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Fort Peck Pallid Sturgeon Study

by

Pat Clancey
Fisheries Biologist
Montana Department of Fish, Wildlife, and Parks

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ABSTRACT

Research on the life cycle requirements of the pallid sturgeon in the Missouri River below Fort Peck Dam began in March, 1989, when three pallids were outfitted with radio transmitters in the Fort Peck tailrace. Interest in the pallid, which had been a candidate species for the U.S. Fish and Wildlife Service Endangered Species List for years, peaked in 1988-89 after recreational SCUBA divers at Fort Peck sighted three pallids in one afternoon in the Fort Peck tailrace in February 1988. The pallids winter in deep holes in the tailrace along with thousands of shovelnose sturgeon, as well as other game and nongame fish, including paddlefish. The transmitted pallids were tracked via aerial and boat surveys. Two of the three pallids moved out of the Fort Peck tailrace by late March, 1989. They were each relocated 9-10 times before we determined that they dropped their transmitters in June. Habitat selection data was collected whenever a relocation was made from the boat. Parameters sampled were depth, water temperature, conductivity, turbidity, dissolved oxygen concentration, and current velocity near the river bottom. A substrate sample was also collected to examine for substrate composition and potential food items. The third pallid was caught by two walleye fishermen in late April in the same hole where it had been captured in March for transmitting. It escaped from them as they got it to their boat. At that time it still had it's transmitter mounted to it's back. We were not able to relocate this pallid by radio telemetry at anytime during the first field season. We did recapture it in a gillnet set in the tailrace in late August. By that time it had lost it's transmitter. A second transmitter was mounted to the fish using a modification of the original method. We have not relocated this fish since, but hope to sight it during this winter's SCUBA surveys to determine if the modified method is a permanent solution to the problem of transmitter loss.

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INTRODUCTION

On February 20, 1988, recreational SCUBA divers reported to the Montana Department of Fish, Wildlife, and Parks (MDFWP) at Fort Peck that they had sighted three large sturgeon while diving in the tailwaters of Fort Peck Dam. It was determined that these sturgeon had to be pallid sturgeon, based solely on their size. At the time, pallid sturgeon were a categorized as a C2 species by the U.S. Fish and Wildlife Service (FWS). This categorization indicated that proposing to list the species as endangered or threatened may be appropriate, but substantial biological information to support the listing is not on file. Interest in the status of the pallid sturgeon intensified throughout the Missouri River basin as word of the sightings spread and as it became evident from subsequent dives that pallids could be sighted relatively consistently in the tailwaters of Fort Peck throughout the winter months. Many photographs and an underwater video film document the presence of the pallid sturgeon at Fort Peck.

The Dakota Chapter of the American Fisheries Society presented a panel on the pallid sturgeon at it's annual meeting in the winter of 1988. As a result of the information gained from listening to that panel, the Dacotah Chapter of the Sierra Club filed a petition on June 16, 1988, with the FWS to list the pallid as endangered. The FWS determined that the petition had merit, and initiated the listing process. A comprehensive sightings list was compiled by the FWS that listed all known sightings of pallids.

Historical data indicated that fewer and fewer pallids were sighted or caught by anglers over the past 20 - 25 years. It is widely known that the Missouri River from South Dakota to it's mouth had been excessively altered for flood control, navigation, and hydroelectric generation (Gilbraith et al 1988). This segment of the river is thought to have been the most suitable for pallid sturgeon prior to these alterations. As a result, sections of the Missouri and Yellowstone Rivers in North Dakota and Montana, which were probably on the fringes of the pallid sturgeon's historic range, appear today to be the last remaining strongholds for the species.

A proposal from MDFWP was sent to the U.S. Army Corps of Engineers (COE) Omaha District Office on June 6, 1988, seeking funding to carry out pallid sturgeon research in the Missouri River below Fort Peck Dam. The logic of MDFWP to carry out the research, given the interest and lack of knowledge about the pallid, was that the COE should know as much about the status, reproductive success, and life-cycle requirements of the pallid prior to it's potential listing so they would have some idea of the effects of dam operations on the species, and so that there would be at least some data available to support or refute the need to list. A contract between the COE and MDFWP was effected on April 1, 1989.

Operating under the presumption that a contract would be negotiated, MDFWP tested radio-telemetry equipment in the waters of the Missouri River, and purchased six transmitters for use on pallid sturgeon. Three pallids were captured by SCUBA divers in the Fort Peck tailrace in March, 1989, and transmitters were mounted on their backs.

STUDY AREA

A thorough description of the Missouri River below Fort Peck Dam is presented in Gardner and Stewart (1987) (Figure 1). Although flows are regulated by the discharge of Fort Peck Dam, this segment of the river is relatively unaltered morphologically from it's natural state, except in the 10 mile stretch immediately below the dam. This stretch of the river was impacted during construction of the dam, the results of these impacts are still evident.

