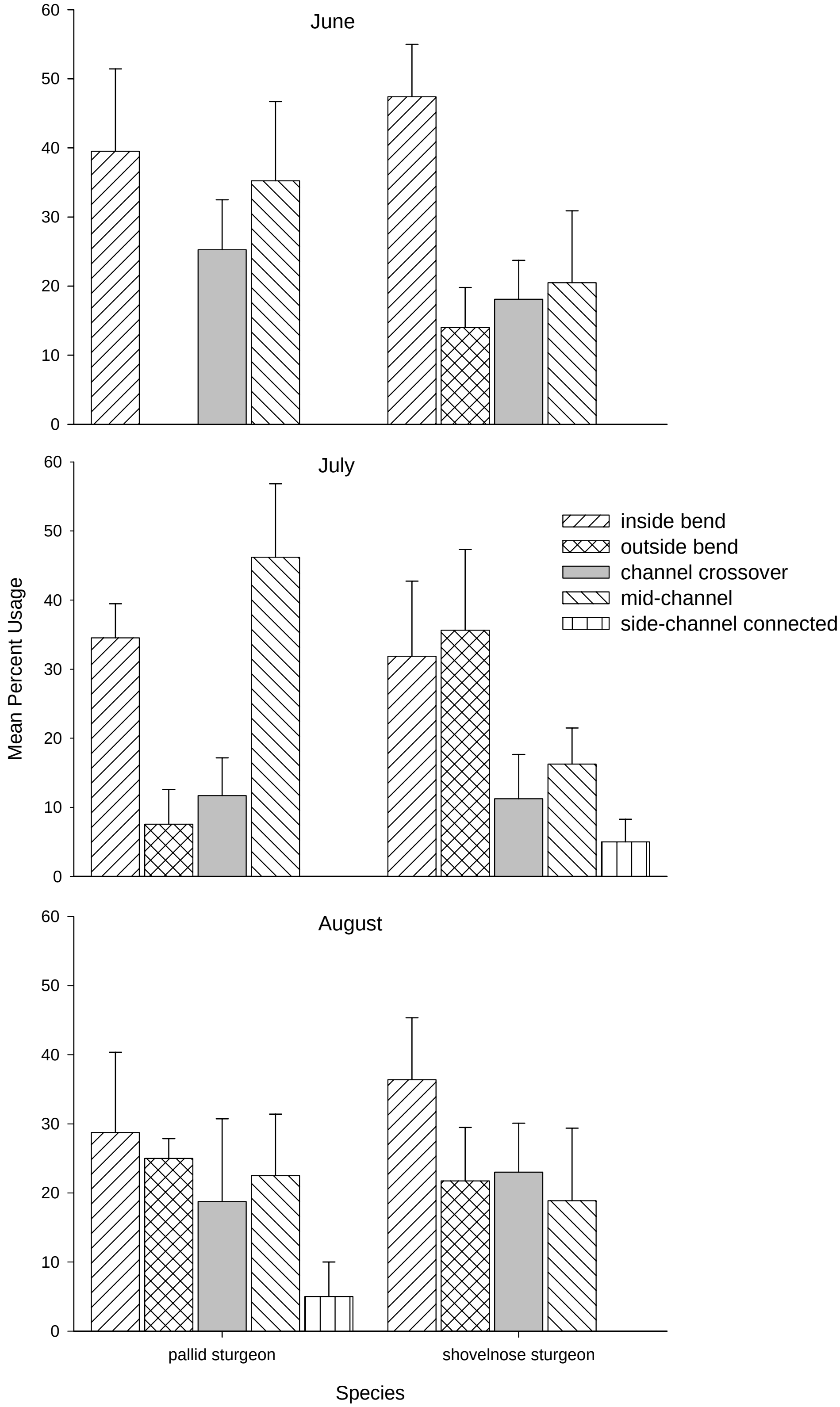

Figure 1. - Mean percent use by macrohabitat and month for HRJPS and JSNS.

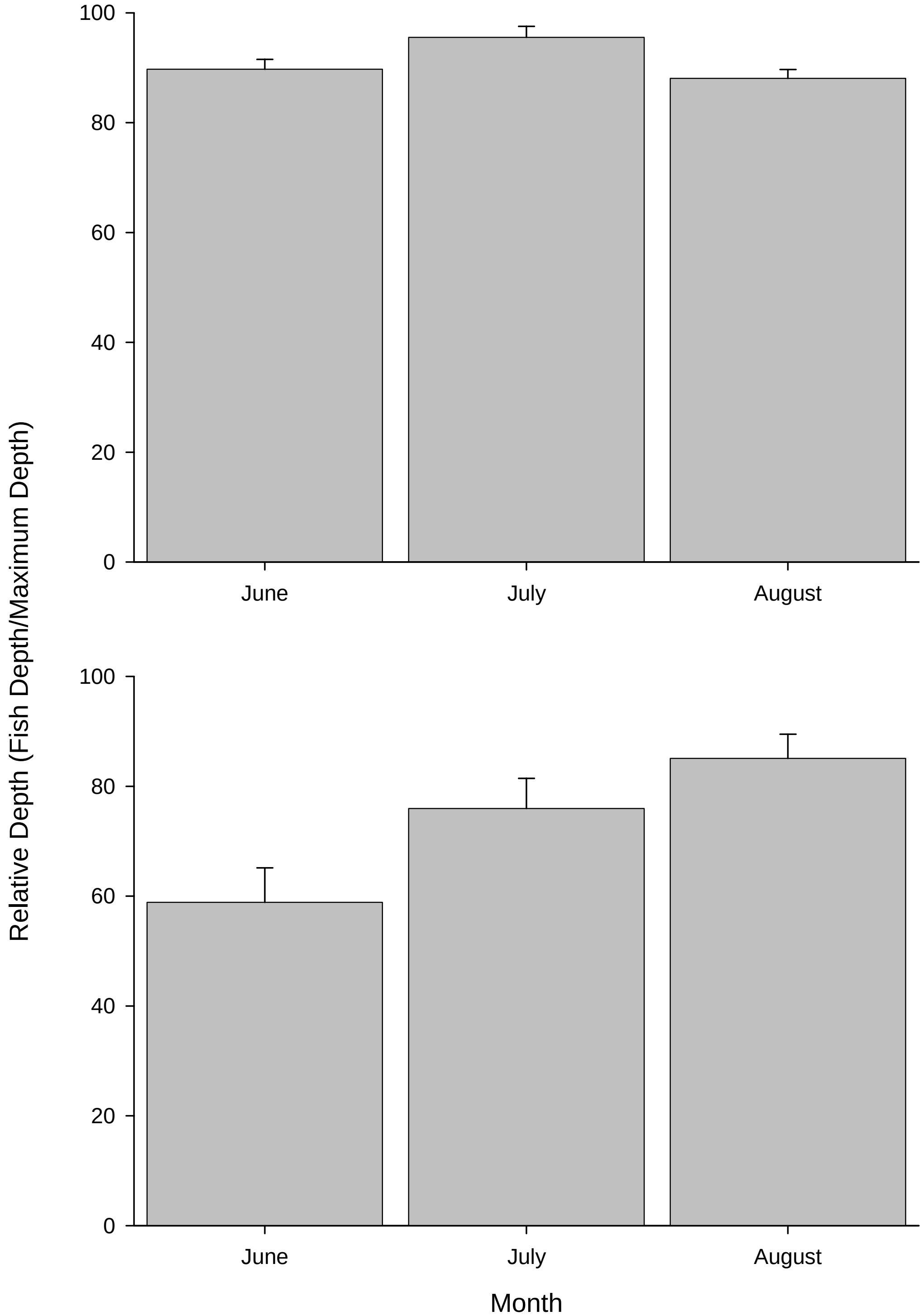

Figure 2. - Mean relative depth by month for HRJPS recorded from longitudinal profiles (top) and cross section profiles (bottom).

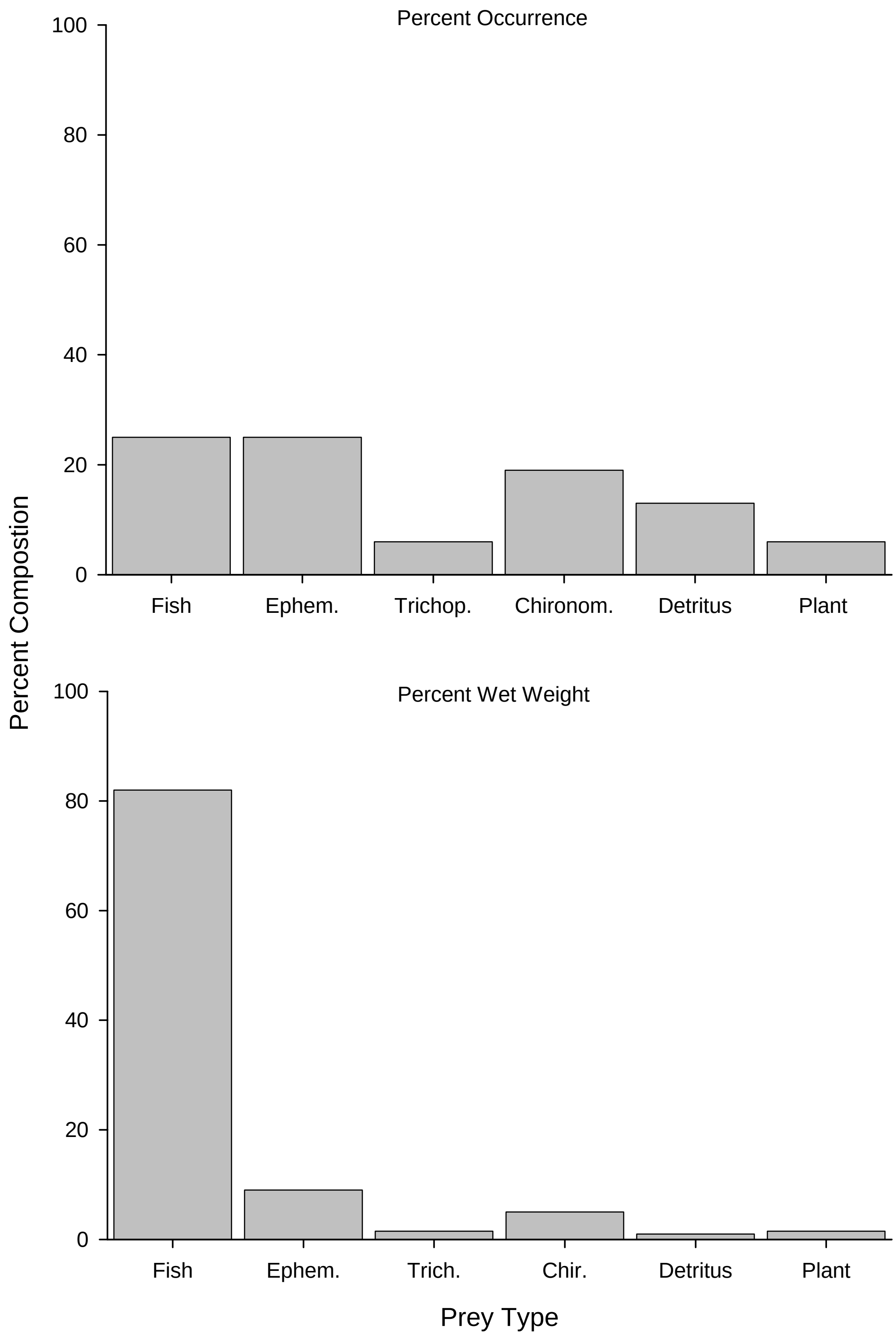

Figure 3. - Percent compostion by occurrence and wet weight for HRJPS diets in 2003.

LOWER MISSOURI AND YELLOWSTONE RIVERS

PALLID STURGEON STUDY

2003 REPORT

by

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Abstract

This report summarizes the fourth year findings of a five-year study investigating pallid sturgeon recovery efforts in the lower Missouri and Yellowstone rivers, deemed recovery-priority management area #2 (RPMA #2) in the pallid sturgeon recovery plan. Specific study objectives were to: 1) capture adult pallid sturgeon for spawning and hatchery propagation efforts; 2) evaluate progress of hatchery-reared pallid sturgeon (HRPS) stocked in RPMA #2 and summarize 2003 stockings; 3) monitor population characteristics of selected native species; and 4) implement a standardized monitoring plan to evaluate responses of native fish to proposed Fort Peck Spillway releases. We captured 20 different adult pallid sturgeon with drifted trammel nets during 2003; 17 during broodstock collection efforts and three while sampling for HRPS. Nineteen of twenty adult pallid sturgeon were scanned for passive integrated transponder (PIT) tags when captured; two of 19 were unmarked fish and 17 were recaptures from previous years (89.47% recapture rate). Three adult pallid sturgeon ranged from 1,265 to 1,385 mm in fork length (FL) and seven ranged from 10,886 to 23,608 g in weight. Sampling efforts to evaluate the progress of HRPS released in RPMA #2, and thereby the augmentation effort, were more successful during 2003 than in previous years. We recaptured 30 HRPS during 2003; 26 in drifted trammel nets and four on setlines. Catch rates of HRPS in the study area were 0.4302 per drift h or 0.0581 per drift in trammel nets, and 0.8862 per 10,000 hook h on setlines. Currently, we have not recaptured enough HRPS in RPMA #2 to quantify their survival, growth, condition, movements, or habitat use and selection. However, if stocking rates are increased to more appropriate levels (i.e. 9,000 yearling HRPS per year in RPMA #2) and sampling efforts are consistent and spatially comprehensive across years, enough HRPS will be recaptured such that vital population characteristics can be quantified. A total of 4,124 age-1 HRPS were stocked in RPMA #2 during 2003. One thousand thirty-three age-1 HRPS were released near Culbertson and 1,164 near Wolf Point in the Missouri River, and 1,040 were released near Intake, and 887 near Fairview in the Yellowstone River. All HRPS were PIT tagged prior to stocking, and 4,121 averaged 280 mm FL and 2,011 averaged 101 g in weight. A total of 67 blue suckers were captured in various gears during 2003, representing 1.25% of all identifiable fish. Blue suckers averaged 686 mm in total length (TL; range 482-772; n = 66) and 2,533 g in weight (range 280-4000; n = 65). No blue suckers less than 482 mm were captured during 2003. The lack of sub-adult blue sucker catches is evidence that reproduction is poor in the study area relative to other species such as river carpsucker, white sucker, and longnose sucker. Poor reproductive success and low relative abundance can be attributed to habitat loss, degradation, and fragmentation caused by Fort Peck Dam and other impoundments. Habitat rehabilitation via proposed spillway releases or modification of Fort Peck Dam's intake structure would aid blue sucker reproduction. A total of 296 river carpsuckers were captured in various gears during 2003, representing 5.50% of all identifiable fish. River carpsuckers averaged 458 mm TL (range 42-750; n = 290) and 1,403 g in weight (range 42-3,300; n = 286). Most river carpsuckers were between 350 and 600 mm TL, but a wide length range were captured. A total of 259 sauger were captured in various gears during 2003, representing 4.82% of all identifiable fish. Sauger averaged 311 mm TL (range 206-532; n = 250) and 732 g in weight (range 65-1,250; n = 245). Sauger of a wide length range were captured, but they were not abundant relative to other species. Sauger reproduction appears to be limited in magnitude but producing consecutive year classes. Habitat rehabilitation via proposed spillway releases or modification of Fort Peck Dam's intake structure

would aid sauger reproduction. Age estimates were completed for 194 sauger using dorsal spine cross-sections and scales. Mean TLs at ages of sauger were similar to those observed during 2002 and 2001. A total of 694 shovelnose sturgeon were captured in various gears during 2003, representing 12.91% of all identifiable fish. Shovelnose sturgeon averaged 561 mm FL (range 176-880; n = 689) and 738 g in weight (range 16-3,675; n = 684). The recapture rate of tagged shovelnose sturgeon was 4.47%, similar to the 4.3% recapture rate observed during 2002 but much higher than the 2.9% and 2.7 % recapture rates observed during 2000 and 2001. Water temperature monitoring demonstrated that cold, hypolimnetic releases from Fort Peck Dam did not warm appreciably until 70 river miles downstream near Wolf Point. However, these temperatures were still considerably cooler than what was observed in the less altered Milk and Yellowstone rivers during 2003, or what might be expected in an unaltered river. High discharge events from the Milk River helped temper Missouri River water temperatures, as evidenced by water temperature peaks at downriver monitoring stations. Standardized sampling to evaluate responses of the native fish community to proposed spillway releases was completed for the fourth consecutive field season, but a spillway release failed to occur for the sixth consecutive year. Bag seine hauls, benthic beam trawl tows, and hoop nets were highly ineffective at catching pallid sturgeon, blue suckers, river carpsuckers, sauger, and shovelnose sturgeon at seven standardized sampling sites. Data collected during four consecutive non-spill years indicates that the Missouri River between the Fort Peck Dam and Poplar, MT (approximately 90 river miles) is not capable of sustaining pallid sturgeon, and species of special concern such as sauger and blue sucker have poor reproductive success in these highly altered habitats. Little more can be learned about pallid sturgeon from the data collected in our standardized sampling efforts during non-spill years. We will suspend our standardized sampling efforts because of the low and variable catch rates of all species, the extremely rare catches of pallid sturgeon, and the expectation of a spillway release occurring no sooner than 2008. Our efforts will be redirected to evaluating the progress of HRPS stocked into RPMA #2. Standardized sampling efforts will resume the next year a spillway release is scheduled. This will allow for the comparison of data collected in spill and non-spill years.

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Introduction

Pallid sturgeon *Scaphirhynchus albus* are a federally protected endangered species that is native to the Missouri and Yellowstone rivers in Montana. Declines in reproduction, growth, and survival of pallid sturgeon have been attributed to the destruction and alteration of habitats by human modification of the river system (Dryer and Sandvol 1993). Pallid sturgeon in Recovery Priority Management Area #2 (RPMA #2) have not recruited for more than 30 years, and the remaining populations are composed of large (> 1,200 mm; > 8 kg; Liebelt 1996, 1998), old (≥ 35 years; S. Krentz, U.S. Fish and Wildlife Service [USFWS], unpublished data) individuals. Larval pallid sturgeon were first sampled in RPMA #2 during 2002 (Braaten and Fuller 2003), but age-1 to sub-adult pallid sturgeon have never been sampled. The abundance of wild pallid sturgeon in RPMA #2 was estimated at 150 individuals (95% confidence interval 88-236; Kapuscinski 2004) at the end of 2003, and this population will likely be extirpated by 2018.

Short-term recovery efforts are directed at preventing extinction and maintaining the genetic variability of pallid sturgeon by augmenting existing populations with progeny produced from wild brood fish. Long-term recovery actions are focused on restoring critical habitat components of the Missouri River that were altered by the closure of Fort Peck Dam in 1937. These actions, as outlined in the Missouri River Biological Opinion (USFWS 2000), propose to modify Fort Peck Dam operations to increase discharge and enhance water temperatures during May and June via spillway releases. It is hypothesized that enhanced flows will provide a spawning cue for pallid sturgeon, and that increased water temperatures will benefit native species in RPMA #2. Unfortunately, spillway releases have yet to be attempted due to current weather patterns and the U.S. Army Corps of Engineers’ dam operation procedures. If spillway releases do not occur in the next few years, there will not be enough wild pallid sturgeon to respond (successfully reproduce) when a delayed spillway release does occur. If wild pallid sturgeon do not successfully reproduce before they die, their genetics will be lost and future populations will consist of genetics from relatively few captive spawners. The persistence of pallid sturgeon in RPMA #2 is dependent upon immediate habitat rehabilitation and the survival and recruitment of hatchery-reared pallid sturgeon (HRPS) to the adult population.

Hatchery-reared pallid sturgeon were released into the lower Missouri and Yellowstone rivers during 1998, 2000, 2002, and 2003. Since the persistence of pallid sturgeon in RPMA #2 is largely dependent upon the survival and recruitment of HRPS to the adult population, quantifying survival, growth, condition, movement, and habitat use and selection of HRPS in RPMA #2 is a crucial component of recovery efforts. In the past, our research efforts were directed at evaluating ongoing short and long-term recovery efforts aimed at rehabilitating pallid sturgeon in their historic range. However, inadequate effort was directed at evaluating the progress of augmentation actions prior to 2003. During 2003, we received additional funds from Western Area Power Administration to more intensively evaluate HRPS stocked into RPMA #2; these funds allowed us to continue most of our ongoing study objectives.

A separate report (Kapuscinski 2004) describes the HRPS evaluation study and summarizes its findings. This report summarizes the fourth year (2003) findings of a five-year study investigating pallid sturgeon recovery efforts in the lower Missouri and Yellowstone rivers. Specific project objectives were to: 1) capture adult pallid sturgeon for spawning and hatchery propagation efforts; 2) evaluate progress of HRPS stocked in RPMA #2 and summarize 2003 stockings; 3) monitor population characteristics of selected native species; and 4) implement a comprehensive monitoring plan for the Missouri River between Fort Peck Dam and near Poplar, MT to evaluate responses of native fish to proposed Fort Peck Spillway releases. Western Area Power Administration provided funding for this study.

Study Area

The study area was composed of the Missouri River from Fort Peck Dam (river mile [RM] 1,770) to the headwaters of Lake Sakakawea (RM 1,538), the Yellowstone River from Intake Diversion Dam (RM 71) to its confluence with the Missouri River (RM 0), and the mouth of the Milk River (RM 1,761; Figure 1). The Missouri River was divided into seven study sections, the Yellowstone into two, and the Milk River into one section (Table 1). Gardner and Stewart (1987), Tews (1994), Liebelt (1996), and Bramblett and White (2001) have previously described these river reaches. We did not conduct any research in study reaches 7 and 8 during 2003.

Mean monthly discharges in the Missouri River below Fort Peck Dam during 2003 ranged from 5,087 cubic feet per second (cfs) during March to 10,130 cfs during February (Table 2). The highest mean daily discharge of 10,800 cfs occurred on 22 May. The lowest mean daily discharge observed in the Missouri River below Fort Peck Dam was 3,900 cfs and occurred on 1 April. Yellowstone River flows at Sidney were much more variable, but greatly reduced relative to historic levels due to continuing drought in the basin (Figure 2). Mean monthly discharge of the Yellowstone River at Sidney during 2003 ranged from a minimum of 2,655 cfs during August to a maximum of 28,200 cfs during June. The daily discharge peaked at 48,400 cfs on 5 June; 1,720 cfs was the minimum mean daily discharge recorded on 30 August. Milk River flows were minimal relative to those observed in the Missouri and Yellowstone rivers. The Milk River hydrograph peaked during May (inserted graph Figure 2). Mean monthly discharges for the Milk River at Nashua ranged from 95 cfs during October to 734 cfs during May. Mean daily flow in the Milk River peaked at 1,790 cfs on 1 April. The lowest mean daily flow in the Milk River was 44 cfs on 5 July.

Methods

Adult Pallid Sturgeon Sampling

Multi-filament trammel nets (1.8 by 30.5 or 45.7 m with a 22.7 kg lead core bottom line, 15.2 cm inner mesh and 25.4 cm outer mesh) were used to capture adult pallid sturgeon near the confluence of the Missouri and Yellowstone rivers, ND, and upstream to the Fairview Bridge area in the Yellowstone River during 22 April-14 May 2003 (Figure 3). Trammel nets were attached to a float on one end and secured to a boat on the opposite end with 4.57-12.19 m of nylon rope. Trammel nets were set perpendicular to the current and were drifted with the aid of a boat for up to 15 minutes, depending on current velocities and snags encountered. Net drifts were timed using a stopwatch. All species other than pallid sturgeon were enumerated. Catch-per-unit-effort (CPUE) rates were determined for individual species by calculating the mean number sampled per individual net drift and per drift h.

All pallid sturgeon were handled according to established protocol. Most adult pallid sturgeon were released immediately after capture in order to reduce the stresses associated with capture and handling. Six standard morphological measurements were taken on three adult pallid sturgeon and 30 HRPS to determine a character index (CI) value for detection of possible pallid-shovelnose sturgeon hybrids. The morphometric measurements used for the CI included fork length (FL), head length, mouth to inner barbel distance, interrostral distance, and outer and inner barbel lengths. These measurements were converted to percent of FL so differences in size of individual fish were standardized (Krentz 1996). Biosonic 125 kHz passive integrated transponder (PIT) tags were implanted in base of the dorsal fin on unmarked adult pallid sturgeon.

Hatchery-reared Pallid Sturgeon Sampling

Sampling for HRPS was attempted with multi-filament trammel nets, setlines, and angling during 19 May-28 October. Locations sampled in the Missouri River were between Anderson Island (RM 1765.8) and just downstream of the confluence area of the Missouri and Yellowstone rivers (RM 1575). Trammel nets (1.8 by 22.86-45.7 m with a 13.6 kg lead core bottom line, 1.91 or 2.54 cm inner mesh and 15.2 cm outer mesh) were attached to a float on one end and secured to a boat on the opposite end with 4.57-12.19 m of nylon rope. Trammel nets were set perpendicular to the current and were drifted with the current for at least 75 m when possible. The main line of each setline was leaded rope, and setlines were 22.86, 30.48, or 45.72 m in length. Circle hooks (size 2 or 4) were tied to about 46 cm of 9.07 kg test Dacron fishing line, and attached to the leaded rope with trotline swivel clips (Figure 4). Each hook was baited before deployment with enough nightcrawler to cover the hook. Setlines were staked to riverbanks or sandbars with a section of rebar or a fencepost, or they were attached directly to snags. The opposite end of each setline was weighted with a 0.91-4.54 kg weight. Setlines were allowed to fish overnight and pulled the next day. Circle hooks (size 2 or 4) baited with nightcrawlers were used when angling. The duration of net drifts, setline sets, and angling hook h was timed with a stopwatch.

All fish sampled were identified and counted, many were weighed (g), measured for total length (TL) or FL (mm), sexed, and tagged, and all HRPS were screened for PIT tag identification, weighed, measured for FL, and released. Information recorded at each recapture location included RM, GPS coordinates at the beginning and end of each trammel net drift and at the stake location of setlines, macrohabitat type (channel cross-over, inside bend, outside bend, or side channel), water temperature, and turbidity (nephelometric turbidity units; NTUs). Trammel net effort was recorded as time (total minutes), and drift distance (m) was calculated from GPS coordinates. Catch-per-unit-effort of HRPS in trammel nets was calculated as the mean number of HRPS sampled per net drift and per drift hour. Setline and angling effort was recorded as the number of hooks fished and total fishing time (minutes), and total hook h (one hook fished for one h) was calculated. Catch-per-unit-effort on setlines and by angling was calculated as the number of HRPS sampled per 10,000 hook h. Shovelnose sturgeon *Scaphirhynchus platorynchus* greater than 425 mm FL were tagged with individually numbered Floy cinch tags.

Population Characteristics of Selected Native Species

Tagging and Radio Transmitter Implantation

A total of 1,415 fish of various species received individually numbered Floy anchor or cinch tags near the base of the dorsal fin during 2003, and 435 anchor-tagged fish also received an additional colored (non-numbered) anchor tag. Tagging and recapture data will be used to quantify growth, abundance, and movements of various species as adequate amounts of data for analysis are collected. Recaptures of double-tagged fish will allow us to calculate anchor tag shedding rates. Two sauger were implanted with Lotek MCFT_3A radio frequency transmitters during 2003. We plan to implant an additional 28 sauger during 2004. Data obtained from relocations of radio transmitter implanted sauger will be used to quantify movements, determine habitat use, and evaluate the response of sauger to proposed Fort Peck Spillway releases.

Dredge Cut Ponds Standardized Netting

Standardized netting was completed in the dredge cut pond complex below Fort Peck Dam to monitor recreational and native fisheries. Netting was completed during June and September at 10 standardized sites with experimental-mesh (1.8 x 38.1 m with equal length panels of 19, 25, 38, 45, and 51 mm bar mesh) sinking gill nets. All fish captured were identified, weighed, measured for TL or FL, and many were tagged with individually numbered and non-numbered Floy anchor tags, or individually numbered cinch tags. Net catch summaries for this sampling are reported annually in other Montana Fish, Wildlife and Parks' job progress reports. This report summarizes all measurement data and tagging information for blue sucker, river carpsucker, sauger, and shovelnose sturgeon sampled in these nets.

Population Characteristics of Blue Sucker, River Carpsucker, Sauger, and Shovelnose Sturgeon

Descriptive population characteristics of blue sucker *Cycleptus elongatus*, river carpsucker *Carpiodes carpio*, sauger *Sander canadenses*, and shovelnose sturgeon captured in the study area were examined. Sauger ages were estimated using dorsal spine cross-sections and scales. The first two anterior spines were removed at the base of the dorsal fin from each sauger with side-cutting pliers. Care was taken to make a perpendicular cut across both spines so that no annuli were lost. A Buehler isomet saw was used to cut several spine cross-sections within 0.5 cm from the base of the spine. Scales were removed from below the lateral line and above the posterior insertion of the left pectoral fin. Both spine sections and scales were used to estimate individual sauger ages. When spine and scale age estimates conflicted, the spine age was accepted because it was considered more reliable.

Standardized Sampling to Evaluate Fort Peck Spillway Releases

Methods for completing standardized sampling in the Missouri River to evaluate responses of native and introduced fishes to proposed surface water releases from the Fort Peck Spillway were described previously (Yerk and Baxter 2001). Sampling was completed at established sites including Anderson Island (RM 1,765.8), Spillway (RM 1,762.8), Below Spillway (RM 1,761.5), mouth of the Milk River (RM 1,761.5), Below Milk River (RM 1,761.4), Nickels Rapids (RM 1,757.5), Frazer Rapids (RM 1,741.5), Wolf Point (RM 1,701.5), and Poplar (RM 1,679-1,681). Liebelt (2000b) described these sites in detail. Onset Computer Corporation Optic StowAway® temperature loggers were installed on the north and south banks at each sampling site and programmed to record water temperatures at one-hour intervals. Additional loggers were installed in the Spillway channel (RM 1,762.8), mouth of the Milk River (RM 1,761.5), Culbertson (RM 1,619), and the lower Yellowstone River (RM 10). Fish were sampled at all sites with several different gear types (such as beach seines, benthic beam trawls, electrofishing, hoop nets, stationary gillnets, and trammel nets) on four occasions during mid May through September. Fish were identified, enumerated, weighed, measured for TL or FL, tagged with Floy anchor or cinch tags, and released. Habitat characteristics including depth, turbidity, and temperature were recorded at each station concurrent with sampling efforts.

Results and Discussion

Adult Pallid Sturgeon Sampling

Broodstock collection efforts of our Pallid Sturgeon Study crew, the Fort Peck Flow Modification crew, and the USFWS resulted in the capture of 49 adult pallid sturgeon, consisting of 42 individuals. Of these 42, seven were transported to the Miles City State Fish Hatchery and 14 were transported to Garrison Dam National Fish Hatchery for possible use in the propagation program. All other pallid sturgeon were released in the vicinity of their capture site, some after measurement data were collected. Unfortunately, three of the pallid sturgeon transported to Miles City State Fish Hatchery and two of the pallid sturgeon transported to Garrison Dam National Fish Hatchery died. Of the five pallid sturgeon that died during 2003, four were post-spawn females and one was a pre-spawn male. The four post-spawn female pallid sturgeon likely died due to accumulated stresses associated with capture, transportation, and induced spawning. The pre-spawn male pallid sturgeon was found dead after it jumped out of a holding tank.

We captured a total of 20 individual adult pallid sturgeon in 593 trammel net drifts (large and small mesh nets) in the Missouri and Yellowstone rivers during 2003. We captured 17 individual pallid sturgeon in broodstock collection efforts during 22 April-14 May near the confluence area of the Missouri and Yellowstone rivers (RM 1,581.5) and upstream to the Fairview Bridge area on the Yellowstone River (RM 8.6; Figure 5). Relatively low and stable flows in both the Missouri and Yellowstone rivers resulted in optimal netting conditions during the broodstock collection effort. Three additional pallid sturgeon were captured while trammel net sampling in the study area during July and September. The July capture site was at RM

1,699.5 near the Wolf Point Bridge, while the two remaining captures were in the same net drift just below the confluence of the Missouri and Yellowstone rivers (RM 1,581). Nineteen of 20 adult pallid sturgeon were scanned for PIT tags when captured. Two of 19 adult pallid sturgeon captured during 2003 were unmarked fish and 17 were recaptures from previous years (Table 3). This recapture rate (89.47%) was greater than the 80% recapture rate observed during 2002 (Kapuscinski and Baxter 2003) and very high compared to recapture rates observed in previous years (53% during 2000 and 2001; Yerk and Baxter 2001; Yerk and Baxter 2002).

Most adult pallid surgeon captured during 2003 were released immediately and not measured in order to reduce the stresses associated with capture and handling. The three adult pallid sturgeon measured during 2003 ranged from 1,265 to 1,385 mm FL and the seven adult pallid sturgeon weighed ranged from 10,886 to 23,608 g in weight. All three of the adult pallid sturgeon we recorded morphometric measurements from during 2003 had CI values characteristic of pure pallid sturgeon (range: 531 to 594; Table 4).

The large-mesh (15.2 cm inner mesh and 25.4 cm outer mesh) trammel net was an effective gear type for capturing adult pallid sturgeon, as reported by Krentz (2000), Yerk and Baxter (2002), and Kapuscinski and Baxter (2003). Catches of other species, except for paddlefish *Polyodon spathula* (23 captured), were minimal—only two shovelnose sturgeon, three sauger, and one each of common carp *Cyprinus carpio*, bigmouth buffalo *Ictiobus cyprinellus*, and walleye *Sander vitreus* were captured during broodstock collection efforts (Table 5). Pallid sturgeon accounted for 35% of the total catch, compared to 34% during 2002 (Kapuscinski and Baxter 2003) and over 50% during 2001 (Yerk and Baxter 2002). Catch-per-unit-effort rates of pallid sturgeon averaged 0.14 per net drifted (Table 5), compared to 0.18 per net drifted during 2002 (Kapuscinski and Baxter 2003) and 0.50 per net drifted during 2001 (Yerk and Baxter

2002), and 1.04 per drift h, compared to 1.37 per drift h during 2002 (Kapuscinski and Baxter 2003) and 1.67 per drift h observed by Krentz (2000).

Previous work indicated pallid sturgeon were concentrated at the confluence area of the Missouri and Yellowstone rivers in the spring and fall (Tews 1994). Liebelt (2000a) suggested that the confluence area of the Missouri and Yellowstone rivers was a staging area for spawning adult pallid sturgeon prior to their migrating upstream into the Yellowstone River in response to a rising hydrograph. Bramblett and White (2001) reported that aggregations in late spring and early summer suggested that pallid sturgeon might spawn in the lower nine river miles of the Yellowstone River. Most adult pallid sturgeon were captured in the Yellowstone River near the Fairview Bridge (RM 8.6) during 2003 broodstock collection efforts (80.65% of the pallid sturgeon captured by the Fort Peck Flow Modification crew and our crew). Surface water temperatures ranged from 11.6 to 16.7 °C during the broodstock collection effort. The relatively warm water temperatures and the seemingly high concentrations of adult pallid sturgeon around the Fairview Bridge area of the Yellowstone River are indicators that pallid sturgeon spawned in this area during 2003. Radio telemetry and larval sampling data further support this theory. Five of 10 adult pallid sturgeon implanted with combination acoustic/radio transmitters were near the Fairview Bridge during June, and two others were between the Fairview Bridge and the confluence of the Missouri and Yellowstone rivers (D. Fuller, Montana Fish, Wildlife & Parks, personal communication). Furthermore, nine Scaphirhynchus spp. larvae collected during 2003, possibly pallid sturgeon, hatched off in the Yellowstone River during late June (P. Braaten, US Geological Survey, personal communication).

Hatchery-reared Pallid Sturgeon Sampling and Stocking

Sampling efforts to evaluate the progress of HRPS released in RPMA #2, and thereby the augmentation effort, were more successful during 2003 than in previous years. This can be attributed to two effects: 1) an increased density of HRPS in the study area (3,061 HRPS were stocked during 2002 and 4,124 were stocked during 2003, compared to 780 stocked during 1998 and 679 stocked during 2000); and 2) a more spatially comprehensive HRPS evaluation effort (funded by Western Area Power Administration; Kapuscinski 2004). A total of 26 HRPS were recaptured in 465 trammel net drifts specifically targeting HRPS; sampling sites were between Anderson Island (RM 1765.8) and just downstream of the confluence area of the Missouri and Yellowstone rivers (RM 1575; Figures 6 and 7). Catch-per-unit-effort of HRPS in drifted trammel nets was 0.0581 per drift, or 0.4302 per drift h compared to 0.1165 per drift h during 2002 (Kapuscinski and Baxter 2003). A total of four HRPS were recaptured on 213 setlines (44,922 hook h) that were fished specifically targeting HRPS; sampling sites were from near Oswego (RM 1,728) to the confluence of the Missouri and Yellowstone rivers (RM 1,581.5; Figures 8 and 9). Catch-per-unit-effort of HRPS on setlines was 0.8862 per 10,000 hook h. No HRPS were recaptured while angling for a total of 45.83 hook h; sampling sites were between the Wolf Point Bridge area (RM 1,701.5) and the confluence of the Missouri and Yellowstone rivers (RM 1,581.5; Figure 10). Of the 30 HRPS sampled during 2003 (26 in drifted trammel nets and four on setlines), 25 were sampled during the 2003 HRPS evaluation study (21 in drifted trammel nets and four on setlines; Kapuscinski 2004), and five HRPS were sampled outside the confines of the study. These five HRPS were recaptured during 6 August-14 October near the Wolf Point Bridge (RM 1,700.5), downstream from the Wolf Point Bridge (two at RM

1,698.5 and one at RM 1,694), and downstream from Brockton (RM 1,643.5; Figure 11). The stocking sites of two of the five recaptured HRPS could not determined because one was not PIT tagged prior to release, and the other has an incomplete stocking record. Two of the remaining three recaptured HRPS were stocked at the Wolf Point Bridge (RM 1,701.5) and were recaptured nearby (RMs 1,698.5 and 1,701.3), and the third was stocked near Intake on the Yellowstone River (RM 70) and recaptured near Brockton (RM 1,643.5). This HRPS moved 132 RMs (70 RM downstream in the Yellowstone River and 62 RM upstream in the Missouri River), the greatest movement distance recorded for any HRPS stocked in RPMA #2.

There were two angler reports of recaptured HRPS in the study area during 2003, one near the confluence of the Big Muddy and Missouri rivers, and one near Sidney in the Yellowstone River. There were no reports of angler recaptures during 2000, 2001, or 2002 (Yerk and Baxter 2001; Yerk and Baxter 2002; Kapuscinski and Baxter 2003), but there were two reported angler recaptures during 1999 (Liebelt 2000a).

The "Stocking / Augmentation Plan for the Pallid Sturgeon (Scaphirhynchus albus) in Recovery Priority Management Areas 1 & 2 in Montana and North Dakota" states that "…population size and survival/mortality rates will be calculated using recapture information of tagged fish" (Krentz et al. 1997). Extensive efforts during both 2001 and 2002 provided little information to evaluate the progress of HRPS in RPMA #2 or the pallid sturgeon augmentation program in general. This was caused primarily by the low numbers of HRPS stocked into RPMA #2, as drifted trammel nets caught many shovelnose sturgeon within the observed length range of recaptured HRPS (Kapuscinski and Baxter 2003). Twenty-six of the 30 HRPS sampled during 2003 were captured in small-mesh drifted trammel nets. A total of 465 small-mesh trammel net drifts were completed in RPMA #2 during 2003, resulting in a catch rate of one

HRPS per 17.9 trammel net drifts, compared to one HRPS per 65.8 trammel net drifts during 2002 (Kapuscinski and Baxter 2003) and one HRPS per 103 trammel net drifts during 2001 (Yerk and Baxter 2002). While poor survival of HRPS and ineffective sampling methods may be contributing to the problem of low recapture rates, the results of our sampling efforts during 2003 clearly show that as densities of HRPS in the study area increase, so do the number of HRPS recaptures (with a one year time lag after stocking; Figure 12). Currently we have not recaptured enough HRPS in RPMA #2 to quantify survival, growth, condition, movements, or habitat use and selection. However, if stocking rates are increased to more appropriate levels (i.e. 9,000 yearling HRPS per year in RPMA #2; Kapuscinski et al. 2004) and sampling efforts are consistent and spatially comprehensive across years, enough HRPS will be recaptured such that vital population characteristics can be quantified.

Hatchery-reared pallid sturgeon were stocked into the Missouri and Yellowstone rivers for the fourth time since augmentation efforts began in 1998. A total of 4,124 age-1 HRPS, spawned during 2002, were stocked during 2003. One thousand thirty-three age-1 HRPS were released near Culbertson and 1,164 near Wolf Point in the Missouri River, and 1,040 were released near Intake, and 887 near Fairview in the Yellowstone River (Figure 13). All HRPS were PIT tagged prior to stocking and 4,121 averaged 280 mm FL and 2,011 averaged 101 g in weight (Table 6). This stocking complemented the 780, 680, and 3,061 HRPS that were released into RPMA #2 during 1998, 2000, and 2002.

Population Characteristics of Selected Native Species

Blue Sucker

We captured a total of 67 blue suckers (1.25% of the total identifiable fish captured) during our 2003 sampling efforts in the Milk and Missouri rivers (Table 7). Capture sites were between Roundhouse Bay (RM 1,770) and just downstream of the confluence with the Yellowstone River (RM 1,581) on the Missouri River. Blue suckers averaged 686 mm TL (range 482-772; n = 66) and 2,533 g in weight (range 280-4000; n = 65). No blue suckers less than 482 mm TL were captured with any gear in the study area during 2003 (Figure 14), similar to 2002 when no blue suckers less than 490 mm TL were captured (Kapuscinski and Baxter 2003). The lack of sub-adult blue sucker catches is evidence that reproduction is poor in the study area relative to other species such as river carpsucker, white sucker, and longnose sucker. Poor reproductive success and low relative abundance can be attributed to habitat loss, degradation, and fragmentation caused by Fort Peck Dam and other impoundments, since there is no recreational or commercial exploitation of blue suckers in the study area. Habitat rehabilitation via proposed spillway releases or modification of Fort Peck Dam's intake structure would aid blue sucker reproduction. We tagged 62 blue suckers during 2003 with individually numbered Floy anchor tags and 32 received an additional colored (non-numbered) Floy anchor tag (Table 8). Of the 67 blue sucker sampled during 2003, one (1.49%) was a recapture from previous tagging events. There were no angler reports of recaptured blue sucker during 2003.

River Carpsucker

We captured a total of 296 river carpsuckers (5.50% of the total identifiable fish captured) during our 2003 sampling efforts in the Milk and Missouri rivers (Table 7). Capture sites were between Roundhouse Bay (RM 1,770) and just downstream of the confluence with the Yellowstone River (RM 1,581) on the Missouri River. River carpsuckers averaged 458 mm TL (range 42-750; n = 290) and 1,403 g in weight (range 42-3,300; n = 286). Most river carpsuckers were between 350 and 600 mm TL, but a wide length range of river carpsucker was sampled (Figure 15). River carpsuckers less than 350 mm TL were only sampled in study sections 3 and 4 (Figure 16). We tagged 230 river carpsuckers during 2003 with individually numbered Floy anchor tags and 69 received an additional colored (non-numbered) anchor tag (Table 8). Of the 296 river carpsuckers sampled during 2003, zero were recaptures from previous tagging events. There were no angler reports of recaptured river carpsuckers during 2003.

Sauger

We captured a total of 259 sauger (4.82% of the total identifiable fish sampled) during our 2003 sampling efforts in the Milk, Missouri, and Yellowstone rivers (Table 7). Capture sites were between the Fort Peck Dredge Cuts and the confluence with the Yellowstone River (RM 1,581.5) on the Missouri River, and up to just upstream of the Fairview Bridge on the Yellowstone River (RM 9.5). Sauger averaged 311 TL (range 206-532; n = 250) and 732 g in weight (range 65-1,250; n = 245). Sauger were well represented throughout their TL range (Figure 17), even though they were not abundant relative to other species. Sauger reproduction appears to be limited in magnitude but producing consecutive year classes. Habitat rehabilitation via proposed spillway releases or modification of Fort Peck Dam's intake structure would aid sauger reproduction. Sauger catches were higher in study sections 1-4 than in sections 0, 5, and 6 (Figure 18), but differences in catches may be influenced by variability in sampling efforts across study sections. We tagged 104 sauger during 2003; 103 sauger were tagged with individually numbered Floy anchor tags, 28 of which received an additional colored (non-numbered) anchor tag, and one sauger was implanted with a radio transmitter (Table 8). Of the 259 sauger captured during 2003, zero were recaptures from previous tagging events.

Age estimates were completed for a total of 194 sauger using dorsal spine cross-sections and scales. Age estimates determined for sauger ranged from age-1 to age-6 (Table 9), consistent with results reported by Kapuscinski and Baxter (2003) for sauger sampled in the study area during 2002. Mean TLs at ages of sauger were similar to those reported by Kapuscinski and Baxter (2003) and Yerk and Baxter (2002) for the same study area during 2002 and 2001 (Figure 19), and Gardner and Stewart (1987) for sauger sampled in the Missouri River during 1979 and 1981.

Anglers reported eight sauger tag returns during 2003. Letters describing the tagging date and location, and the length and weight of the sauger at the time of tagging were sent to each angler.

Shovelnose Sturgeon

We captured a total of 694 shovelnose sturgeon (12.91% of the total identifiable fish sampled) during our 2003 sampling efforts in the Milk, Missouri, and Yellowstone rivers (Table 7). Capture sites were between the tailrace of the Fort Peck Dam and just downstream of the confluence of the Missouri and Yellowstone rivers (RM 1,581), and up to just upstream of the

Fairview Bridge on the Yellowstone River (RM 9). Shovelnose sturgeon averaged 561 mm FL (range 176-880; n = 689; Figure 20) and 738 g in weight (range 16-3,675; n = 684). Size ranges of shovelnose sturgeon captured in the study area did not differ greatly across study sections, but appreciable numbers of shovelnose sturgeon less than 400 mm FL were only sampled in sections 3, 4, and 5 (Figure 21). We tagged a total of 446 shovelnose sturgeon in the Milk and Missouri rivers during 2003 (Table 8). Of the 694 shovelnose sturgeon sampled during 2003, 31 (4.47%) were recaptures from previous tagging events during 1994-2002. This recapture rate is greater than the recapture rates observed during 2002 (4.03%; Kapuscinski and Baxter 2003), 2001 (2.7%; Yerk and Baxter 2002), and 2000 (2.9%; Yerk and Baxter 2001), but less than the recapture rate observed during 1999 (8.8%; Liebelt 2000a). Most (54.84%) recaptures occurred in study section 1 (Figure 22). In previous years, many more shovelnose sturgeon were tagged in the Milk River (section 0; Liebelt 2000a), the Fort Peck Dam tailwater-dredge cut complex (section 1; Liebelt 2000a; Kapuscinski and Baxter 2003), and the confluence area of the Missouri and Yellowstone rivers (sections 6 and 9; Yerk and Baxter 2001; Yerk and Baxter 2002; Kapuscinski and Baxter 2003). Thus, it is likely more tagged shovelnose sturgeon were vulnerable to recapture in these study sections.

Anglers reported two shovelnose sturgeon tag returns during 2003. Letters describing the tagging date and location, and the length and weight of shovelnose sturgeon at the time of tagging were sent to each angler. Anglers reported three shovelnose sturgeon tag returns during 2002 (Kapuscinski and Baxter 2003), and an angler reported a single shovelnose sturgeon tag return during 2000 (Yerk and Baxter 2001). Liebelt (1996, 1998, 2000a) also reported low angler return rates of tagged shovelnose in previous years. This suggests that angler exploitation of shovelnose sturgeon is very low and likely insignificant in the Missouri River between Fort Peck Dam and Lake Sakakawea.

Standardized Sampling to Evaluate Fort Peck Spillway Releases

Water Temperature Monitoring

Mean daily water temperatures in the Missouri River immediately below Fort Peck Reservoir (Anderson Island) varied little (6.98 °C) during 5 May-19 October 2003 (Figure 23) due to the cold, hypolimnetic releases from the dam. The USFWS's Missouri River Biological Opinion (2000) called for a mini-test, full test, and full enhancement flows from the Fort Peck Spillway during 2001, 2002, and 2003 in order to maintain 18 °C at Frazer Rapids for a minimum of three weeks between May and the end of June. Mean daily water temperatures at Frazer Rapids during the months of May and June 2003 did not exceed 14.82 °C. At no time during the year did water temperatures exceed 17.20 °C at Frazer Rapids (Figure 24).

Water temperature ranges were much greater at Wolf Point in the Missouri River, and at sites in the Milk and Yellowstone rivers compared to water temperatures observed at Anderson Island in the Missouri River immediately below Fort Peck Dam (Figure 23; Figure 24). Obvious warming of the dam's discharge was not evident until Wolf Point, about 70 RMs downstream (Figure 23). Water temperatures at Wolf Point were generally 5 to 10 °C warmer than those recorded just below the dam at Anderson Island from June until September (Figure 23). However, these temperatures were still considerably cooler than what was observed in the less altered Milk and Yellowstone rivers during 2003 (Figure 23), or what might be expected in an unaltered river. Galat et al. (2001) reported that water temperatures recorded in this reach of the

Missouri during 1998 were significantly cooler than those observed in the Missouri River above Fort Peck Reservoir and the lower Yellowstone River.

The highest water temperature observed in the Missouri River just below Fort Peck Dam at Anderson Island was 15.7 °C on 11 August, compared to 15.7 °C on 4 September 2002 (Kapuscinski and Baxter 2003). Water temperature in the Missouri River near Poplar peaked at 22.2 °C on 14 August. The gradual warming of the dam's discharge was attributed to increasing ambient temperatures and precipitation run-off events, as evidenced by the coinciding of mid-May temperature peaks with increased flows from the Milk River (Table 2; Figure 2; Figure 23; Figure 24). Periodic flow events from other sizeable tributaries (e.g., Prairie Elk Creek, Poplar River, Redwater River, Big Muddy Creek) also likely helped temper the cold discharge from Fort Peck Dam as suggested by Yerk and Baxter (2001). The Milk River attained its maximum temperature of 26.98 °C on 13 August, compared to 25.8 °C on 16 July 2002 (Kapuscinski and Baxter 2003). The influence of the Milk River's inflows was evident in the Missouri River downstream of their confluence. Water temperatures recorded below the mouth of the Milk River on the north bank were consistently warmer than river temperatures on the south bank during the summer months (Figure 24). The influence of warmer discharges was still evident at Nickels Rapids (RM 1,759) during the summer months, and these discharges did not fully assimilate with the colder, denser Missouri River water until Frazer Rapids, about 15 RMs downstream.

Fish Community Monitoring

We captured a total of 32 species in our standardized sampling efforts during 2003, consisting of 21 native and 11 introduced species. This was similar to the 32, 28, and 31 species sampled during 2002, 2001, and 2000 (Kapuscinski and Baxter 2003; Yerk and Baxter 2002; Yerk and Baxter 2001). The most common species sampled was emerald shiner *Notropis atherinoides* (N = 763), composing 26.61% of the 2,867 total identifiable fish sampled (Table 10). This is consistent with the 2002 results reported by Kapuscinski and Baxter (2003), but contrary to the 2000 and 2001 results where goldeye *Hiodon alosoides* was the most common species sampled (Yerk and Baxter 2001; Yerk and Baxter 2002).

A single HRPS was captured in a drifted trammel net near Wolf Point in standardized sampling efforts during 2003. This is the third HRPS captured in the four field seasons that standardized sampling has been completed. All three HRPS recaptured in standardized sampling efforts were stocked at the Wolf Point Bridge and recaptured nearby. No HRPS have been recaptured at any of the other standardized sampling sites, indicating that either HRPS are not moving to these sites, or these sites are unsuitable for HRPS.

Several Montana ‘Species of Special Concern’ including blue sucker, sturgeon chub *Hybopsis gelida*, and sauger were sampled at some of the standardized sites. Few sturgeon chubs were captured (N = 7), but blue suckers (N = 49) and sauger (N = 88) were more common (Table 10). Catches of blue suckers at or just downstream of the mouth of the Milk River during May were substantial (38.78% of the total sampled), but much less than catches observed during 2002 (76.74%; Kapuscinski and Baxter 2003) and 2001 (Yerk and Baxter 2002). Yerk and Baxter (2002) suggested that blue suckers staged in these areas during May before ascending the Milk River to spawn, and observations during 2002 supported this theory. Results from our 2003 sampling efforts, however, were inconsistent with previous years; the inconsistency in observed catches may be a result of inadequate temporal coverage of our sampling efforts at the mouth of the Milk River.

Catch rates of selected native species are presented for individual gear types (Figures 25-30). Generally, CPUE rates of most species were low and variable. Shovelnose sturgeon captured in drifted trammel nets, and river carpsuckers captured by electrofishing and in stationary gillnets were widely distributed, but in limited numbers. Drifted trammel net CPUE rates of shovelnose sturgeon were highly variable, ranging from 0 to 66 per hour sample time (Figure 27). The maximum catch rate was approximately twice that observed during 2001 and 2002 (Yerk and Baxter 2002; Kapuscinski and Baxter 2003). Blue suckers, river carpsuckers, sauger, and shovelnose sturgeon were commonly sampled at or just below the mouth of the Milk River (Figures 25-30), indicating that the Milk River meets some or all of the life history requirements of these species.

Three juvenile sauger and no juvenile blue suckers were captured, similar to what we observed during 2002 (Kapuscinski and Baxter 2003). This indicates that natural reproduction of sauger and blue suckers is very poor relative to other species (such as river carpsuckers and white suckers) in the study area. Only large (≥486 mm TL) adult blue suckers were sampled, as was observed during 2002 (≥490 mm TL; Kapuscinski and Baxter 2003).

Bag seine hauls, benthic beam trawl tows, and hoop nets were highly ineffective at catching blue suckers, river carpsuckers, sauger, and shovelnose sturgeon at seven standardized sampling sites (Figures 25, 26, and 29), as reported by Yerk and Baxter (2001) and Kapuscinski and Baxter (2003). Data collected during four consecutive non-spill years indicates that the 70 RMs of the Missouri River below the Fort Peck Dam is not capable of sustaining pallid sturgeon in its current state, and Montana "Species of Special Concern" such as sauger and blue sucker have poor reproductive success in these highly altered habitats. Furthermore, Kapuscinski and Baxter (2003) reported that species diversity and the total number of fish sampled increased with distance from the dam, site temperature, and site turbidity. Kapuscinski and Baxter (2003) concluded that because ambient temperature and turbidity levels influence both the diversity and abundance of the Missouri River fish community, the fish community would benefit from increased temperature and turbidity levels below Fort Peck Dam either via modification of the dam's intake structure or by spillway releases.

Little more can be learned about pallid sturgeon and other native species from the data collected in our standardized sampling efforts during non-spill years. We have decided to suspend our standardized sampling efforts because of the low and variable catch rates of all species, the extremely rare catches of pallid sturgeon, and the expectation of a spillway release occurring no sooner than 2008. Our efforts will be redirected to evaluating HRPS stocked into RPMA #2 until a spillway release is expected. Standardized sampling efforts will resume the next year a spillway release is scheduled. This will allow for the comparison of data collected in spill and non-spill years.

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Appendix 1. Phylogenetic list of fish species sampled in the Missouri and Yellowstone rivers during 2003. Asterisks denote introduced species.

Pallid sturgeon (*Scaphirhynchus albus*)
Shovelnose sturgeon (*S. platorynchus*)
Paddlefish (*Polyodon spathula*)
Channel catfish (*Ictalurus punctatus*)
Black bullhead* (*I. melas*)
Stonecat (*Noturus flavus*)
River carpsucker (*Carpiodes carpio*)
Longnose sucker (*Catostomus catostomus*)
White sucker (*C. commersoni*)
Blue sucker (*Cycleptus elongatus)*
Smallmouth buffalo (*Ictiobus bubalus*)
Bigmouth buffalo (*I. cyprinellus*)
Shorthead redhorse (*Moxostoma macrolepidotum*)
Common carp* (*Cyprinus carpio*)
Brassy minnow (*Hybognathus hankinsoni*)
Western silvery minnow (*H. argyritis*)
Plains minnow (*H. placitus*)
Sturgeon chub (*Macrohybopsis gelida*)
Flathead chub (*Platygobio gracilis*)
Emerald shiner (*Notropis atherinoides*)
Spottail shiner* (*N. hudsonius*)
Fathead minnow (*Pimephales promelas*)
Longnose dace (*Rhinichthys cataractae*)
Goldeye (*Hiodon alosoides*)
Cisco* (*Coregonus artedii*)
Lake whitefish* (*C. clupeaformis*)
Rainbow smelt* (*Osmerus mordax*)
Brown trout* (*Salmo trutta*)
Rainbow trout* (*Oncorhynchus mykiss*)
Northern pike* (*Esox lucius*)
Burbot (*Lota lota*)
White crappie* (*Pomoxis annularis*)
Smallmouth bass*(*Micropterus dolomieu*)
Yellow perch* (*Perca flavescens*)
Sauger (*Sander canadenses*)
Walleye* (*S. vitreus*)
Freshwater drum (*Aplodinotus grunniens*)

Table 1. Section number, physical location, and location by river mile (RM) of individual river study sections on the Milk, Missouri, and Yellowstone rivers.

Section	Location
0	Lower 15 miles of Milk River
1	Fort Peck Dam to the mouth of Milk River (RM 1,770 to 1,761)
2	Mouth of Milk River to Wolf Point (RM 1,761 to 1,708)
3	Wolf Point to mouth of Redwater River (RM 1,708 to 1,683)
4	Mouth of Redwater River to mouth of Big Muddy Creek (RM 1,683 to 1,630)
5	Mouth of Big Muddy Creek to mouth of Yellowstone River (RM 1,630 to 1,582)
6	Mouth of Yellowstone River to Highway 85 bridge (RM 1,582 to 1,553)
7	Highway 85 bridge to Lake Sakakawea (RM 1,553 to 1,530)
8	Yellowstone River from Intake to Highway 23 bridge (RM 71 to 30)
9	Highway 23 bridge to mouth of Yellowstone River (RM 30 to 0)

Table 2. Monthly mean, minimum, and maximum discharges from January through December for the Missouri River below Fort Peck, the Milk River and Yellowstone River during 2003.

Location	Month	Discharge (cfs) Mean	Minimum	Maximum
Missouri River below Fort Peck Dam (RM 1,763.5)	January	9784	8300	10100
	February	10130	9800	1060
	March	5087	3700	9100
	April	7003	3900	9100
	May	9061	8100	10800
	June	8700	8200	9100
	July	8077	7800	8600
	August	7084	6400	8300
	September	6280	4200	7300
	October	4616	4400	4900
	November	5673	4600	9000
	December	8895	8300	9300
Milk River at Nashua (RM 22.7)	January	Ice	Ice	Ice
	February	Ice	Ice	Ice
	March	Ice	Ice	Ice
	April	516	172	1790
	May	734	113	2590
	June	183	87	380
	July	99	44	206
	August	100	46	157
	September	103	57	323
	October	95	52	154
	November	-	-	-
	December	-	-	-
Yellowstone River at Sidney (RM 29.5)	January	Ice	Ice	Ice
	February	Ice	Ice	Ice
	March	Ice	Ice	Ice
	April	6304	4990	8430
	May	11540	7400	32400
	June	28200	13600	48400
	July	8471	4550	13900
	August	2655	1720	5050
	September	3198	1850	4100
	October	4232	3830	5080
	November	-	-	-
	December	-	-	-

-Incomplete discharge data

Table 3. Capture statistics of adult pallid sturgeon sampled in the Missouri and Yellowstone rivers during 2003.

Date	RM	FL	Weight	Tag	Recapture?	Sex	Original capture date
4/23/2003	1,581.5	-	-	220E5F6E26	Y	U	8/7/2002
4/23/2003	1,581.5	-	-	1F4A363031	Y	M	4/16/1998
4/24/2003	6.0[y]	-	-	CART #34	Y	M	4/17/2000
4/25/2003	1,575.0	-	-	7F7B081579, CART #26	Y	M	10/19/1992
4/30/2003	7.8[y]	-	-	7F7D365422	Y	M	9/27/1994
4/30/2003	9.0[y]	-	-	None	N	U	-
5/6/2003	9.0[y]	-	-	220E4E4E5D	Y	M	5/6/2003
5/7/2003	6.5[y]	-	-	22045E534D	Y	U	5/7/2003
5/7/2003	9.0[y]	-	-	2204583665	Y	U	1991
5/13/2003	9.0[y]	-	17,690	1F4A5A5A63	Y	U	9/28/1994
5/13/2003	9.0[y]	-	23,587	115556461A	Y	M	4/22/2002
5/13/2003	9.0[y]	-	-	1F53312736	Y	M	9/29/1995
5/13/2003	9.0[y]	-	-	1F4A33194B, CART #46	Y	M	4/12/2000
5/13/2003	9.0[y]	-	-	7F7D2D723D	Y	U	9/28/1994
5/13/2003	9.0[y]	1265	10,886	220E770F3F	N	U	-
5/13/2003	9.0[y]	-	-	7F7F065834	Y	M	6/15/1994
5/14/2003	9.0[y]	-	-	1F4849755B, CART #18	Y	U	4/13/2000
7/28/2003	1,700.0	1365	13,721	Not scanned	-	U	-
9/30/2003	1,580.5	-	-	CART	Y	-	-
9/30/2003	1,580.5	1385	15,422	None	N	U	-

Table 4. Morphological measurements and Character Index (CI) values of three pallid sturgeon captured during 2003.

Pit tag #	Fork length	Head length	Mouth to inner barbel	Interrostral length	Outer barbel	Inner barbel	CI
None	1,385	443	60	198	181	47	594
Not scanned	1,365	435	60	188	129	40	531
220E770F3F	1,265	415	54	182	141	52	545

Table 5. Species, number sampled, and percent of total number sampled, catch per drift (C/drift), and catch per drift hour (C/drift h) of identifiable fish sampled with drifted trammel nets (1.8 by 30.5 or 45.7 m with a 22.7 kg lead core bottom line, 15.2 cm inner mesh and 25.4 cm outer mesh) during 2003 broodstock collection efforts.

Species	Number sampled	Percent of total	C/drift	C/drift h
Bigmouth buffalo	1	2	0.01	0.06
Common carp	1	2	0.01	0.06
Paddlefish	23	48	0.19	1.40
Pallid sturgeon	17	35	0.14	1.04
Sauger	3	6	0.02	0.18
Shovelnose sturgeon	2	4	0.02	0.12
Walleye	1	2	0.01	0.06
Total	48		0.39	2.93

Table 6. Stocking locations and length statistics of 2002 year-class hatchery-reared pallid sturgeon that were released into the Missouri and Yellowstone rivers between Fort Peck Dam and Lake Sakakawea during 2003.

Stocking site	River	Number stocked	Number measured	FL range	Mean FL (SD)	Number weighed	Weight range	Mean weight (SD)
Culbertson	M	1,033	1,032	161-380	280 (35)	544	24-193	101 (30)
Wolf Point	M	1,164	1,162	135-396	276 (36)	488	40-200	108 (26)
Intake	Y	1,040	1,040	209-344	267 (36)	490	28-188	92 (31)
Fairview	Y	887	887	187-397	273 (31)	489	20-193	100 (31)
Total		4,124	4,121		280 (35)	2,011		101 (30)

Table 7. Species, number sampled, and percent of total number sampled for all identifiable fish captured in sampling efforts during 2003.

Species	Number sampled	Percent of total
Black bullhead	1	0.02
Bigmouth buffalo	14	0.26
Brassy minnow	1	0.02
Brown trout	2	0.04
Blue sucker	67	1.25
Burbot	4	0.07
Channel catfish	377	7.01
Cisco	97	1.80
Common carp	93	1.73
Emerald shiner	764	14.21
Flathead chub	418	7.77
Fathead minnow	130	2.42
Freshwater drum	2	0.04
Goldeye	919	17.09
Western silvery or plains minnow	21	0.39
Lake whitefish	11	0.20
Longnose dace	16	0.30
Longnose sucker	76	1.41
Northern pike	73	1.36
Paddlefish	23	0.43
Pallid sturgeon	54	1.00
Rainbow smelt	2	0.04
Rainbow trout	10	0.19
River carpsucker	296	5.50
Smallmouth bass	2	0.04
Stonecat	26	0.48
Sauger	259	4.82
Sauger x walleye hybrid	1	0.02
Shorthead redhorse	114	2.12
Smallmouth buffalo	88	1.64
Shovelnose sturgeon	694	12.91
Sturgeon chub	7	0.13
Spottail shiner	7	0.13
Walleye	54	1.00
White sucker	638	11.87
White crappie	2	0.04
Yellow perch	14	0.26
Total	5,377	

Table 8. Species, number captured (N_c), number tagged (N_t) with an individually numbered Floy anchor tag, number double tagged (N_d) with an additional non-numbered Floy anchor tag, number tagged in each study section, number recaptured (N_r), and percent recaptures of total number captured for blue sucker, river carpsucker, sauger, and shovelnose sturgeon captured in the study area during 2003. Shovelnose sturgeon were tagged with individually numbered Floy cinch tags.

				Study section								
Species	N_c	N_t	N_d	0	1	2	3	4	5	6	N_r	Percent recaptures
Blue sucker	67	62	32	30	5	10	5	4	3	5	1	1.49
River carpsucker	296	230	69	43	37	50	37	56	3	4	0	0.00
Sauger	259	104*	28	3	5	36	23	28	8	1	0	0.00
Shovelnose sturgeon	694	446	-	2	120	104	92	45	52	31	31	4.47

*One sauger was implanted with a radio transmitter

Table 9. Number (N), mean total length (mm), and ranges of sauger sampled in the Milk, Missouri, and Yellowstone rivers during 2003. Standard deviations of mean total lengths are listed in parentheses.

	Age					
	1	2	3	4	5	6
N	8	54	74	43	14	1
Mean	240	291	335	405	453	-
	(22.6)	(32.9)	(35.8)	(41.1)	(35.3)	-
Range	206-269	213-368	285-451	310-486	404-532	520

Table 10. Species, number sampled, and percent of total number sampled of fish sampled in our standardized sampling efforts during 2003.

