Pallid Sturgeon and Shovelnose Sturgeon in the Missouri River from Fort Peck Dam to Lake Sakakawea and in the Yellowstone From Intake to its Mouth

Fort Peck Pallid Sturgeon Study

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ABSTRACT

Pallid and shovelnose sturgeon were observed throughout the study area by netting, radio telemetry, SCUBA and angler contacts. From 1989 - 1993, 55 different pallid sturgeon and over 1000 shovelnose sturgeon were captured by the Montana Department of Fish Wildlife and Parks during netting and SCUBA diving. A character index, based on morphological measurements, differentiated pallid from shovelnose sturgeon. Based on this index and field observation, no suspected pallid/shovelnose hybrids were captured during the study. Pallids ranged in fork length from 1090 - 1566 mm, while shovelnose ranged from 190 - 943 mm. Drift netting effort was concentrated in known pallid habitat and resulted in average catch rates during 123 hours of netting (1012 drifts) of 0.4 pallids/hour and 8.0 shovelnose/hour. All pallids caught with drift netting were captured on the Yellowstone near its mouth or below the confluence of the Yellowstone and Missouri Rivers. Seven pallids and three shovelnose were recaptured during drift netting. Radio and/or sonic transmitters were placed on 29 pallid and 30 shovelnose sturgeon. All pallids in the confluence/Yellowstone area generally resided below the confluence from August - April and moved up into the Yellowstone in April and May. Most shovelnose in this area remained in the Yellowstone year long, but some were found downstream of the confluence from August - October. Sturgeon telemetered in the Fort Peck tailrace exhibited different behavior patterns. Pallids tended to move downstream in April and return to the tailrace by the winter months, while shovelnose stayed in the tailrace area year long. Pallid sturgeon movement from the tailrace to below the confluence (300 km) was documented. Standardized sampling done in 1993, constituted 22.8 hours and 249 drifting efforts of 90 total km and resulted in capture of 184 shovelnose and 0 pallid sturgeon. During standardized sampling shovelnose were captured most frequently in upstream stations in both the Yellowstone and Missouri over gravelly substrate. Gill nets (2.5 and 5 cm mesh) were found to be better than trammel nets (25.4 cm outer, 5 cm inner mesh) at capturing sturgeon less than 651 mm. Four candidate endangered species were captured during the study, including sicklefin chub, sturgeon chub, blue sucker and paddlefish.

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DISCLAIMER

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INTRODUCTION

In response to sightings of pallid sturgeon (*Scaphirhynchus albus*) in the Fort Peck tailrace and potential listing of this candidate endangered species, the U. S. Army Corps of Engineers (USACOE) began funding pallid sturgeon research downstream of Fort Peck Dam in April 1989. The USACOE continued to fund this study through 1993. In 1993, the Montana Department of Fish, Wildlife and Parks (MDFWP) and U.S. Fish and Wildlife Service (USFWS) Section 6 dollars provided additional funds. This report summarizes research completed from 1989 - 1993. Much of this information has been previously reported (Tews and Clancey 1993; Clancey 1992, 1991, 1990). The pallid sturgeon was listed as endangered in October, 1990 and a pallid sturgeon recovery plan was signed on November 8, 1993. The draft recovery plan (USFWS 1993a) lists the study area as a priority reach for pallid sturgeon recovery efforts. North Dakota does not allow harvest of pallid or shovelnose sturgeon *(S. platorynchus)*, and Montana regulations prohibit harvest of pallid sturgeon and harvest of shovelnose greater than 16 pounds.

From 1989 - 1992 research focused on finding pallid sturgeon with drift netting and SCUBA surveys, perfecting telemetry in the deep, high conductivity water of the 480 kilometers (km) study area, and obtaining habitat measurements from telemetered fish. In 1993, the USACOE changed the focus of the study to a standardized sampling scheme. Shovelnose sturgeon are closely related to pallid sturgeon (Phelps and Allendorf, 1983) and have been studied throughout this project.

The objectives of this study were to; 1) identify potential spawning areas, seasonal habitat use and migration patterns of adult shovelnose and pallid sturgeon in the study area by using telemetry and habitat measurements; 2) conduct drift netting surveys for adults, juvenile and YOY sturgeon in efforts to find evidence of reproduction; 3) tag all sturgeon and 4) measure morphometric characteristics to investigate pallid/shovelnose hybridization. Standardized sampling was used to obtain sturgeon distribution and abundance information from a variety of reaches and habitat types. Initiation of standardized sampling in 1993, required the MDFWP to decrease the use of radio telemetry and netting for pallid sturgeon in likely habitats. The void in telemetry research was filled by the Montana Cooperative Fish Research Unit at Montana State University (MSU) when they began a three year pallid sturgeon telemetry project in 1992. That project continues to complement the MDFWP/USACOE study.

MDFWP is conducting two other pallid sturgeon studies, one on the Missouri River between Fort Peck Reservoir and Fort Benton (Gardner 1990, 1991, 1992), and one in cooperation with the Bureau of Reclamation, on the Yellowstone River, between Intake Diversion Dam near Glendive and Cartersville Diversion Dam near

Forsyth (Watson and Stewart 1991; Backes et al. 1992). MDFWP has also been studying the post-hatch drift of larval sturgeon and paddlefish in the Yellowstone and in the Missouri near the confluence since 1991 (Gardner 1992).

In conjunction with these other studies the Fort Peck Pallid Sturgeon Study continues to provide insight into the population status of pallid sturgeon. The study area is unique in that it contains two large rivers with extremely different characteristics; the Missouri, with flow and sediment regimes which have been dramatically altered by man, and the undammed Yellowstone, which even today exhibits qualities similar to those under which the pallid evolved. Presence of relatively high numbers of adult pallid sturgeon along with four candidate endangered fish species including, blue sucker (*Cycleptus elongatus*), sicklefin chub (*Machrybopsis meeki*), sturgeon chub (*M. gelida*) and paddlefish (*Polyodon spatulata*), indicate the biological integrity of this ecosystem and its importance in maintaining native fish species. This area is also home to the endangered least tern (*Sterna antillarum*) and the threatened piping plover (*Charadrius melodus*).

STUDY AREA

The study area is the approximately 370 km of the regulated but unchannelized Missouri River from Fort Peck Dam, Montana downstream to the headwaters of Lake Sakakawea, North Dakota, and the 114 km of the Yellowstone River from its mouth upstream to Intake Diversion Dam (Figure 1). The study area can be divided into four distinctly different reaches; 1) Fort Peck tailrace and dredge cuts; 2) Missouri above the Yellowstone; 3) Missouri below the Yellowstone confluence; 4) Yellowstone River.

The Missouri River has been dramatically altered by seven mainstem dams. Hesse et al. (1989) discuss these changes, which include channelization, changes in temperature regime, hydrographs, turbidity, nutrient cycling and sedimentation patterns. Fort Peck Dam, built in 1936, alters the characteristics of the majority of the study area. Below Fort Peck Dam the Missouri River is regulated and exhibits typical dam caused modifications such as daily peaking flows, a compressed hydrograph with reduced spring run-off, increased winter flows (Figure 2), a decrease in summer water temperatures and increased water clarity. Annual discharge of the Missouri River averages 9713 cubic feet per second (cfs) at Fort Peck Dam and 10670 cfs at Culbertson (Table 1). However, drought from 1988 - 1992 and management of Fort Peck Reservoir in 1993, resulted in below normal flows throughout the study period. Annual discharge varied from 67 - 99% at Fort Peck and from 63 - 95% at Culbertson from 1988 - 1992 (Table 1). By September 1993, discharge was only 55% of the annual average.

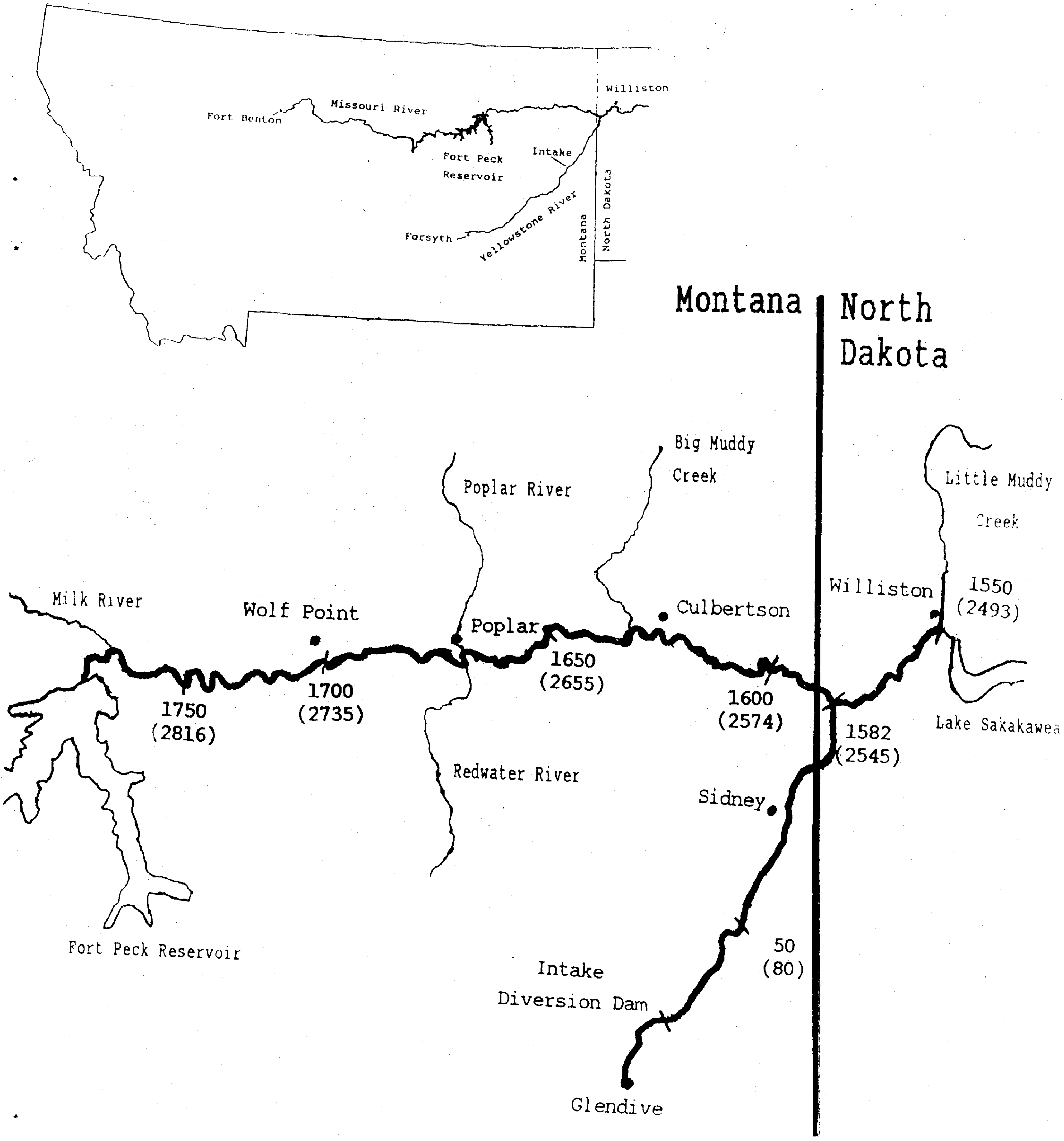

Figure 1. Map of Fort Peck pallid sturgeon study area with river miles (kilometers).

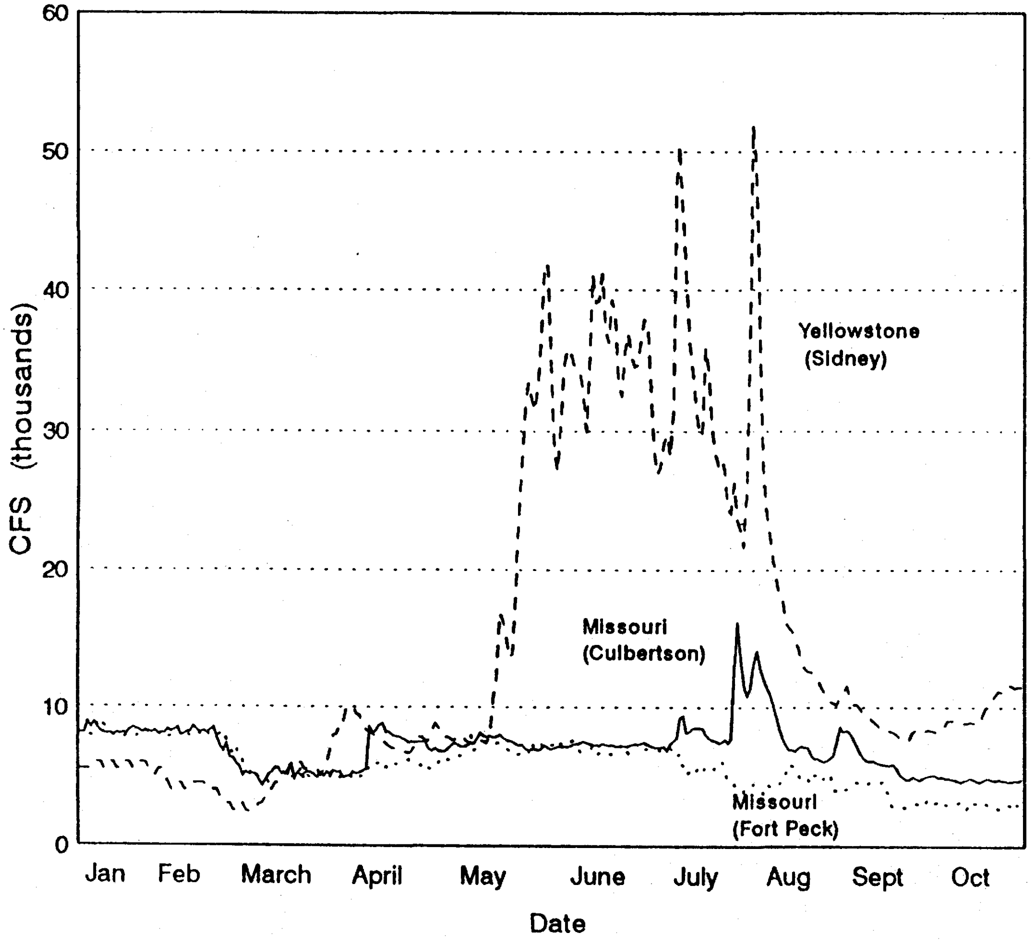

Figure 2. Hydrographs for 1993 of the Missouri River below Fort Peck Dam, the Missouri at Culbertson and the Yellowstone River at Sidney from preliminary USGS data.

Table 1. Average daily mean, maximum and minimum flow at three sites in the study area for 1988 - 1993 calendar year.

Year	Station	Minimum	Maximum	Mean
1988	Fort Peck	4300	12200	7862
	Culbertson	4100	13000	8118
	Sidney	1390	32200	6971
1989	Fort Peck	5000	13400	9623
	Culbertson	5940	13700	10080
	Sidney	800	36700	9096
1990	Fort Peck	3295	13100	8082
	Culbertson	4500	14000	8430
	Sidney	1800	36600	9321
1991	Fort Peck	2995	8190	7234
	Culbertson	3400	16100	7948
	Sidney	3500	62200	13050
1992[1]	Fort Peck	2830	8800	6530
	Culbertson	3210	9200	6700
	Sidney	4310	39300	10253
1993[2]	Fort Peck	2700	8700	5731
	Culbertson	4300	16200	7061
	Sidney	2400	51900	14814
Average[3]				
1944-1992	Fort Peck	16	35400	9713
1958-1992	Culbertson	2000	52000	10670
1967-1992	Sidney	800	111000	12660

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[1] preliminary data

[2] preliminary data from January - October 20

[3] water year (October - September)

The hydrograph has been further compressed for threatened and endangered species management. For instance, during 1993, as flow in the Milk River increased, outflow from Fort Peck dam was decreased to prevent flooding of nesting sites for the piping plover and least tern (USACOE 1993). Future plans call for similar management (Ibid). Such management accentuates the lack of high flows, which are likely needed for sturgeon spawning and rearing (USFWS 1993a) and are the conditions under which birds as well as fish evolved.

Power peaking was curtailed from April 1990 - July 1992 during a Fort Peck powerhouse retrofit. Once modifications were complete, daily fluctuations were usually over 60 cm (2 feet) in the Fort Peck tailrace (Figure 3). Power peaking was also curtailed during extremely low flows (mean releases of 3000 - 4000 cfs) from September - November 1992 and 1993.

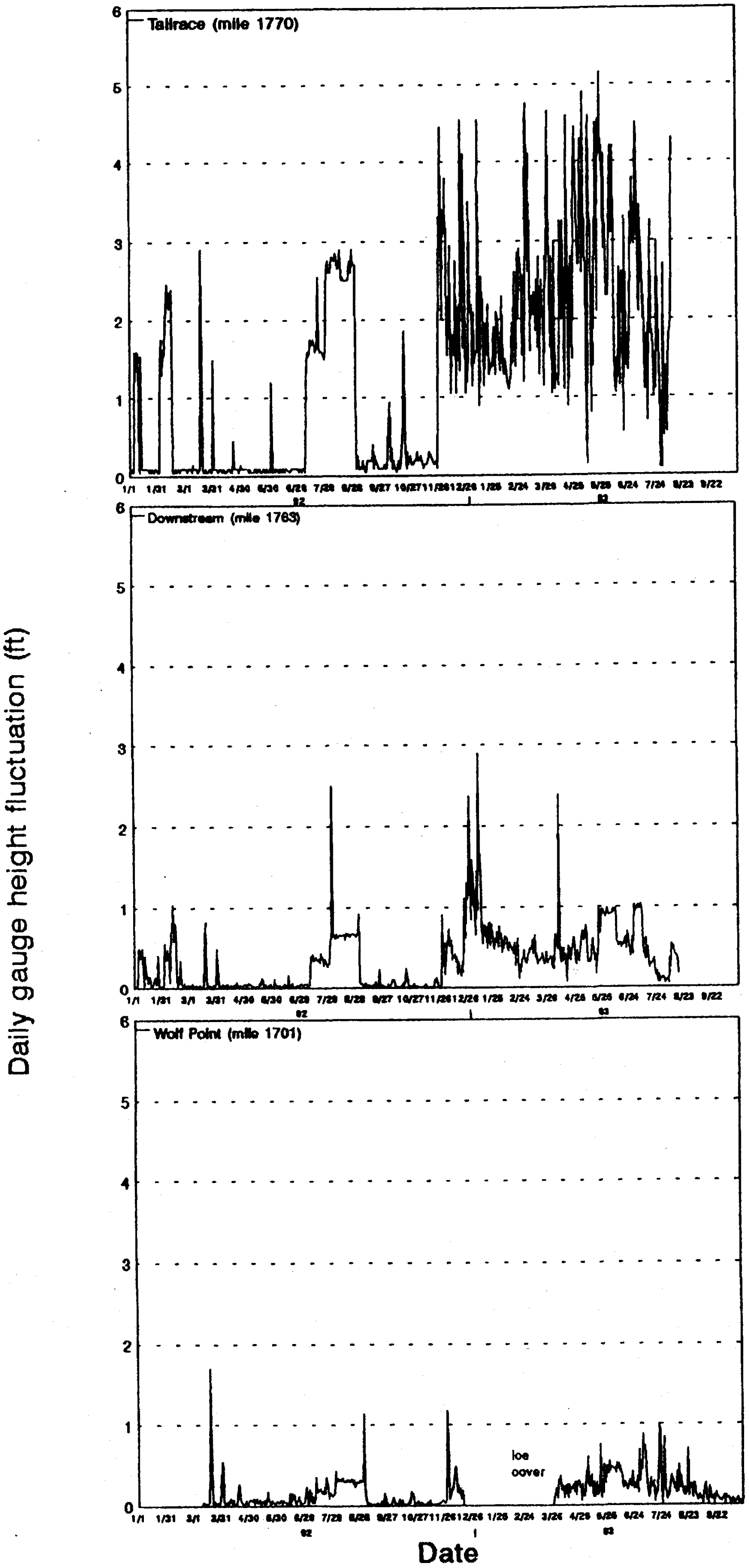


Figure 3. Daily hydrograph of the Missouri at three sites below Fort Peck Dam.

Comparison of gauge height fluctuations from April 1 - July 1 during 1992 and 1993 shows that once power peaking was re-initiated, average daily fluctuations increased from 3 cm (0.10 ft) to 80 cm (2.64 ft) in the Fort Peck tailrace. The 80 cm change was dampened to 18 cm (0.60 ft) 11 km downstream and to 9 cm (0.29 ft) 113 km below Fort Peck dam. This is about 50% of the fluctuation found below Garrison Dam (Elstad et al. 1992).

The 16 km of river from Fort Peck Dam to the Milk River confluence have severe erosion problems and have been physically altered. The lotic habitat has rock and gravel substrate that is typically covered with green-algae mats and is from 0.3 - 1.5 m deep. This area also contains the Fort Peck tailrace and the dredge cuts, lake-like areas that were excavated during dam construction (Gardner and Stewart 1987). These dredge cuts provide a sport fishery and rise and fall with the tailrace, thereby diminishing the downstream effects of power peaking. In this area, much of the "river" is up to 14 m deep and current velocity is extremely slow.

Inflow from the Milk (km 2831) and Poplar Rivers (km 2701) increase turbidity and temperature in the Missouri River. However, temperature is about 3° C colder at Culbertson (km 2608) than would be found in natural conditions (Gardner and Stewart 1987). In Montana, the Missouri River gradient varies from 0.6 ft/mile near the Milk River to 1.5 ft/mile near the Redwater River. The river becomes depositional near Wolf Point and is characterized by shifting sandbars near Culbertson (Gardner and Stewart 1987). The confluence of the Missouri and the Yellowstone Rivers is 5 km downstream of the Montana border. Below this confluence, the Missouri is up to 11 m deep, has shifting sand bars, moderate to fast current and numerous snags. When Lake Sakakawea is at full pool (564 m) there are only about 24 km of river between the confluence and the headwaters of Lake Sakakawea (Power et al. 1992). However, due to abnormally low pool conditions in Lake Sakakawea, throughout this study there have been about 50 - 80 km of free flowing river downstream of the Yellowstone confluence.