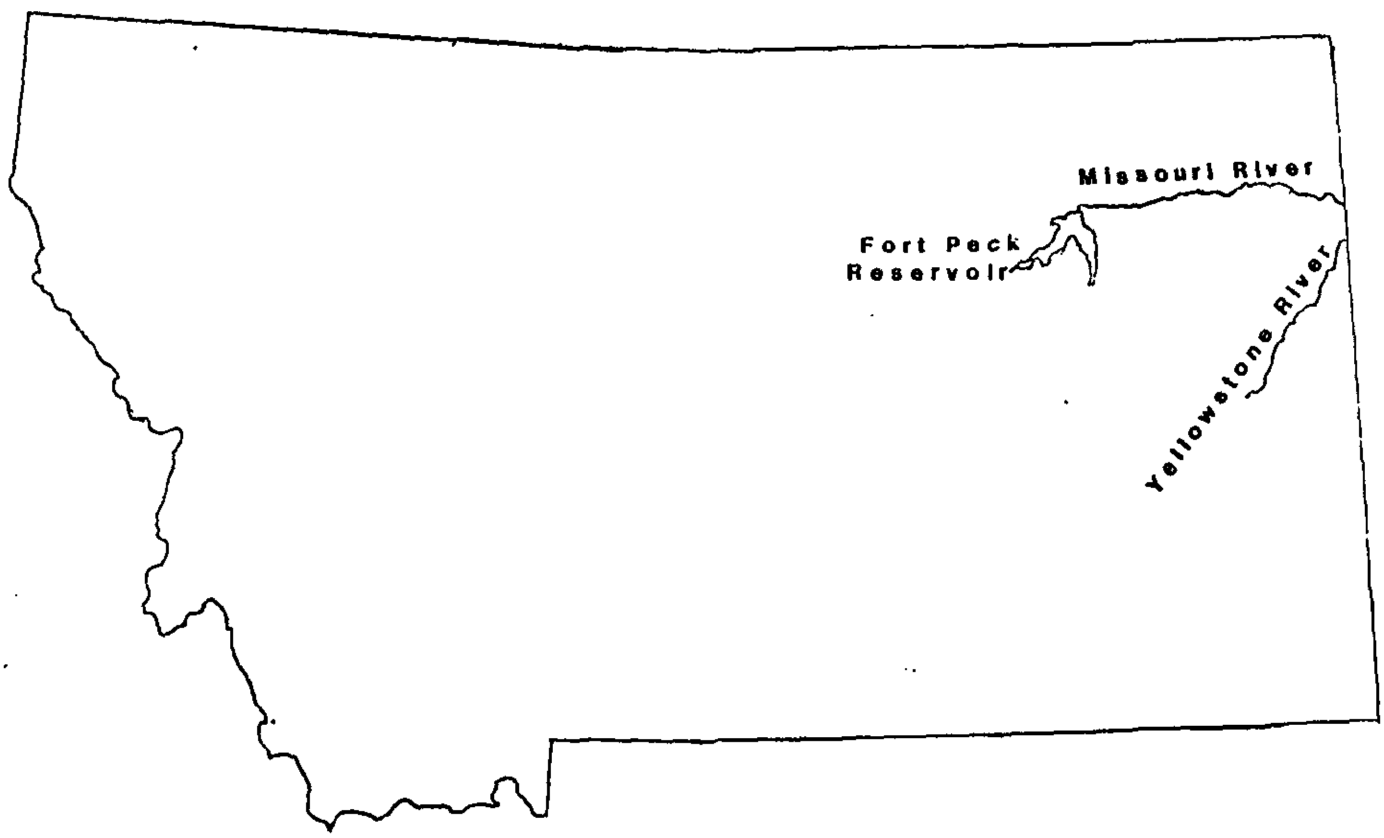

Figure 1. Map of Montana showing Missouri River below Fort Peck Reservoir and Yellowstone River below Glendive.

METHODS

Pallid sturgeon were captured in the Fort Peck tailrace by SCUBA divers from the Prairie SCUBA Club who were able to capture the fish by hand and place them in a large net bag with a drawstring for transporting them to the surface. Once at the surface, the fish were handed over to a crew in a boat, and the fish was weighed to the nearest kilogram on a spring scale. Morphological and meristic measurements were made on each fish (Figure 2), and they were tagged through the posterior base of the dorsal fin with a numbered fingerling dangler tag. A radio transmitter was attached to each pallid in a fashion similar to the diagram in Figure 3. This was accomplished by drilling two holes through the dorsal scutes of the fish, passing a stainless steel wire through a hole at each end of the transmitter and through the holes in the scute, and using crimping sleeves to secure the wire on the opposite side of the fish. A recurved plastic plate was placed between the wire and the fish on the side of the fish opposite the transmitter to prevent the wire or the crimping sleeves from irritating the fish (Figure 3). This technique, or a slight modification of it, was used successfully on white sturgeon in Washington (Haynes et al. 1978), and on shortnose and atlantic sturgeon in South Carolina (Smith et al 1988). External transmitter mounts were used because they are less stressful to the fish than implants. The transmitters were designed to emit a signal roughly every 1.5 seconds for a minimum of 18 months, and were built with whip transmitting antenna.

The morphological measurements taken from each pallid were computed into percent of standard length for comparison to other studies and to shovelnose sturgeon. Shovelnose were captured by gillnetting throughout the Missouri and Yellowstone Rivers, and the same measurements were taken from them to compare to those of the pallids to try to determine if hybridization had occurred.

Passive Integrated Transponder (PIT) tags were to be injected into the dorsal musculature of the pallids near the dorsal fin to serve as long-term identification for each individual fish. However, neither the tags nor the tag applicator were available when the pallids were in hand in March.

Primary locations of the transmitted pallid sturgeon were made from an airplane by attaching a whip antenna to the wingstrut of the craft with the tip pointed toward the ground and following the course of the river. A scanning receiver was employed to monitor all frequencies simultaneously. Once a location was made, it was noted on a map. We then returned to the location by boat to attempt a more precise location and to collect habitat selection data. A directional hand-held loop antenna was used to locate the fish from the boat. Parameters collected were water depth, water temperature, conductivity, turbidity, dissolved oxygen concentration (D.O.), and current velocity near the river bottom. A substrate sample was collected by dragging a pipe dredge through the area where the sturgeon had been located. The samples were examined for substrate composition and potential food items.