Species	Number sampled	Percent of total
Black bullhead	1	0.03
Bigmouth buffalo	9	0.31
Brassy minnow	1	0.03
Brown trout	2	0.07
Blue sucker	49	1.71
Burbot	2	0.07
Channel catfish	144	5.02
Cisco	1	0.03
Common carp	49	1.71
Emerald shiner	763	26.61
Flathead chub	136	4.74
Fathead minnow	130	4.53
Goldeye	239	8.34
Western silvery or plains minnow	21	0.73
Lake whitefish	2	0.07
Longnose dace	16	0.56
Longnose sucker	69	2.41
Northern pike	44	1.53
Pallid sturgeon	1	0.03
Rainbow trout	10	0.35
River carpsucker	195	6.80
Smallmouth bass	2	0.07
Sauger	88	3.07
Shorthead redhorse sucker	30	1.05
Smallmouth buffalo	64	2.23
Shovelnose sturgeon	184	6.42
Sturgeon chub	7	0.24
Spottail shiner	6	0.21
Walleye	6	0.21
White sucker	585	20.40
White crappie	2	0.07
Yellow perch	9	0.31
Total	2,867	

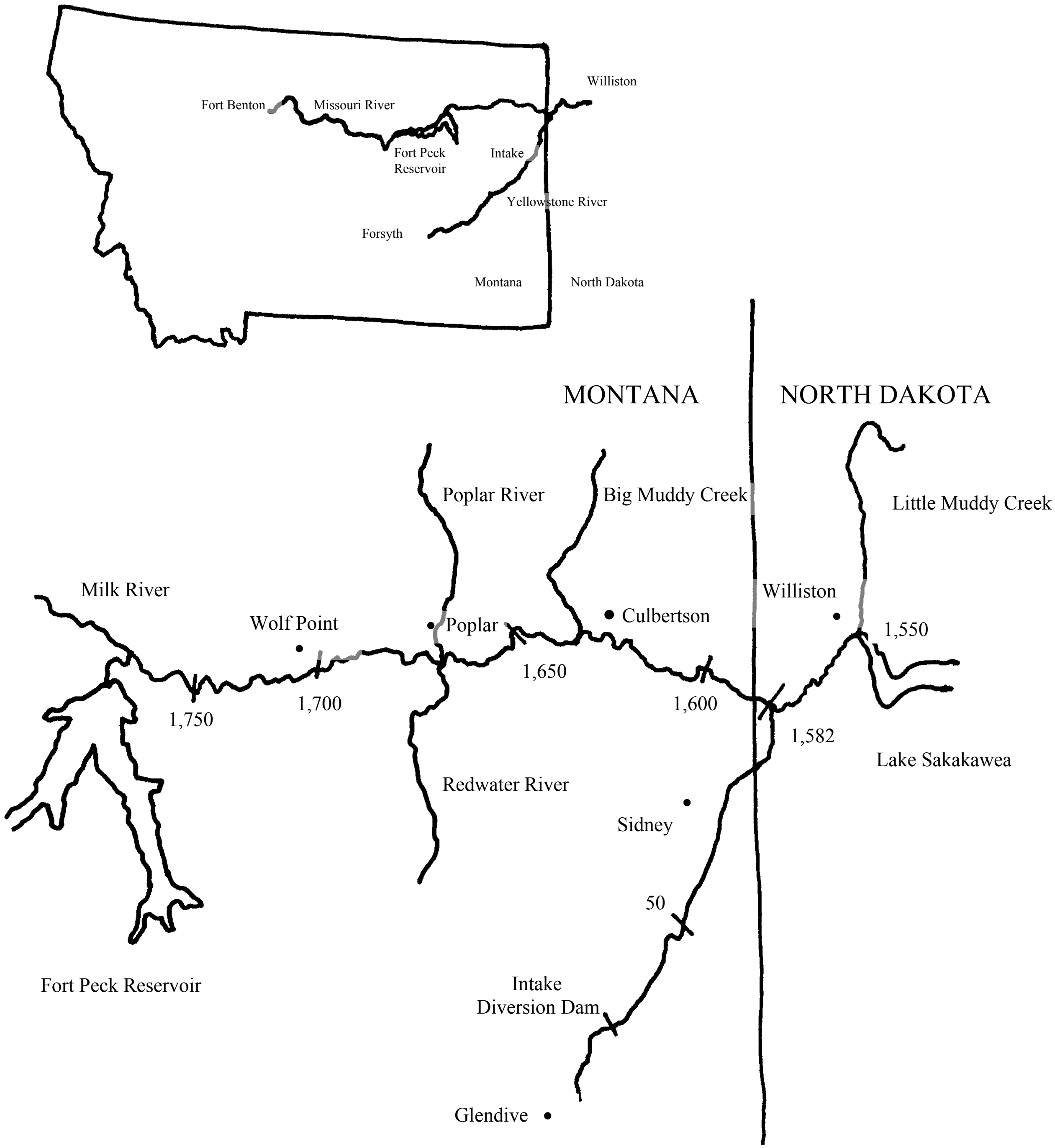


Figure 1. Map of the lower Missouri and Yellowstone rivers pallid sturgeon study area and associated river miles.

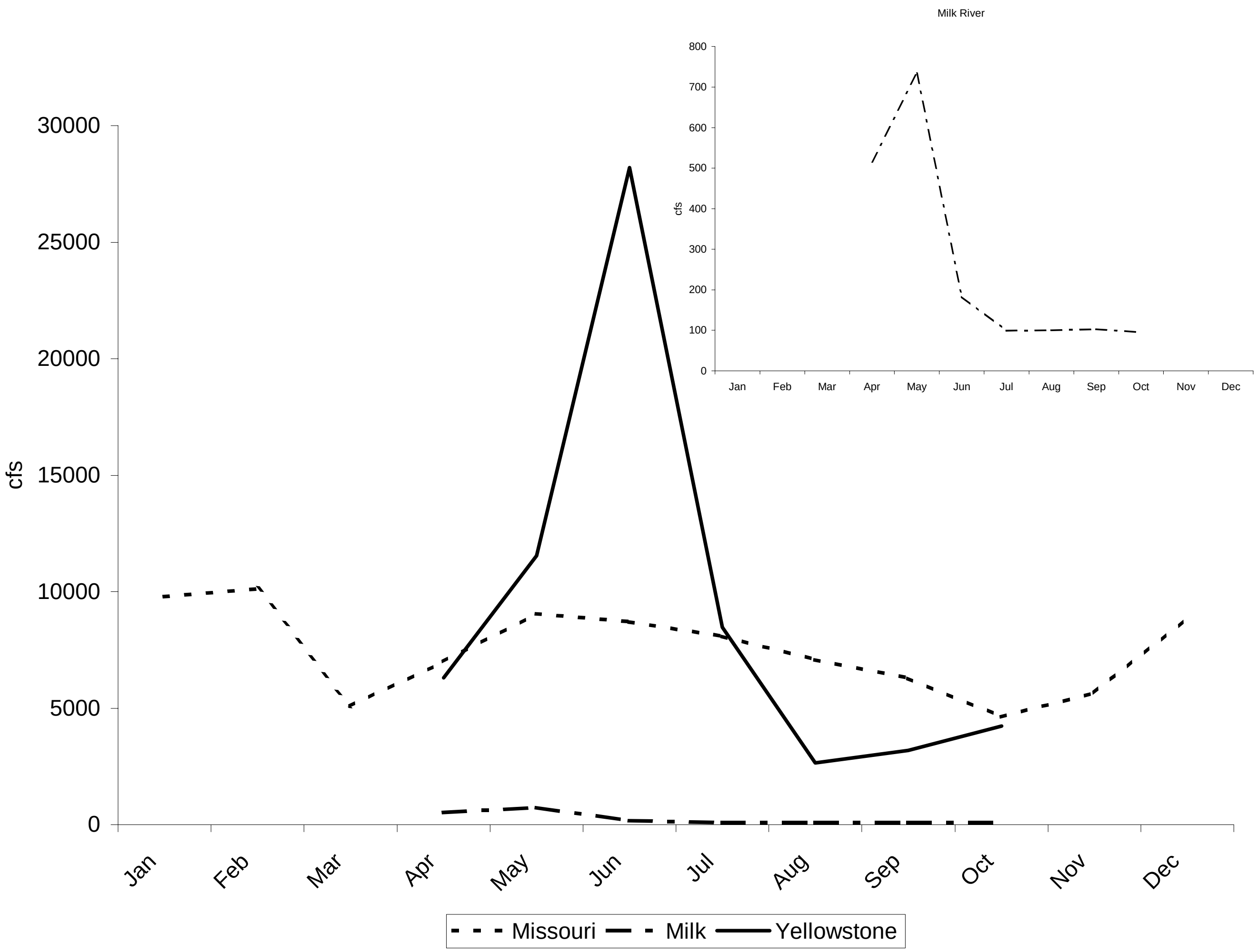


Figure 2. Mean monthly discharges during 2003 for the Yellowstone River at Sidney (solid line), Missouri River below Fort Peck Dam (dashed line), and the Milk River at Nashua (bar-dash-bar line). Inserted graph shows the Milk River data at a smaller scale. Provisional data provided by USGS, Fort Peck Field Office, Fort Peck, MT.

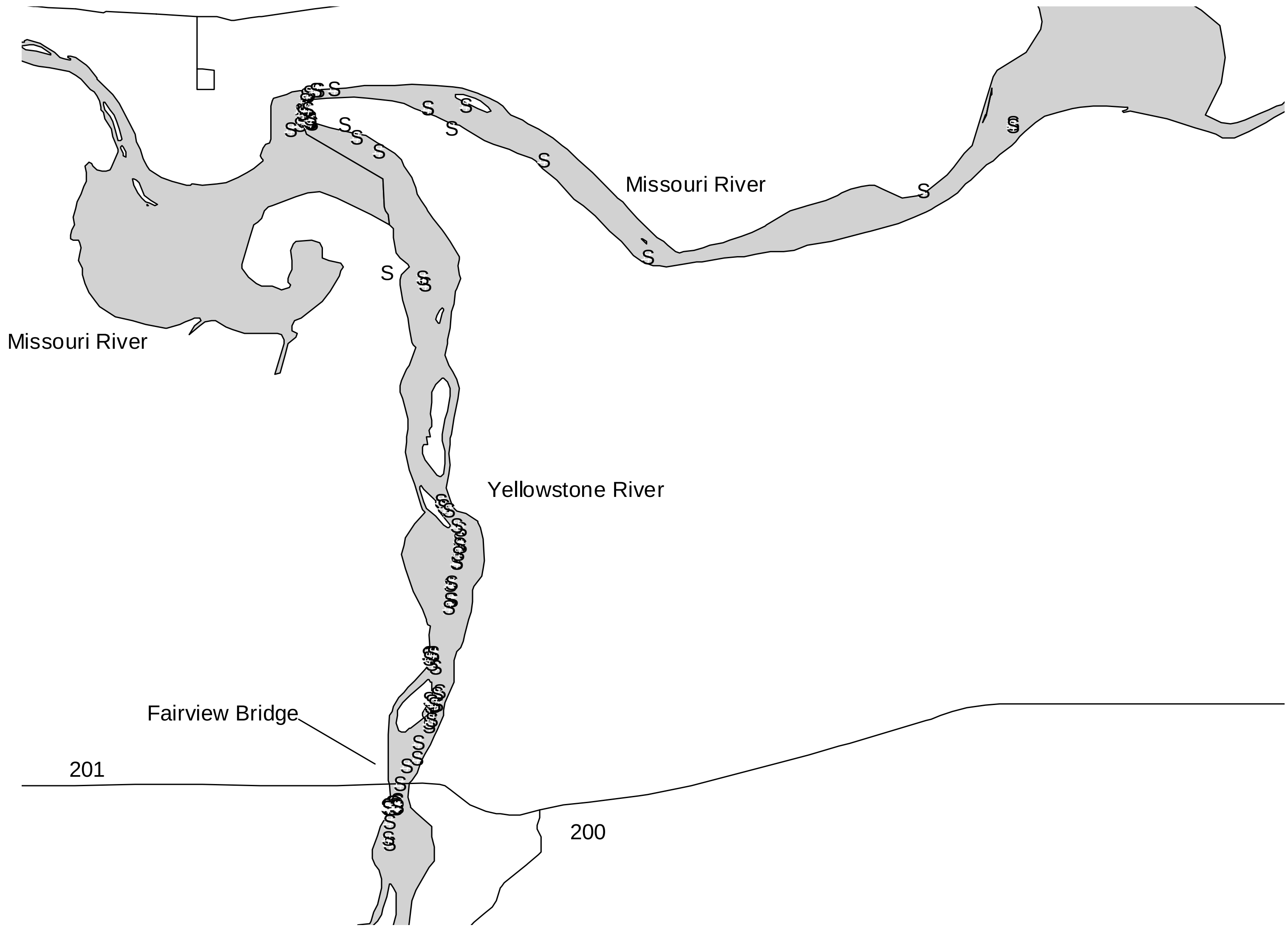


Figure 3. Sites sampled (white circles) for adult pallid sturgeon in the Missouri and Yellowstone rivers during 22 April-14 May 2003.

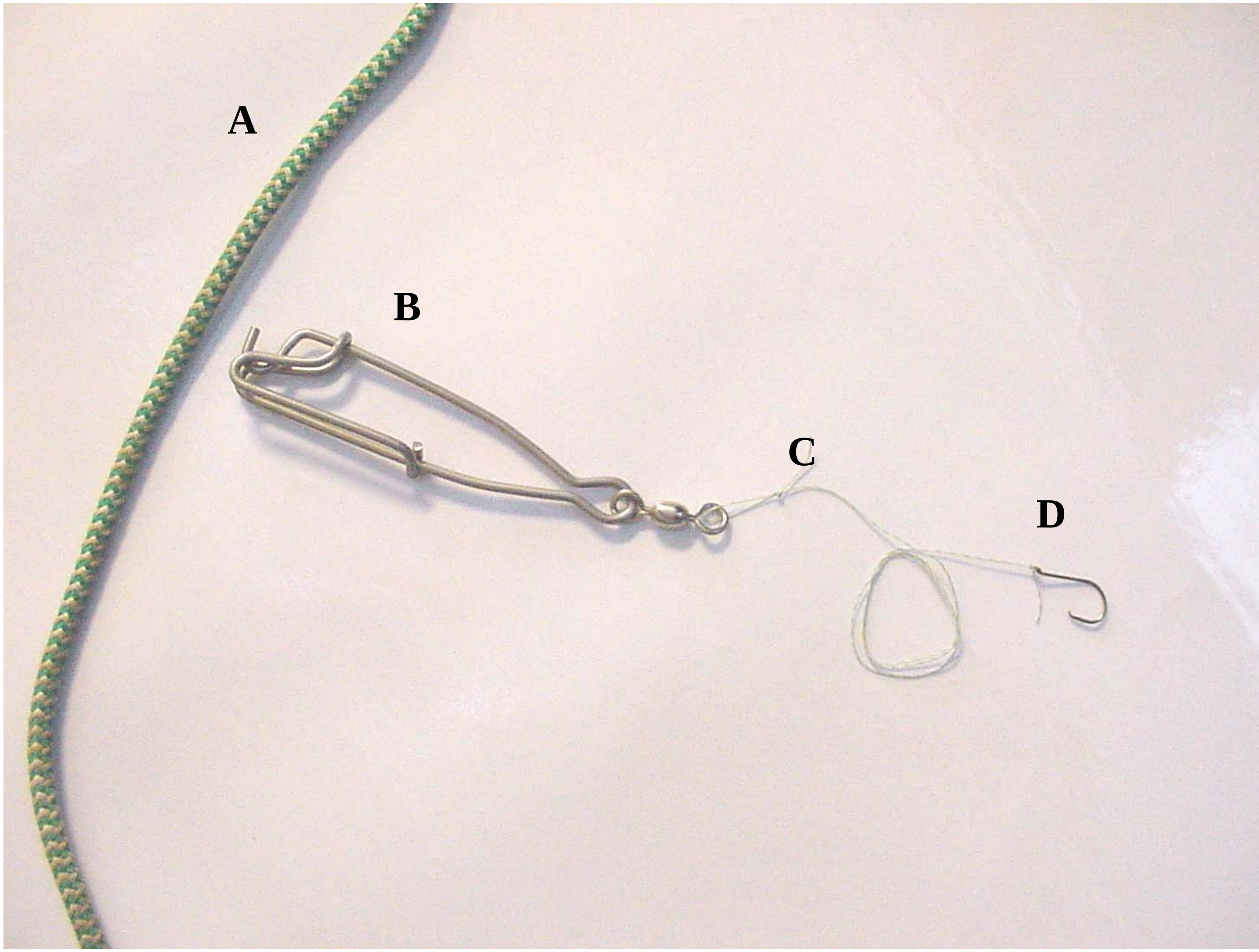
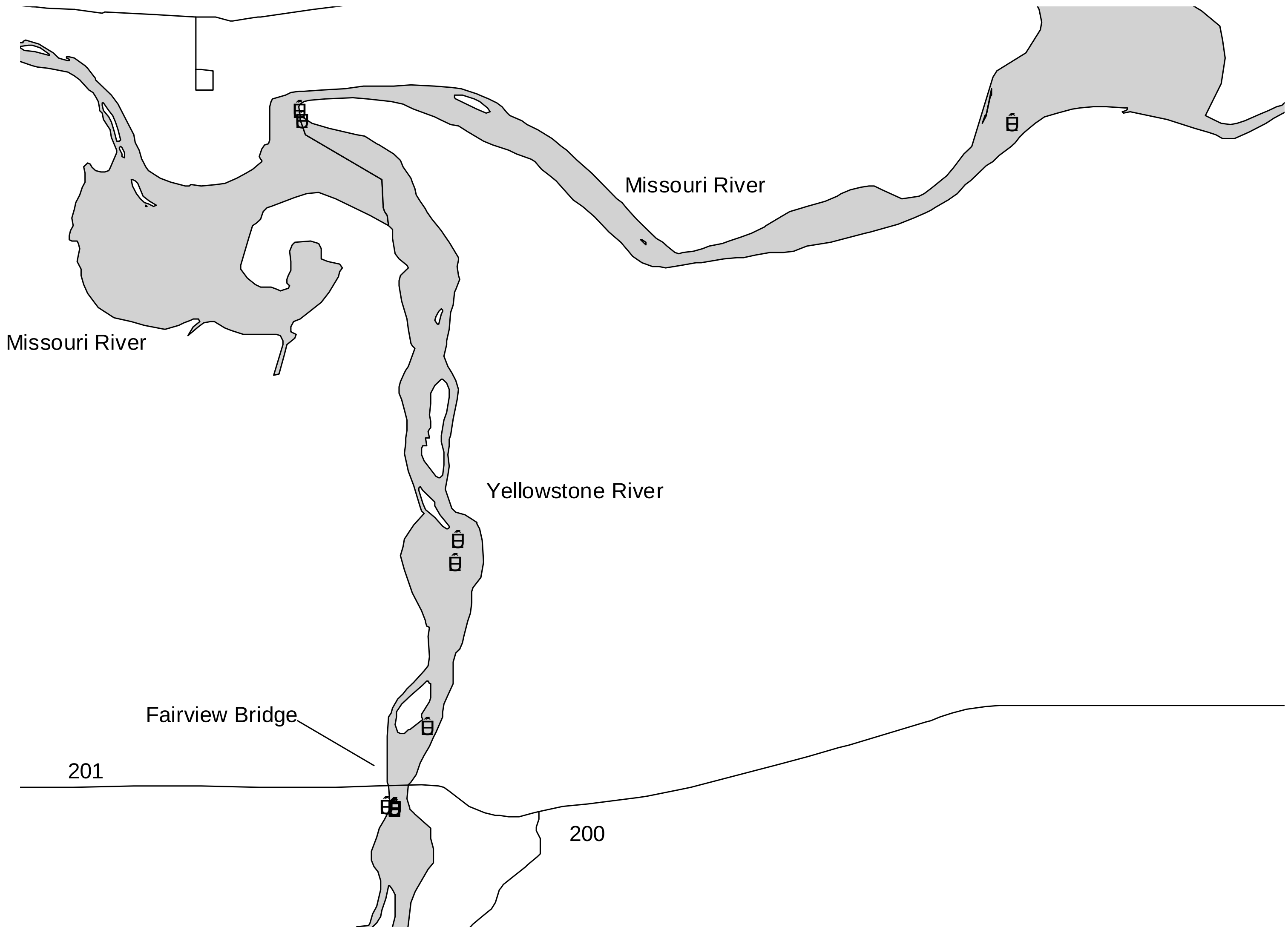


Figure 4. Digital image of setline components. (A) A section of main leaded line; (B) a trotline swivel clip; (C) an 45.72 cm, 9.072 kg test Dacron leader; (D) a circle hook.

Fig. 5. Capture sites (black stars) of adult pallid sturgeon in the Missouri and Yellowstone rivers during 22 April-14 May 2003



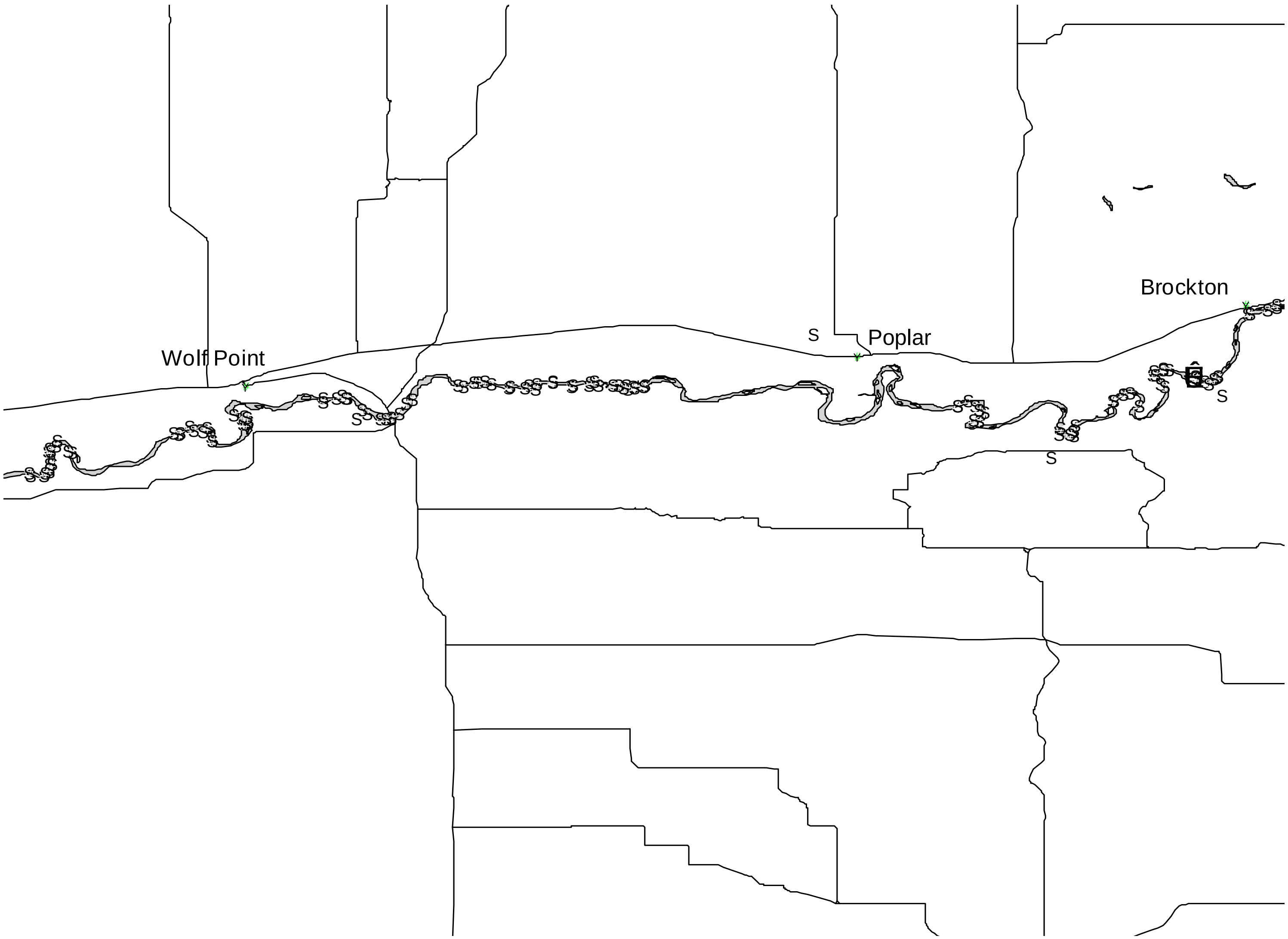


Figure 6. Sites sampled (white circles) with drifted trammel nets and recapture sites (black stars) of hatchery-reared pallid sturgeon in the Missouri River from near Oswego to near Brockton, MT during 2003.

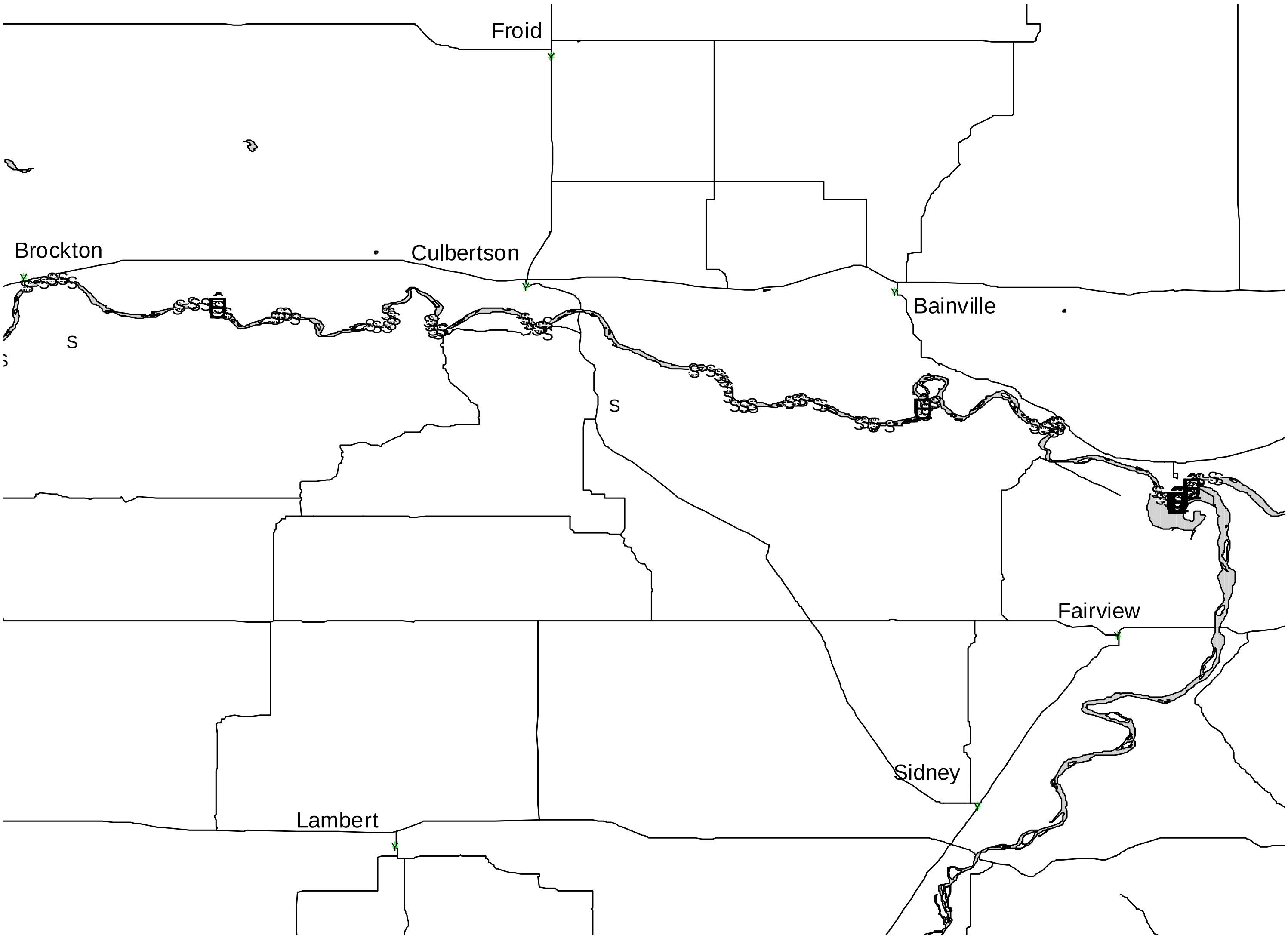


Figure 7. Sites sampled (white circles) with drifted trammel nets and recapture sites (black stars) of hatchery-reared pallid sturgeon from near Brockton, MT to near the confluence of the Missouri and Yellowstone rivers, ND during 2003.

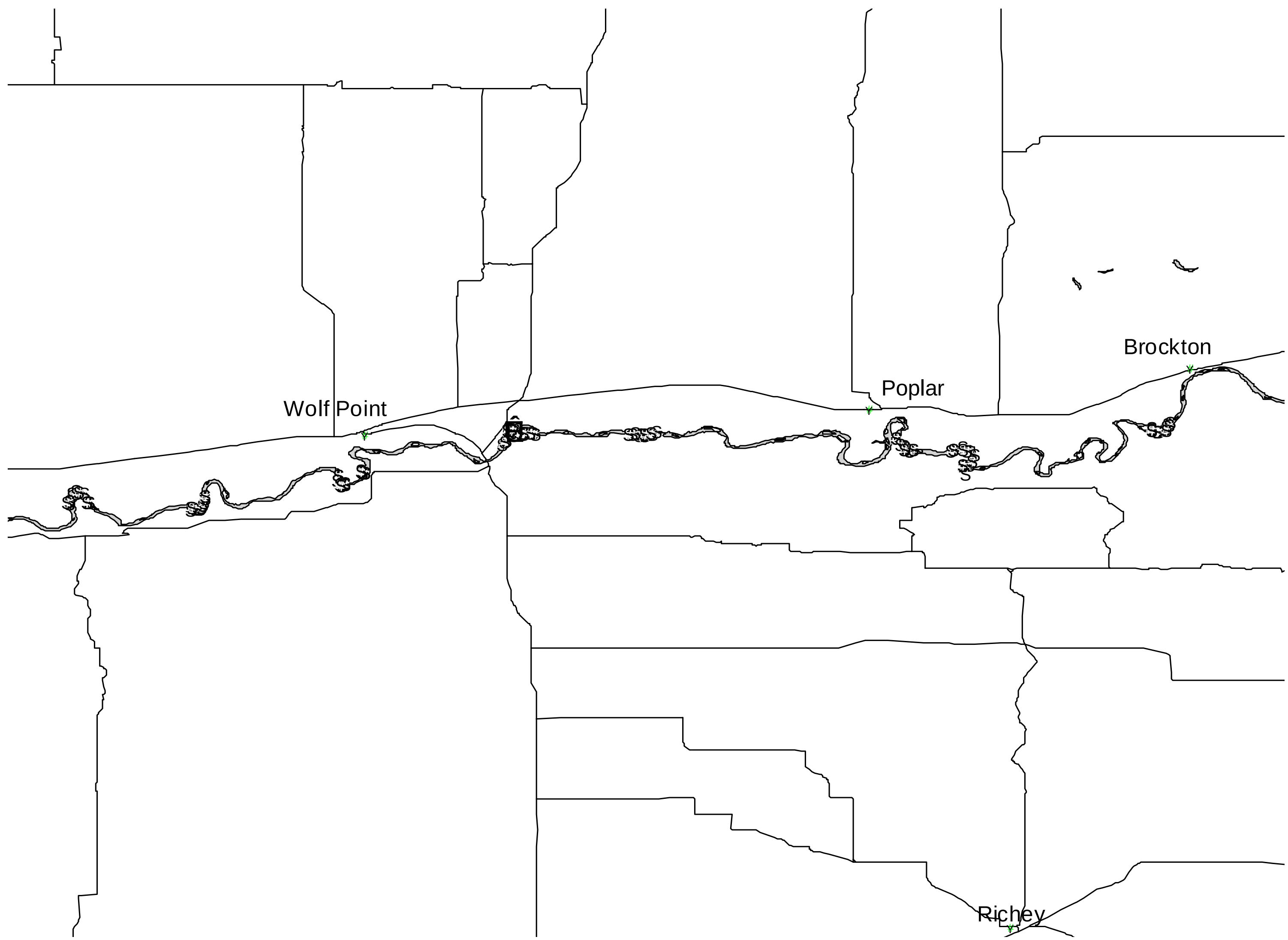


Figure 8. Sites sampled (white circles) with setlines and recapture sites (black stars) of hatchery-reared pallid sturgeon from near Oswego to near Brockton, MT during 2003.

Figure 9. Sites sampled (white circles) with setlines and recapture sites (black stars) of hatchery-reared pallid sturgeon from near Brockton, MT to near to near the confluence of the Missouri and Yellowstone rivers, ND during 2003.

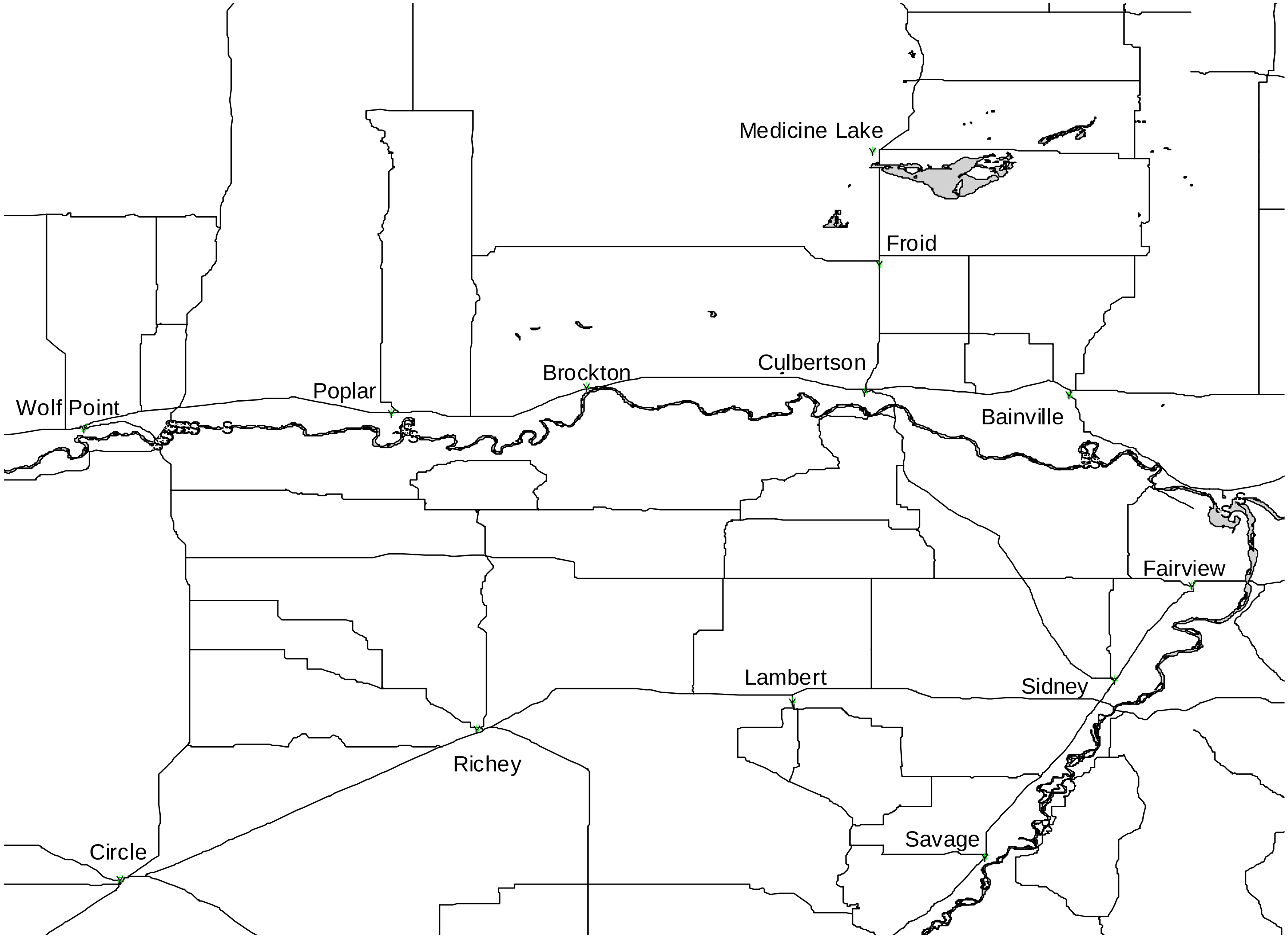


Figure 10. Sites sampled (white circles) by angling for hatchery-reared pallid sturgeon from near Wolf Point, MT to near the confluence of the Missouri and Yellowstone rivers, ND during 2003.

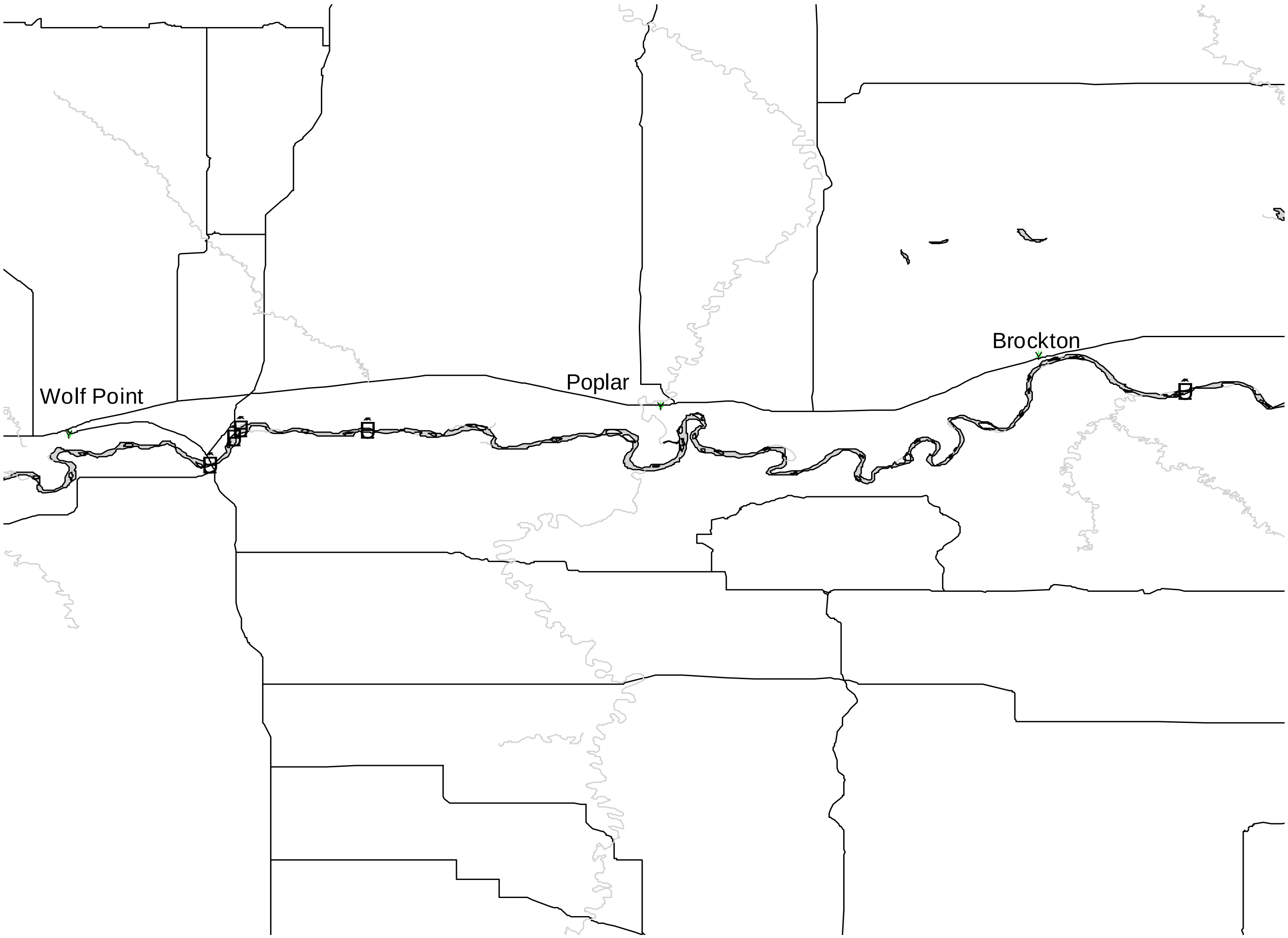


Figure 11. Recapture sites (black stars) of hatchery-reared pallid sturgeon recaptured from near Wolf Point to near Brockton, MT during 6 August-14 October 2003.

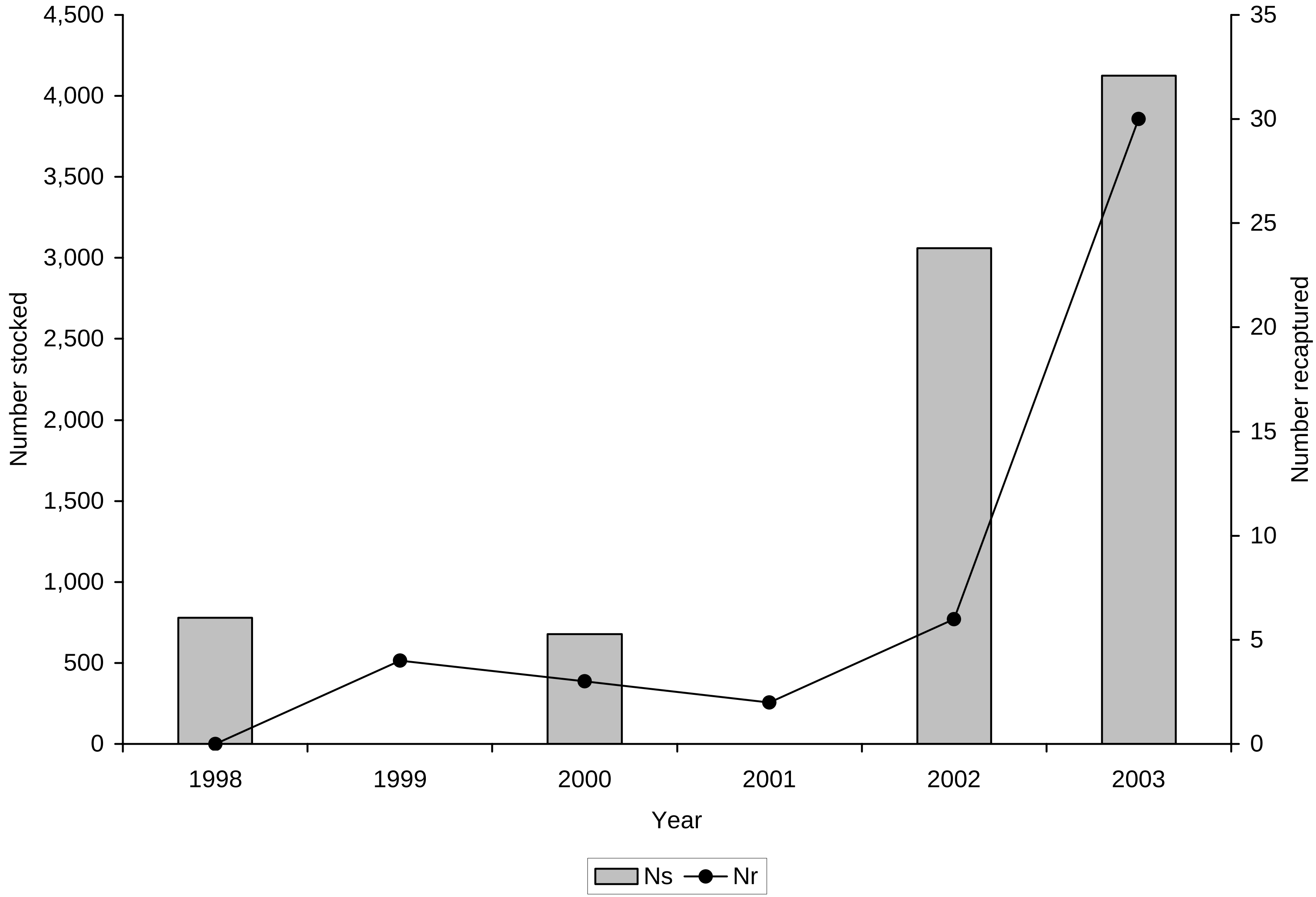


Figure 12. Number stocked (N_s) and number recaptured (N_r) verses year for hatchery-reared pallid sturgeon in the study area during 1998-2003.

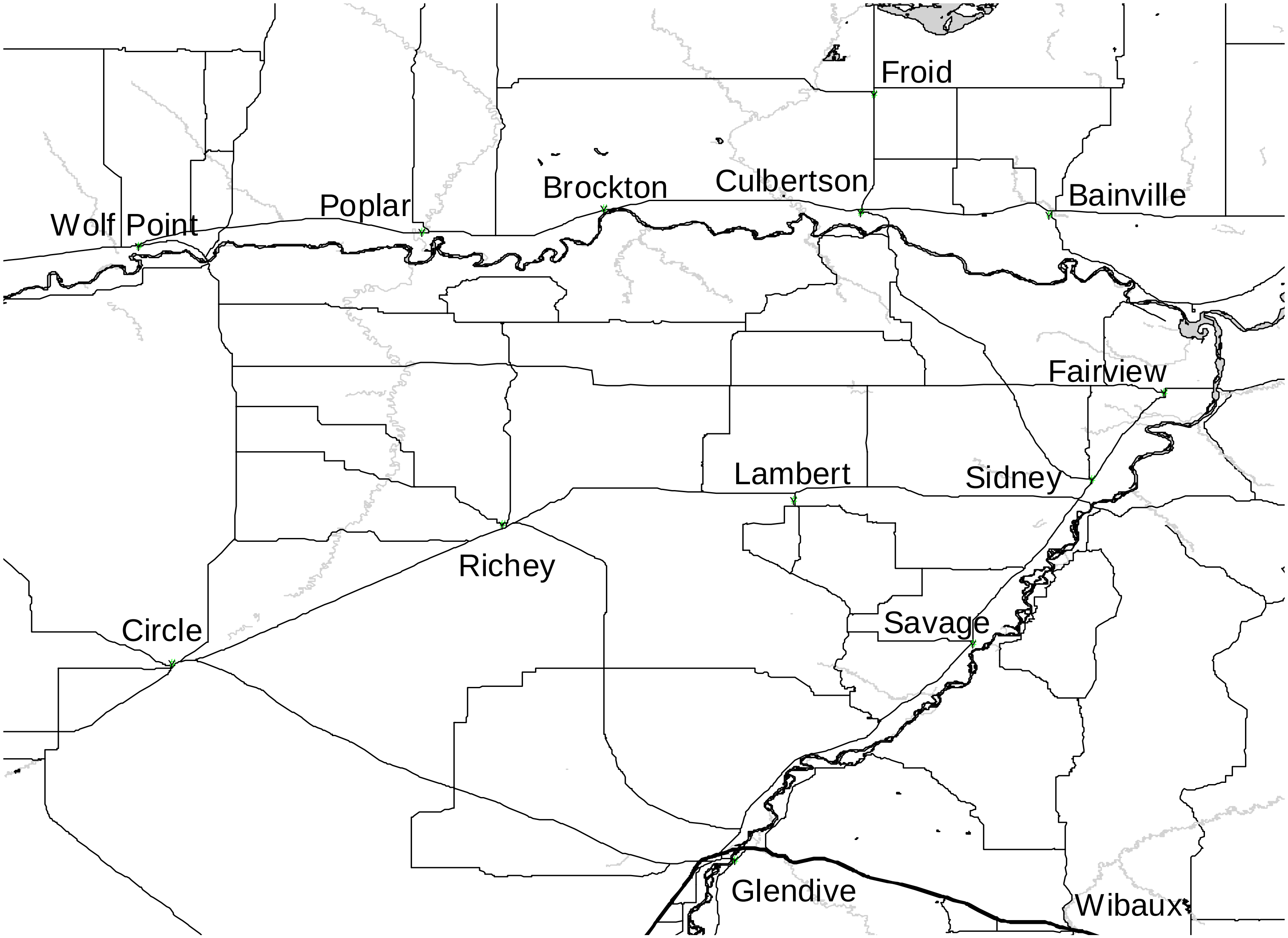


Figure 13. Hatchery-reared pallid sturgeon stocking sites during 2003.

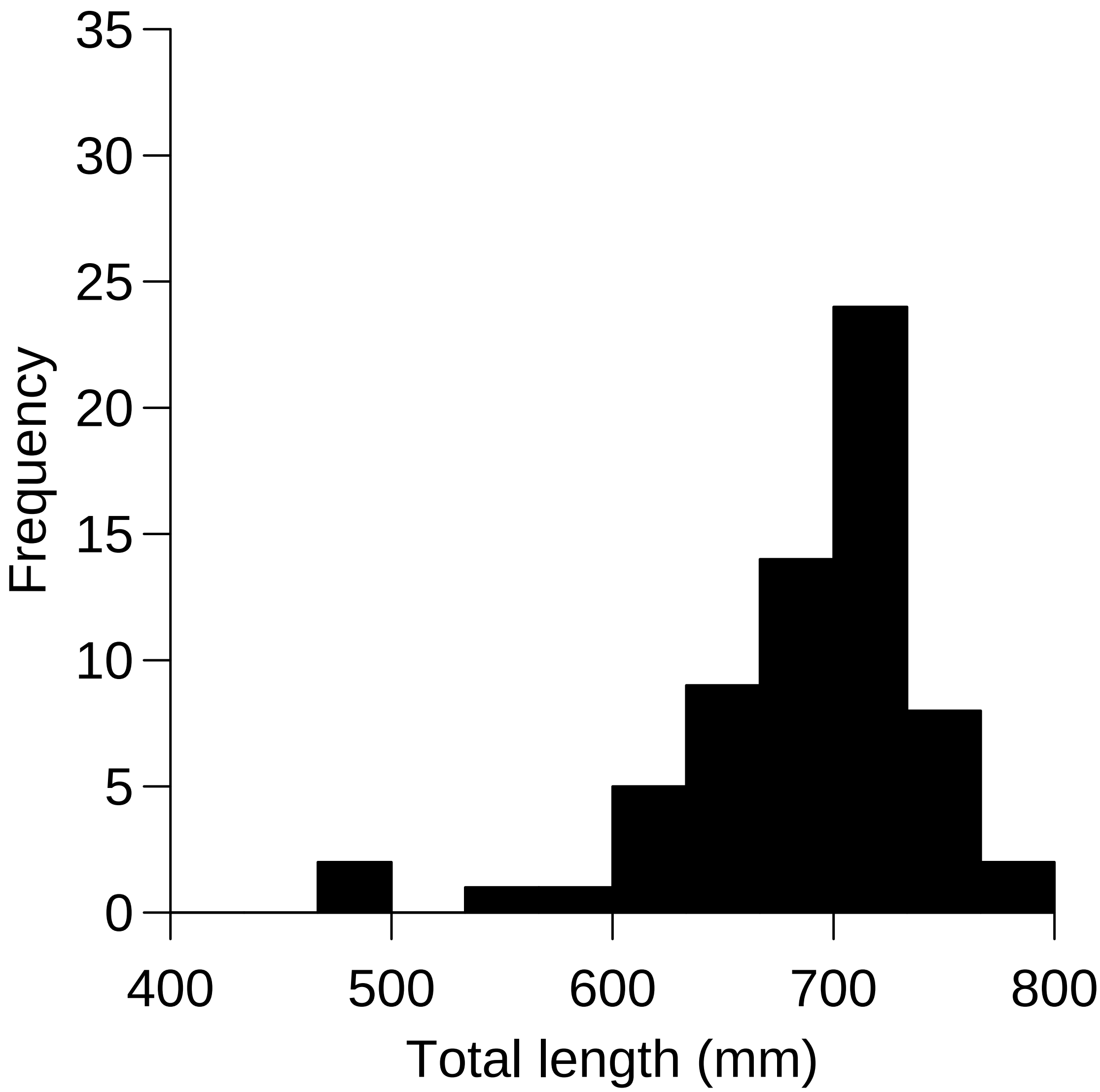


Figure 14. Total length-frequency plot for blue suckers captured in the study area during 2003.

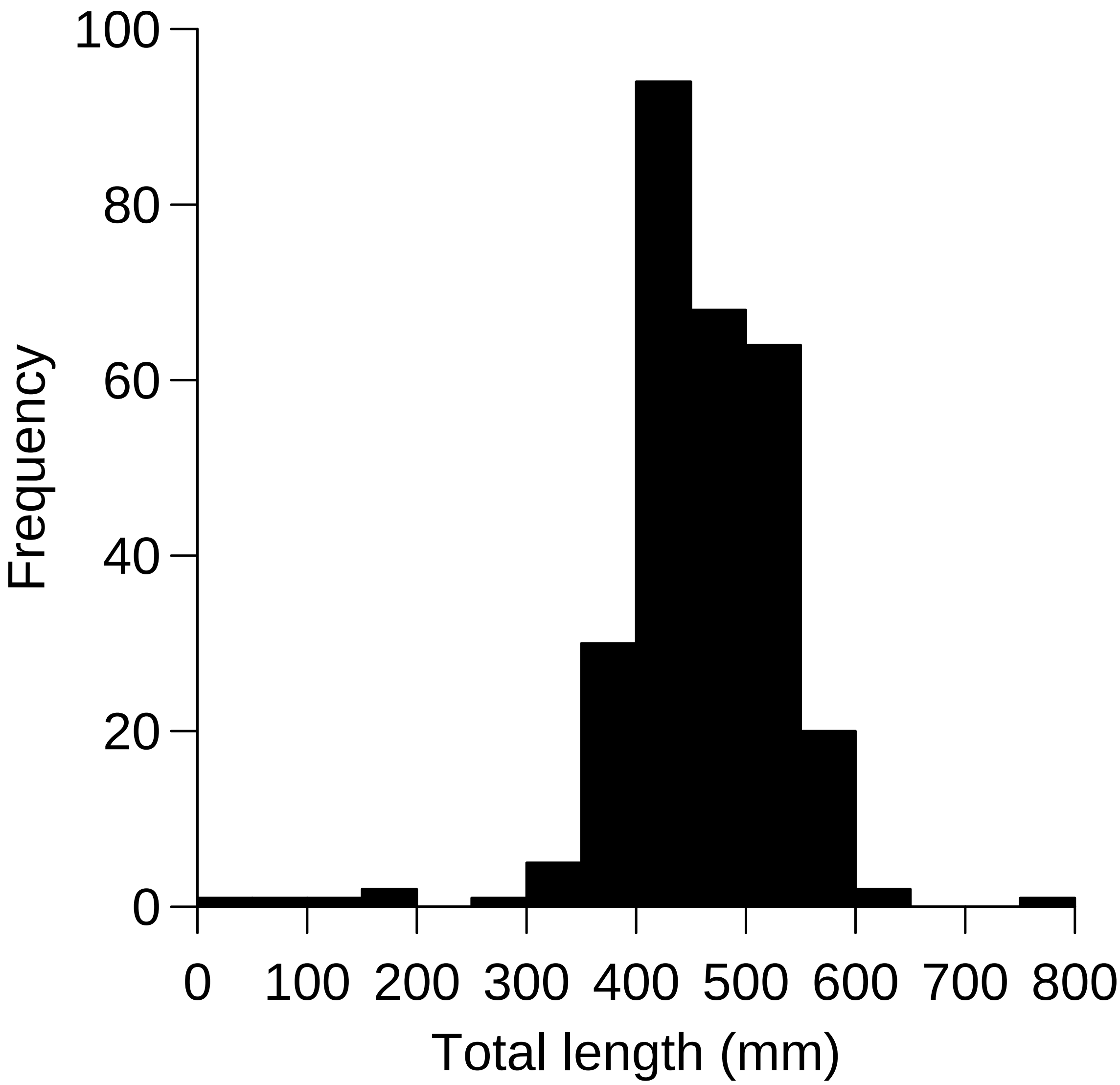


Figure 15. Total length-frequency plot for river carpsuckers captured in the study area during 2003.

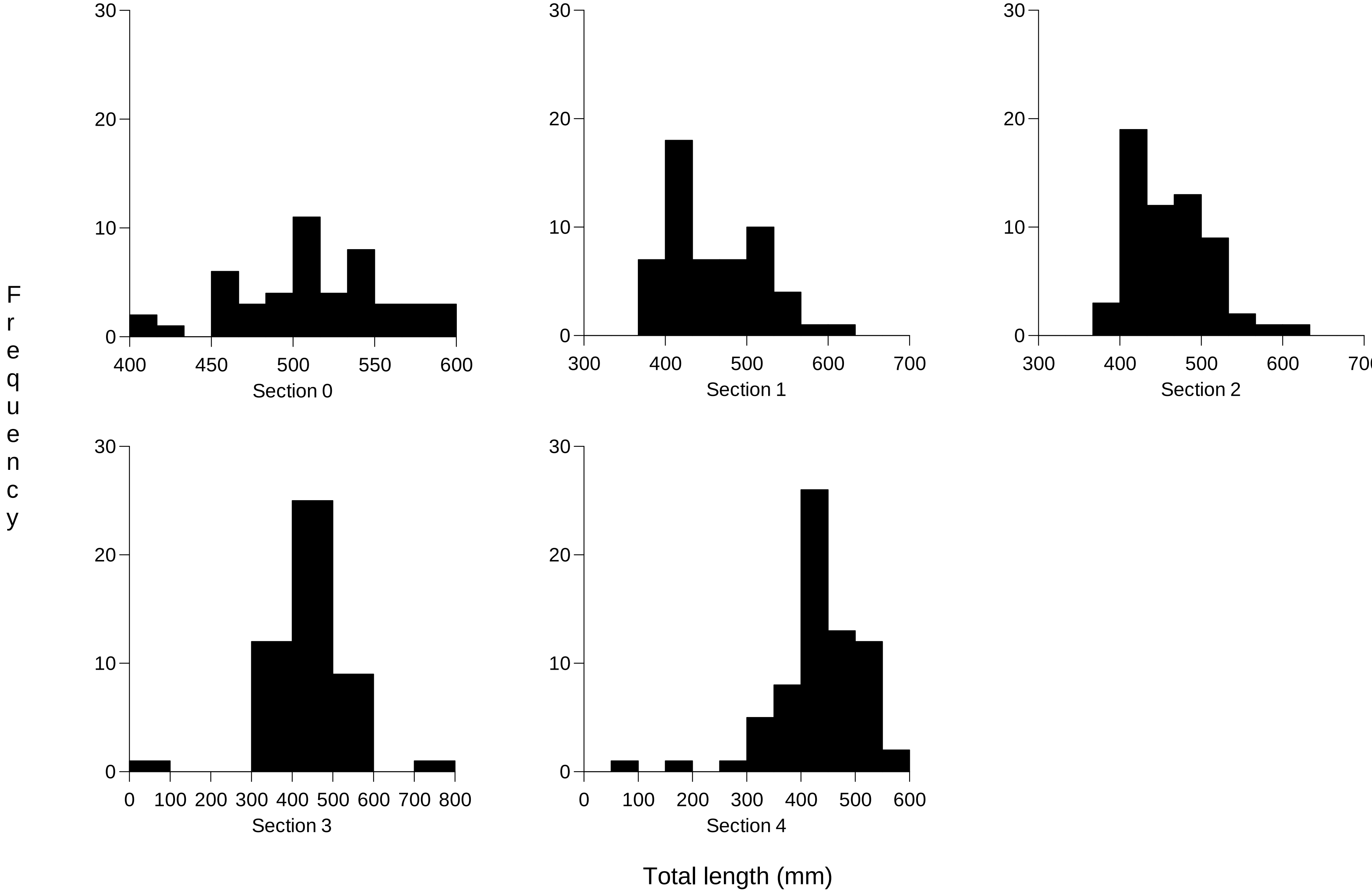


Figure 16. Total length-frequency plots by study section for river carpsuckers captured during 2003

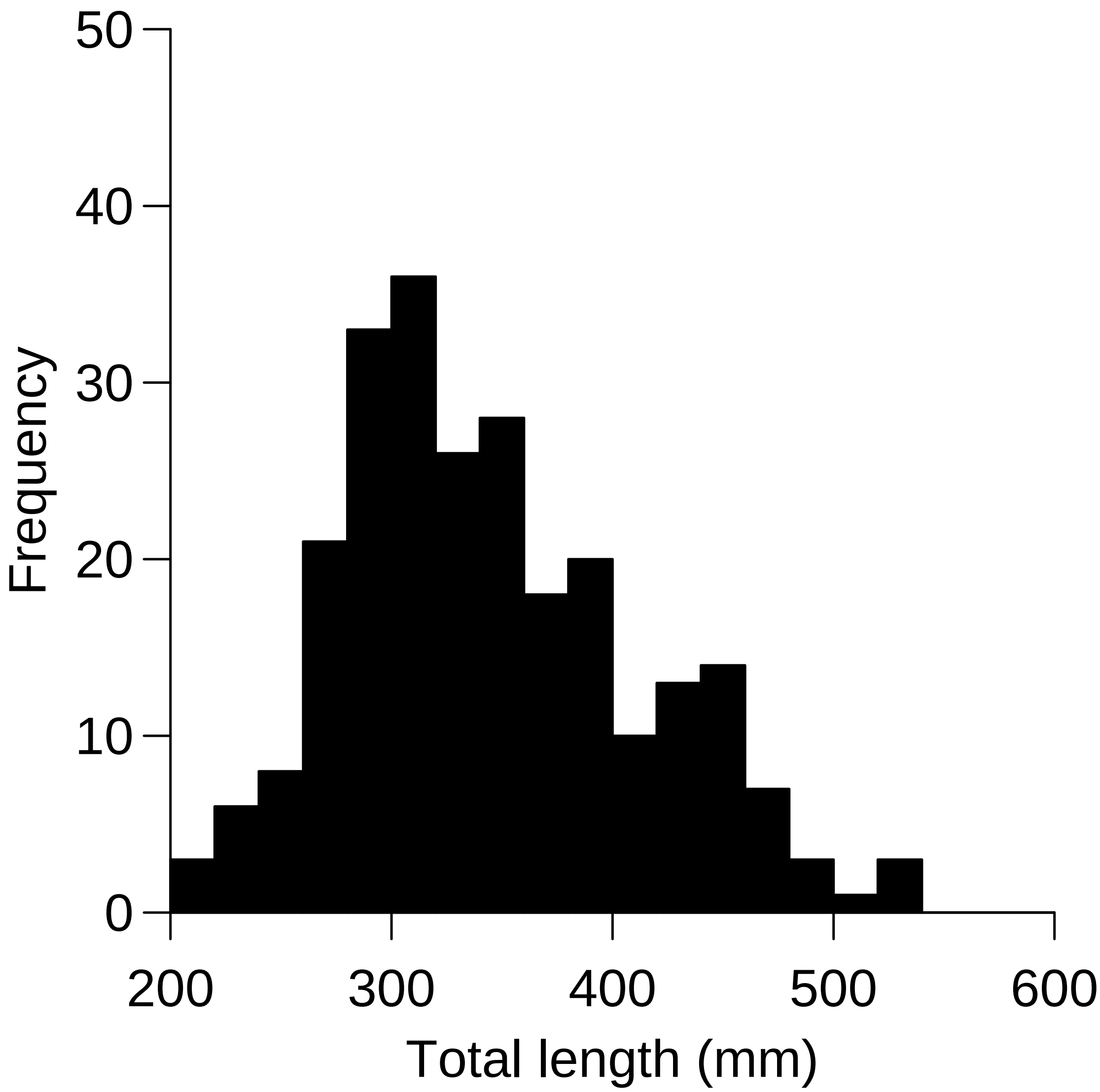


Figure 17. Total length-frequency plot for sauger captured in the study area during 2003.

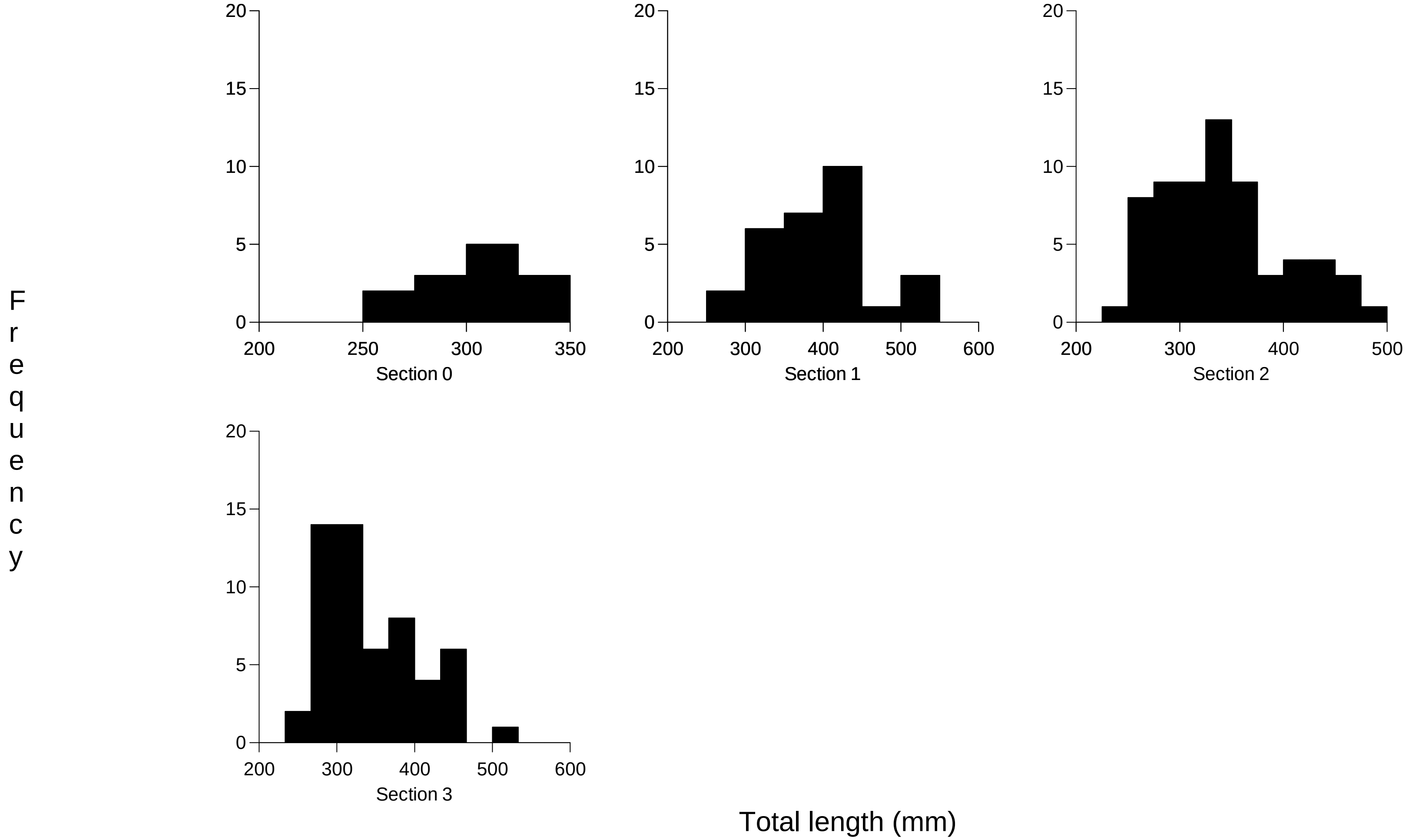


Figure 18. Total length-frequency plots by study section for sauger sampled during 2003.