In contrast to the Missouri, the Yellowstone River has no major dams. Run-of-the-river irrigation dams are present and when Yellowtail Dam was built on the Bighorn River in 1966, 30% of Yellowstone's flow (at Sidney) was regulated (Koch et al. 1977). Yellowtail Dam operations do compress seasonal maximum and minimum flow (Ibid), but the Yellowstone still exhibits a near natural hydrograph (Figure 2) and water quality characteristics. Average annual discharge of the Yellowstone is 12,660 cfs. In contrast to the Missouri which had below average flows for all 6 years of the study, the Yellowstone was below average for just 4 years, ranging from 55 - 103% of normal from 1988 - 1992. Based on flows through October 1993, the Yellowstone may exceed 110% of normal in 1993. The Yellowstone River below Intake is characterized by shifting gravel beds and numerous islands (Koch et al. 1977). Depth is generally less than 4.5 m and current velocity is high. Gradient varies from 1 - 3 feet per mile from Intake to the confluence, and averages 2.8 feet per mile downstream of the Bighorn River (Haddix and Estes 1976).

METHODS

Flows were obtained from the Fort Peck field office of the U.S. Geological Survey (USGS) and the USACOE. Missouri River distances are miles or km upstream from the confluence of the Missouri and Mississippi Rivers and were obtained from the USACOE 1983 aerial photos. Yellowstone River mileages were obtained from the River Mile index of the Yellowstone River (1976). All river miles less than 1530 (2460 km) referred to in this report are Yellowstone River miles. The study area was divided into 9 sections for comparison of effort and fish abundance (Table 2).

Table 2. Study area sections with locations and river miles (km).

Section	Location
1	Fort Peck Dam to the mouth of Milk River; 1761.5 - 1770 river miles (2834 -2848).
2	Milk River to Wolf Point (filtration plant); 1708 - 1761.5 river miles (2748 - 2834).
3	Wolf Point to mouth of Redwater River; 1683 - 1708 river miles (2708 - 2748).
4	Mouth of Redwater River to the mouth of Big Muddy Creek; 1630.4 - 1683 river miles (2623 - 2708).
5	Big Muddy Creek to the Yellowstone River; 1582 - 1630.4 river miles (2545 - 2623).
6	Missouri/Yellowstone confluence to Highway 85 Bridge; 1553 - 1582 river miles (2499 - 2545).
7	Highway 85 Bridge to Lake Sakakawea, approximately 1530 - 1553 river miles (2462 - 2499).
8	Yellowstone River from Intake to Highway 23 Bridge; 29.5 - 71.1 river miles (47 - 114).
9	Yellowstone River from Highway 200 Bridge to the Missouri/Yellowstone confluence; 0.0 - 29.5 river miles (0 - 47 km).

Drift netting

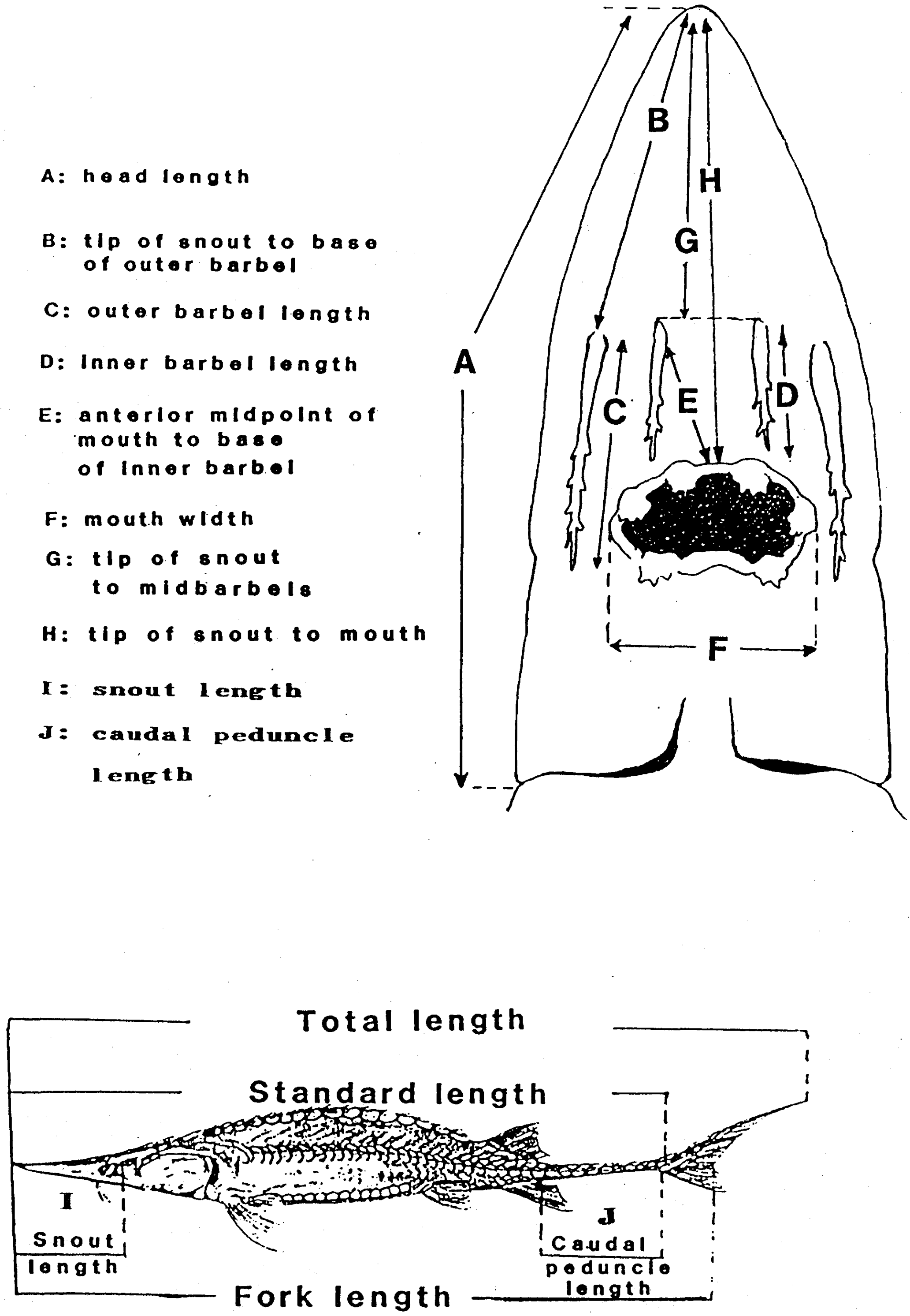
From 1990 - 1993 sturgeon were caught by drifting sinking gill nets and trammel nets from a 6.4 m Wooldridge inboard jet boat. One end of the net was attached to the boat by a 6 m rope while the other end was attached by 3 - 6 m of rope to 2 floats. Depth and temperature were recorded. Several types of nets, all with 1.8 m high panels were employed. Multifilament and monofilament gill nets from 15 - 30 meters long were used throughout the study. Most were experimental nets with 2 - 5 cm bar mesh, but some had 8 cm bar mesh. After September 1992, 15 - 46 m trammel nets with a 5 cm bar inner and 25 cm outer mesh were also used. Nets were set perpendicular to the current and were drifted from 1 - 42 minutes. Average drift time was 7 minutes overall and varied from 6 minutes in 1993 to 11 minutes in 1991. A drift began as the net was being set and ended when retrieval began. In 1993, distance of each drift was estimated. After September 15, 1992 a small approximately one pound weight was attached to the lead line, to insure this lead line was dragging on the river bottom. Hourly catch was tabulated as catch per unit effort (CPUE). However, much of our effort was intensified in areas of known pallid habitat, therefore, CPUE does not necessarily reflect abundance of other species for the entire study area or even sections of the study area.

Most shovelnose caught in the section 1 were from stationary 24 hour, 38 m gill nets, set in the Fort Peck Tailrace, the Dredge cuts and Nelson Dredge during annual monitoring by MDFWP. Three hour stationary sets were also completed in the vicinity of pallid sturgeon. Stationary nets were unsuccessfully set in slow areas of other sections of the river in 1989 - 1990.

Morphological measurements and tagging

Figure 4 illustrates the characteristics measured on all pallid sturgeon and on 608 shovelnose sturgeon. Measurements were taken in inches or feet and converted to millimeters (mm). Percent of standard length (SL) was calculated from these measurements. Weights were taken from pallid sturgeon and from most shovelnose sturgeon.

To evaluate hybridization between pallid and shovelnose sturgeon, percent SL of head length, inner barbel length, outer barbel length, snout to outer barbel length, mouth to inner barbel length and mouth width were transformed into a character index as done by Tews and Clancey (1992), and Gardner (1992). This character index is similar to the one developed by Carlson and Pflieger (1981). The smallest numbers reflect the most shovelnose-like characteristics and the largest numbers the most pallid-like characteristics. The six numbers were added for a character index value between 0 and 600. Appendix 1 gives a detailed description of this index.



A: head length

B: tip of snout to base of outer barbel

C: outer barbel length

D: inner barbel length

E: anterior midpoint of mouth to base of inner barbel

F: mouth width

G: tip of snout to midbarbels

H: tip of snout to mouth

I: snout length

J: caudal peduncle length

Figure 4. Morphological measurements taken from pallid and shovelnose sturgeon.

Pallid sturgeon were injected with 400 kilohertz (kHz) passive integrated transponder (PIT) tags at the base of the dorsal fin. Yellow dangler tags were also attached to pallids netted prior to 1993. Green dangler tags were attached to some shovelnose, including all shovelnose transmittered from 1989 - 1992. After August 31, 1992 spaghetti tags were attached to the dorsal fin of all shovelnose sturgeon of adequate size. Genetic samples from 11 pallids and 36 shovelnose were taken for Genetic Analysis of Smithville Texas. Blood samples were taken and placed in 7.5 milliliters of lysis buffer. A tissue sample cut from the tail and a muscle plug taken from the body of the fish were placed in 75% ethanol. Gloves were worn and tools were wiped with alcohol and flamed prior to use. Fish tissues were wiped with alcohol prior to removal.

Radio telemetry

The transmitter attachment systems used during this study can be divided into 4 categories; 1) external back mount; 2) external dorsal fin mount; 3) internal and; 4) protruding, an internal transmitter with an external protruding antenna (Table 3). Transmitters were purchased from four companies, had total weights from 14 - 190 grams and battery lives from 40 - 1500 days (Table 3). Both radio and sonic transmitters were used. Radios were required in the extensive study area and ultrasonic signals were needed in several deep stretches which could not be penetrated by radio signals. Radio transmitters were in the 48.00 - 49.99 megahertz (mHz) range, with a unique frequency to allow individual fish to be identified. Radios had a wide range of power output ranging from 3 to 9 volts with power drain from 0.1 to 0.9 mA. Initially, sonic transmitters had a variety of frequencies, but after 1991 all sonic transmitters were set at 74 kHz and were uniquely coded. Both regular and high output sonic transmitters were used. From April 1989 - May 1993, 56 radio transmitters were deployed on 30 pallid and 26 shovelnose sturgeon. Sonic transmitters were used on 25 sturgeon, 3 of which did not have radios.

External back transmitters were attached by drilling holes between the 6th and 9th dorsal scutes from 1989 - 1991. Attachment was similar to that used successfully by Hall et al. (1991) for shortnose sturgeon (*Acipenser brevirostrum*). External dorsal transmitters were first attached in 1992 using the methods of Winter (1983). Wires were inserted through holes 30 mm apart in the fleshy part of the dorsal fin. Plastic discs or plates were attached as protection to the opposite side of the fin and the wires were then crimped in place. Stainless crimps were used through April 1993. During September 1993 copper crimps were used to insure radios would fall off within one year

Table 3. Transmitter types used on sturgeon from 1989 - 1993.

	Transmitter type	Years used	# of fish	Weight (g) in air
1.	External back (radio or radio/sonic)	1989-1991	10 pallids 2 shovelnose	85-126
2.	Dorsal fin external (radio or radio/sonic)	1992-1993	17 pallids 2 shovelnose	14-144
3.	Internal (radio, sonic, radio/sonic)	1990-1993	1 pallid 7 shovelnose	28-70
4.	Protruding (radio or radio/sonic)	1991-1992	1 pallid 19 shovelnose	33-188

of deployment (Buckley and Kynard 1985). When both sonic and radio components were employed the transmitters sandwiched the dorsal fin. Internal transmitters with internal antenna were used in 1990 - 1993 and were inserted into a 50 mm ventral incision lateral to the midline. Internal radio transmitters with external protruding antennae were used in 1991 and 1992 and were implanted using the catheter technique (Clancey 1991). Incisions from both types of implants were closed with inverted mattress sutures. Transmitters and all surgical equipment for implants were disinfected with Nolvasan disinfectant.

Relocation of sturgeon was done as funds permitted. When transmitters were active, relocations were attempted at least twice monthly from May - October, and every 4 - 6 weeks during the rest of the year. After May 1993, MSU completed most flight relocations. A programmable scanning radio telemetry receiver (ATS Challenger) with a whip or loop antenna was used to locate sturgeon from a Cessna 172 plane and inboard jet boats. A hydrophone and sonic receiver (Sonotronics Model USR-5) were also used to track sturgeon from a boat.

Microhabitat measurements including depth, conductivity, temperature, bottom velocity, substrate type, and turbidity were usually taken once fish were located and at many sites where pallids were netted. Radio telemetry was used to initially find the fish and the sonic signal was used to precisely determine its location. Radio triangulation was used for those fish without sonic transmitters.

Depth was measured with an Impulse 2800 plus fish finder. Conductivity and temperature were taken in the field with a Yellow Springs Model 33M S-C-T meter and conductivity was corrected to 25° C using a conversion factor of 2.5% per degree (Lind 1979). Velocity was recorded with a General Oceanics Model 2035-MK III meter. A weight was attached to the velocity meter and lowered to the river bottom. Substrate was determined by dragging a weight on the bottom of the channel. Surface water was sampled in the field and turbidities read in the lab with a Cole Palmer model 8391-35 turbidimeter. In 1993 secchi disk measurements were taken.

Standardized sampling

Seven standardized sampling sites were sampled in 1993 (Table 4). Sampling was attempted monthly from May - October. Sampling sites were not randomly chosen but were selected based on access, river reach, previous sampling success for pallid sturgeon, and to insure one tributary mouth was sampled. Sites were not randomized due to the extreme rarity and migratory habits of the pallid sturgeon. As dictated by common sense and as cited in Gordon et al. (1992) it is impractical to attempt randomized sampling with a species of these characteristics. Four drifting areas (two in deep habitats and two in shallow habitats) were established at sites 2 - 7. One deep and one shallow area were sampled at site 8. Deep habitats were in the main channel. Shallow habitats were usually in main channel border (classified as such, by being less than 50% of maximum depth) or side channel areas. However, in the Missouri above the Yellowstone confluence, shallow sampling was sometimes done in shallow main channel areas. The configuration of the river during the low flows of 1993 made this necessary.

Standardized drifts were done with 23 m nets. Each drift area was sampled twice; once with a trammel net (25 cm outer, 5 cm inner) and once with an experimental gill net with 2.5 and 5 cm bar mesh. The net type drifted first was alternated. Drifts were about 380 m long but lasted no longer than 10 minutes. Standardized drifts were shorter than other drifts to attempt netting in a single habitat type. Habitat information was collected, using the equipment described above, at the mid-point of each drift site. Habitat parameters monitored included bottom, average, and surface velocities, maximum depth at river cross-section, temperature, channel width, and secchi disk. Maximum and minimum depths during the drift were also recorded. Conductivity was measured at each station.

Table 4. Description of standardized sites sampled in 1993.

Standardized site	Description
1:	Not sampled in 1993.
2:	Missouri River at Milk River confluence river mile 1761 (2833 km) and downstream 5 km. In section 2. This site was the sole tributary mouth site sampled. It was sampled in main channel and main channel border habitats. This site was also unique in its location just 16 km downstream of Fort Peck Dam.
3:	Missouri River from 1 km above bridge, river mile 1701 (2737 km) to 3 km below bridge. In section 3. All sites were main channel or main channel border. Drifting was done in the vicinity of a highway bridge. Sampling sites at this station had to change as shifting sandbars and dead trees altered channel morphology.
4:	Missouri River at Nohly railroad bridge, river mile 1589 (2557 km) and downstream 4 km. In section 5. All sites were main channel or main channel border. When the Yellowstone was at extremely high flow, it backed up into the Missouri, at times creating lake-like conditions until just below the bridge (approximately 5 miles). Under these conditions two sampling sites had to be moved upstream.
5:	Missouri River downstream of confluence. From pipeline downstream 5 km, miles 1572 - 1575 (2529 - 2534 km). In section 6. All sites were main channel or main channel border. This site has been somewhat altered by man. The upstream part of this area contains a gas pipeline crossing and the lowest stretch was channelized by the USACOE in the spring of 1958. This channelized area is where 25 pallids were captured in September - October 1992, and 5 pallids were caught in September 1993.
6:	Yellowstone River at Elk Island Access Site from 3 km upstream to boat ramp, river mile 51 - 53 (82 - 85 km). In section 8. This site was located in a very braided area of the Yellowstone. Two sites were side channel, one main channel border, and one main channel.
7:	Yellowstone at Diamond Willow access site from 3 km upstream to 2 km downstream, river mile 23.5 - 21.5 (km 37.8 - 34.6). In section 9. Sites were main channel or main channel border.
8:	Yellowstone 4 km above the Missouri confluence. In section 9. This site had 50% of the effort of other stations. One main channel and one main channel border habitat was sampled. This site is very close to a site that North Dakota used during 1992 standardized sampling.

Statistical differences in catch rates were evaluated using ANOVA tests and Kruskal-Wallis non-parametric tests from Statgraphics 6.1. Further evaluations were done using the Dunn's test (Hollander and Wolfe 1973). Statistical tests were considered significant at P = 0.1.

In August three seine hauls were completed at each of 6 standardized sampling sites. Some additional seining was also done. A 15.4 m, 1.2 m deep beach seine with 3 mm ace mesh was used. Hauls were about 55 m long and were completed in main channel border areas of 0.3 - 1 m deep, with a hard bottom.

RESULTS AND DISCUSSION

Pallid and shovelnose sturgeon

Pallid and shovelnose sturgeon were observed throughout the study area. Fifty-five different pallid sturgeon and over 1000 shovelnose sturgeon were caught from 1989 - 1993. Pallid and shovelnose sturgeon were found with SCUBA diving, stationary and drift netting, radio telemetry and angler reports. Two shovelnose were also captured during beach seining. Over 99% of the shovelnose measured in this study were caught during gill and trammel netting.

The pallid population within the study area consists of large adult fish. Pallids caught during the study ranged in fork length (FL) from 1123 - 1566 mm and averaged 1398 mm. Their weight ranged from 8.4 - 28.1 kg and averaged 15.9 kg (Appendix 2). Ninety-six percent of the pallids were longer than 1200 mm FL (Figure 5). Only 2 pallids (4%) weighed less than 10 kg (Figure 6). A pallid which had a FL and weight of 965 mm and 4.2 kg was captured on the Yellowstone in North Dakota on April 25, 1993 by the USFWS (USFWS 1993b). This was the smallest pallid documented within the study area. One pallid was caught by MDFWP at river mile 129 on the Yellowstone in 1991 (Watson and Stewart 1991). The USFWS has also captured several other pallid sturgeon in the confluence area in the past few years. Four of these were transmittered for this study and have been used in length and weight analysis. The USFWS also has removed 6 pallid sturgeon from this area for use as captive broodstock (Bollig 1993).

To compare the length/weight relationship of the pallid sturgeon in the study area with other populations, a regression of FL (mm) versus weight (kg) was calculated (Table 5). This equation yielded much heavier fish at shorter lengths than the one given by Keenlyne (1993) and is similar to those summarized by Kallemeyn (1983). Lack of data from small pallids likely make this equation unreliable for pallids less than 1000 mm. However a length/weight equation for shovelnose (Table 5) also results in

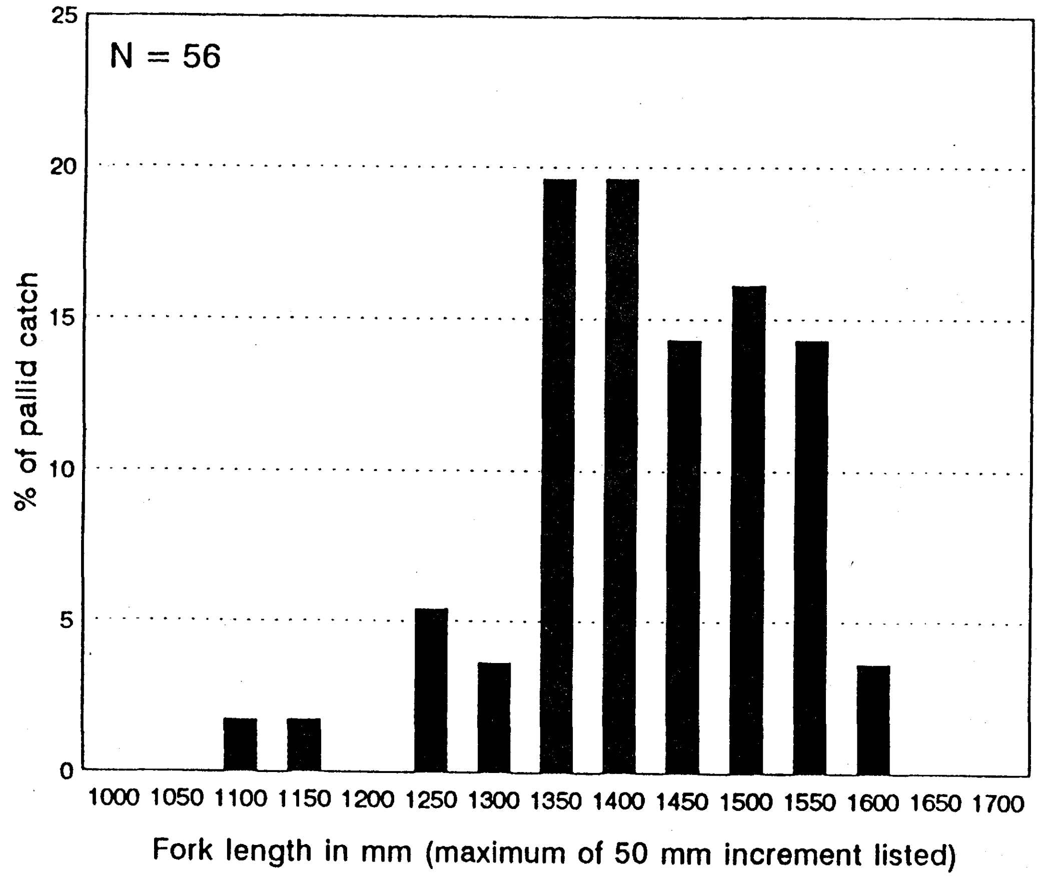


Figure 5. Fork length distribution of pallid sturgeon.