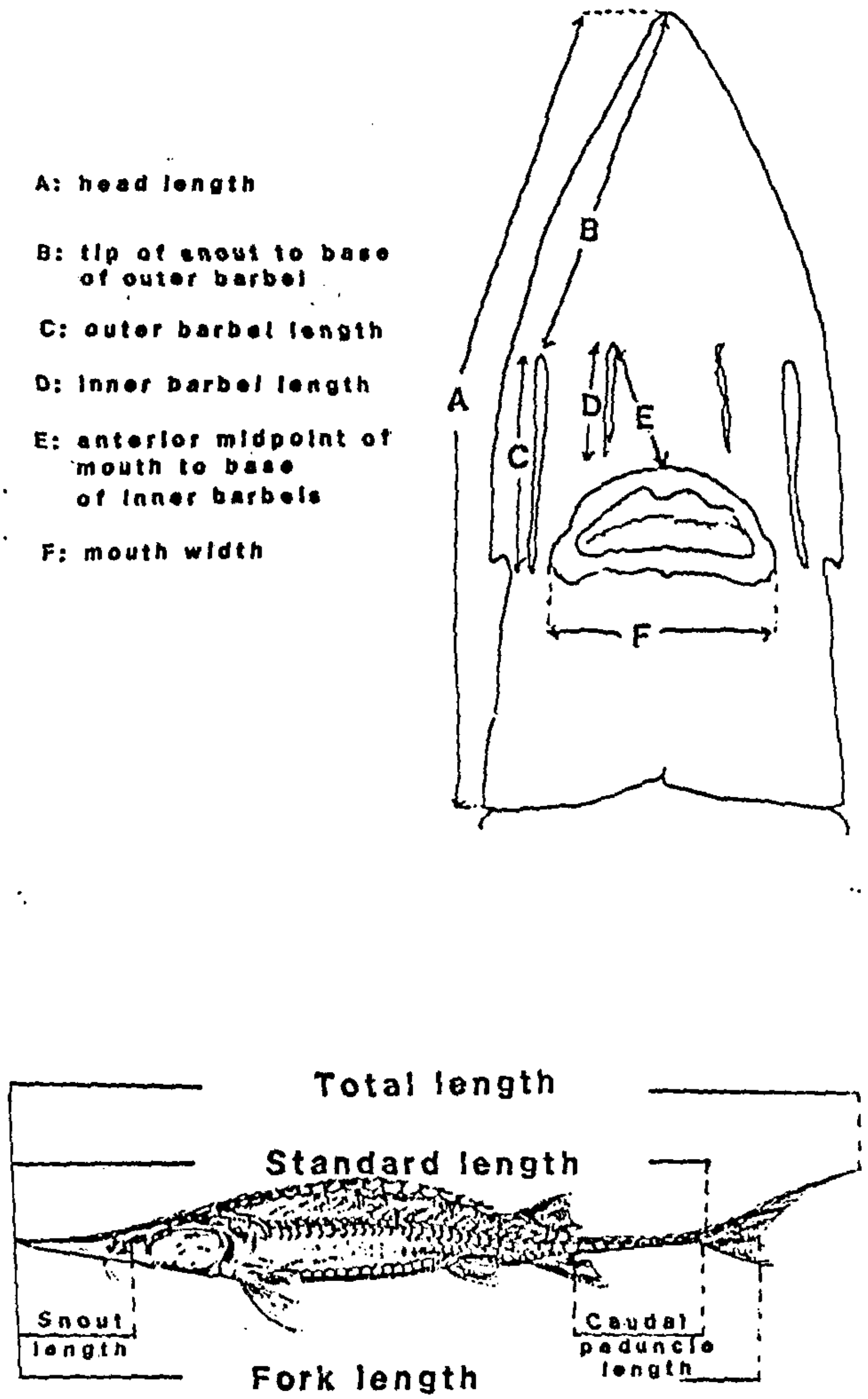

Figure 2. Morphological measurements taken from pallid and shovelnose sturgeon in the Missouri and Yellowstone Rivers.

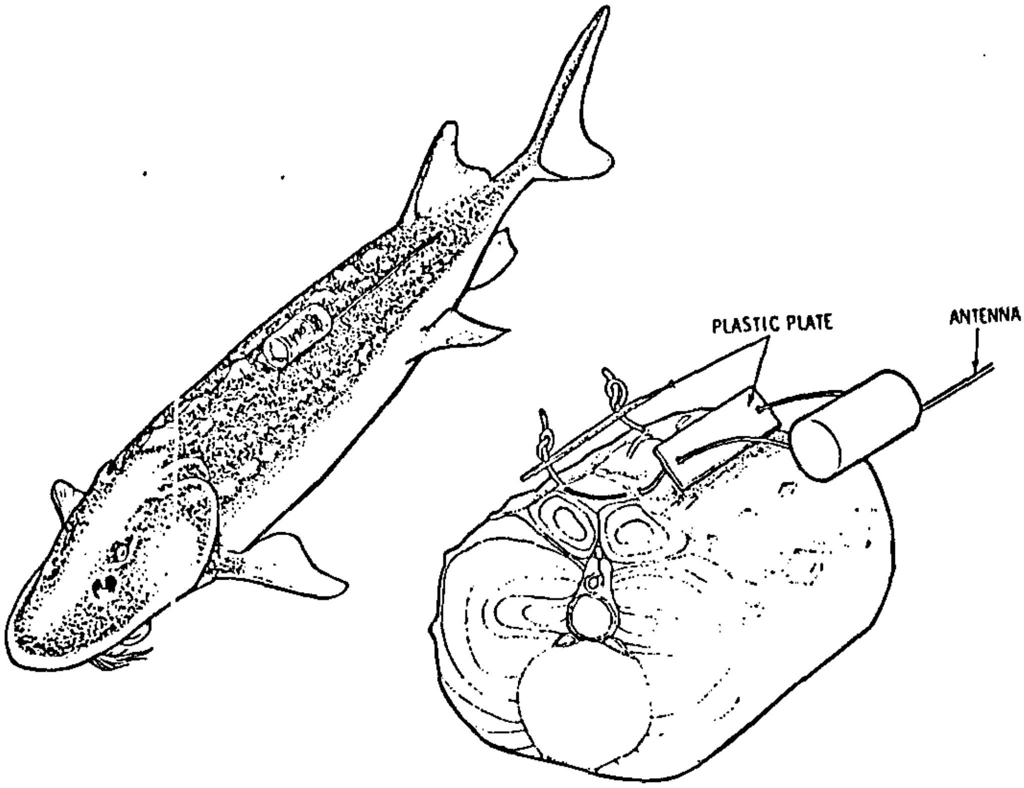

Figure 3. Transmitter attachment method (from Haynes it al 1978)

Two shovelnose sturgeon were implanted with internal transmitters in August, 1989, to test the feasibility of using implants on pallids. Both shovelnose were released in the river at Wolf Point, but neither has been relocated since the day after their release. Both implant transmitters were built with internal coil antennae. A coil antenna transmits more efficiently than a whip, but a whip antenna radiates a more powerful signal than a coil. Comparisons of the implant and external transmitters showed that the external transmitter, with a whip antenna, gave a stronger signal than the implant transmitter before either was deployed. Our experiences show that the same held true after the transmitters were deployed- the signals from the external transmitters were easily received while those from the implant transmitters were lost shortly after deployment.

RESULTS AND DISCUSSION

Three pallid sturgeon were captured by SCUBA divers during March, 1989, morphological and meristic measurements were taken (Table 1), and they were mounted with radio transmitters. The thickness of the fins made accurate counts of the number of fin-rays difficult. The fish were released along the shoreline near where they were captured, and were observed for several minutes before they moved back into deeper water. During the few minutes that they were visible, none of the pallids exhibited any ill effects from being handled or tagged.