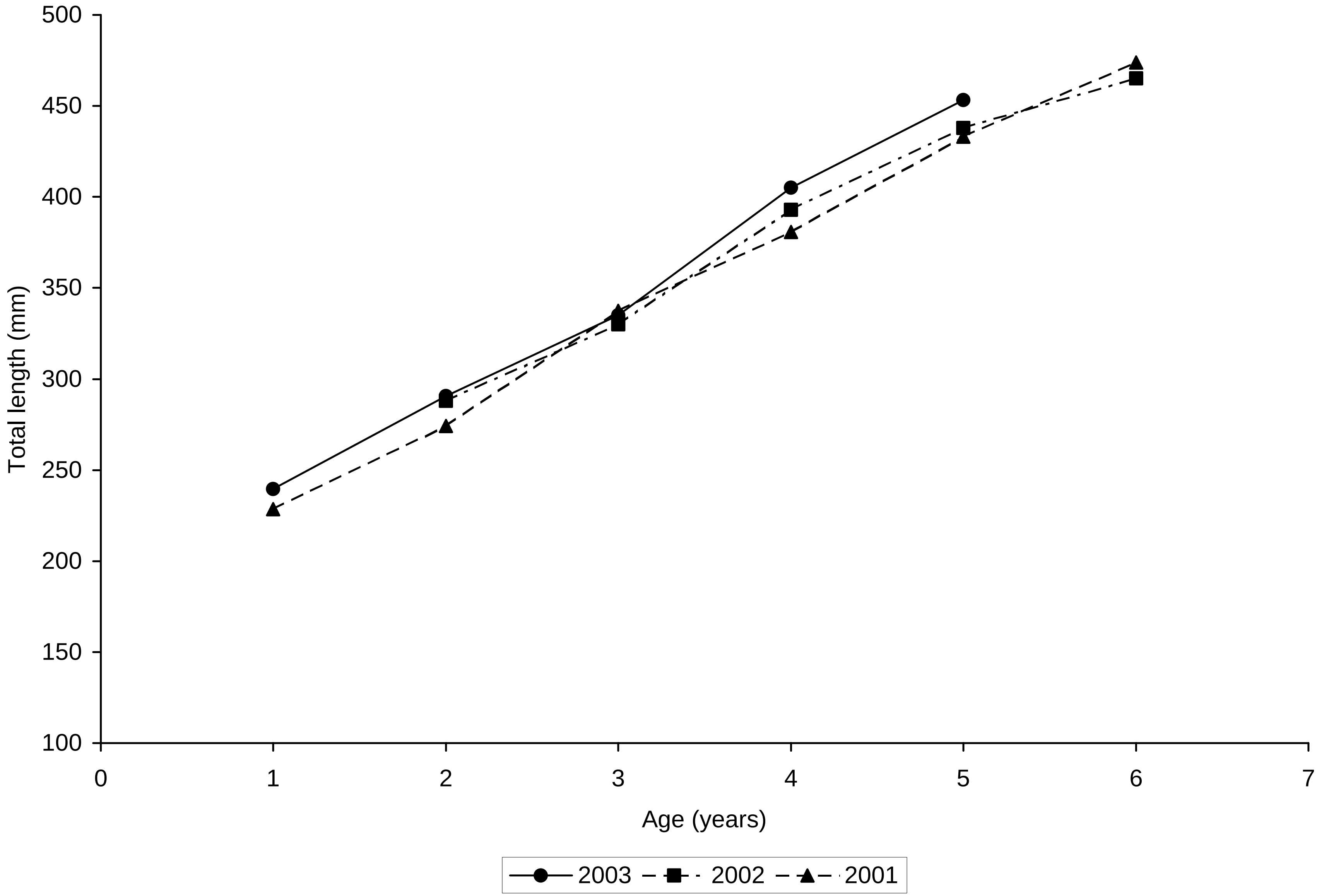


Figure 19. Mean total length at age for sauger sampled in the study area during 2001-2003.

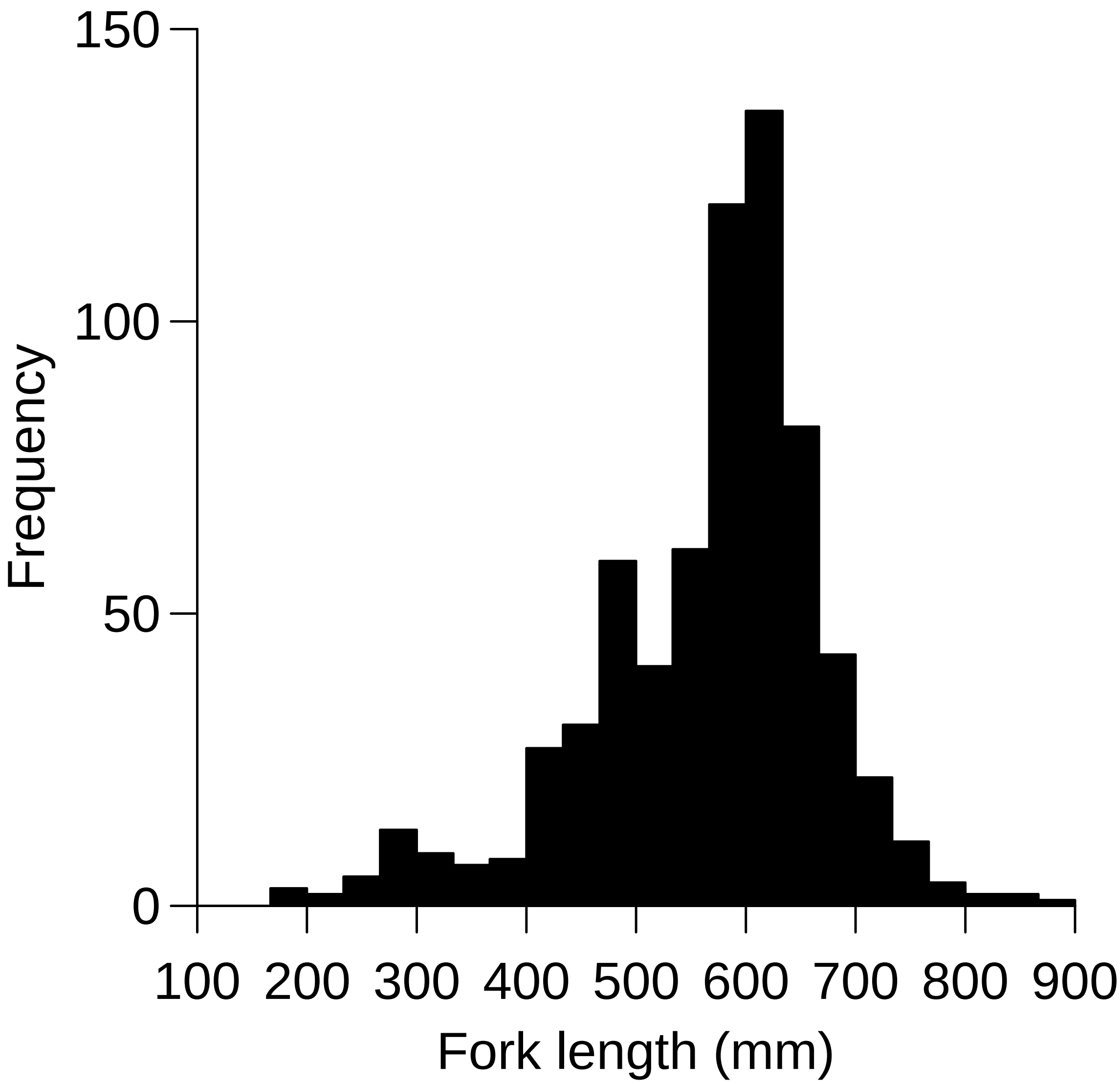


Figure 20. Fork length-frequency plot for shovelnose sturgeon captured in the study area during 2003.

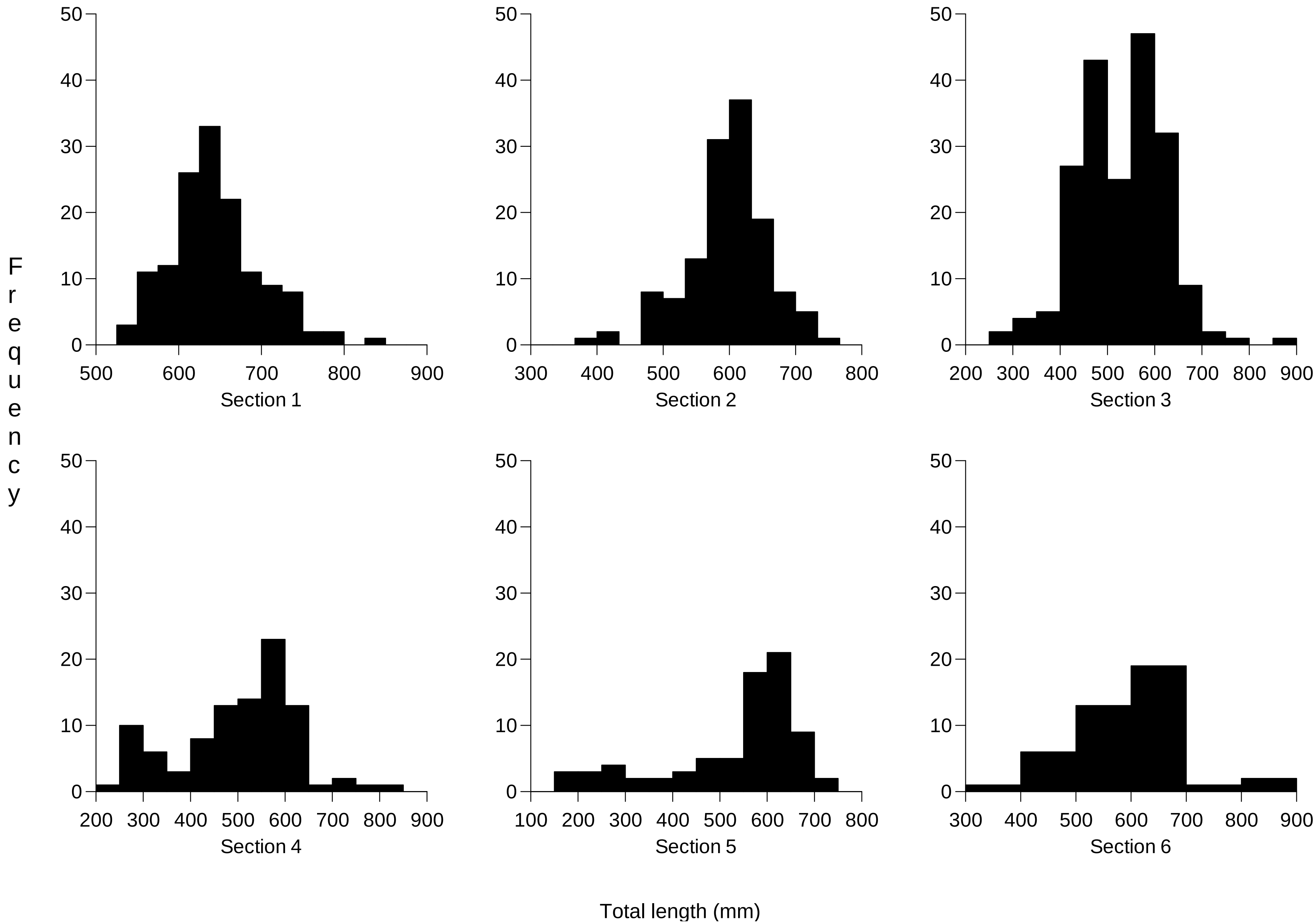


Figure 21. Fork length-frequency plots by study section for shovelnose sturgeon sampled during 2003.

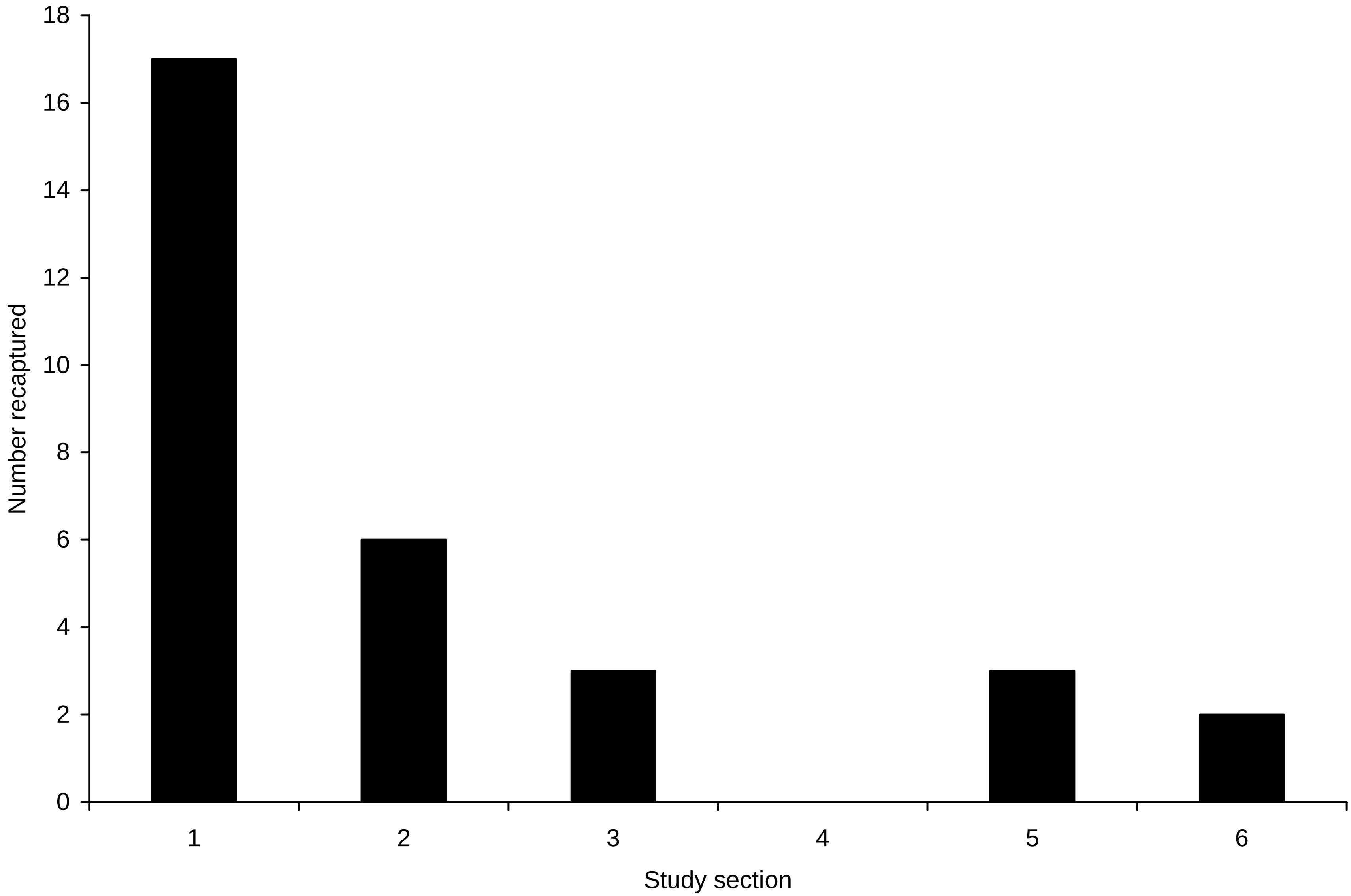
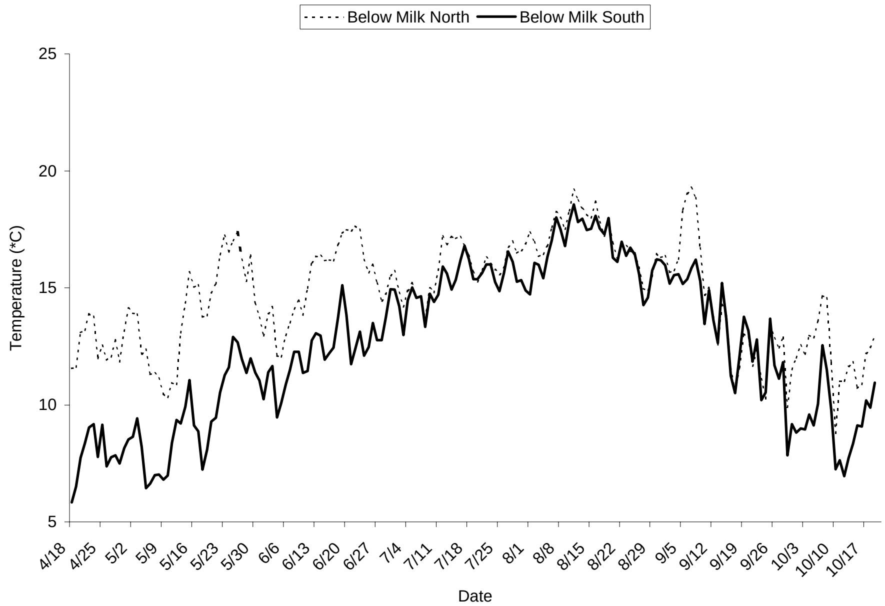
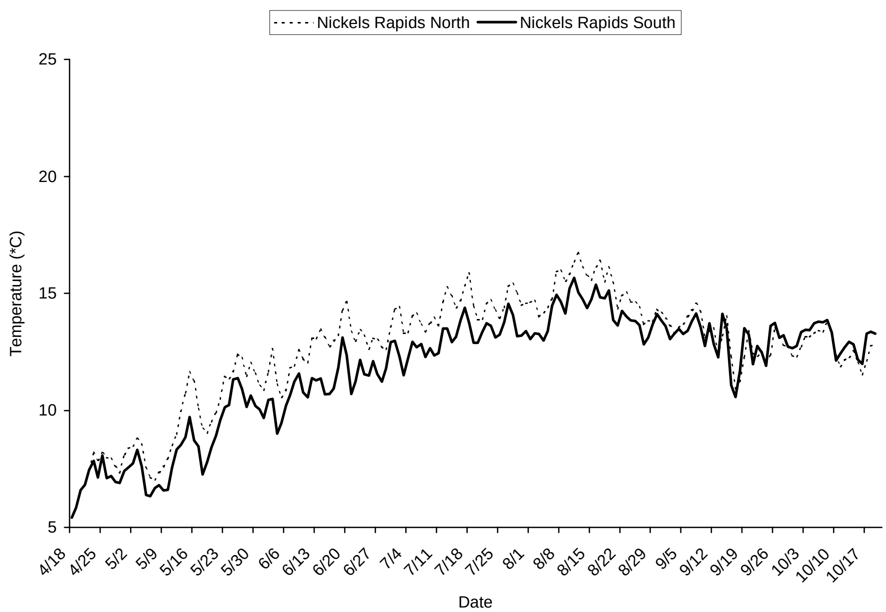


Figure 22. Number of previously tagged shovelnose sturgeon recaptured by study section during 2003.

Figure 23. Mean daily water temperature (ºC) versus date observed at sites on the Milk, Missouri, and Yellowstone rivers during 2003.


Below Milk North
Below Milk South
Temperature (*C)
25
20
15
10
5
4/18
4/25
5/2
5/9
5/16
5/23
5/30
6/6
6/13
6/20
6/27
7/4
7/11
7/18
7/25
8/1
8/8
8/15
8/22
8/29
9/5
9/12
9/19
9/26
10/3
10/10
10/17
Date


Nickels Rapids North
Nickels Rapids South
Temperature (*C)
25
20
15
10
5
4/18
4/25
5/2
5/9
5/16
5/23
5/30
6/6
6/13
6/20
6/27
7/4
7/11
7/18
7/25
8/1
8/8
8/15
8/22
8/29
9/5
9/12
9/19
9/26
10/3
10/10
10/17
Date

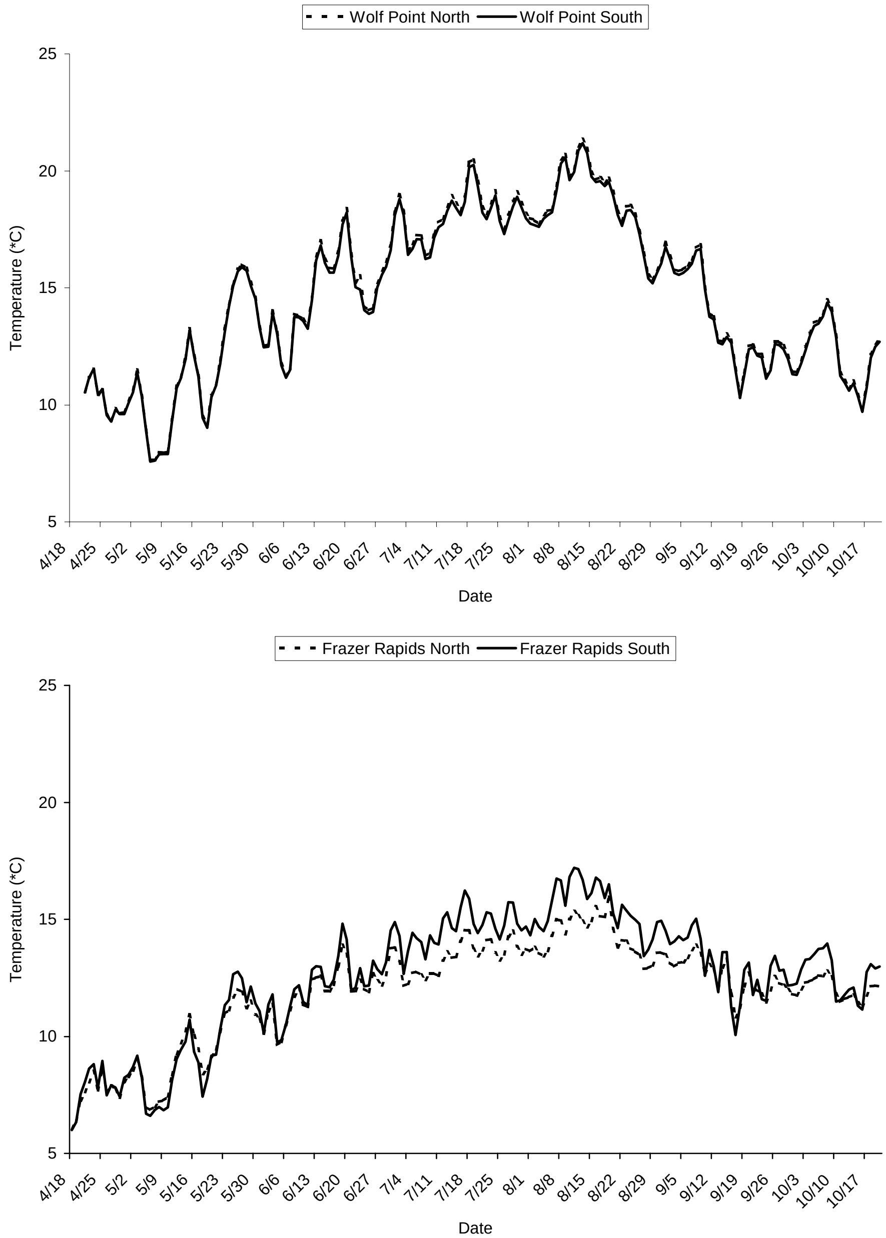


Figure 24. Comparisons of north and south bank mean daily water temperature (ºC) versus date observed at Below Milk (1,761.5), Nickels Rapids (RM 1,759), Frazer Rapids (RM 1,744), and Wolf Point (RM 1,708) during 18 April-20 October 2003.

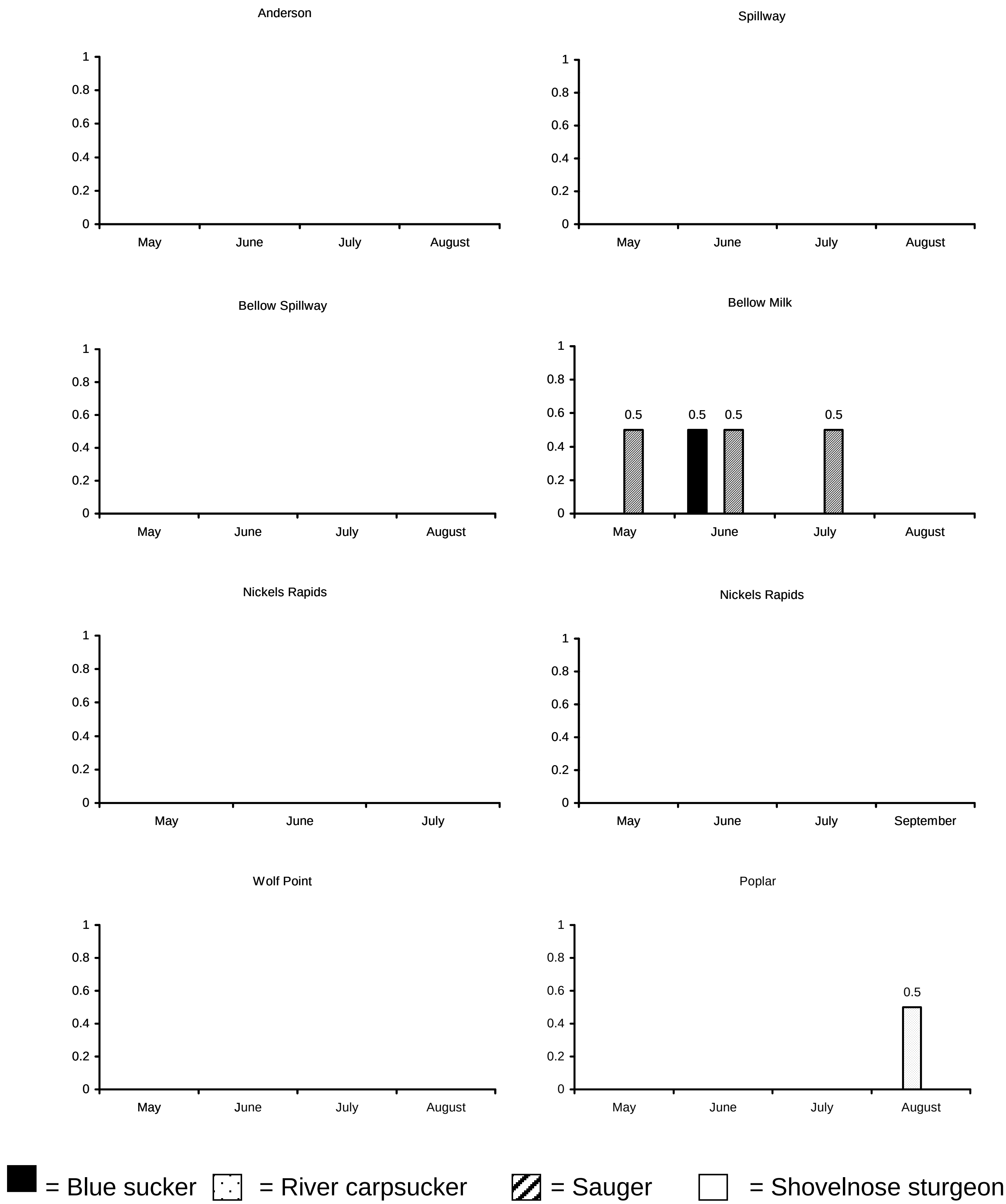


Figure 25. CPUE rates (number per 50’ seine haul) for blue sucker, river carpsucker, sauger, and shovelnose sturgeon sampled in bag seine hauls at standardized sites on the Missouri River, MT, during 2003.

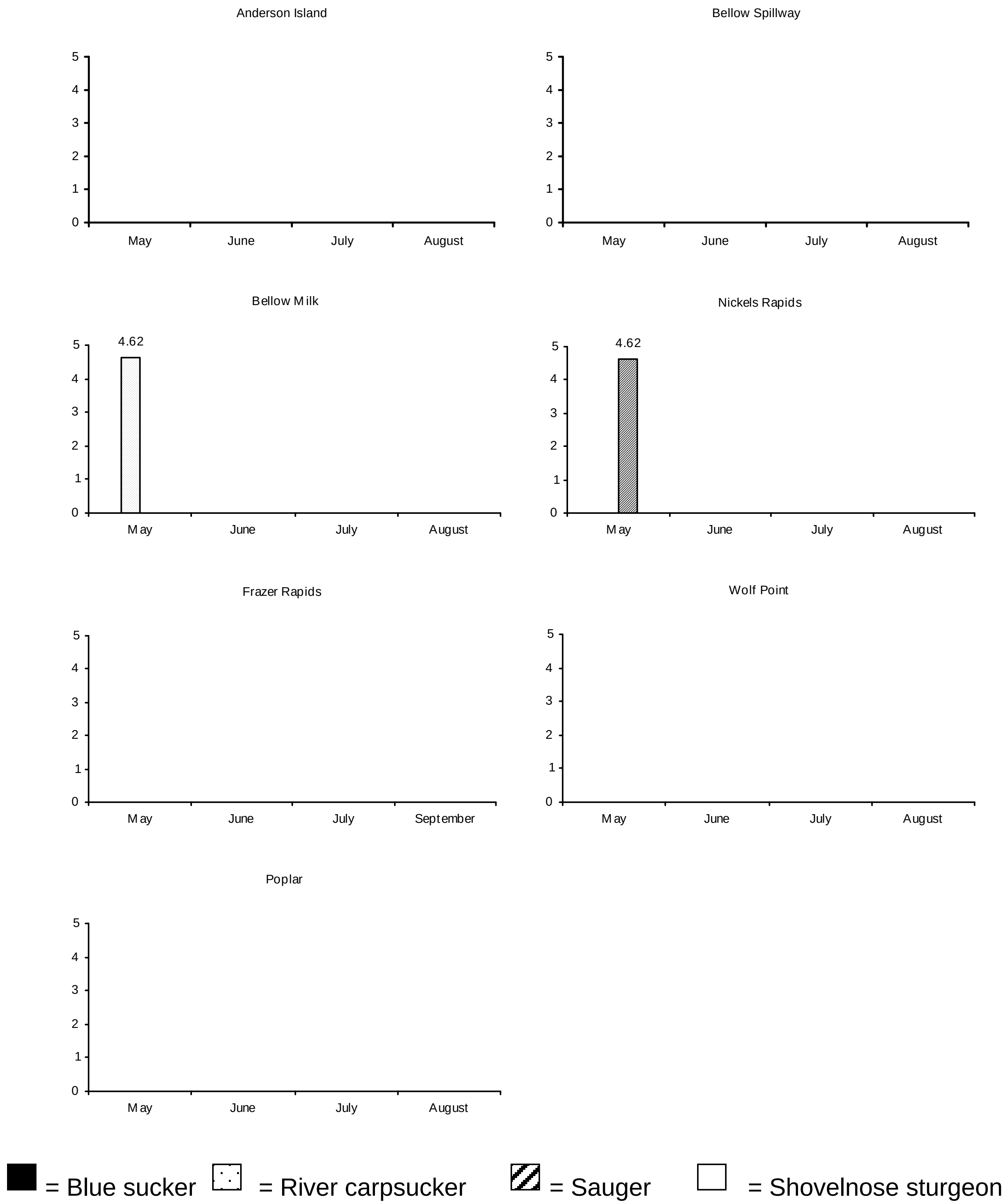


Figure 26. CPUE rates (number per hour sample time) for blue sucker, river carpsucker, sauger, and shovelnose sturgeon sampled in benthic beam trawl tows at standardized sites on the Missouri River, MT, during 2003.

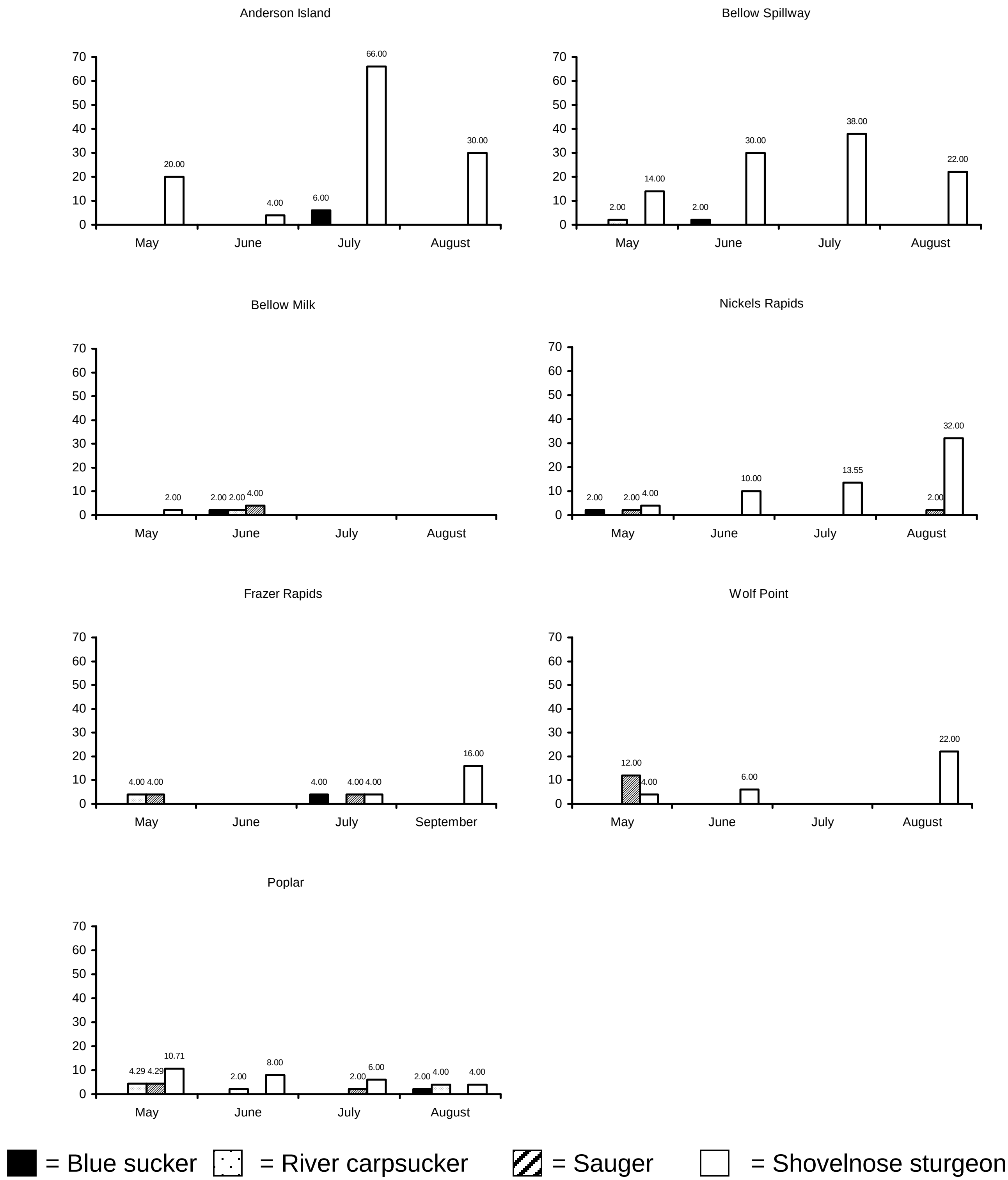
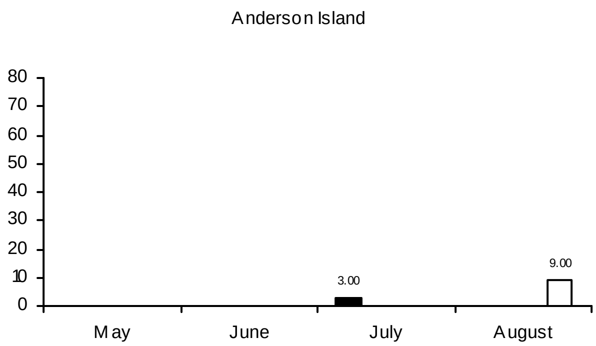
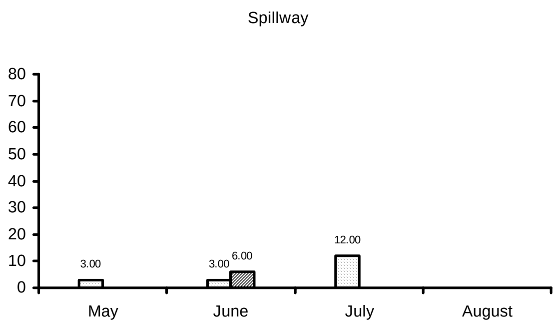
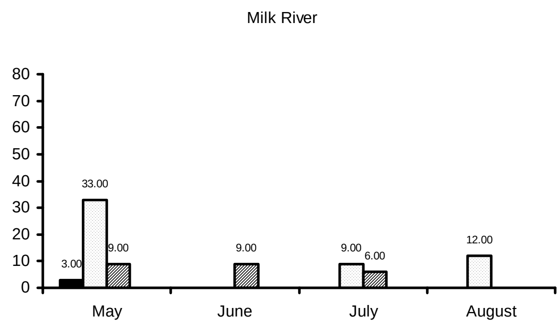
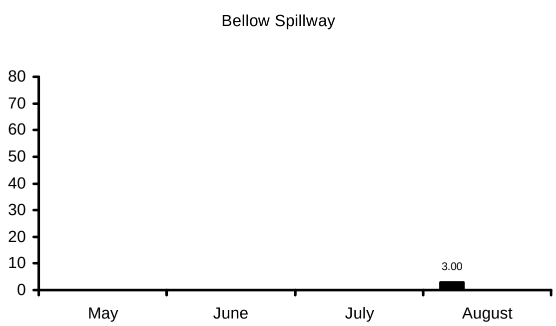


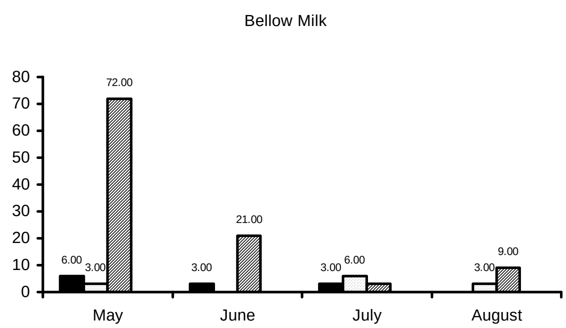
Figure 27. CPUE rates (number per hour sample time) for blue sucker, river carpsucker, sauger, and shovelnose sturgeon sampled in 2.5 cm inner mesh drifted trammel nets at standardized sites on the Missouri River, MT, during 2003.


Anderson Island
80
70
60
50
40
30
20
10
0
3.00
9.00
May
June
July
August


Spillway
80
70
60
50
40
30
20
10
0
3.00
3.00
6.00
12.00
May
June
July
August


Milk River
80
70
60
50
40
30
20
10
0
3.00
33.00
9.00
9.00
9.00
6.00
12.00
May
June
July
August


Bellow Spillway
80
70
60
50
40
30
20
10
0
3.00
May
June
July
August


Bellow Milk
80
70
60
50
40
30
20
10
0
6.00
3.00
72.00
3.00
21.00
3.00
6.00
3.00
9.00
May
June
July
August

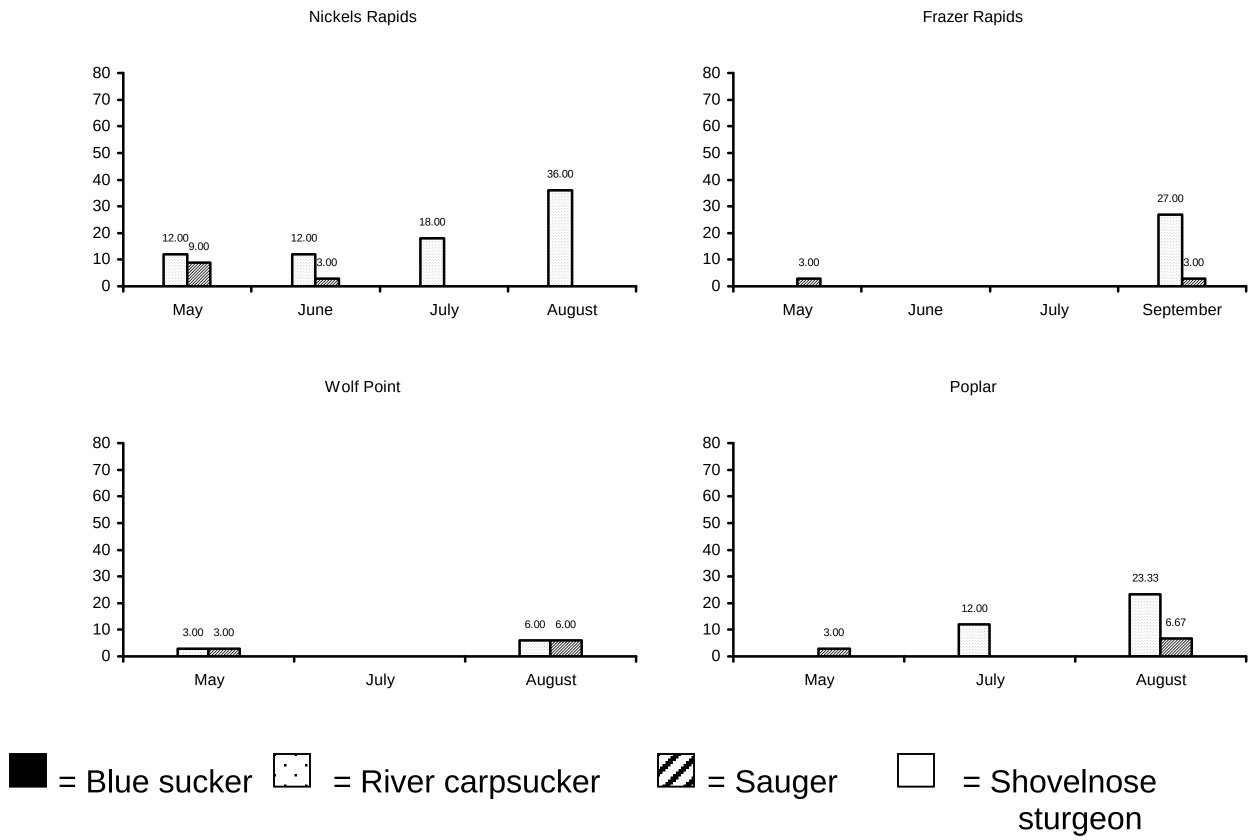


Figure 28. CPUE rates (number per hour sample time) for blue sucker, river carpsucker, sauger, and shovelnose sturgeon sampled in electrofishing runs at standardized sites on the Missouri River, MT, during 2003.

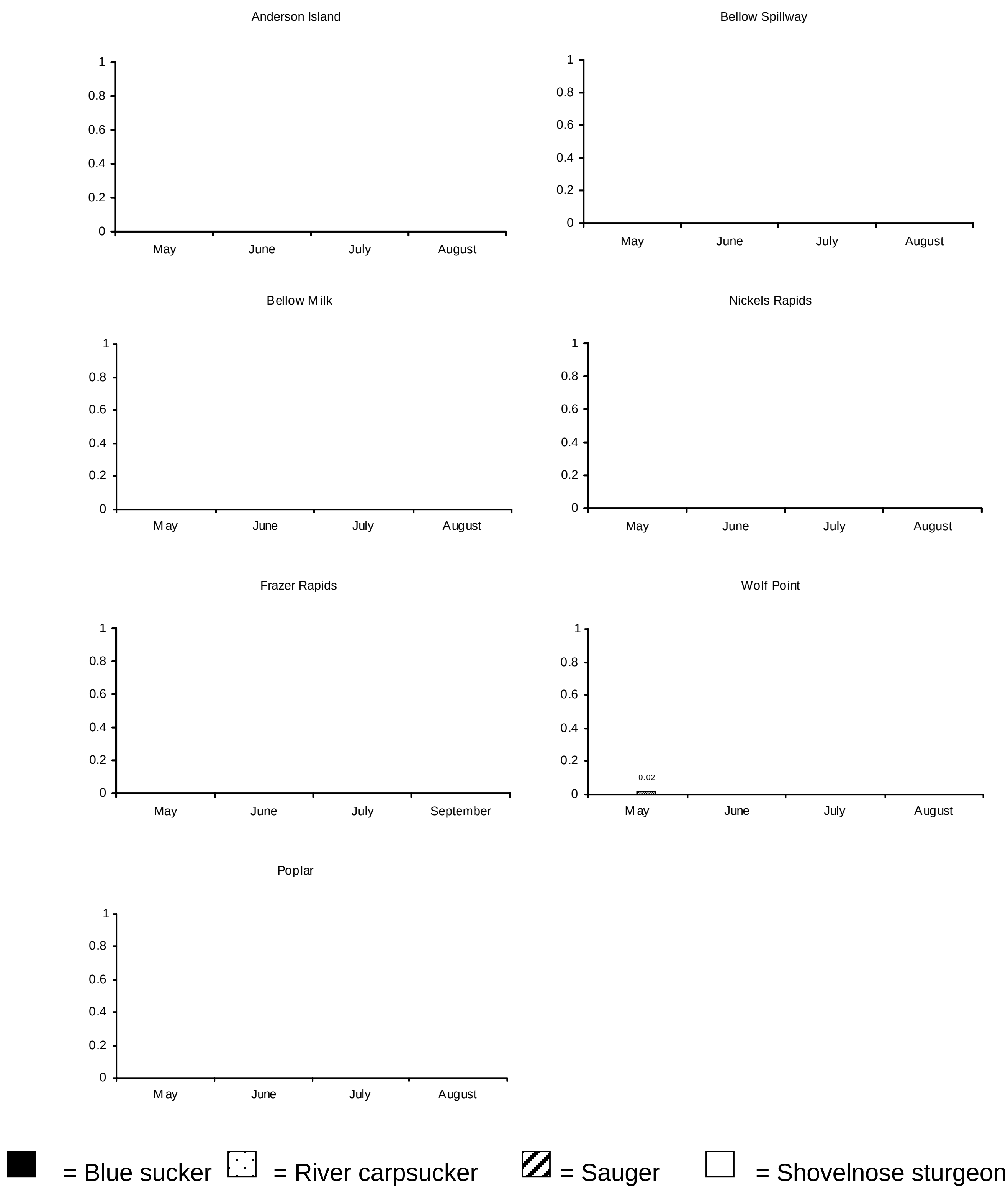
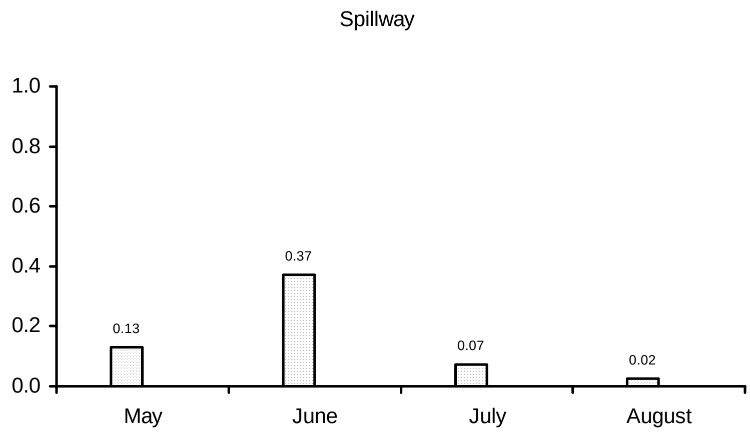
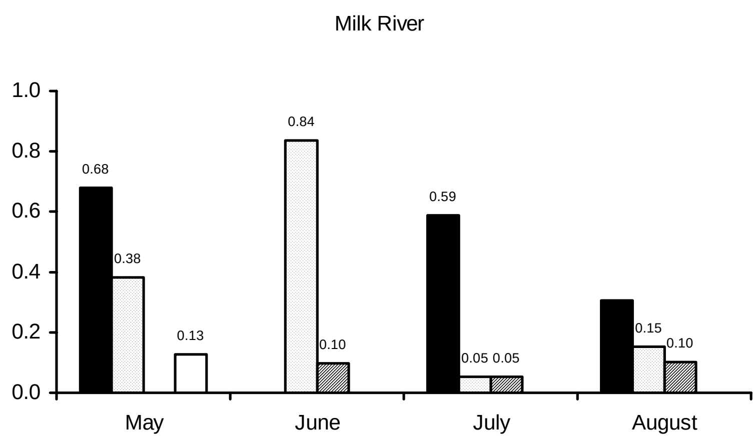


Figure 29. CPUE rates (number per hour sample time) for blue sucker, river carpsucker, sauger, and shovelnose sturgeon sampled in hoop nets at standardized sites on the Missouri River, MT, during 2003.


Spillway
1.0
0.8
0.6
0.4
0.2
0.0
0.13
0.37
0.07
0.02
May
June
July
August


Milk River
1.0
0.8
0.6
0.4
0.2
0.0
0.68
0.38
0.13
0.84
0.10
0.59
0.05 0.05
0.15
0.10
May
June
July
August

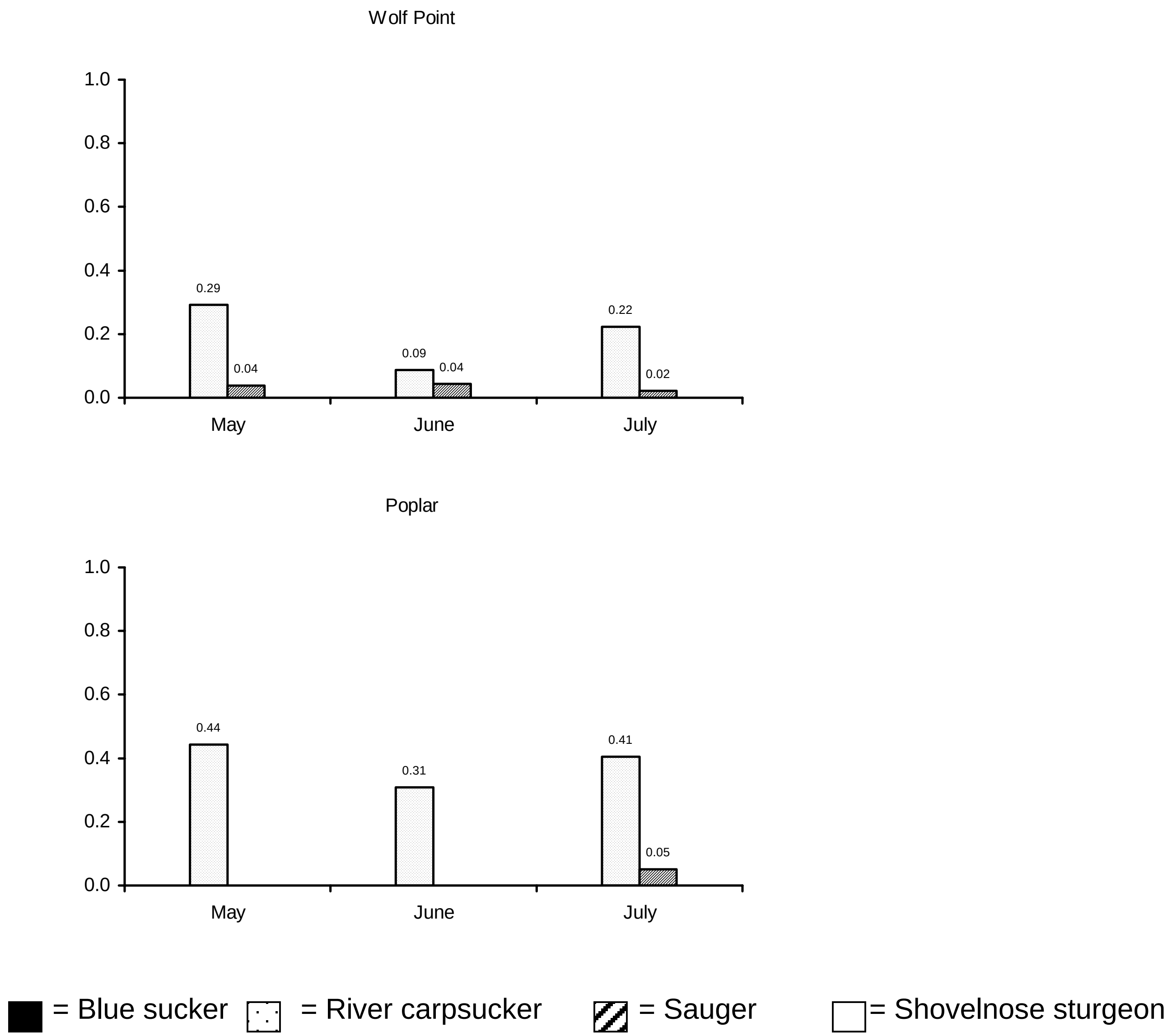


Figure 30. CPUE rates (number per hour sample time) for blue sucker, river carpsucker, sauger, and shovelnose sturgeon sampled in stationary gillnet sets at standardized sites on the Missouri River, MT, during 2003.

Fort Peck Flow Modification Biological Data Collection Plan

Summary of 2003 Activities

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Prepared for:
U. S. Army Corps of Engineers
Contract Number 00-UGPR-34

June 2004

Extended Abstract

The Missouri River Biological Opinion developed by the U. S. Fish and Wildlife Service formally identified that seasonally atypical discharge and water temperature regimes resulting from operations of Fort Peck Dam have precluded successful spawning and recruitment of pallid sturgeon *Scaphirhynchus albus* in the Missouri River below Fort Peck Dam. In response, the U. S. Army Corps of Engineers (USACE) proposes to modify operations of Fort Peck Dam to enhance environmental conditions for spawning and recruitment of pallid sturgeon. The Fort Peck Flow Modification Biological Data Collection Plan (hereafter Fort Peck Data Collection Plan) was implemented in 2001 to evaluate the influence of proposed flow and temperature modifications on physical habitat and biological response of pallid sturgeon and other native fishes. Similar to 2001 and 2002, primary research activities of the multi-year Fort Peck Data Collection Plan during 2003 included: 1) measuring water temperature and turbidity at several locations downstream from Fort Peck Dam, 2) examining movements by pallid sturgeon that inhabit areas immediately downstream from Fort Peck Dam, 3) examining flow- and temperature-related movements of paddlefish *Polyodon spathula*, blue suckers *Cycleptus elongatus*, and shovelnose sturgeon *Scaphirhynchus platorynchus*, 4) quantifying larval fish distribution and abundance, and 5) quantifying the reproductive success of shovelnose sturgeon and pallid sturgeon based on captures of young-of-year sturgeon. The Fort Peck Data Collection Plan is supported by the USACE, and jointly implemented by the Montana Department of Fish, Wildlife, and Parks and the U. S. Geological Survey - Columbia Environmental Research Center.

Proposed flow modifications were not implemented in 2003 due to inadequate precipitation and insufficient reservoir levels. For research component 1, continuous-recording water temperature loggers (40 total) positioned at 18 locations in the Missouri River, selected tributaries, and selected off-channel areas provided baseline water temperature profiles to which changes in water temperatures resulting from modified dam operations could be compared. Water temperature between mid-April and mid-October in the Missouri River upstream from Fort Peck reservoir averaged 18.0^{o}C. During this same time period, the mean water temperature was 11.7^{o}C 7.7 km downstream from Fort Peck Dam, and 16.9^{o}C 288 km downstream from Fort Peck Dam. Thus, despite an extended length of free-flowing river, thermal impacts of Fort Peck Dam on water temperature were still evident in downstream reaches. For research component 2, one pallid sturgeon was sampled in the Fort Peck Dam tailwaters in November 2003 and implanted with a radio transmitter. This individual represents the first pallid sturgeon sampled in the tailwaters since 1996. The pallid sturgeon implanted in the tailwaters will be tracked during the next few years. Under research component 3, extensive radiotracking was conducted between April and October in the lower Yellowstone River and in the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea. A total of 22 individual tracking events were conducted throughout the river systems resulting in a cumulative distance of 9,347 km tracked. We obtained 520 relocations of blue suckers, 237 relocations of paddlefish, and 708 relocations of shovelnose sturgeon via boat. An additional 360 movement events were logged by six continuous-recording telemetry logging stations. In addition, a total of 129 relocations of pallid sturgeon implanted by U. S. Fish and Wildlife Service personnel were obtained. Weekly movement patterns and movement rates are presented. In September 2003, radio transmitters were implanted in an additional 20 shovelnose sturgeon, 19 blue suckers, and 1 paddlefish. These individuals, added to the existing population of implanted fish, will be relocated during the next few years to ascertain discharge- and temperature-related movement patterns and aggregations prior to, during, and after proposed flow changes are implemented. Under research

component 4, larval fishes were sampled two times per week between late-May and early-August at three sites in the mainstem Missouri River, two tributaries (Milk River, Yellowstone River), and the spillway channel. A total of 2,051 larval fish samples and 2,899 larvae representing ten families were collected. Numerically dominant taxa included Catostomidae (59.9%), Cyprinidae (17.7%), and Percidae (13.3%). Cumulatively, 16 larval sturgeon (*Scaphirhynchus* sp.) were sampled in the Missouri River near Nohly and Wolf Point, and in the lower Yellowstone River. Larval paddlefish were sampled in the Missouri River at Wolf Point (N = 3) and Nohly (N = 5), and in the Yellowstone River (N = 67). For research component 5, weekly sampling for young-of-year sturgeon (*Scaphirhynchus* sp.) was conducted from early-August through early-September in the Yellowstone River, and Missouri River upstream and downstream from the Yellowstone River confluence. Only one young-of-year sturgeon was sampled in the Yellowstone River. Conversely, several young-of-year sturgeon were sampled from the Missouri River upstream (N = 16) and downstream (N = 125) of the Yellowstone River confluence. Several young-of-year sturgeon sampled during 2003 have been tentatively identified as pallid sturgeon; however, in-progress genetic testing and detailed morphological examinations will more thoroughly designate these individuals as pallid sturgeon or shovelnose sturgeon. Twenty-five hatchery-raised juvenile pallid sturgeon were sampled in 2003 while conducting routine netting operations. Lastly, a larval shovelnose sturgeon drift study was conducted to examine larval drift dynamics in a side channel of the Missouri River. Results for the drift study are presented in a separate report.

Introduction

The U.S. Army Corps of Engineers (USACE) proposes to modify operations of Fort Peck Dam following specifications outlined in the Missouri River Biological Opinion (USFWS 2000). Modified dam operations are proposed to increase discharge and enhance water temperature during late May and June to provide spawning cues and enhance environmental conditions for pallid sturgeon *Scaphirhynchus albus* and other native fishes. In contrast to "normal" cold water releases through Fort Peck Dam, water from Fort Peck Reservoir will be released over the spillway during flow modifications to enhance water temperature conditions. The USACE proposes to conduct a mini-test of the flow modification plan to evaluate structural integrity of the spillway and other engineering concerns (USACE 2004). A full-test of the flow modifications will occur when a maximum of 537.7 m^3/s (19,000 ft^3/s) will be routed through the spillway. Spillway releases will be accompanied by an additional 113.2 m^3/s (4,000 ft^3/s) released through the dam. Pending results from the full-test, modified flow releases from Fort Peck Dam in subsequent years will be implemented in an adaptive management framework. All proposed flows are dependent on adequate inflows to Fort Peck Reservoir and adequate water levels in the reservoir.

The original schedule of events for conducting the flow modifications called for conducting the mini-test during 2001 and conducting the full-test in 2002. However, insufficient water levels in Fort Peck Reservoir during 2001, 2002, and 2003 precluded conducting these tests. As a consequence, physical and biological data collected during 2001, 2002, and 2003 represent baseline conditions under existing dam operations.

The Fort Peck Flow Modification Biological Data Collection Plan (hereafter referred to as the Fort Peck Data Collection Plan) is a multi-component research program designed to examine the influence of proposed flow modifications from Fort Peck Dam on physical habitat and biological response of pallid sturgeon and other native fishes. Similar to 2001 and 2002, primary research activities of the multi-year Fort Peck Data Collection Plan during 2003 included: 1) measuring water temperature and turbidity at several locations upstream and downstream from Fort Peck Dam, 2) examining movements by pallid sturgeon that inhabit areas immediately downstream from Fort Peck Dam, 3) examining flow- and temperature-related movements of paddlefish *Polyodon spathula*, blue suckers *Cycleptus elongatus*, and shovelnose sturgeon *Scaphirhynchus platorynchus*, 4) quantifying larval fish distribution and abundance, and 5) quantifying the reproductive success of shovelnose sturgeon and pallid sturgeon based on captures of young-of-year sturgeon. The Fort Peck Data Collection Plan is funded by the USACE, and implemented by the Montana Department of Fish, Wildlife, and Parks (MTFWP) and the U. S. Geological Survey Columbia Environmental Research Center – Fort Peck Project Office.

Study Area

The Missouri River study area extends from Fort Peck Dam located at river kilometer (rkm) 2,850 (river mile, RM 1,770) to the headwaters of Lake Sakakawea near rkm 2,496 (RM 1,550; Figure 1). The study area also includes the lower 113 rkm (70 miles) of the Yellowstone River (Figure 1). See Gardner and Stewart (1987), White and Bramblett (1993), Tews (1994), Bramblett and White (2001), and Bowen et al. (2003) for a complete description of physical and hydrological characteristics of the study area.

Methods

Monitoring Component 1 - Water temperature and turbidity.

Water temperature logger deployment. Water temperature loggers (Optic StowAway, -5°C – +37°C, 4 min response time, accuracy ± 0.2°C from 0 - 21°C) were deployed from early April to late October at sites in the Missouri River, Yellowstone River, selected tributaries, and off-channel areas (Table 1). Duplicate loggers were secured adjacent to the north and south bank lines at sites in the Missouri River to assess lateral variations in water temperature. Water temperature loggers were positioned near the bottom of the river channel. An additional logger was stratified in the water column at selected sites to assess vertical variations in water temperature. Water temperature loggers were programmed to record water temperature at 1-hr intervals, and periodically downloaded during the deployment period. The water temperature logger deployed in the Missouri River upstream from Fort Peck Lake (i.e., at Robinson Bridge) was maintained by Bill Gardner (MTFWP, Lewiston).

Statistical analysis of water temperature. Analysis of variance or t-tests were used to compare mean daily water temperature among water temperature loggers positioned on the north and south bank locations, and stratified in the water column. Analysis of variance was used to compare mean daily water temperature among all logger locations.

Assessment of water temperature logger precision. Precision of water temperature loggers was assessed prior to and following retrieval from the field. In April 2003, all water temperature loggers (except the logger deployed at Robinson Bridge and the logger deployed in Fort Peck Lake) were subjected to a series of common water bath treatments to evaluate precision and accuracy among loggers. The water bath treatments were comprised of two temperature ranges (cold, < 10°C, loggers placed in one of the dredge cuts; cool, 15-20°C, loggers placed in laboratory bath) with 5 – 10 temperature measurements recorded within each temperature range. Following retrieval from the field, water temperature loggers were subjected to a series of common water bath treatments (cold, < 10°C, in the tailwaters of Fort Peck Dam; cool, 10-20°C, in the laboratory; warm, > 20°C, in the laboratory).

Statistical analysis of water temperature logger precision. Pre- and post-deployment precision of loggers for each water bath treatment was evaluated with univariate statistics (mean, standard deviation, minimum, maximum, and range) computed over all loggers. The mean, minimum, maximum, and range were screened for precision. If precision was low (e.g., broad range of temperature for an individual water bath trial), logger data were scrutinized to determine which logger(s) was contributing to the extreme values. After identifying and deleting the "suspect" logger(s), univarite statistics were computed again to assess precision.

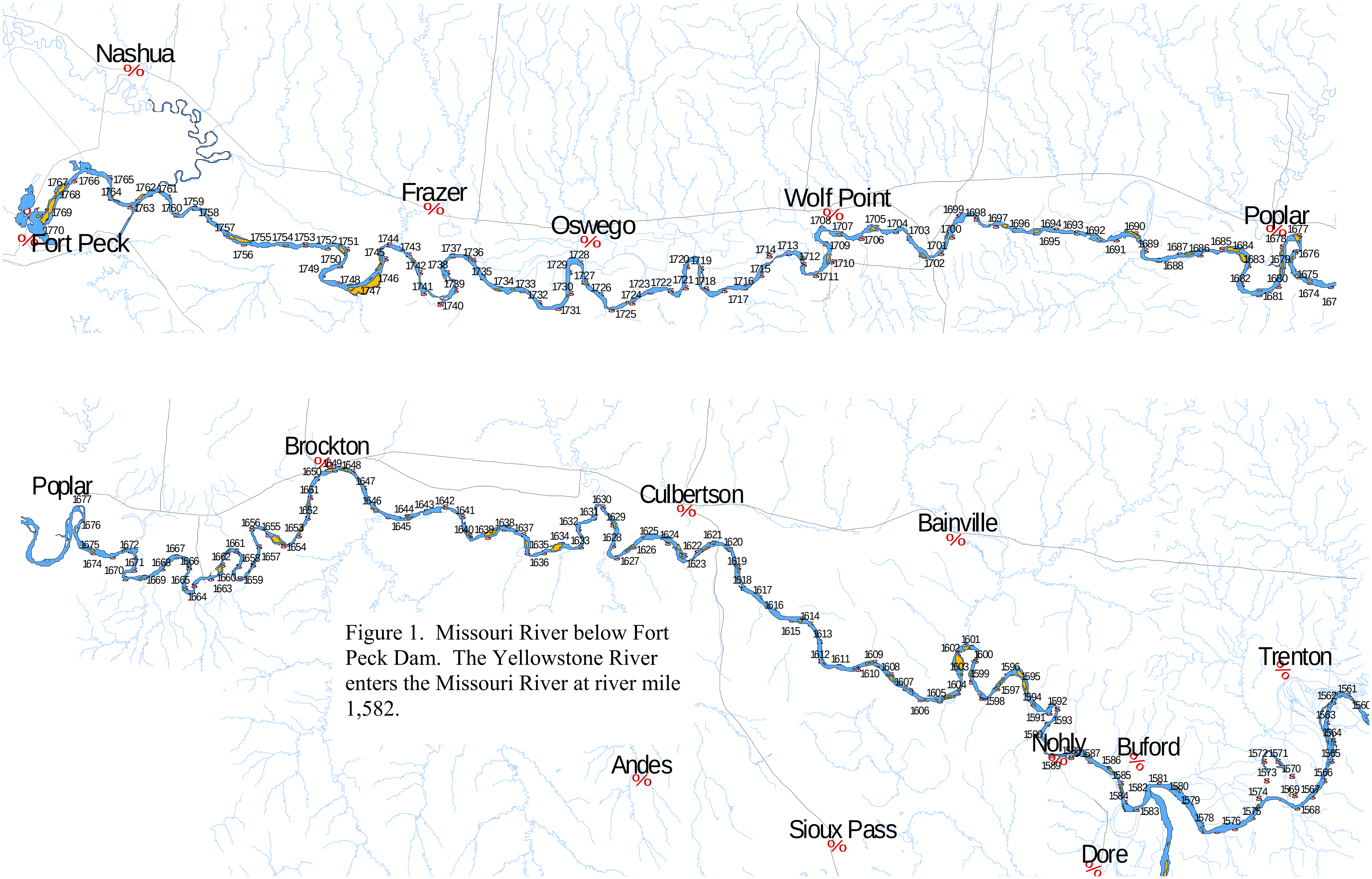

Figure 1. Missouri River below Fort Peck Dam. The Yellowstone River enters the Missouri River at river mile 1,582.

Table 1. Sites, approximate river mile (RM; distance upstream from the Missouri River-Mississippi River confluence or distance upstream in a specified tributary), bank locations (north, south, strat = stratified in the water column), serial numbers, and dates of deployment for water temperature loggers deployed in the Missouri River and adjacent areas during 2003. NR = not recovered at the end of the season, ND = recovered, but no data retrieved due to logger malfunction.