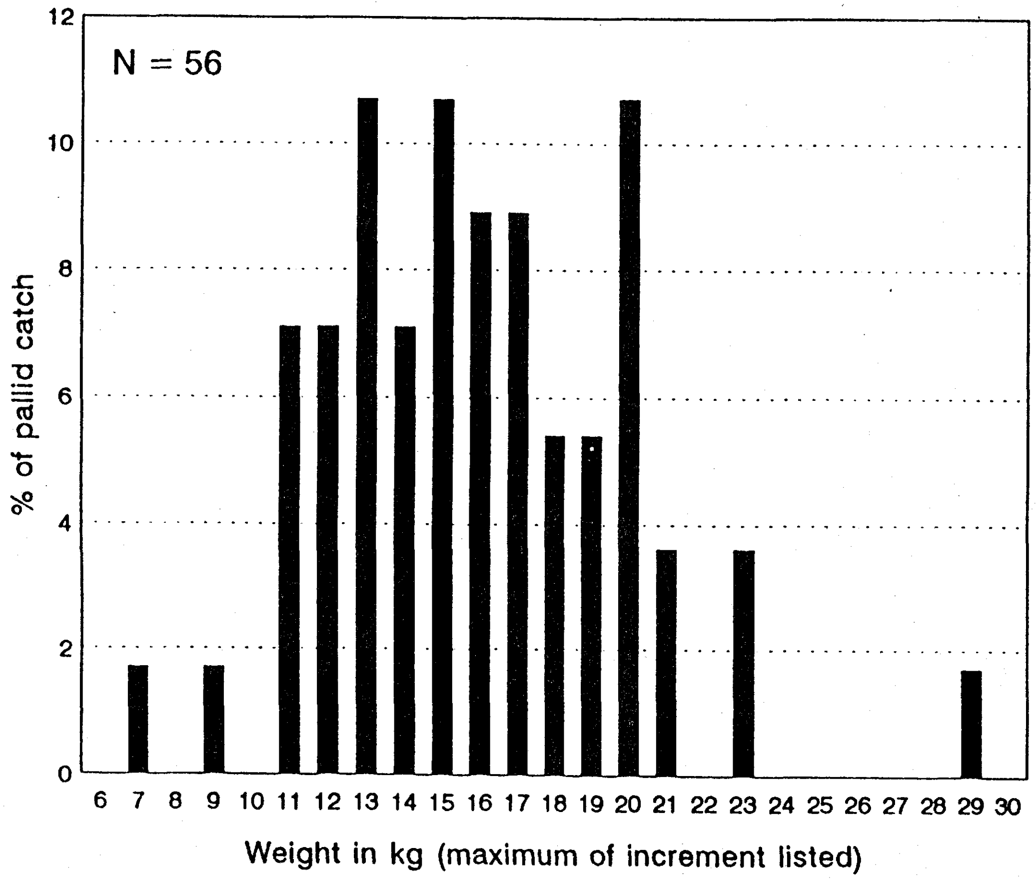


Figure 6. Weight distribution of pallid sturgeon.

heavier small sturgeon than the equation of Keenlyne and Maxwell (1993). As postulated by Keenlyne and Maxwell (1993), this may indicate that sturgeon found within the study area are heavier and have better condition than those found elsewhere in the upper Missouri.

Table 5. Regression equations for pallid and shovelnose sturgeon length (mm)/weight (kg) and shovelnose FL to TL in the study area.

Species	N		Corr coeff
Pallid sturgeon	56	$\log_{10} W = -8.912 + 3.212 \log_{10} Fl$	0.925
Shovelnose sturgeon	534	$\log_{10} W = -9.569 + 3.416 \log_{10} Fl$	0.965
Shovelnose sturgeon	984	$FL = 0.92\ TL - 4.39$	0.984

In contrast to pallid sturgeon, shovelnose exhibited a diverse size structure (Figure 7). Shovelnose ranged from 236 - 947 mm FL and averaged 630 mm. A smaller shovelnose with 167 mm SL was also captured. This fish would have had a FL of about 190 mm.

To make shovelnose FL comparisons between years and sections, Yellowstone River data from Cartersville to Intake diversion dams (114 - 332 river km, Yellowstone sections 1 - 5) was obtained from Watson and Stewart (1991) and Backes et al. (1992) and past data from the Missouri below Fort Peck was compiled from Gardner and Stewart (1987). To compare shovelnose in this study with the total length (TL) data of Gardner and Stewart (1987), a regression was calculated to estimate FL based on TL (Table 5). This regression differed greatly from one (FL= 1.07 TL - 117) used by Elser et al. (1977) for sturgeon in the Tongue River, but was similar to the one calculated by Moos (1978), FL = 0.94 TL - 22.7 for South Dakota sturgeon from the unchannelized Missouri.

Average shovelnose FL by section is listed in Appendix 3. Shovelnose captured in the Missouri above the confluence were slightly longer in the upstream sections and slightly shorter in downstream areas than those found by Gardner and Stewart (1987) (Figure 8). The shovelnose found in the Missouri were generally shorter than those on the Yellowstone (Figure 8). On the Yellowstone and on the Missouri above the confluence, shovelnose FL decreased downstream. This trend was also observed by Penkal (1981) on the Yellowstone and by Berg (1981) on the Missouri above Fort Peck Reservoir.

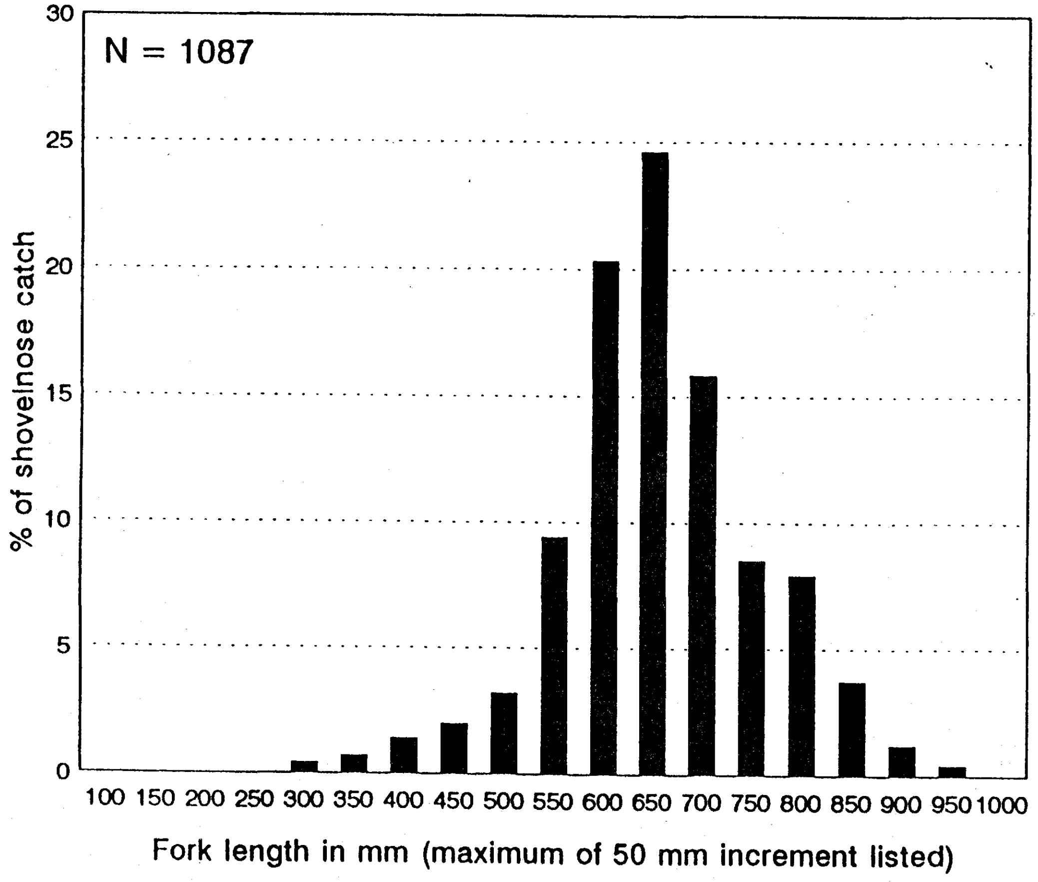


Figure 7. Fork length distribution of shovelnose sturgeon.

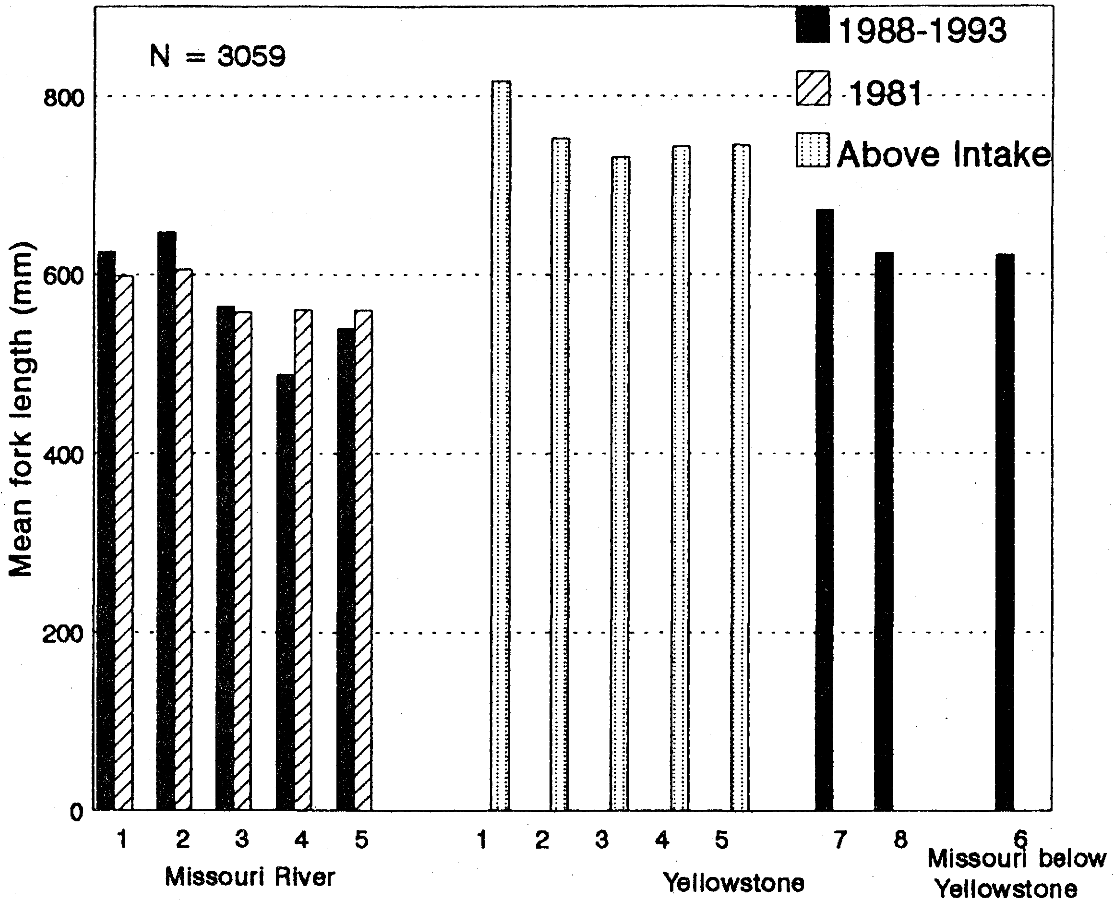


Figure 8. Mean shovelnose fork length by section, compared with shovelnose captured in 1981 by Gardner and Stewart (1987) and those captured above Intake by Backes et al. (1992) and Watson and Stewart (1991). Section 1 is furthest upstream for both rivers.

Morphological Measurements

Percent of SL and ratios of several morphological measurements were used to differentiate pallid from shovelnose sturgeon. Measurements were taken from 608 shovelnose from 1988 - 1992 and 55 pallids from 1988 - 1993. Percent of SL of shovelnose and pallids, and pallid ratios for sturgeon sampled in past years are listed in Tews and Clancey (1993) and Clancey (1990, 1991 and 1992). Ratios and percent pallid SL obtained in 1993 are listed in Appendices 4 and 5. The data show that percent SL of individual morphometric measurements is a poor way to differentiate pallid from shovelnose sturgeon. Though mean values differed, individual pallids overlapped those of individual shovelnose for all measurements (Table 6). Mean ratio values for pallids captured in this study exceeded those found by Bailey and Cross (1954) (Table 7). Size as well as geographic location may have been responsible for this variation. The pallids used by Bailey and Cross had SL from 200 - 700 mm, while all pallids captured in this study exceeded 1000 mm. Only ratio 1 (snout to outer barbel:mouth to inner barbel) was unique for pallid and shovelnose in both study areas. Data from 320 shovelnose and 33 pallids caught in 1992 (Tews and Clancey 1993) demonstrated all 6 ratios could be used to distinguish pallid and shovelnose in the study area. However, when the sample size was expanded to the 608 shovelnose and 55 pallids measured from 1988 - 1993 only ratios 1 and 3 proved unique for individual fish within the study area (Table 7).

Table 6. Range and mean of percent standard length of selected morphological characteristics of pallid and shovelnose sturgeon captured from 1989 - 1993.

	Pallids (n = 53-55)		Shovelnose (n=607-608)	
	Range	(Mean)	Range	(Mean)
Head length	30.0 - 35.5	(32.5)	22.5 - 34.1	(28.7)
Mouth width	7.6 - 10.4	(9.3)	4.4 - 11.3	(7.5)
Snout to outer barbels	11.9 - 16.3	(14.6)	7.0 - 14.6	(9.7)
Mouth to inner barbels	3.6 - 5.6	(4.5)	4.9 - 8.5	(6.5)
Inner barbels	2.1 - 4.5	(3.6)	3.4 - 9.3	(6.4)
Outer barbels	2.9 - 11.7	(9.7)	5.5 - 11.3	(8.7)

Table 7. Comparison of morphometric ratios[1] of pallid and shovelnose sturgeon[2] found by Bailey and Cross (1954) and those captured in this study.

	Pallid sturgeon				Shovelnose sturgeon			
	1989-1993 (n=53-55)		B&C (n=12-14)		1989-1992 (n=607)		B&C (n=47)	
Ratio[1]	Range	(Mean)	Range	(Mean)	Range	(Mean)	Range	(Mean)
1	2.66- 4.11	(3.28)	2.29-3.26	(2.87)	1.12-2.13	(1.51)	1.27-2.19	(1.60)
2	1.46- 2.72	(2.10)	1.63-2.00	(1.80)	0.78-1.85	(1.16)	1.07-1.42	(1.25)
3	5.82- 9.28	(7.27)	5.54-7.00	(6.31)	3.40-5.71	(4.44)	4.00-5.04	(4.37)
4	2.76- 5.70	(4.14)	2.63-3.73	(3.26)	1.00-3.00	(1.53)	1.26-2.50	(1.64)
5	1.91- 3.57	(2.73)	1.72-2.41	(1.98)	1.00-2.00	(1.36)	1.17-1.48	(1.34)
6	6.96-13.20	(9.17)	6.35-8.00	(7.17)	3.05-8.76	(4.50)	3.65-5.76	(4.47)

[1] Ratios are 1= snout to outer barbel:mouth to inner barbel, 2= mouth width:mouth to inner barbel, 3= head length:mouth to inner barbel, 4= snout to outer barbel:inner barbel, 5= outer barbel:inner barbel, 6= head length:inner barbel.
[2] B & C values for shovelnose > 200 mm standard length.

Occasionally, one or more morphometric measurements from a single sturgeon were characteristic of the congeneric species. For instance, a single shovelnose with extremely short inner barbels caused overlap of ratios 4 - 6 for pallids and shovelnose. Therefore, it was necessary to use a character index which looked at several morphological measurements to make species determinations. Character index values (Appendix 1) resulted in distinct groupings of pallids and shovelnose (Figure 9). The character index value for 53 pallids and 607 shovelnose varied from 368 to 478 for pallids, and 164 to 307 for shovelnose. This index shows the aforementioned sturgeon with the short inner barbels was accurately categorized as a shovelnose. It had an index value of 278.

Based on field observation, the character index, percent SL and ratios of several morphological measurements, no suspected pallid-shovelnose hybrids were captured from 1989 - 1993.

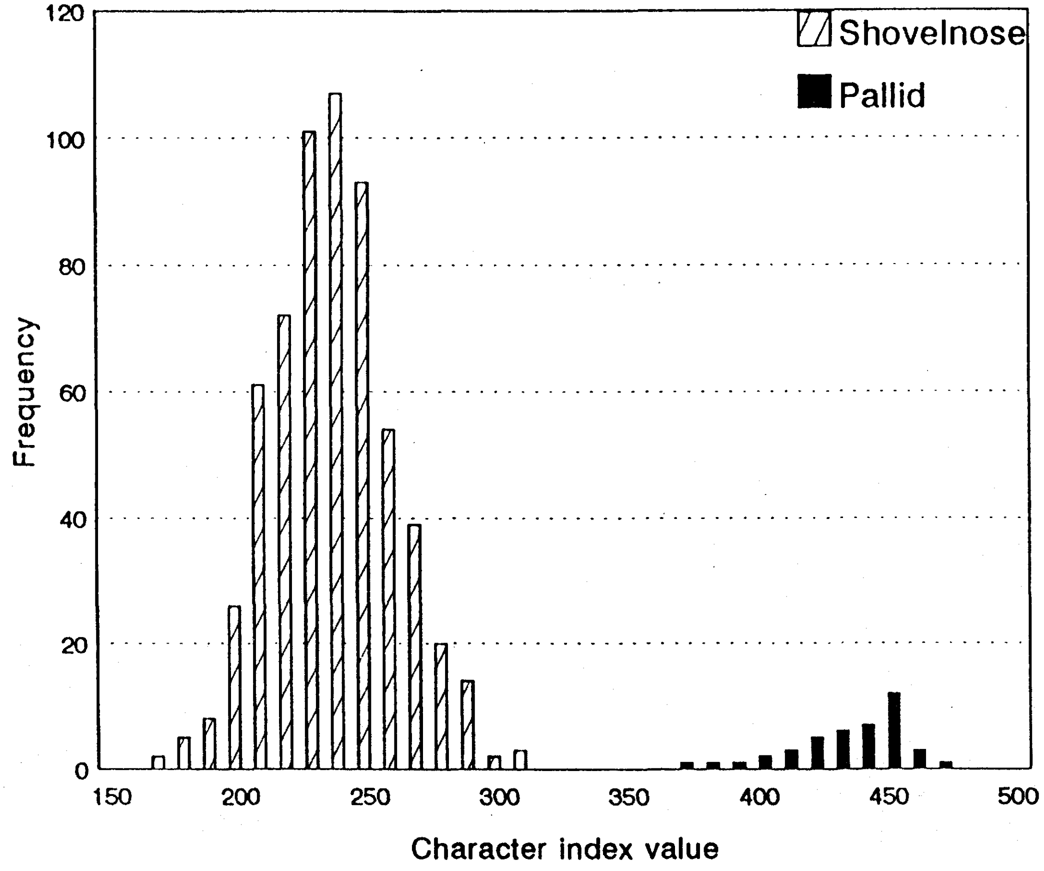


Figure 9. Character index value frequency for pallid and shovelnose sturgeon.

Unfortunately morphological measurements are a poor way to identify species. Past electrophoretic work (Phelps and Allendorf 1983) could not distinguish between pallid and shovelnose sturgeon or between shovelnose populations. Phelps and Allendorf analyzed samples of shovelnose from the study area but the few pallid specimens (N = 10) were taken in state of Missouri from an area where pallid sturgeon and hybrid pallid/shovelnose were found in about equal abundance (Carlson et al. 1985). Morphometric characteristics indicated pure pallid and shovelnose sturgeon were present in the state of Missouri population (Ibid). However, the high amount of hybridization and the small size of the pallids taken (mean FL = 623 mm) may signify that the amount of hybridization in the Missouri population was far greater than was indicated by morphometric measurements. Traits from these pallids should not be directly equated to the pallid sturgeon population in Montana and western North Dakota. Analysis of genetic samples taken during this study is ongoing. DNA analysis of these samples will hopefully give definitive answers concerning hybridization within the study area.

SCUBA

From 1988 - 1991, SCUBA was the primary tool used to capture pallid sturgeon. Water clarity increases in the tailrace in the winter, after Fort Peck Reservoir freezes. Low winter water temperatures meant limited areas could be surveyed during the brief 20 - 30 minute dive time. Most dives occurred in a deep pool about 2 km below the Fort Peck powerhouse and most pallids were seen in this area. A few dives were also completed near the Fort Peck power house. Pallids were observed from January through March and were often seen throughout the diving season. Seven different pallids were caught by SCUBA of which 6 were PIT tagged. Divers (Pat Clancey and Glen Meier personal communications) reported 100's of shovelnose as well as paddlefish, blue suckers, sauger *(Stizostedion canadense)*, channel catfish *(Ictalurus punctatus)* and burbot (*lota lota*) were found with pallids in the Fort Peck tailrace. Annual sightings of different pallids varied from 0 in 1992 to 3 in 1989 and 1991, with a total of 21 sightings in 1991 (Table 8). Nineteen-ninety-two was a unique year in that it was extremely warm, Fort Peck Reservoir did not freeze, and it was the second winter with limited flow fluctuations in the tailrace.