Two of the three transmitted pallids, the two largest, were located on March 28, downstream from the mouth of the Milk River (Figure 4). Both of these fish remained in their respective areas of the river until about mid-May, then began migrating farther downstream. The largest fish, which weighed 53 pounds, moved approximately 105 river miles downstream from Fort Peck by mid-June, while the other, which weighed 33 pounds, moved about 45 river miles downstream. The third pallid, which weighed 29 pounds, was never relocated by radio telemetry. It was caught and released by two walleye anglers in the Fort Peck tailrace on April 28, very close to the sight where it was originally captured by us. The anglers snagged the fish while jigging for walleye, but were not able to boat the fish. It escaped from them at the side of the boat as they were trying to remove the hook. The anglers said that the transmitter appeared to be snugly attached to the fish when they caught it.

The two pallids which migrated downstream both dropped their transmitters around mid-June. Both of these fish were mounted with transmitters on March 10, and both fish dropped their transmitters at nearly the same time. We suspect that the stainless steel wire used to mount the transmitter through the dorsal scutes was too rigid, and that the vibrations on the wire caused by water moving past the transmitter caused the wire to "slice" through the scutes, eventually causing the transmitter to become detached from the fish. Researchers in South Carolina used monel wire, a softer wire than stainless steel. They had virtually no loss of transmitters from either shortnose or atlantic sturgeon. We have obtained a spool of monel wire for use this winter in mounting transmitters to pallids.

The 29 pound pallid was recaptured in a gillnet in the Fort Peck tailrace on August 25. It apparently had remained in the deep waters of the tailpool all summer, and it also had lost it's transmitter. The 40 foot deep waters of the tailpool are too deep for the transmitter signal to penetrate. The maximum depth that the signal could be detected during testing was about 20 feet. Examination of the dorsal scutes indicated that the stainless steel wire had torn it's way through the scutes, leaving abrasions on the back of the fish. It did not appear that the fish's immune system had rejected the wire and caused it to be expelled from the fish, as has been the problem in some paddlefish studies. The fingerling dangler tag was still intact, and the vinyl thread used to attach it to the ventral base of the

Table 1. Morphological and meristic measurements taken from three pallid sturgeon captured in the Fort Peck tailrace in 1989. Morphological measurements are in inches and percent of standard length is in parentheses.

	pallid sturgeon transmitter number			
	502	526	552	452[1]
weight (kg)	15.0	24.0	13.0	12.0
total length	62.0	64.0	56.5	55.1
fork length	58.4	60.5	52.0	50.3
standard length	55.0 (100)	60.0 (100)	49.5 (100)	47.5 (100)
head length	18.5 (33.6)	20.0 (33.3)	16.0 (32.3)	15.9 (33.4)
mouth width	5.0 (9.1)	5.8 (9.7)	4.5 (9.1)	4.6 (9.7)
snout to outer barbel	8.0 (14.6)	8.1 (13.5)	7.0 (14.1)	6.9 (14.5)
mouth to inner barbel	2.3 (4.1)	2.5 (4.2)	2.0 (4.0)	2.0 (4.2)
inner barbels[2]	1.4 (2.5)	1.8 (3.0)	1.5 (3.0)	1.6 (3.4)
outer barbels[3]	4.3 (7.8)	6.0 (10.0)	3.9 (7.9)	3.9 (8.2)
snout length	10.0 (18.2)	10.5 (17.5)	8.5 (17.2)	8.4 (17.7)
caudal peduncle length	6.5 (11.8)	7.0 (11.7)	6.5 (13.1)	6.4 (13.4)
girth at widest	21.0 (38.2)	25.0 (41.7)	21.3 (43.0)	20.4 (42.9)
dorsal fin rays	31	27	30	32
anal fin rays	16	15	18	15
pelvic fin rays	19	18	17	17
pectoral fin rays	25	37	44	36
belly scutellation	no	no	no	no

1 same fish as 552, caught 5 months later
2 average of the 2 inner barbel lengths
3 average of the 2 outer barbel lengths

symbol	transmitter number
a	502
b	526
c	552

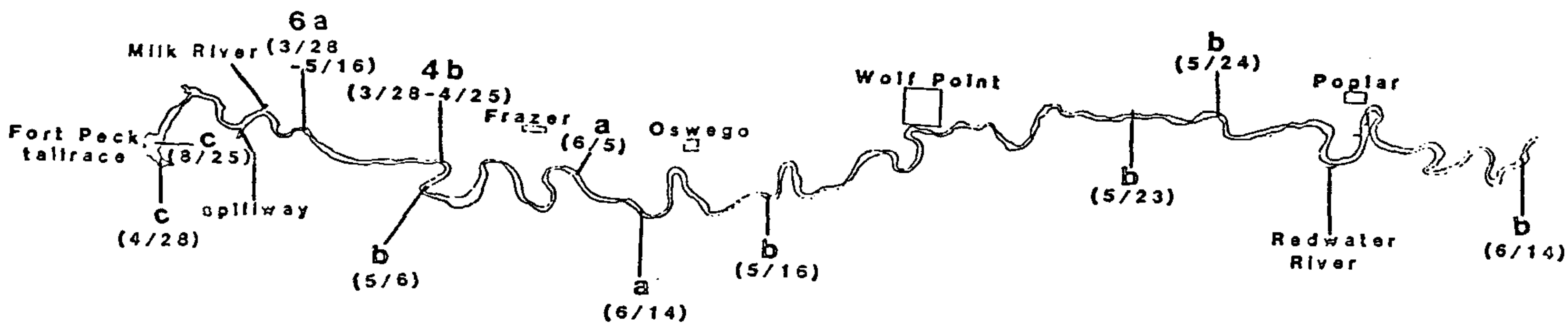

Figure 4. Sights of pallid sturgeon relocations in the Missouri River. Dates of the relocations are in parentheses. Transmitter symbols preceeded by a number (i.e. 6a) indicate the number of relocations at that sight between the corresponding dates.

dorsal fin was well imbedded in the fin. This pallid was remounted with another transmitter, and two strands of monel wire, one 30 lb. test and one 40 lb. test, were used to attach the transmitter. These strands of monel wire had been given to us as samples. We hope that we will sight this pallid during our winter SCUBA surveys, and at that time will be able to determine if the monel wire prevents transmitter loss. If this fish has lost, or is losing, it's transmitter when we sight it, we will implant the transmitters rather than mount them externally. A local veterinarian may be willing to volunteer his time to assist in implanting the transmitters. A PIT tag was injected into the dorsal musculature of this fish at this time.