Site	RM	Bank location	Latitude	Longitude	Logger serial no.	Deploy date	Retrieval date
Above Fort Peck Lake	1,920.5	South				4/08/03	10/29/03
Spillway Bay (in Fort Peck Lake)					429720	5/01/03	8/29/03
Downstream from	1,765.2	North	48 03.342	106 21.883	389561	4/17/03	10/20/03
Fort Peck Dam		South	48 03.695	106 22.685	389503	4/17/03	10/20/03
		Strat	48 03.725	106 22.716	429714	4/17/03	10/20/03
Spillway			48 02.398	106 20.459	389574	4/17/03	10/20/03
Milk River	4.0		48 04.014	106 18.184	389560	4/17/03	10/20/03
Nickels Ferry	1,759.9	North	48 02.713	106 17.250	389488	4/17/03	6/2/03,NR
		South	48 02.706	106 17.117	429713	4/17/03	10/20/03
		Strat	48 02.706	106 17.117	407322	4/17/03	10/20/03
Nickels Rapids	1,757.5	North	48 02.123	106 15.062	389563	4/17/03	10/20/03
		South	18 02.137	106 15.290	389571	4/17/03	10/20/03
		Strat	18 02.137	106 15.290	389504	4/17/03	10/20/03
Frazer Pump	1,751.5	North	48 01.850	106 07.477	389489	4/17/03	10/20/03
		South	48 01.815	106 07.571	389565	4/17/03	10/20/03
		Strat	48 01.850	106 07.477	429715	4/17/03	10/20/03
Frazer Rapids	1,746.0	North	48 00.443	106 07.797	389490	4/17/03	10/21/03
		South	48 00.387	106 07.736	389501	4/17/03	10/21/03
		Strat	48 00.457	106 08.047	429712	4/17/03	9/8/03
Grandchamps	1,741.5	North	48 00.300	106 01.873	389575	4/17/03	10/21/03
		South	48 00.215	106 01.855	389497	4/17/03	10/21/03
		Strat	48 00.300	106 01.873	407323	4/17/03	10/21/03
Wolf Point	1,701.5	North	48 04.233	105 31.784	389493	4/17/03	10/21/03
		South	48 04.792	105 31.193	389500	4/17/03	10/22/03
		Strat	48 04.233	105 31.784	429711	4/17/03	10/21/03
Redwater River	0.1		48 03.676	105 12.697	429717	4/14/03	10/22/03
Poplar	1,680	North	48 03.981	105 12.430	429708	4/14/03	6/6/03,NR
		South	48 03.760	105 12.925	429719	4/14/03	10/22/03
		Strat	48 03.760	105 12.925	429709	4/14/03	10/22/03
Poplar River	0.4		48 05.029	105 11.698	429710	4/14/03	NR
Culbertson	1,620.9	North	48 05.442	104 25.582	389572	4/15/03	10/22/03
		South	48 05.119	104 25.226	429726	4/15/03	10/22/03
		Strat	48 05.442	104 25.582	429696	4/15/03	10/22/03
Nohly	1,591.2	North	48 01.038	104 06.083	429697	4/15/03	10/22/03
		South	48 00.796	104 06.469	429723	4/15/03	10/22/03
		Strat	48 00.482	104 06.213	429725	4/15/03	10/22/03,ND
Yellowstone River	3.5		47 51.785	103 57.956	389562	4/15/03	NR
Below	1,576.5	North	47 57.637	103 53.869	389564	4/21/03	8/19/03
Yellowstone River		South	47 57.520	103 53.841	389566	4/21/03	10/22/03
		Strat	47 57.520	103 53.841	429704	4/21/03	10/22/03

Field measurements of turbidity. Turbidity (nephelometric turbidity units; NTU) was measured from late May through August with continuous-recording (1-hr interval) turbidity data loggers (Hydrolab Datasonde 4a, serial numbers 39046, 39047, 39048, 39049, measurement range 0 – 1000 NTU, accuracy $\pm$ 2%). Turbidity loggers were deployed in the Missouri River near Frazer Rapids (rkm 2,811; RM 1,746), near Poplar (rkm 2,708; RM 1,682) and near Nohly (rkm 2,558; RM 1589), and in the Yellowstone River 0.81 km (0.5 miles) upstream from the confluence.

A*ssessments of turbidity logger precision.* Precision of turbidity loggers was assessed prior to, during, and following field deployment. Prior to field deployment, three of four turbidity loggers (Poplar, Nohly, Yellowstone River) were subjected to a series of common turbidity treatments. The fourth turbidity logger (Frazer) was sent to the factory for repair and recalibration and was not included in the pre-deployment tests. The three turbidity loggers were placed in homogenous turbidity environments (Fort Peck tailwater, Milk River), and recorded turbidity at 5-min intervals for an extended period of time. After deployment in the field, turbidity loggers were subjected to a series of common turbidity treatments to assess precision of turbidity measurements among the turbidity loggers. The loggers were placed in a water bath to which sediment had been added. Sediments in the bucket were periodically mixed to increase turbidity. After turbidity declined due to particle settling, the sediments were again stirred to increase turbidity. Turbidity loggers were programmed to record turbidity at 15-min intervals during the post-deployment assessments. Thus, turbidity measurements declined for all loggers as sediments settled. A subsample of turbidity measurements was randomly selected from the total number of observations for post-deployment comparisons. In addition to post-deployment assessments of precision, the turbidity loggers were subjected to a series of common formazin turbidity solutions to assess accuracy and precision. Turbidity of the formazin solutions was assessed with a factory-calibrated Hach Model 2100P portable turbidimeter (measurement range 0 – 1000 NTU, accuracy $\pm$ 2%).

Turbidity loggers at Nohly and in the Yellowstone River were located within areas where fish sampling activities were conducted (e.g., larval fish sampling, trawling). Turbidity was measured several times between late May and August at these sites in conjunction with fish sampling activities. Thus, time- and date-specific turbidity measurements logged by the turbidity loggers were compared to measured turbidities.

Statistical analysis of turbidity logger precision. For pre- and post-deployment tests, analysis of variance was used to compare a randomly selected subset of turbidity measurements among loggers for low (< 100 NTU), medium (200-500 NTU), and high (>500 NTU) turbidity treatments. Correlation analysis was used to assess the degree of association between turbidities measured by the turbidity loggers and those obtained with the Hach meter during field sampling. In addition, t-tests were used to compare mean turbidity recorded by the loggers those obtained during field sampling activities.

Monitoring Component 2 – Movements by pallid sturgeon.

In November 2003, areas of the Fort Peck Dam tailwaters were netted in an effort to sample pallid sturgeon. Pallid sturgeon netted in the tailwaters were targeted for transmitter implantation.

Monitoring Component 3 – Flow- and temperature-related movements of paddlefish, blue suckers, and shovelnose sturgeon.

Manual tracking of implanted fish.- Manual tracking by boat of fish implanted with CART tags in 2001 and 2002 began in April 2003. The Missouri River between Fort Peck Dam and the Highway 85 bridge near Williston, N.D. (354 km), and the Yellowstone River from the confluence to Intake Diversion (116 km) were tracked at weekly intervals from April through July, and biweekly from August through October. Two radio frequencies (149.760 MHz, 149.620 MHz) were simultaneously monitored during the boat-tracking run using two 4-element Yagi antennae. A hydrophone was used to scan acoustic frequencies (65.6 kHz, 76.8 kHz) in deep areas of the two rivers. The entire study area could be tracked in a 3-4 day time interval. Several variables (radio/acoustic frequency, fish code, latitude, longitude, river mile, water depth, habitat type, water temperature, turbidity, time-of-day) were recorded at fish locations.

Aerial tracking was conducted twice during the fall with a Lotek SRX-400 receiver in conjunction with a single 4-element Yagi antennae. The first aerial survey served as a "trial run," as ambient temperatures were too high for the airplane which resulted in overheating and covering only 50 river miles of the Yellowstone River above Miles City, MT. However, the second flight was more successful covering the Yellowstone River from Miles City, MT (rkm 274, RM 170) to the confluence, and the Missouri River from the Highway 85 bridge to the headwaters of Lake Sakakawea.

Stationary telemetry logging stations.- Stationary telemetry logging stations were deployed in April 2003 at six sites (Milk River, rkm 4.0, RM 2.5; Nickels, rkm 2,828, RM 1,756.5; near Wolf Point, rkm 2,755, RM 1,711; near Poplar, rkm 2,706, RM 1,681; near Brockton, rkm 2,658, RM 1,651; near Culbertson, rkm 2,603, RM 1,616.5). The logging stations (2.4-m x 2.4-m floating platform) were positioned away from the bankline, and secured to the bankline using cables and an iron arm. Each logging station was equipped with a battery powered receiver (Lotek SRX- 400), two unidirectional hydrophones (one pointing upstream, one pointing downstream), solar panels, and an environmental enclosure kit containing dual 12-volt batteries, two ultrasonic upconverters, and an antennae switchbox. Data recorded by the logging stations were downloaded to a laptop computer two times per month between April and October.

Transmitter implantation.-Sampling for paddlefish, blue suckers, and shovelnose sturgeon for transmitter implantation was conducted in September 2003. Species were sampled using drifted trammel nets, hoop nets (primarily targeting blue suckers), and surface-drifted gill nets (primarily targeting paddlefish). A minimum of 20 suitable-sized individuals of each species were targeted for transmitter implantation. Our goal was to extend flow- and temperature-related movement inferences to all areas of the Missouri River below Fort Peck Dam and Lake Sakakawea. Therefore, species were collected in several areas between rkm 2,850 (RM 1,770) and rkm 2,545 (RM 1,581; Figure 1).

The three species were implanted with two varieties of combined acoustic/radio tags (CART tags, Lotek Wireless Incorporated, New Market, Ontario). The CART tag emits alternating radio and acoustic coded signals at established time intervals. The coded signal emitted by each CART tag is unique to facilitate identification of individual fish. Blue suckers and shovelnose sturgeon were implanted with the CART 16-2S (16 mm x 68 mm, air weight = 31.5 g, 865-day longevity, 4-second pulse interval, 149.620 Mhz, 76.8 kHz). Paddlefish were implanted with the CART 32-1S (32 mm x 101 mm, air weight = 114 g, 1,095-day longevity.

Surgical implantation of transmitters was conducted after 1-6 individuals were captured at a sampling location. After being sampled, fish were placed in streamside live cars. Individuals were placed in a partially submerged V-shaped trough during surgical implantation of transmitters, and water was continually flushed over the gills using a bilge pump apparatus. After making an abdominal incision about midway between the pectoral fin and pelvic fin, a shielded needle technique (Ross and Kleiner 1982) was used to extrude the transmitter antennae through the body cavity. The transmitter was then inserted into the body cavity, and the incision was closed with silk sutures. Fish were placed in live cars for a brief period prior to release to assess post-surgery health. Surgical implantation of transmitters was conducted at water temperatures between 9.3^{o}C and 19.6^{o}C.

Analyses of telemetry data.-A complete analysis of telemetry data will be conducted after completion of the study; however, summary analyses were conducted to report and illustrate trends. For each complete manual tracking event covering the entire study area, we calculated the number of fish relocations per km of river searched for each species. This process was conducted for four river reaches including the Missouri River from Fort Peck Dam to Wolf Point, the Missouri River from Wolf Point to the Yellowstone River confluence, Yellowstone River, and the Missouri River downstream from the Yellowstone River confluence. Weekly net movement rates (km per day) for each species were calculated for the Missouri River and Yellowstone River independently. Diel movements of blue suckers, paddlefish, and shovelnose sturgeon were assessed for the time frame spanning April through October based on the time of day transmitter contacts were first recorded by the logging stations. Sunrise - sunset schedules from Culbertson, Montana, were used to delineate diel time periods as day and night, and the number of day and night hours was summed for the April through October time frame. Logging station contacts were classified as day or night according to the sunrise-sunset schedules, and summed for the April through October time frame. Because the number of day and night hours did not conform to a 50:50 ratio, we calculated expected frequencies for day and night contacts based on the ratio of total day hours and night hours. Observed and expected frequencies of day and night contacts were compared using the TESTP option in SAS Proc Freq (SAS Online Documention, V. 8).

Monitoring Component 4 – Larval Fish

Sampling protocols. Larval fish were sampled two times per week from late May through early August at six sites (Table 2). Similar to 2001 and 2002, sites on the mainstem Missouri River were located just downstream from Fort Peck Dam, near Wolf Point, and near Nohly. Sites located off the mainstem Missouri River included the spillway channel, the Milk River, and the Yellowstone River. Larval fish at all sites were sampled with 0.5-m-diameter nets (750 µm mesh) fitted with a General Oceanics Model 2030R velocity meter.

Specific larval fish sampling protocols varied among sites and were dependent on site characteristics (Table 2). Two to five replicates were collected at the sites, where one replicate was comprised of four subsamples (two subsamples simultaneously collected on the right and left side of the boat at sampling locations near the left and right shorelines). At all sites except the spillway site, the left and right sampling locations corresponded to inside bend and outside bend locations at the mid-point of a river bend. The spillway channel had minimal sinuosity;

therefore, samples did not reflect inside and outside bend locations. Only two replicates were available in the spillway channel (one replicate in both of the spillway channel pools), and three replicates were available at the site downstream from Fort Peck Dam. The full compliment of

Table 2. Larval fish sampling locations , number of replicates, samples, and net locations for 2003 sampling events. Abbreviations for net location are as follows: B = bottom, M = mid-water column, S = surface (0.5 - 1.0 m below the surface).

Site	Approximate river mile	Replicates	Samples per replicate	Net location
Missouri River below Fort Peck Dam	1,763.5-1,765.3	3	4	B/M
Spillway	1,762.8	2	4	S
Milk River	0.5-4.0	5	4	S
Missouri River near Wolf Point	1,701.0-1,708.0	5	4	B/M
Missouri River near Nohly	1,584-1,592	5	4	B/M
Yellowstone River	0.1-3.0	5	4	B/M

five replicates was available at the other sites. At sites exclusive of the spillway and Milk River, paired subsamples near the left and right bank locations were comprised of one net fished on the bottom and one net fished in the middle of the water column. Thus, each replicate was comprised of two bottom subsamples and two mid-water column subsamples. Nets were maintained at the target sampling location by affixing lead weights to the net. Larval nets were fished for a maximum of 10 minutes (depending on detrital loads). The boat was anchored during net deployment (e.g., “passive” sampling) except when high velocities warranted use of the outboard motor to maintain a fixed position. Irregular bottom contours, shallow depths, and silt substrates were not conducive to bottom sampling in the Milk River and spillway channel. In addition, minimal current velocity in these two locations required an “active” larval fish sampling approach. Therefore, larval fish in the Milk River and spillway channel were sampled in the upper 1-m of the water column as the boat was powered upstream for a maximum of 10 minutes. Larval fish samples were placed in a 5-10% formalin solution containing phloxine-B dye and stored.

Larval fish were sampled at the same replicate and subsample locations throughout the sampling period except when changes in discharge necessitated minor adjustments in the sampling location. For example, an attempt was made to sample larval fish at total water column depths between 1.5 m and 3.0 m. This protocol was used to minimize variations in larval fish density associated with vertical stratification of larvae in the water column. When river discharge decreased (or increased), water depth in a previously sampled location exceeded the required range. Therefore, the specific sampling location changed but was always near ($\pm$ 300 m) the general vicinity of the earlier samples.

Laboratory methods. Larval fish were extracted from samples and placed in vials containing 70% alcohol. Larvae were identified to family and enumerated. Damaged individuals that could not be identified were classified as unknown. Eggs were identified as paddlefish/sturgeon or other, and enumerated.

Monitoring Component 5 – Young-of-year sturgeon

Sampling for young-of-year sturgeon was conducted with a benthic (beam) trawl between early August and early September 2003 in the Missouri River above the Yellowstone River confluence (i.e., ATC), Missouri River below the Yellowstone River confluence (i.e., BTC), and in the Yellowstone River. Four replicate sampling locations were established at each site (Table 3) where each replicate was comprised of an inside bend, outside bend, and channel crossover habitat complex (IOCX) associated with a river bend. Habitats within the IOCX were treated as subsamples for the replicate. A dual sampling protocol was followed to quantify young-of-year sturgeon. Standard sampling consisted of conducting a single trawl in each habitat type within the IOCX. If a young-of-year sturgeon was collected in the standard trawl, two additional "targeted trawls" were conducted in the exact same location. If young-of-year sturgeon were sampled in either of the two targeted trawls, two additional targeted trawls were conducted. This process was repeated up to a maximum of eight targeted trawls. Targeted sampling was conducted to obtain information on aggregations and to acquire additional individuals for food habits and growth information. An exception to the IOCX sampling protocol was followed at replicate 1 in the Missouri River BTC where nine standard trawl subsamples were used to characterize this location. This location produced several young-of-year sturgeon in previous years (Braaten and Fuller 2002, 2003), thus intensive sampling was conducted at this location. The targeted sampling protocol was followed at this site.

Young-of-year sturgeon were processed in the field and laboratory. Total length (mm, excluding the caudal filament) was measured in the field. One of the pectoral fins or fin buds was clipped and placed in alcohol. After fin clipping, the fish was placed in a 5-10% formalin solution. In the laboratory, diagnostic morphological criteria (Snyder 2002) were used to tentatively distinguish young-of-year sturgeon as pallid sturgeon or shovelnose sturgeon. Individuals tentatively identified as pallid sturgeon were sent to Dr. Darrel Snyder (Colorado State University) for detailed examination. In addition, pectoral fin tissue from individuals tentatively identified as pallid sturgeon was sent to Dr. Ed Heist (Southern Illinois University) for genetic testing.

Table 3. Young-of-year sturgeon sampling sites used in 2003. ATC = above the Yellowstone River confluence, BTC = below the Yellowstone River confluence. River km denotes distance upstream from the mouth.

Site	Replicate	River km
Missouri River ATC	1	2,548
	2	2,555
	3	2,558
	4	2,563
Missouri River BTC	1	2,499
	2	2,540
	3	2,542
	4	2,545
Yellowstone River	1	0.4
	2	1.2
	3	3.2
	4	6.4

Results and Discussion

Monitoring Component 1 - Water temperature and turbidity

General comments on water temperature loggers. Of the 40 water temperature loggers deployed during 2003, no data was obtained from only three loggers (Table 1). The logger in the Poplar River was not recovered. The stratified logger at Nohly was apparently working correctly in the field, but this logger would not download at the end of the season. The two other loggers at Nohly (north and south banks) functioned correctly and provided complete data sets for this site. The logger positioned in the Yellowstone River was unrecoverable due to snag accumulations. The North Dakota Game and Fish Department positioned a logger in the Yellowstone River near the unrecoverable logger. These data were obtained (Fred Ryckman, North Dakota Game and Fish Department, Williston, personal communication) to depict water temperature conditions in the Yellowstone River, and were used in water temperature analyses for this study.

Partial water temperature data sets were obtained for three loggers. The water temperature logger positioned on the north bank at Poplar was downloaded on 6 June 2003, but this logger was unrecoverable at the end of the season. The stratified logger at Frazer Rapids was retrieved in early September; however, loggers on the north and south banks at Frazer Rapids provided complete data sets for this site. The water temperature logger in Fort Peck Lake was retrieved in August.

Pre- and post-deployment assessments of water temperature logger precision. We conducted pre-deployment tests on 38 loggers (Table 4). Univariate analyses from the pre-deployment tests indicated that one logger (serial number 429707) consistently deviated (contributed to a high range) from all other loggers during the water bath treatments. When this logger was omitted from the univariate analysis, precision increased (e.g., range decreased) and resulted in a temperature range of 0.43 – 0.66^{o}C for the cool water bath (15 - 20^{o}C) and a temperature range of 0.89 – 1.32^{o}C for the cold water bath (< 10^{o}C). After excluding the one suspect logger, pre-deployment precision was considered satisfactory. Logger 429707 was discarded from field deployments, and replaced with a new logger (serial number 429719). This new logger was not subject to pre-deployment assessments.

Post-deployment precision tests were conducted on 31 loggers; however, all loggers were not tested together in all water bath comparisons due to an unanticipated programming a change in the loggers. For example, all loggers were programmed to record water temperature at 5 minutes past the hour when initially deployed. When the loggers were periodically downloaded during the April – October deployment period, the internal programming changed and loggers recorded hourly water temperature at various times (e.g., 3 min past the hour, 38 min past the hour, 52 min past the hour). However, the recording time remained constant for an individual logger. This incident is characteristic of the Optic StowAway Model used because field downloading changes the pre-programmed recording time (Onset Computer Corporation, personal communication). The change in recording time did not affect the quality of the field data because the loggers still recorded 24 hourly observations per day, but did change the specific times within the hour when data were recorded. After retrieval from the field, the loggers were not downloaded and re-programmed. Unknowing that the recording times had changed, the loggers were subjected to water bath treatments under the existing recording times.

As a consequence, all loggers did not record temperature at the same time. Thus, the protocol for testing precision had to be modified as follows.

In the cold water bath treatment conducted in the tailwater of Fort Peck Dam, water temperature was temporally constant over a several hour period when the comparisons were conducted. Therefore, the different recording time of the loggers did not have an effect on precision comparisons. All loggers were tested together for the cold water bath treatment. The different recording times of the loggers had minimal influence on precision tests during the cool water bath comparisons because water temperatures were maintained at ambient room temperature. Thus, all loggers were tested together for the cool comparisons. For the warm water bath created using warm tap water, the water temperature declined during the comparison period. The loggers were divided into three groups for the warm comparisons representing groups of loggers that recorded water temperature at close time intervals.

Post-deployment analyses indicated a broad temperature range (i.e., low precision) for the cold, cool, and warm (Group 1) comparisons (Table 5). The broad temperature range was mainly attributed to one logger (serial number 429714; stratified logger downstream from Fort Peck Dam). When this logger was omitted from the analysis, the temperature range decreased substantially. These results indicated that logger 429714 was recording erroneous water temperatures. Thus, this logger was omitted from all subsequent water temperature analyses. The water temperature range for the warm comparisons (group 2, group 3) of all three groups varied from 0.6 – 2.1°C. However, there was no indication that an individual logger was recording erroneous water temperatures. Rather, the broader temperature range may be attributed to the slightly different recording times that occurred during the warm water bath treatments.

Table 4. Pre-deployment summary statistics for water temperature comparisons among water temperature loggers in common water bath treatments for 2003. The first line for each treatment shows univariate statistics (°C) for all loggers. The second lines shows univariate statistics after the suspect logger (serial number 429707) was omitted. Slight discrepancies in the range (maximum-minimum) occur due to rounding.

Sample	Treatment	Logger mean	Logger minimum	Logger maximum	Logger range	Logger SD	Number of loggers
1	Cold	5.4	4.8	8.9	4.1	0.6	38
		5.3	4.8	5.9	1.2	0.3	37
2	Cold	6.4	5.6	9.3	3.8	0.6	38
		6.3	5.6	6.9	1.3	0.4	37
3	Cold	6.0	5.2	9.0	3.8	0.6	38
		5.9	5.2	6.5	1.2	0.3	37
4	Cold	5.4	4.9	8.7	3.8	0.6	38
		5.3	4.9	5.8	0.9	0.2	37
5	Cold	5.9	5.4	9.2	3.8	0.6	38
		5.8	5.4	6.4	1.0	0.2	37
6	Cool	19.4	17.8	19.7	2.0	0.3	38
		19.4	19.1	19.7	0.7	0.2	37
7	Cool	19.0	17.4	19.2	1.8	0.3	38
		19.0	18.6	19.2	0.7	0.1	37

8	Cool	18.6	17.3	18.9	1.6	0.3	38
		18.6	18.3	18.9	0.6	0.1	37
9	Cool	18.3	17.1	18.6	1.5	0.2	38
		18.3	18.0	18.6	0.6	0.1	37
10	Cool	18.0	17.0	18.2	1.3	0.2	38
		18.1	17.8	18.2	0.4	0.1	37
11	Cool	17.8	16.8	18.1	1.3	0.2	38
		17.9	17.6	18.1	0.4	0.1	37
12	Cool	17.7	16.7	17.9	1.3	0.2	38
		17.7	17.3	17.9	0.6	0.1	37
13	Cool	17.5	16.7	17.8	1.1	0.2	38
		17.5	17.2	17.8	0.6	0.1	37
14	Cool	17.4	16.5	17.6	1.1	0.2	38
		17.4	17.0	17.6	0.6	0.1	37
15	Cool	17.2	16.5	17.5	1.0	0.2	38
		17.2	16.8	17.5	0.6	0.1	37

Table 5. Post-deployment summary statistics for water temperature comparisons among water temperature loggers in common water bath treatments for 2003. The first line for each treatment shows univariate statistics (^{o}C) for all loggers. The second lines shows univariate statistics after the suspect logger (serial number 429714) was omitted. Slight discrepancies in the range (maximum-minimum) occur due to rounding.

Treatment	Sample	Group	Logger mean	Logger minimum	Logger maximum	Logger range	Logger SD	Number of loggers
Cold	1		7.2	6.6	13.0	6.4	1.1	31
			7.0	6.6	7.5	0.9	0.2	30
	2		7.1	6.6	13.0	6.4	1.1	31
			6.9	6.6	7.2	0.6	0.1	30
	3		7.2	6.7	13.2	6.5	1.1	31
			7.0	6.7	7.2	0.4	0.1	30
	4		7.3	6.7	13.3	6.6	1.1	31
			7.1	6.7	7.3	0.6	0.1	30
Cool	1		19.0	12.6	19.6	7.0	1.2	31
			19.3	18.8	19.6	0.8	0.1	30
	2		19.0	12.7	19.4	6.7	1.2	31
			19.2	18.8	19.4	0.6	0.1	30
	3		19.0	12.9	19.4	6.5	1.1	31
			19.2	18.8	19.4	0.6	0.1	30
	4		19.0	13.2	19.4	6.2	1.1	31
			19.2	18.8	19.4	0.6	0.1	30
	5		19.1	13.3	19.6	6.2	1.1	31
			19.3	18.9	19.6	0.6	0.1	30
Warm	1	1	24.4	13.0	26.0	12.9	2.7	21
			24.9	23.9	26.0	2.1	0.6	20

2	1	23.1	12.9	24.5	11.6	2.4	21
		23.6	22.8	24.5	1.7	0.4	20
3	1	22.3	12.9	23.3	10.4	2.2	21
		22.7	22.2	23.3	1.2	0.3	20
1	2	26.4	25.1	27.1	2.1	0.8	5
2	2	24.4	23.5	25.4	1.9	0.7	5
3	2	23.3	22.7	24.0	1.3	0.5	5
1	3	25.9	25.4	26.5	1.1	0.4	5
2	3	24.3	24.0	24.6	0.6	0.2	5
3	3	23.2	23.0	23.5	0.6	0.2	5

Lateral and vertical comparisons of water temperature. Comparisons of water temperature among north bank, south bank, and stratified locations were conducted for 11 sites (Table 6). The stratified logger (serial number 429714) at the site downstream from Fort Peck Dam was not included in the analysis due to the likelihood that this logger was recording erroneous data. Mean water temperature did not differ significantly between the north and south banks of the river at 7 sites (below Fort Peck Dam, Frazer Pump, Grand Champs, Wolf Point, Poplar, Culbertson, Nohly). There was evidence of lateral variations in water temperature at four sites where water temperature was significantly higher on the north bank of the river (Nickels Ferry and Nickels Rapids) or south bank of the river (Frazer Rapids, below the Yellowstone River). Braaten and Fuller (2003) also documented that water temperatures were significantly higher on the north bank of the Missouri River at Nickels Ferry and Nickels Rapids during 2002. Conversely, Braaten and Fuller (2002) reported that water temperature during 2001 did not differ laterally between bank locations.

For 2003, there were no significant differences in mean water temperature between loggers positioned on the bottom and stratified in the water column at all sites (Table 6). These results indicate that the river was vertically homeothermal. Braaten and Fuller (2003) similarly found that the mainstem Missouri River was vertically homeothermal during 2002.

Influence of Milk River inflows on water temperature. Lateral differences in water temperature at some sites below Fort Peck suggested that Milk River inflows differentially influenced water temperatures on north and south bank locations due to incomplete lateral mixing. During 2003, the Milk River exhibited periods of increasing and decreasing flows primarily during mid-May, mid-June, and mid-July (Figure 2, 3, 4). Between May 1 and July 31, the difference in mean daily water temperature between north and south bank locations (north bank – south bank) was positively correlated with Milk River discharge at Nickels Ferry ($r = 0.70$, $P < 0.0001$, $N = 33$ days), Nickels Rapids ($r = 0.20$, $P = 0.06$, $N = 92$ days), Frazer Pump ($r = 0.66$, $P < 0.0001$, $N = 92$ days), Frazer Rapids ($r = 0.59$, $P < 0.0001$, $N = 92$ days), and Grand Champs ($r = 0.69$, $P < 0.0001$, $N = 92$ days. The maximum difference between water temperatures on the north and south bank locations declined from upstream to downstream and was 4.1^{o}C at Nickels Ferry, 2.6^{o}C at Nickels Rapids, 2.0^{o}C at Frazer Pump, 0.7^{o}C at Frazer Rapids, 0.6^{o}C at Grand Champs, and 0.4^{o}C at Wolf Point. Braaten and Fuller (2003) reported similar results for data collected during 2002, but the maximum differences observed between bank locations was slightly higher. Earlier studies in the Missouri River (Gardner and Stewart

1987; Yerk and Baxter 2001; Braaten and Fuller 2002; Kapuscinski and Baxter 2003) also showed similar results, and suggest that Milk River inputs most strongly influence lateral variations in water temperature during the spring and early summer when Milk River discharge is high and Missouri River water temperatures are cold.

Table 6. Summary statistics and probability values (P, from ANOVA or t-tests) for comparisons of mean daily water temperature (^{o}C) among water temperature loggers located on the north bank and south bank, and stratified in the water column during 2003. Means with the same superscript within sites are not significantly different ($P > 0.05$). The letter listed in parentheses designates whether the stratified logger was positioned on the north bank (N), south bank (S), or mid-channel (M).

Site	Logger location	Number of days	Mean	SD	Minimum	Maximum	P
Below Fort Peck Dam	North	181	11.7	2.3	6.3	15.4	0.61
	South		11.8	2.4	6.3	15.5	
Nickels Ferry	North	41	10.4a	1.7	7.9	13.4	<0.0001
	South		8.2b	1.4	6.3	11.5	
	Stratified(S)		8.2b	1.4	6.3	11.5	
Nickels Rapids	North	181	12.7a	2.3	7.0	16.8	<0.0001
	South		11.7b	2.3	6.2	15.5	
	Stratified(S)		11.9b	2.3	6.4	15.6	
Frazer Pump	North	181	12.6	2.3	6.9	17.1	0.26
	South		12.3	2.4	6.4	16.3	
	Stratified(N)		12.7	2.3	7.0	17.2	
Frazer Rapids	North	138	12.0b	2.3	6.8	15.7	0.0045
	South		12.7a	2.9	6.6	17.4	
	Stratified(N)		11.7b	2.2	6.6	14.7	
Grandchamps	North	181	12.8	2.4	6.9	17.3	0.98
	South		12.8	2.6	6.8	17.6	
	Stratified(N)		12.7	2.4	6.9	17.4	
Wolf Point	North	181	14.6	3.4	7.4	21.2	0.70
	South		14.4	3.4	7.3	21.0	
	Stratified(N)		14.7	3.4	7.4	21.4	
Poplar	North	45	11.7	2.5	7.6	16.6	0.93
	South		11.8	2.5	7.8	16.8	
	Stratified(S)		11.9	2.5	7.7	16.8	
Culbertson	North	181	16.6	4.5	8.5	24.7	0.94
	South		16.8	4.5	8.5	24.8	
	Stratified(N)		16.5	4.5	8.4	24.7	
Nohly	North	43	13.3	2.8	8.7	19.6	0.98
	South		13.2	2.7	8.7	19.4	
	Stratified(M)		13.3	2.8	8.7	19.7	
Below Yellowstone River	North	85	15.3b	2.7	9.1	20.8	<0.0001
	South		17.2a	3.9	9.8	23.7	
	Stratified(S)		17.6a	3.9	10.1	24.2	

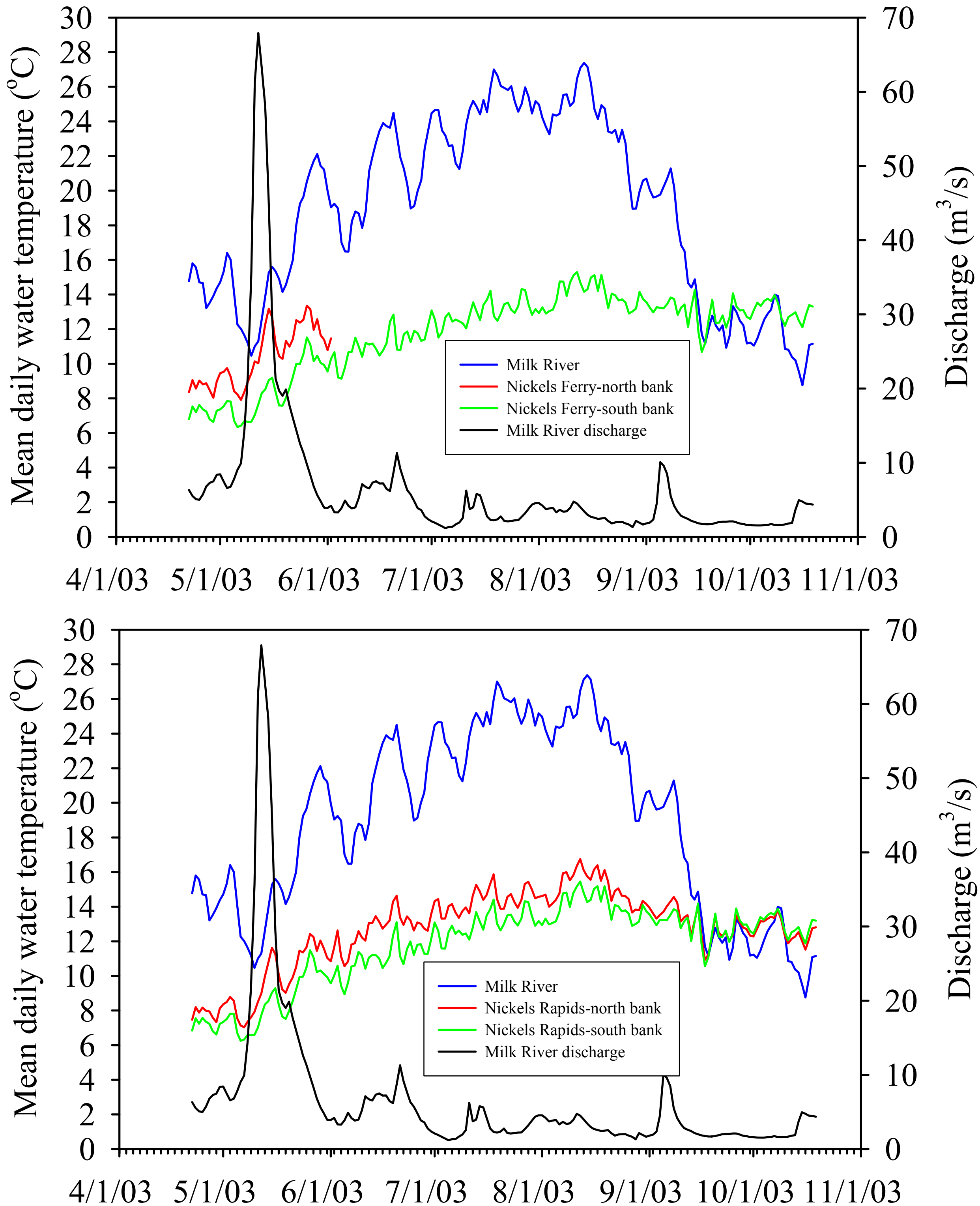

Figure 2. Water temperature profiles and discharge for the Milk River, and water temperatures profiles for the Missouri River at Nickels Ferry and Nickels Rapids during 2003.

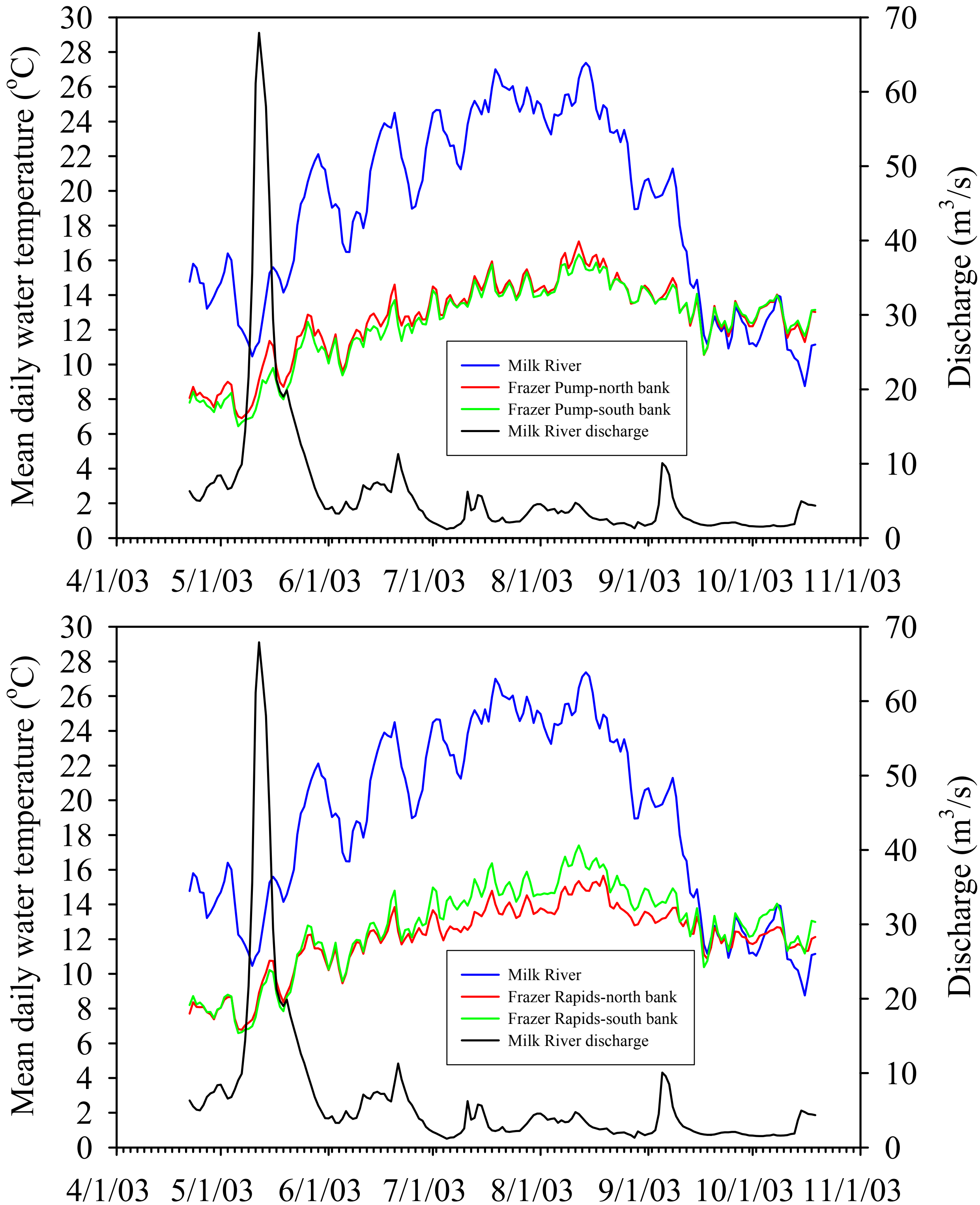

Figure 3. Water temperature profiles and discharge for the Milk River, and water temperatures profiles for the Missouri River at Frazer Pump and Frazer Rapids during 2003.

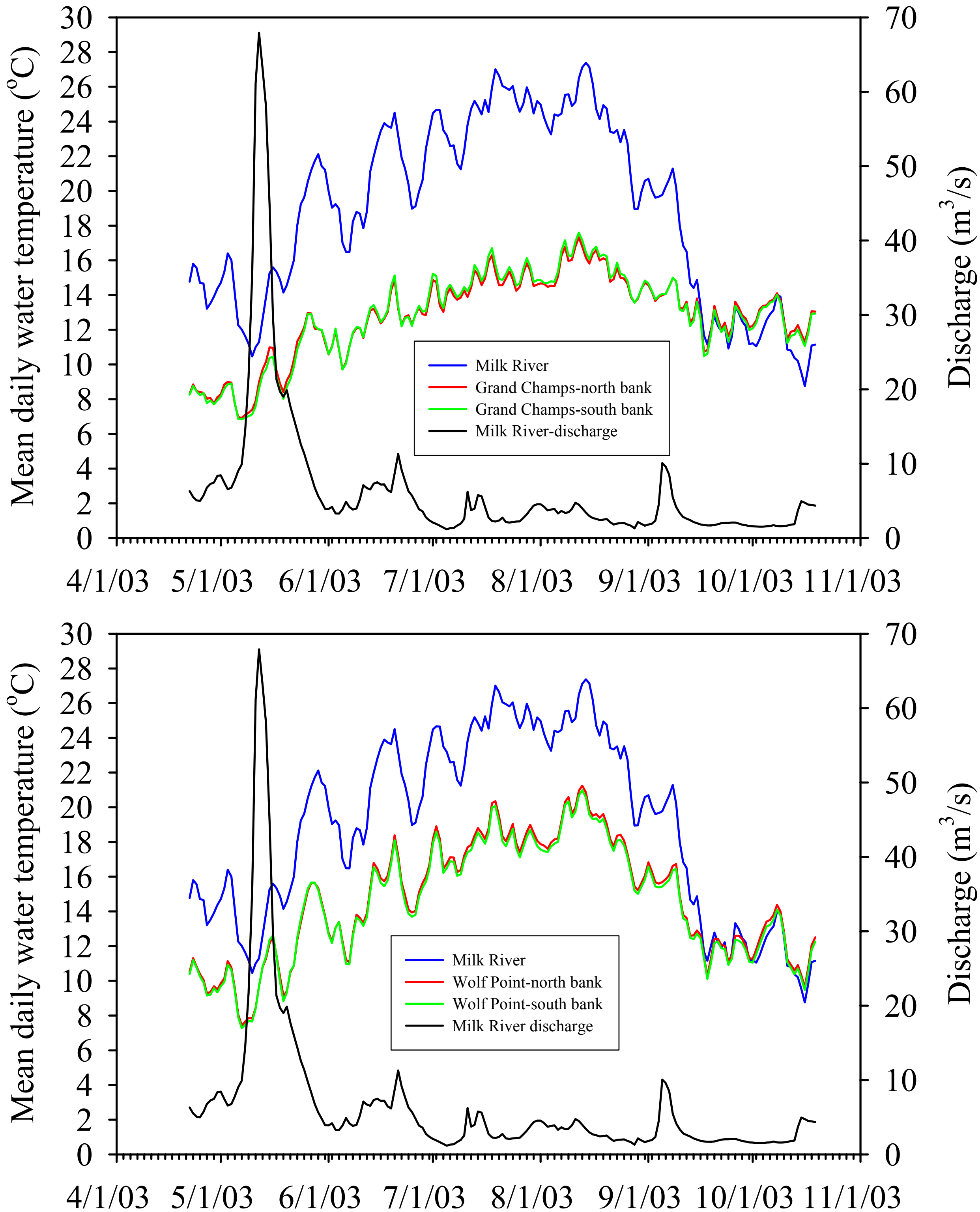

Figure 4. Water temperature profiles and discharge for the Milk River, and water temperatures profiles for the Missouri River at Grand Champs and Wolf Point during 2003.

Longitudinal water temperatures. Mean daily water temperature for all sites was averaged among north bank, south bank, and stratified locations to depict average thermal conditions in the river. Mean daily water temperature for the common deployment period (4/22/03-10/19/03) differed significantly among 12 Missouri River mainstem sites (ANOVA, $F = 88.23$, $df = 11, 2{,}160$, $P < 0.0001$; Table 7, Figure 5) and four off-channel locations (ANOVA, $F = 49.02$, $df = 3, 720$, $P < 0.0001$; Table 7). Mean daily water temperature for Missouri River mainstem sites was highest and significantly greater at Robinson Bridge (18.0^{o}C) and the Missouri River (17.6^{o}C) downstream from the Yellowstone River confluence than other sites. Mean daily water temperature was lowest (11.7^{o}C) at the site downstream from Fort Peck Dam, and longitudinally increased to Nohly (mean = 16.9^{o}C) prior to being influenced by the Yellowstone River. Daily water temperature at the Missouri River mainstem locations was most variable at Nohly (CV = 27.7), Culbertson (CV = 27.2), and below the Yellowstone River confluence (CV = 27.3), but least variable at Nickels Ferry (CV = 17.3). For off-channel locations, mean daily water temperature was highest and significantly greater in the Milk River (18.9 ^{o}C) and Yellowstone River (18.7^{o}C) than other sites.

The longitudinal progression of increasing water temperatures in conjunction with the timing of temperature increases is fundamental to pallid sturgeon recovery efforts in the Missouri River below Fort Peck Dam. Under existing dam operations, water temperatures below Fort Peck Dam are atypical and several degrees cooler than ambient river conditions upstream from Fort Peck Lake. The USFWS (2000) mandated that a minimum water temperature of 18^{o}C be established and maintained via spillway releases at Frazer Rapids, about 39 km downstream from the dam. The elevated water temperature would provide more suitable conditions for pallid sturgeon in the upper reaches below the dam. During 2003, maximum mean daily water temperatures recorded at Frazer Rapids were 15.7^{o}C on August 19 (north bank) and 17.4^{o}C on August 12 (south bank; Figure 3). In 2002, a mean daily water temperature of 18^{o}C occurred on a single date (June 29) on the north bank of the river, but this coincided with a warm discharge pulse from the Milk River (Braaten and Fuller 2003). In the absence of spillway releases during 2001, water temperatures did not reach 18^{o}C at Frazer Rapids (Braaten and Fuller 2002). Yerk and Baxter (2001) similarly showed that the maximum mean daily water temperature at Frazer Rapids only slightly exceeded 17^{o}C during 2000.

Table 7. Mean daily water temperature (^{o}C) summary statistics (mean, minimum, maximum, standard deviation, SD; coefficient of variation, CV) for Missouri River mainstem locations and off-channel locations in 2003. Summary statistics for all sites were calculated for common deployment dates (4/22/03-10/19/03, N = 181 days) to standardize comparisons among all loggers. Means with the same superscript within a location are not significantly different ($P > 0.05$). See Figure 5 for a graphical representation of mean daily water temperatures.

Location	Site	Mean	Minimum	Maximum	SD	CV
Missouri River mainstem	Robinson Bridge	18.0^{a}	9.4	25.2	4.6	25.8
	Below Fort Peck Dam	$11.7^{f,g,h}$	6.4	15.5	2.3	20.0
	Nickel Ferry	$11.9^{e,f,g,h}$	6.9	15.3	2.1	17.3
	Nickels Rapids	$12.1^{d,e,f,g}$	6.6	15.9	2.3	18.8
	Frazer Pump	$12.6^{d,e}$	6.8	16.7	2.3	18.6
	Frazer Rapids	$12.2^{d,e,f}$	6.7	15.7	2.2	17.9
	Grandchamps	12.8^{d}	6.9	17.4	2.5	19.3
	Wolf Point	14.6^{c}	7.4	21.2	3.4	23.4
	Poplar	15.2^{c}	7.7	22.3	3.8	24.8
	Culbertson	16.6^{b}	8.6	24.7	4.5	27.2
	Nohly	16.9^{b}	8.3	25.0	4.7	27.7
	Below Yellowstone River	17.6^{a}	8.8	27.8	4.8	27.3
Off-channel or tributary	Spillway	15.9^{b}	9.5	22.5	3.4	21.5
	Milk River	18.9^{a}	8.8	27.4	5.3	27.9
	Redwater River	14.2^{c}	7.0	20.0	3.4	24.2
	Yellowstone River	18.7^{a}	9.1	27.2	5.1	27.2

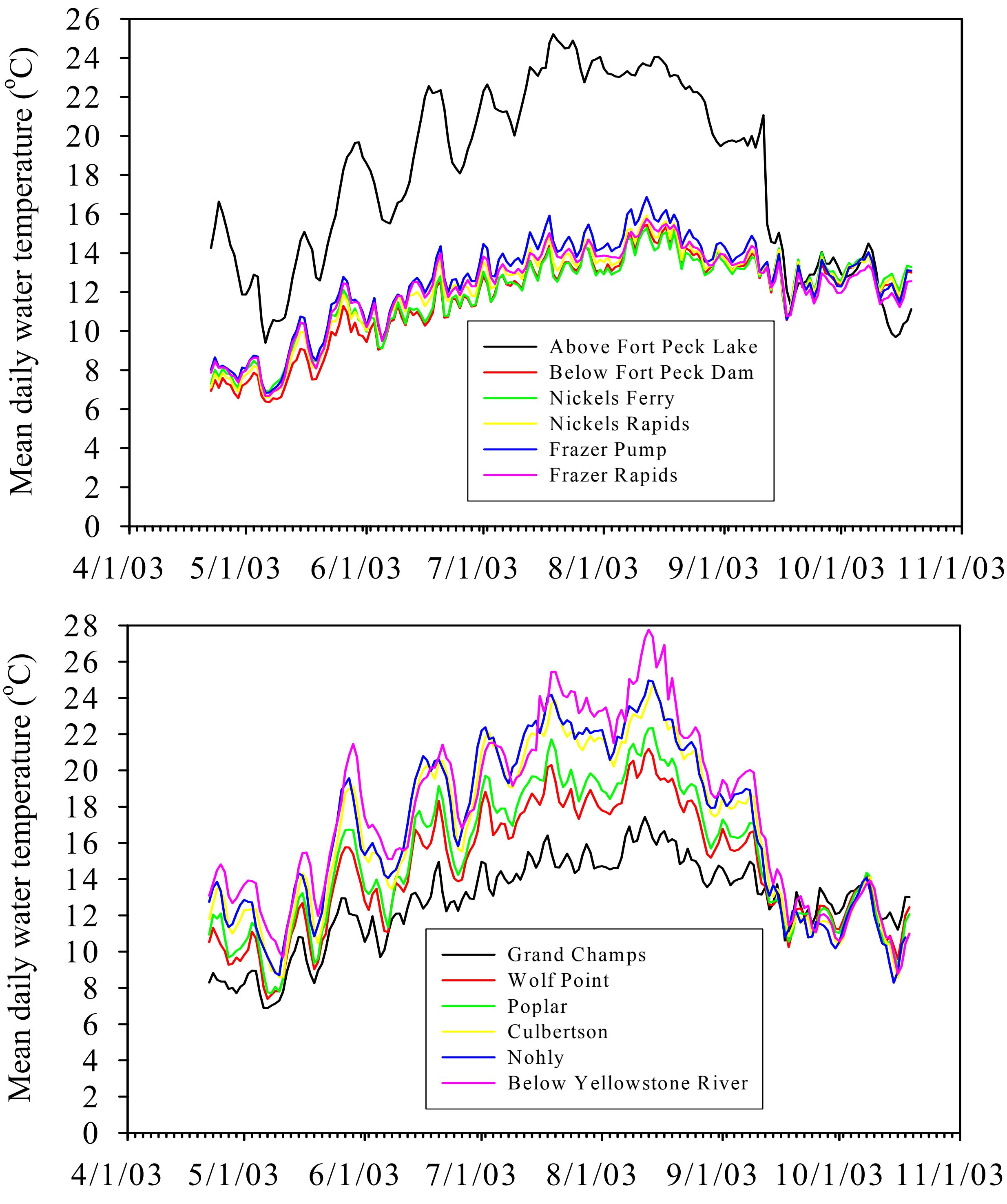

Figure 5. Mean daily water temperature (°C) at 12 sites on the mainstem Missouri River during 2003.

Inter-annual comparisons of mean daily water temperature within sites. Mean daily water temperature differed significantly ($P < 0.05$) among 2001, 2002, and 2003 at nine of 12 mainstem Missouri River sites (Table 8). For all of these sites, mean water temperature was significantly greater in 2001 than 2002 and 2003 with the exception of Nickels Ferry where mean water temperature was similar between 2001 and 2002. The three mainstem sites that did not differ significantly among years included Poplar (data available only for 2001 and 2003), Culbertson (marginal P-value of 0.07), and the Missouri River downstream from the Yellowstone River confluence. Mean daily water temperature differed significantly among years in three of four off-channel sites (Table 8). In the spillway channel and Redwater River, mean daily water temperature was significantly greater in 2001 than 2002 or 2003. The Milk River exhibited significantly greater water temperatures during 2003. For the Yellowstone River, mean daily water temperature was similar among years.

Inter-annual comparisons of mean daily air temperatures. Mean daily air temperatures were obtained from the National Weather Service in Glasgow, MT to assess water temperature regimes during 2001, 2002, and 2003 in the context of air temperatures. For dates spanning May 1 through October 31 ($N = 184$ days), there was a significant difference in mean daily air among years (ANOVA, $F = 5.85$, $P = 0.0031$). Mean daily air temperature was similar ($P = 0.48$) between 2003 (mean = 17.1^{o}C) and 2001 (mean = 16.5^{o}C), but 2001 and 2003 were significantly warmer ($P = 0.01$) than 2002 (mean = 14.5^{o}C).

Results from the air temperature analysis do not corroborate results from the water temperature analysis discussed above. For example, although not statistically significant, air temperatures averaged 0.6^{o}C warmer in 2003 than 2001. However, most of the mainstem Missouri River sites below Fort Peck Dam exhibited significantly greater water temperatures during 2001. These results suggest that air temperatures alone cannot be used to accurately estimate inter-annual water temperature regimes in the Missouri River below the dam. Conversely, inter-annual water temperature variations in the Milk River were corroborated by air temperature patterns, as water temperature in the Milk River was greater during 2003.

Table 8. Summary statistics (mean, °C; minimum, maximum, standard deviation, SD; coefficient of variation, CV; ANOVA probability value, P) for comparisons of mean daily water temperature among 2001, 2002, and 2003 at mainstem Missouri River sites and off-channel sites. Common dates for all years are 5/17-10/9 (146 days). Means with the same letter within a site are not significantly different (P > 0.05).

Site	Year	Mean	Minimum	Maximum	SD	CV	P
Missouri River above Fort Peck Lake	2001	20.1[a]	10.3	25.8	3.7	18.4	0.0085
	2002	18.7[b]	9.2	26.7	4.2	22.5	
	2003	19.3[a,b]	11.4	25.2	4.0	20.5	
Below Fort Peck Dam	2001	13.0[a]	8.2	15.2	1.5	11.6	0.0002
	2002	12.2[b]	6.3	15.4	2.0	16.6	
	2003	12.4[b]	7.5	15.5	1.7	13.7	
Spillway	2001	18.4[a]	10.7	23.8	3.0	16.6	<0.0001
	2002	15.7[b]	8.6	20.0	2.7	16.9	
	2003	16.9[c]	11.5	22.5	3.0	17.9	
Milk River	2001	19.1[b]	9.9	26.2	3.8	19.6	0.011
	2002	18.9[b]	8.4	26.9	4.5	23.8	
	2003	20.3[a]	10.9	27.4	4.7	23.2	
Nickels Ferry	2001	13.4[a]	8.3	18.4	1.8	13.6	0.0003
	2002	13.2[a]	6.5	19.1	2.5	18.7	
	2003	12.5[b]	8.5	15.3	1.5	11.7	
Nickels Rapids	2001	13.5[a]	8.5	16.6	1.7	12.5	0.006
	2002	12.9[b]	6.7	16.1	2.2	16.9	
	2003	12.8[b]	8.1	15.9	1.6	12.3	
Frazer Pump	2001	13.9[a]	8.5	17.0	1.8	13.1	0.025
	2002	13.3[b]	7.1	17.9	2.3	17.6	
	2003	13.3[b]	8.5	16.9	1.7	12.6	
Frazer Rapids	2001	13.8[a]	8.3	17.3	1.8	13.3	<0.0001
	2002	13.1[b]	7.1	17.1	2.3	17.2	
	2003	12.9[b]	8.1	15.7	1.5	11.8	
Grandchamps	2001	14.4[a]	8.5	18.1	2.0	14.1	0.0003
	2002	13.5[b]	7.5	17.3	2.3	16.9	
	2003	13.6[b]	8.3	17.4	1.8	13.4	
Wolf Point	2001	16.5[a]	9.4	22.7	3.1	18.7	0.0002
	2002	15.0[b]	9.3	19.4	2.8	18.8	
	2003	15.6[b]	9.0	21.2	2.9	18.4	
Redwater River	2001	19.0[a]	8.5	26.8	4.2	22.3	0.0001
	2003	15.3[b]	9.3	20.0	2.9	18.7	
Poplar	2001	16.8[a]	9.9	21.2	2.8	16.8	0.16
	2003	16.3[a]	9.4	22.3	3.2	19.9	
Culbertson	2001	17.9[a]	9.7	24.0	3.5	19.3	0.07
	2002	17.0[a]	8.3	23.9	3.9	23.0	
	2003	17.9[a]	10.4	24.7	4.0	22.5	
Nohly	2001	18.9[a]	11.4	25.3	3.8	20.0	0.021
	2002	17.5[b]	7.7	25.4	4.3	24.6	
	2003	18.2[b]	10.2	25.0	4.2	23.0	
Yellowstone River	2001	19.3[a]	10.7	26.6	4.2	21.7	0.24
	2002	19.3[a]	8.4	27.9	4.8	24.7	
	2003	20.1[a]	11.1	27.2	4.7	23.1	
Below Yellowstone River	2001	19.4[a]	9.8	26.0	4.1	20.9	0.44
	2002	18.8[a]	8.2	27.3	4.5	24.2	
	2003	18.9[a]	10.6	27.8	4.4	23.2	

Water temperature in Fort Peck Lake.-Water temperature in Fort Peck Lake was measured in the spillway bay area between 5/1/03 and 8/29/03 to obtain baseline data related to spillway release temperatures (Figure 6). Between these dates, mean daily water temperature was 17.6°C (minimum = 6.7°C, maximum = 23.6°C, SD = 5.0, CV = 28.3). Mean daily water temperature in the spillway bay first exceeded 15°C on May 25 (15.3°C), first exceeded 16.0°C on May 29 (16.7°C), first exceeded 17.0°C on June 14 (17.7°C), first exceeded 18.0°C on June 16 (18.2°C), and consistently exceeded 18°C from June 29 to the end of the deployment period. Mean daily water temperature in the spillway bay fluctuated with air temperature, and was strongly correlated with mean daily air temperature at Glasgow ($r = 0.90$, $P < 0.0001$, $N = 121$). Similarly, spillway bay water temperatures were strongly correlated with mean daily water temperature in the Missouri River at Robinson Bridge ($r = 0.97$, $P < 0.0001$, $N = 121$). However, mean water temperature in the spillway bay (17.6°C) averaged 2.1°C less than at Robinson Bridge (mean = 19.7°C).

As proposed under the Fort Peck spillway release scenario, the target dates for achieving and maintaining 18°C at Frazer Rapids span from about May 15 through July 1 (USFWS 2000; USACE 2004). The following discussion presents possible scenarios for meeting the water temperature requirements at Frazer Rapids based on 2003 lake and river temperature data. A modified version of river discharge - water temperature mixing models presented in USACE (2002, 2004) was used to predict water temperatures at Frazer Rapids as if the full-test spillway release scenario (537 m^3/s spillway releases, 113.2 m^3/s hypolimnetic dam releases) had been conducted in 2003. This model also includes discharge and water temperature inputs from the Milk River. We estimated water temperature at Frazer Rapids for the four specific dates noted above when water temperature in the spillway bay first reached 15°C, 16°C, 17°C, and 18°C. Date-specific water temperatures from loggers positioned below the dam, and date-specific temperature and discharges from the Milk River were used in the model. Discharge rates through the dam and over the spillway were fixed in the model to represent maximum full-test conditions. We modified the mixing models in two ways. First, a slight warming of water released through the spillway may occur as it travels along the 1.6-km long (1 mile) spillway ramp, and we estimated a 0.5°C warming along the spillway ramp. Thus, lake water traveling down the spillway ramp was increased 0.5°C. Second, between May 15 and June 30, 2003, water temperature increased by an average of about 1.0°C between temperature loggers positioned just upstream of the spillway and Frazer Rapids. Thus, after the mixing models had generated a predicted water temperature for the mixing of spillway, hypolimnetic (e.g., powerhouse), and Milk River discharges, we added 1.0°C to account for warming enroute to Frazer Rapids.

The predicted water temperature at Frazer Rapids for the static discharge and water temperature conditions present on specific dates was 15.9°C (May 25, lake temperature = 15.3°C), 17.1°C (May 29, lake temperature = 16.7°C), 18.0°C (June 14, lake temperature = 17.7°C), and 18.3°C (June 16, lake temperature = 18.2°C). These results suggest that the goal of 18°C at Frazer Rapids could have been achieved in mid-June 2003 if the full test had been implemented in 2003. Implementation of the full-test would have increased water temperatures at Frazer Rapids by an average of 5.5°C over actual temperatures observed in 2003. Although dynamic conditions (e.g., Milk River discharge and temperature, spillway bay water temperatures) occurring during the spillway releases will influence the temporal consistency of the target temperature at Frazer Rapids, results based on 2003 data suggest that the target water temperatures can be achieved.

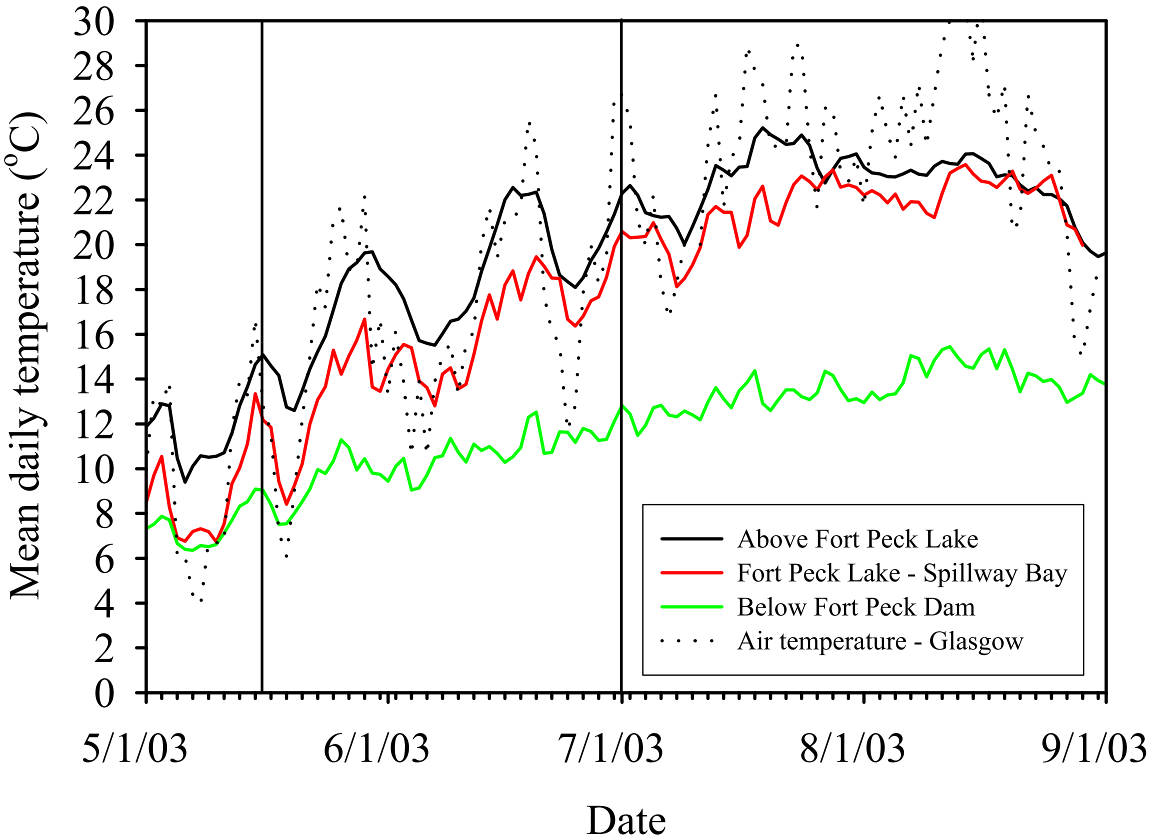

Figure 6. Mean daily water temperature at three sites (Missouri River above Fort Peck Lake, in the spillway bay, below Fort Peck Dam) and mean daily air temperature measured at Glasgow, Montana, during 2003. For reference, the vertical lines delimit dates when the proposed mini-test and full-test are to be conducted when sufficient water levels are available in Fort Peck Lake.

General comments on turbidity loggers. Turbidity loggers deployed near Poplar, Nohly, and in the Yellowstone River functioned during the late-May through August deployment period. However, output from the logger deployed in the Yellowstone River indicated that this logger experienced brief episodes of power loss in early June that did not occur later during the deployment period. The Yellowstone River turbidity logger also recorded several hourly measurements of zero turbidity between June 28 and July 1suggesting that the logger was not functioning properly. These suspect data were excluded from the analysis. The logger deployed near Frazer Rapids did not function correctly despite factory repairs and recalibration during spring 2003.

Precision of turbidity loggers. Pre-deployment comparisons indicated there was no significant difference ($P = 0.66$) in mean turbidity among loggers in the low turbidity treatment (< 100 NTU), but mean turbidity differed significantly ($P < 0.0001$) among loggers in the medium turbidity treatment (200 – 500 NTU; Table 9). In the medium turbidity treatment, the

Poplar logger recorded significantly lower ($P < 0.05$) mean turbidity than the Nohly and Yellowstone River loggers.

For the post-deployment comparisons, mean turbidity differed significantly among loggers for the low ($P = 0.007$) and high ($P = 0.026$) turbidity treatments, and there was a marginally significant difference among loggers for the medium turbidity treatment ($P = 0.062$; Table 9). The Poplar turbidity logger tended to record significantly lower mean turbidity in all treatments, and was 12.8-16.5 NTU less than the Nohly and Yellowstone River logger in the low turbidity treatment, 71.8-74.9 NTU less in the medium turbidity treatment, and 152.9-193.6 NTU less in the high turbidity treatment.

Post-deployment assessments of turbidity logger accuracy and precision were also conducted with mixed formazin solutions of 60.8 NTU, 202 NTU, and 323 NTU. The Nohly turbidity logger recorded 75.5 NTU, 251.4 NTU, and 413.2 NTU for the formazin solutions, respectively. The Yellowstone River turbidity logger recorded 71.9 NTU, 254.6 NTU, and 421.5 NTU for the formazin solutions respectively. The Poplar turbidity logger recorded 52.0 NTU, 225.0 NTU, and 364 NTU for the formazin solutions, respectively. Across formazin solutions, these results indicated that turbidity readings averaged about 25% higher for the Nohly logger, 25% higher for the Yellowstone River logger, and 3% higher for the Poplar logger than “true” turbidities.

Measurements of turbidity obtained near the Nohly turbidity logger and Yellowstone River turbidity logger with a Hach meter during other field activities facilitated an evaluation of turbidity logger performance during the deployment period. Mean turbidity at Nohly differed significantly (t-test, $t = -2.34$, $P = 0.023$) between the Hach meter (mean = 73.0 NTU, STD = 30.4, $N = 24$) and turbidity logger (mean = 109.5 NTU, STD = 70.3, $N = 24$). Mean turbidity in the Yellowstone River did not differ significantly (t-test, $t = -0.55$, $P = 0.58$) between the Hach meter (mean = 215.8 NTU, STD = 318.7 $N = 24$) and turbidity logger (mean = 269.6, STD = 351.9, $N = 24$). Measurements of turbidity obtained from the hach meters and turbidity loggers were not significantly correlated at Nohly ($r = 0.24$, $P = 0.26$, $N = 24$), but there was a significant correlation in the Yellowstone River ($r = 0.63$, $P = 0.0009$, $N = 24$; Figure 7). At the Nohly site, turbidity values recorded by the logger deviated excessively (> 168 NTU) from Hach measurements on June 19, June 30, and July 2. In the Yellowstone River, differences in turbidity measured by the logger and Hach meter exceeded 336 NTU on June 6, June 19, June 24, June 26, and July 2.

Table 9. Pre- and post-deployment summary statistics (mean NTU; minimum; maximum, standard deviation, STD, N = number of samples, P-value) for comparisons of low (<100 NTU), medium (200-500 NTU), and high (>500 NTU) turbidity among site-specific turbidity loggers for 2003. Means within treatments and sites with the same letter are not significantly different (P > 0.05).