Table 8. Annual (January - March) pallid sturgeon counts in the Fort Peck tailrace from 1988 - 1993 (from Pat Clancey's dive log).

Year	# dives	# pallids sighted	# of different pallids caught
1988	5	4	unknown
1989	10	5	at least 3
1990	15	2	2
1991	14	21	3
1992	15	0	0
1993[1]	6	3	2

[1] 1993 information from Glen Meier

Drift netting

Drift netting effort was concentrated in adult pallid habitat, so effort varied with season and section (Appendix 6). A total of 50 pallids were caught during 1012 drifts of 123 hours duration (Appendices 7 and 8). Seven of these pallids were recaptures. Thirty-five (70%) pallids were caught in 1992 and 14 (28%) in 1993. Pallid sturgeon were only caught with drift netting in sections 6 and 9 (Figure 10, Appendix 7). One pallid was caught in June while the rest were captured in April, September and October (Figure 10, Appendix 8). The overall catch rate was 0.4 pallids per hour.

No pallids were recaptured by netting until 1992, when 2 pallids were recaptured within two weeks, at the same location where they were initially caught. In 1993, 5 of 14 (36%) pallids caught by drift netting were recaptures. These numbers do not include the pallid with an active transmitter that we caught after much effort. One of the 1993 recaptured pallids had been tagged by the USFWS in 1989. Most recaptures occurred within 10 km of the initial capture site. One pallid, recaptured after nearly 3 years, had travelled over 300 km downstream from where it was first caught. At this time a population estimate of pallids would be very inaccurate due to low numbers and violation of several assumptions required to make a mark recapture estimate (for example: sampling throughout the study area). Nevertheless, the high number of recaptures found in 1993 raises concern over the actual status of this species.

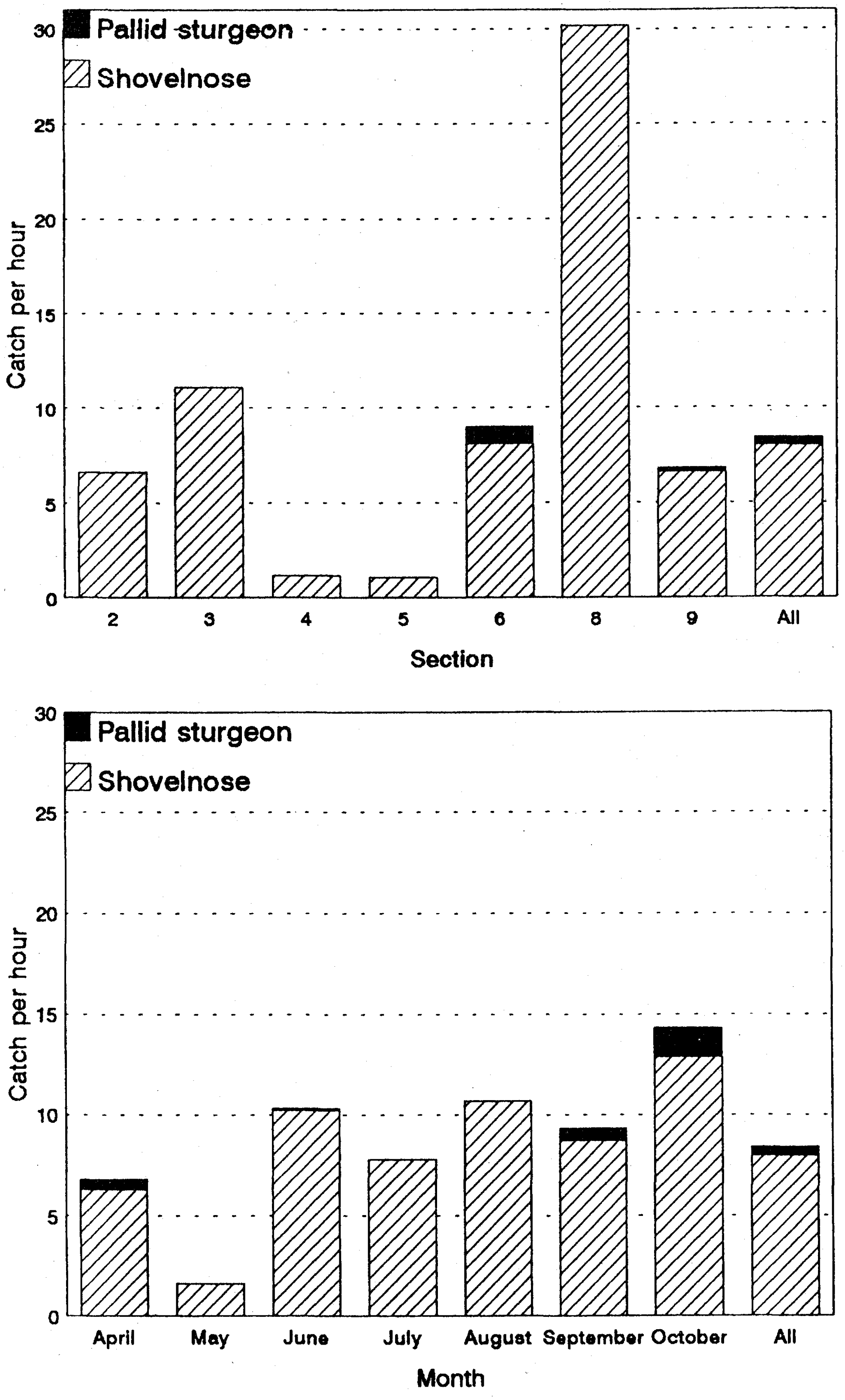


Figure 10. Shovelnose and pallid catch rate from 1990 - 1993 by section and month.

A total of 993 shovelnose were caught during the 123 hours of netting for a catch rate of 8.0 per hour (Appendices 7 and 8). The pallid:shovelnose ratio of 1:19 (4.8%) was greater than any population mentioned by Kallemeyn (1983). Shovelnose were caught throughout the study area and in every season. Seasonal variation of catch rates for shovelnose sturgeon was less than spatial variation (Figure 10; Appendices 7, 8 and 9). Catch was very low in May and highest in October.

Catch rates below Intake in section 8 were nearly 3 times higher than any found elsewhere in the study area, and were about 30 times higher than those seen in the lowest 100 miles of the Missouri above the confluence (Figure 10). Drift netting catch rates in the Missouri above the confluence were similar to electrofishing catch found by Gardner and Stewart (1987). As in this study, Gardner and Stewart found that shovelnose catch was highest near Wolf Point and lowest in the 100 miles of river above the confluence. Catch rates in the Yellowstone above Intake (Watson and Stewart 1991; Backes et al. 1992) suggest that shovelnose catch below Intake is higher than anywhere else within the Yellowstone. Their combined hourly catch rates between Glendive and the Powder River were about 50% of the catch below Intake. Catch rates were less elsewhere above Intake (Watson and Stewart 1991; Backes et al. 1992). The drift technique used by Watson and Stewart (1991) and Backes et al. (1992) differed from this study, in that their drifts averaged 23 minutes compared to 7 minutes. Data from this study indicates drift time does not influence catch rate, however too many factors confound data analysis to make conclusions. Further evaluation of how drift time effects catch per hour is needed to determine if data can accurately be compared when drift times differ greatly.

Nine species were caught with pallid sturgeon during drift netting. Six of these species were caught at least 12% of the time pallid sturgeon were netted (Table 9). Shovelnose sturgeon were the species most frequently caught with pallids, but only represented 6% of the shovelnose netted in sections of the river where pallid sturgeon were caught. This compares with 32% of sauger, 20% of river carpsuckers *(Carpoides carpio)*, 14% of buffalo species *(Ictiobus sp.)*, and 12% of blue suckers captured in sections 6 and 9 that were netted with pallids (Table 9). Other species caught with pallid sturgeon during drift netting include paddlefish, walleye *(Stizostedion vitreum)*, goldeye (*Hiodon alosoides*) and channel catfish. Twenty-four percent of pallids were caught with no other species. Due to low numbers of some species, net selectivity and a large variety of habitats netted during a single drift, these associations only reflect coexistence of these species and should not be regarded as a direct index of affinity.

Table 9. Incidental catch during 33 drifts in which 50 pallid sturgeon were caught from 1991 - 1993.

	Species					
	Shovelnose sturgeon	River carpsucker	Buffalo species	Sauger	Blue sucker	Pallid only species caught
# (%) of pallid drifts containing species	16 (48%)	11 (33%)	7 (21%)	5 (15%)	4 (12%)	9 (27%)
# of individuals of species caught with pallids	35	28	10	9	7	12[1]
% of total species catch in sections 6 and 9 which were caught with pallids	6%	20%	14%	32%	12%	24%[1]

[1] number and % of pallids caught alone

Food habits were not evaluated in this study. However, during this study one pallid regurgitated four flathead chubs *(Platygobio gracilis)* after it was netted. Other researchers have also found that fish are a food source for adult pallid sturgeon (Carlson et al. 1985; Kallemeyn 1983).

Radio telemetry
Evaluation of transmitters

External back, external dorsal, internal and protruding radios all had good signal reception in the Yellowstone and in the shallower sections of the Missouri. Signals were lost for long periods from all types of radios when pallids were occupying areas downstream of the confluence and in the Fort Peck tailrace. Much of the pallid habitat in these areas is too deep for radio signals to penetrate. A total of 59 radio and/or sonic tags were deployed on pallid and shovelnose sturgeon. Appendices 2 and 10 give fish and radio statistics for each transmitter deployed.

External back transmitter

External back transmitters, attached through the dorsal scutes from 1989 - 1991 did not work well on pallid sturgeon. Radios were attached following methods used in previous studies of shortnose sturgeon, (Hall et al. 1990; Buckley and Kynard 1985) and white sturgeon *(Acipenser transmontanus)* (Haynes et al. 1978), but all pallid sturgeon in this study apparently shed their transmitters within 15 weeks. Due to transmitter failure and deep water below Fort Peck, most pallids were never relocated more than one week after initial capture. Relocations more than one month after deployment were obtained from just 3 of 10 pallids. Four pallids with dorsal back transmitters were recaptured. One, recaptured one month after tagging still held a transmitter. All of these recaptured pallids appeared healthy, but were scarred at the attachment sites. A pallid tagged by MDFWP above Fort Peck had a severe reaction to its radio, but recuperated once the radio was removed (William M. Gardner, MDFWP, personal communication). Haynes (1978) found 80% of dummy dorsal back mounted transmitters fell off white sturgeon in circular tanks within three months and determined they stayed attached from 1 -12 months in the field. In contrast to pallid and white sturgeon, Buckley and Kynard (1985) successfully attached dorsal back transmitters to shortnose sturgeon but used methods to insure transmitters would fall off within one year.

External dorsal transmitters

Transmitter size and potential removal of transmitters from recaptured fish are the primary benefits of the dorsal fin attachment system. External radios require less power for an adequate signal than those with internal antennae; a transmitter weighing 40 grams with an external antenna will last more than 600 days but only last 100 days with an internal antenna. Reception from dorsal fin transmitters was excellent; signals were obtained from external radio transmitters in water 5 - 6 m deep when field conductivity was 600 μmhos/cm.

Retention of dorsal fin transmitters was initially successful. Pallid sturgeon tagged with dorsal fin transmitters in the fall of 1992 moved downstream immediately after tagging, but usually returned to the initial tagging site within two weeks, and all active transmitters moved upstream during spring run off. One pallid with a dorsal fin transmitter is still being monitored more than one year after attachment. Another pallid with a 40 g transmitter was recaptured 1 month after tagging. This pallid was healthy and was running eggs (Steve Krentz, USFWS, personal communication). Reports of 3 other pallids recaptured 1 - 6 months after tagging also indicated that this transmitter attachment worked well (William Gardner, Fred Ryckman (ND Game and Fish), personal communications). Apperson and Anders (1991) successfully used dorsal fin attachment on white sturgeon in the Kootenai River. However, retention of external transmitters on pallid sturgeon during 1993 was mixed. Balance, snagging and drag problems found with external transmitters (Winter 1983) probably caused transmitters to pull off several pallid sturgeon. As indicated by stationary signals, transmitters apparently fell off 5 pallids, 1 - 10 months after deployment. One pallid was recaptured without its radio. The attachments had pulled through the dorsal fin. This fish was in the process of healing at the attachment sites. In the future these transmitters should always be deployed with copper crimps (Buckley and Kynard 1985), as they were in September 1993, to insure transmitters fall off within 4 - 12 months.

Internal

Internal transmitters are considered the best for long term attachment and are recommended by several telemetry researchers (Mellas and Haynes 1985; Tyus 1988; Winter 1983). However internal implants should not be used during extreme water temperatures or on fish in poor condition (Winter 1983). Implantation is especially suitable for sonic systems. Increased power output for sonic transmitters is not required to compensate for internal placement. Without the balance problems associated with external placement larger transmitters can be used (Winter 1983). Internal transmitters were somewhat successful. No initial downstream movement was recorded for any fish. Signals were obtained from internal radios at base flows in water up to 3.6 m deep. As mentioned above, radios with internal antennae required stronger signals and thus, larger batteries then external antennaed systems. Cold water temperatures limit when and where internal transmitters or protruding transmitters should be used. One recapture, initially tagged in the cold waters of the Fort Peck tailrace in July was not completely healed within 5 months. Internal transmitters have also been successfully removed and replaced in pallid sturgeon (William M. Gardner, personal communication).

Protruding

The internal transmitter with protruding antenna offers a lack of drag problems and the signal transmitting range of an external whip antenna and have been used successfully on lake sturgeon *(Acipenser fulvescens)* (Mosindy and Rusak 1991). Several years of data can be collected using one transmitter, a beneficial feature for long term studies. Internal transmitters with protruding antenna were consistently relocated throughout their expected battery life. Some fish were relocated 19 months after they were transmittered. All sturgeon transmittered with this attachment system and relocated within 2 weeks had moved downstream, but most of these fish had moved upstream within one month and many exhibited extensive up and downstream seasonal movements. Retention problems occurred in 2 of 19 (10%) shovelnose implanted with protruding radios. One transmitter was found on the beach and another did not move for over one year. One pallid and one shovelnose sturgeon with internal radios with protruding antenna were recaptured about one year after implantation. These fish had completely healed at the radio insertion site, but had inflammation where the antennae hole exited the fish. The shovelnose held a radio with a broken antenna which aggravated the exit wound. These healing problems may mean this type of transmitter is inappropriate for the endangered pallid sturgeon. Once implanted with this style of transmitter a pallid would likely have it for life since it would be very difficult to remove without harming the fish.

Sonic transmitters had similar reception whether internal or external. Reception range was drastically reduced by interference caused by silt during high flow periods. Signal range was always limited to a few hundred yards. The huge study area made it impractical to locate sturgeon by relying on the sonic system, however sonic transmitters were indispensable in the deep, clear, relatively small area of the Fort Peck tailrace. Sonic signals also helped pinpoint fish during relocations, but accurate relocations could be done with triangulation of radio signals (Bob Bramblett, personal communications). Therefore, the extra weight of sonic transmitters was not warranted in the confluence area, but was a necessity in the tailrace area.

Due to poor retention and bad inflammation in one pallid sturgeon, I found the external back attachment to be unacceptable and do not recommend it for pallid sturgeon telemetry. The other three transmitter systems worked better, but had limitations. Internal transmitters with dipole antennae required high output resulting in short battery life, protruding radios did not heal at the antenna exit site, and some external dorsal transmitters fell off the fish.

Long term movement and reception was similar for these three types of transmitters. Movement of telemetered fish is a mix of both transmitter caused and natural movement patterns. During every season and flow most sturgeon with external and protruding transmitters moved downstream immediately after release, but usually returned to the location of deployment within two weeks. Fish with internal transmitters did not move downstream. There is evidence that transmitted pallids followed normal behavior patterns. As indicated by drift netting and angler contacts, pallids with and without transmitters were often found together. During the 1993 spring run-off, pallid sturgeon with dorsal, internal and protruding transmitters with loading of 0.1 - 1.1% moved within an 8 km section of river and were found with non-transmittered pallids. Presence of sexually mature non-radioed and radioed pallids was documented in this area (Steve Krentz, USFWS, personal communication).

All of the transmitters had drawbacks which were exacerbated by signal attenuation in the deep high conductivity waters of the study area. Internal radios probably have the least impact on the recipient when used on fish in good condition (Winter 1983). Unfortunately the high power I found necessary for internal dipole antennae resulted in limited radio life. Dorsal fin transmitters, if used, should be very small (10 - 20 g), applied without sonic transmitters, and applied with copper crimps designed to break in about six months. In the study area, all sturgeon retained this type of transmitter for at least six months, when applied by an experienced researcher. In the Missouri above Fort Peck retention was less (William M. Gardner, personal communication). During a long term study the use of protruding antennae on a limited number of fish should be considered. Further evaluation of transmitter types is needed. Perhaps modified trailing whip antennae can be used inside the body cavity and may require less power than dipole antennae. Perhaps, copper protruding antennae can be used, which will eventually corrode and allow healing of the antenna exit wound. Width of wires used in dorsal fin attachment may be crucial to radio retention; thin wire may easily pull through the fin. Radio telemetry is an indispensable tool for the rare, migratory pallid sturgeon. However, the extremely limited numbers of pallids make it important for researchers to carefully weigh the benefits of telemetry with its potential impacts on the health and population of pallid sturgeon.

Movements

Both pallid and shovelnose sturgeon were very mobile. Movements of over 300 km have been documented for both species in the study area. Figure 11 exhibits movement patterns from one pallid sturgeon in the confluence area. Graphs of movements from other pallids are in Appendices 11 and 12.

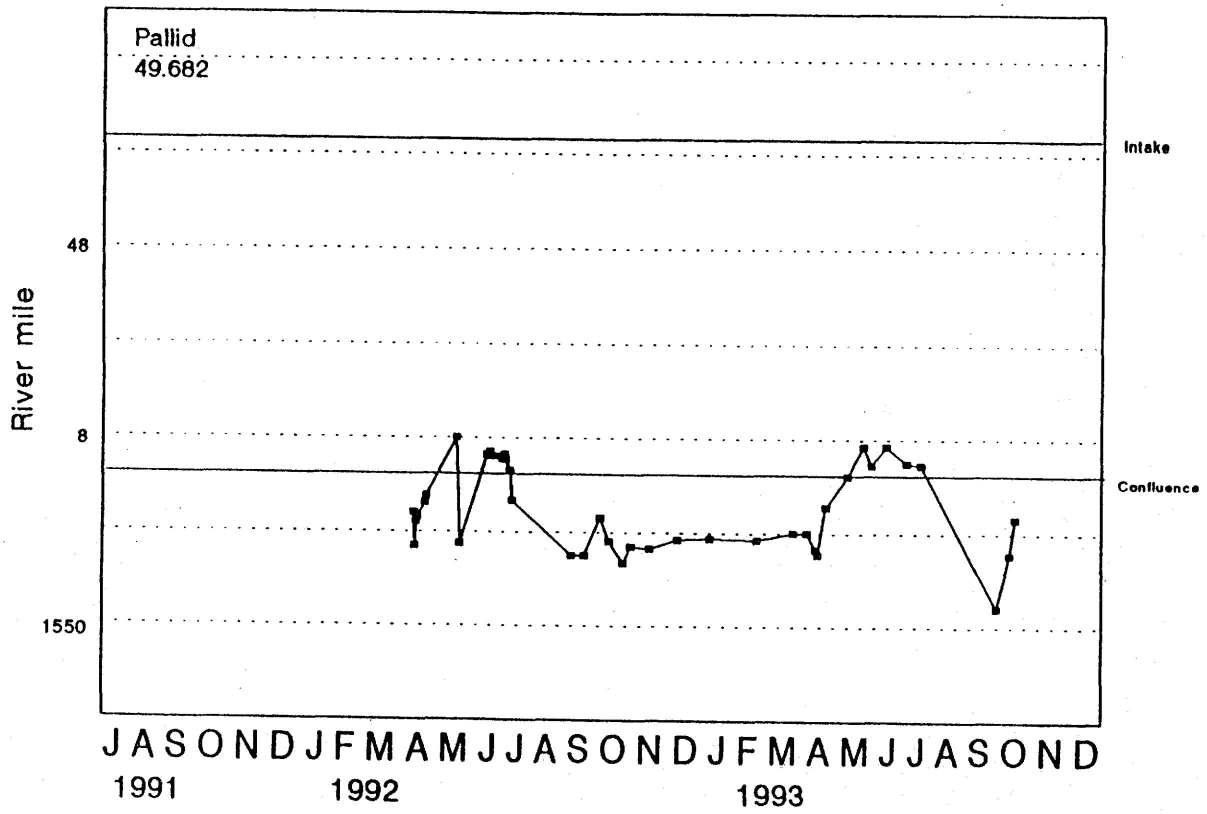


Figure 11. Movement of a pallid sturgeon tagged in April 1992.

The pallid in Figure 11 exhibits four characteristics found in 100% of 14 pallids telemetered near the confluence: 1) April or May movement into the Yellowstone River; 2) residency in the Yellowstone River throughout much of May, June and July; 3) downstream movement to below the confluence in late summer and; 4) limited winter movement. Some pallid signals were found in the Yellowstone in August - October 1993, but these radios had probably fallen off fish as described above. Six pallids tagged in the confluence area were recaptured within 15 km of where they were initially tagged.

Pallids tagged in the Fort Peck tailrace exhibited much different movement patterns than those found at the confluence (Appendix 12). These pallids typically occupied the tailrace and the Missouri below Fort Peck Dam. Only 3 telemetered pallids, monitored in 1989 and 1993, moved downstream into the river from the Fort Peck tailrace. One other pallid was recaptured twice in the tailrace in mid-summer, indicating year round residency. Other radioed pallids in the tailrace area were not relocated more than one month after transmittering.

Pallids in the Fort Peck tailrace moved downstream in the spring. Two of three returned to the tailrace before winter and the third has not been relocated since moving downstream in 1989 (Appendix 12). A fourth pallid transmittered in the Fort Peck Tailrace in February 1990 was recaptured by anglers near Culbertson in July 1992, and had lost its transmitters. This fish had moved downstream about 240 km since last observed. One other angler-caught pallid (verified with photos) was caught in the Culbertson area in May of 1990. Two of seven pallids (28%) initially PIT tagged in the Fort Peck tailrace were recaptured below the confluence area. One of these fish had moved over 300 km in 9 months. The second fish was recaptured more than 2 years after it was initially tagged.