Each time the pallids were located from the boat, habitat selection parameters were collected (Table 2). Because our D.O., conductivity, and turbidity meters didn't arrive until May, we were able to collect data from only five locations before the fish dropped their transmitters. Each time the pallids were located near Fort Peck, they were along the north bank of the Missouri River. This is most likely due to the fact that the Milk River, which enters the Missouri from the north, creates a large sediment plume. As the pallids migrated downstream in the Missouri, they selected the most turbid water until the Milk River water became well mixed with the Missouri River water. The Missouri River water was substantially less turbid than that of the Milk because of the hypolimnial releases from Fort Peck Reservoir.

Table 2. Pallid sturgeon habitat selection data.

pallid number	date	D.O.	cond. mhos	turb.	water temp.	depth	current vel(m/s)
502	6/6/89	12.8	430	12	13 C	--	--
	6/14/89	11.6	495	12	13	6.5'	.85-.90
526	5/1/89	13.0	440	>100	7.5	8.9'	--
	5/24/89	12.6	510	62	14	6-8'	.35-.40
	6/15/89	10.0	505	51	17	5.5'	.46

The ratio of pallid sturgeon characteristics used by Bailey and Cross (1954) are compared to those attained during our first field season in Table 3. Our values exceeded their's on almost all accounts. They also state that the caudal peduncle lengths of the pallids used in their study were 15-26 percent of standard length. The greatest caudal peduncle length to this point in our study is 13.4 percent of standard length.

Comparisons of pallid and shovelnose sturgeon morphometric characteristics are shown in Table 4. Too few pallids were captured and measured to allow valid statistical comparisons, but cursory examination of the data shows that the variation of any one characteristic among the shovelnose is very wide. Several

Table 3. Comparison of characteristics of pallid sturgeon used by Bailey and Cross (1954) and those of this study. See Figure 2 for ratio definitions.

	pallid sturgeon number				
	502	526	552	452[1]	Bailey & Cross
E in B=	3.47	3.24	3.50	3.45	2.3-3.3
E in F=	2.17	2.32	2.25	2.30	1.6-2.0
E in A=	8.04	8.00	8.00	7.95	5.5-7.0
D in B=	5.71	4.50	4.67	4.31	2.6-3.7
D in C=	3.07	3.33	2.60	2.44	1.6-2.4
D in A=	13.21	11.11	10.67	9.94	6.3-8.0

[1] same fish as 552, caught 5 months later

Table 4. Average percent of standard length of morphological measurements of pallid sturgeon compared to shovelnose sturgeon from the Missouri and Yellowstone Rivers.

		shovelnose	
	pallid	Missouri	Yellowstone
number	4	54	22
head length	33.2	29.0	29.5
mouth width	9.4	7.8	8.0
snout to outer barbels	14.2	9.9	10.4
mouth to inner barbels	4.1	6.6	6.5
inner barbels	3.0	6.1	6.5
outer barbels	8.5	8.1	8.8
snout length	17.6	15.6	15.6
caudal peduncle length	12.5	16.2	15.5
girth at widest	41.4	34.5	35.9

shovelnose exhibit two or more characteristics that appear more similar to pallid characteristics than to other shovelnose, however, much more data collection and detailed study is necessary to validate or refute any hybridization claims. Pflieger (1975) uses the number of fin rays in the dorsal and anal fins to distinguish between pallid and shovelnose sturgeon. He states that pallids will have 37 or more dorsal fin rays and 24 or more anal fin rays, while shovelnose will have fewer than 37 and 24, respectively. Our counts of fin rays in shovelnose sturgeon substantiated those characteristics, but the thickness of the fins and the large number of fin rays in the pallids made accurate counts extremely difficult. By our counts, the pallids we handled averaged 30 dorsal fin rays and 17 anal fin rays.

Four substrate samples were collected from pallid sturgeon location sights. All four were composed entirely of sand, and none contained any food particles such as insects or fish remains.

Much of the field season was spent drifting and setting gillnets in the Missouri and Yellowstone Rivers for pallid and shovelnose sturgeon. Several gillnets were either lost completely or damaged beyond use due to the large volume of debris in the rivers.

Sea Farms of Norway, a commercial fish marketing company, has applied to the State of Montana to build and operate a white sturgeon hatchery on Warm Springs Creek near Lewistown, Montana. They propose to raise white sturgeon for commercial sale of the meat. Water from Warm Springs Creek ultimately drains into the Missouri River. We are concerned that the accidental introduction of white sturgeon, or disease or parasites carried by white sturgeon, into the Missouri River may adversely impact the fisheries of the Missouri River, specifically pallid sturgeon. Sea Farms put their application on hold for a period of several months after juvenile white sturgeon in their California hatchery experienced unexplainably high mortality rates. They have since isolated a virus which they believe caused the mortality, but have yet to identify it or determined if it is transmissible to species other than white sturgeon.

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Appendix Table 1. Empirical measurements and percent of standard length of shovelnose sturgeon captured in the Missouri and Yellowstone Rivers, Montana. Definitions of abbreviations precede the table, and some are illustrated in Figure 2.