Treatment	Site	Mean	Minimum	Maximum	Std	N	P
				Pre-deployment			
Low	Nohly	2.7[a]	0	10.7	3.1	10	0.66
	Poplar	2.1[a]	0	3.6	1.2	10	
	Yellowstone	2.8[a]	2.3	3.8	0.5	10	
Medium	Nohly	234.3[a]	226.2	245.5	5.5	10	< 0.0001
	Poplar	204.7[b]	195.8	221.6	8.4	10	
	Yellowstone	235.9[a]	225.9	247.5	7.1	10	
				Post-deployment			
Low	Nohly	35.6[a]	21.6	81.6	17.1	10	0.007
	Poplar	19.1[b]	3.4	23.8	5.9	10	
	Yellowstone	31.9[a]	19.1	43.5	7.3	10	
Medium	Nohly	348.3[a]	245.1	471.6	76.2	10	0.062
	Poplar	273.4[a]	201.2	365.9	58.2	10	
	Yellowstone	345.2[a]	231.9	488.1	91.0	10	
High	Nohly	867.7[a]	667.0	1000	143.2	10	0.026
	Poplar	714.8[b]	457.6	947.6	207.2	10	
	Yellowstone	908.4[a]	727.2	1000	106.2	10	

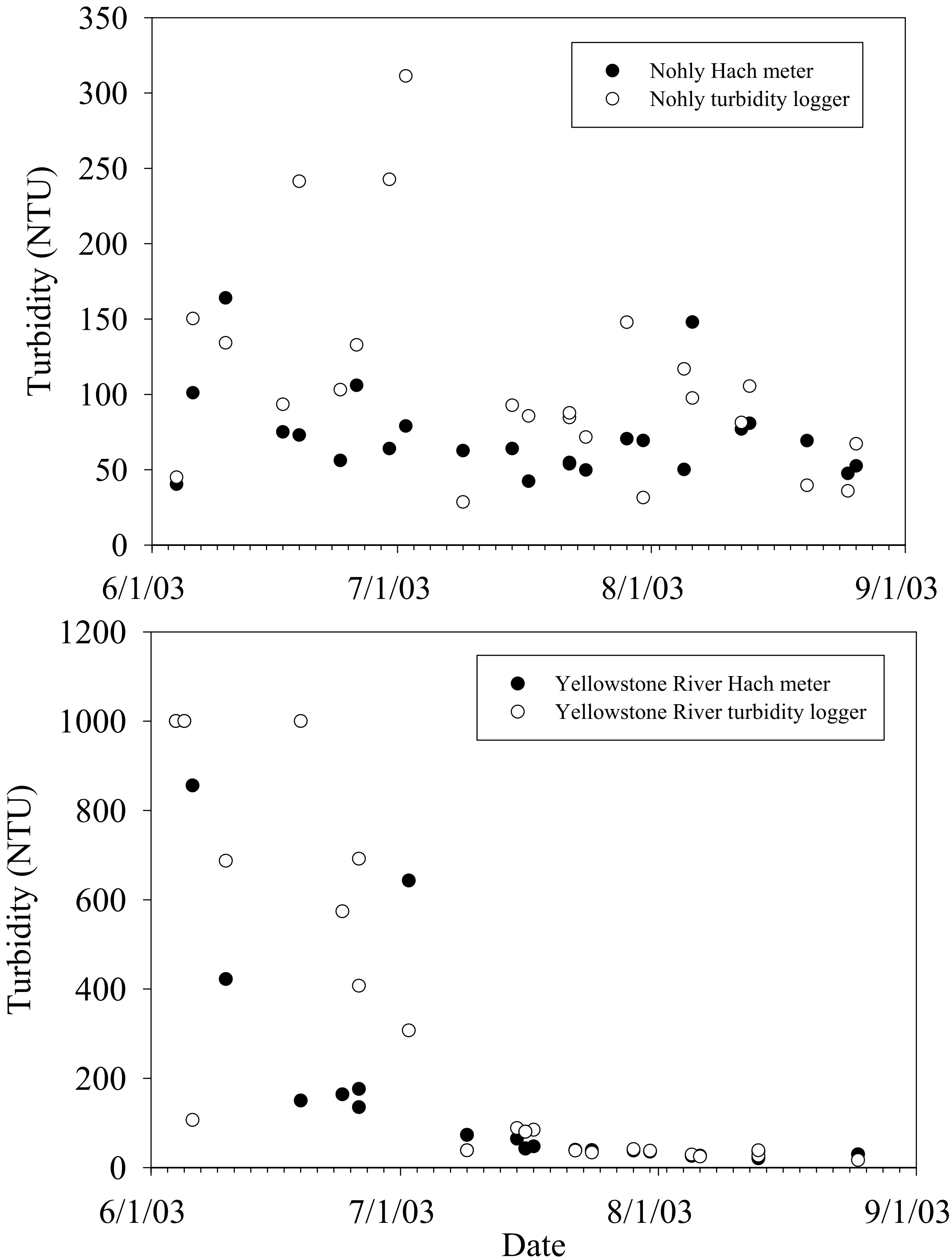

Figure 7. Hour-specific instantaneous turbidities (NTU) by date measured with a Hach meter during sampling activities and turbidity loggers at Nohly (upper panel) and in the Yellowstone River (lower panel).

Field turbidity measurements. Turbidity recorded by the turbidity loggers at Poplar, Nohly and in the Yellowstone River varied greatly during late-May through August deployment period. At Poplar, hourly turbidity measurements exceeded 1000 NTU (maximum value of logger) during a 24-hr period on the following dates (number of times in parentheses): July 28 (1), July 29 (4), August 5 (2), August 6 (10), August 7 (20), August 8 (8), August 10 (1), August 22 (2), and August 23 (2). At Nohly, turbidity exceeded 1000 NTU on June 18 (1), June 19 (2), June 20 (4), June 21 (1), June 23 (2), and June 29 (1). In the Yellowstone River, turbidity exceeded 1000 NTU from May 29 through June 4 (24 measurements for all dates), June 5 (13), June 13 (23), June 14 (8), June 15 (2), June 16 (19), June 17 (15), June 18 (22), June 19 (19), June 20 (23), June 21 (6), June 23 (1), June 24 (1), and July 3 (2). Because the turbidity loggers did not record turbidity exceeding 1000 NTU, turbidity readings that exceeded 1000 NTU were truncated to 1000 NTU for estimations of mean daily turbidity. Truncation of turbidity data reduced the accuracy of mean daily estimates, resulted in conservative estimates of mean daily turbidity, and precluded quantitative statistical comparisons of spatial and temporal differences in mean daily turbidity. Therefore, only general trends in turbidity are reported. Spatially, turbidity during the common deployment period in 2003 (May 28 – August 31) tended to be higher in the Missouri River at Nohly (median NTU = 88.7, minimum = 10.2, maximum = 658.3, N = 96) than in the Missouri River at Poplar (median NTU = 55.3 NTU, minimum = 24.6, maximum = 861.7, N = 96) and in the Yellowstone River (median NTU = 49.3, minimum = 5.4, maximum = 1000, N = 91; Figure 8). Temporally, mean daily turbidity at Poplar was low and fairly stable from early-June through late-July, increased between late-July and early August, then remained low through August with the exception of an increase in late-August (Figure 8). At Nohly, mean daily turbidity increased from early-June to a maximum in mid-June, then generally declined through August (Figure 8). In the Yellowstone River, mean daily turbidity peaked in early and mid-June, then declined through August (Figure 8). Changes in river discharge influenced turbidity, but the influence of discharge was most evident in the Missouri River at Poplar and in the Yellowstone River. Slight increases and rapid decreases in discharge during late-July and early August accentuated turbidity at Poplar. Turbidity in the Yellowstone River increased with elevated discharge during early and mid-June, but declined to low levels as Yellowstone River discharge decreased to low base flows.

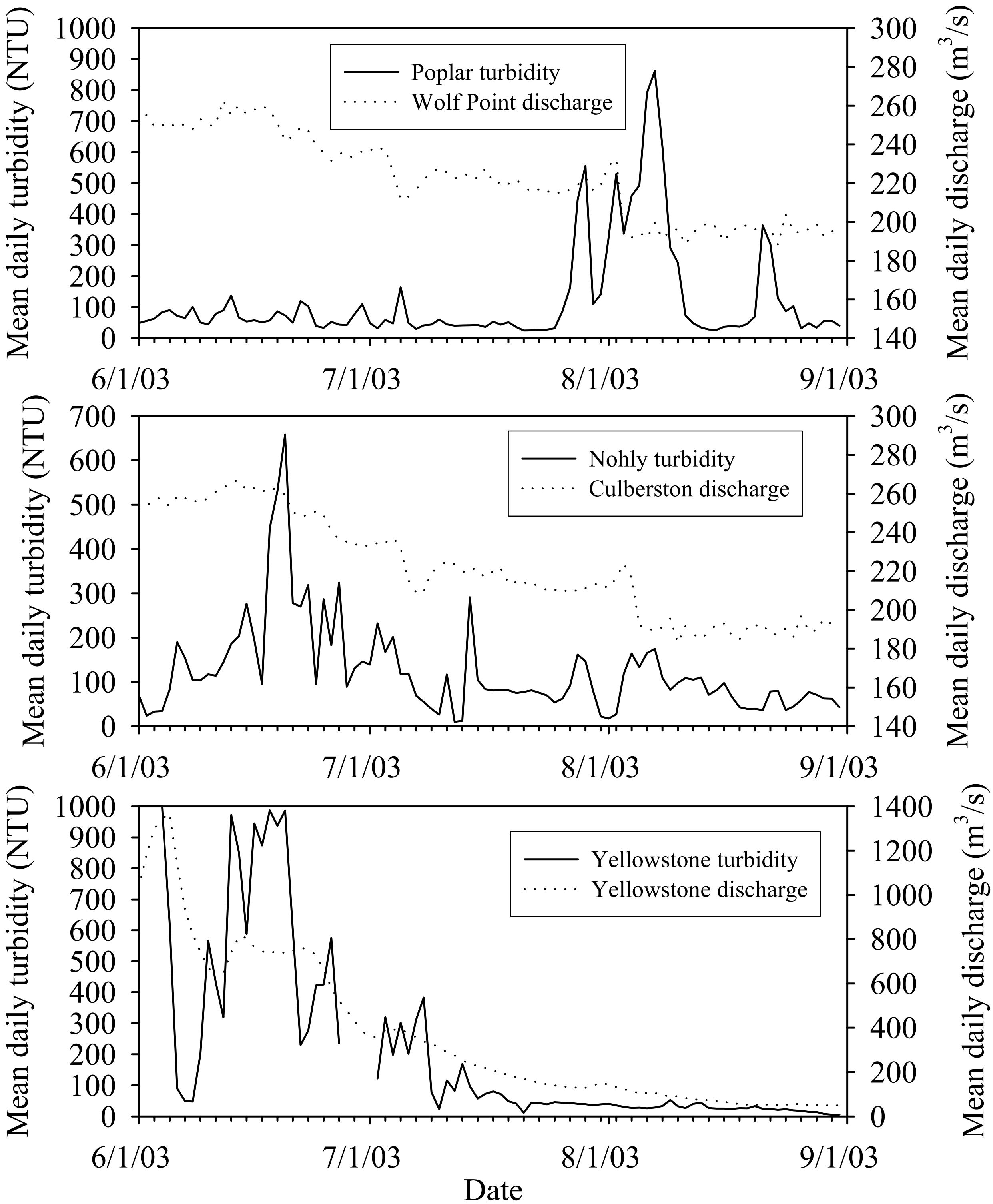

Figure 8. Mean daily turbidity (NTU; solid line) from turbidity loggers and discharge (m^3/s; dotted line) in the Missouri River near Poplar (upper panel), Nohly (middle panel), and in the Yellowstone River (lower panel) during 2003.

Inter-annual trends in turbidity.-Complete deployment data sets for 2002 and 2003 are available for turbidity loggers at Nohly and in the Yellowstone River to facilitate inter-annual comparisons of turbidity. Median turbidity during the deployment period tended to be higher during 2002 than 2003 at both locations (Table 10).

Table 10. Summary statistics for turbidity (NTU; median, 25%-75% quartiles, minimum, maximum) from turbidity loggers deployed in the Missouri River at Nohly and in the Yellowstone River during 2002 and 2003. Common deployments dates for both years span June 1 – August 27 (88 days) except for 2003 in the Yellowstone River where four days (June 28, 29, 30, July 1) were omitted.

Site	Year	Median	25-75% quartiles	Minimum	Maximum
Nohly	2002	172.8	102.7-302.2	13.2	1000
	2003	96.5	69.1-157.8	10.2	658.3
Yellowstone River	2002	163.3	104.7-326.9	18.2	1000
	2003	51.1	31.5-319.0	11.6	1000

Monitoring Component 2 – Movements by pallid sturgeon

One pallid sturgeon adult was captured in the tailwaters of Fort Peck Dam on November 18, 2003. The pallid sturgeon measured 1,272 mm and weighed 11.150 kg. A PIT tag or other identifier was not found suggesting that this pallid sturgeon represented a new addition to the pallid sturgeon population database. A PIT tag was implanted (PIT tag number 43105C602B). This individual was implanted with a CART Tag (radio frequency 149.760, acoustic frequency 65.5, code 96). Sex of this individual could not be readily determined. This pallid sturgeon will be tracked for the next few years, and complement existing telemetry studies of pallid sturgeon conducted by the U. S. Fish and Wildlife Service.

Monitoring Component 3 – Flow- and temperature-related movements of paddlefish, blue suckers, and shovelnose sturgeon

Tag retention, m*anual relocations and ground station contacts*.- At the onset of manual tracking in April 2003, there were 45 shovelnose sturgeon (6 males, 34 females, 5 unknown sex), 36 blue suckers (12 males, 12 female, 12 unknown), and 40 paddlefish (26 males, 11 females, 3 unknown) implanted with CART tags throughout the study area. Tag retention in blue suckers and shovelnose sturgeon was exceptional as all blue suckers retained their tags, and only one gravid female shovelnose sturgeon shed the CART tag (on a gravel bar in the Milk River). Five paddlefish implanted by University of Idaho personnel shed their tags; four tags were shed in the Yellowstone River (one at Fairview, two below Sidney, one at Seven Sisters), and one paddlefish shed the CART tag near Oswego on the Missouri River. Four of these fish were females. Wade King (USFWS, personal communication) reported that three female pallid sturgeon implanted in past years also shed their tags.

We conducted 22 tracking runs between April and October, and cumulatively searched 9,347 km of riverine habitat in the Missouri River and Yellowstone River (Table 11). Sixteen tracking events covered the entire study area; whereas, six tracking events covered only selected reaches. Between May 12 and May 18, a special tracking run was conducted in the Milk River when the Milk River logging station indicated movements of several fish into the Milk River. We obtained 520 relocations of blue suckers, 237 relocations of paddlefish, and 708 relocations of shovelnose sturgeon. We also obtained 129 relocations of pallid sturgeon implanted by the USFWS. In addition, we also obtained relocations of blue suckers (N = 4), paddlefish (N = 15), shovelnose sturgeon (N = 33), and pallid sturgeon (N = 16) while conducting other field activities.

Table 11. Dates, reaches, total river kilometers tracked, and numbers of relocations obtained for blue suckers, paddlefish, shovelnose sturgeon, and pallid sturgeon by boat during 2003. The Milk River was tracked during 5/12 – 5/18.

Dates	Reaches tracked	Total km	Blue sucker	Paddlefish	Shovelnose sturgeon	Pallid sturgeon
4/7 - 4/13	All	457.6	30	15	36	7
4/14 - 4/20	1,2	303.2	23	2	22	4
4/21 - 4/28	All	457.6	25	15	38	8
4/28 – 5/4						
5/5 – 5/11	All	457.6	22	18	39	5
5/12 – 5/18	All	557.6	27	16	38	7
5/19 – 5/25	All	457.6	20	21	38	3
5/26 – 6/1	All	457.6	25	15	38	5
6/2 – 6/8	All	457.6	29	18	37	8
6/9 – 6/15	All	457.6	26	11	33	9
6/16 – 6/22	All	457.6	24	9	35	7
6/23 –6/29	All	457.6	24	9	38	8
6/30 – 7/6	3,4,5	153.6	8	2	18	7
7/7 – 7/13	All	457.6	24	5	34	3
7/14 – 7/20	All	457.6	22	5	34	4
7/21 – 7/27	All	457.6	27	3	28	2
7/28 – 8/3	All	457.6	25	7	33	3
8/4 – 8/10						
8/11 – 8/17	All	457.6	30	5	36	6
8/18 – 8/24						
8/25 – 8/31	1,2,3	342.4	18	10	28	7
9/1 – 9/7						
9/8 – 9/14	1,2,3	342.4	18	16	28	6
9/15 – 9/21						
9/22 – 9/28	All	457.6	27	13	31	7
9/29 – 10/5						
10/6 – 10/12	1,2,3,4	392	24	12	28	8
10/13 – 10/18						
10/20 – 10/25	1,2,3,4	392	22	10	18	5
Total		9347.2	520	237	708	129

The six continuous-recording logging stations deployed during 2003 contributed additional movement and relocation information that augmented the manual tracking data set (Table 12). The logging stations recorded 225 contacts for 15-21 individual blue suckers, 46 contacts of 5-8 individual paddlefish, and 80 contacts of 1-11 shovelnose sturgeon. The Nickels logging station recorded the highest numbers of contacts for blue suckers and shovelnose sturgeon. The number of paddlefish contacts was generally similar among logging stations positioned at Wolf Point, Poplar, Brockton, and Culbertson.

Table 12. Number of contacts and number of individual fish recorded by six logging stations for blue suckers, paddlefish, and shovelnose sturgeon during 2003.

	Blue sucker		Paddlefish		Shovelnose sturgeon	
Logging station	**Contacts**	**Individual fish**	**Contacts**	**Individual fish**	**Contacts**	**Individual fish**
Milk River	**20**	**15**			**1**	**1**
Nickels	**70**	**18**			**36**	**11**
Wolf Point	**27**	**18**	**11**	**5**	**11**	**8**
Poplar	**37**	**18**	**13**	**8**	**8**	**6**
Brockton	**34**	**20**	**12**	**7**	**10**	**6**
Culberston	**37**	**21**	**10**	**7**	**14**	**8**

Blue sucker relocations and movements.-Of the 36 tagged blue suckers, 32 were relocated during 2003. One fish was never found after implanting in 2001, two fish were never relocated after implanting in 2002, and one was last seen by the Highway 85 bridge in April 2002, and is presumed to be somewhere in Lake Sakakawea.

The distribution and relative abundance of blue suckers varied among river reaches through time. In the Missouri River reach between Fort Peck Dam and Wolf Point, relative abundance of blue suckers was high (0.13 relocations/km) during April, generally declined through early September, then increased and remained stable (0.12 relocations /km) through late October (Figure 9). A notable exception to this pattern occurred during the week of May 12 when relative abundance declined due to movements of 15 blue suckers from the reach into the Milk River when the Milk River exhibited a large increase in discharge. The residence time of blue suckers in the Milk River spanned within a 2-week time period as evidenced by ground station information and the increase in relative abundance of blue suckers in the Missouri River (Figure 9). From May 15 to May 27, blue suckers emigrated from the Milk River as discharge decreased.

The relative abundance of blue suckers in the reach between Wolf Point and the Yellowstone River confluence was low (< 0.07 relocations/km) during all tracking events (Figure 9). Relative abundance increased in this reach between mid-May and early June, and this increase was likely related to the mass down-stream movements of blue suckers emigrating from the Milk River. A secondary increase in the relative abundance of blue suckers in the Missouri River reach between Wolf Point and the Yellowstone River occurred during early

September that was primarily due to movements of blue suckers out of the Yellowstone River when flows were low and water temperature was high.

The occurrence of blue suckers in the Missouri River downstream from the Yellowstone River confluence varied among dates (Figure 9). Relative abundance was initially high (0.13 relocations/km) in early April, but declined through late July. A slight increase in use of this reach was observed in late August.

Use of the Yellowstone River by radio tagged blue suckers exhibited a distinct pattern among tracking periods. Relative abundance of blue suckers in the Yellowstone River was low (0.01 relocations/km) in early April, consistently increased to a maximum of 0.14 relocations/km in early August, then declined during late September and early October (Figure 9). The increase in relative abundance during June, July, and August was primarily due to migrations of blue suckers out of the Milk River and the Dam-Wolf Point reaches into the Yellowstone River.

In summary, the general trend for blue suckers in 2003 was a migration up the Missouri River and up the Milk River in early May. When flows regressed in mid- to late-May, blue suckers moved out of the Milk River and down the Missouri River. When the blue suckers encountered the Yellowstone River, approximately 288 km below the Milk River, they migrated upstream. Between May 23 and June 12, four blue suckers passed over the Intake diversion dam. The furthest upstream movement in the Yellowstone River was rkm 384. Blue suckers remained in the Yellowstone River during summer and exited in mid-August. At that point, blue suckers moved upstream in the Missouri River. There were four fish that resided in reach 1 for the remainder of the season, after their migration up the Milk. Three fish resided in reach 2 for the entire season. Only one fish remained below the confluence for the season. The average movement for blue suckers was nearly 480 kilometers for the season. See Appendix A for a map view of blue sucker relocations in the Missouri River and Yellowstone River by month.

Weekly movement rates of blue suckers varied among tracking intervals and between the Missouri River and Yellowstone River (Figure 10). In the Missouri River, blue suckers had positive net weekly movement rates during April and the first week of May indicating movements were directed primarily upstream. Between early May and late June, blue suckers exhibited negative net weekly movement rates movement rates indicating movements were directed primarily downstream. During July and early August, blue suckers exhibited minimal directed movements in the Missouri River as net movement rates were close to zero. A second period of directed upstream movements occurred between early August and late September as net movement rates were positive. Movement rates declined from late September through October, but were still positive indicative of primarily upstream movements. Blue sucker movements in the Yellowstone River followed a consistent pattern through time as net movement rates were positive (directed upstream) from mid-May through late July, then became negative (directed downstream) from late July through late September.

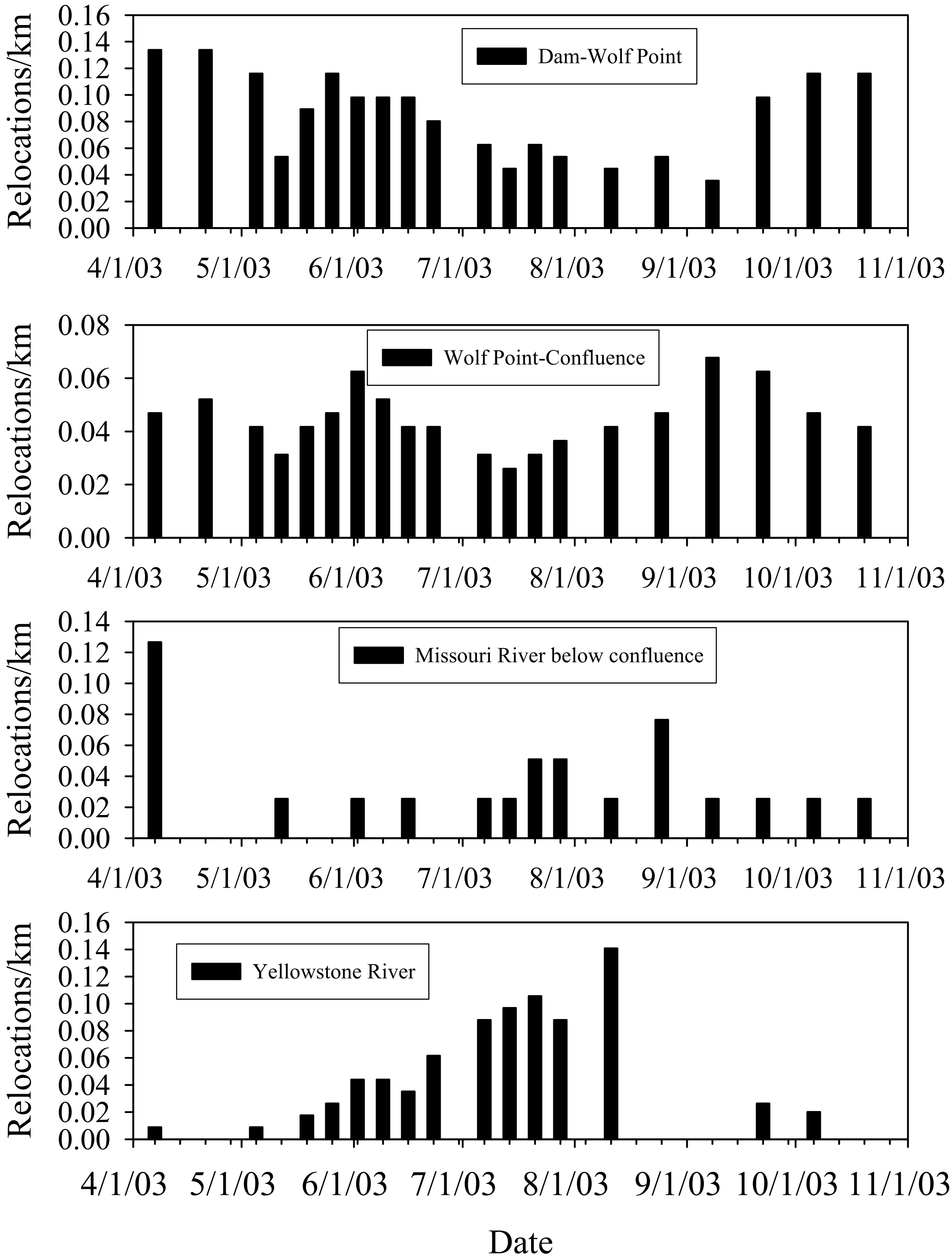

Figure 9. Number of blue sucker relocations per km in reaches of the Missouri River and Yellowstone River during 2003.

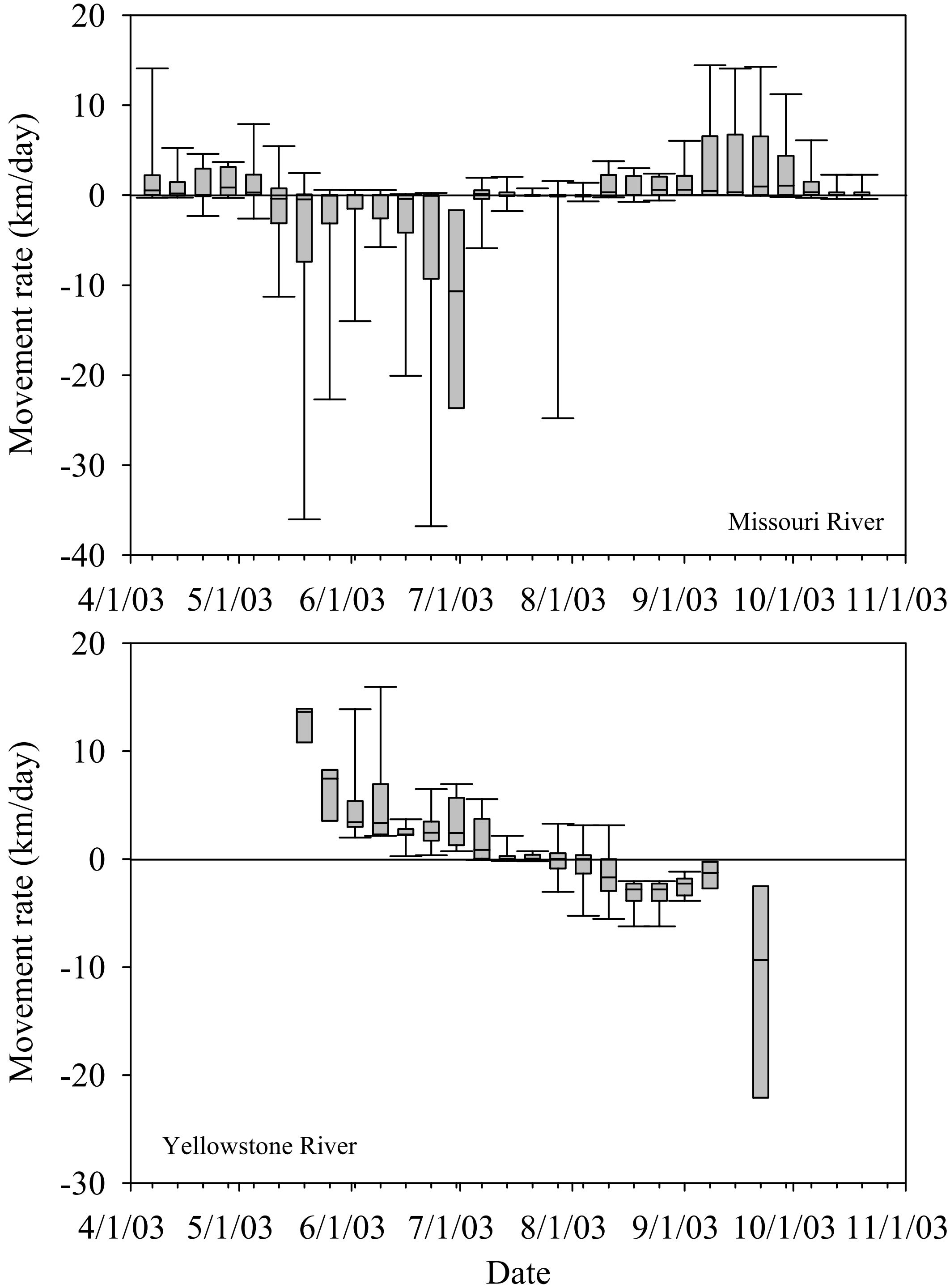

Figure 10. Box and whisker plots of net movement rates (km/day) of blue suckers in the Missouri River and Yellowstone River during 2003. Median movement rate is denoted as a line within the box. The box delimits 25th and 75th percentiles of the data, and whiskers delimit the 5th and 95th percentiles.

Paddlefish relocations and movements.-Thirty-four of the 40 paddlefish implanted with CART tags were relocated during 2003. The six paddlefish not relocated were assumed to have spent the seasons in Lake Sakakawea.

Paddlefish exhibited distinct use patterns of Missouri River reaches and the Yellowstone River. Relative abundance of paddlefish in the Missouri River between Fort Peck Dam and Wolf Point increased from 0.01 relocations/km in early April to a maximum of 0.05 relocations/km in late June (Figure 11). Use of this reach declined through July, and only one paddlefish was present in the reach in early September. About 18% of the paddlefish implanted migrated into the reach between Fort Peck Dam and Wolf Point. The maximum upstream location of paddlefish in this reach was at rkm 2,809 (RM 1,745). No implanted paddlefish moved into the Milk River. One paddlefish over-wintered in the Missouri just upstream from Wolf Point.

The Missouri River between Wolf Point and the Yellowstone River confluence was used by paddlefish; however, relative abundance reflected limited temporal use of the reach (Figure 11). Two individuals were relocated in this reach in early and mid-May (0.01 relocations/km), and one individual was relocated during other dates.

Relative abundance of paddlefish in the Missouri River downstream from the Yellowstone River confluence followed distinct seasonal patterns (Figure 11). Relative abundance declined from an initial maximum of 0.36 relocations/km in early April through May, and there were no occurrences of tagged paddlefish in this reach during June. Use of this reach steadily increased through early September (maximum 0.38 relocations/km), then declined through late October.

Temporal use of the Yellowstone River by paddlefish occurred during a 2.5 month period (Figure 11). Relative abundance steadily increased from late April to a maximum in late-May and early June (0.10 fish/km), then declined through mid-July. The maximum upstream location of paddlefish occurred at rkm 108 (RM 67.1). About 33% of the implanted paddlefish moved up the Yellowstone River. See Appendix B for a map view of paddlefish relocations in the Missouri River and Yellowstone River by month.

Movement rates of paddlefish in the Missouri River and Yellowstone River exhibited distinct temporal patterns (Figure 12). Net movement rates of paddlefish in the Missouri River were positive from April through late May indicating upstream movements. From June through late July, net movement rates were negative and increased in magnitude as paddlefish moved downstream at an increasing rate. After late July, movement rates of paddlefish in the Missouri River were minimal, and not specifically directed upstream or downstream. Paddlefish in the Yellowstone River also exhibited positive net movement rates and upstream movements between mid-April and late May, then movement rates were negative during early June as individuals migrated downstream. The few paddlefish remaining in the Yellowstone River during late June and early July exhibited positive net movement rates between relocation events.

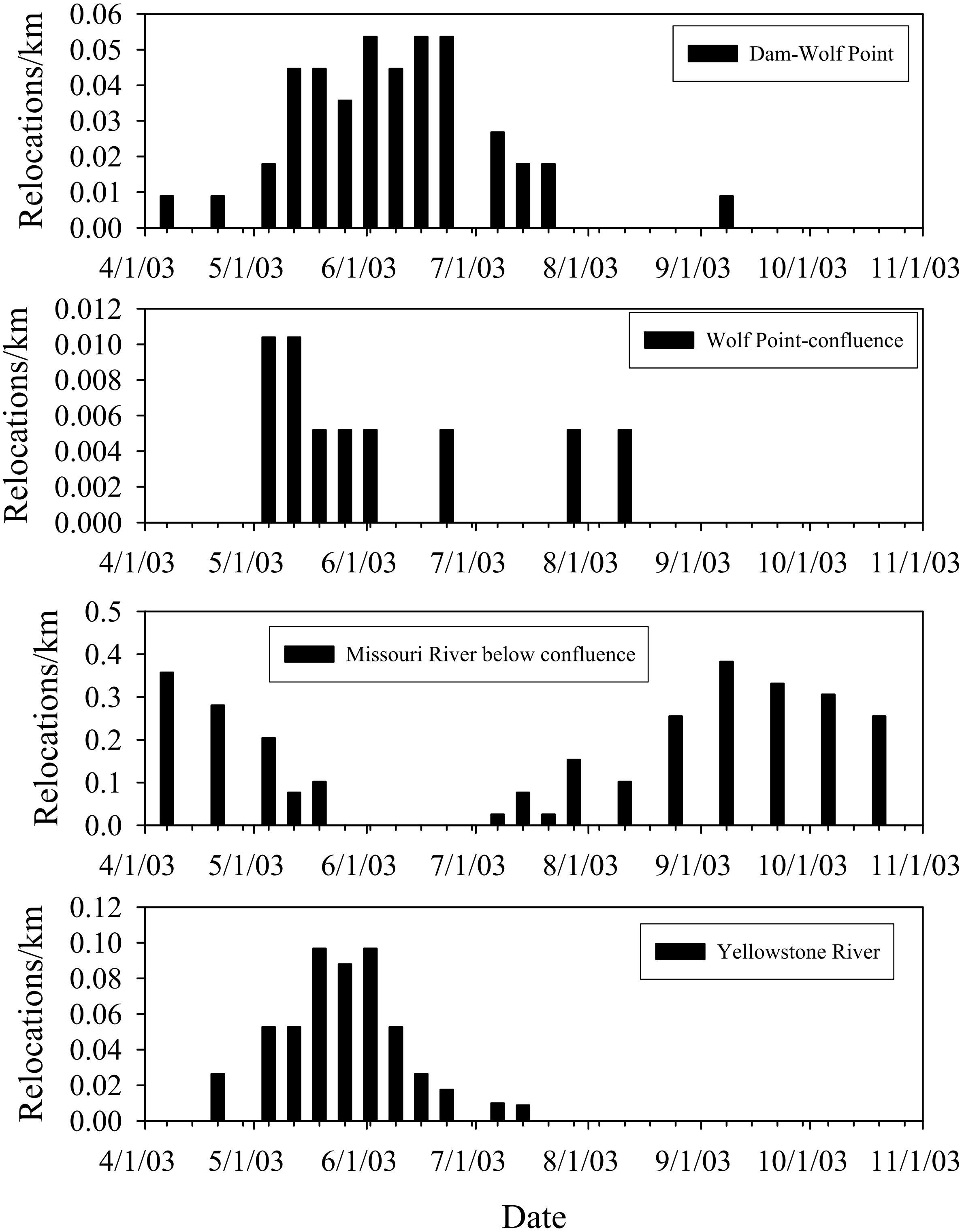

Figure 11. Number of paddlefish relocations per km in reaches of the Missouri River and Yellowstone River during 2003.

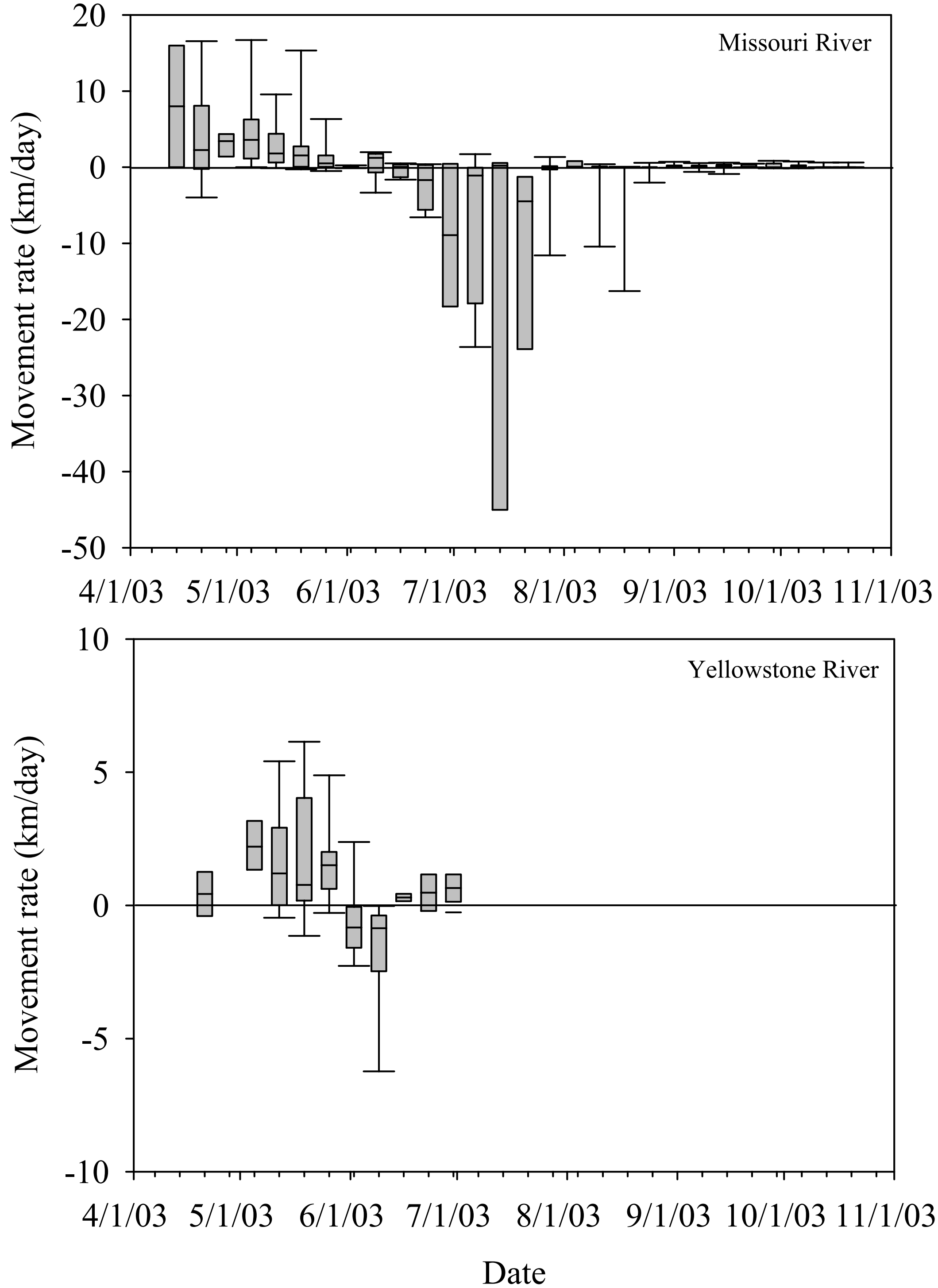

Figure 12. Box and whisker plots of net movement rates (km/day) of paddlefish in the Missouri River and Yellowstone River during 2003. Median movement rate is denoted as a line within the box. The box delimits 25th and 75th percentiles of the data, and whiskers delimit the 5th and 95th percentiles.

Shovelnose sturgeon relocations and movements.-Forty-two of 45 radio-tagged shovelnose sturgeon in the study area during 2003 were relocated. One fish was never found after implanting in 2001, one fish was never relocated after implanting in 2002, and one was last relocated below the Intake diversion dam in July 2002. The latter is assumed to have either passed over the diversion and assumed residence in the upper Yellowstone River out of the study area or to have been harvested.

Use of the Missouri River between Fort Peck Dam and Wolf Point by shovelnose sturgeon declined slightly from initial tracking runs in early April to the final tracking run in late October (Figure 13). This was due to one fish that shed the CART tag in the Milk River, two individuals that moved up the Yellowstone River, and one individual that went below the Yellowstone River confluence. However, 12 individuals remained in the study reach for the duration of the season, while two additional fish went below Wolf Point for a short time and returned to the upper reach.

Relative abundance of shovelnose sturgeon in the Missouri River between Wolf Point and the Yellowstone River confluence varied during the radio tracking period. Relative abundance was initially high (0.035 – 0.045 relocations/km) in April, then declined through late July (Figure 13). Use of this reach steadily increased from early August through early October, then declined during late October.

Use of the Missouri River downstream from the Yellowstone River confluence by shovelnose sturgeon was low (< 0.08 relocations/km) from early April through July (Figure 13). Relative abundance increased during August to a maximum of 0.33 relocations/km in early September, then declined during October.

Relative abundance of shovelnose in the Yellowstone River increased from early April through early May, remained fairly stable through late July, then declined during September and October (Figure 13). Similar to the reach above Wolf Point, there was minimal exchange of fish that resided in the Yellowstone with other reaches until mid-August. There were 22 fish that spent the entire spring and summer in the Yellowstone River. In mid-August, 15 individuals exited the Yellowstone River. Twelve of 15 individuals continued downstream in the Missouri River while the other three went upstream in the Missouri River. Four shovelnose sturgeon were relocated above the Intake diversion dam during an aerial survey in October. One individual passed over Intake during 2002, another after May 23, one after June 26, and one other sometime in September. The furthest upstream location was 277 km up the Yellowstone River. See Appendix C for a map view of shovelnose sturgeon relocations in the Missouri River and Yellowstone River by month.

Movement rates and patterns of shovelnose sturgeon varied between the Missouri River and Yellowstone River (Figure 14). In the Missouri River, net movement rates were low between April and early September, and not specifically directed either upstream or downstream. Net movement rates increased in mid-September and were positive through late October indicative of upstream movements. Shovelnose sturgeon in the Yellowstone River exhibited primarily positive net movement rates from early May through mid-July. From mid-July through August, movement rates increased but were negative indicating net downstream movements in the Yellowstone River. Net movement rates of shovelnose sturgeon in the Yellowstone River between early September and early October were positive indicating upstream movements.

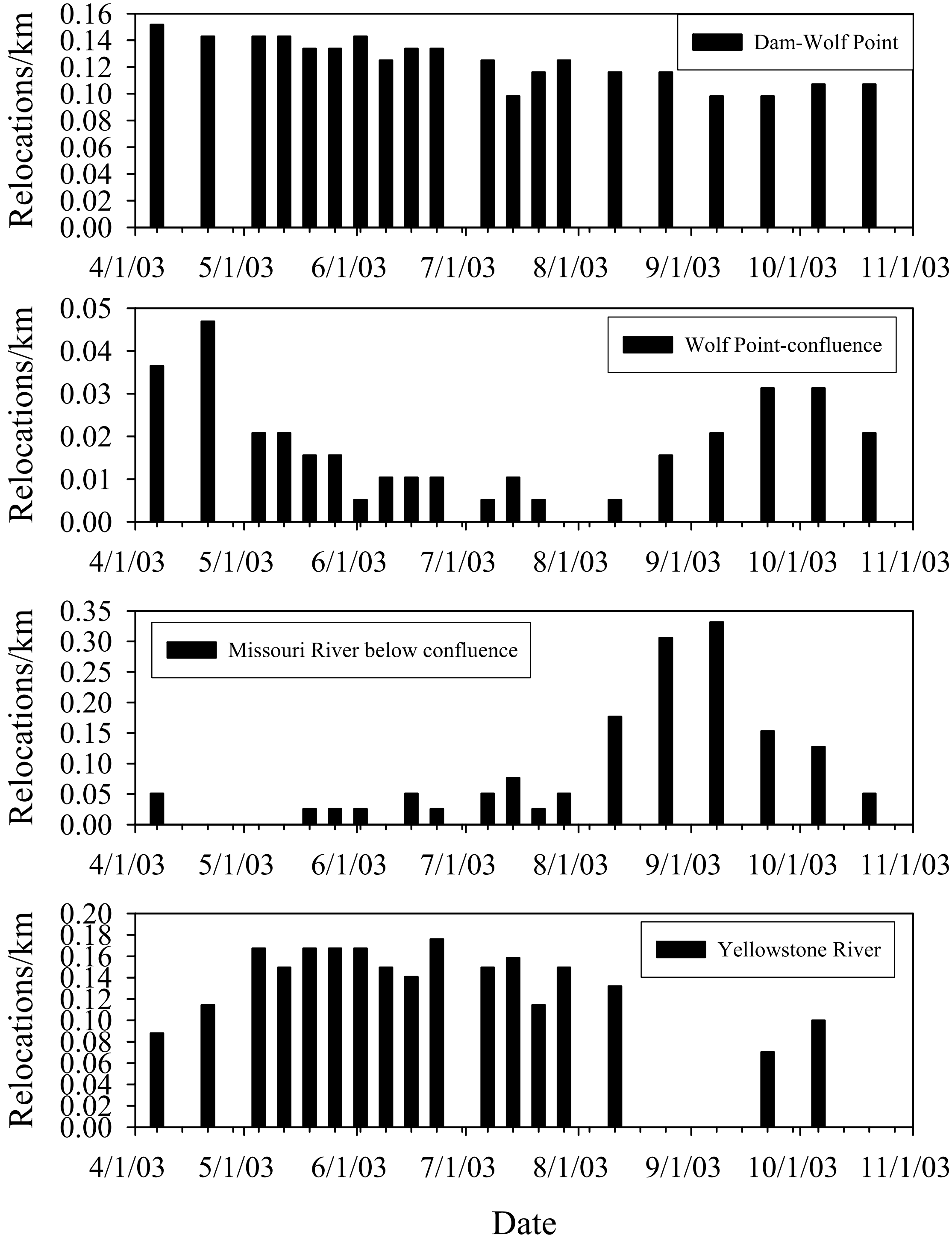

Figure 13. Number of shovelnose sturgeon relocations per km in reaches of the Missouri River and Yellowstone River during 2003.

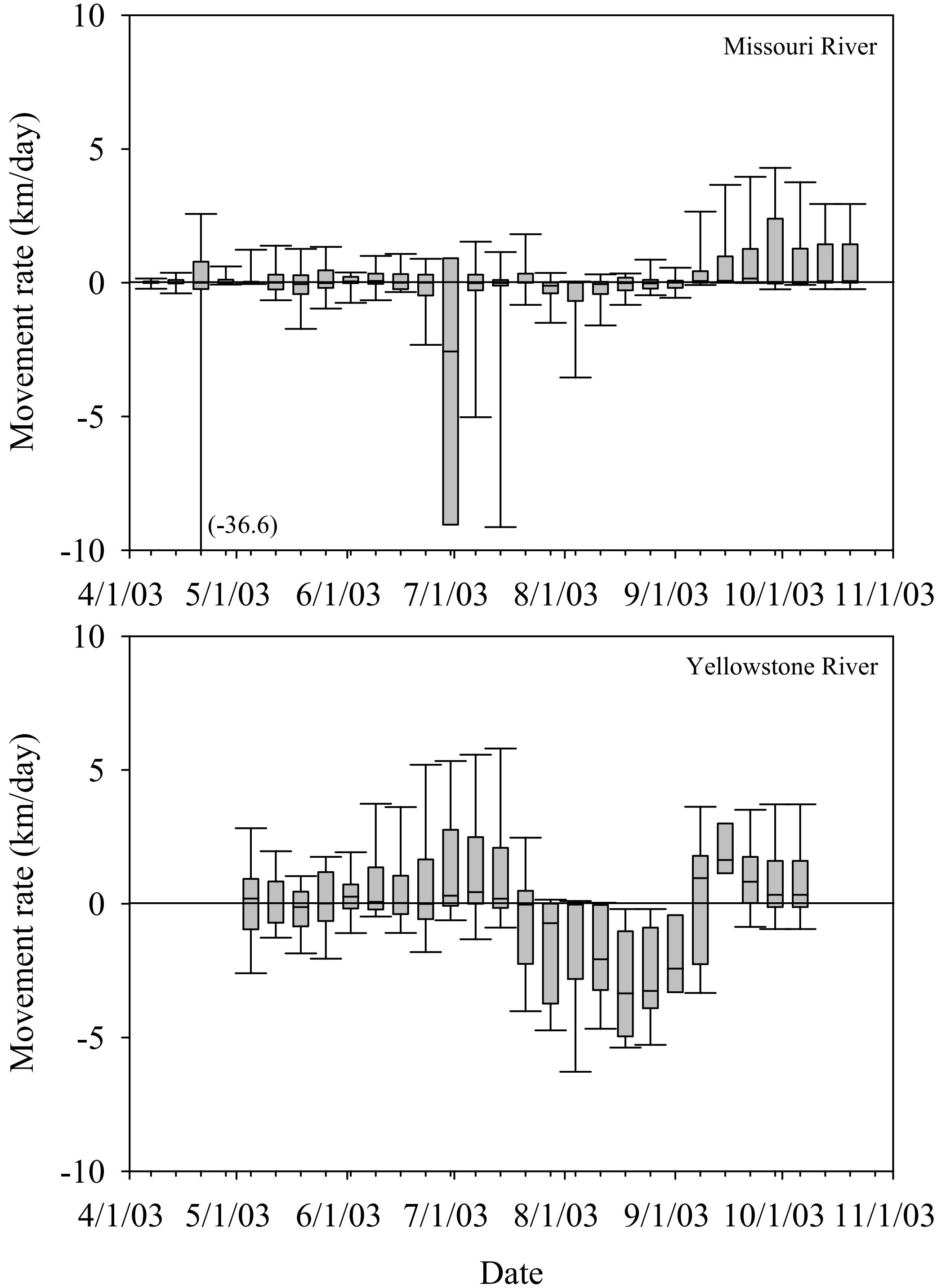

Figure 14. Box and whisker plots of net movement rates (km/day) of shovelnose sturgeon in the Missouri River and Yellowstone River during 2003. Median movement rate is denoted as a line within the box. The box delimits 25th and 75th percentiles of the data, and whiskers delimit the 5th and 95th percentiles.

Diel movements.-Patterns of diel movements varied among the three species. Observed and expected frequencies of day and night movements differed significantly for blue suckers ($P = 0.02$) and shovelnose sturgeon ($P < 0.0001$), and both species moved more than expected during the night. For paddlefish, observed and expected frequencies did not differ significantly ($P = 0.15$) indicating that paddlefish did not exhibit diel changes in movements.

Transmitter implantation.- Sampling during September 2003 resulted in capturing 20 shovelnose sturgeon, 19 blue suckers, and 1 paddlefish suitable for implanting CART tags (Table 13). Shovelnose sturgeon and blue suckers were collected in the Missouri River from the Milk River confluence to the Yellowstone River confluence. Because the Fort Peck project is not granted permission to implant paddlefish in the North Dakota portions of the Missouri River where paddlefish are abundant and can be readily caught, sampling efforts for paddlefish were restricted to the upper reach of the Missouri River below Fort Peck Dam where paddlefish are not as abundant. As a consequence, only one paddlefish was implanted in 2003 and this individual was sampled in the Fort Peck Dam tailwaters.

Table 13. Number, sex ratio (male:female:undetermined), length (mm), and weight (g) for shovelnose sturgeon, blue suckers, and paddlefish implanted with transmitters during September 2003.

Species	Number	Sex Ratio	Metric	Mean	Minimum	Maximum
Shovelnose sturgeon	20	6:11:3	Length	785	720	874
			Weight	2,218	1,625	3,350
Blue sucker	19	7:10:2	Length	708	576	785
			Weight	3,047	1,650	4,150
Paddlefish	1	0:0:1	Length	1,220		
			Weight	12,000		

Monitoring Component 4 – Larval Fish

Larval fish during 2003 were sampled on 21 individual sampling events between May 21 and August 5. The larval fish sampling regime resulted in a total of 2,051 larval fish subsamples (245 samples at the site downstream from Fort Peck Dam, 168 samples in the spillway, 378 samples in the Milk River, 420 samples at Wolf Point, 420 samples at Nohly, 420 samples in the Yellowstone River). Mean volume of water sampled per subsample was 68.7 m^3 at the site downstream from Fort Peck Dam (total = 16,835 m^3), 23.1 m^3 in the spillway (total = 3,883 m^3), 87.1 m^3 in the Milk River (total = 32,908 m^3), 78.1 m^3 at Wolf Point (total = 32,797 m^3), 75.4 m^3 at Nohly (total = 31,682 m^3), and 59.4 m^3 in the Yellowstone River (total = 24,929 m^3).

Relative abundance of larval fishes and eggs. A total of 2,899 larvae representing ten families were sampled from all sites during 2003 (Table 14). The numerically dominant taxa sampled included Catostomidae (suckers, 59.9%), Cyprinidae (minnows and carps, 17.7%), Percidae (perches, 13.3%), Hiodontidae (exclusively goldeye, 4.3%), and Polyodontidae (exclusively paddlefish, 2.6%). Taxa infrequently sampled included Acipenseridae (river sturgeons, 0.6%), Sciaenidae (exclusively freshwater drum, 0.2%), Salmonidae (salmonids, 0.2%), and Centrarchidae (sunfishes, 0.1%). A total of 33 larvae (1.1%) could not be identified. In addition, 3 larvae from the Yellowstone River (0.1%) were identified as sturgeon or paddlefish, but could not be differentiated further due to damage.

Table 14. Number (N) and frequency (%) of larval fishes, and numbers of juveniles, adults, and eggs sampled at six sites during 2003.

	Below Fort Peck Dam		Spillway		Milk River		Wolf Point		Nohly		Yellowstone River	
Taxon	N	%	N	%	N	%	N	%	N	%	N	%
Acipenseridae							4	0.5	3	1.0	9	1.0
Catostomidae	160	94.7	77	85.6	332	57.0	578	68.2	90	30.0	499	57.8
Centrarchidae							1	0.1	1	0.3	1	0.1
Cyprinidae	4	2.4	6	6.7	238	40.9	29	3.4	53	17.7	182	20.0
Hiodontidae	1	0.6					1	0.1			122	13.4
Percidae	1	0.6	5	5.6			221	26.1	141	47.0	17	1.9
Polyodontidae							3	0.4	5	1.7	67	7.4
Salmonidae					3	0.5	1	0.1	3	1.0		
Sciaenidae					5	0.8						
Unknown-sturgeon/paddlefish											3	0.3
Unknown-other	3	1.8	2	2.2	4	0.7	9	1.1	4	1.3	11	1.2
Total larvae	169		90		582		847		300		911	
Juveniles			4		310		2		1		2	
Adults					106							
Sturgeon/paddlefish eggs											14	
Misc. eggs	2,815		20		720		3,807		1,362		4,190	

Composition of the larval fishes sampled in 2003 varied among taxa and sites (Table 14). Two taxa (Catostomidae, Cyprinidae) were sampled at all sites. Representatives of Percidae were sampled at all sites except in the Milk River. Three families (Acipenseridae, Centrarchidae, Polyodontidae) were sampled exclusively in the Missouri River at Wolf Point and Nohly, and in the Yellowstone River. Salmonids were sampled at three sites including the Milk River, and Missouri River at Wolf Point and Nohly. Freshwater drum (Sciaenidae) were sampled exclusively in the Milk River. The greatest number of families occurred in the Missouri River at Wolf Point (8), whereas seven families were sampled in the Missouri River at Nohly and in the Yellowstone River. Larval fish representing four families were sampled in the Milk River and Missouri River downstream from Fort Peck Dam, and three families were sampled in the spillway channel. Catostomidae was the most abundant taxon (> 57%) sampled at all sites except in the Missouri River at Nohly where Percidae (47%) was numerically dominant to

Catostomidae (30%). Cyprinidae was the second most abundant group of larval fishes sampled in the Missouri River below Fort Peck Dam (2.4%), spillway channel (6.7%), Milk River (40.9%), and in the Yellowstone River (20%). The Yellowstone River produced the highest number of larval paddlefish (67 individuals), whereas few paddlefish were sampled in the Missouri River at Wolf Point (3 individuals) and Nohly (5 individuals). The 16 larval sturgeon sampled in 2003 were distributed among Wolf Point (4 individuals), Nohly (3 individuals), and the Yellowstone River (9 individuals).

Spatial and temporal periodicity and densities of larval Scaphirhynchus sp. and larval paddlefish. Larval sturgeon (*Scaphirhynchus sp.*) and paddlefish during 2003 were sampled exclusively in the Missouri River at Wolf Point and Nohly, and in the Yellowstone River. At Wolf Point, a total of four larval sturgeon were sampled on July 25, July 28, and August 1 (Table 15). Mean densities were low (≤ 0.13 larvae/100 m^3), and maximum densities did not exceed 0.34 larvae/100 m^3). Larval paddlefish at Wolf Point were sampled on two dates (July 17 and July 21), and mean densities were low (≤ 0.13 larvae/100 m^3; Table 15).

Table 15. Total number sampled (N), mean density (mean; number/100 m^3), median density (median), minimum density (min.), and maximum density (max.) of larval sturgeon (*Scaphirhynchus* sp.) and larval paddlefish by date in the Missouri River at Wolf Point.

	Date 2003																				
	May		June								July									Aug	
Metric	23	29	3	5	9	13	16	18	23	26	1	3	7	9	14	17	21	25	28	1	4
	Scaphirhynchus sp.																				
N																		1	1	2	
Mean																		0.06	0.06	0.13	
Median																		0	0	0	
Min.																		0	0	0	
Max.																		0.31	0.30	0.34	
	Paddlefish																				
N																2	1				
Mean																0.13	0.07				
Median																0	0				
Min.																0	0				
Max.																0.35	0.37				

Three larval sturgeon in the Missouri River at Nohly were sampled on July 11, July 17, and July 22; Table 16). Similar to Wolf Point, mean densities of larval sturgeon sampled at Nohly were low (≤ 0.06 larvae/100 m^3), and maximum densities did not exceed 0.30 larvae/100 m^3). Five larval paddlefish were sampled at Nohly between June 19 and July 15, but mean densities were low (≤ 0.07 larvae/100 m^3; Table 16).

Table 16. Total number sampled (N), mean density (mean; number/100 m^3), median density (median), minimum density (min.), and maximum density (max.) of larval sturgeon and larval paddlefish by date in the Missouri River at Nohly.

	Date 2003																				
	May		June									July									Aug
Metric	22	28	4	6	10	12	17	19	24	26	30	2	9	11	15	17	22	24	29	31	5
											Scaphirhynchus sp.										
N														1		1	1				
Mean														0.06		0.06	0.05				
Median														0		0	0				
Min.														0		0	0				
Max.														0.30		0.29	0.25				
											Paddlefish										
N								1	1	1	1				1						
Mean								0.09	0.05	0.06	0.07				0.06						
Median								0	0	0	0				0						
Min.								0	0	0	0				0						
Max.								0.46	0.25	0.31	0.35				0.32						

Nine larval sturgeon were sampled in the Yellowstone River between July 2 and July 15 (Table 17). Mean densities varied between 0.13 larvae/100 m^3 and 0.26 larvae/100 m^3 during this time period. A total of 67 larval paddlefish were sampled in the Yellowstone River between May 28 and July 2 (Table 17). Mean density of larval paddlefish was 1.48 larvae/100 m^3 on May 28, but mean density was less than 1.0 larvae/100 m^3 on other dates.

Table 17. Total number sampled (N), mean density (mean; number/100 m^3), median density (median), minimum density (min.), and maximum density (max.) of larval sturgeon (*Scaphirhynchus* sp.) and larval paddlefish by date in the Yellowstone River.

	Date 2003																				
	May		June									July									Aug
Metric	22	28	4	6	10	12	17	19	24	26	30	2	9	11	15	17	22	24	29	31	5
											Scaphirhynchus sp.										
N												3	3	2	1						
Mean												0.18	0.26	0.13	0.13						
Median												0	0.28	0	0						
Min.												0	0	0	0						
Max.												0.55	0.65	0.38	0.66						
											Paddlefish										
N		10			5	5	20	4	2	1	13	7									
Mean		1.48			0.42	0.29	0.96	0.20	0.13	0.05	0.90	0.43									
Median		0.64			0.21	0.33	0.65	0.18	0	0	0.88	0.55									
Min.		0.50			0	0	0	0	0	0	0	0									
Max.		3.70			1.0	0.54	2.35	0.60	0.38	0.25	1.57	1.01									

Larval nets fished on the bottom tended to sample a greater proportion of larval sturgeon than larval net fished in the mid-water column. For example, 75% of the 16 larval sturgeon sampled during 2003 were obtained from bottom samples. For paddlefish, 56% of the 75 larvae sampled were collected in bottom samples.

Spatial and temporal periodicity and densities of larval fishes exclusive of Acipenseridae and Polyodontidae. Temporal variations in the density of larval fishes at the site downstream from Fort Peck Dam were primarily attributed to temporal variations in Catostomidae (Figure 15). The initial period of high densities occurred on July 2 (mean density = 4.05 larvae/100 m^3) when Catostomidae composed 98% of the larvae sampled. The second period of high densities occurred on July 10 (mean density = 4.71 larvae/100 m^3) when Catostomidae composed 96% of the larvae sampled. Cyprinidae, represented exclusively by common carp on June 12 and July 2, were infrequently sampled at this site. Goldeye and Percidae were sampled only during late-May and early-June, and at low densities.

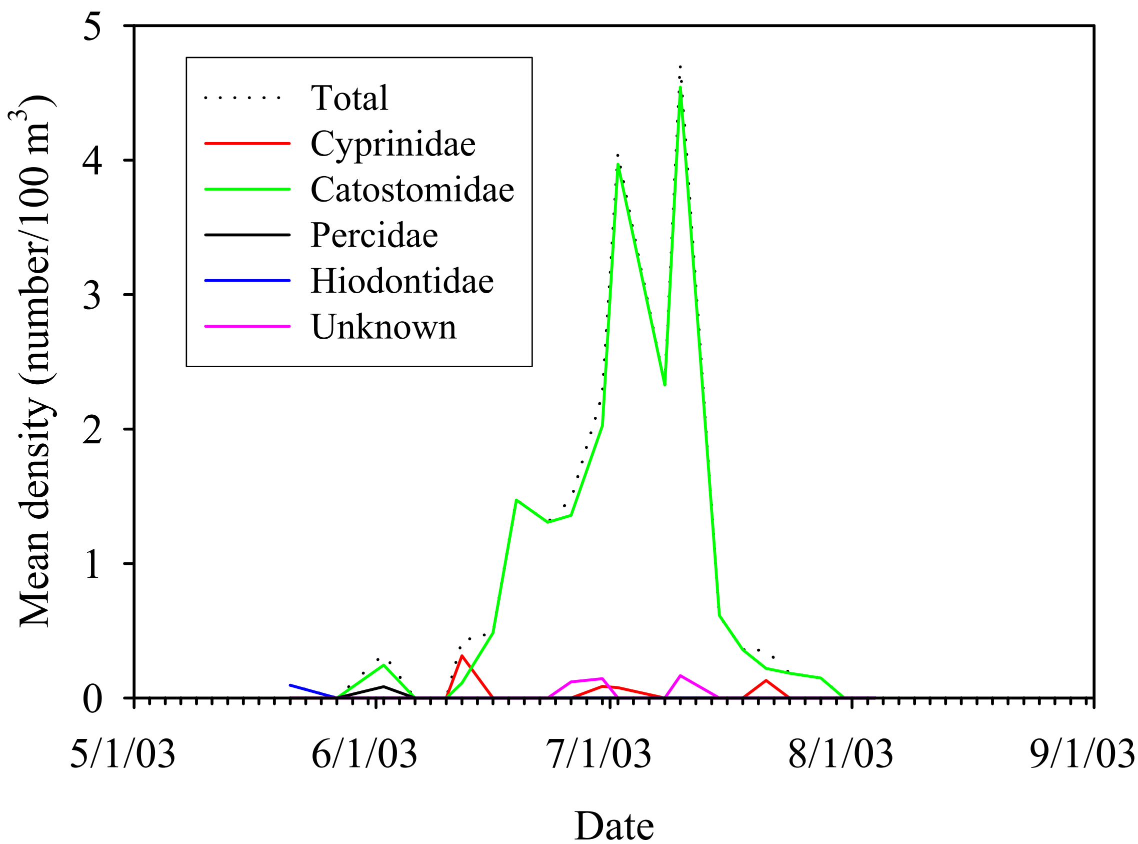

Figure 15. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Percidae, Hiodontidae, and unknown sampled in the Missouri River at the site downstream from Fort Peck Dam during 2003.

The larval fish community in the spillway channel exhibited four periods of elevated densities that were primarily attributed to Catostomidae abundance and to a lesser extent the abundance of Cyprinidae and Percidae (Figure 16). High densities in the spillway channel occurred on June 16 (mean = 8.56 larvae/100 m^3), June 19 (mean = 7.88 larvae/100 m^3) and July

8 (mean = 7.68 larvae/100 m^3) when Catostomidae composed 100% of the larvae sampled. Elevated densities also occurred on June 26 (mean density = 7.23 larvae/100 m^3) when Catostomidae composed 64% of the larvae, but Cyprinidae and Percidae also exhibited elevated densities. About 80% of the Cyprinidae sampled on June 26 was comprised of common carp larvae.

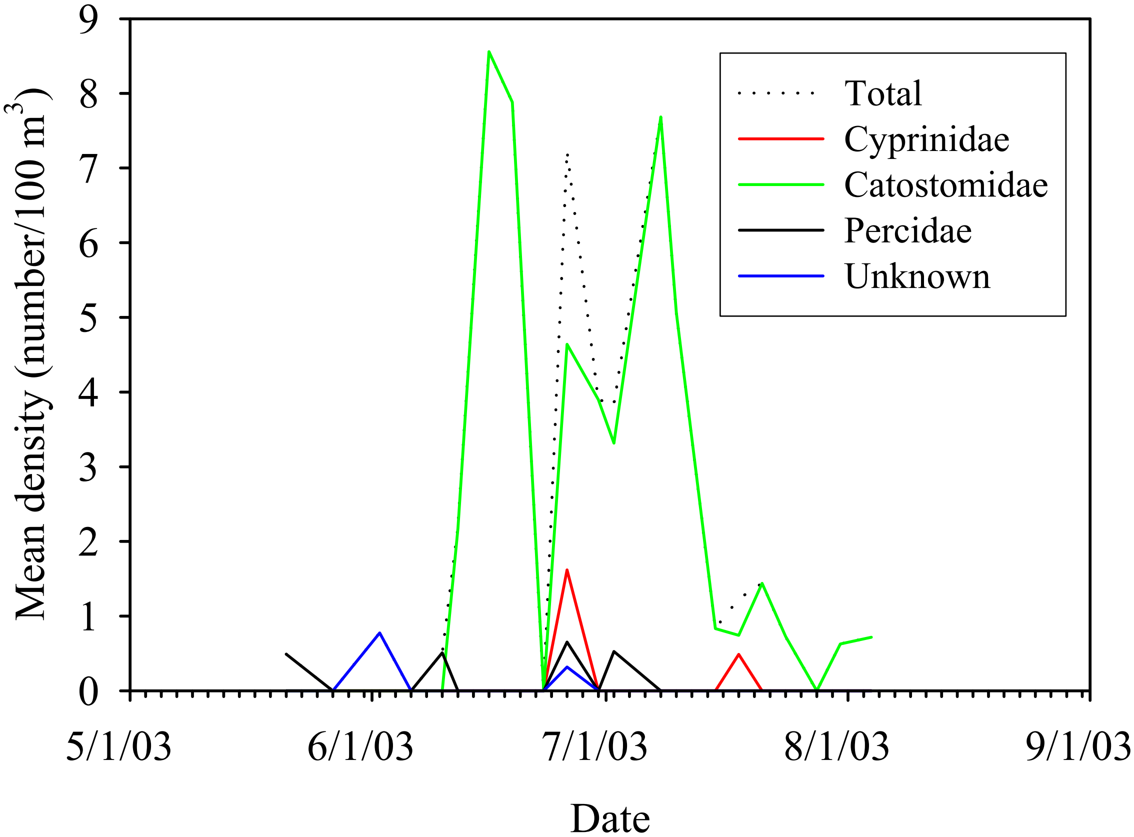

Figure 16. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Percidae, and unknown sampled in the Fort Peck spillway channel during 2003.