Shovelnose movements differed from those of pallid sturgeon. Seven of the 11 (64%) shovelnose monitored during the spring in the confluence area had seasonal long distance movements of 80 - 115 km. These movements were exhibited by shovelnose tagged near Intake as well as those tagged near the confluence. The other four shovelnose monitored from April - July exhibited seasonal movements of less than 30 km and stayed within the Yellowstone throughout the time they were tagged (Appendix 10). Figure 12 shows the movements of a typical wide-ranging shovelnose. As with all wide-ranging shovelnose this fish spent most of its time within the Yellowstone River, did not move much during the winter and exhibited upstream movements in the spring. Three shovelnose moved over Intake diversion dam, one at extremely low flow (about 5000 cfs) when the side channel was dry. In the confluence/Yellowstone area 40% of shovelnose with long term radios were relocated below the confluence at least once.

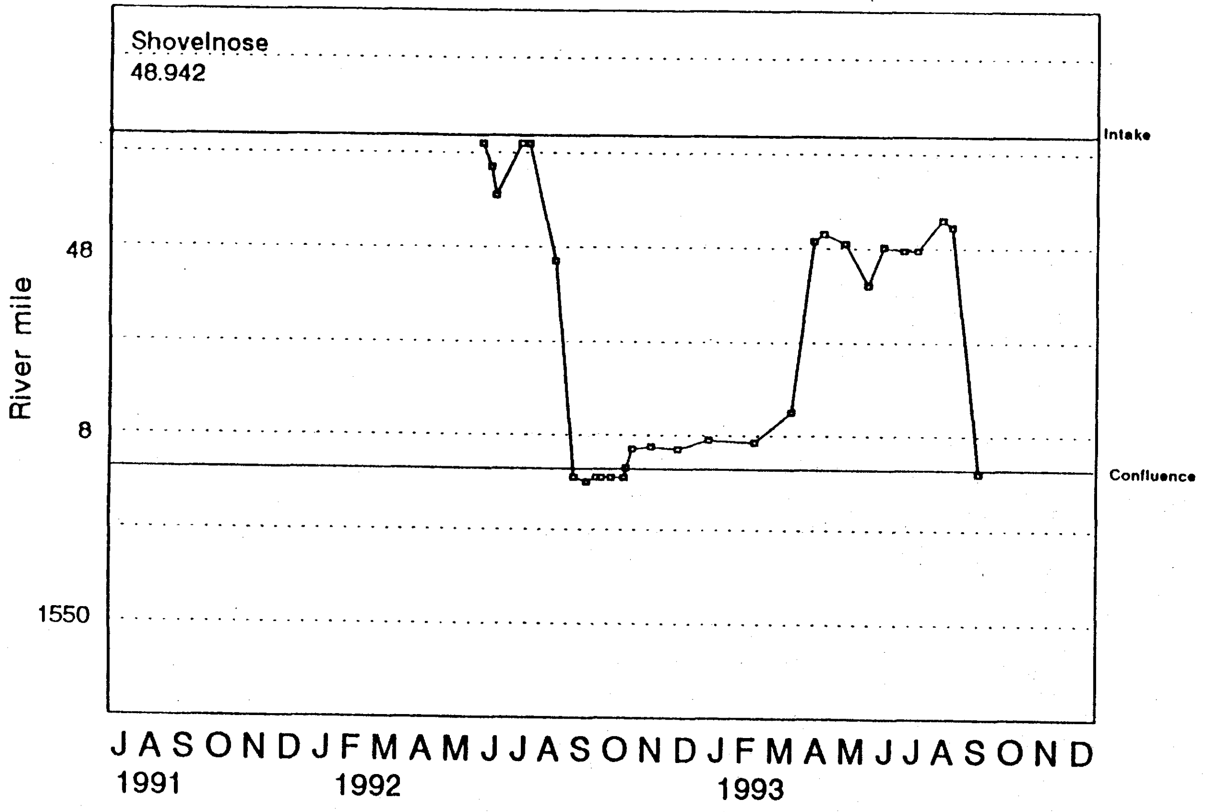


Figure 12. Movement of a wide-ranging shovelnose sturgeon implanted with transmitters near the confluence of the Yellowstone and Missouri Rivers in 1992.

Shovelnose which moved less did not have predictable patterns. Shovelnose tagged in the Fort Peck tailrace exhibited very little movement and were only relocated within the tailrace area.

Three spaghetti-tagged shovelnose were recaptured during this study. One was recaptured in 1992, 12 years after it was tagged. This fish had moved downstream from the Tongue River to below the confluence and had grown 41 mm and 0.2 kg. The other two sturgeon were both tagged and recaptured below the confluence 2 weeks and one year after they were tagged. Gardner and Stewart (1987) report that 2 tagged shovelnose migrated more than 400 km from the Yellowstone River down to the confluence and up the Missouri to below Fort Peck Reservoir.

Cinch-up, dangler, PIT and spaghetti tags were found on sturgeon recaptured one or more years after tagging. A pallid recaptured after one year was sore at the dangler tag attachment site and the tag looked as if it would soon come off the fish. PIT tag implants were totally healed and were read up to four years after implantation. However a pallid implanted in 1992 no longer had a functioning PIT tag. The pallid was identified by a dangler tag. A cinch-up tag on a shovelnose was still readable 12 years after attachment.

Habitat measurements

Habitat data collected from 1989 - 1992 by MDFWP and in 1992 by MSU is listed in Tews and Clancey (1992), and Clancey (1989, 1990, 1991). Habitat measurements taken by MDFWP in 1993 are listed in Appendix 14. Bob Bramblett, doctoral candidate from MSU is conducting an intensive study of shovelnose and pallid sturgeon habitat use in the confluence area, and will present habitat data and analysis in his dissertation. Consequently, limited analysis of habitat data are presented here. Table 10 summarizes habitat information taken for shovelnose and pallid sturgeon in 4 distinctly different areas from 1989 - 1993. Some very general trends can be seen. Mean pallid depth was greater than mean shovelnose depth in all areas. Velocities were similar for the two species in riverine areas. Pallids occupied slower and deeper areas in the Fort Peck tailrace than shovelnose. All pallids were found over substrate that contained some sand, while shovelnose were also found over gravelly substrates. Bramblett and White (1993) found that pallid sturgeon preferred sandy substrate in the Yellowstone/confluence area, but found no significant differences in depth or velocity between pallid and shovelnose sturgeon.

Table 10. Summary of pallid and shovelnose sturgeon habitat measurements taken from 1988 - 1993 by MDFWP.

		Area			
	River miles	Fort Peck tailrace (1768-1770)	Missouri above confluence (1583 - 1760)	Missouri below confluence (1540-1582)	Yellowstone (0-71)
Pallid	# fish	1	3	11	10
	# measurements	(6-7)	(4-6)	(24-25)	(4-11)
	Years	1993	1989,1993	1990-1993	1992,1993
	Months	April,May September, October	May,June,July	April,May, June,September October	April,May, June, October
	CFS	4671 (3200-7300)	8587 (6200-12600)	15413 (9210-47420)	12228 (7390-21200)
Velocity (m/s)		<0.01	0.60 (0.38-0.87)	0.59 (0.25-0.90)	0.62 (0.55-0.80)
Depth (m)		9.4 (6.7-11.3)	2.1 (1.7-2.7)	2.9 (0.8-5.2)	2.3 (0.9-4.9)
Temperature (°C)		8.3 (2.8-15.0)	14.1 (7.5-20.0)	10.7 (4.0-20.0)	14.8 (8.0-20.0)
Turbidity (NTU)		790 (12-4500)		451 (32-6400)	496 (39-755)
Substrate		100% sand	100%sand	88% sand 12%sand/gravel	90% sand 10%sand/gravel
Shovelnose	# fish	7	0	6	9
	# measurements	26-31		11-13	19-21
	Years	1991-1992	-	1991-1992	1991-1992
	Months	August,September October	-	May, September October	May,September October
	CFS	7062 (3000-7956)	-	10978 (9140-22170)	8905 (3900-17600)
Velocity (m/s)		0.16 (<0.01-0.6)	-	0.58 (0.40-0.70)	0.65 (0.35-1.5)
Depth (m)		5.3 (2.7-10.1)	-	1.7 (1.2-3.0)	1.8 (0.9-4.0)
Temperature (°C)		13.6 (11.7-15.0)	-	13.0 (7.0-15.0)	12.8 (8.5-21.0)
Turbidity (NTU)		5 (4-5)	-	90 (36-510)	211 (15-890)
Substrate		100% Sand	-	100% sand	73% sand 27% gravel

Other species

Table 11 lists all species caught from 1989 - 1993. Sampling effort and gear were not consistent throughout the study area. However, all sections except 4 and 7 were sampled during most seasons (Appendix 6). Therefore, it is possible to look at trends in species number distribution. Only 3 non-shovelnose species had drift net catch rates greater than 1.0/hour (Appendices 7 and 8). These included goldeye (4.0/hour), channel catfish (1.6/hour) and river carpsuckers (1.3/hour). Buffalo species and blue sucker were also fairly common.

Table 11. Fish species caught during the Fort Peck Pallid sturgeon study from 1989-1993.

Pallid sturgeon	*(Scaphirhynchus albus)*
Shovelnose sturgeon	*(S. platorynchus)*
Paddlefish	*(Polyodon spatulata)*
Goldeye	*(Hiodon alosoides)*
Cisco	*(Coregonus artedii)*
Rainbow trout	*(Oncorhynchus mykiss)*
Rainbow smelt	*(Osmerus mordax)*
Northern pike	*(Esox lucius)*
Carp	*(Cyprinus carpio)*
Longnose dace	*(Rhinichthys cataractae)*
Flathead chub	*(Platygobio gracilis)*
Sickelfin chub	*(Macrhybosis meeki)*
Sturgeon chub	*(Machrybopsis gelida)*
Emerald shiner	*(Notropis atherinoides)*
Plains minnow	*(Hybognathus placitus)*
River carpsucker	*(Carpoides carpio)*
Blue sucker	*(Cycleptus elongatus)*
Smallmouth buffalo	*(Icitobus bubalus)*
Bigmouth Buffalo	*(Ictiobus cyprinellus)*
Shorthead redhorse	*(Moxostoma macrolepidotum)*
Longnose sucker	*(Catostomus catostomus)*
White sucker	*(Catostomus commersoni)*
Channel catfish	*(Ictalurus punctatus)*
Yellow perch	*(Perca flavescens)*
Sauger	*(Stizostedion canadense)*
Walleye	*(Stizostedion vitreum)*

Catch rates of all species varied greatly between river section and month (Figure 13; Appendices 7 and 8). Goldeye were always common, but represented a greater percentage of the catch in the Missouri above the Yellowstone than elsewhere. Channel catfish, river carpsuckers, and buffalo sp., like pallid sturgeon, were only caught in large numbers in sections of the river influenced by the Yellowstone. Blue suckers were found most frequently below the confluence and in the upper reaches of both the Yellowstone and Missouri Rivers. As with pallid and shovelnose sturgeon, catch rates of goldeye, river carpsuckers, and blue sucker peaked in October (Figure 13). Low water levels which concentrated fish in the fall surely influenced catch rates. However, catch rates during other months indicated that fish migration and/or seasonal habitat preferences also influenced catch. For example catch rates of goldeye and channel catfish were very high in June (Figure 13) when high flows occurred.

Blue suckers were the fifth most common species found during this study. Little is known about the life history of this species. In the study area, like other areas, blue suckers tended to be large (Werdon 1993c). During 1993, they ranged in TL from 513 to 777 mm and averaged 653 mm. They ranged from 0.8 - 3.8 kg and averaged 2.2 kg. More than 80% were greater than 550 mm in total length (Figure 14). Backes et al. (1992) caught 75 blue suckers, which averaged 702 mm, in the Yellowstone River above Intake.

Earlier studies reported a similar species composition to that observed here (Haddix and Estes 1976; Gardner and Stewart 1987). Gardner and Stewart's (1987) data even reported similar species trends in the Missouri above the confluence. The higher numbers of sauger, walleye, carp, river carpsuckers and shorthead redhorse found in their study presumably reflect methodologies more than they represent ecosystem change during the past 10 years. In contrast to the drift netting which was used to sample deep, swift and shallow habitats in this study, Gardner and Stewart's techniques of electrofishing and stationary gill nets concentrated effort in shallow or slow areas.

Flathead chubs were by far the most common species found during seining effort. **Surprisingly, sturgeon chub were the second most common species.** Catostomids were common in the Missouri above the confluence but were rare in other areas. Emerald shiners *(Notropis placitus)* were only found in the Yellowstone (Figure 15; Appendix 15). Other species sampled included longnose dace *(Rhinichthys cataractae)* and plains minnow *(Hybognathus placitus)* in the Yellowstone, and **sicklefin chub** and shorthead redhorse *(Moxostoma macrolepidotum)* in the Missouri (Appendix 15). Average catch per seine haul was higher in the Yellowstone than in the Missouri.

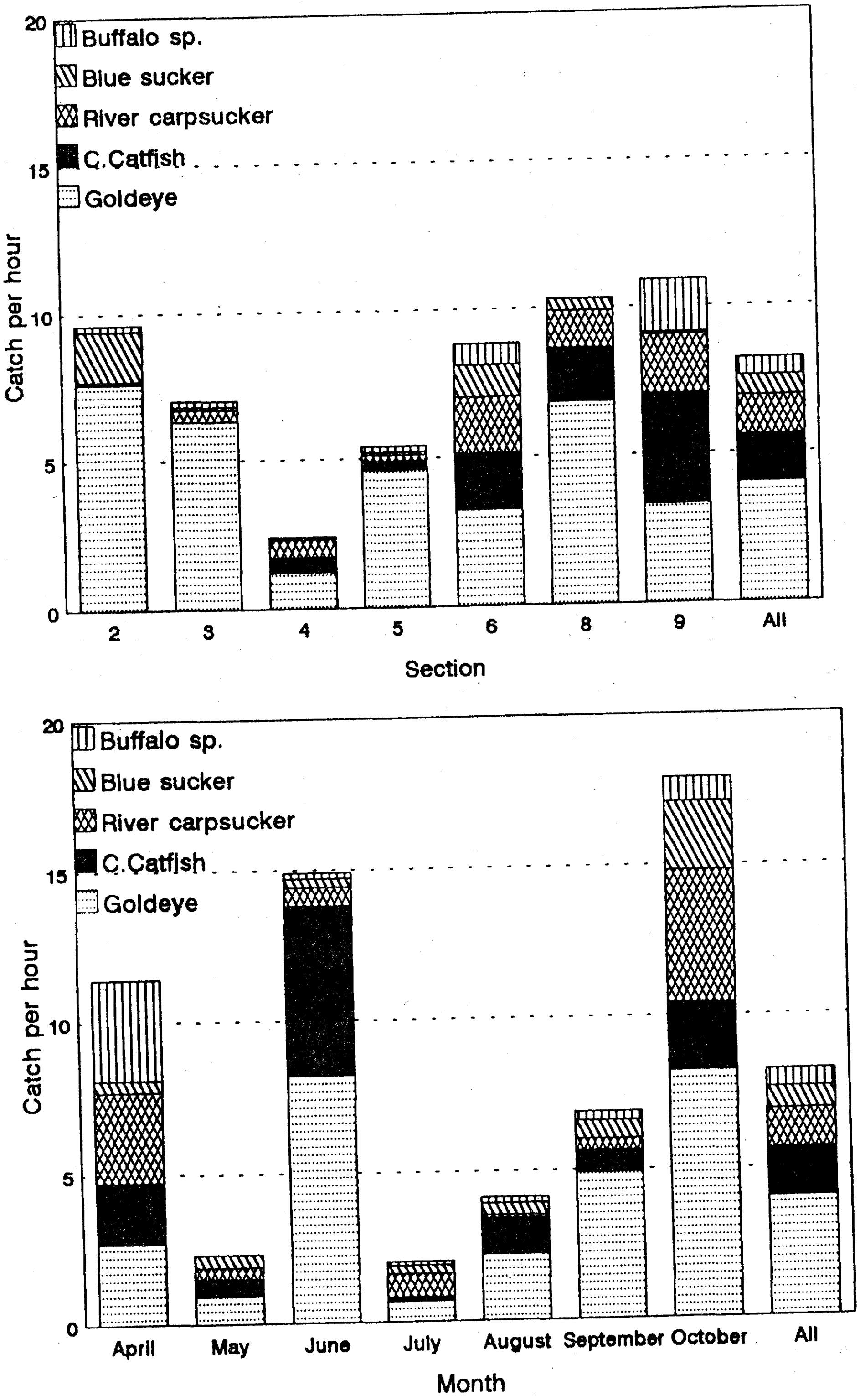


Figure 13. Drift netting catch of common non-Scaphirhynchus species from 1990 - 1993.

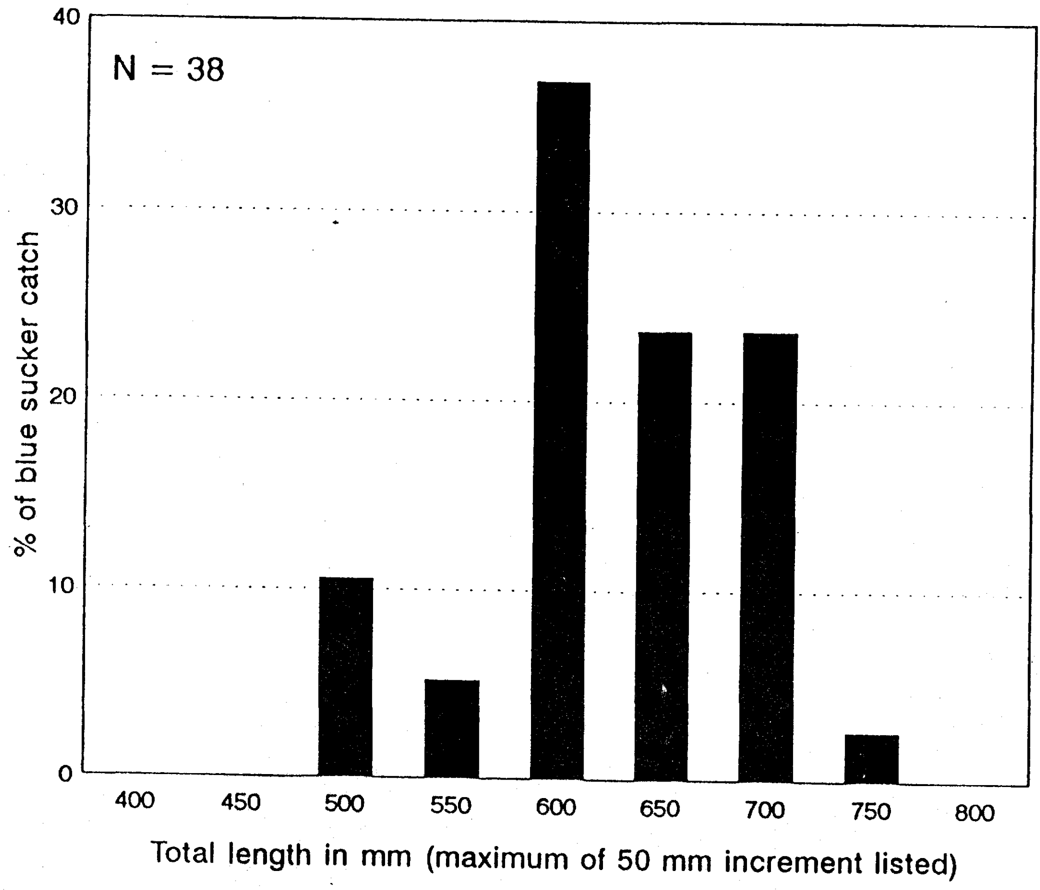


Figure 14. Length distribution of 1993 blue sucker catch.

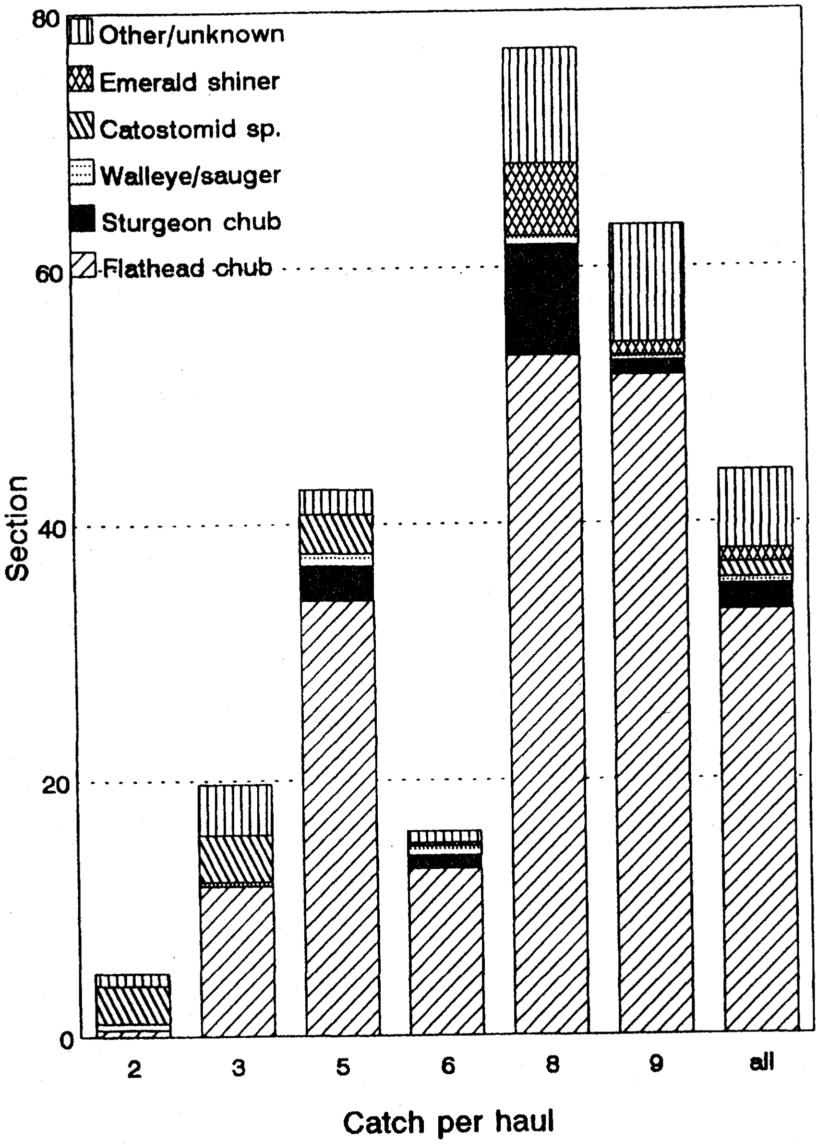


Figure 15. Catch of common species during 1993 seining effort.