TL- total length
FL- fork length
SL- standard length
HL- head length (distance from tip of snout to posterior edge of gill opening)
MW- mouth width
SNTOUT- distance from tip of snout to base of outer barbels.
MTHIN- distance from anterior midpoint of mouth to base of inner barbels.
SNTL- distance from tip of snout to anterior edge of eye.
CDPED- distance from posterior base of anal fin to anterior base of caudal fin.
GIR- girth at the widest point of the body (usually just behind the pectoral fins)
DF- number of dorsal fin rays
AF- number of anal fin rays
PV- number of pelvic fin rays
PC- number of pectoral fin rays
INBRBS- average length of the two inner barbels
OUTBRBS- average length of the two outer barbels

Missouri River
empirical measurements

row	TL	FL	SL	HL	MW	SNTOUT	MTHIN	SNTL	CDPED	GIR	DF	AF	PV	PC	INBRBS	OUTBRBS
1	31.5	28.0	27.0	8.0	2.0	2.9	1.9	4.5	4.0	9.8	30	18	24	43	1.80	2.1
2	24.0	23.1	22.5	6.6	1.6	2.2	1.6	3.8	3.5	7.9	30	18	28	48	1.30	1.9
3	31.4	28.9	26.7	8.0	2.0	2.6	1.8	4.3	4.0	8.7	30	17	19	42	1.80	2.4
4	26.6	25.0	23.0	6.6	1.8	2.1	1.5	3.7	4.2	7.2	26	12	20	36	1.35	1.8
5	27.2	24.8	23.0	6.5	1.9	2.2	1.6	3.5	3.1	7.0	24	14	12	27	1.80	1.6
6	29.0	26.0	24.8	7.5	2.0	2.4	1.5	3.8	4.1	8.8	19	11	17	24	1.25	2.1
7	24.0	22.2	20.6	5.8	1.6	2.0	1.5	3.1	3.8	7.1	18	12	13	27	1.20	1.6
8	27.1	25.0	23.2	6.4	1.8	2.2	1.5	3.8	4.1	7.4	18	11	16	29	1.30	1.6
9	26.0	23.8	22.0	6.5	1.8	2.3	1.4	3.6	3.7	8.3	21	13	12	33	1.40	1.6
10	27.5	25.5	23.5	6.5	1.8	2.0	1.5	3.5	4.0	8.2	27	15	20	33	1.40	1.9
11	27.2	25.9	24.0	6.9	1.6	2.2	1.5	3.1	4.0	8.4	26	15	17	32	1.15	1.8
12	24.8	22.2	20.6	5.8	1.5	1.8	1.5	3.1	3.5	8.0	21	25	18	33	1.30	1.9
13	24.1	21.2	20.1	5.2	1.5	1.7	1.4	2.9	3.5	7.5	25	14	18	35	0.85	1.3
14	25.9	23.4	21.9	6.2	1.6	3.2	1.5	3.4	3.2	6.5	23	12	16	34	1.30	1.7
15	26.5	24.5	22.5	6.5	1.8	2.4	1.6	3.7	3.6	8.0	26	13	18	34	1.20	1.8
16	25.5	23.0	21.5	6.0	1.4	1.9	1.4	3.1	3.2	8.4	25	12	15	33	1.35	1.9
17	27.8	24.5	22.6	6.5	1.9	2.3	1.5	3.6	3.8	7.4	22	12	17	33	1.40	1.9
18	28.3	26.6	24.5	6.9	1.8	2.5	1.6	3.8	3.8	8.2	26	12	18	34	1.25	1.8
19	28.9	26.5	24.9	7.0	1.9	2.2	1.5	3.7	4.0	8.8	25	12	21	35	1.65	2.3
20	28.0	22.2	20.5	6.2	1.5	2.2	1.5	3.5	3.2	7.0	23	13	16	32	1.40	1.9
21	24.1	22.5	21.1	5.9	1.5	2.1	1.4	3.2	4.0	7.1	25	13	21	41	1.20	1.5
22	27.3	23.8	21.8	6.4	1.8	2.2	1.4	3.5	3.9	7.0	21	14	17	34	1.30	1.9
23	27.0	24.2	22.5	6.8	2.0	2.4	1.5	3.9	3.4	8.1	20	15	20	30	1.30	1.6
24	30.0	27.0	24.8	7.8	2.0	2.6	1.8	4.0	4.4	9.1	25	14	18	33	1.30	2.2
25	25.6	24.9	22.9	6.5	1.9	2.3	1.6	3.8	3.9	8.0	26	14	19	34	1.40	2.2
26	28.1	23.3	21.4	6.3	1.8	2.0	1.5	3.3	3.6	7.0	26	16	20	38	1.40	1.9
27	29.5	27.6	25.5	7.5	2.0	2.5	1.6	4.0	3.8	9.5	27	13	15	31	1.35	1.9
28	27.9	24.5	22.8	6.3	1.8	2.1	1.4	3.4	4.4	7.6	23	12	15	31	1.35	1.8
29	30.5	28.9	26.9	7.8	2.4	2.6	1.8	4.0	4.0	10.0	20	10	14	24	1.45	2.2
30	32.6	27.5	25.4	7.5	2.3	2.8	1.8	4.0	3.9	8.6	22	12	13	30	1.50	2.0
31	26.5	22.4	20.5	6.8	1.6	2.0	1.3	3.4	3.1	6.5	22	9	12	30	1.10	1.6
32	27.6	25.9	24.0	7.0	2.3	2.5	1.4	3.6	3.6	7.9	23	11	15	29	1.50	1.9
33	29.0	27.0	24.6	6.8	1.6	2.3	1.6	3.8	4.4	8.1	24	12	17	32	1.80	2.1
34	28.4	25.9	23.9	6.8	1.9	2.1	1.6	3.6	4.0	9.4	24	13	14	30	1.55	2.1
35	24.5	21.9	19.9	5.5	1.5	1.9	1.3	3.0	3.8	6.5	25	12	19	33	1.30	1.6
36	36.1	34.0	31.5	9.0	2.8	3.0	1.9	4.6	4.5	12.4	21	12	16	31	1.55	2.4
37	28.1	25.8	24.3	7.5	1.9	2.4	1.6		3.8	7.9	23	13	18	32	1.80	2.4
38	27.8	24.8	23.8	6.9	1.8	2.4	1.5	3.5	4.0	7.9	24	14	17	29	1.45	1.9
39	25.0	23.5	22.8	6.6	1.6	2.3	1.5	3.6	3.0	6.9	22	12	17	28	1.55	2.1
40	27.5	25.0	23.0	6.8	1.9	2.1	1.8	3.5	3.8	7.9	23	13	12	26	0.95	1.4
41	26.9	24.1	22.3	6.5	2.0	2.4	1.6	3.8	3.8	7.5	21	11	12	29	1.40	1.9
42	25.8	23.5	22.0	6.3	1.8	2.1	1.4	3.3	3.9	6.6	21	9	13	27	1.40	2.0
43	30.0	27.9	25.5	7.9	2.3	2.6	1.8	4.1	3.9	8.6	25	13	17	32	1.85	2.2
44	29.4	27.4	25.5	7.8	1.6	2.6	1.8	4.0	3.9	8.8	21	11	15	30	1.40	2.0
45	28.1	26.0	24.6	6.5	1.5	2.3	1.5	3.4	4.5	8.5	21	10	18	28	1.50	2.0
46	28.1	25.6	24.1	7.3	2.0	2.4	1.6	3.9	3.8	9.0	25	12	16	29	1.55	2.3
47	34.5	31.3	28.9	8.0	2.1	2.9	1.4	4.4	4.5	10.5	24	14	20	31	1.95	2.8
48	25.3	23.6	22.5	6.6	1.4	2.5	1.5	3.8	3.4	6.6	23	12	20	27	1.50	2.0
49	29.5	28.4	26.4	8.0	2.0	2.5	2.0	4.3	4.4	10.1	21	12	13	28	1.65	2.4
50	26.6	23.0	21.3	6.4	1.6	2.1	1.3	3.4	3.6	7.1	22	12	12	29	1.40	1.7
51	33.9	29.4	27.4	7.5	2.3	2.8	1.6	3.9	3.9	10.4	23	12	14	26	1.80	2.4
52	34.0	31.0	28.9	8.8	2.8	2.9	2.0	4.6	3.9	11.3	21	10	11	28	1.95	2.5
53	27.1	24.5	22.4	6.3	1.8	2.0	1.4	3.4	3.9	7.6	23	10	12	26	1.25	1.6
54	29.8	26.5	24.5	7.5	2.0	2.5	1.5	4.0	3.9	8.6	20	9	11	24	1.60	2.1