Densities and taxon composition of the larval fish community in the Milk River varied greatly during the late-May through early-August sampling period (Figure 17). Maximum densities occurred on June 19 (mean density = 5.21 larvae/100 m^3) as the larval community was comprised primarily of Catostomidae (70%) and Cyprinidae (27%). Larval common carp composed 66% of the Cyprinidae sampled on June 19. Following a decrease in larval fish densities on June 23, densities increased on June 30 (mean density = 3.39 larvae/100 m^3) as Catostomidae composed 95% of the larvae sampled. A secondary peak in larval fish densities occurred on July 8 (mean density = 4.85 larvae/100 m^3) when the larval fish community was comprised exclusively of Catostomidae (57%) and Cyprinidae (43%). Common carp larvae were not present in Cyprinidae on July 8. Larval fish densities declined through late-July, then increased in early-August when Cyprinidae (exclusive of common carp) composed 94% of the larvae sampled on August 4 (mean density = 2.81 larvae/100 m^3).

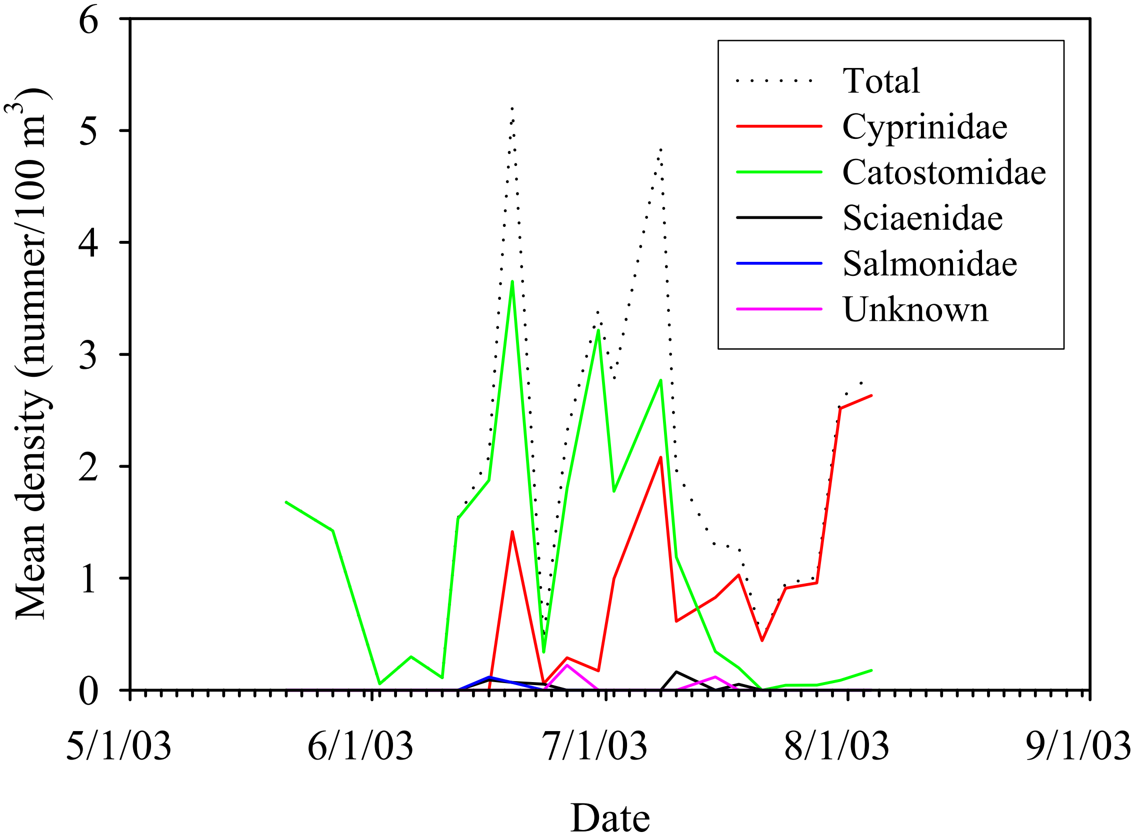

Figure 17. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Sciaenidae, Salmonidae, and unknown sampled in the Milk River during 2003.

The larval fish community at Wolf Point exhibited four periods of elevated densities that were primarily attributed to temporal variations in the densities of Percidae and Catostomidae (Figure 18). An initial peak in larval fish densities occurred on May 29 (mean density = 8.38 larvae/100 m^3) when Percidae composed 94% of the larvae sampled. Densities of Percidae and the larval fish community declined through late June, but densities increased on July 1 (mean density = 6.35 larvae/100 m^3), July 3 (mean density = 7.68 larvae/100 m^3), and July 14 (mean density = 4.55 larvae/100 m^3) as Catostomidae composed 94 – 99% of the larvae sampled. Larval fish densities declined through early-August. Representatives of Cyprinidae, Centrarchidae, and Salmonidae exhibited limited temporal occurrence in the drift and at low densities.

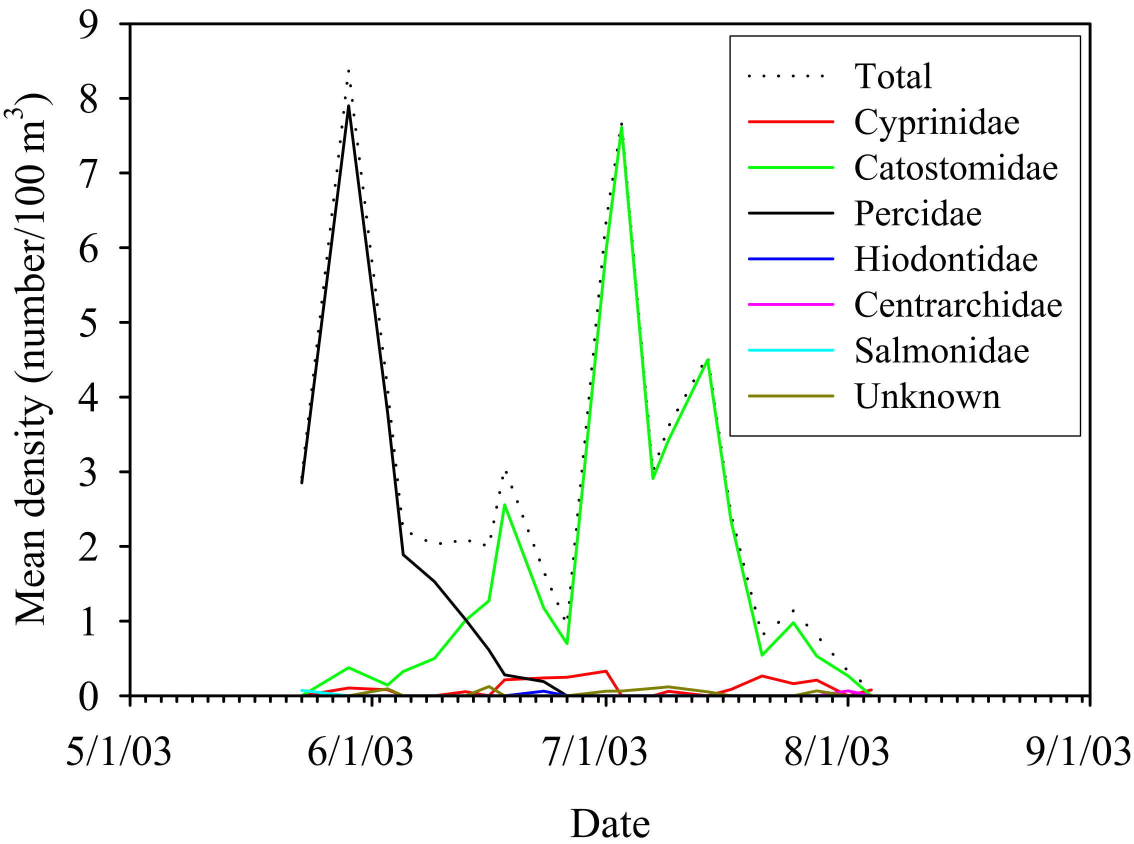

Figure 18. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Hiodontidae, Percidae, Centrarchidae, Salmonidae and unknown sampled in the Missouri River at Wolf Point during 2003.

Temporal variations in the total density of larval fishes occurred at Nohly, and were attributed to the temporal periodicity of various families (Figure 19). The highest density of larval fishes at Nohly occurred on May 28 (mean density = 3.82 larvae/100 m^3) as Percidae composed 97% of the larvae sampled. As the density of Percidae declined through June 24, the addition of other taxa between mid-June and early August contributed to several periods of elevated densities. On June 30, mean density increased to 1.08 larvae/100 m^3 when Catostomidae composed 82% of the larval fish community sampled. Densities of larval fish increased on July 9 (mean density = 1.02 larvae/100 m^3) when Cyprinidae and Catostomidae comprised the larval fish community. Two families (Centrarchidae, Salmonidae) exhibited limited occurrence in the larval fish community.

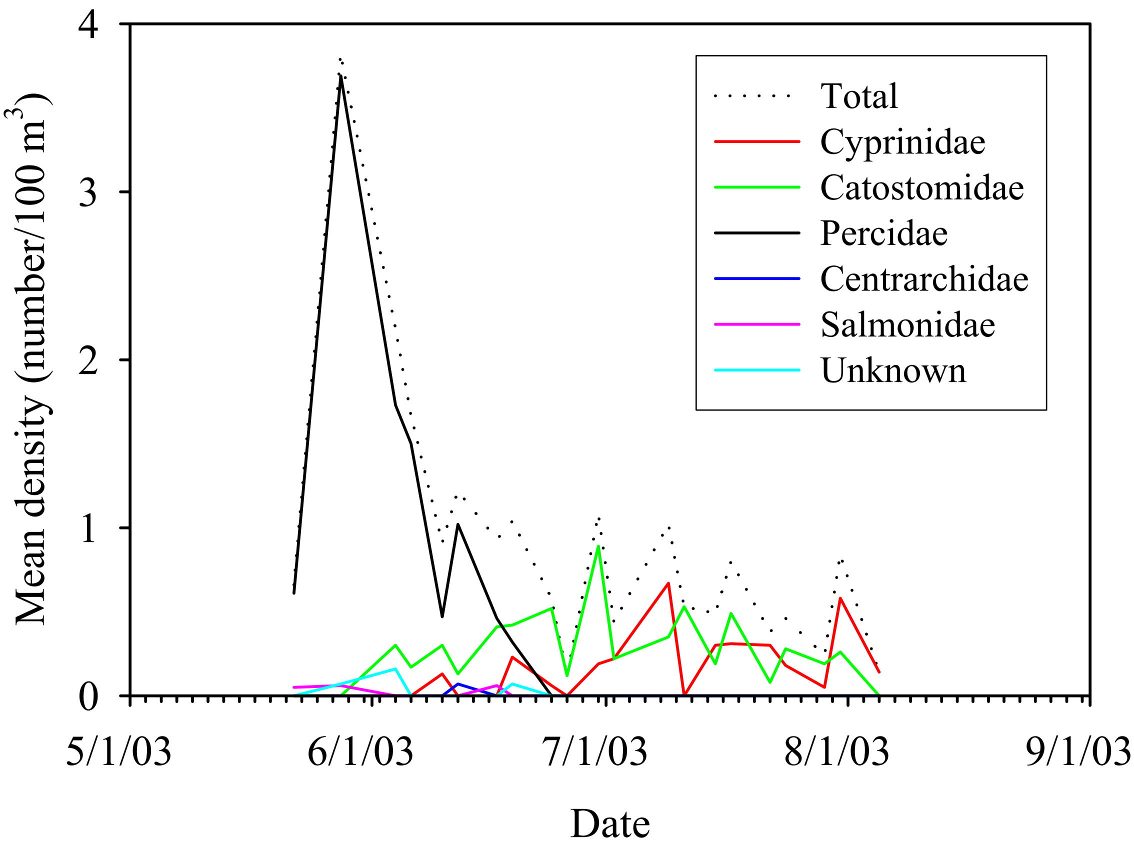

Figure 19. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Percidae, Salmonidae, Centrarchidae, and unknown sampled in the Missouri River near Nohly during 2003.

Larval fish in the Yellowstone River exhibited temporal shifts in community composition during the sampling season as evidenced by five relatively well-defined periods of high density (Figure 20). An initial period of elevated density occurred on May 28 (mean = 8.96 larvae/100 m^3) when goldeye composed 79% of the larval fish density. Mean density was maximized on June 4 (14.08 larvae/100 m^3) as the density of goldeye decreased but the density of Cyprinidae increased (63% of the larval composition). Common carp larvae represented 77% of the Cyprinidae densities on June 4. Additional periods of elevated densities occurred on June 19 (11.31 larvae/100 m^3), July 2 (4.95 larvae/100 m^3), and July 17 (mean density = 7.2 larvae/100 m^3) when Catostomidae composed 83 – 92% of the larval fish composition. Two taxa exhibited limited occurrences in the larval fish community as Percidae and Centrarchidae were sampled only during late-May and early June.

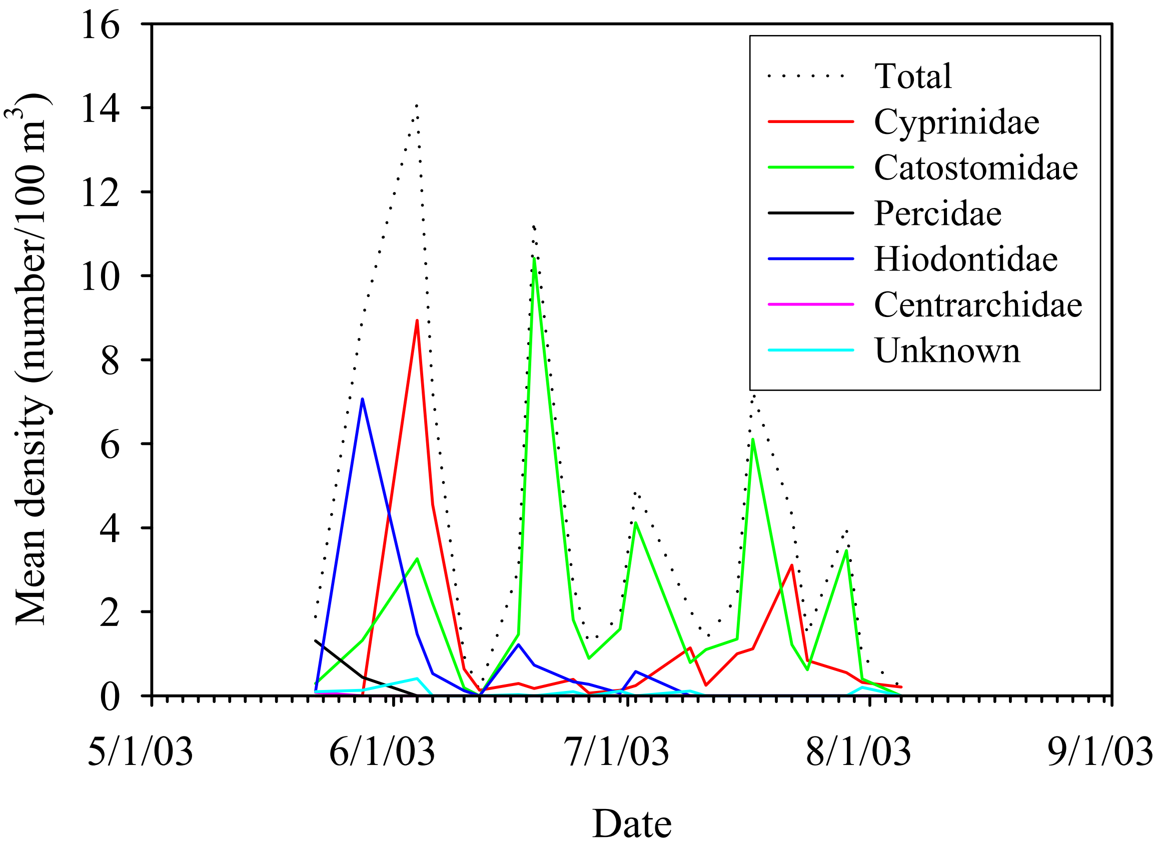

Figure 20. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Hiodontidae, Percidae, Centrarchidae, and unknown sampled in the Yellowstone River during 2003.

Inter-annual trends in larval fish densities.- A comprehensive analysis of the spatial and temporal patterns of larval fish densities will be conducted following completion of the final field season. However, general comparisons of data collected in 2001, 2002 and 2003 were conducted (Figure 21). Across sampling periods within years, median density of larval fishes tended to be lower during 2003 than other years at all sites except downstream from Fort Peck Dam where median density tended to be lower during 2001.

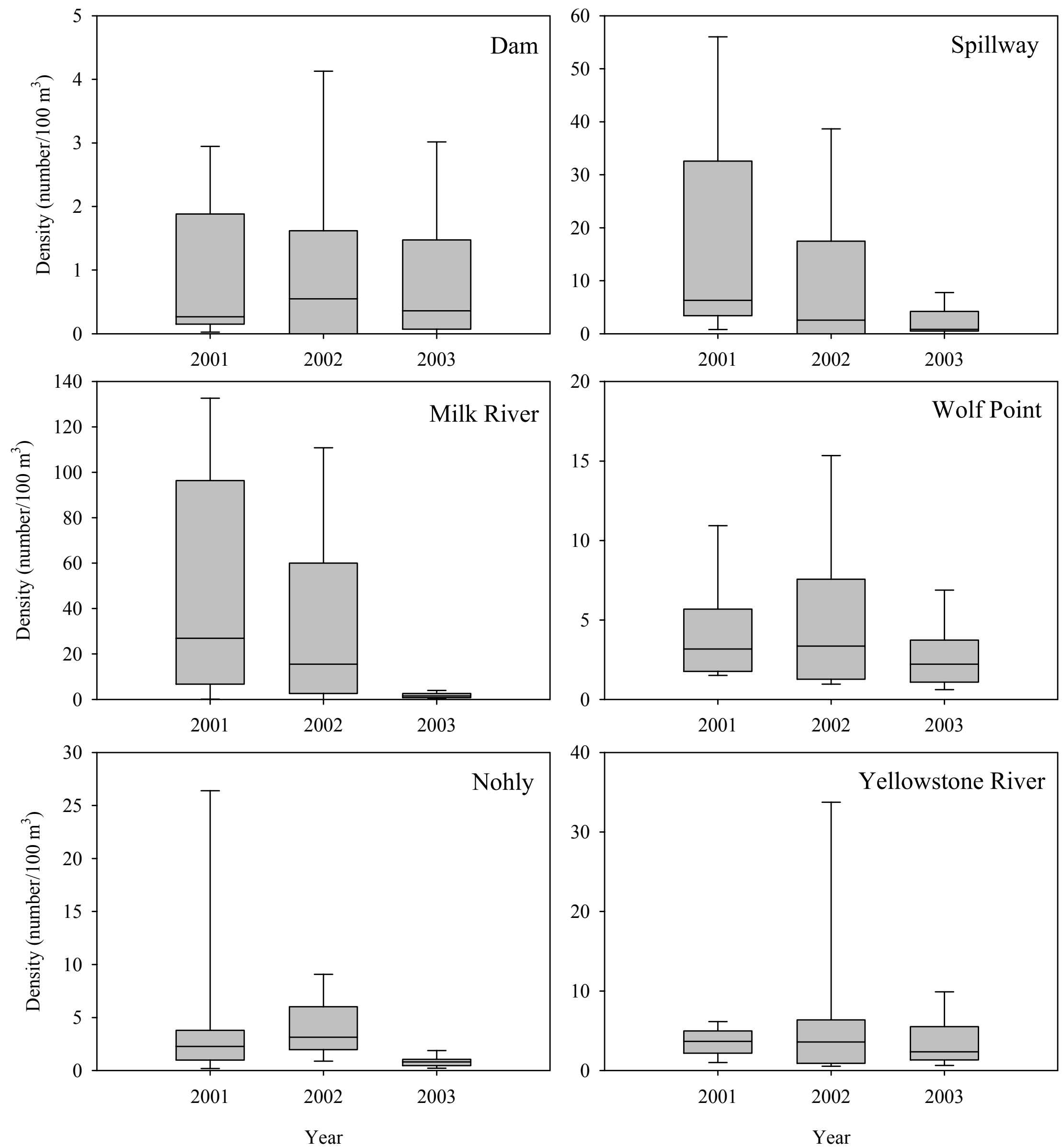

Figure 21. Box and whisker plots of total density (all taxa; number/100 m^3) of larval fishes sampled at six sites in 2001, 2002, and 2003. Boxes delimit the 25^{th} and 75^{th} percentiles of the data, lines within the boxes denote median density, and whiskers delimit the 5^{th} and 95^{th} percentiles.

Monitoring Component 5 – Reproductive success of shovelnose sturgeon and pallid sturgeon.

Young-of-year sturgeon sampling.-A total of 142 young-of-year sturgeon were sampled during August and September 2003. Thirty-nine individuals were tentatively identified as pallid sturgeon, and sent to Dr. Darrel Snyder for detailed examination. Tissue samples from 29 of the 39 tentative pallid sturgeon were sent to Dr. Ed Heist for genetic analysis. Results from additional examinations and genetic analyses are not yet available, but will be disseminated when completed.

The occurrence and number of young-of-year sturgeon sampled varied greatly among sampling sites and sampling periods (Table 18). Young-of-year sturgeon in the Missouri River ATC were sampled on two dates (August 20, August 25). Whereas standard trawl sampling (i.e., first trawl only at a specific location) resulted in one individual on both dates, targeted sampling (intensive sampling at the specific location when young-of-year sturgeon were sampled in the first trawl) resulted in an additional 14 young-of-year sturgeon. All of the young-of-year sturgeon collected in the Missouri River ATC on both dates were sampled at the exact same location - an inside bend within replicate 3.

Only one young-of-year sturgeon was sampled in the Yellowstone River (August 13; Table 18). Targeted sampling did not result in additional individuals. The Yellowstone River was not sampled during the September 3 – 4 sampling interval due to extremely low flows, shallow water, and silt accumulations that were not conducive to trawling.

Sampling in the Missouri River BTC yielded 125 (88%) of the young-of-year sturgeon sampled in 2003, and individuals were sampled on all dates (Table 18). Standard sampling resulted in the collection of 37 young-of-year sturgeon, targeted sampling added 79 individuals, and extra sampling resulted in the collection of nine individuals. Of the 125 young-of-year sturgeon sturgeon sampled in the Missouri River BTC, 112 individuals (89.6%) were sampled at or just downstream from replicate 1 (immediately downstream from the U.S. Highway 85 bridge) during standard, targeted, and extra sampling. Eleven of the remaining 13 young-of-year sturgeon were distributed among replicate 2 (2 individuals), replicate 3 (3 individuals), and replicate 4 (6 individuals). The two other young-of-year sturgeon were sampled during extra sampling at rkm 2,524 (RM 1,568; 1 individual) and rkm 2,505 (RM 1,556; 1 individual). Whereas a complete analysis of young-of-year sturgeon catch rates will be conducted after completion of the study, standard sampling mean catch rates tended to be greatest in the Missouri River BTC during the August 18 – 20 (mean = 0.167 fish/min) and August 25 – 27 (mean = 0.153 fish/min) sampling intervals.

Table 18. Number of young-of-year sturgeon sampled and sampling effort expended in 2003 by site and date. Sampling protocols include Standard (first trawl only at a specific location), Targeted (additional trawls at a specific location when a young-of-year sturgeon was sampled in the first trawl), and Extra (additional sampling above and beyond the Standard and Targeted sampling). ATC = Missouri River upstream from the Yellowstone River confluence, BTC = Missouri River downstream from the Yellowstone River confluence.

			Dates				
Site	Sampling protocol	Metric	8/6-8/7	8/12-8/13	8/18-8/20	8/25-8/27	9/3-9/4
Missouri River ATC	Standard	Sturgeon sampled	0	0	1	1	0
		Effort (trawls)	12	12	12	12	12
		Effort (min)	48.3	48	47.75	48	48
	Targeted	Sturgeon sampled			5	9	
		Effort (trawls)			8	8	
		Effort (min)			32	32	
Missouri River BTC	Standard	Sturgeon sampled	4	5	12	11	5
		Effort (trawls)	15	18	18	18	18
		Effort (min)	61	72	71.8	72	72
	Targeted	Sturgeon sampled	16	8	34	11	10
		Effort (trawls)	18	6	28	14	20
		Effort (min)	73.6	24	113	56	80
	Extra	Sturgeon sampled			2	2	5
		Effort (trawls)			8	13	6
		Effort (min)			32	53	24
Yellowstone River	Standard	Sturgeon sampled	0	1	0	0	
		Effort (trawls)	12	12	8	12	
		Effort (min)	45.9	47.5	30	48	
	Targeted	Sturgeon sampled		0			
		Effort (trawls)		2			
		Effort (min)		8			

The size distribution of young-of-year sturgeon varied between sites and among sampling periods (Figure 22). In the Missouri River ATC, lengths of young-of-year sturgeon sampled varied from 22 mm to 31 mm on August 20. On August 25, lengths of young-of-year sturgeon covered a broader distribution and varied from 21 mm to 58 mm.

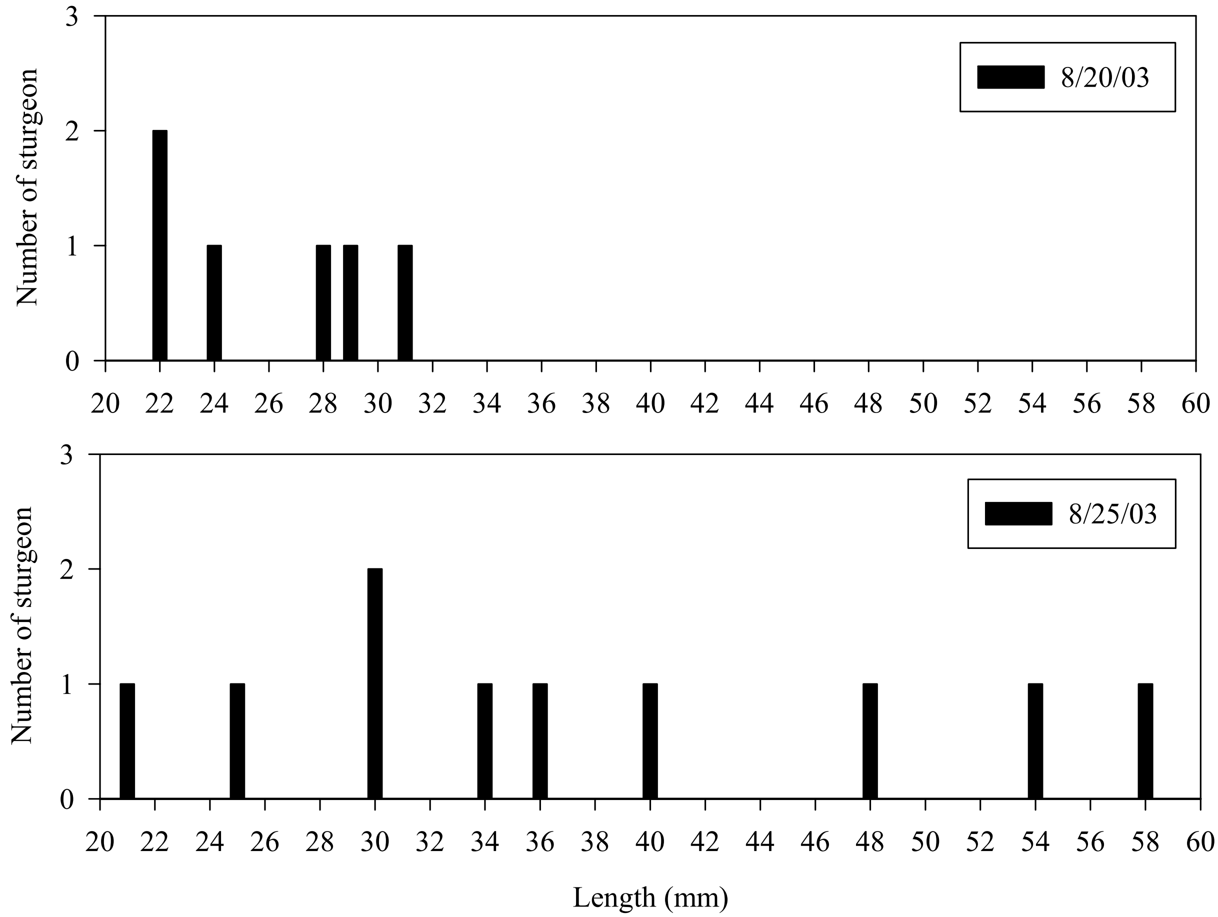

Figure 22. Length distributions of young-of-year sturgeon sampled during 2003 in the Missouri River above the confluence (ATC) of the Yellowstone River.

Young-of-year sturgeon sampled in the Missouri River BTC exhibited a broad length range on all dates, and despite relatively small sample sizes, there was a general progression in length (e.g., growth) through time (Figure 23). Small individuals (e.g., ≤ 70 mm) composed the samples on August 7 and August 12. Maximum lengths in the distribution increased to 140 mm when sampling was terminated on September 3. The length-at-capture data suggest individuals less than 16 mm are not effectively sampled by the benthic trawl. Length-at-date information will be used to more thoroughly examine natural growth rates of young-of-year sturgeon.

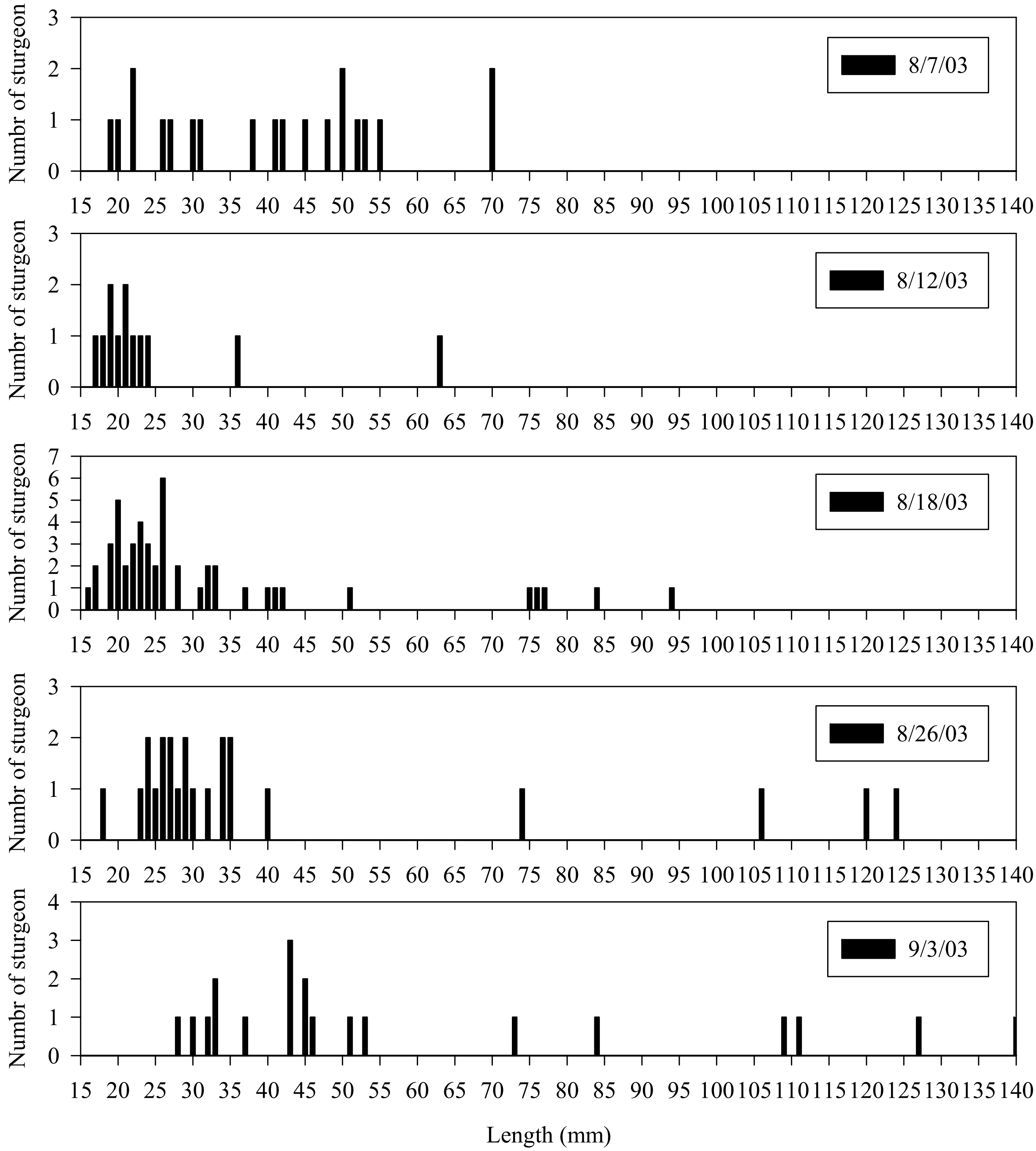

Figure 23. Length distributions of young-of-year sturgeon sampled during 2003 in the Missouri River below the confluence (BTC) of the Yellowstone River.

Related Activities

Incidental sampling of adult and hatchery-raised juvenile pallid sturgeon.- Crews working on various research components of the Fort Peck Data Collection Plan incidentally sampled adult and juvenile pallid sturgeon during 2003. Two adult pallid sturgeon were sampled during early September in the Missouri River downstream from the Yellowstone River confluence. During August and September, a total of 25 hatchery-raised juvenile pallid sturgeon were sampled. These individuals were sampled in the Missouri River downstream from the Yellowstone River confluence (N = 12), in the Yellowstone River (N = 1), and in the Missouri River near Nohly (N = 1) and near Culbertson (N = 11). All pertinent information on these collections (e.g., length, weight, location, etc.) was forwarded to Kevin Kapuscinski (pallid sturgeon biologist for Montana Fish, Wildlife and Parks).

Activities for 2004

The MTFWP and USACE entered into a 5-year contract (Fiscal Years 2004-2008) to continue research activities associated with the Fort Peck Data Collection Plan. The new contract includes several existing research activities, but additional research activities were added and refined to examine specific life history characteristics of pallid sturgeon. Additions and refinements of activities were justified on the basis of results generated during the initial three years of baseline data collection. Activities included in the 5-year research contract are: 1) examining the influence of modified discharge releases from the spillway on water temperature and turbidity, 2) examining seasonal use of the Missouri River below Fort Peck Dam and movements by pallid sturgeon via telemetry, 3) examining flow- and temperature-related movements of blue suckers, paddlefish, and shovelnose sturgeon via telemetry, 4) quantifying larval fish distribution and abundance, 5) quantifying the distribution and abundance of young-of-year sturgeon, 6) examining drift rate, drift behavior, and transport of larval sturgeon, 7) examining food habits of potential piscivores (when the spillway releases occur), 8) evaluating the effectiveness of a fish barrier to prevent fish escapement from Fort Peck reservoir (when the spillway releases occur), and 9) determining the location of and capturing adult pallid sturgeon for spawning and propagation. Research activities associated with the 5-year agreement will be conducted jointly by the MTFWP and USGS-Columbia Environmental Research Center.

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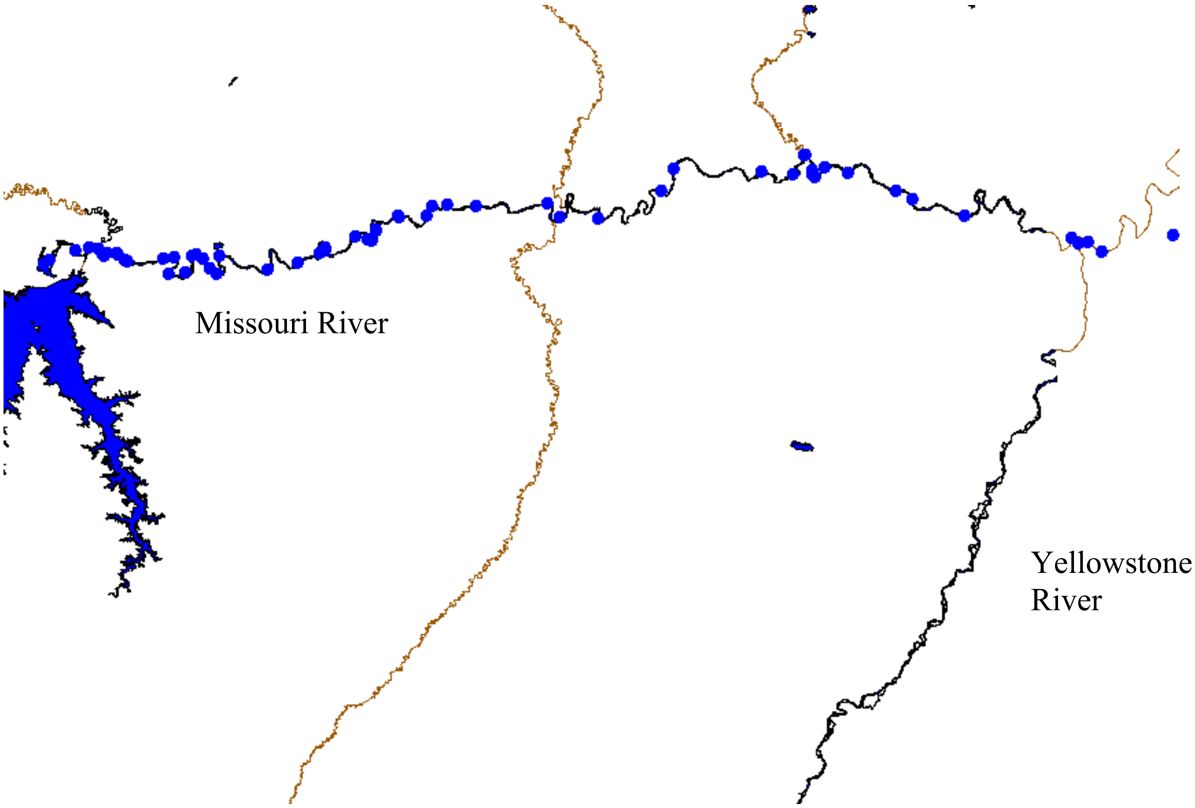
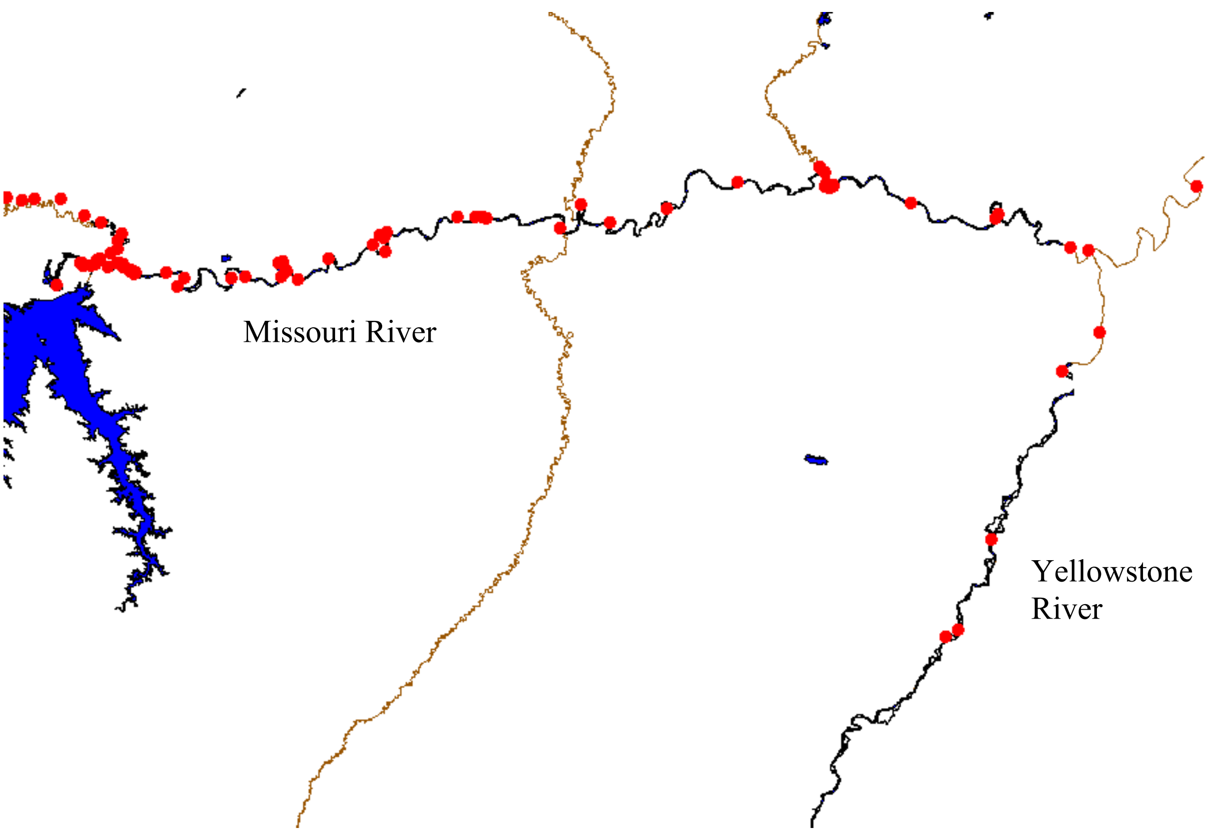
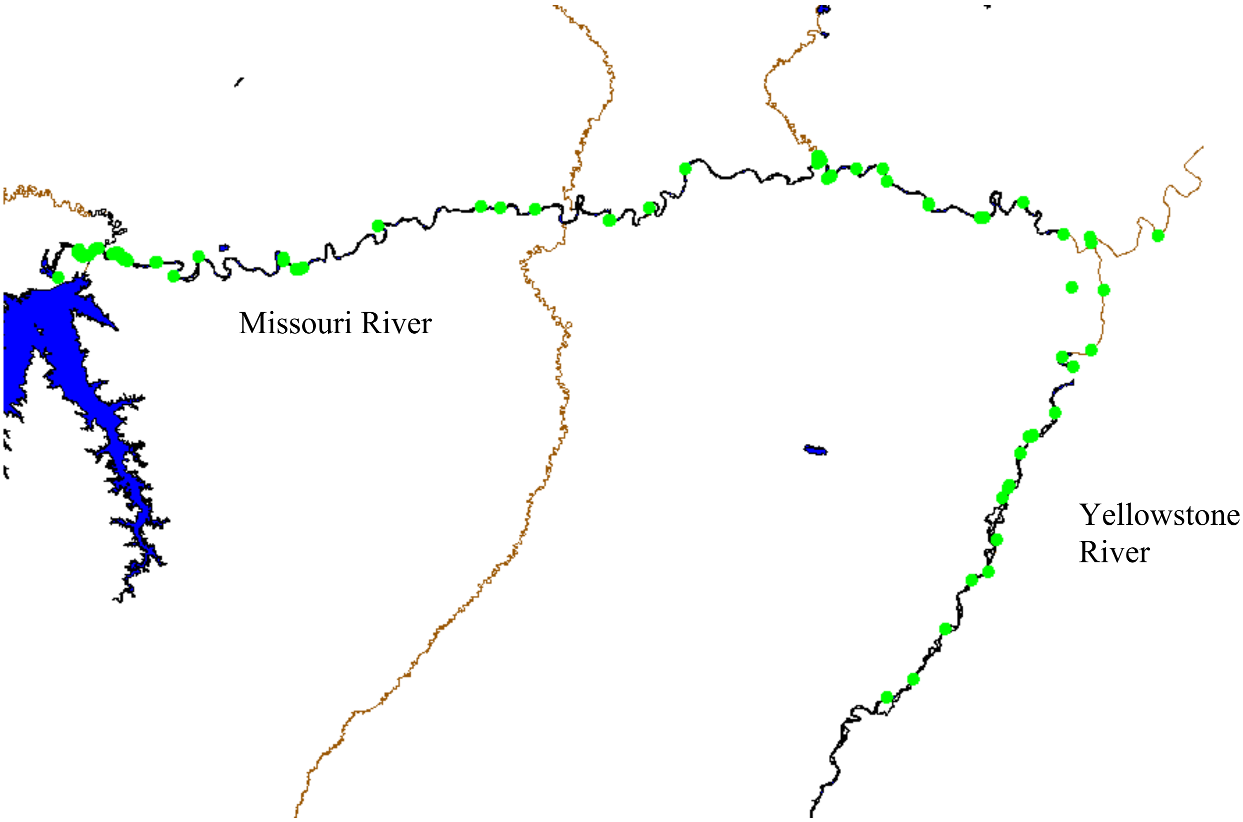


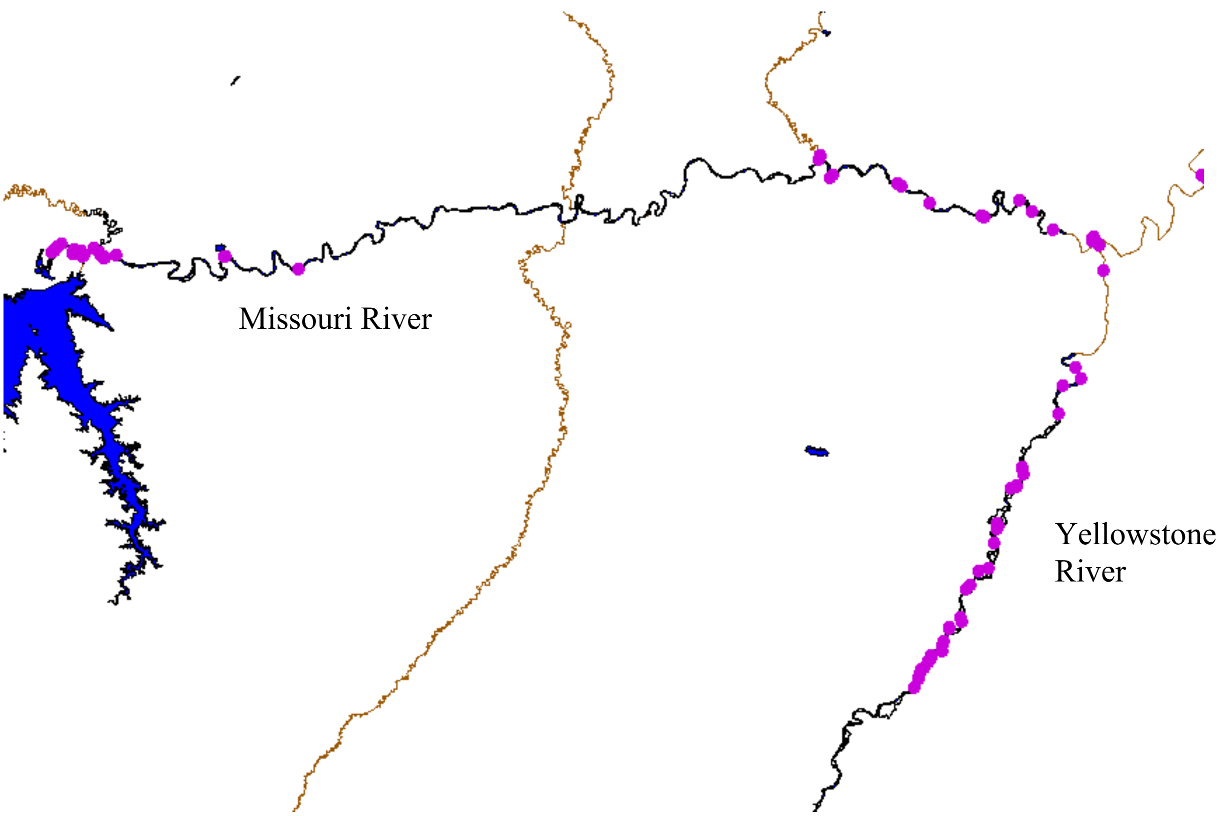
Appendix A.1. Blue sucker relocations in April 2003.



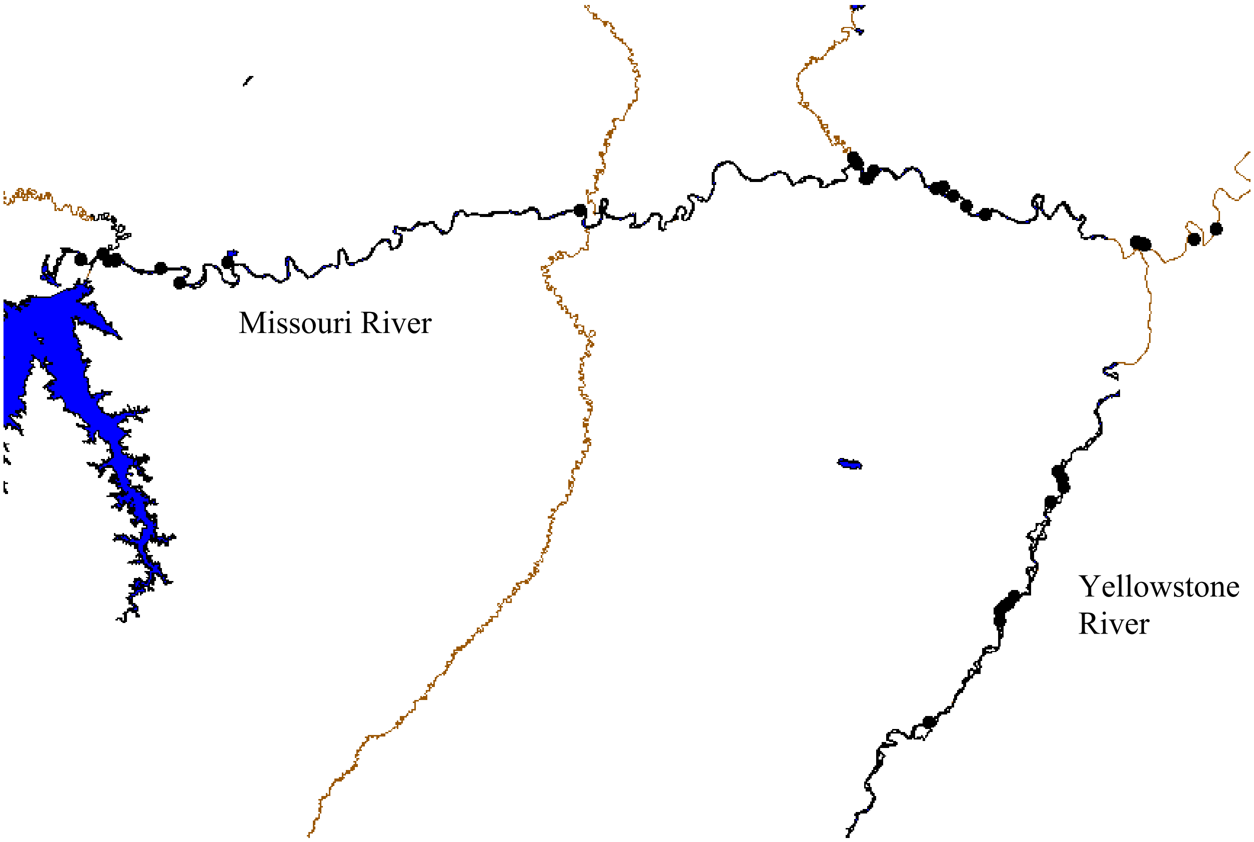
Appendix A.2. Blue sucker relocations in May 2003.



Appendix A.3. Blue sucker relocations in June 2003.

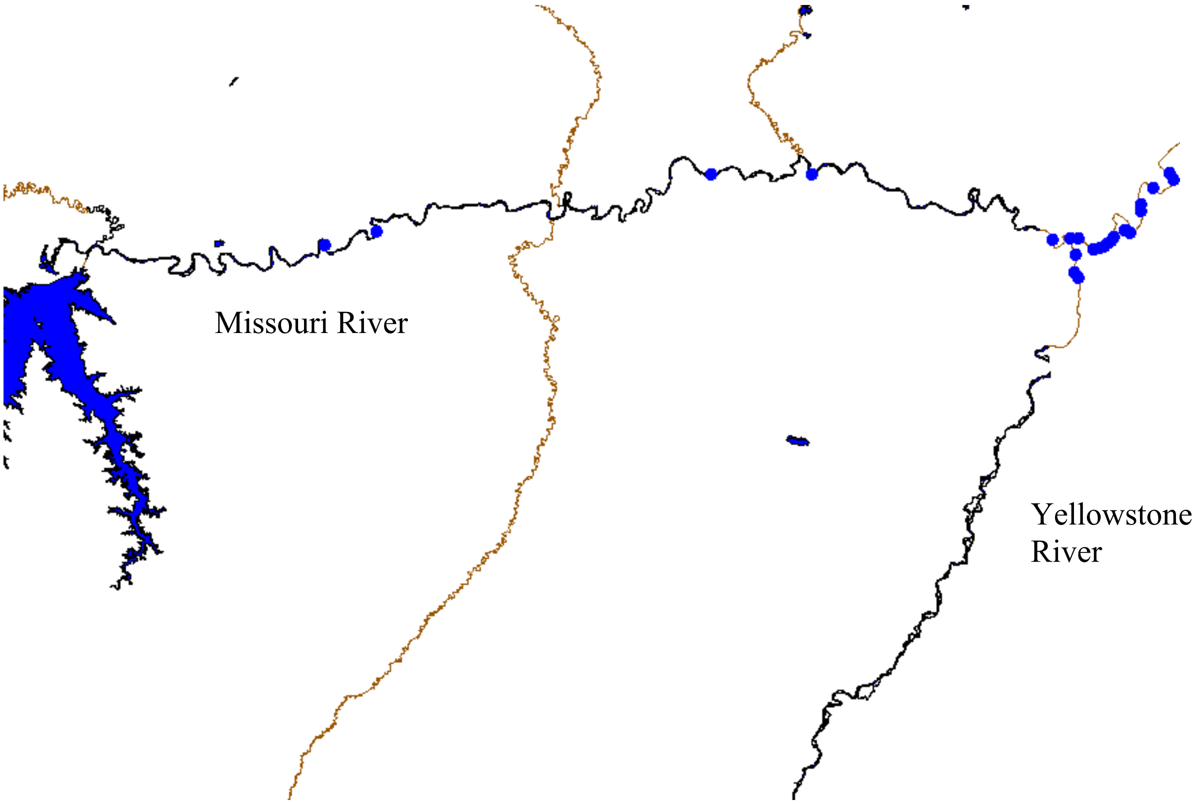


Appendix A.4. Blue sucker relocations in July 2003.

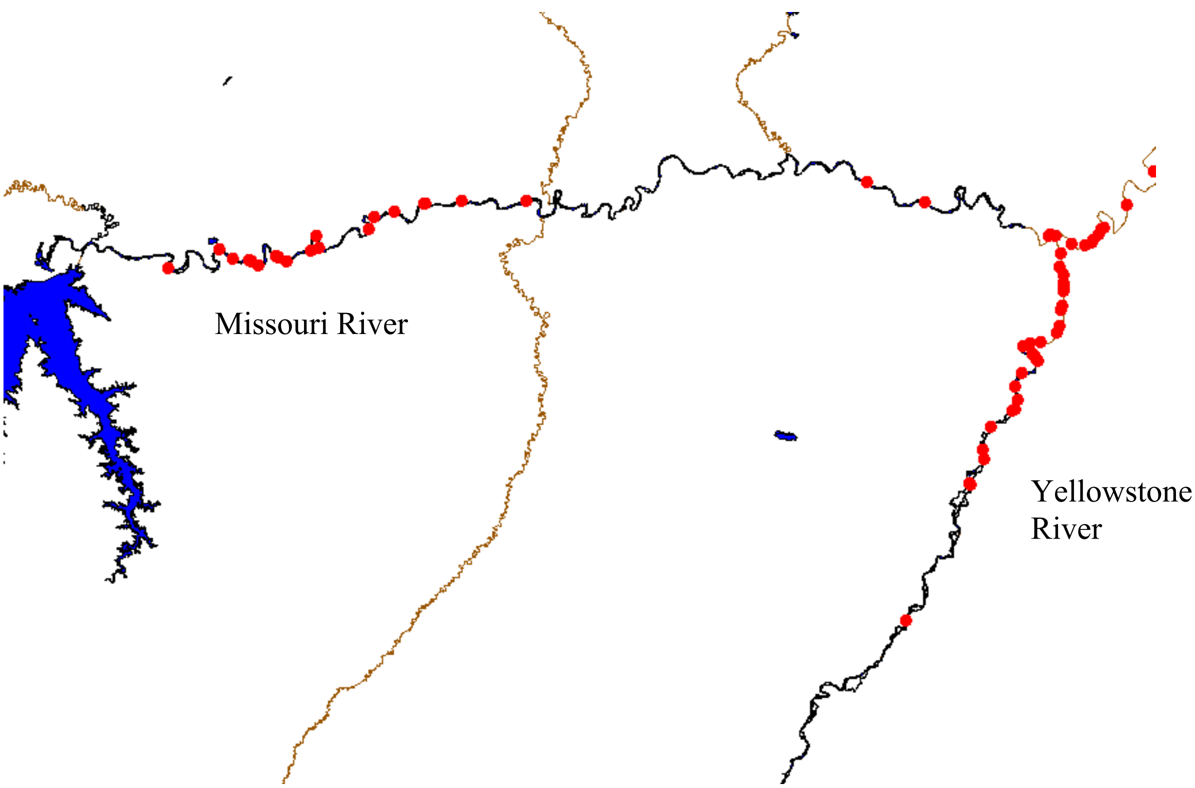


Appendix A.5. Blue sucker relocations in August 2003.

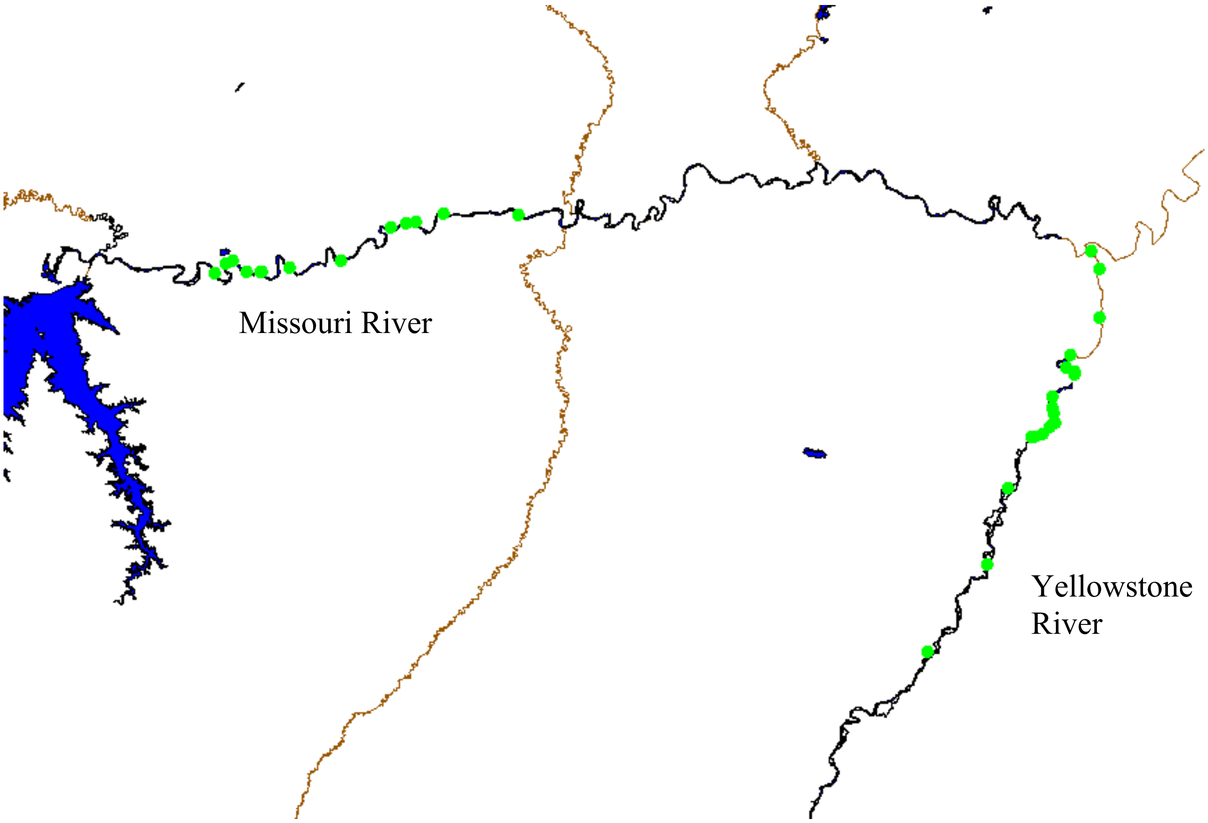
Appendix B. Map extent of paddlefish relocations during 2003.



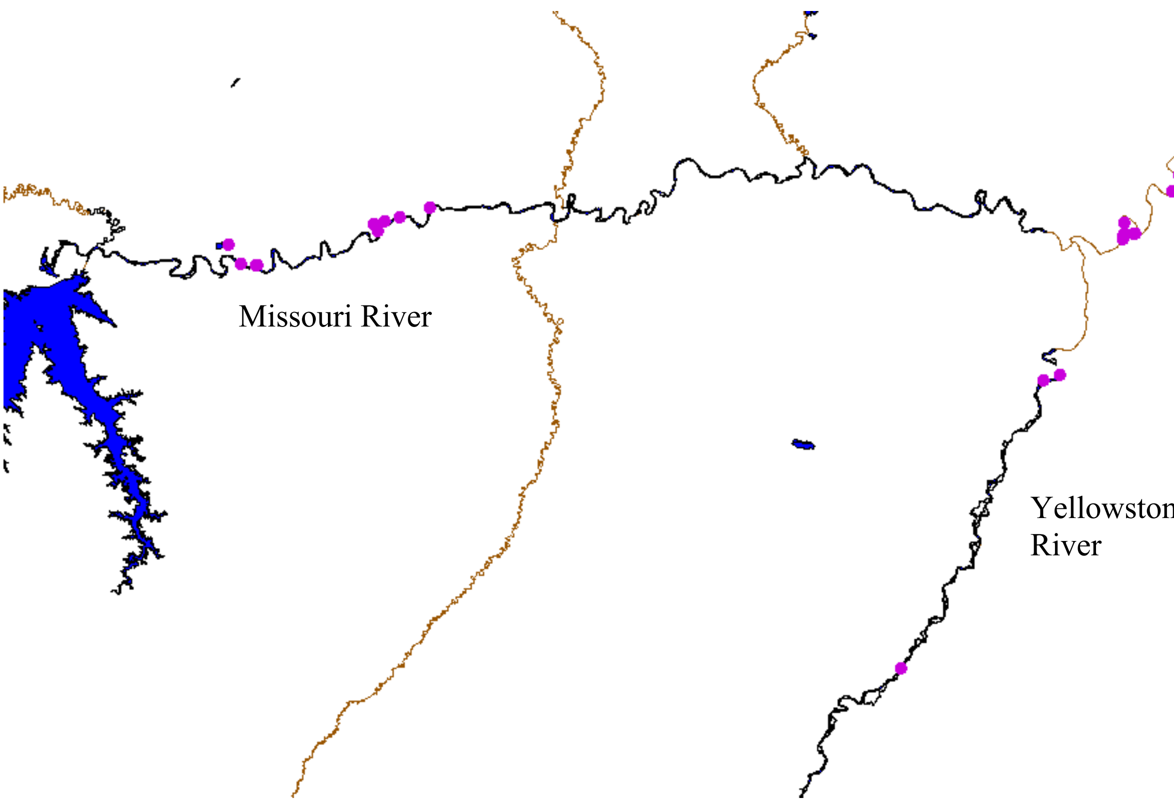
Appendix B.1. Paddlefish relocations in April 2003.



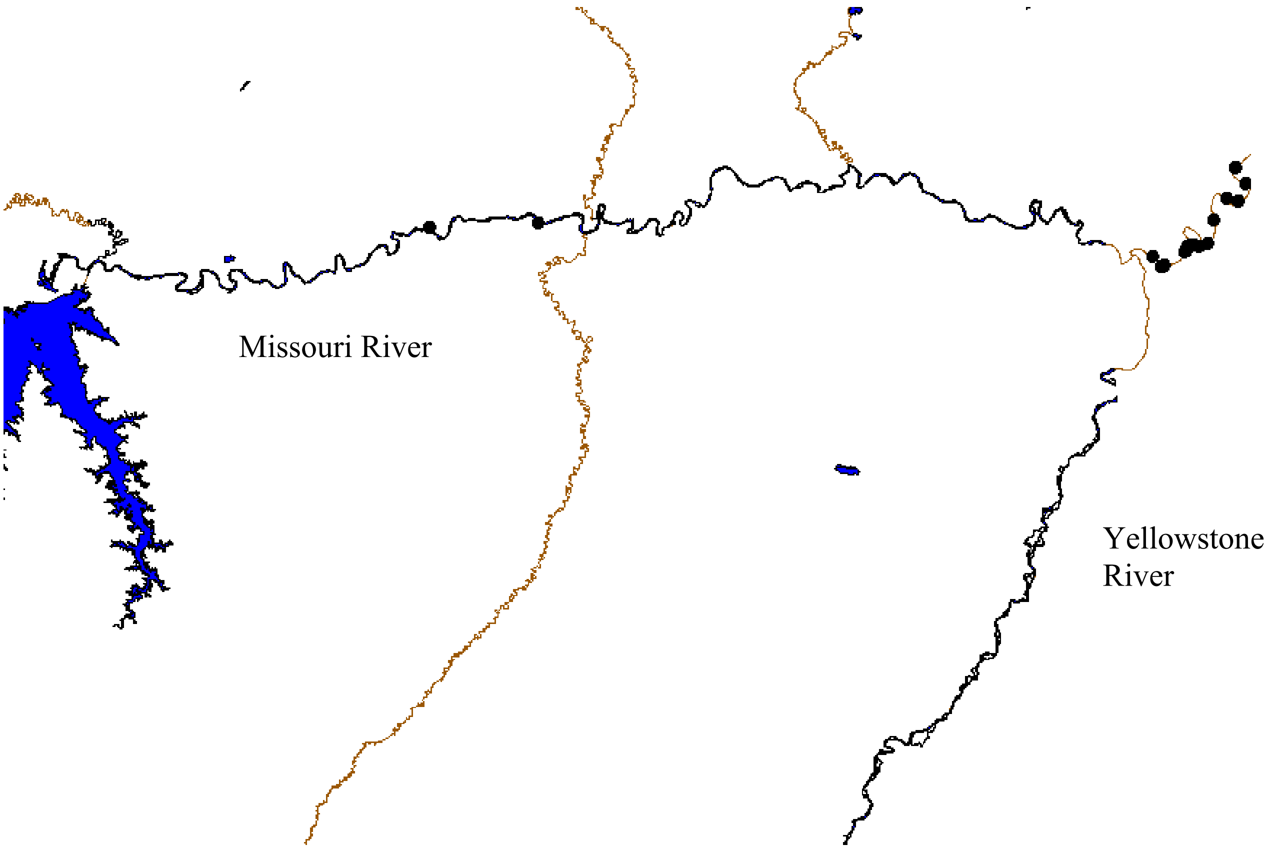
Appendix B.2. Paddlefish relocations in May 2003.



Appendix B.3. Padllefish relocations in June 2003.