Haddix and Estes (1976) found a species diversity similar to that found here, during main channel sampling for forage fish in the Yellowstone. In the Missouri above the confluence, Gardner and Stewart (1987) found similar species but a much greater diversity and different numbers than found during this study. For example, they caught very few flathead chubs and found that numbers of fish decreased downstream, the opposite of what was found in this study. Limited sampling effort contributed to these differences and also restricts the utility of the data. Only 8 seine hauls were completed during this study in the Missouri above the confluence, while Gardner and Stewart completed 62.

Reviews by the USFWS (Werdon 1993a, 1993b) document recent catches of both sicklefin and sturgeon chub in the Yellowstone just above the confluence and indicate they may be in danger of extinction in the study area. A total of ~~27~~ 47 sturgeon chub were sampled from mile 2 - 51 (3 - 82 km) on the Yellowstone and from miles 1575 - 1589 (2534 - 2557 km) on the Missouri in just 18 seine hauls. This may indicate the perceived rarity of sturgeon chub in the study area is due to inadequate sampling. Other sturgeon chub recently collected near the confluence (Werdon 1993b) also leads to this conclusion. The single sicklefin chub caught during this study extends the recent catch of this species downstream about 10 km which shows promise for this species. However, the limited sampling done make it impossible to draw conclusions concerning the abundance of sickelfin chub.

A population of large rainbow trout *(Oncorhynchus mykiss)* resides in the Missouri between Fort Peck and the Milk River and spawns in a side channel near the Fort Peck tailrace. The USACOE has sponsored studies as well as physical enhancement of spawning gravel for these fish. These studies suggested a minimum instantaneous flow of 7800 cfs during the spawning season (Clancey 1989). Rainbow redd counts increased from 1990 - 1992 during powerhouse retrofitting, when discharge did not fluctuate and was usually greater than the recommended minimum. Redd counts dropped dramatically in 1993 (Figure 16) when flows power peaking resumed (Figure 3), resulting in minimum discharge below the recommended level on a daily basis. Discharge was often even below the absolute minimum of 4500 cfs. Dewatering of most redds was observed at these flows.

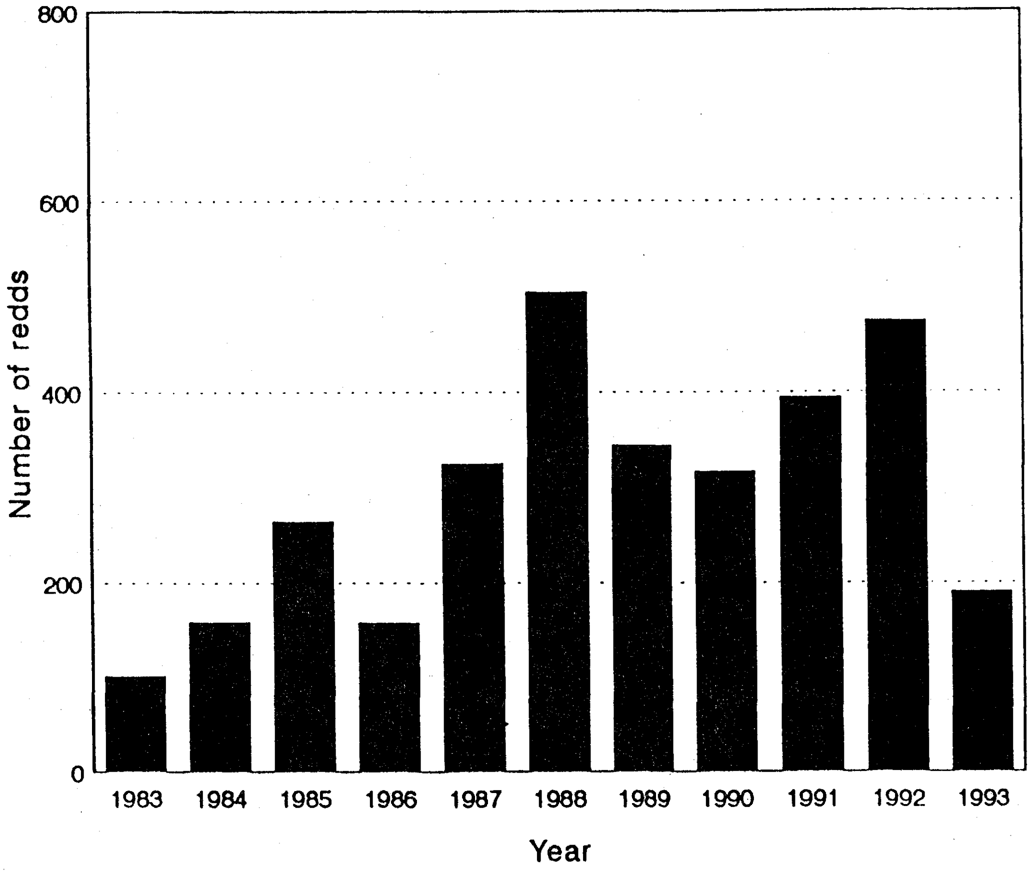


Figure 16. Rainbow trout redd counts from 1983 - 1993 in a side channel immediately below Fort Peck dam.

Standardized sampling

Standardized sampling constituted 22.8 hours and 277 drifts of 90 total km and resulted in capture of 184 shovelnose and 0 pallid sturgeon. For analysis, standardized drifts were evaluated as catch per effort. An effort equals about 370 m. Due to snagging, standardized efforts occasionally involved 2 or more drifts, therefore the 277 drifts were evaluated as 249 efforts. A total of 127 fish of 14 other species were also sampled (Appendix 16). Catch and habitat data are listed in Appendices 17 - 24. Due to access and boat problems all stations were not sampled during all planned times. This makes statistical analysis of the data inaccurate, since seasonal and spatial variation was found for both habitat and catch parameters. However, statistical analysis was completed for some size statistics and for habitat type.

Shovelnose catch rates varied dramatically. Only 29% of the 249 drifting efforts caught shovelnose. Forty shovelnose, 22% of the entire standardized shovelnose catch, were sampled during 2 drifts in October. Shovelnose catch rates were slightly higher in shallow than in deep habitats (Figure 17), with 74 shovelnose (40%) captured in deep habitats and 110 (60%) captured in shallow habitats. These differences were not statistically significant. Shovelnose were more common in deep habitats at the two sampling sites within 115 km of Fort Peck Dam. It is interesting to speculate why these sturgeon occupied deeper habitats. It seems likely that fluctuating water levels and/or water clarity were important. Shovelnose catch rates were highest at the most upstream stations on the Missouri and the Yellowstone and lowest on each of those rivers at stations just above the confluence (Figure 17). When catch rates were analyzed with Kruskal-Wallis ranks, differences between stations were found ($P<0.01$). Further analysis using the conservative Dunn's test (Hollander and Wolfe 1973) indicated the only difference was between stations 2 and 4 ($P=0.1$), the lowest and highest ranked stations.

Shovelnose caught during standardized sampling ranged from 267 - 914 mm FL, and averaged 606 mm. They weighed from 0.04 - 4.3 kg and averaged 1.0 kg. Size structure differed between stations. The most upstream stations (2 and 6) had the largest shovelnose (Figure 18). These results concur with the shovelnose catch throughout this study (Figure 8). The Yellowstone and Missouri both had shovelnose ranging from less than 300 mm to nearly 900 mm. The smallest and largest shovelnose were found on the Missouri above the confluence but station 6 on the Yellowstone was the station that exhibited the widest size range.

Habitat measurements varied with station and season. The data followed trends that were expected based on the nature of the Yellowstone and Missouri Rivers. Temperatures were lowest below

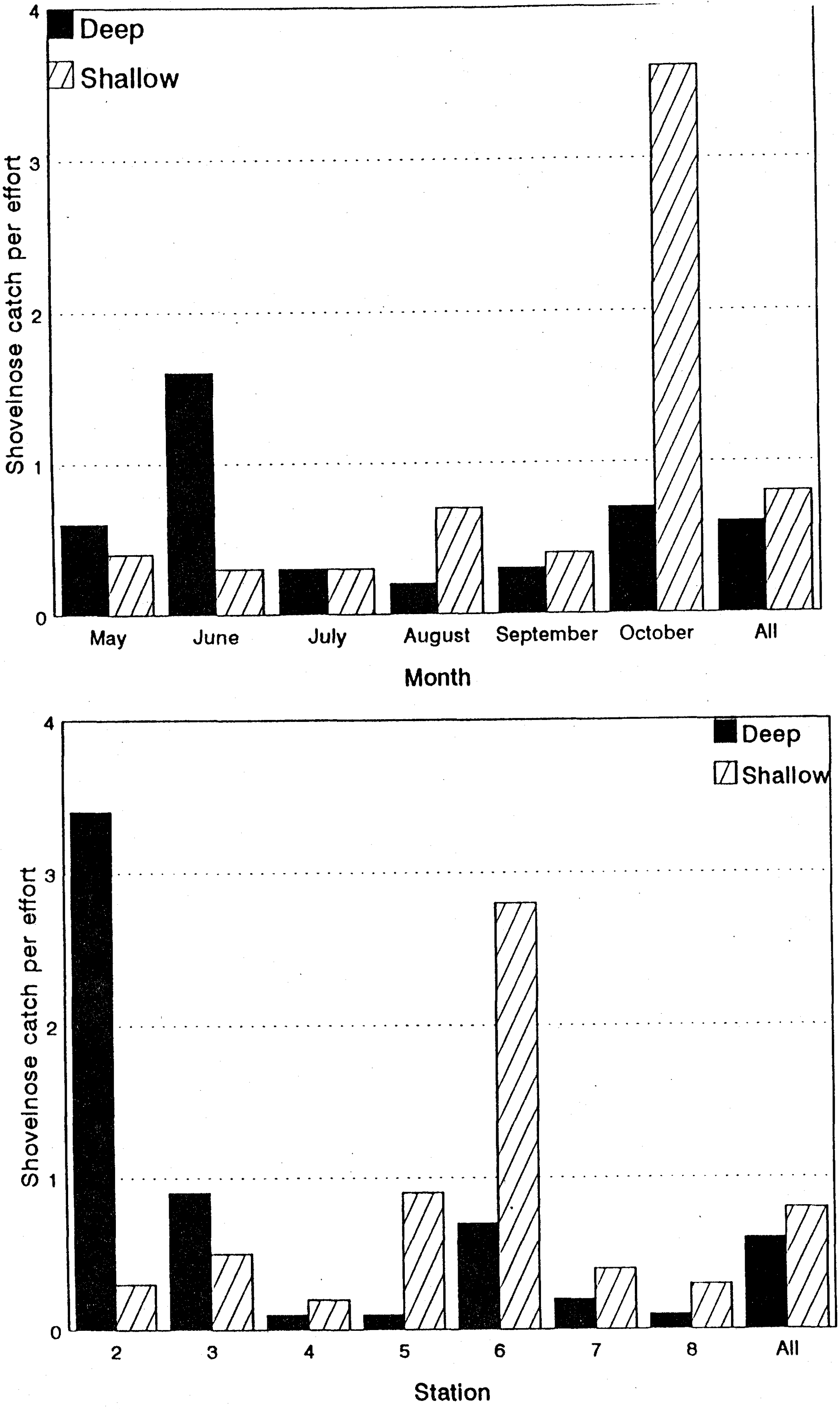


Figure 17. Shovelnose catch per effort by month and station during 1993 standardized sampling.

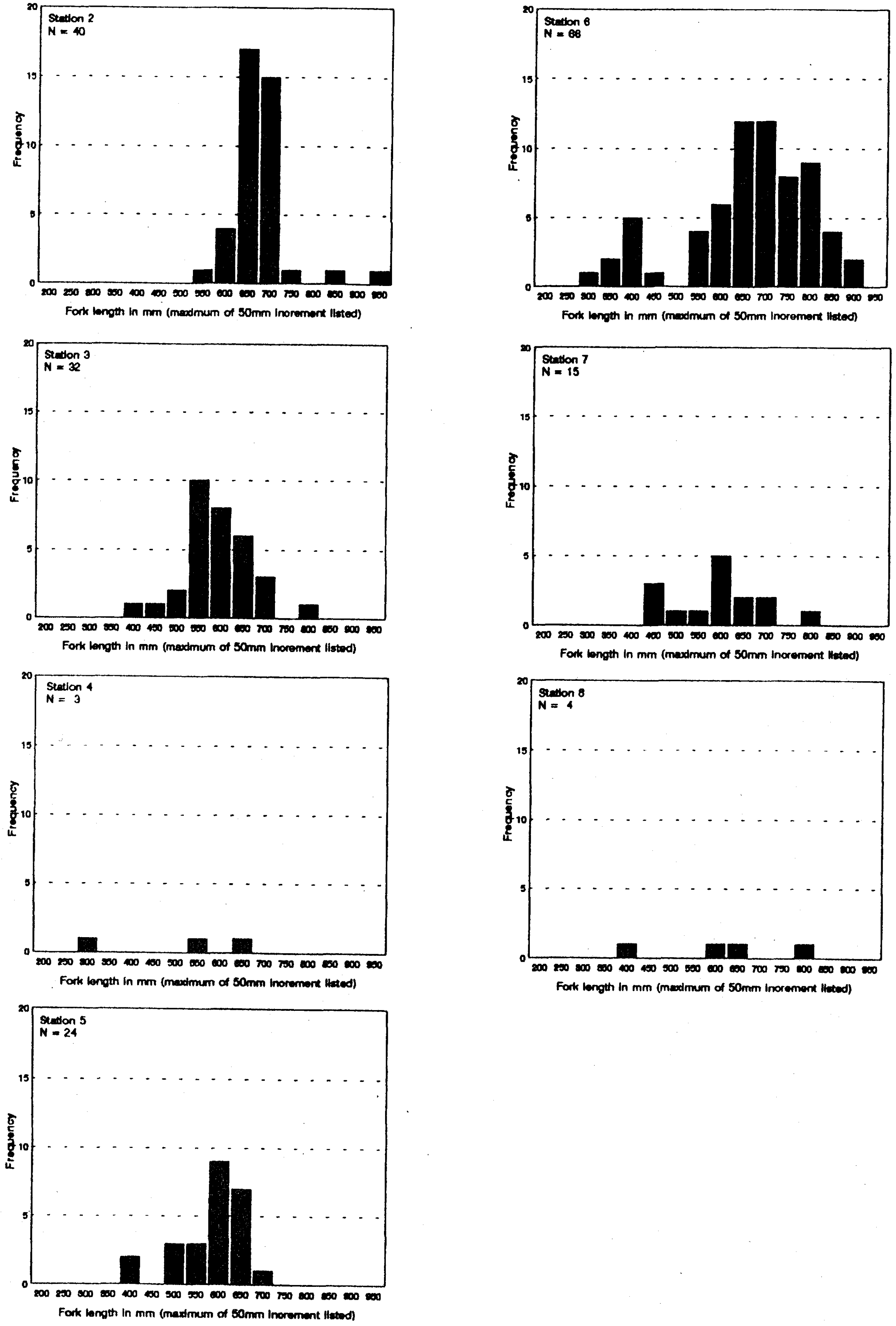


Figure 18. Shovelnose fork length distribution at standardized sampling stations during 1993.

Fort Peck Dam and tended to be highest at the most downstream stations. The highly regulated Missouri tended to be shallower, have slower velocities and be clearer then the unregulated Yellowstone (Appendices 20 - 23). The shallow nature of the Missouri in 1993 can be at least partially attributed to releases from Fort Peck Reservoir; in 1993 the Missouri was only about 59 - 66% of normal, while the Yellowstone was nearly 120% of normal (Table 1). Velocity and depth generally increased downstream, while water clarity decreased downstream for both rivers. Conductivity varied from 400 - 730 μmhos/cm (Appendix 24) and was generally highest when flows were lowest. Surface velocity was less in shallow than in deep habitats with the exception of station 3. The river configuration at station 3 necessitated sampling a shallow main channel area as one of the sites, resulting in these higher velocities.

Regressions of secchi disk, velocity, and depth versus catch were not significant. Shovelnose had the highest catch rates in depths less than 3 m, and in water with surface velocities of 0.21 - 0.31 m/sec, however these high catch rates were probably artifacts of sampling. Nets are probably more effective in water less than 3 m and the high catch rate from 0.21 - 0.3 m/sec was caused by just 2 drifts in which 22% of the 184 shovelnose were captured. Substrate type was classified based on presence or absence of gravel and was compared with shovelnose catch rates. Substrate with gravel present had a significantly higher catch (P= 0.06). The association of shovelnose with gravel substrate is probably real. However, drifting efficiency may be higher over gravel than sand (unlikely), and the upstream stations tended to have more gravel; factors other than the presence of gravel may be very important for shovelnose.

Nearly identical effort was expended with 23 meter gill (2.5 cm and 5.0 cm bar mesh) and trammel nets (5 cm inner and 25 cm outer bar mesh) during standardized sampling effort in 1993. Effort during May at stations 2 and 3 used 15 m experimental gill nets (0.6 - 7.6 cm bar mesh) and 30 m trammel nets. Each net was used in the same area within an hour, and the net type initially drifted was alternated. More shovelnose were caught with gill nets than with trammel nets (Figure 19). Sturgeon less than 451 mm were captured much more frequently with gill nets and comprised 16.9% (N = 18) of the shovelnose gill net catch and only 2.6% (N = 2) of the trammel net catch (Figure 20). However, 60 large shovelnose greater than 650 mm were caught by each net type. Fork length averaged 588 mm with the gill net and 630 mm with the trammel net, a difference that was statistically significant (P = 0.01). Shovelnose were the most common species caught with both net types but catch of other species varied dramatically (Figure 19). Greater species diversity was found with trammel nets. River carpsuckers were the second most

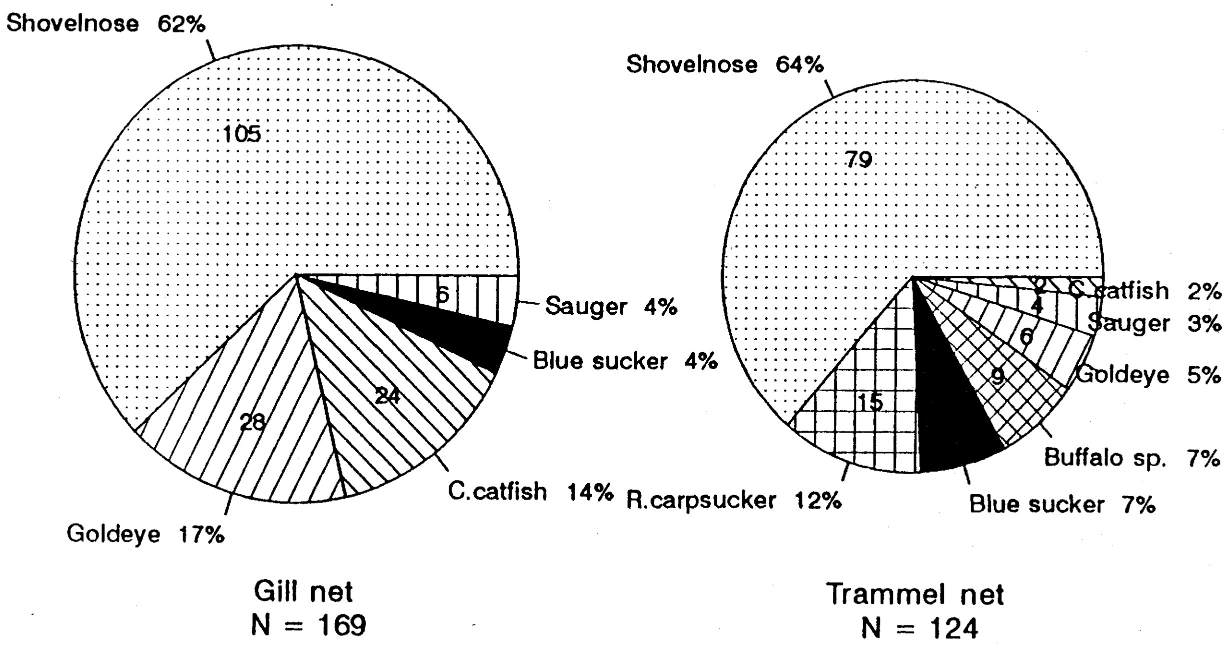


Figure 19. Pie chart comparing catch and species diversity of gill and trammel nets during 1993 standardized sampling (N = number of fish caught).