Missouri River
percent of standard length

row	HLP	SNTLP	MWF	SNTOUTP	MTHINP	CDPEPP	GIRP	OUTBRBSP	INBRBSP
1	29.6	16.7	7.4	10.7	7.0	14.8	35.3	7.6	6.7
2	29.3	16.9	7.1	9.8	7.1	15.6	35.1	8.2	5.8
3	30.0	16.1	7.5	9.7	6.7	15.0	32.6	8.8	6.7
4	28.7	16.1	7.8	9.1	6.5	18.3	31.3	7.8	5.9
5	28.3	15.2	8.3	9.6	7.0	13.5	30.4	6.7	7.8
6	30.2	15.3	8.1	9.7	6.0	16.5	35.5	8.5	5.0
7	28.2	15.0	7.8	9.7	7.3	18.4	34.5	7.5	5.8
8	27.6	16.4	7.8	9.5	6.5	17.7	31.9	6.9	5.6
9	29.5	16.4	8.2	10.5	6.4	16.8	37.7	7.0	6.4
10	27.7	14.9	7.7	8.5	6.4	17.0	34.9	7.9	6.0
11	28.8	12.9	6.7	9.2	6.3	16.7	35.0	7.5	4.8
12	28.2	15.0	7.3	8.7	7.3	17.0	38.8	9.0	6.3
13	25.9	14.4	7.5	8.5	7.0	17.4	37.3	6.5	4.2
14	28.3	15.5	7.3	14.6	6.8	14.6	29.7	7.5	5.9
15	28.9	15.4	8.0	10.7	7.1	16.0	35.6	7.8	5.3
16	27.9	14.4	6.5	8.8	6.5	14.9	39.1	8.8	6.3
17	28.8	15.9	8.4	10.2	6.6	16.8	32.7	8.4	6.2
18	28.2	15.5	7.3	10.2	6.5	15.5	33.5	7.1	5.1
19	28.1	14.9	7.6	8.8	6.0	16.1	35.3	9.2	6.6
20	30.2	17.1	7.3	10.7	7.3	15.6	34.1	9.0	6.8
21	28.0	15.2	7.1	10.0	6.6	19.0	33.6	7.1	5.7
22	29.4	16.1	8.3	10.1	6.4	17.9	32.1	8.7	6.0
23	30.2	16.9	8.9	10.7	6.7	15.1	36.0	6.9	5.8
24	31.5	16.1	8.1	10.5	7.3	17.7	36.7	8.9	5.2
25	28.4	16.6	8.3	10.0	7.0	17.0	34.9	9.6	6.1
26	29.4	15.4	8.4	9.3	7.0	16.8	32.7	8.6	6.5
27	29.4	15.7	7.8	9.8	6.8	14.9	37.3	7.3	5.3
28	27.6	14.9	7.9	9.2	6.1	19.3	33.3	7.7	5.9
29	29.0	14.9	8.9	9.7	6.7	14.9	37.2	8.0	5.4
30	29.5	15.7	9.1	11.0	7.1	15.4	33.9	7.9	5.9
31	33.8	16.6	7.8	9.8	6.3	15.1	31.7	7.8	5.4
32	29.1	15.0	9.6	10.4	5.8	15.0	32.9	7.9	6.3
33	27.5	15.4	6.5	9.2	6.5	17.9	32.9	8.5	7.3
34	28.5	15.1	7.9	8.8	6.7	16.7	35.1	8.6	6.5
35	27.5	15.1	7.5	9.5	6.5	19.1	33.2	8.0	6.5
36	28.6	14.6	8.9	9.5	6.0	14.3	39.4	7.5	4.9
37	30.9		7.8	9.9	6.6	15.6	32.5	9.9	7.4
38	29.0	14.7	7.6	10.1	6.3	16.8	33.2	9.0	6.1
39	28.9	15.8	7.0	10.1	6.6	13.2	30.3	9.0	6.8
40	29.6	15.2	8.3	9.1	7.8	16.5	34.3	6.1	4.1
41	29.1	17.0	9.0	10.8	7.2	17.0	33.6	8.3	6.3
42	28.6	15.0	8.2	9.5	6.4	17.7	30.0	8.9	6.4
43	31.0	16.1	9.0	10.2	7.1	15.3	33.7	8.6	7.3
44	30.6	15.7	5.3	10.2	7.1	15.3	34.5	7.6	5.5
45	26.4	13.8	6.1	9.3	6.1	18.3	34.6	8.1	6.1
46	30.3	16.2	8.3	10.0	6.6	15.8	37.3	9.5	6.4
47	27.7	15.2	7.3	10.0	4.8	15.6	36.3	9.7	6.7
48	29.3	16.9	6.2	11.1	6.7	15.1	29.3	8.9	6.7
49	30.3	16.3	7.6	9.5	7.6	16.7	38.3	9.1	6.3
50	30.0	16.0	7.5	9.9	6.1	16.9	33.3	7.7	6.6
51	27.4	14.2	8.4	10.2	5.9	14.2	38.0	8.6	6.6
52	30.4	15.9	9.7	10.0	6.9	13.5	39.1	8.7	6.7
53	28.1	15.2	8.0	8.9	6.3	17.4	33.9	7.1	5.6
54	30.6	16.3	8.2	10.2	6.1	15.9	35.1	8.6	6.5