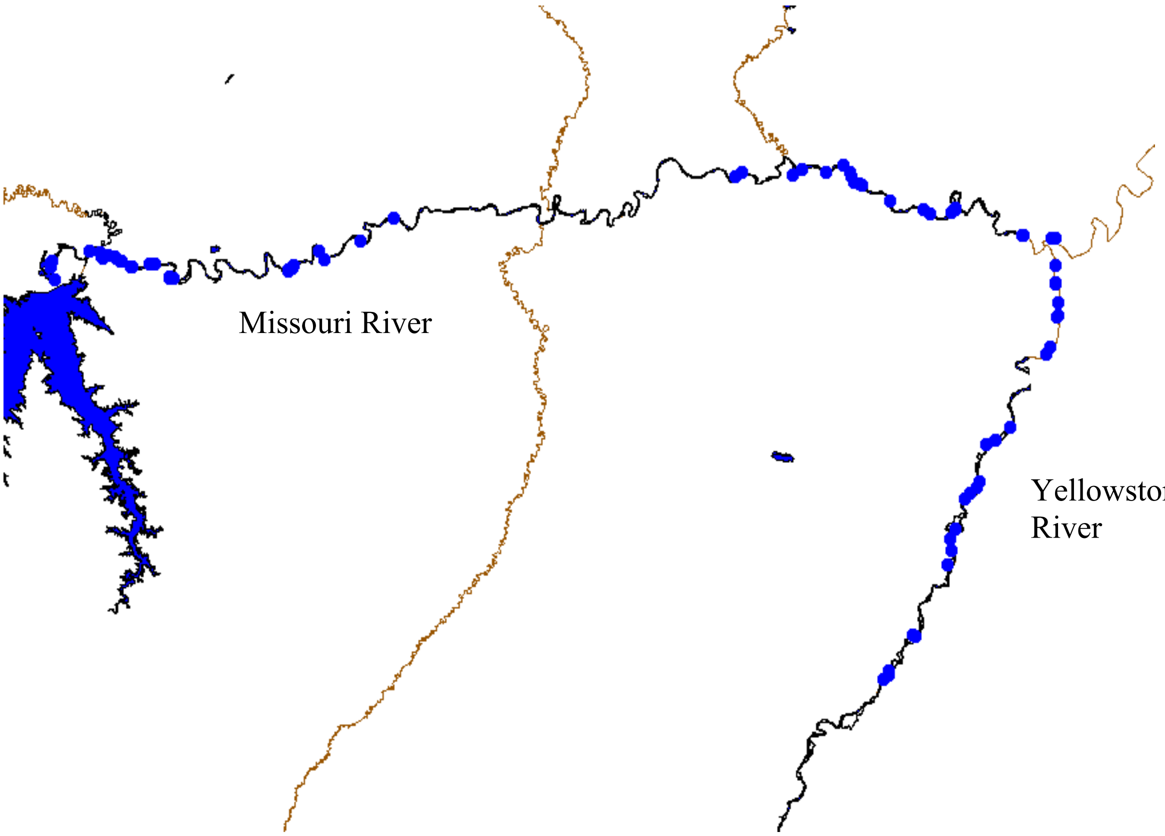


Appendix B.4. Paddlefish relocations in July 2003.

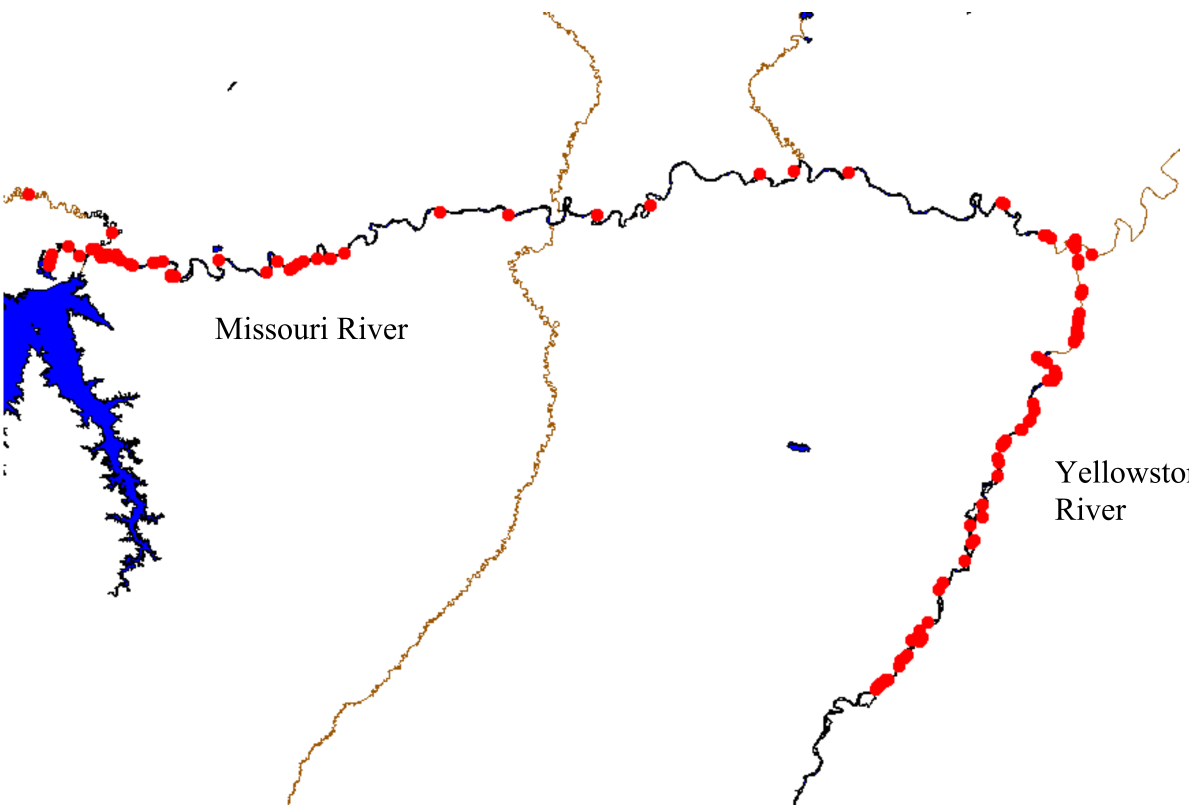


Appendix B.5. Paddlefish relocations during fall 2003.

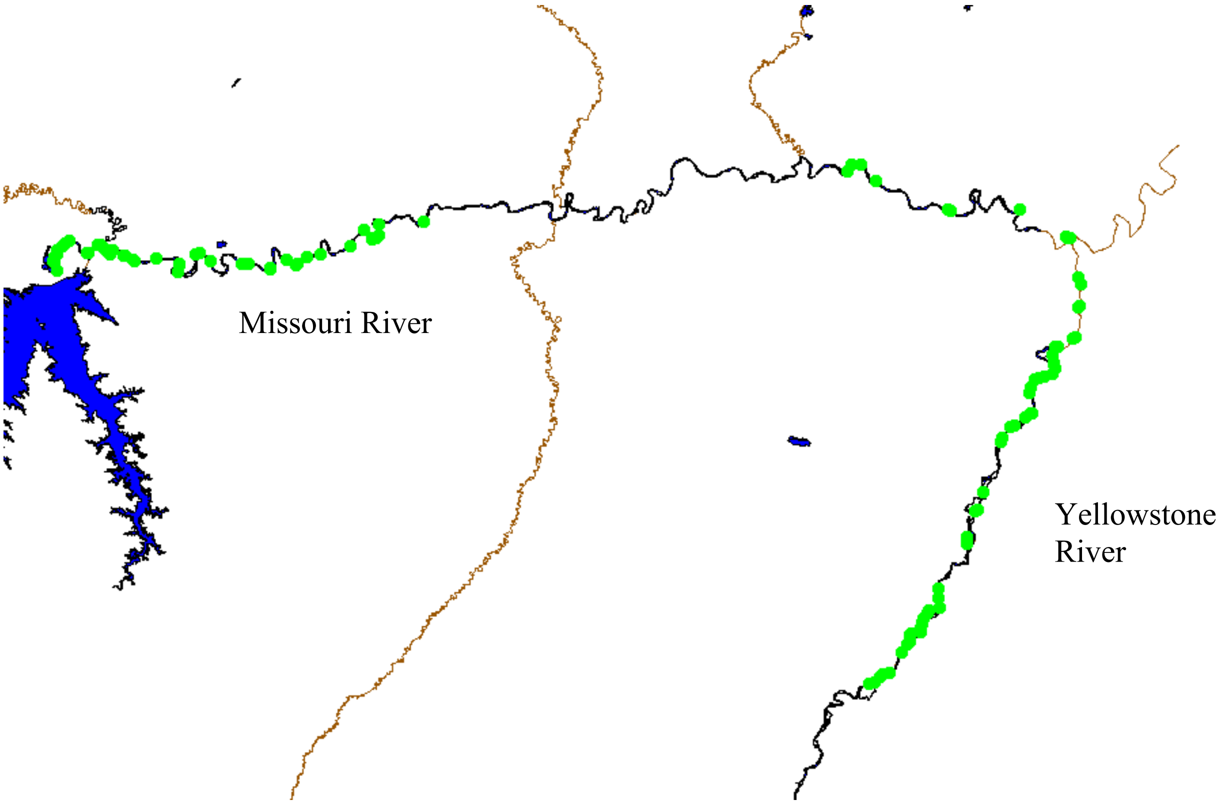
Appendix C. Map extent of shovelnose sturgeon relocations during 2003.



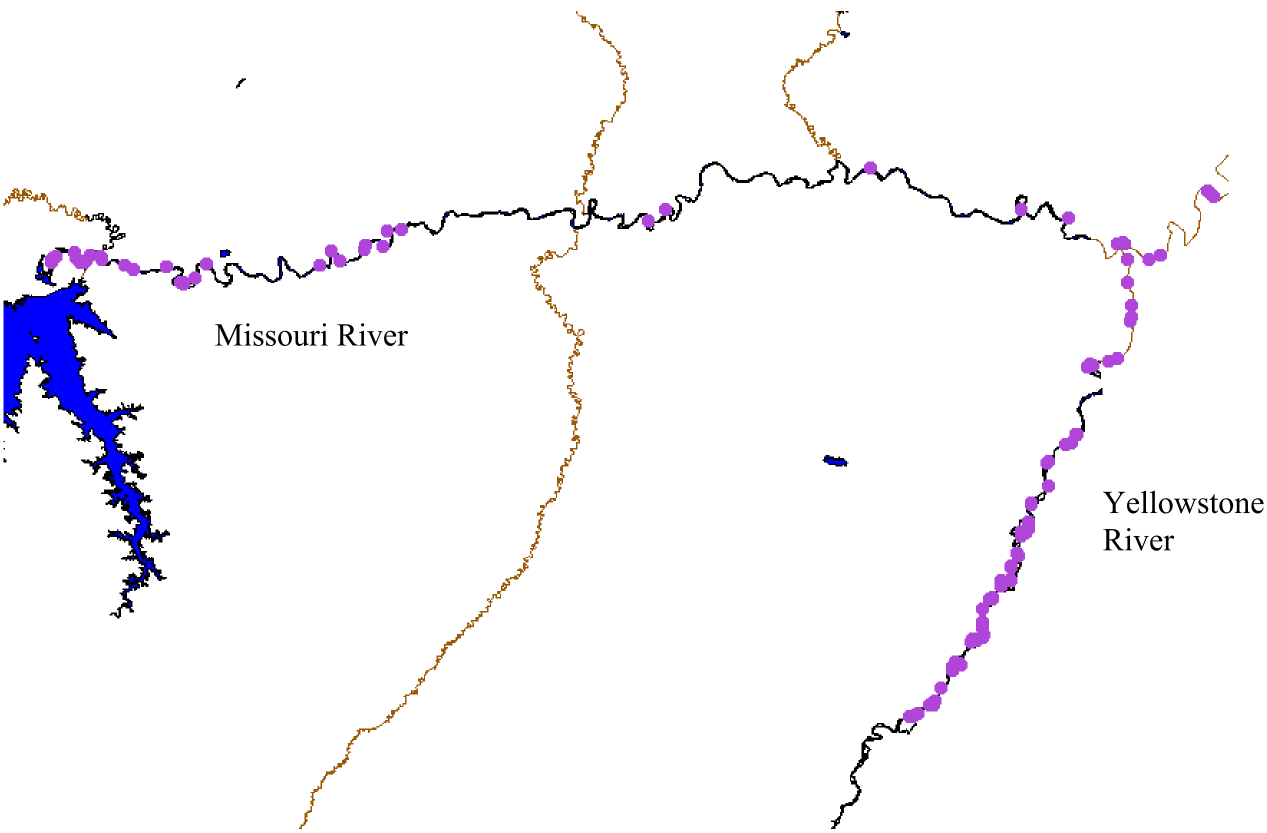
Appendix C.1. Shovelnose sturgeon relocations in April 2003.



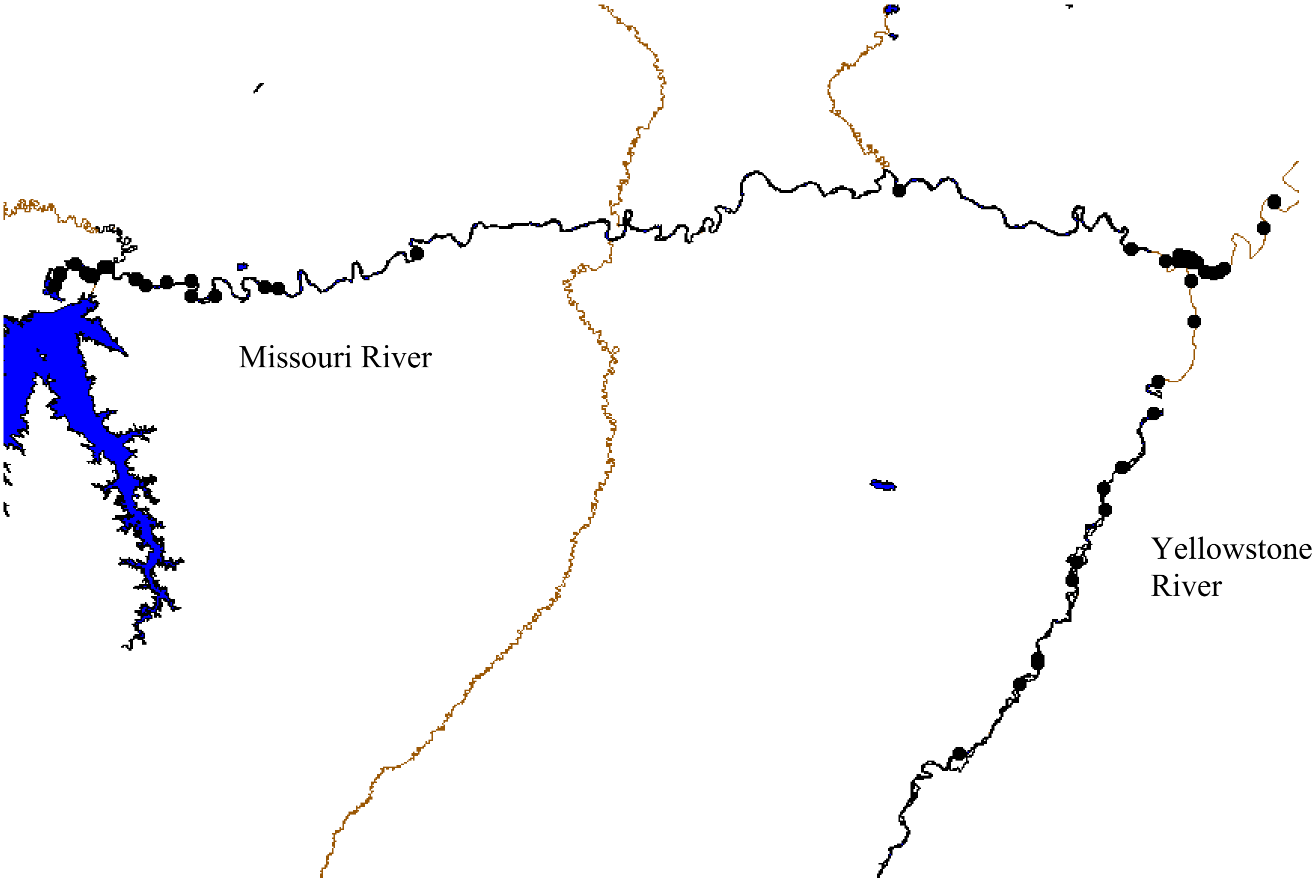
Appendix C.2. Shovelnose sturgeon relocations in May 2003.



Appendix C.3. Shovelnose sturgeon relocations in June 2003.



Appendix C.4. Shovelnose sturgeon relocations in July 2003.



Appendix C.5. Shovelnose sturgeon relocations in August 2003.

Movements and Habitat Preferences of Adult Post Spawn Pallid Sturgeon

2003 Progress Report
March 20, 2004

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This report submitted to:

Cooperators

Bureau of Reclamation

Garrison Dam National Fish Hatchery

Montana Fish, Wildlife and Parks
Fort Peck Field Office

North Dakota Game and Fish Department

Upper Pallid Sturgeon Workgroup

US Army Corps of Engineers

US Geological Survey
Fort Peck Field Office

Western Area Power Administration

Introduction

This report summarizes the research and field activities conducted in April through October of the 2003 field season. The main goals of this study are to monitor post spawn migrational movements to help identify pallid sturgeon spawning areas, determine pallid sturgeon response to “ Spring Test Flows ” out of Fort Peck Dam to see if mimicking natural flows will expand pallid use and habitat into the Missouri River above the confluence of the Yellowstone River, and to evaluate reproductive stages of known post spawn females. We also hope telemetered pallid sturgeon will serve as an important tool for future broodstock capture by utilizing and netting possible aggregations in relation to telemetered fish. Netting additional fish and marking them with Passive Integrated Transponder (PIT) tags will also serve to help strengthen current population estimates.

Study Area

The pallid sturgeon study area (see Figure 1 for study area), for the most part, is a semi-confined stretch of approximately 290 river miles encompassing the Missouri River from Fort Peck Dam to the headwaters of Lake Sakakawea, and from the Yellowstone River confluence (~ RM 1582.0) up the Yellowstone River to the Diversion Dam Intake, Montana.

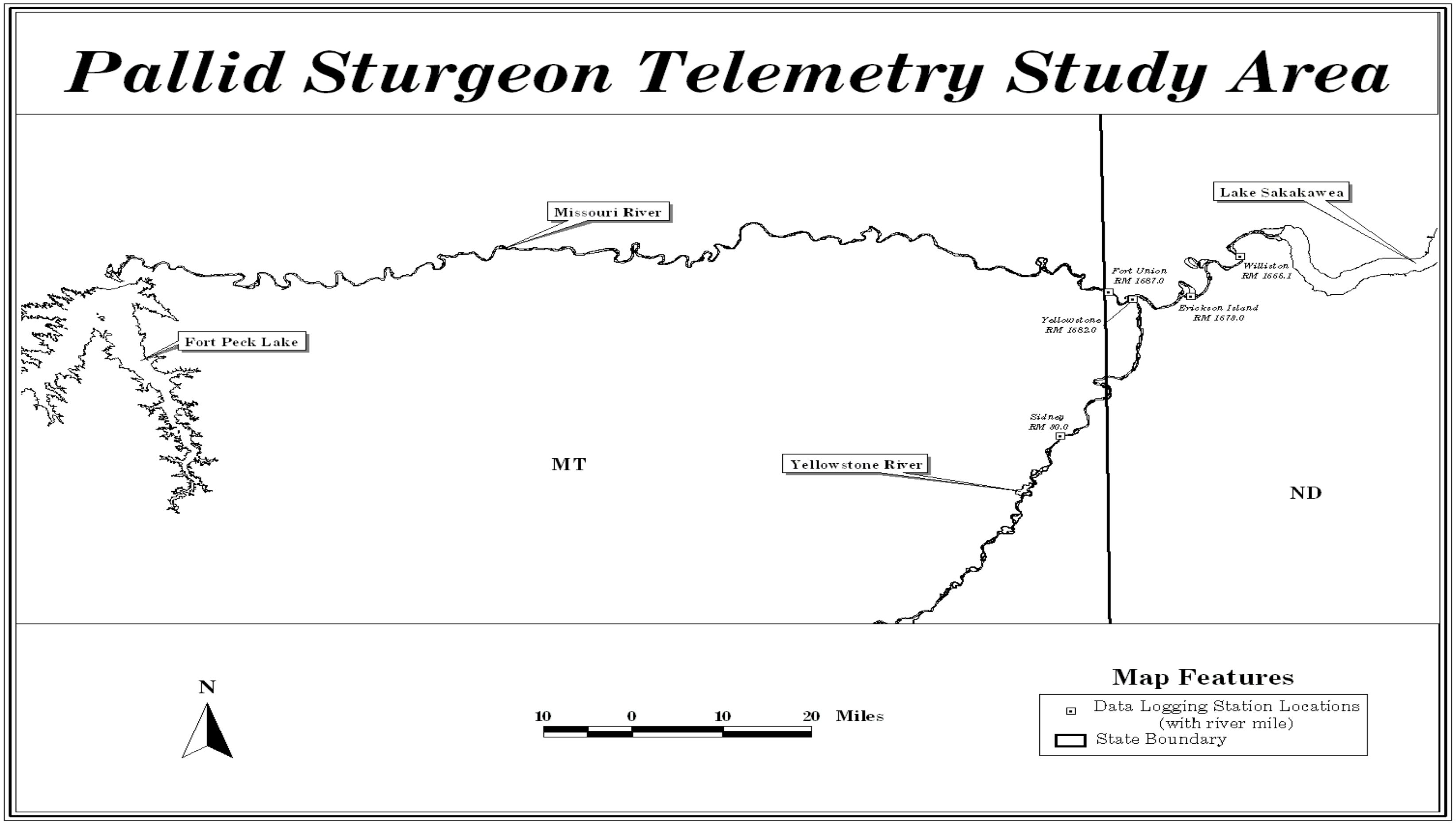

Figure 1. Map of pallid sturgeon study area.

Methods

Tracking methodology, as well as other methods, have been described in previous years progress reports and the USFWS's draft proposal plan; therefore, one can refer to the previous literature.

Since the inception of the pallid sturgeon telemetry study in 2000, we have tagged three pallid sturgeon females with internal CART tags. Unfortunately, all three females have shed their tags before we were able to collect any data needed to help ascertain information regarding spawning sites and the times from one spawn to another.

Therefore, we decided to tag the 2003 post spawn sturgeon externally on an experimental basis to test for an increase in tag retention. Biologists working with the white sturgeon project have had excellent success with retention, as well as tissue healing and reduced stress at the time of tagging. After consultation with them, they felt using the same procedure on the pallid sturgeon would be beneficial to the project.

On September 8, 2003, twelve post-spawn pallid sturgeon were externally tagged at Garrison Dam National Fish Hatchery with the assistance of Jack Siple, a fishery biologist employed with the Kootenai Tribe from Bonners Ferry, Idaho. Mr. Siple is involved with the white sturgeon project and has been externally tagging sturgeon with telemetry tags for nearly a decade for various studies.

The twelve fish were all tagged with the same CART-32 tag utilized in the internal tagging, although it was modified slightly to work externally. An 18-inch length of 150 pound-test, braided steel leader was epoxied to the tag and then secured additionally with electrical, rubber shrink tubing over the leader.

Tags were affixed by inserting a six-inch, 12-gauge needle through the dorsal ray and tissue, which was used as a catheter to thread the steel leader through the rays at the front and back of the tag. After the leader was catheterized through the tissue, it was fit through a one-inch diameter plastic tube acting as ballast, parallel to the CART tag on the opposite side of the dorsal fin. Both ends of the leader were then threaded through a series of four leader crimps and secured by crushing the four evenly spaced crimps. The extraneous leader wire beyond the front and back crimps was then removed with a wire cutter. Before the fish were released, the two catheter holes in the dorsal ray were treated with liquid furazone to combat infection.

The fish were monitored for two days at the hatchery after implantation and were returned to their capture site at the Sundheim Park boatramp near Fairview, Montana, on September 10, 2003.

Results

A total of 22 pallid sturgeon remain in the study and were tracked throughout the 2003 field season; six tagged in 2000, four tagged in 2001, and twelve tagged in 2003. (See tables 1,2 and 3) An additional pallid sturgeon was tagged by Montana Fish, Wildlife and Parks in the upper Missouri River to augment the U.S. Fish and Wildlife Service's ongoing telemetry study, but no data is available at this time.

Although twenty-two fish are currently in the study, the ten fish tagged in 2000 and 2001 represented the majority of the data, considering the 2003 pallid sturgeon introduced to the study were not released back into the river until September 10, 2003.

Cumulatively, the fixed datalogging stations and boat relocations helped to log over 373 locations of pallid sturgeon during the field season, as well as several hundred other locations on paddle fish and other native river species studied by other agencies.

Unfortunately, the part of the study trying to identify female pallid sturgeon spawning areas and times between spawns suffered another crucial setback as Annie (fish # 25), the only female remaining in the study, shed her tag shortly into the field season in mid-April. The loss of this fish was devastating to the study as we had data from 2001 and 2002 showing no egg development and had hoped to start seeing some stage of development going into her third year after her last spawn.

Another setback with the loss is the issue of following this fish to spawning grounds in the hopes of solidifying or identifying true spawning areas for these endangered fish. Although many assumptions have been made in regards to pallid sturgeon spawning in the lower reaches of the Yellowstone River, Annie's movements were confined to the upper and lower Missouri River exclusively with no relocations in the Yellowstone River at all. All of her movements, since 2000 in the Missouri reaches, may have been indicative of the possibility that she might have selected the Missouri River to spawn in.

Long-term internal tag retention on female pallid sturgeon has thus far been poor, at best, and hopefully the external method of tagging will provide better long-term retention to answer important questions concerning the female physiological aspect.

Addendum: Unfortunately, the use of external tags, placed in the dorsal fin of pallid sturgeon, has shown to be ineffective for long-term use. In three different instances during the broodstock capture in April 2003, CART telemetry tags were torn from the dorsal fins with the trammel netting. Another fish's tag was only attached by one end of the wire. It seems the dorsal tissue in pallid sturgeon isn't as rigid as it is in the white sturgeon and, therefore, external tagging pallids on the dorsal will cease. Other options need to be explored.

In regards to channel selection, 93.4% of pallid sturgeon boat relocations were found in the main channel, 5.0% were found in main channel outside bends, and 1.6% of the locations were in side channel outside bends.

Data concerning locations associated with islands and emergent sandbars *(N = 61)* was also recorded with 37.7% of the fish found in no relation with islands of sandbars, 36.5% found in main channel upstream of islands, 11.3% found in main channel upstream of sandbars, 8.1% found in main channel downstream of islands, 4.9% found in main channel downstream sandbars, and 1.6% of the locations were found in side channels upstream of islands.

Pallid sturgeon movements past fixed datalogging stations *(N = 162)* were also broke down into diel periods. This field season, movements during the night periods were highest at 48.8%, day movements at 36.4%, dawn movements at 9.8% and dusk at 5.0%.

Eight of ten pallid sturgeon were relocated up the Yellowstone River during the field season with exceptions of fish #26 and #144. Fish #26 was located four times in April and May in the lower Missouri River (RM 1566 on May 23) and was not found throughout the rest of the field season. This fish was spawned and tagged in 2000 and possibly his tag expired, or he possibly moved down into the reservoir. Fish #144 spent the majority of the tracking season below the confluence in the lower Missouri without ever being located in the Yellowstone or upper Missouri Rivers above the Confluence. In the 2002 field season, this fish made a major migration up the Missouri River to the Wolf Point, Montana, ground station (RM 1717) and returned. He also made two brief appearances up the Yellowstone, but never reached any higher than RM 3.2. This fish was spawned in 2001.

The only fish to make a major migration up the Missouri River this field season was #14. This 2001 spawned male moved all the way up the Missouri River to Nickels Rapids (RM 1756) starting on May 4 from the confluence and returned to the confluence on June 4. He then moved up the Yellowstone until the first week in July and spent the rest of the season in the lower Missouri.

Other fish movements were fairly consistent with past years, spending April, May, and the majority of June in the Yellowstone and then returning to the lower Missouri throughout the rest of the year.

The twelve pallid sturgeon spawned in 2003 that were tagged and released on the afternoon of September 10, all traveled downstream past the Yellowstone datalogging station between September 12-14. Interestingly, all movements past the station within the three-day period happened all between 23:04 hours and 5:22 hours, except for one, which passed at 7:37 hours.

Acknowledgements

I'd like to thank Terri Thorn of the Fish and Wildlife Service for the assistance with the mapping and conversion of data. Also, I'd to thank Dave Fuller and crew, as well as Shannon Miller for the data swapping between projects; the extra data helps to fill in the gaps missed when our crew can't be on the water.

Table 1. Fish spawned in 2000.

Name	Code	Sex	Pit tag #	Weight in Pounds	Weight in Milograms	Fork Length in Inches	Fork Length in Millimeters
Art	18	M	1F4849755B	33	14982	51	1295
Andre	26	M	7F7B081579	32	14528	56	1444
Alex	34	M	115525534A	36	16344	55	1404
Arnie	44	M	2202236E31	61	27694	60	1542
Archie	46	M	1F4A33194B	45	20340	57	1468
Andrew	50	M	115713555A	28	12712	53	1352

Table 2. Fish spawned in 2001.

Name	Code	Sex	Pit tag #	Weight in Pounds	Weight in Milligrams	Fork Length in Inches	Fork Length in Millimeters
Butch	2	M	1F4A27214F	50	22857	61	1541
Bart	14	M	115631222A	29	13257	52	1340
Bob	116	M	7F7D3C5708	30	13714	55	1405
Ben	144	M	1F4A111C6A	43	19657	55	1394

Table 3. Fish spawned in 2003.

Name	Code	Sex	Pit tag #	Weight in Pounds	Weight in Milligrams	Fork Length in Inches	Fork Length in Millimeters
Dirk	6	M	7F7D372A6B	32	14528	54.4	1381
Dick	17	M	220E4E4E5D	35	15875	57.2	1452
Donald	23	M	132313521A	40	18143	57.4	1456
David	24	M	41475D3C5D	43	19504	56.1	1424
Dan	27	M	1F521B1E56	45	20411	55.5	1409
Darvin	28	M	132157621A	40	18143	55.1	1398
Drew	29	M	7F7D291A07	37	16782	56.1	1424
Denzell	30	M	1F4A363031	45	20411	57.1	1449
Dinkins	31	M	220E5F6E26	48	21772	60.2	1529
Davis	33	M	115675486A	27	12246	51.4	1304
Dorothy	35	F	7F7B026102	44	19958	58.5	1486
Darrell	128	M	1F4A13592B	36	16329	58.3	1479
Dontno	96	U	43105C602B	25	11339	50.1	1272

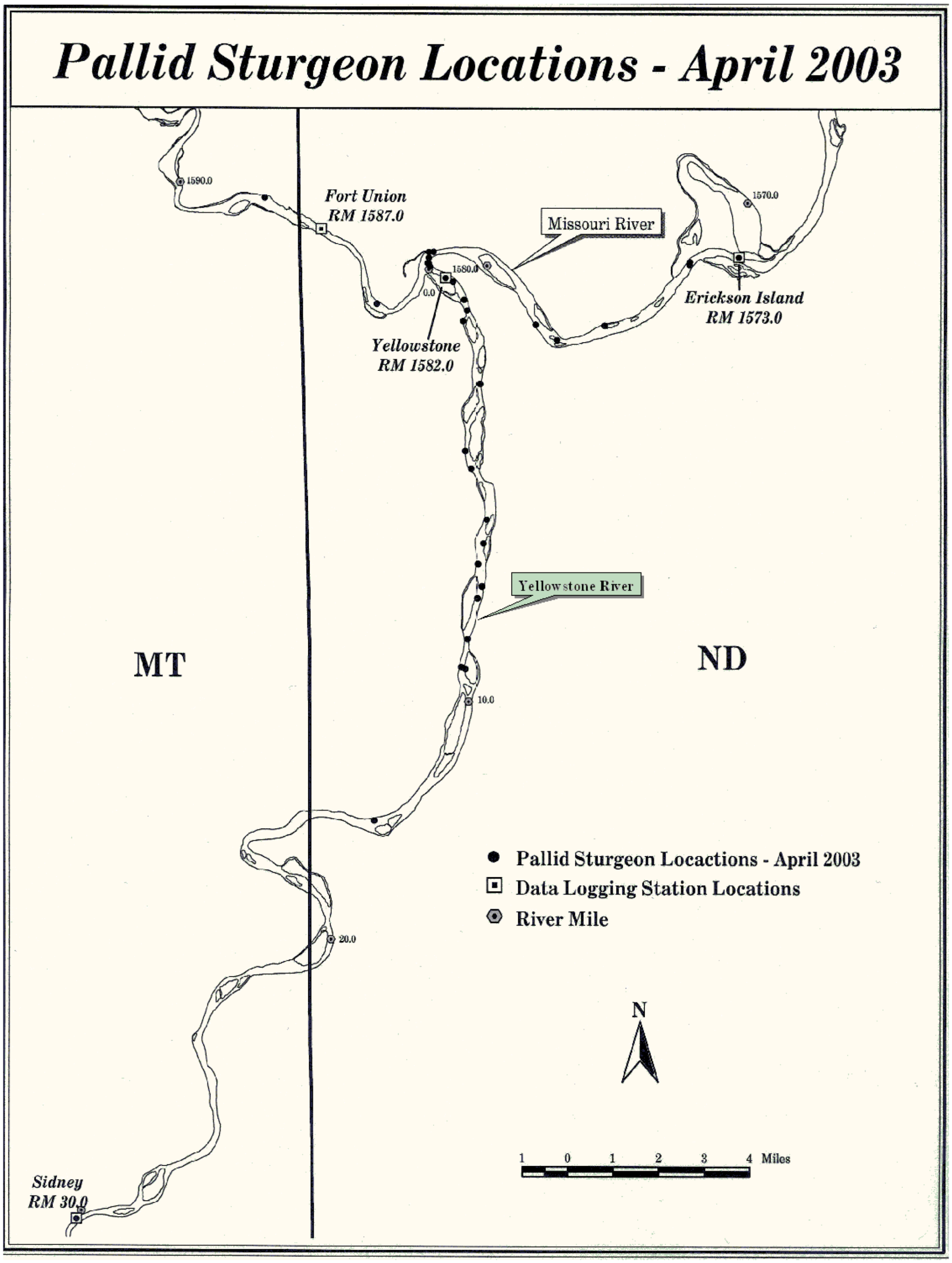

Figure 2. Locations of all pallids in April.

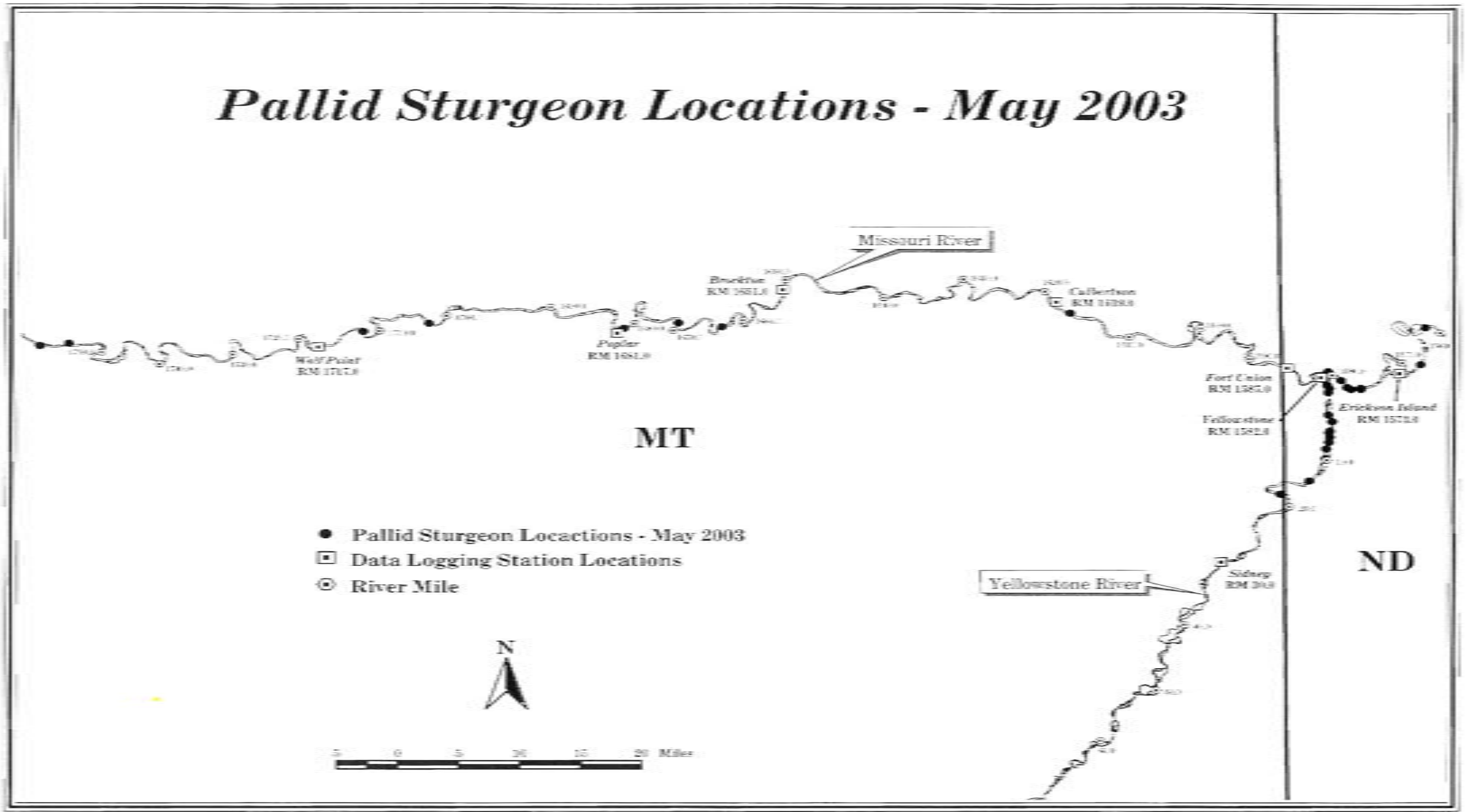

Figure 3. Locations of all pallids in May.

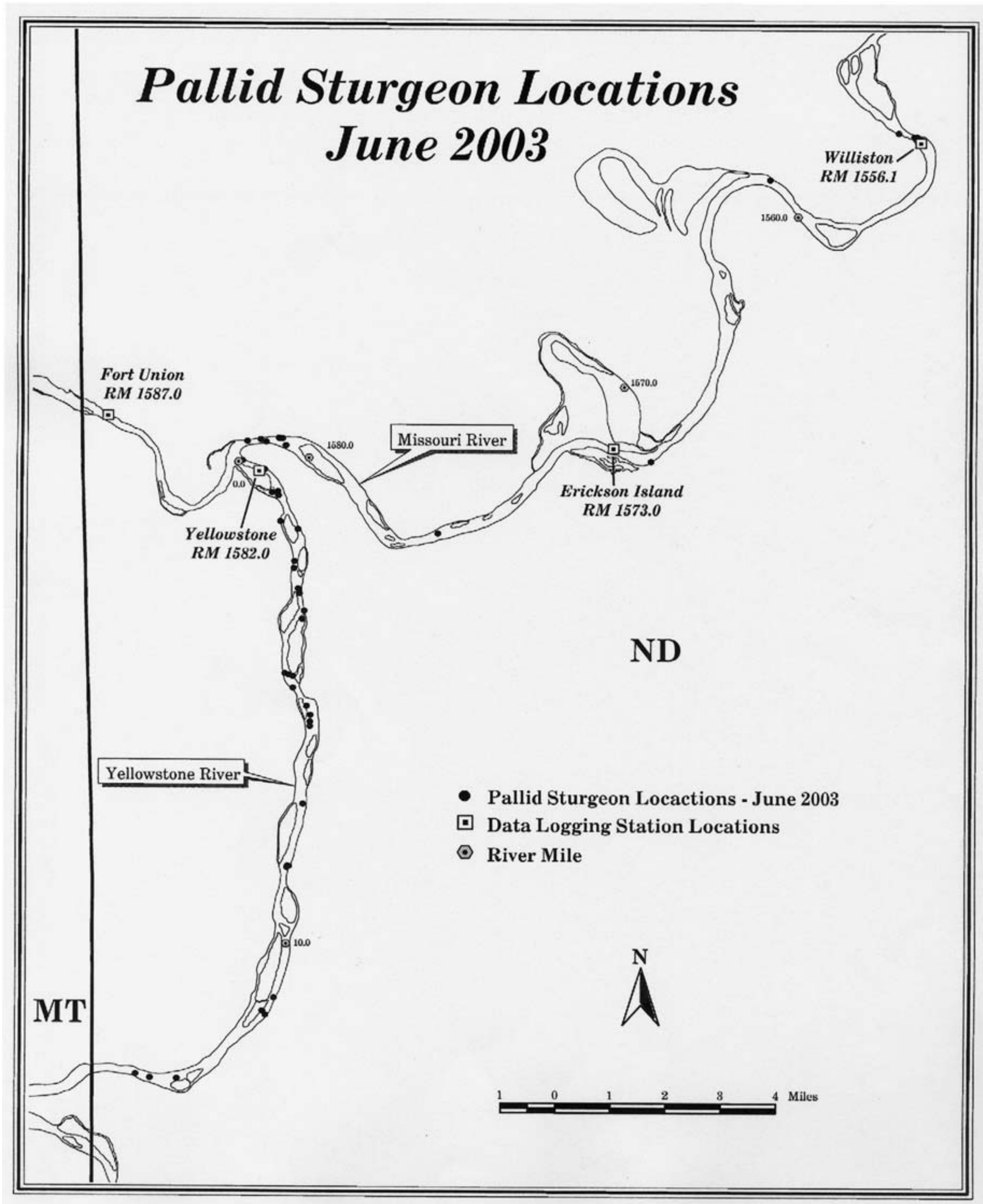

Figure 4. Locations of all pallids in June.

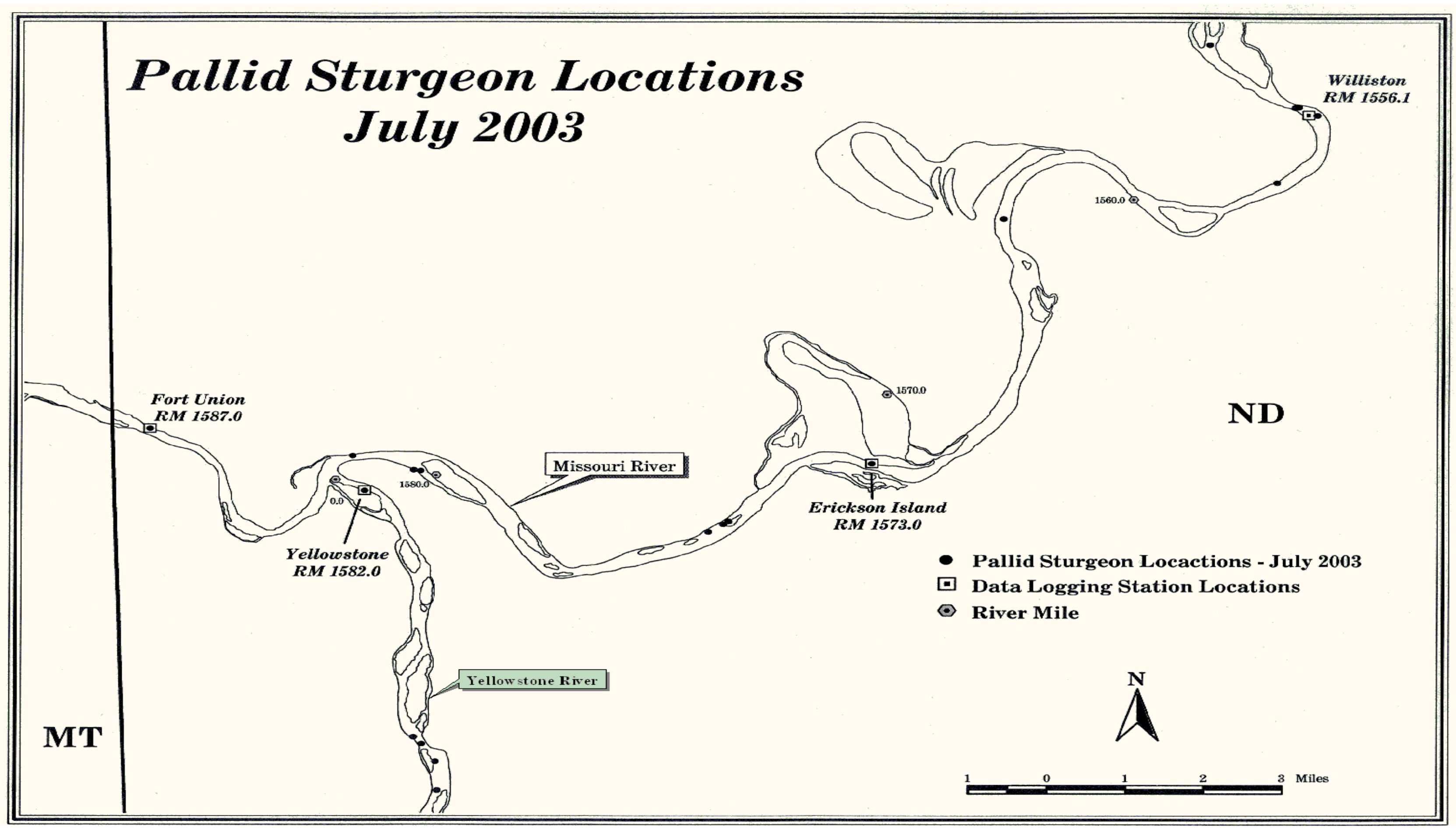

Figure 5. Locations of all pallids in July.

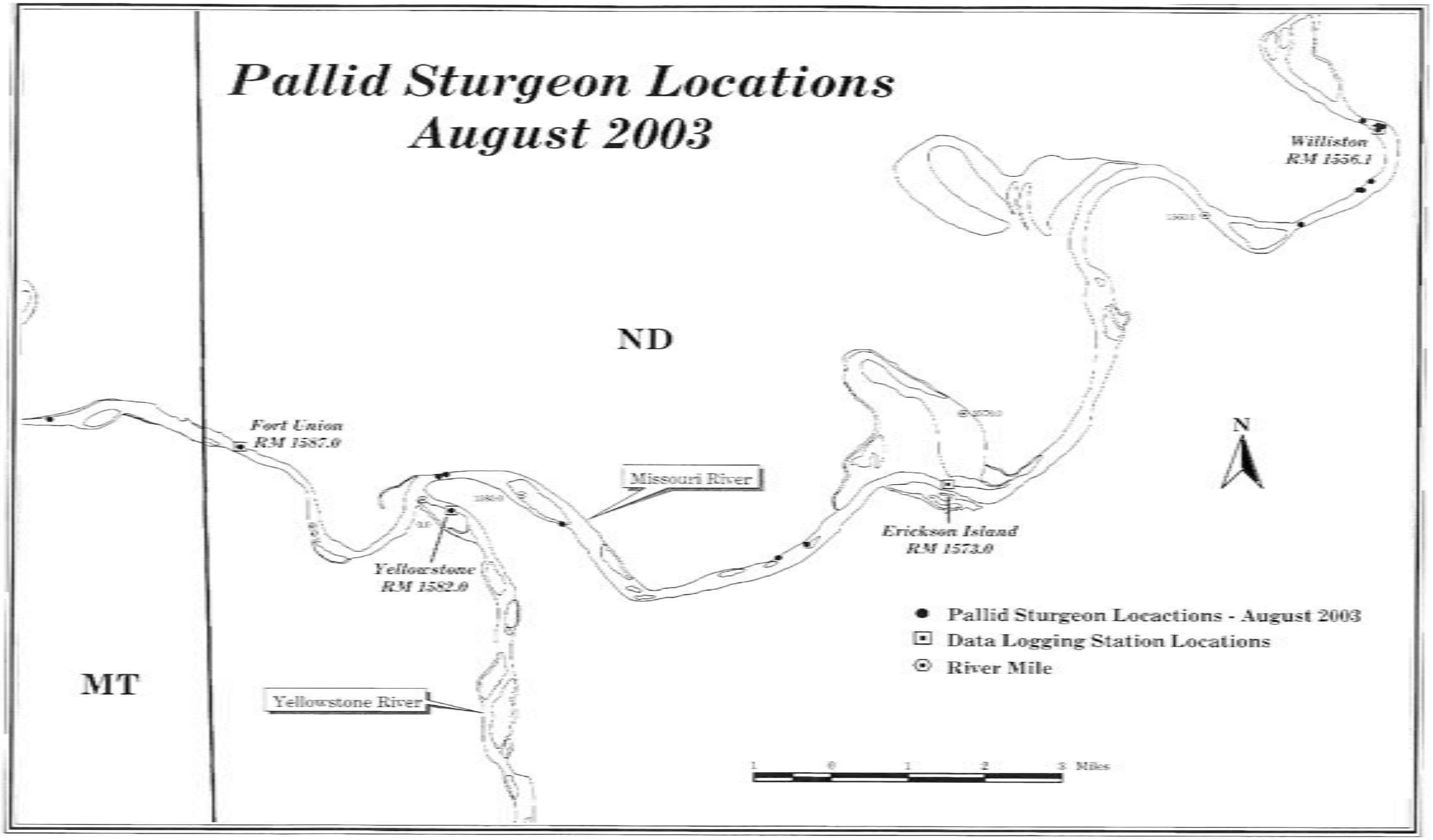

Figure 6. Locations of all pallids in August.

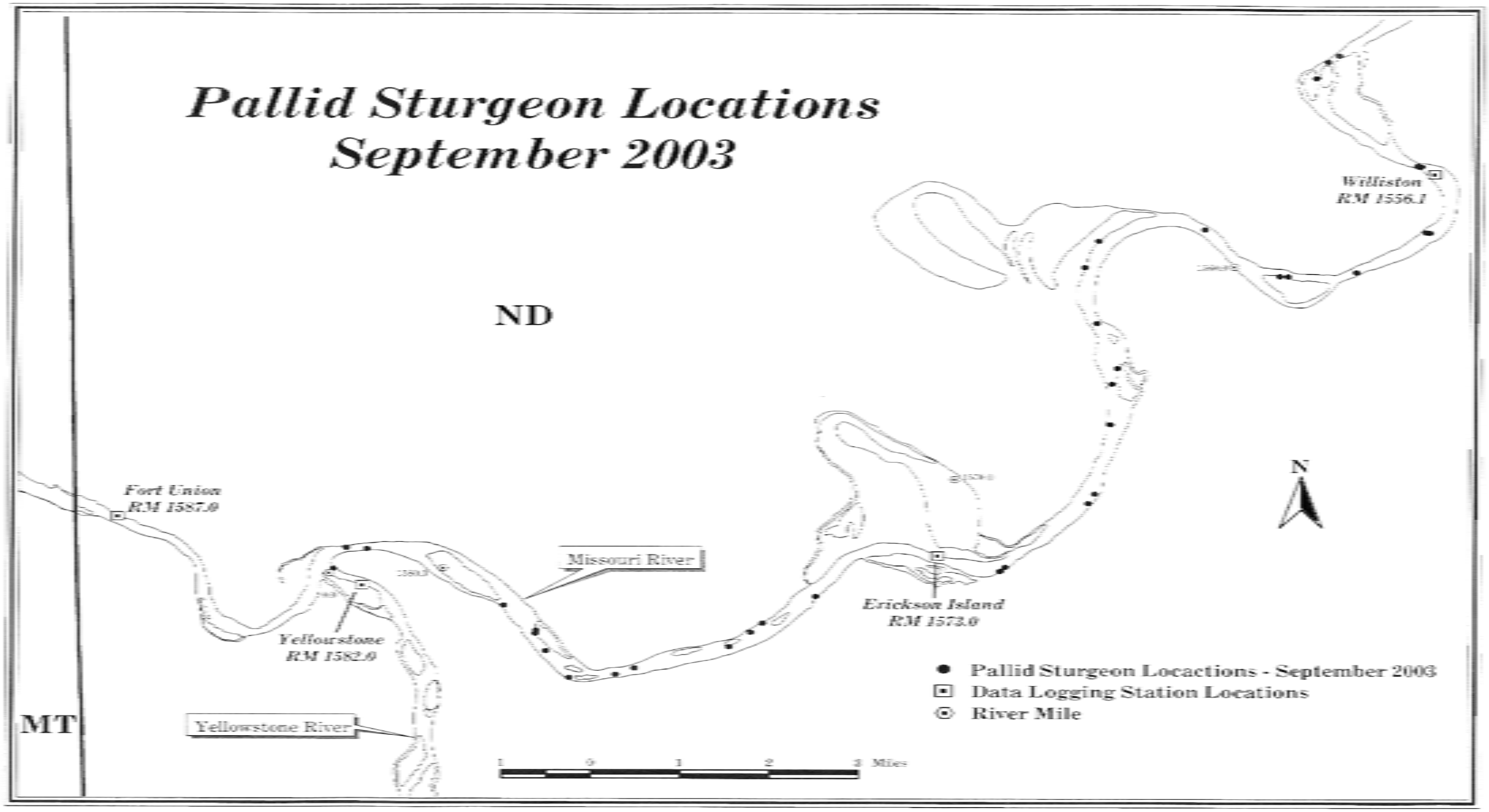

Figure 7. Locations of all pallids in September.

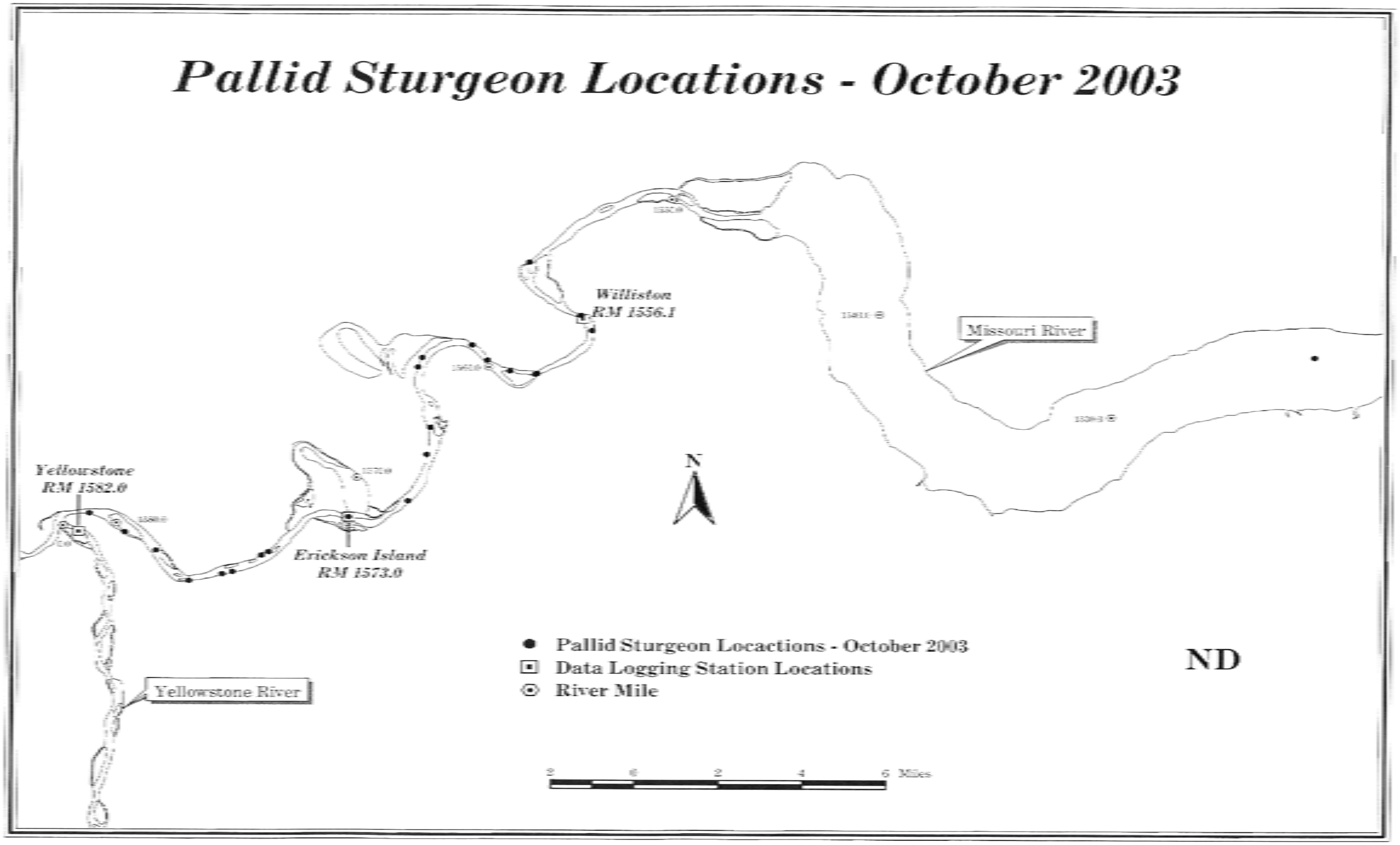

Figure 8. Locations of all pallids in October.

Drift Dynamics of Larval Shovelnose Sturgeon in a Side Channel of the Upper Missouri River in Eastern Montana

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Project completed under the following agreements with the Corps of Engineers:

Project Number W59XQG02493006 to the USGS Columbia Environmental Research Center
Project Number 00-UGPR-34 to the Montana Department of Fish, Wildlife and Parks

June 2004

Executive Summary

The behavior and drift dynamics of larval pallid sturgeon *Scaphirhynchus albus* and larval shovelnose sturgeon *S. platorynchus* are poorly understood because minimal research has been conducted on the early life history of these species. In 2003, the U. S. Army Corps of Engineers entered into agreements with the Montana Department of Fish, Wildlife and Parks and the U. S. Geological Survey – Biological Resources Division (Conte Anadromous Fish Research Center, Columbia Environmental Research Center) to initiate laboratory and field studies of the early life history of pallid sturgeon and shovelnose sturgeon. The overall goal of this project is to obtain an understanding of larval sturgeon drift behavior and drift dynamics related to river hydraulic conditions in the upper Missouri River of eastern Montana. This report summarizes initial studies of larval shovelnose sturgeon behavior and drift dynamics in a natural river channel under the following research objectives: (1) to quantify the vertical distribution of drifting larval shovelnose sturgeon (age-0 through age-2-day-old) in the water column, (2) to determine drift rates of larval shovelnose sturgeon in a natural river channel, and (3) to provide initial considerations for modeling larval sturgeon drift dynamics in the Missouri River.

Larval shovelnose sturgeon were released at the head of a 1,400-m-long side channel of the upper Missouri River on June 25, 2003 (40,000 larvae, age-0 and age-1-day-old) and June 27 (30,000 larvae, age-0 through age-2-day-old). The larvae were sampled continuously for up to 90-min post-release with nets positioned 0 – 0.5-m below the surface and 0 – 0.5-m above the channel bottom at locations 100-m, 500-m, 900-m, and 1,300-m downstream from the release point. About 5.4% and 3.4% of the larvae released on June 25 and June 27, respectively, were recaptured during sampling procedures. Larval shovelnose sturgeon were not equally distributed between surface and bottom nets, as significantly more larvae were sampled near the bottom at all sampling locations with the exception of the 100-m sampling location on June 25. The proportion of larvae sampled on the bottom increased from upstream to downstream sampling locations, and greater than 87% of the larvae sampled at the 1,300-m location were sampled on the bottom. Thus, larvae exhibited a strong tendency to drift near the bottom. The range of time that larvae were sampled in the drift at each sampling location increased from upstream to downstream sampling locations. The mean drift velocity of larvae arriving at each transect was significantly slower than mean water column velocity as would be expected because larvae drifted predominantly near the bottom where water velocities are lower than mean column velocity. Comparisons of near-bottom current velocity and near-bottom drift rates of larval shovelnose sturgeon indicated that the rate of larval drift on June 25 (0.34 m/s) and June 27 (0.37 m/s) was similar to mean near-bottom current velocity (0.32 m/s). Results from this initial field study suggest that hydraulic modeling of drift rates and drift duration of age-0 through age-2-day-old larval shovelnose sturgeon should be based on near-bottom water velocities. Based on this recommendation, we estimate that age-0 through age-2-day-old larval shovelnose sturgeon may drift 83 – 96 km during the first three days of life in the Missouri River.

Introduction

The persistence of many sturgeon species in rivers is dependent upon migration and dispersal mechanisms operating during their life history. Upstream migrations stimulated by discharge, temperature, or other environmental cues initiate the spawning process during spring and early summer (Kieffer and Kynard 1996; Sulak and Clugston 1998; Auer 1996; Auer and

Baker 2002). Downstream dispersal of larvae from spawning grounds and continued downstream migration of juveniles typify the 2-step migration pattern of sturgeon (Kynard and Horgan 2002), and complete the early life history of sturgeon. Fragmentation of the river corridor by dams poses a serious threat to population persistence because dams without passage technologies inhibit migration and dispersal mechanisms. In addition, atypical discharge and water temperature regimes resulting from dam operations may disrupt the natural cues that stimulate upstream spawning migrations (Paragamian and Kruse 2001). Improvements in dam operations to emulate natural discharge and water temperature regime can restore the stimuli considered necessary for upstream migrations and spawning (Auer 1996; Paragamian and Kruse 2001); however, dispersal bottlenecks operating during the larval and juvenile life stages can impede recruitment, especially when downstream river reaches are fragmented by dams and reservoirs (Jager et al. 2002).

Pallid sturgeon *Scaphirhynchus albus* and shovelnose sturgeon *S. platorynchus* are sympatric in the Missouri River. Although shovelnose sturgeon are common, pallid sturgeon are rare throughout their range and were classified as endangered in 1990 under the Endangered Species Act (Dryer and Sandvol 1993). A population of 96 – 351 pallid sturgeon (Kapuscinski 2002) occurs in the upper Missouri River of Montana and lower Yellowstone River in Montana and North Dakota, but this population is effectively landlocked between an upstream dam (Fort Peck Dam in Montana) and downstream dam (Garrison Dam in North Dakota). About 330 km of free-flowing river occur between Fort Peck Dam and the head waters of the downstream reservoir (Lake Sakakawea, created by Garrison Dam). There is little evidence of pallid sturgeon reproduction and recruitment in this population, as the population is comprised of large and presumably old individuals. Young-of-year pallid sturgeon were found in 2002 (Braaten and Fuller 2003); however, this was the first documented account of reproduction in this population and only two individuals were found. Shovelnose sturgeon successfully spawn in the upper Missouri River and Yellowstone River (Braaten and Fuller 2002, 2003), and although recruitment is irregular (Quist et al. 2002; Braaten, personal observation), several year classes are present in the adult population (Quist et al. 2002). However, young-of-year shovelnose sturgeon have been sampled only in the most downstream reaches of the river upstream from the headwaters of Lake Sakakawea (Braaten and Fuller 2002, 2003)

Lack of reproduction and recruitment by pallid sturgeon in the upper Missouri River has been attributed to seasonally atypical discharge regimes and cold hypolimnetic releases resulting from operations of Fort Peck Dam (USFWS 2000). Modified operations of Fort Peck Dam including more natural discharge regimes and enhancement of water temperatures are currently being planned to provide migration and spawning cues for pallid sturgeon, and increase recruitment (USFWS 2000). However, there is also evidence to suggest that the lack of recruitment may be partially attributable to bottlenecks that occur during the dispersive larval life stage. For example, although little is known about the larval life stage of pallid sturgeon and shovelnose sturgeon, preliminary laboratory studies on these species suggest that larvae may drift for 5 – 13 days before settling to the bottom (Kynard et al. 1998; Kynard et al. 2002). The extended drift period is significant when viewed in the context of available riverine habitat because only 330 km of riverine habitat are available between Fort Peck Dam and the headwaters of the downstream reservoir. If larval sturgeon are obligate to riverine conditions, reservoir habitat conditions may be an impediment to survival because larvae may drift into the reservoir during the extended drift period and die.

The need for additional information on the drift dynamics of larval shovelnose sturgeon and larval pallid sturgeon is well recognized due to the limited suite of laboratory conditions under which the studies by Kynard et al. (1998; 2002) were conducted. For example, laboratory tests included velocities ranging from 2-12 cm/s and depths less than 150 cm. Depth and velocity conditions in the Missouri River downstream from Fort Peck Dam exceed the laboratory conditions used by Kynard et al. (Galat et al. 2001); therefore, results on the behavior and drift characteristics of larval sturgeon may not be directly extrapolated to natural river conditions. Moreover, inferences pertinent to determining the length of river needed by larval sturgeon to complete their ontogenetic development vary, and do not provide a well-defined framework towards sturgeon recovery or restoration in the upper Missouri River. Kynard et al. (2002) estimated that the cumulative downstream migration distance of larval pallid sturgeon and larval shovelnose sturgeon was about 13 km. Incorporating behavioral data from Kynard et al. (1998) with limited hydraulic data from the Yellowstone River, Krentz (2000) estimated the minimum drift distance for larval sturgeon was 55 – 89 km. Also based on initial larval sturgeon drift data from Kynard et al. (1998), the USFWS (2000) estimated larval sturgeon may drift in the water column for 64 – 643 km. These wide-ranging inferences establish the need for more refined information on larval drift dynamics.

In addition to limited information on larval sturgeon drift dynamics, there is a substantial information gap relative to how hydraulic forces (e.g., water velocity) and behavior during the early larval life stages interact to influence larval sturgeon drift rates and cumulative drift distance. Depending on the behavioral responses of larval sturgeon to water velocity, at least three general types of larval drift rate models could be developed for shovelnose sturgeon and pallid sturgeon. First, if the drift rate of larval sturgeon is equal to the mean current velocity in the river channel, a “passive drift rate model” based on mean current velocity could be used to quantify larval drift duration, travel time in the river channel, and length of river necessary for ontogenetic development. Second, larval sturgeon may travel faster or slower than mean velocity, and in these cases an “active drift rate model” would best describe the drift characteristics of larval sturgeon. Third, larval sturgeon may drift downstream at a constant rate independent of mean current velocity. In this case, a “constant drift rate model” could be used to describe the drift characteristics of larval sturgeon. Additional variants of these models could also be developed based on larval behavior. For example, if larval sturgeon drift near the bottom at a drift speed equal to bottom velocities, then the passive drift behavior model based on bottom velocities could be developed.

This study is one part of a comprehensive study of larval sturgeon drift dynamics. The overall goal of the study is to obtain an understanding of larval sturgeon drift behavior and drift dynamics related to hydraulic conditions in the upper Missouri River of eastern Montana. This goal will be obtained using laboratory and field studies. Initial laboratory studies conducted in 1998 (Kynard et al. 1998; Kynard et al. 2002) were expanded during 2003 (Boyd Kynard, U. S. Geological Survey Conte Anadromous Fish Research Center; report in preparation). Initial field studies in 2003 were conducted jointly by the Montana Department of Fish, Wildlife and Parks (Dave Fuller) and the U. S. Geological Survey Columbia Environmental Research Center (Pat Braaten). Additional field and laboratory studies will be conducted in 2004 to complement the initial studies. This report summarizes the 2003 field activities. The objectives were (1) to quantify the vertical distribution of drifting larval shovelnose sturgeon (age-0 through age-2-day-old) in the water column, (2) to determine drift rates of larval shovelnose sturgeon in a natural river channel, and (3) to provide initial considerations for modeling larval sturgeon drift dynamics in the Missouri River.