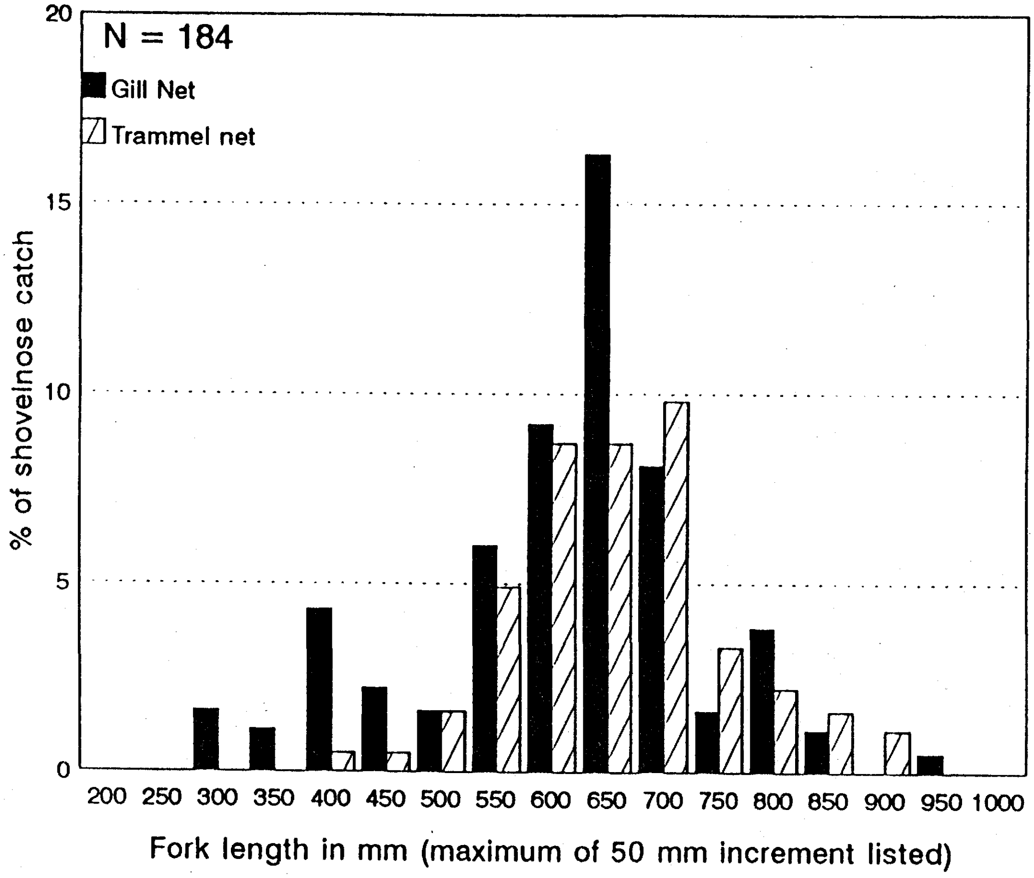


Figure 20. Shovelnose length distribution with gill and trammel nets from 1993 standardized sampling.

common species found with trammel nets but were not captured with gill nets. Buffalo species were also captured only with trammel nets. Goldeye and channel catfish were caught more frequently in gill than in trammel nets. These results are not surprising considering the morphology of these fish, the smaller mesh size of the gill net and the bagging characteristic of trammel nets. If we continue with standardized sampling it may be worthwhile to use a trammel net with 25 mm inner bar mesh.

The controlled hypolimial releases from Fort Peck Dam have changed the character of the Missouri River downstream (Gardner and Stewart 1987). Seasonal flows do not follow historical patterns and typical spring peaks do not occur. This lack of a "flood pulse" prevents dynamic equilibrium, seasonal use of flood plain habitats for fish, and reduces nutrient cycling (Junk et al. 1989). This study provides indirect evidence that Fort Peck Dam has indeed altered the biological community as well as physical aspects of the Missouri River below Fort Peck Dam. Overall catch rates from 1989 - 1993 of native fish fauna (including sturgeon) during drift netting and seining were less in the Missouri above the confluence than in the Yellowstone (Figures 10, 13 and 15; Appendices 7, 8 and 15). These catch rates may appear to contradict the standardized sampling of 1993 which found similar shovelnose catch rates in the Missouri above the confluence and in the Yellowstone (Appendices 17 and 18). However, the extremely high volume of water in the Yellowstone and the below normal flows in the Missouri above the Yellowstone confluence during 1993 (Figure 2, Table 1) likely resulted in reduced netting efficiency on the Yellowstone as well as increased netting efficiency on the Missouri. Pallid and shovelnose sturgeon, sturgeon chub, blue sucker, paddlefish and several other common native fish species were found in the Missouri above the Yellowstone confluence. This native species diversity as well as the size structure of shovelnose indicate that fish populations below Fort Peck, though impacted, may be in better shape than those found below other Missouri mainstem dams.

Range of shovelnose FL (267 - 914 mm) found below Fort Peck Dam and above the confluence (Figure 18) differ greatly from the size structure of shovelnose (500 - 710 mm) found by Elstad et al. (1992) below Garrison Dam. Both dams influence water temperature, water clarity, and the annual and daily hydrographs. However, the Missouri below Fort Peck Dam has several characteristics that benefit riverine species more than the river below Garrison Dam. These include, physical connection to the Milk and Yellowstone Rivers, 50% less daily river height fluctuation, and 2 - 3 times more free flowing river than is available below Garrison Dam. Movements of shovelnose, sauger, walleye, paddlefish and catfish between the Yellowstone and Missouri above the confluence have been documented (Gardner and Stewart 1987). The nearly natural hydrograph of the Yellowstone surely benefit species in both rivers, and during high flow years, the warm turbid Milk River provides critical paddlefish spawning habitat (Gardner and Stewart 1987) and moderates the cold clear waters of the Missouri below Fort Peck.

Of great interest are the different behavior patterns of pallid sturgeon found in the Yellowstone/confluence area versus those below Fort Peck Dam. During this study, the importance of the Yellowstone was demonstrated. All telemetered sturgeon in the confluence area moved up the Yellowstone; none went up the Missouri. Pallid sturgeon were apparently going up the Yellowstone to spawn. One radioed female pallid was recaptured about 15 km up the Yellowstone while running eggs. Questions remain about what motivated these fish to chose the Yellowstone. It is likely that differences in physical parameters such as turbidity and flow played important roles.

Hesse and Sheets (1993) claim the only way to protect large river native species is to restore natural conditions. The wide diversity of native species below Fort Peck may mean these populations will flourish if conditions such as temperature, turbidity and flow are returned to near historic levels. Hesse and Mestl (1993) argue for return of the natural hydrograph, which would influence channel morphology, nutrients and turbidity in ways that would help native fishes. The USACOE plans on a somewhat natural spring-early summer discharge from Fort Peck Dam in 1994. Under normal flow conditions, May average releases from Fort Peck Reservoir are planned to increase to 12,000 cfs in May and decrease to 8,000 cfs by June 15 (USACOE 1993). May releases were not this high throughout the pallid sturgeon study. Responding changes or behaviors in the fish community should be monitored. If spring flows are similar in both the Yellowstone and Missouri Rivers, it will be instructive to see which tributary is chosen by migratory pallid sturgeon. Imprinting and other stimuli, as well as flow patterns may play important roles. Pallid spawning movements up the Missouri could increase potential spawning habitat by 300 km. Since gradient and substrate differ greatly between the Yellowstone and Missouri, it is essential to discover requirements for pallid spawning and rearing habitats. Perhaps only one tributary has the right combination for successful pallid reproduction. The Missouri may be prime pallid habitat. It has mostly sandy substrate while gravel is more typical of the Yellowstone. Sandy substrate is associated with pallid sturgeon (Table 10, Bramblett and White 1992; William M. Gardner, personal communication), and using statistical analysis Bramblett and White (1993) found pallids actually preferred sand over other substrate types.

We must strive for answers to these questions with continued research. Only then, can the most intelligent and least expensive options be utilized for pallid sturgeon recovery.

STURGEON RESEARCH RECOMMENDATIONS

1. Intensify pallid sturgeon research throughout the study area. A long-term and increased commitment is necessary to determine size structure, spawning sites, abundance, migration patterns and habitat use. An important part of any study is planning, which has been an impossibility with the ongoing situation of last minute, short-term contracts with marginal budgets. Long-term planning is required by the endangered species act and is important so study plans can be designed which best utilize the resources available and thought can be given to discern and seek answers to meaningful questions regarding pallid sturgeon biology.

2. Coordinate effort of all agencies working in the study area. The pallid sturgeon working group is a good beginning, however a series of meetings resulting in a cohesive plan is needed. A coordinator is needed for this effort.

3. Pallid sturgeon spawning should be verified within the study area. Ripe pallids were captured near Sundheim park in 1993. Researchers should closely investigate this area with both larval and adult sampling. If spawning is documented, habitat parameters including temperature, substrate, velocities and flow should be examined. Larval fish should be collected at several sites between Fort Peck and the confluence in attempts to document *Scaphirhynchus sp.* spawning.

4. Surveys for adult and juvenile pallid sturgeon should continue. To date limited netting has occurred from Fort Peck to the Montana border. Surveys for juveniles and YOY have been extremely limited, especially in backwater and headwater areas.

5. A concerted effort involving MDFWP, ND Game and Fish, and the USFWS, should be undertaken to PIT tag pallid sturgeon from mid-September through early October in the Missouri River below the confluence. During this time pallids congregate and are relatively easy to catch. This tagging effort will result in conclusions concerning population size during future years.

6. Telemetry should be directed to the area below Fort Peck Dam. Limited radios/sonic transmitters should be deployed in this area. These fish would be monitored for movements and may lead to discovery of spawning areas.

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Appendix 1. Calculations used to determine character index values found in Figure 9.

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1. Calculate percent standard length for head length, mouth width, snout to outer barbel, mouth to inner barbel, inner barbel, and outer barbel.

2. Find a single lowest and highest percent standard length for each characteristic using both pallid and shovelnose data. Then calculate the difference for these 2 values. For 607 shovelnose and 53 pallid sturgeon the following values were determined:

	Minimum	Maximum
Head length	22.5 (S)	35.5 (P)
Mouth width	4.4 (S)	11.3 (S)
Mouth to inner barbel	2.5 (P)	9.3 (S)
Snout to outer barbel	7.0 (S)	16.3 (P)
Inner barbel	3.6 (P)	8.5 (S)
Outer barbel	5.5 (S)	11.6 (P)

3. Calculate a character index value for head length with the formula:

   100 x (head length - minimum head length)/(max head length - minimum head length)

4. Calculate index values for mouth width, snout to outer barbel, and outer barbel the same way. For inner barbel and mouth to inner barbel calculate as for head length but subtract that number from 100. This will insure that the most pallid like characteristics result in the highest numbers.

5. Add the 6 character index values for a total character index value.

Appendix 2. Statistics of pallid sturgeon captured from 1989 - 1993.

				Length (mm)														
Capture date			River mile	total	fork	stand.	Head	Mouth width	Snout to outer barbel	Mouth to inner barbel	inner barbel	outer barbel	Weight (kg)	Frequency (mHz)	Radio[1] type	% loading	PIT tag (7F7)	Recapture
1989	3	10	1769	1575	1483	1397	470	127	203	58	30	107	15.0	47.502	1	0.3	F065C30	N
1989	3	10	1769	1626	1537	1524	508	147	208	64	46	152	24.0	49.526	1	0.2	-	N
1989	3	21	1770	1435	1321	1257	406	114	178	51	41	99	13.2	49.552	1	0.4	F065841	N
1990	2	10	1770	1600	1494	1417	503	132	229	61	64	163	20.0	49.277	1	0.6	F055428	N
1990[2]	9	13	1577	1455	1379	1308	452	104	0	0	48	147	15.0	49.477	1	0.3	F066A0E	N
1990[2]	9	13	1577	1499	1397	1346	427	109	0	0	51	132	15.9	49.127	1	0.3	F072442	N
1990[2]	9	14	1575	1554	1455	1356	457	124	208	56	43	122	17.7	49.101	1	0.3	F066613	N
1990[2]	9	17	1575	1554	1448	1372	460	0	198	58	48	142	18.1	49.076	1	0.3	F054855	N
1991	1	26	1769	1328	1240	1158	391	102	170	56	36	117	12.7	-	-	-	F054864	N
1991	2	10	1769	1341	1247	1184	411	112	193	58	46	107	10.4	-	-	-	F066471	N
1991[3]	7	18	129	1441	1340	1275	424	120	193	60	40	128	11.3	-	-	-	-	N
1991	10	10	1577	1392	1311	1278	401	96	180	66	46	109	11.8	49.151	1	0.3	F065F04	N
1992	4	10	1568	1631	1537	1478	488	137	213	61	58	112	22.2	49.682	3	0.8	F065A4E	N
1992	6	17	4	1435	1336	1275	424	124	188	46	53	124	12.7	49.100	2	1.1	F06627E	N
1992	9	15	1568	1702	1600	1537	483	137	231	76	56	160	24.5	48.540	2	0.1	F065E12	N
1992	9	30	1573	1615	1478	1356	447	127	216	64	56	152	18.4	-	-	-	F06697C	N
1992	9	30	1573	1590	1481	1435	444	122	201	64	51	137	19.7	-	-	-	F055C21	N
1992	9	30	1573	1676	1463	1387	437	135	188	64	53	142	-	-	-	-	F065A3D	N
1992	9	30	1573	1349	1242	1174	404	112	183	53	51	135	10.7	48.520	2	0.1	F065A4D	N
1992	9	30	1573	1646	1524	1478	470	140	206	64	51	145	22.2	49.050	2	0.6	F054773	N
1992	9	30	1573	1143	1090	1016	307	81	135	43	28	84	6.8	-	-	-	F064F27	N
1992	9	30	1573	1565	1463	1382	437	130	201	66	41	145	19.7	-	-	-	F056360	N
1992	9	30	1573	1519	1402	1316	437	135	211	64	46	127	15.9	-	-	-	F054D0D	N
1992	10	6	1573	1392	1334	1280	412	127	178	64	51	130	12.2	-	-	-	D4A7758	N
1992	10	6	1573	1410	1303	1247	386	112	173	48	46	114	12.7	-	-	-	-	N
1992	10	6	1573	1692	1539	1473	442	142	175	66	64	142	19.5	-	-	-	E427F69	N
1992	10	6	1573	1430	1336	1270	414	122	190	71	48	112	14.7	-	-	-	E6B3364	N
1992	10	7	1568	1448	1359	1265	417	117	193	53	51	137	10.8	-	-	-	F066502	N
1992	10	8	1573	1471	1397	1336	427	132	190	56	46	119	15.9	-	-	-	F06685C	N
1992	10	8	1573	1466	1339	1275	424	119	190	61	43	127	12.9	-	-	-	F056372	N
1992	10	8	1573	1554	1463	1356	442	130	193	64	58	158	19.1	-	-	-	F06672B	N
1992	10	19	1573	1453	1366	1308	419	127	190	53	38	127	16.1	49.020	2	0.1	F065014	N
1992	10	19	1573	1529	1402	1351	437	132	198	58	51	137	16.6	49.070	2	0.1	B026102	N
1992	10	19	1573	1384	1308	1240	391	114	190	56	46	122	10.8	49.130	2	0.1	B082208	N
1992	10	19	1573	1519	1407	1346	427	124	190	53	46	122	13.6	-	-	-	B024F2D	N
1992	10	19	1573	1504	1415	1359	442	124	211	61	46	132	17.0	-	-	-	B035740	N

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[1] See Table 3 for transmitter specifics.
[2] Caught by USFWS
[3] Caught by Watson and Stewart, 1991.

Appendix 2 continued. Statistics of pallid sturgeon captured from 1989 - 1993.

Capture date			River mile	Length (mm)									Weight (kg)	Frequency (mHz)	Radio[1] type	% loading	PIT tag #	Recapture
				total	fork	stand.	Head	Mouth width	Snout to outer barbel	Mouth to inner barbel	inner barbel	outer barbel						
1992	10	21	1568	1562	1445	1372	457	132	206	61	46	137	14.3	-	-	-	B023408	N
1992	10	21	1568	1331	1265	1219	394	112	183	56	48	132	11.6	-	-	-	B015B78	N
1992	10	21	1566	1585	1486	1435	462	127	218	64	43	142	19.3	49.170	2	0.1	B020D71	N
1992	10	22	1574	1422	1359	1283	409	114	185	53	43	107	12.2	-	-	-	D3E6D23	N
1992	10	22	1574	1191	1123	1072	353	112	145	53	41	109	8.4	-	-	-	B025248	N
1992	10	22	1574	1483	1389	1321	424	137	190	58	43	135	17.0	-	-	-	D3C5708	N
1992	10	27	1573	1428	1341	1283	419	124	196	61	43	107	13.6	-	-	-	D441A7C	N
1992	10	27	1573	1593	1478	1410	444	127	201	69	41	107	17.9	-	-	-	B023253	N
1992	10	29	1573	1529	1422	1331	450	127	213	64	46	140	15.6	-	-	-	B024922	N
1993	3	20	1770	1631	1524	1485	495	145	215	70	53	174	17.4	49.870	2	0.3	B081169	N
1993	4	15	1566	1470	1385	1335	425	115	189	56	41	114	13.8	48.582	2	0.3	D7B1607	N
1993	4	15	1566	1620	1514	1448	455	140	201	59	55	132	20.2	49.830	2	0.2	F055B56	Y
1993	4	22	0	1470	1373	1293	428	130	197	58	54	135	15.0	49.810	2	1.3	B035C47	N
1993	4	23	0	1650	1566	1500	494	145	233	61	54	146	28.1	49.030	2	0.2	B021573	N
1993	4	24	2	1570	1365	1335	438	130	200	62	59	138	14.5	49.671	3	0.4	B01862E	N
1993	5	21	71	1245	-	-	-	-	-	-	-	-	-	48.572	2	-	E690405	N
1993	9	14	1574	1540	1410	1335	440	130	210	65	46	128	17.5	49.851	2	0.2	B081579	N
1993	9	16	1580	1400	1292	1190	390	110	175	52	42	124	10.8	49.242	2	0.4	F054864	Y
1993	9	28	1573	1640	1525	1450	442	127	200	65	47	140	20.6	49.711	2	0.2	B035D1B	N
1993	9	28	1573	1545	1430	1368	429	125	198	66	46	125	16.8	49.651	2	0.2	B031F17	N
1993	9	28	1573	1428	1325	1245	384	117	173	56	54	117	15.9	49.370	2	0.3	D7C2E4B	N
1993	9	28	1574	1625	1519	1445	435	140	207	60	55	132	18.4	-	-	-	F055B56	Y
1993	9	29	1573	1519	1400	1348	449	122	217	64	49	139	14.5	49.630	2	0.3	B024922	Y
1993	9	29	1573	1360	1275	1220	405	115	173	62	47	121	12.0	-	-	-	D44647E	N

[1] See Table 3 for transmitter specifics.

Appendix 3. Length and weight of shovelnose sturgeon captured by drift netting and stationary sets from 1988 - 1993 by section.

	Fork length (mm)			Weight (kg)		
Section	N	Mean	Range	N	Mean	Range
1	69	625	510 - 879	39	1.0	0.5 - 1.9
2	63	648	546 - 914	44	1.1	0.6 - 4.3
3	93	564	376 - 762	70	0.7	0.1 - 1.7
4	5	549	660 - 747	0	-	-
5	20	540	266 - 762	8	0.8	0.3 - 1.6
6	377	622	259 - 909	220	1.0	0.1 - 3.3
8	210	672	269 - 947	124	1.2	0.1 - 4.2
9	164	624	333 - 876	100	1.2	0.1 - 2.9
Average	1001	628	259 - 947	597	1.0	0.1 - 4.3

Appendix 4. Morphometric ratios[1] described by Bailey and Cross (1954) for pallid sturgeon caught in 1993.

Total length (mm)	Fork length (mm)	Standard length (mm)	Ratio 1	Ratio 2	Ratio 3	Ratio 4	Ratio 5	Ratio 6	PIT tag (7F7)
1631	1524	1485	3.07	2.07	7.07	4.06	3.28	9.34	B081169
1620	1514	1448	3.41	2.37	7.71	3.65	2.40	8.27	F055B56
1470	1385	1335	3.38	2.05	7.59	4.61	2.78	10.37	D7B1607
1470	1373	1293	3.40	2.24	7.38	3.65	2.50	7.93	B035C47
1650	1566	1500	3.82	2.38	8.10	4.31	2.70	9.15	B021573
1570	1365	1335	3.23	2.10	7.06	3.39	2.34	7.42	B01862E
1400	1292	1190	3.37	2.12	7.50	4.17	2.95	9.29	F054864
1428	1325	1245	3.09	2.09	6.86	3.20	2.17	7.11	D7C2E4B
1640	1525	1450	3.08	1.95	6.80	4.26	2.98	9.40	B035D1B
1545	1430	1368	3.00	1.89	6.50	4.30	2.72	9.33	B031F17
1360	1275	1220	2.79	1.85	6.53	3.68	2.57	8.62	D44647E

[1] Ratios: 1 = snout to outer barbel:mouth to inner barbel, 2 = mouth width:mouth to inner barbel, 3 = head length:mouth to inner barbel, 4 = snout to outer barbel:inner barbel, 5 = outer barbel:inner barbel, 6 = head length:inner barbel.

Appendix 5. Percent of standard length of morphometric measurements[1] of pallid sturgeon captured in 1993.

Total length (mm)	Fork length (mm)	Standard length (mm)	A Head	F Mouth width	B Snout to Outer	E Mouth to Inner	D Inner barbel	C Outer Barbel	PIT tag (7F7)
1631	1524	1485	33.3	9.8	14.5	4.7	11.7	3.6	B081169
1620	1514	1448	31.4	9.7	13.9	4.1	9.1	3.8	F055B56
1470	1385	1335	31.8	8.6	14.2	4.2	8.5	3.1	D7B1607
1470	1373	1293	33.1	10.1	15.2	4.5	10.4	4.2	B035C47
1650	1566	1500	32.9	9.7	15.5	4.1	9.7	3.6	B021573
1570	1365	1335	32.8	9.7	15.0	4.6	10.3	4.4	B01862E
1400	1292	1190	32.8	9.2	14.7	4.4	10.4	3.5	F054864
1428	1325	1245	30.8	9.4	13.9	4.5	9.4	4.3	D7C2E4B
1640	1525	1450	30.5	8.8	13.8	4.5	9.7	3.2	B035D1B
1545	1430	1368	31.4	9.1	14.5	4.8	9.1	3.4	B031F17
1360	1275	1220	33.2	9.4	14.2	5.1	9.9	3.9	D44647E

[1] See figure 4 for placement.