Yellowstone River
empirical measurements

row	TL	FL	SL	HL	SNTL	MW	SHTOUT	MTHIN	CDPED	GIR	DF	AF	PV	PC	OUTBRBS	INBRBS
1	37.4	34.8	32.5	10.0	5.0	3.0	3.1	2.0	4.8	11.3	26	10	13	25	2.9	2.2
2	31.9	28.8	27.3	7.6	4.1	2.1	2.6	1.5	3.9	10.9	27	10	13	28	2.0	1.4
3	32.1	29.3	27.3	8.0	4.3	2.6	2.9	1.6	5.0	11.0	25	11	14	31	2.0	1.2
4	20.0	17.9	16.4	5.0	2.8	1.4	1.8	1.0	3.0	5.4	25	10	14	29	1.2	1.1
5	31.3	30.0	28.0	8.4	4.3	2.5	2.8	2.0	3.6	11.4	22	12	14	34	2.5	1.9
6	28.6	25.9	24.0	7.3	3.9	2.3	2.8	1.5	3.8	9.0	23	13	15	33	2.2	1.6
7	28.1	24.9	23.1	6.6	3.8	1.8	2.6	1.5	3.6	8.5	24	14	15	29	1.9	1.4
8	33.5	30.6	29.0	8.1	4.3	2.1	2.9	1.9	4.0	10.5	21	10	13	26	2.6	2.0
9	35.1	32.3	30.0	9.1	4.8	2.1	3.0	2.1	3.6	10.8	25	12	19	27	3.0	2.0
10	29.5	24.0	23.0	6.5	3.6	1.5	2.6	1.6	3.8	7.5	24	12	18	31	1.9	1.5
11	28.3	25.0	23.1	6.9	3.8	1.8	2.5	1.5	3.4	7.8	23	11	16	30	2.3	1.5
12	30.9	28.3	26.8	7.9	2.3	1.8	2.8	1.4	4.3	9.5	25	12	17	26	2.8	1.9
13	34.9	31.9	29.4	8.5	4.6	2.3	2.9	2.5	4.6	11.6	25	13	18	25	2.6	2.2
14	24.3	19.0	17.1	5.1	2.9	1.5	2.0	1.1	3.0	6.4	25	10	17	29	1.2	0.9
15	28.0	24.1	22.4	6.5	3.5	1.5	2.4	1.4	3.9	7.9	18	11	12	28	1.9	1.4
16	28.4	23.4	21.5	6.3	3.4	1.9	2.1	1.3	3.1	7.5	26	10	12	28	1.8	1.3
17	33.3	30.5	28.5	8.3	4.4	2.1	2.8	1.9	4.0	9.4	24	12	13	29	3.0	2.0
18	29.0	26.4	24.5	7.5	4.0	1.8	2.5	1.6	4.0	9.5	24	11	15	30	2.4	1.7
19	32.4	30.3	28.1	8.9	4.8	2.4	3.0	2.1	4.1	10.1	23	11	13	28	3.0	2.2
20	28.8	27.1	25.9	8.0	4.3	2.3	2.5	1.8	3.5	8.4	21	12	17	28	2.4	2.0
21	24.6	21.6	19.8	5.6	3.1	1.4	2.0	1.3	3.5	6.6	23	11	14	25	1.7	1.3
22	25.9	19.6	18.5	5.1	2.9	1.3	1.9	1.1	3.1	6.1	25	11	15	28	1.5	1.1

Yellowstone River
percent of standard length

row	HLP	SNTLP	MWP	SNTOUTP	MTHINP	CDPEDP	GIRP	OUTBRBSP	INBRBSP
1	30.8	15.4	9.2	9.5	6.2	14.8	34.8	8.9	6.8
2	27.8	15.0	7.7	9.5	5.5	14.3	39.9	7.3	5.1
3	29.3	15.8	9.5	10.6	5.9	18.3	40.3	7.3	4.4
4	30.5	17.1	8.5	11.0	6.1	18.5	32.9	7.3	5.4
5	30.0	15.4	8.9	10.0	7.1	12.9	40.7	8.8	6.8
6	30.4	16.3	9.6	11.7	6.3	15.8	37.5	9.2	6.7
7	28.6	16.5	7.8	11.3	6.5	15.6	36.8	8.2	6.1
8	27.9	14.8	7.2	10.0	6.6	13.8	36.2	8.8	6.9
9	30.3	16.0	7.0	10.0	7.0	12.0	36.0	10.0	6.7
10	28.3	15.7	6.5	11.3	7.0	16.5	32.6	8.3	6.3
11	29.9	16.5	7.8	10.8	6.5	14.7	33.8	10.0	6.3
12	29.5	8.6	6.7	10.4	5.2	16.0	35.4	10.4	7.1
13	28.9	15.6	7.9	9.9	8.5	15.6	39.5	8.7	7.5
14	29.8	17.0	8.8	11.7	6.4	17.5	37.4	7.0	5.3
15	29.0	15.6	6.7	10.7	6.3	17.4	35.3	8.3	6.3
16	29.3	15.8	8.8	9.8	6.0	14.4	34.9	8.4	6.0
17	29.1	15.4	7.4	9.8	6.7	14.0	33.0	10.5	7.0
18	30.6	16.3	7.3	10.2	6.5	16.3	38.8	9.6	6.9
19	31.7	17.1	8.5	10.7	7.5	14.6	35.9	10.7	7.8
20	30.9	16.6	8.9	9.7	6.9	13.5	32.4	9.1	7.5
21	28.3	15.7	7.1	10.1	6.6	17.7	33.3	8.6	6.6
22	27.6	15.7	7.0	10.3	5.9	16.8	33.0	8.1	5.9