Study Area

The drift rate of larval shovelnose sturgeon was examined in a natural connected side channel of the upper Missouri River located near Culbertson, Montana (Figure 1). The side channel is located at river kilometer 2,631 (rkm; distance upstream from the confluence at the Mississippi River), 219 km downstream from Fort Peck Dam. Discharge through the study area is regulated primarily by releases from Fort Peck Dam, but additional inputs from upstream tributaries seasonally augment releases from the dam. The side channel was 1,400-m-long, averaged 25.5 m in width, averaged 1.5 m in depth, and had an average water velocity of 0.48 m/s (see Results for more detailed information on velocity). Sand was the dominant substrate throughout the channel, although silt was common in low-velocity channel-margin areas. The Missouri River near the study area has several side channels of various lengths and morphological complexities (Bowen et al. 2003); however, the side channel used in this study was selected because it was one of the longest side channels in the area.

Methods

Larval shovelnose sturgeon

Adult shovelnose sturgeon were sampled during mid-June 2003 from the Yellowstone River and Tongue River in Montana, and transported to the Montana Fish, Wildlife, and Parks state fish hatchery in Miles City for spawning. Adult shovelnose sturgeon were injected with lutenizing hormone releasing hormone (LHRHa) on June 17, and spawned on June 18. The eggs started to hatch on June 24. On June 25, an estimated 40,000 larvae (age-0 and age-1 day old) were packaged in plastic bags at 0900 hrs, placed in coolers, and transported to the side channel. On June 27, an estimated 30,000 larvae (age-0, age-1 and age-2 day old) were packaged at 0900 hrs, and transported to the side channel.

Sampling locations

Four sampling locations were established in the side channel. The sampling locations were located 100-m, 500-m, 900-m, and 1,300-m downstream from the head of the side channel, and were positioned in the thalweg. At each sampling location, a cable was secured to the river banks and stretched to span the side channel. The cable served as a fixed attachment site for the boats during sampling.

Sampling apparatus

The apparatus used to sample larval shovelnose sturgeon at each site was comprised of two pairs of conical plankton nets, where each pair of nets consisted of one net positioned to sample the upper 0.5 m of the water column (hereafter surface) and one net positioned to sample the lower 0.5 m of the water column (hereafter bottom). A lead ball was used to maintain the

Figure 1. Aerial view (top panel; flow is from left to right) and ground view (lower panel) of the side channel used in larval drift studies during 2003. The aerial photograph was obtained from http://terraserver-usa.com/image.aspx?t=1&s=12&x=657&y=6660&z=13&w=1.

bottom net on the river bed and maintain both nets at the sampling location. Each conical plankton net (750µ mesh, 1.5-m-long, 0.5-m in diameter at the leading end, 0.09-m-diameter cod end) was secured to a 0.5-m-diameter ring and bridle. The cod end of each plankton net was fitted with a PVC sleeve, and a 0.754-l PVC collecting cup partially screened with 750µ mesh was used to retain samples. The collecting cup was attached to the sleeve using an elastic cord to facilitate quick removal and replacement. A metal tube with eye bolts secured to each end was affixed across the width of the boat near the bow. Each pair of nets was secured via bridles to a single rope that was attached to eye bolts at one end of a metal tube. Thus, one pair of nets was prepared to sample on the port side of the boat, and the other pair of nets prepared to sample on the starboard side of the boat. A crew of 5 individuals was stationed in each boat.

Velocity estimation and travel time

Two methods were used to quantify velocity conditions in the side channel. First, surface velocity was estimated by releasing ten floats (i.e., oranges) at the head of the side channel and measuring the elapsed time between release and arrival at each sampling location (Gordon et al. 1992). Because surface velocities are greater than mean velocity and provide a closer approximation to maximum velocities than mean velocities (Gordon et al. 1992), the travel time of floats provided estimations of time-of-first-arrival (TOFA) and velocity-of-first-arrival (VOFA) to each sampling location under the possibility that larval shovelnose sturgeon drift near the surface where current velocities are greatest. Drift tests with the floats were conducted in the evening on June 24 (prior to the June 25 drift test), and immediately following the drift test on June 27. A staff gauge was placed in the side channel on the evening of June 24.

Second, mean velocity in the side channel was estimated using an acoustic Doppler current profiler (ADCP). It was not logistically feasible to conduct ADCP measurements on both days of the experiment; therefore, ADCP measurements were obtained on June 26. Two estimates of mean velocity and discharge were obtained with the ADCP on 14 transects. The transects were spaced at 100-m intervals starting from the 100-m sampling location with the exception of one transect located 50-m downstream from the head of the side channel. Velocity data obtained from the ADCP on June 26 was used to describe velocity conditions during the June 25 and June 27 drift tests.

Sampling protocol

The drift study was conducted on June 25 and June 27 using the following protocol. Larval shovelnose sturgeon were released en masse from plastic shipping bags at the head of the side channel. The larvae were released at the substrate in the thalweg. The release process was completed within 15-seconds. A signal was sounded at release, and boats positioned at the four sample sites started to log time. The travel time of drifting floats from the head of the side channel to each transect was used to predict the TOFA of larval shovelnose sturgeon to sampling locations and establish the sampling regime. Sampling at the 500-m, 900-m and 1,300-m sample sites was initiated at least 5-min prior to predicted TOFA. Sampling at the 100-m sample site was initiated 30 sec post-release. The sampling protocol was as follows. At the established sampling time, two crew members deployed one pair of nets from the boat. After a 30-sec sampling interval, the pair of nets initially deployed was retrieved and two other crew members simultaneously deployed the second pair of nets from the opposite side of the boat. After retrieval, the collecting cups were removed and given to the fifth crew member who deposited the pair of collecting cups in a storage unit. The fifth crew member then labeled two new cups according to time and net location (surface, bottom), and handed the cups to the first crew for attachment to the nets. When the next 30-sec sampling interval was completed, the second 2-

member crew retrieved their nets while the two other crew members simultaneously deployed the next pair of nets. The alternating process of deploying and retrieving nets every 30 sec continued for 15, 30, 60, and 90 min at the 100-m, 500-m, 900-m, and 1,300-m sampling points, respectively. After sampling was completed, the number of larval sturgeon sampled in the surface and bottom collecting cups for each 30-sec sampling interval was enumerated. Larvae sampled were preserved in 10% formalin solution. A random sample of 500 larval shovelnose sturgeon from each day of the experiment were measured in the laboratory using a stereo microscope fitted with a calibrated ocular micrometer.

Results

Hydrologic conditions

Discharge in the Missouri River and the side channel changed slightly during the course of the study. Discharge (as recorded by USGS gage station 06185500 located 23 km downstream from the side channel) was 249 m^3/s on June 24 when the staff gage was installed and the first TOFA velocities estimates were obtained. Immediately prior to the conducting the first drift study on June 25, stage in the side channel had declined 2.5 cm. However, the stage recorded at the downstream gaging station was unchanged. When the ADCP was used to estimate velocity conditions and discharge in the side channel on June 26, the staff gage in the side channel had declined an additional 5 cm and this decline corresponded to a 3.7-cm decrease in stage at the downstream gaging station. There was an additional 7.6-cm decrease in stage in the side channel on June 27 when the second drift study was conducted and TOFA was estimated. A 1.8-cm decline in stage was evident for the same time period at the downstream gaging station. Declining stages during the study corresponded to mean daily discharge values of 247 m^3/s on June 25, 239 m^3/s on June 26, and 234 m^3/s on June 27 in the mainstem Missouri River. Thus, discharge decreased about 6% between the first and last study dates. Discharge in the side channel as determined from ADCP measurements on June 26 was 18.2 m^3/s. Estimates of VOFA from the evening of June 24 (mean = 0.63 m/s) and June 27 (mean = 0.68) were similar, suggesting that slight changes in stage and discharge between dates had minimal influence on velocity conditions in the side channel.

Drift characteristics of larval shovelnose sturgeon

Larval shovelnose sturgeon were collected at all sampling locations on both days of the study. Larval shovelnose sturgeon sampled on June 25 were significantly smaller (Wilcoxon two-sample test, $P < 0.0001$) than larvae sampled on June 27 (Figure 2). On June 25, the greatest number of larval shovelnose recaptured was sampled at the 100-m sampling location (801 larvae; Figure 3). Cumulatively, about 5.4% of the 40,000 larval sturgeon released were recaptured on June 25. On June 27, about 3.4% of the 30,000 larvae released were recaptured, and the greatest number of recaptures occurred at the 1,300-m sampling location (425 larvae; Figure 4). The original data sheet for the 500-m sampling location on June 27 blew out of the boat unnoticed; therefore, there was no data for this sampling location.

Larval shovelnose sturgeon were not equally distributed between surface and bottom samples at all sampling locations. On June 25, significantly more larvae were sampled in the surface net at the 100-m sampling location (Chi-square = 86.35, df = 1, $P < 0.0001$), but significantly more larvae were sampled in the bottom net at the 500-m, 900-m, and 1,300-m sampling locations (Chi-square = 110.54 – 519.90 for all locations, df = 1, P < 0.0001; Figure 3). On June 27, significantly more larvae were sampled in the bottom net at the three sampling

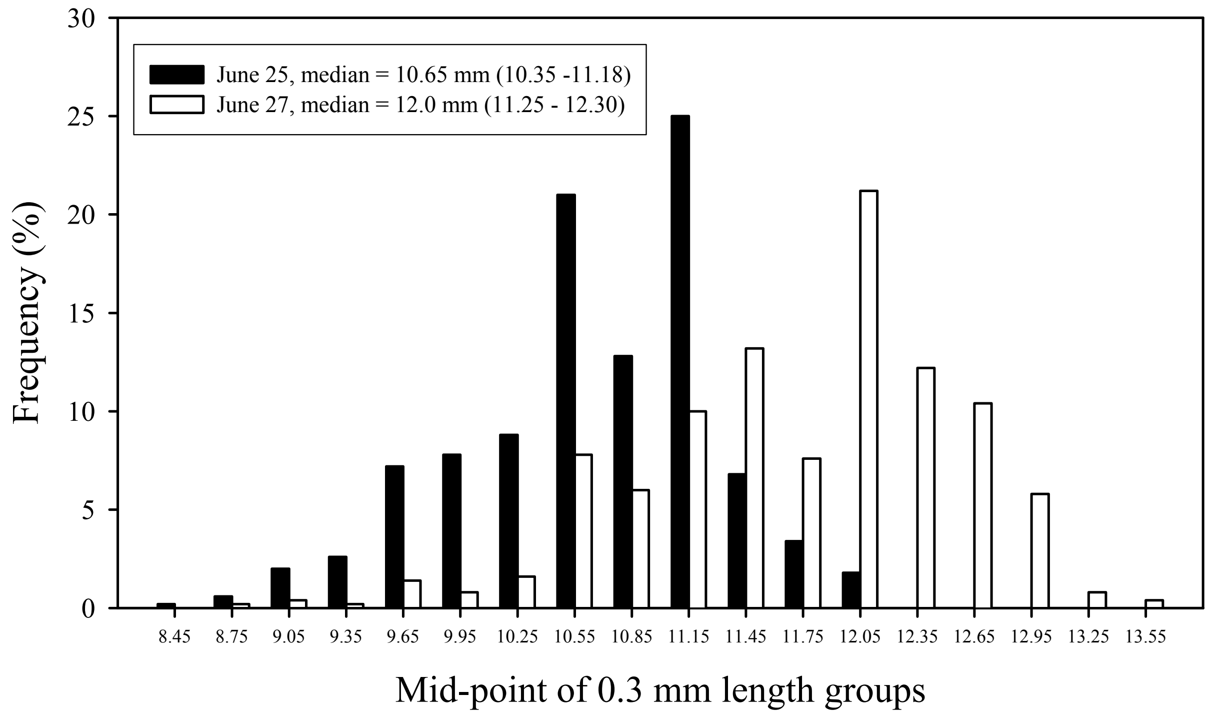

Figure 2. Length-frequency histogram of 500 randomly selected larval shovelnose sturgeon sampled on June 25 and June 27. Hyphenated values in parentheses are the 25% - 75% length quartiles.

locations (Chi-square = 81.31 – 236.44 for all locations, df = 1, P < 0.0001; Figure 4). The proportion of larval shovelnose sturgeon sampled in bottom nets increased between the 100-m and 1,300-m sampling locations; however, this trend was stronger on June 25 than June 27 (Figure 3, 4).

The range of time that larval shovelnose sturgeon were sampled in the drift varied among sampling locations on both days of the experiment. On June 25, larval shovelnose sturgeon were sampled between 150 sec and 540 sec post-release at the 100-m sampling location, between 780 sec and 1,770 sec post-release at the 500-m sampling location, between 1,410 sec and 2,940 sec post-release at the 900-m sampling location, and between 2,250 sec and 4,470 sec post-release at the 1,300-m sampling location (Figure 3). On June 27, larval shovelnose sturgeon were sampled between 150 sec and 570 sec post-release at the 100-m sampling location, between 1,590 sec and 2,850 sec post-release at the 900-m sampling location, and between 2,490 sec and 5,220 sec post-release at the 1300-m sampling location (Figure 4). The range of time that larvae were sampled in the drift increased with sampling location distance.

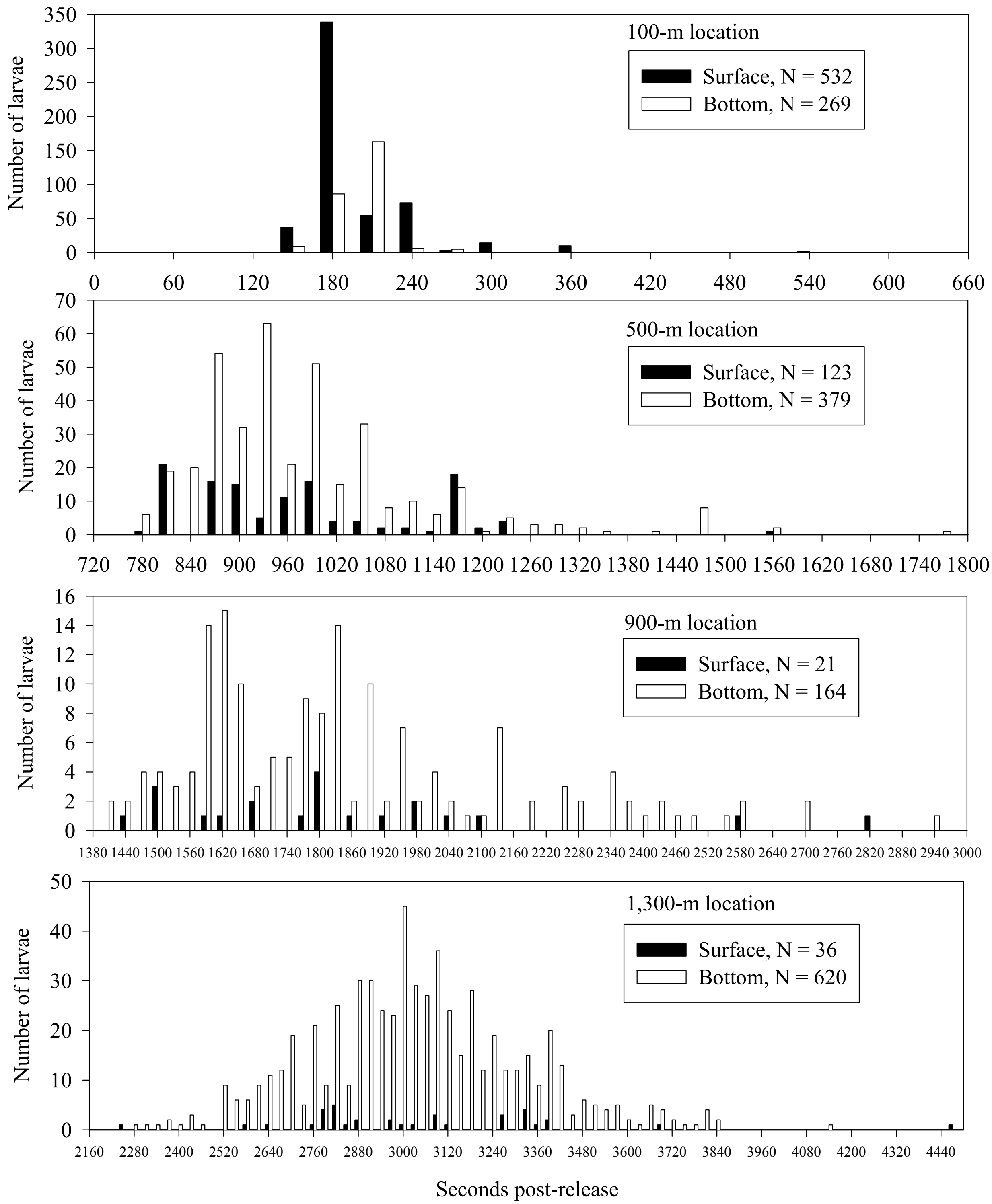

Figure 3. Number of larval shovelnose sturgeon sampled by time in surface and bottom nets at the 100-m, 500-m, 900-m, and 1,300-m sampling locations on June 25. Sampling continued for 900 sec, 1,800 sec, 3,600 sec, and 5,400 sec post-release for the increasing sampling location distances, respectively, but the abscissa is truncated.

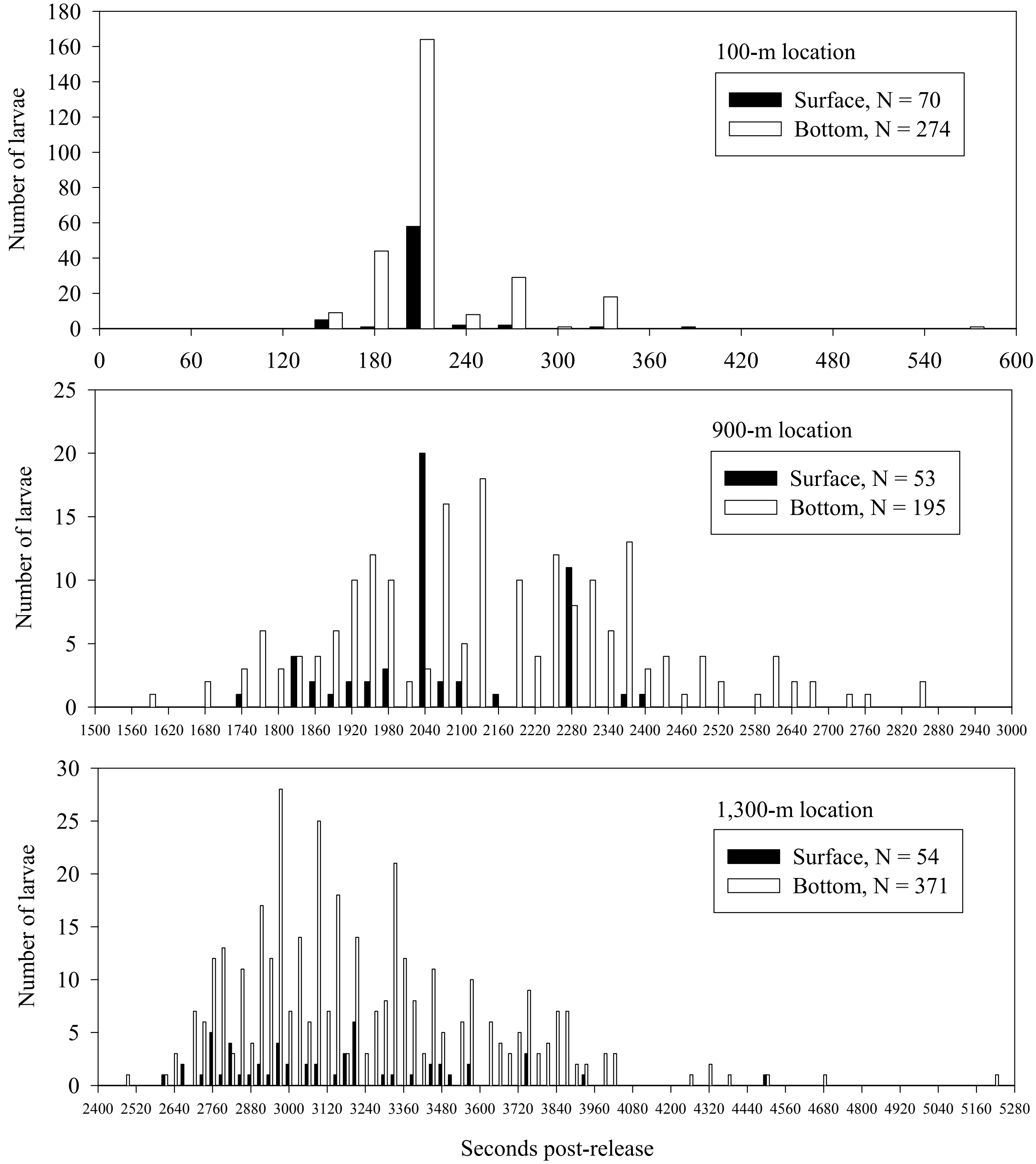

Figure 4. Number of larval shovelnose sturgeon sampled by time in surface and bottom nets at the 100-m, 900-m, and 1,300-m sampling locations on June 27. Sampling continued for 900 sec, 1,800 sec, 3,600 sec, and 5,400 sec post-release for the increasing sampling location distances, respectively, but the abscissa is truncated.

Predicted TOFA to each sampling location based on surface velocities estimated from drifting floats varied from 180 sec to 2,090 sec on June 25, and from 140 sec to 2,040 sec on June 27 (Table 1). There was no significant difference between predicted and measured TOFA (paired t-test, mean time difference = 139 sec, $t = 2.13$, $P = 0.08$, $N = 7$). However, the difference between measured and predicted TOFA increased with sampling location distance on both days of the experiment. On June 25, the measured TOFA was 30 sec less than predicted TOFA at the 100-m sampling location, whereas measured TOFA was 15-160 sec greater than predicted TOFA at the 500-m, 900-m and 1,300-m sampling locations. On June 27, measured TOFA was 10 sec greater (100-m sampling location), 280 sec greater (900-m sampling location), and 450 sec greater (1,300-m sampling location) than predicted TOFA. The predicted TOFA corresponded with predicted VOFA between 0.56 m/s and 0.68 m/s on June 25, and between 0.64 m/s and 0.71 m/s on June 27 (Table 1). There was no significant difference between predicted and measured VOFA (paired t-test, mean velocity difference = 0.04 m/s, $t = 1.27$, $P = 0.25$, $N = 7$). However, the difference between predicted and measured VOFA varied among sampling locations. On June 25, measured VOFA was 0.11 m/s faster (100-m sampling location), 0.01 m/s slower (500-m sampling location), and 0.04 m/s slower (900-m and 1,300-m sampling location) than predicted VOFA. On June 27, the measured VOFA was 0.04 m/s slower than predicted VOFA at the 100-m sampling location, and 0.12 m/s slower than predicted VOFA at the 900-m and 1,300-m sampling locations.

Table 1. Measured and predicted travel time (time-of-first-arrival; TOFA) and drift speed (velocity-of-first-arrival; VOFA) of larval shovelnose sturgeon and floats, and mean travel time and mean velocity of larval shovelnose sturgeon and the water mass to the 100-m, 500-m, 900-m, and 1,300-m sampling locations by date. Values in parentheses represent one standard deviation. No data were available for first arrival of larvae on June 27 at the 500-m sampling location. Mean time and mean velocity of the water mass was estimated from ADCP measurements on June 26, and applied to June 25 and June 27 for comparison.

		First arrival of larvae		First arrival of floats		Mean arrival of larvae		Mean arrival of water mass	
Day	Sampling location (m)	Measured TOFA (sec)	Measured VOFA (m/s)	Predicted TOFA (sec)	Predicted VOFA (m/s)	Mean time (sec)	Mean velocity (m/s)	Mean time (sec)	Mean velocity (m/s)
June 25	100	150	0.67	180	0.56	198 (374)	0.52 (0.77)	183	0.55
	500	780	0.64	765	0.65	980 (671)	0.52 (0.31)	962	0.52
	900	1,410	0.64	1,320	0.68	1,848 (664)	0.50 (0.16)	1,789	0.50
	1,300	2,250	0.58	2,090	0.62	3,040 (1003)	0.43 (0.14)	2,708	0.48
June 27	100	150	0.67	140	0.71	218 (281)	0.47 (0.49)	183	0.55
	500			720	0.69			962	0.52
	900	1,590	0.57	1,310	0.69	2,135 (614)	0.43 (0.12)	1,789	0.50
	1,300	2,490	0.52	2,040	0.64	3,222 (1,095)	0.41 (0.13)	2,708	0.48

The mean arrival time of larval shovelnose sturgeon to each sampling location varied from 198 sec to 3,040 sec post-release on June 25, and from 218 sec to 3,222 sec post-release on June 27 (Table 1). The mean arrival times corresponded to mean drift velocities between 0.43 m/s and 0.52 m/s on June 25, and between 0.41 m/s to 0.47 m/s on June 27 (Table 1). The mean arrival time of larval shovelnose sturgeon to the sampling locations was significantly greater than arrival time estimated from mean water velocity as measured by ADCP (paired t-test, mean time difference = 188 sec, $P = 0.05$, $N = 7$). However, the difference between mean arrival time of larvae and mean arrival time based on mean water velocities varied among sampling locations and day of experiment, and increased from the upper to lower sampling locations. On June 25, the mean arrival time of larvae was 15 sec greater at the 100-m sampling location, 18 sec greater at the 500-m sampling location, 59 sec greater at the 900-m sampling location, and 332 sec greater at the 1,300-m sampling location. The mean arrival time of larvae on June 27 was 35 sec greater at the 100-m sampling location, 346 greater at the 900-m sampling location, and 514 sec greater at the 1,300-m sampling location. The mean drift velocity of larval shovelnose sturgeon was significantly slower than mean water velocity (paired t-test, mean velocity difference = 0.04 m/s, $t = 3.38$, $P = 0.01$, $N = 7$). Similar to mean arrival time, the difference between mean drift velocity and mean water velocity varied among sampling locations and day of experiment. On June 25, drift rates of larval shovelnose sturgeon were 0.03 m/s slower than mean velocity at 100-m sampling location, equal to mean velocity at the 500-m and 900-m sampling locations, and 0.05 m/s slower at the 1,300-m sampling location. On June 27, drift rates were 0.08 m/s (100-m sampling location) and 0.07 m/s (900-m and 1,300-m sampling location) slower than mean water velocity.

Differences between the mean drift velocity of larval shovelnose sturgeon and mean water velocity had a significant influence on the cumulative drift patterns of larvae. On June 25, a significantly higher proportion of larval shovelnose sturgeon drifted faster than mean water velocity at the 100-m (Chi-square = 24.82, $df = 1$, $P < 0.0001$) and 500-m (Chi-square = 8.68, $df = 1$, $P = 0.003$) sampling locations (Figure 5). Conversely, the proportion of larvae drifting faster or slower than mean water velocity did not differ significantly from a 50:50 ratio at the 900-m sampling location (Chi-square = 0.26, $df = 1$, $P = 0.61$). At the 1,300-m sampling location, a significantly greater proportion of larval shovelnose sturgeon drifted at or slower than mean water velocity (Chi-square = 360.05, $df = 1$, $P < 0.0001$). On June 27, the proportion of larval shovelnose sturgeon drifting at or slower than mean water velocity was significantly greater than the proportion of larvae drifting faster than mean water velocity at all sampling locations (Chi-square = 148.48 – 367.12 for all sites, $df = 1$, $P < 0.0001$; Figure 5).

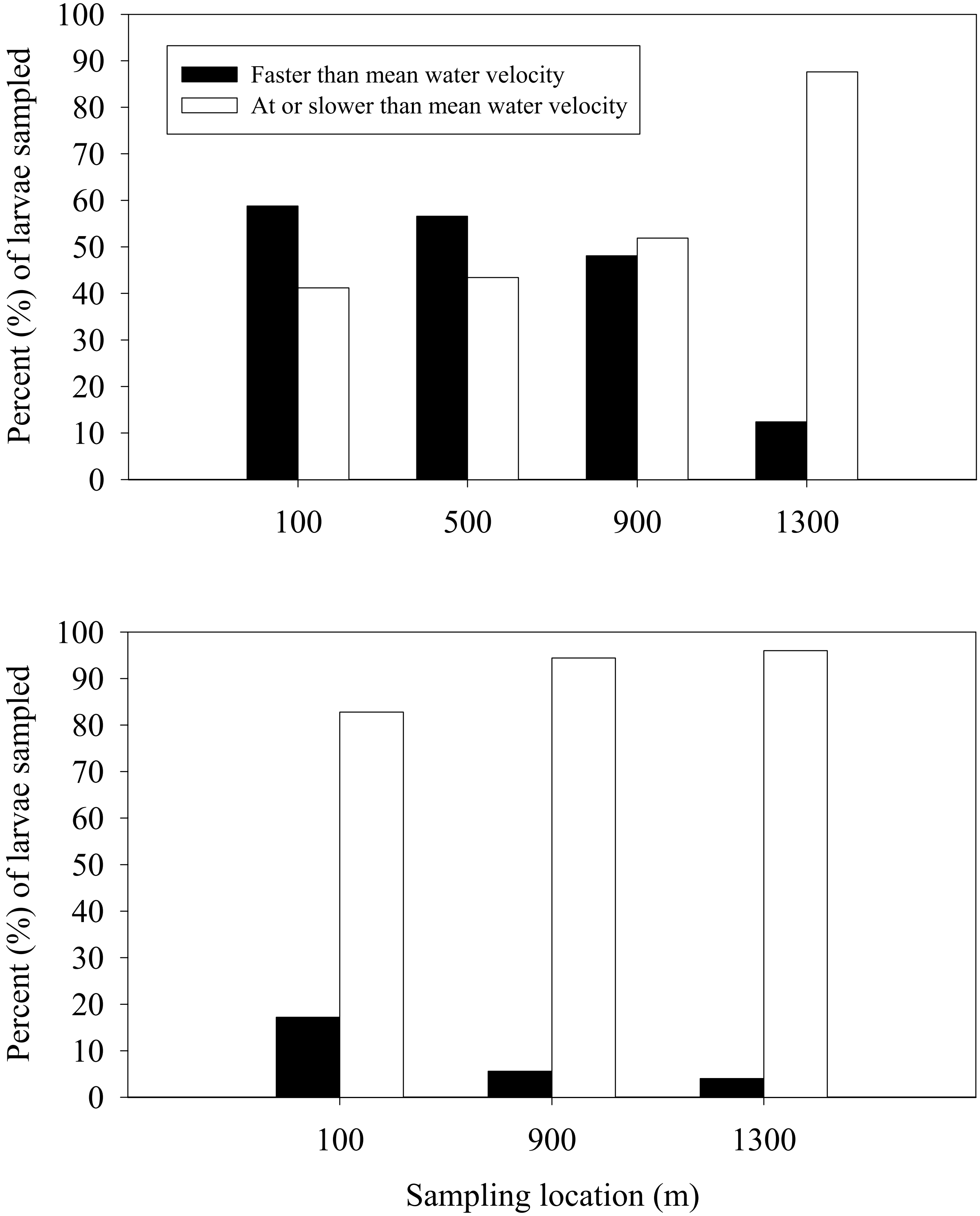

Figure 5. Percent of larval shovelnose sturgeon drifting faster than, and at or slower than mean water velocity by sampling location on June 25 (top panel) and June 27 (bottom panel).

Discussion

Results from this study suggest that interactions between larval behavior and the physical environment influenced the downstream drift dynamics of age-0 through age-2-day-old larval shovelnose sturgeon. Laboratory studies indicate that the vertical distribution of larval shovelnose sturgeon in the water column changes with age and ontogenetic development. In vertical tubes (150-cm deep, 2 cm/s velocity), Kynard et al. (2002) found that 1-day to 3-day-old larval shovelnose sturgeon swam predominantly in the lower one-third of the water column. Our results from a natural river channel corroborate these findings and indicate that age-0 through age-2-day-old shovelnose sturgeon drifted primarily in the lower 0.5 m of the water column. However, an exception to this pattern occurred on June 25 when significantly more shovelnose sturgeon larvae were sampled in the surface net at the 100-m sampling location. One possible explanation for this incidence is that larval shovelnose sturgeon after release were quickly entrained into higher velocities near the surface, and were sampled in the surface net at the 100-m sampling location before they could escape the near-surface high velocities. This argument is supported by the TOFA and VOFA analyses that showed larval shovelnose sturgeon drifted faster than predicted to the 100-m sampling location, further indicating that individuals were drifting primarily near the surface where maximum velocities occur and where the surface net was placed.

It is possible that larval shovelnose sturgeon experienced a period of acclimation to river conditions following release. We do not know how long the acclimation period might have persisted; however, there is strong evidence to suggest that age-0 through age-2-day-old larval shovelnose sturgeon have an innate affinity to drift primarily near the bottom. For example, the proportion of larvae sampled in the bottom nets increased from the upstream to downstream sampling locations. These results indicate that larval shovelnose sturgeon were seeking near-bottom areas at an increasing rate as they drifted downstream. If there was an acclimation period, results from the 1,300-m sampling location would provide the most accurate information on drift behavior because larvae reaching this location would have experienced the longest acclimation period. Based on results from the 1,300-m sampling location, it is possible that greater than 87% of age-0 through age-2-day-old larval shovelnose in the river channel drift near the bottom. Using bottom and mid-water column drift nets, Braaten and Fuller (2002, 2003) found that 64 – 71% of the newly hatched larval sturgeon sampled in the Yellowstone River and Missouri River downstream from Fort Peck Dam were sampled in drift nets fished on the bottom.

The range of time that larval shovelnose sturgeon were sampled in the drift increased from upstream to downstream sampling locations on both days of the experiment. These results follow Auer and Baker (2002) who also found that drift time of larval lake sturgeon *Acipenser fulvescens* increased from upstream to downstream sampling stations. The increased range of time from upstream to downstream was likely caused by a combination of active and passive mechanisms. For example, larval shovelnose sturgeon actively increased their use of near-bottom areas from upstream to downstream. Because water velocity is less in the lower than upper portions of the water column (Gordon et al. 1992), there would be an increase in time-of-travel from upstream to downstream sampling sites. Active vertical swimming movements in the water column would also increase the range of velocities encountered by larval shovelnose sturgeon, and contribute to the increased range of time from upstream to downstream that larvae were sampled. Although the majority of larvae were sampled near the bottom, individuals were also sampled near the surface at all sampling sites indicating that vertical exchange occurred throughout the drift period. In laboratory studies, Kynard et al. (2002) also found that drifting larvae exhibited vertical movements in the water column. Advection of larvae to varying velocities in combination with increasing lateral dispersion resulting from turbulence are also passive mechanisms that could account for the increasing range of sampling time that were observed. For example, entrainment of larvae in small eddies and low-velocity flow fields would slow the transport of larvae, and cumulatively result in a protracted time of occurrence in the drift from upstream to downstream as we observed in this study. The fate of larvae entrained in eddies is not specifically known, but results suggest that nearly all larvae re-entered (either actively or passively) the drift and were transported downstream within our sampling time frame. This conclusion is supported by the findings that very few larval shovelnose sturgeon were present in the drift when sampling was terminated at each sampling location.

Interactions involving larval behavior, either active or passive, and the physical environment resulted in downstream drift rates that were either similar to or slower than ambient velocity conditions in the river channel. First, whereas TOFA was initially estimated for logistic purposes (i.e., to establish the initiation of sampling at the sampling locations under the possibility that larvae drifted at near-maximum velocities), comparisons of predicted and measured TOFA contributed to a greater understanding of larval shovelnose sturgeon drift dynamics. For example, our findings that predicted and measured TOFA and VOFA were statistically similar suggests that a small percentage of larvae will be rapidly transported downstream at near-maximum water velocities. Although the difference between measured and predicted TOFA and VOFA exhibited an increase from upstream to downstream sampling locations, travel time based on near-maximum water velocity can be used to roughly estimate arrival time at downstream locations. However, estimates of TOFA based on near-maximum water velocity have little application to understanding the population drift dynamics because only a few individuals in the population traveled at near-maximum water velocities. Second, in contrast to TOFA and VOFA, the mean arrival time of larvae to each sampling location was greater than predicted based on mean water velocities, and the mean velocity of larvae arriving at each sampling location was less than the mean water column velocity. These results cumulatively reflect the findings that larval shovelnose sturgeon drifted primarily near the bottom where velocities are less than surface or mid-water column velocities (Gordon et al. 1992). Entrainment of larvae into eddies or low-velocity flow fields as earlier discussed would slow larval transport and reduce drift velocity. There was also some indication that downstream drift velocities of larger and older larvae used on June 27 were slower than smaller and younger larvae used on June 25. This difference could be attributed to the fact that larger and older larvae drifted near the bottom immediately after release due to age- or size-specific behavioral characteristics or improved swimming abilities associated with larger size. In experimental stream studies, Kynard et al. (2002) found that age-0 to age-2-day-old shovelnose sturgeon migrated downstream faster than ambient velocities in 1997 (experimental tank velocities = 5 - 12 cm/s), but slower than ambient velocities in 1998 (experimental tank velocities = 4 - 9 cm/s). For example, the mean velocity of larval shovelnose sturgeon drifting around a 7.3-m circumference oval tank in 1997 was 7 cm/s (age-0), 5 cm/s (age-1), and 7 cm/s (age-2). In 1998, shovelnose sturgeon mean drift rates were 3 cm/s (age-0), 2 cm/s (age-1), and 3 cm/s (age-2).

Modeling Applications

Results from this study provide initial insights relevant to modeling the drift dynamics of larval shovelnose sturgeon in natural river channels. Data from all sampling locations were useful for determining upstream to downstream changes in larval sturgeon drift behavior; however, inferences on drift behavior, travel time, and drift velocity from the 100-m, 500-m, and 900-m sampling locations has little value towards modeling larval sturgeon drift dynamics because of the limited spatial length. Conversely, inferences from the 1,300-m sampling location likely provide the most relevant information for modeling applications. These conclusions are supported by the following rationale. First, occurrence in the drift at 100-m, 500-m and 900-m sampling locations was completed in a narrow time interval (i.e., 49 minutes post-release on June 25, 47.5 min post-release on June 27 at the 900-m location), and we believe these results characterize the initial drift period of larvae spawned naturally in the river channel. For example, larval shovelnose sturgeon immediately after release (e.g., hatching) ascended the water column, were entrained into high near-surface velocities, and transported rapidly downstream as we observed on June 25 at the 100-m sampling location. Although larvae used on June 25 were not hatched in-situ at the head of the side channel and did not represent newly hatched larvae, this bias was minimal because it is unlikely the newly hatched larvae would have better swimming abilities than the larvae used on June 25. Thus, although some behavioral and hydraulic interactions occurred during the early drift stage, the brief period of time that these interactions occur is insignificant when viewed in the context of the entire larval drift stage. Second, results clearly illustrated that age-0 through age-2-day old sturgeon exhibited an innate behavior to drift near the bottom. Results from the 100-m, 500-m, and 900-m sampling locations described transitory behaviors and drift speed as larvae descended from higher locations in the water column to their preferred drift location near the bottom. Conversely, results from the 1,300-m sampling location provided more accurate information on the most preferred vertical drift location in the water column and drift speed after the initial short period of transitory behaviors. We do not know if age-0 to age-2-day-old sturgeon would have continued to drift near the bottom beyond 1,300 m; however, results from Kynard et al. (2002) suggest that the preference to drift near the bottom persists through at least day 4. The transitory drift behavior of larval shovelnose sturgeon is also supported by a closer examination of Figure 5 where the percentage of larvae drifting faster than mean water velocity decreased from upstream to downstream sampling locations. Larval descent from high-velocity locations in the upper water column to low-velocity locations in the lower portion of the water column cumulatively reduced the drift rate of larvae to the 1,300-m location, and resulted in the majority of the population drifting at or slower than mean velocity.

Based on the conclusions discussed above, we refined the analysis to examine drift dynamics and velocity conditions exclusively between the 900-m and 1,300-m sampling locations. We did not recalculate surface velocities based on drifting floats because surface velocity had little relevance to larval shovelnose sturgeon drifting primarily near the bottom. Mean velocity between the 900-m and 1,300-m sampling locations was 0.45 m/s as estimated from ADCP measurements. Based on the difference between mean arrival time of larvae at the 900-m and 1,300-m sampling locations (see Table 1), the estimated travel time between the two sampling locations was 1,192 sec (June 25) and 1,087 sec (June 27). These travel time estimates corresponded to mean drift velocities of 0.34 m/s (June 25) and 0.37 m/s (June 27).

Bottom velocities from the 900-m sampling location to the 1,300-m sampling location were estimated from the ADCP data. The ADCP could not reliably estimate velocity on the streambed; however, the ADCP provided reliable velocities at points 0.25-m and 0.5-m above the streambed. These points correspond to the near-bottom area sampled by the 0.5-m nets used in this study. Because velocity on the streambed is zero (Gordon et al. 1992), we could estimate mean bottom velocity between the 900-m and 1,300-m sampling locations by averaging bottom velocity (i.e., zero), velocity at 0.25-m above the streambed (from the ACDP), and velocity at 0.5-m above the streambed (from the ADCP) for each transect. Two estimates of near-bottom velocities were obtained for each transect; therefore, we obtained a total of 10 estimates (5 transects x 2 estimates per transect) of near-bottom velocities between the 900-m and 1,300-m sampling locations. This technique resulted in a mean near-bottom velocity estimate of 0.32 m/s (SD = 0.06 m/s, CV = 18.2, N = 10). This estimate of near-bottom mean velocity is similar to the mean near-bottom drift speed of larval shovelnose sturgeon on June 25 (0.34 m/s) and June 27 (0.37 m/s). Based on these results, we conclude that age-0 through age-2-day-old larval shovelnose sturgeon drift downstream near the bottom at a rate similar to near-bottom mean velocities.

The initial estimates of near-bottom larval drift velocity and mean near-bottom current velocity can be used to initially estimate total drift length of larval shovelnose sturgeon for the first few days of life. Using these near-bottom larval drift velocities, the estimated cumulative drift distance would be 88.1 km to 95.9 km for larval shovelnose sturgeon 0 – 2 days old (i.e., 3 days). Assuming that larval shovelnose continue to drift near the bottom through age-4 (e.g., 5 days) as indicated by Kynard et al. (2002), the estimated drift distance would be 146.9 km to 159.8 km. Based on mean near-bottom current velocity estimates of 0.32 m/s, larval shovelnose sturgeon could cumulatively drift 82.9 km during the first three days of life and 138 km during the first five days post-hatch. These estimates for only the first four days of the larval stage (i.e., 138 km – 159.8 km) exceed those presented by Kynard et al. (2002) for the entire larval drift stage (e.g., 12-13 km); however, studies by Kynard et al. (2002) were conducted in much lower velocities as described above.

This initial study of larval shovelnose sturgeon behavior and drift dynamics in a natural river setting depicted some similarities and differences between field and laboratories of larval shovelnose sturgeon. Thus, additional studies are warranted to better assess the differences, and importantly, provide accurate information that can be coupled with additional hydraulic data from the upper Missouri River to quantify larval sturgeon drift dynamics and drift duration. Specifically, we direct the following research objectives. First, in natural river channels, do larval shovelnose sturgeon continue to drift near the bottom through age-4-days-old then ascend the water column at older ages as suggested by Kynard et al. (2002)? Second, do larval shovelnose sturgeon during the first few days post-hatch "passively" drift at the rate of mean near-bottom current velocities as suggested by the present study? Conversely, is the near-bottom drift rate of 0.34 – 0.37 m/s a relatively fixed drift rate, indicative of a true near-bottom downstream migration rate? Third, do larval behavior and drift dynamics observed in the side parallel those that would be observed in the mainstem of the upper Missouri River? Fourth, are the drift behaviors and drift dynamics of larval shovelnose sturgeon and larval pallid sturgeon similar to such an extent that inferences from shovelnose sturgeon can readily be applied to pallid sturgeon? Initial laboratory studies suggest some differences between the two species may exist (Kynard et al. 2002); however, additional field studies are necessary to thoroughly evaluate this question.

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Evaluation of Sampling Techniques for Juvenile Pallid Sturgeon and Food Habits of Sturgeon in the Missouri River Below Fort Randall Dam, South Dakota

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Introduction

The U. S. Army Corps of Engineers (USACE) (USACE 2002) has proposed to develop standard operating procedures (SOP) for a long-term monitoring program of pallid sturgeon. However, there is no knowledge of when or where to effectively capture pallid sturgeon. The Upper Missouri River Basin Pallid Sturgeon Work Group (UBPSWG 2002) has also identified the need to evaluate sampling techniques and gear, particularly for juvenile pallid sturgeon. Gear type, habitat, and species behavior, all contribute to seasonal variability in catch per unit effort (CPUE) (Pope and Willis 1996; Jordan and Willis 2001).

Recruitment through the juvenile stage is believed to be one of the major factors limiting pallid sturgeon recovery. Currently, there is no diet studies completed on juvenile pallid sturgeon. Knowledge of the food habits of juvenile pallid sturgeon and the sympatric shovelnose sturgeon is vital to identifying the limiting factors to pallid sturgeon recruitment and eventual recovery. The information from this study will fill a gap in the life history of the endangered pallid sturgeon and evaluate the utility of RPA III as a recovery site. Fisheries managers will have a better understanding of the diets of the juvenile pallid sturgeon enabling sound decisions for recovery efforts such as stocking/augmentation programs. The diet information gained in this study is also essential for future studies including bioenergetics modeling (Klumb 2002).

Study Objectives

Objective 1**:** To determine the effectiveness of a benthic beam trawl, drifting trammel nets, static gill nets, hoop nets, and set lines to capture juvenile pallid sturgeon in different seasons and habitats.

Objective 2**:** To determine growth and condition of juvenile pallid sturgeon in the riverine portion of Lewis and Clark Lake and assess Recovery Priority Area III as a suitable area for continued sturgeon stocking and recovery efforts.

Objective 3**:** To determine the relative weights (Wr) of shovelnose sturgeon in the riverine portion of Lewis and Clark Lake compared to other shovelnose sturgeon populations within the geographic distribution of the species.

Objective 4: To compare the food habits of juvenile pallid sturgeon and adult shovelnose sturgeon in the riverine portion of Lewis and Clark Lake.

Objective 5: To determine the seasonal food habits of juvenile pallid sturgeon and adult shovelnose sturgeon.

Study Area – Recovery Priority Area III (RPA III)

The riverine section of Lewis and Clark Lake extends approximately 71 km with a maximum depth of 12 m and a channel width of 45-90 m, from Fort Randall Dam to Springfield, SD where its features become more like a reservoir.

Methods

Sampling Gear

Fish sampling occurred once every two weeks from April through October during 2003. Techniques included four "standard gears" for pallid sturgeon assessment in the protocol described in a proposal (USACE 2002) for a standard operating procedure (SOP) for long-term monitoring of the fish community in the Missouri River. The standard gears are static gill net sets, drifted trammel nets, hoop nets, and a benthic beam trawl. Additionally, I targeted shovelnose sturgeon and juvenile pallid sturgeon with set lines as a "wild gear."

When water temperatures were below 12 EC, gill nets were set overnight for a maximum of 18 hours. I used multi-filament gill nets that were 1.8 m deep X 38 m in length consisting of five 8 m long panels with bar mesh sizes of 2.54 cm, 3.81 cm, 5.08 cm, 7.62 cm, and 10.16 cm, float lines of 1.27 cm poly-foamcore, and lead line of 22.7 kg leadcore.

Trammel nets were drifted for a target distance of 300 m. A global positioning system (GPS) unit was used to quantify the distance sampled. Trammel nets were 1.8 m deep X 38 m with outside wall panels of 15.24 cm bar mesh and an inside wall panel of 2.54 cm bar mesh with a float line of 1.27 cm poly-foamcore and lead line of 22.7 kg leadcore.

The beam trawl used was 0.5 m deep and 2 m wide with an outer chafing net with bar mesh of 0.635 cm, an inner net with bar mesh of 0.318 cm, and a cod length of 2 m. As with the trammel net, the target towing distance for each beam trawl was 300 m.

Hoop nets (1.2 m diameter hoop; 4.8 m in length with 3.81 cm bar mesh) were set overnight for a maximum of 18 h.

I used set lines throughout the sampling periods using Mustad Tuna Circle hooks (10/0 and 12/0) (Figure 1). Each set line was 2 m in length and anchored to keep the bait near the river bottom (3 pound anchor). The line size was #60 braided nylon twine with barrel swivels and hooks were staged at 1 m intervals from the anchor. The set lines were marked with a float attached to a 40 ft line attached to the anchor with snap hooks. Set lines were set overnight baited with earthworms and leeches (when available May through August) for a maximum of 18 h.

Figure 1. Set line with Mustand Tuna Circle hooks (10/0 and 12/0) baited with worms and leeches.

Food Habits

The materials used for the gastric lavage were similar to those used by Foster (1977) and Brosse et al. (2002). The apparatus used was a hand pumped pressurized garden sprayer tank. A polyethylene tube with an outside diameter of 6.4 mm was fitted on the end of the garden sprayer hose. With the sturgeon held dorsal side down at a 45-degree angle, the polyethylene tube was slowly inserted down the esophagus as far as the first stomach loop. Water was then lightly pulsed into the stomach to dislodge food items as the tube was slowly withdrawn from the stomach and esophagus. After the stomach was filled with water, the ventral side of the sturgeon, approximately where the stomach is, was lightly massaged to facilitate regurgitation. The food items were regurgitated onto a 500 Φm-mesh sieve. This process was repeated until regurgitation ceased, assuming the stomach was emptied. The procedure lasted approximately 2-3 min for each fish, during which time the gills were constantly hosed with freshwater. The food items collected on the 500 Φm-mesh sieve were then preserved in 10% formalin. The safety of the gastric lavage technique was evaluated on hatchery reared juvenile pallid sturgeon at the Bozeman Fish Technology Center before being attempted on fish in the field.

2003 Results

<u>Gill nets</u>

11 pallid sturgeon were captured in April (2), October (2), and November (7) in 106 gill net nights.

<u>Trammel nets</u>

33 pallid sturgeon were captured in April (3), June (1 adult), July (1), August (23), September (2), and October (3).

534 trammel nets were drifted for approximately 114,077 m.

<u>Hoop nets</u>

No pallid sturgeon were captured in 198 (4,005 hours) hoop net nights from April through September.

<u>Beam Trawl</u>

No pallid sturgeon were captured in 353 beam trawl tows for approximately 105,900 m from April to August. Beam trawling was abandoned after the apparent failure to catch any fish species. In 2004, a new trawl design will be used to sample the fish community.

<u>Set lines</u>

16 juvenile pallid sturgeon were captured in April (3), May (1), July (2), August (2), September (2), and October (6) (Table 1).

Set lines were set for 2,002 hook nights for 14,897 hours. All pallid and shovelnose sturgeon were captured on nightcrawlers. Only two smallmouth buffalo were captured in 472 hook nights with leeches.

Table 1. Mean lengths (standard error) and weights (standard error) of juvenile pallid and adult shovelnose sturgeon captured on setlines.

Species	Hook size	N	Length (mm)	Weight (g)
Pallid sturgeon	10/0	11	611.7 (25.8)	721.1 (78.6)
Pallid sturgeon	12/0	5	569.0 (38.7)	581.2 (106.0)
Shovelnose	10/0	8	650.8 (20.8)	1082.5 (88.5)
Shovelnose	12/0	8	671.5 (22.1)	1213.1 (87.5)

Juvenile Pallid Sturgeon Relative Condition Factor (Kn)

Condition indices on juvenile pallid sturgeon were evaluated using the relative condition factor (Kn; Anderson and Neumann 1996). Relative condition factor is calculated as Kn = (W/W′), where W is weight of the individual and W′ is the length-specific mean weight predicted by a weight-length equation calculated for that population. Keenlyne and Evanson (1993) provided a weight-length regression [$\log_{10}W = -6.378 + 3.357 \log_{10}L$ ($r^2 = 0.974$)] for pallid sturgeon throughout its range.

Although all juvenile pallid sturgeon have declined in Kn, most appeared healthy and doing well at the time of being recaptured (Table 2).

Table 2. Mean length (SE), weight (SE), and Kn (SE) of juvenile pallid sturgeon by year class when stocked and recaptured.

Year Class	N	Stocked Length (mm)	Stocked Weight (g)	Stocked Kn	Recapture Length (mm)	Recapture Weight (g)	Recapture Kn
1997	25	529 (5.7)	650 (27.2)	1.12 (0.04)	647 (6.9)	822 (29.1)	0.71 (0.01)
1998	3	499 (34.4)	460 (111.1)	0.91 (0.04)	566 (37.3)	530 (128 .3)	0.70 (0.04)
1999	6	465 (20.2)	426 (63.3)	1.09 (0.11)	514 (31.9)	429 (75.6)	0.77 (0.02)
2001	6	210 (8.2)	?	?	392 (12.4)	187 (18.8)	0.87 (0.02)
2002	1	294	91	1.12	385	143	0.71

Shovelnose Sturgeon Relative Weight (Wr)

Relative weight was calculated for shovelnose sturgeon captured in 2003 (Table 3). Relative weight (Wr) is calculated as: Wr = W/Ws X 100 where W is the actual weight and Ws is the length-specific standard weight for that species (Wege and Anderson 1978). A standard weight (Ws) equation was developed for shovelnose sturgeon by Quist et al. (1998).

Table 3. Mean relative weight (Wr) of shovelnose sturgeon captured in 2003. Length categories are stock, 250 mm; quality, 380 mm; preferred, 510 mm; memorable, 640; and trophy, 810 mm.

N	Stock Wr (SE)	N	Quality Wr (SE)	N	Preferred Wr (SE)	N	Memorable Wr (SE)	N	Trophy Wr (SE)
0		0		59	1.00 (0.01)	103	0.91 (0.01)	0	

Food habits of juvenile pallid and adult shovelnose sturgeon

Gastric lavage was performed on all sturgeon captured in 2003. Analysis of diet contents has not occurred. 100 % of the prey items collected from shovelnose sturgeon were aquatic insect larvae. Most of the prey items collected from juvenile pallid sturgeon were aquatic insect larvae, although a few minnows were collected from two pallid sturgeon.

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Evaluation of a Gastric Lavage Method on Juvenile Pallid Sturgeon

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Abstract

Due to the endangered status and the limited knowledge on the early life history of the pallid sturgeon *Scaphirhynchus albus*, a non-lethal method for investigating food habits was tested for safety and efficiency on age-1 pallid sturgeon. Pallid sturgeon were fed a mixture of prey items including earthworms *Lumbriscus terrrestris*, red worms *Alloloborpha calliginosa*, meal worms *Tenebrio molitor*, and wax worms *Galleria mellonella*. Two test groups were gastric lavaged and one group was not lavaged but held as a control (N = 30 in each group). Over a 60 d test period, no mortality was observed. No significant differences were detected in the lengths and relative condition between the gastric lavaged groups and the control group over the 60 d test period. The efficiency of the lavage procedure also was evaluated on juvenile pallid sturgeon (N = 29). A proportion of food items were recovered from 100% of the sturgeon with food items in their stomach. The average recovery rate for all food items combined by number and by weight was 74.9% and 73.7% respectively.

Introduction

The pallid sturgeon *Scaphirhynchus albus* was listed as a federally endangered species in 1990 (Dryer and Sandvol 1993). The early life history of the pallid sturgeon is not completely understood, at least partially because little to no recruitment has occurred on the Missouri River above Gavins Point Dam for more than 40 years, which coincides with the closure of Missouri River dams (Keenlyne and Jenkins 1993). Currently there is no information available on the food habits of juvenile pallid sturgeon.

Most studies on food habits have involved sacrificing large numbers of fish. Examination of food contents from the stomach of carcasses has been conducted for pallid sturgeon and shovelnose sturgeon *S. platorynchus* (Carlson et al. 1985); Atlantic sturgeon *Acipenser oxyrinchus* (Johnson et al. 1997); lake sturgeon *A. fulvescens* (Choudhury et al. 1996); Gulf sturgeon *A. o. desotoi* (Mason and Clugston 1993); and white sturgeon *A. transmontanus* (Sprague et al. 1993). Given the endangered status of most sturgeon species, a safe method of studying food habits is needed.

Gastric lavage, or stomach flushing, is an effective and efficient method used to safely remove food items without sacrificing the fish (Meehan and Miller 1978). Gastric lavage involves inserting a tube down the esophagus into the stomach where water is flushed to induce regurgitation. Gastric lavage has been used in food habit studies of various sturgeon species with varying success and differential mortality rates. While performing gastric lavage on juvenile white sturgeon, Sprague et al. (1993) found that water injected at too high pressure could rupture the swim bladder and result in death. Brosse et al. (2002) evaluated gastric lavage methods on adult Siberian sturgeon *A. baeri* with fork lengths (FL) of 780 – 1050 mm and recovered food items with no mortality, but found a significant difference in weight change between the lavaged and the control sets of sturgeon after 60 d ($P = 0.008$). Haley (1998) found no mortality while using gastric lavage techniques on shortnose sturgeon *A. brevirostrum* (mean FL, 732 mm; range 533 - 937 mm) and juvenile Atlantic sturgeon (mean FL, 718 mm; range 484 – 1,150 mm). Although there was no mortality, the fish were anesthetized in tricaine methanesulfonate (MS-222) allowing the muscular region of the alimentary canal to relax. The Pallid Sturgeon Recovery Team has prohibited the use of MS-222 on pallid sturgeon due to detrimental effects, including mortality (Steve Krentz, Pallid Strugeon Recovery Team Leader, personal communication; U. S. Fish and Wildlife Service [USFWS], Bismarck, ND; December 2002). Food items have also been recovered with ease from the shovelnose sturgeon with no mortality (Dane A. Shuman, personal communication; University of Nebraska-Lincoln, School of Natural Resource Sciences, Lincoln, NE; November 2002). The objective of this study was to evaluate the safety, in terms of mortaility or growth after being gastric lavaged, and to evaluate the efficiency of this technique to recover food items from juvenile pallid sturgeon.

Methods

The safety and efficiency of the gastric lavage technique was tested at the Bozeman Fish Technology Center (USFWS) in Bozeman, MT from February to April 2003. The tests were performed on hatchery-reared, age-1 pallid sturgeon (mean FL, 408 mm; range 179-515 mm and mean weight, 215 g; range 80-480 g). The pallid sturgeon were not fed for a period of 4 d before being fed a mixture of different types of prey including earthworms *Lumbriscus terrrestris*, red worms *Alloloborpha calliginosa*, meal worms *Tenebrio molitor*, and wax worms *Galleria mellonella*,. Two test groups (lavage 1 and lavage 2) were gastric lavaged and one test group was kept as a control ($N = 30$ in each group). The control group was measured, weighed, fed, and maintained at similar temperatures (22°C to 23°C) over the same period of time as the sturgeon that were gastric lavaged. Another group ($N = 29$; mean FL, 407 mm; range 179 – 490 mm and mean weight 219 g; range 135 – 350 g) was gastric lavaged, then sacrificed to evaluate food removal efficiency.

A gastic lavage method was performed that followed the techniques of Foster (1977) and by using a pressurized reservoir (Light et al. 1983; and Brosse et al. 2002) on juvenile pallid sturgeon. The advantage of using a pressurized air tank is that it provided a continuous supply of water during the gastric lavage process. The apparatus was a 5.5-L hand pumped pressurized garden sprayer tank fitted with a 3.18 mm outside diameter polyethylene tube. The pulsed gastric lavage procedure began 30 min after feeding. With the pallid sturgeon held dorsal side down at a 45-degree angle, the polyethylene tube was slowly inserted through the esophagus as far as the first stomach loop. Water was then lightly pulsed into the stomach to dislodge food items as the tube was slowly withdrawn from the stomach and esophagus. After the stomach filled with water, the anterior of the sturgeon, approximately where the stomach is located, was lightly massaged to facilitate regurgitation. The food items were regurgitated onto a 500 :m-mesh sieve. This process was repeated until regurgitation ceased, assuming the stomach was emptied. The procedure lasted approximately 2-3 min for each fish, during which time the gills were constantly hosed with fresh water.

All pallid sturgeon were measured and weighed before being gastric lavaged, at 30 d, and at 60 d. Differences in mean length were examined between the gastric lavaged and control sturgeon groups over the 30 d and 60 d test period using a two-way analysis of variance (ANOVA) with a least-squares means multiple range test (SAS 1988).

Condition indices between the gastric lavaged and control test groups of sturgeon were compared using the relative condition factor (Kn; Anderson and Neumann 1996). Relative condition factor is calculated as Kn = (W/W′), where W is weight of the individual and W′ is the length-specific mean weight predicted by a weight-length equation calculated for that population. Keenlyne and Evanson (1993) provided a weight-length regression [$\log_{10}W = -6.378 + 3.357 \log_{10}L$ ($r^2 = 0.974$)] for pallid sturgeon. Because of a significant interaction term in a two-way ANOVA, differences in mean Kn between groups over the 30-d and 60-d period was determined using a one-way ANOVA with the least-squares means multiple range test. Examining the growth and Kn over the test period will indicate whether the sturgeon resumed feeding and grew after being gastric lavaged.

A group of 29 pallid sturgeon was tested for gastric lavage efficiency. After a fish was gastric lavaged and regurgitation was presumed to have ceased, the food items collected on the 500 :m-mesh sieve were identified and weighed. The sturgeon was then sacrificed to examine remaining food items in the stomach. The remaining food items were also identified and weighed. Efficiency was calculated as the percent by number and weight of food items recovered from a sturgeon.

Results

Safety of the method

Throughout the 60 d test period, no mortality was observed in the gastric lavaged or control groups. In all groups, there was no significant growth in length after 30 d ($P = 0.261$). However, the pallid sturgeon showed a significant increase in length between 30 d and 60 d for all groups ($P = 0.002$). There was no significant differences between the control group and the two lavaged groups at 0 d (lavage 1, $P = 0.400$; lavage 2, $P = 0.229$), at 30 d (lavage 1, $P = 0.350$; lavage 2, $P = 0.0958$), or at 60 d (lavage 1, $P = 0.585$; lavage 2, $P = 0.0952$) (Table 1).

Table 1. Mean length (standard deviation) of juvenile pallid sturgeon of the two gastric lavaged groups and the control group at 0 d, 30 d, and 60 d.

Group	N	Mean Length (mm)		
		0 d	30 d	60 d
Lavage 1	30	418.30 (39.26)	427.30 (36.17)	443.03 (33.28)
Lavage 2	30	397.07 (39.99)	400.27 (38.39)	420.00 (39.92)
Control	30	409.57 (46.86)	417.60 (43.89)	437.37 (42.06)

Mean Kn did not significantly differ between the control group and the two gastric lavaged groups at 0 d (lavage 1, P = 0.319; lavage 2, P = 0.520), at 30 d (lavage 1, P = 0.8903; lavage 2, P = 0.500), or at 60 d (lavage 1, P = 0.123; lavage 2, P = 0.132) (Table 2). Throughout the 60-d test period, the control group Kn was nearly intermediate between the two gastric lavaged groups.

Table 2. Mean Kn (standard deviation) of juvenile pallid sturgeon of the two gastric lavaged groups and the control group at 0 d, 30 d, and 60 d.

Group	N	Mean Kn		
		0 d	30 d	60 d
Lavage 1	30	0.864 (0.090)	0.859 (0.067)	0.847 (0.057)
Lavage 2	30	0.832 (0.049)	0.868 (0.064)	0.897 (0.063)
Control	30	0.844 (0.079)	0.856 (0.067)	0.873 (0.070)

After the 60 d test period, five of the gastric lavaged sturgeon were sacrificed to examine the digestive tract at the Bozeman Fish Health Center (USFWS). No damage was observed through the digestive tract. Gross examinations of the swim bladder revealed no water. However, four of the five sturgeon had inflated swim bladders. A histological examination of the swim bladder tissues was conducted, but was inconclusive in determining that any changes were due to the gastric lavage procedure (Staton 2003).

Efficiency of the method

Juvenile pallid sturgeon (N = 29) were tested for food removal efficiency. Some food items were recovered in all sturgeon that had food items in the stomach when the gastric lavage procedure began (N=25). Overall, the average food recovery rate for all food items by numbers and by weight recovered was 74.9% and 73.7% respectively. The percent composition by weight of food items recovered from the sturgeon were earthworms 86.7% (N = 11, SE = 0.249, Range 0-100), red worms 82.9% (N = 21, SE = 0.239, Range 0-100), meal worms 49.4% (N = 14, SE = 0.376, Range 0-100), and wax worms 75.0% (N = 4, SE = 0.391, Range 0-100).

Discussion

Due to the endangered status and limited knowledge of the early life history of the pallid sturgeon, the safety of gastric lavage was investigated. Gastric lavaging is considered a safe and effective method for removing food items from fish stomachs (Meehan and Miller 1978; Hyslop 1980; Hartleb and Moring 1995; Haley 1998; Brosse et al. 2002). No pallid sturgeon mortality was observed over the 60 d test period, similar to gastric lavage findings on other sturgeons (Haley 1998; Brosse et al. 2002). Haley (1998) attributed the success and presumed safety of the technique to using flexible intramedic tubing and anesthetizing the sturgeon with MS-222. The Pallid Sturgeon Recovery Team has prohibited the use of MS-222 on pallid sturgeon so a gastric lavage technique was tested without anesthesia. The results of the growth and Kn analysis of the juvenile pallid sturgeon tests indicate that the gastric lavage procedure did not cause undue stress and feeding resumed soon after handling. Using a pressurized tank with a constant supply of water and not anesthetizing the sturgeon has the advantage of limiting handling time to 2-3 min per fish compared to 20 min per fish in the study by Haley (1998).

A proportion of food items were recovered from 100% of the pallid sturgeon with food items in their stomach. Food items were recovered up to 2 h after fish were fed. Meal worms were recovered at a much lower rate compared to earthworms, red worms, and wax worms. Meal worms have a hardened exoskeleton compared to the soft-bodied earthworms, red worms, and wax worms, which may explain the variation of recovery rates. Brosse et al. (2002) also found variations in the recovery rate of prey items, where only 50% of the vermiform prey and 75% of larger prey, fish and shrimp, were recovered. Brosse et al. (2002) also found that the recovery rate of food items after 2 h or more was much lower, indicating the technique will most likely recover the most recently ingested food items. Further investigations are needed on the recovery rate of different prey items in the wild. Without knowledge of recovery rates, the gastric lavage technique may only provide a qualitative determination of food habits (Haley 1998).

Extreme caution is advised while employing gastric lavage for juvenile pallid sturgeon, as the small, 3.18 mm outside diameter tubing could easily puncture the swim bladder if excessive pressure is used to insert the tube down the esophagus. In some cases, constriction of the alimentary canal was experienced while inserting the tube and while injecting water into the stomach. Care was taken to reduce the amount of water injected into the stomach which allowed time for the sturgeon to relax and begin regurgitation. Brosse et al. (2002) inserted a large diameter tube (12 mm) into the digestive tract of an adult Siberian sturgeon, then a smaller diameter tube (6 mm) within the larger tube to prevent puncturing the swim bladder and allow food items to flush out while injecting water. Further studies are needed to determine the appropriate tube sizes for various sizes of pallid sturgeon.

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Continued development of a bioenergetics model for juvenile pallid sturgeon

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Project accomplishments 2003

At present, 19 respiration experiments measuring the routine metabolic rates of juvenile pallid sturgeons have been completed. Measurements were made on 139 individual pallid sturgeon at 11 temperatures (range: 4 to 21.5 °C) from three year classes: 34 fish from the 2001 year class, 94 fish from the 2002 year class, and 11 fish from the 2003 year class. Experiments on pallid sturgeon from the 2001 year class were conducted at the Bozeman Fish Technology Center (BFTC) while experiments using the 2002 and 2003 year classes were done at the Gavins Point National Fish Hatchery. Survival of fish during the experiments was excellent, only 5 fish died during trials conducted with the 2001 year class at BFTC. Data analysis is ongoing and initial results will be presented on December 8, 2003 in the Sturgeon and Paddlefish session at the 64th Midwest Fish and Wildlife Conference in Kansas City, Missouri.