Appendix 6. Drift netting effort by year, month and section from 1990 - 1993.[1]

		Month															
		April		May		June		July		August		September		October		Totals	
Section	Year	Hours	sets	Hours	sets	Hours	sets	Hours	sets	Hours	sets	Hours	sets	Hours	sets	Hours	sets
1	1993	0.5	6	-		-		-		-		0.5	7	-		1.0	13
	1991	-		-		-		-		-		0.3	2	-		0.3	2
	Total	0.5	6	-		-		-		-		0.8	9	-		1.3	15
2	1993	-		0.8	10	0.8	13	1.2	21	-		-		-		2.8	44
	1992	-		-		1.8	12	-		-		-		-		1.8	12
	1991	-		1.3	5	1.0	12	-		-		2.8	21	2.2	12	7.3	50
	Total	-		2.1	15	3.6	37	1.2	21	-		2.8	21	2.2	12	11.9	106
3	1993	-		0.4	6	0.9	11	1.8	18	0.8	11	0.8	10	0.6	9	5.3	65
	1992	-		-		-		0.5	5	1.1	7	1.3	17	-		2.9	29
	Total	-		0.4	6	0.9	11	2.3	23	1.9	18	2.1	27	0.6	9	8.2	94
4	1991	-		5.2	16	-		-		-		-		-		5.2	16
	1990	-		-		-		-		-		2.6	9	-		2.6	9
	Total	-		5.2	16	-		-		-		2.6	9	-		7.8	25
5	1993	-		0.8	9	1.2	9	2.4	20	0.8	8	-		-		5.2	46
	1992	-		-		-		-		1.0	15	1.7	15	-		2.7	30
	1991	-		4.5	13	-		-		-		-		-		4.5	13
	Total	-		5.3	22	1.2	9	2.4	20	1.8	23	1.7	15	-		12.4	89
6	1993	5.6	56	0.6	8	0.5	8	0.7	8	1.8	18	5.2	47	2.8	25	17.2	170
	1992	4.0	35	1.1	9	0.6	4	5.2	22	<0.1	1	4.2	51	6.3	65	21.4	187
	1991	-		2.5	3	1.8	10	-		0.9	9	3.6	21	3.7	23	12.5	66
	1990	-		-		-		-		-		1.6	4	-		1.6	4
	Total	9.6	91	4.2	20	2.9	22	5.9	30	2.7	28	14.6	123	12.8	113	52.7	427
7	1992	-		-		-		2.1	7	-		-		-		2.1	7
8	1993	-		0.4	4	0.4	7	1.7[2]	-4	0.7	9	0.9	9	0.7	8	4.8	71
	1992	-		1.1	10	1.6	15	-		-		-		-		2.7	25
	1991	-		-		-		-		0.7	4	-		-		0.7	4
	Total	-		1.5	14	2.0	22	1.7	- 4	1.4	13	0.9	9	0.7	8	8.2	70
9	1993	2.7	28	2.7	27	0.8	12	1.6	20	1.7	21	1.4	14	1.1	12	12.0	134
	1992	-		1.1	13	3.3	18	-		-		0.1	2	-		4.5	33
	1991	-		-		-		-		-		1.7	6	0.5	6	2.2	12
	Total	2.7	28	3.8	40	4.1	30	1.6	20	1.7	21	3.2	22	1.6	18	18.7	179
All	Total	12.8	125	22.5	133	14.7	131	17.2	125	9.5	103	28.7	235	17.9	160	123.3	1012

[1] includes standardized drift net effort

[2] data from K.M. Backes, MDFWP, personal communication.

Appendix 7. Catch rates by month and section[1] for common species caught during drift netting effort 1990 -1993.[1]

Month	Section	Hours	drifts	Species																					
				Shovelnose sturgeon		Pallid sturgeon		River-carpsucker		Goldeye		Channel catfish		Sauger		Paddle-fish		Blue sucker		Buffalo species		Flathead chub		Shorthead redhorse	
				CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#
April	1	0.5	6	4.0	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	6	9.6	91	3.0	29	0.4	4	1.2	11	2.7	26	2.2	21	1.2	11	1.8	17	0.5	5	0.9	9	0.0	0	0.0	0
	9	2.7	28	18.5	50	1.1	3	10.0	27	3.3	9	1.8	5	2.2	6	0.0	0	0.0	0	12.2	33	0.0	0	0.0	0
	All	12.8	125	6.3	81	0.5	7	3.0	38	2.7	35*	2.0	26	1.3	17	1.3	17	0.4	5	3.3	42	0.0	0	0.0	0
May	2	2.1	15	6.0	12	0.0	0	0.5	1	3.5	7	0.5	1	2.0	4	0.0	0	4.5	9	0.0	0	0.0	0	0.0	0
	3	0.4	6	10.0	4	0.0	0	0.0	0	2.5	1	0.0	0	10.0	4	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	4	5.2	16	1.0	5	0.0	0	0.2	1	0.8	4	0.6	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.4	2
	5	5.3	22	0.3	2	0.0	0	0.3	2	0.2	1	0.0	0	0.3	2	0.0	0	0.0	0	0.2	1	0.0	0	0.0	0
	6	4.2	20	0.2	1	0.0	0	0.2	1	0.7	3	0.5	2	0.5	2	0.0	0	0.0	0	0.0	0	0.2	1	0.0	0
	8	1.5	14	3.3	5	0.0	0	0.0	0	3.3	5	4.7	7	0.7	1	0.7	1	0.0	0	0.0	0	0.0	0	0.0	0
	9	3.8	40	1.6	6	0.0	0	1.0	4	0.0	0	0.3	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	All	22.5	133	1.6	35	0.0	0	0.4	9	0.9	21	0.6	14	0.6	13	<0.1	1	0.4	9	<0.1	1	<0.1	1	0.1	2
June	2	3.6	37	13.0	47	0.0	0	0.3	1	5.6	20	0.0	0	1.9	7	0.0	0	1.1	4	0.6	2	0.0	0	0.0	0
	3	0.9	11	10.0	9	0.0	0	2.2	2	1.1	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	5	1.2	9	0.8	2	0.0	0	0.0	0	0.8	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	6	2.9	22	3.8	11	0.0	0	0.0	0	3.4	10	8.9	26	0.0	0	0.3	1	0.0	0	0.0	0	0.0	0	0.0	0
	8	2.0	22	34.0	68	0.0	0	1.0	2	23.0	46	2.0	4	0.0	0	0.0	0	0.5	1	0.0	0	0.0	0	0.0	0
	9	4.1	30	5.9	25	0.2	1	1.0	4	10.2	43	12.3	52	0.0	0	0.2	1	0.0	0	0.2	1	0.0	0	0.0	0
	All	14.7	131	10.2	162	0.1	1	0.6	9	8.2	122	5.6	82	0.5	7	0.1	2	0.3	5	0.2	3	0.0	0	0.0	0
July	2	1.2	21	7.5	9	0.0	0	2.5	3	5.0	6	0.0	0	0.0	0	0.0	0	5.0	6	0.0	0	0.0	0	0.0	0
	3	2.3	23	11.3	26	0.0	0	1.3	3	1.3	3	0.0	0	0.0	0	0.4	1	0.0	0	0.9	2	0.4	1	0.0	0
	5	2.4	20	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	6	5.9	30	4.2	25	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.2	1	0.0	0
	7	2.1	7	0.0	0	0.0	0	0.0	0	1.4	3	0.5	1	0.0	0	0.0	0	0.0	0	0.0	0	0.5	1	0.0	0
	8	1.7	4	41.2	70	0.0	0	4.1	7	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	9	1.6	20	1.2	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	All	17.2	123	7.8	132	0.0	0	0.8	13	0.7	12	0.1	1	0.0	0	0.1	1	0.3	6	0.1	2	0.2	3	0.0	0
August	3	1.9	18	12.8	23	0.0	0	0.0	0	5.2	10	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.5	1	0.0	0
	5	1.8	23	1.8	3	0.0	0	0.0	0	4.7	8	0.6	1	0.0	0	0.0	0	0.6	1	0.6	1	0.0	0	0.0	0
	6	2.7	28	5.2	14	0.0	0	0.0	0	0.0	0	0.7	2	0.0	0	0.0	0	0.0	0	0.4	1	0.0	0	0.0	0
	8	1.4	13	40.1	57	0.0	0	0.0	0	0.7	1	2.1	3	0.0	0	0.0	0	1.4	2	0.0	0	0.0	0	0.0	0
	9	1.7	21	2.9	5	0.0	0	0.6	1	1.2	2	2.9	5	0.0	0	0.0	0	0.6	1	0.0	0	0.0	0	0.0	0
	All	9.5	103	10.7	102	0.0	0	0.1	1	2.2	21	1.2	11	0.0	0	0.0	0	0.4	4	0.2	2	0.1	1	0.0	0

[1] includes standardized drift net effort

Appendix 7 continued. Catch rates by month and section for common species caught[1] during drift netting effort 1990 - 1993 by month.

Month	Section	Hours	drifts	Species																					
				Shovelnose sturgeon		Pallid sturgeon		River-carpsucker		Goldeye		Channel catfish		Sauger		Paddle-fish		Blue sucker		Buffalo species		Flathead chub		Shorthead redhorse	
				CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#
September	1	0.8	9	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	2	2.8	21	2.8	8	0.0	0	0.0	0	1.8	5	0.0	0	0.0	0	0.0	0	0.5	1	0.0	0	0.0	0	0.0	0
	3	2.1	27	8.1	17	0.0	0	1.0	0	17.1	36	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	2	0.0	0
	4	2.6	9	1.5	4	0.0	0	0.0	0	1.9	5	0.4	1	0.0	0	0.0	0	0.4	1	0.0	0	0.0	0	1.5	4
	5	1.7	15	4.1	7	0.0	0	0.6	1	27.0	46	1.8	3	0.0	0	0.0	0	0.0	0	0.0	0	1.2	2	0.0	0
	6	14.6	123	13.5	194	1.2	17	0.6	9	2.8	41	0.7	10	0.1	1	0.2	3	1.0	14	0.7	10	0.1	1	0.0	0
	8	0.9	9	3.3	3	0.0	0	2.2	2	5.6	5	1.1	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.1	1
	9	3.2	22	6.3	17	0.0	0	0.4	1	1.5	4	2.2	6	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	All	28.7	235	8.7	250	0.6	17	0.4	13	4.9	142	0.7	21	<0.1	1	0.1	3	0.6	16	0.3	10	0.2	5	0.2	5
October	2	2.2	12	1.4	3	0.0	0	0.0	0	24.0	53	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.3	5	1.4	3
	3	0.6	9	20.0	12	0.0	0	0.0	0	1.7	1	0.0	0	0.0	0	0.0	0	1.7	1	0.0	0	0.0	0	1.7	1
	6	12.8	113	11.9	152	1.9	25	6.2	79	6.9	88	3.0	39	0.5	6	0.6	8	3.1	40	1.2	15	0.2	2	0.0	0
	8	0.7	8	64.3	45	0.0	0	0.0	0	0.0	0	0.0	0	1.4	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
	9	1.6	18	11.9	19	0.0	0	0.0	0	2.5	4	0.0	0	1.2	2	0.0	0	0.6	1	0.0	0	0.0	0	0.0	0
	All	17.9	160	12.9	231	1.4	25	4.4	79	8.2	146	2.2	39	0.5	9	0.4	8	2.3	42	0.8	15	0.4	7	0.2	4
Total		123.3	1012	8.0	993	0.4	50	1.3	162	4.0	499	1.6	194	0.4	47	0.2	32	0.7	87	0.6	75	0.1	17	0.1	11

1 includes standardized drift net effort

Appendix 8. Catch rates and number of common species caught during drift netting effort 1990 - 1993 by section.[1]

Month	Section	Hours	drifts	Shovelnose sturgeon		Pallid sturgeon		River-carpsucker		Goldeye		Channel catfish		Sauger		Paddle-fish		Blue sucker		Buffalo species		Flathead chub		Shorthead redhorse	
				CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#
April	1	0.5	6	4.0	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
September	1	0.8	9	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
All		1.3	15	1.5	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
May	2	2.1	15	6.0	12	0.0	0	0.5	1	3.5	7	0.5	1	2.0	4	0.0	0	4.5	9	0.0	0	0.0	0	0.0	0
June	2	3.6	37	13.0	47	0.0	0	0.3	1	5.6	20	0.0	0	1.9	7	0.0	0	1.1	4	0.6	2	0.0	0	0.0	0
July	2	1.2	21	7.5	9	0.0	0	2.5	3	5.0	6	0.0	0	0.0	0	0.0	0	5.0	6	0.0	0	0.0	0	0.0	0
September	2	2.8	21	2.8	8	0.0	0	0.0	0	1.8	5	0.0	0	0.0	0	0.0	0	0.5	1	0.0	0	0.0	0	0.0	0
October	2	2.2	12	1.4	3	0.0	0	0.0	0	24.0	53	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.3	5	1.4	3
All		11.9	106	6.6	79	0.0	0	0.4	5	7.6	91	0.1	1	0.9	11	0.0	0	1.7	20	0.2	2	0.4	5	0.2	3
May	3	0.4	6	10.0	4	0.0	0	0.0	0	2.5	1	0.0	0	10.0	4	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
June	3	0.9	11	10.0	9	0.0	0	2.2	2	1.1	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
July	3	2.3	23	11.3	26	0.0	0	1.3	3	1.3	3	0.0	0	0.0	0	0.4	1	0.0	0	0.9	2	0.4	1	0.0	0
August	3	1.9	18	12.8	23	0.0	0	0.0	0	5.3	10	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.5	1	0.0	0
September	3	3.1	27	8.1	17	0.0	0	1.0	0	17.1	36	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	2	0.0	0
October	3	0.6	9	20.0	12	0.0	0	0.0	0	1.7	1	0.0	0	0.0	0	0.0	0	1.7	1	0.0	0	0.0	0	1.7	1
All		8.2	94	11.1	91	0.0	0	0.6	5	6.3	52	0.0	0	0.5	4	0.1	1	0.1	1	0.2	2	0.5	4	0.2	2
May	4	5.2	16	1.0	5	0.0	0	0.2	1	0.8	4	0.6	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.4	2
September	4	2.6	9	1.5	4	0.0	0	0.0	0	1.9	5	0.4	1	0.0	0	0.0	0	0.4	1	0.0	0	0.0	0	1.5	4
All		7.8	25	1.2	9	0.0	0	0.1	1	1.2	9	0.5	4	0.0	0	0.0	0	0.1	1	0.0	0	0.0	0	0.8	6
May	5	5.3	22	0.3	2	0.0	0	0.3	2	0.2	1	0.0	0	0.3	2	0.0	0	0.0	0	0.2	1	0.0	0	0.0	0
June	5	1.2	9	0.8	2	0.0	0	0.0	0	0.8	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
July	5	2.4	20	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
August	5	1.8	23	1.8	3	0.0	0	0.0	0	4.7	8	0.6	1	0.0	0	0.0	0	0.6	1	0.6	1	0.0	0	0.0	0
September	5	1.7	15	4.1	7	0.0	0	0.6	1	27.0	46	1.8	3	0.0	0	0.0	0	0.0	0	0.0	0	1.2	2	0.0	0
All		12.4	89	1.1	14	0.0	0	0.2	3	4.6	57	0.3	4	0.2	2	0.0	0	0.1	1	0.2	2	0.2	2	0.0	0
April	6	9.6	91	3.0	29	0.4	4	1.2	11	2.7	26	2.2	21	1.2	11	1.8	17	0.5	5	0.9	9	0.0	0	0.0	0
May	6	4.2	20	0.2	1	0.0	0	0.2	1	0.7	3	0.5	2	0.5	2	0.0	0	0.0	0	0.0	0	0.2	1	0.0	0
June	6	2.9	22	3.8	11	0.0	0	0.0	0	3.4	10	8.9	26	0.0	0	0.3	1	0.0	0	0.0	0	0.0	0	0.0	0
July	6	5.9	30	4.2	25	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.2	1	0.0	0
August	6	2.7	28	5.2	14	0.0	0	0.0	0	0.0	0	0.7	2	0.0	0	0.0	0	0.0	0	0.4	1	0.0	0	0.0	0
September	6	14.6	123	13.5	194	1.2	17	0.6	9	2.8	41	0.6	10	0.1	1	0.2	3	1.0	14	0.7	10	0.1	1	0.0	0
October	6	12.8	113	11.9	152	1.9	25	6.2	79	6.9	88	3.0	39	0.5	6	0.6	8	3.1	40	1.2	15	0.2	2	0.0	0
All		52.7	427	8.1	426	0.9	46	1.9	100	3.2	168	1.9	100	0.4	20	0.6	29	1.1	59	0.7	35	0.1	5	0.0	0
July	7	2.1	7	0.0	0	0.0	0	0.0	0	1.4	3	0.5	1	0.0	0	0.0	0	0.0	0	0.0	0	0.5	1	0.0	0

1 includes standardized drift net effort

Appendix 8 continued. Catch rates and number of common species caught during drift netting effort 1990 - 1993 by section.[1]

				Species																					
				Shovelnose sturgeon		Pallid sturgeon		River-carpsucker		Goldeye		Channel catfish		Sauger		Paddle-fish		Blue sucker		Buffalo species		Flathead chub		Shorthead redhorse	
Month	Section	Hours	drifts	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#
May	8	1.5	14	3.3	5	0.0	0	0.0	0	3.3	5	4.7	7	0.7	1	0.7	1	0.0	0	0.0	0	0.0	0	0.0	0
June	8	2.0	22	34.0	68	0.0	0	1.0	2	23.0	46	2.0	4	0.0	0	0.0	0	0.5	1	0.0	0	0.0	0	0.0	0
July	8	1.7	4	41.2	70	0.0	0	4.1	7	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
August	8	1.4	13	40.1	57	0.0	0	0.0	0	0.7	1	2.1	3	0.0	0	0.0	0	1.4	2	0.0	0	0.0	0	0.0	0
September	8	0.9	9	3.3	3	0.0	0	2.2	2	5.6	5	1.1	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.1	1
October	8	0.7	8	64.3	45	0.0	0	0.0	0	0.0	0	0.0	0	1.4	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
All		8.2	70	30.2	248	0.0	0	1.3	11	6.9	57	1.8	15	0.2	2	0.1	1	0.4	3	0.0	0	0.0	0	0.1	1
April	9	2.7	28	18.5	50	1.1	3	10.0	27	3.3	9	1.8	5	2.2	6	0.0	0	0.0	0	12.2	33	0.0	0	0.0	0
May	9	3.8	40	1.6	6	0.0	0	1.0	4	0.0	0	0.3	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
June	9	4.1	30	5.9	25	0.2	1	1.0	4	10.2	43	12.3	52	0.0	0	0.2	1	0.0	0	0.2	1	0.0	0	0.0	0
July	9	1.6	20	1.2	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
August	9	1.7	21	2.9	5	0.0	0	0.6	1	1.2	2	2.9	5	0.0	0	0.0	0	1.8	1	0.0	0	0.0	0	0.0	0
September	9	3.2	22	5.3	17	0.0	0	0.3	1	1.2	4	1.9	6	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
October	9	1.6	18	11.9	19	0.0	0	0.0	0	2.5	4	0.0	0	1.2	2	0.0	0	0.6	1	0.0	0	0.0	0	0.0	0
All		18.7	179	6.6	124	0.2	4	2.0	37	3.3	62	3.7	69	0.4	8	<0.1	1	0.1	2	1.8	34	0.0	0	0.0	0
Total		123.3	1012	8.0	993	0.4	50	1.3	162	4.0	499	1.6	194	0.4	47	0.2	32	0.7	87	0.6	75	0.1	17	0.1	11

1 includes standardized drift net effort

Appendix 9. Annual shovelnose catch rates (CPUE = catch/hour) with absolute numbers of shovelnose caught by month and section from 1990 - 1993.[1]

		April		May		June		July		August		September		October		Totals	
Section	Year	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#	CPUE	#
1	1993	4.0	2	-		-		-		-		0.0	0	-		2.0	2
	1991	-		-		-		-		-		0.0	0	-		0.0	0
	Total	4.0	2	-		-		-		-		0.0	0	-		1.5	2
2	1993	-		11.2	9	33.8	27	7.5	9	-		-		-		16.1	45
	1992	-		-		3.9	7	-		-		-		-		3.9	7
	1991	-		2.3	3	13.0	13	-		-		2.8	8	1.4	3	3.7	27
	Total	-		5.7	12	13.0	47	7.5	9	-		2.8	8	1.4	3	6.6	79
3	1993	-		10.0	4	10.0	9	13.9	25	3.8	3	6.2	5	20.0	12	10.9	58
	1992	-		-		-		2.0	1	18.1	20	9.2	12	-		11.4	33
	Total	-		10.0	4	10.0	9	11.3	26	12.1	23	8.1	17	20.0	12	11.1	91
4	1991	-		1.0	5	-		-		-		-		-		1.0	5
	1990	-		-		-		-		-		1.5	4	-		1.5	4
	Total	-		1.0	5	-		-		-		1.5	4	-		1.2	9
5	1993	-		1.3	1	1.7	2	0.0	0	0.0	0	-		-		0.6	3
	1992	-		-		-		-		3.0	3	4.1	7	-		3.7	10
	1991	-		0.2	1	-		-		-		-		-		0.2	1
	Total	-		0.4	2	1.7	2	0.0	0	1.7	3	4.1	7			1.1	14
6	1993	2.5	14	0.0	0	0.0	0	4.3	3	0.6	1	9.6	50	7.5	21	5.2	89
	1992	3.8	15	0.9	1	16.7	10	4.2	22	300.0	6	25.8	108	13.8	87	11.6	249
	1991	-		0.0	0	0.6	1	-		7.8	7	7.2	26	11.9	44	6.2	78
	1990	-		-		-		-		-		7.1	10	-		7.1	10
	Total	3.0	29	0.2	1	3.8	11	4.2	25	5.2	14	13.3	194	11.9	152	8.1	426
7	1992	-		-		-		0.0	0	-		-		-		0.0	0
8	1993	-		2.5	1	7.5	3	41.2	70	20.0	14	3.3	3	64.3	45	21.3	66
	1992	-		3.6	4	40.6	65	-		-		-		-		25.6	69
	1991	-		-		-		-		61.4	43	-		-		61.4	43
	Total	-		3.3	5	34.0	68	41.2	70	40.7	57	3.3	3	64.3	45	27.4	178
9	1993	18.5	50	2.2	6	1.2	1	1.2	2	2.9	5	3.6	5	4.5	5	6.2	74
	1992	-		0.0	0	7.3	24	-		-		100.0	10	-		7.6	34
	1991	-		-		-		-		-		1.7	2	28.0	14	7.3	16
	Total	18.5	50	1.6	6	6.1	25	1.2	2	2.9	5	5.3	17	11.9	19	6.6	124
All	Total	6.3	81	1.6	35	11.0	162	7.7	132	10.7	102	8.7	250	12.9	231	8.0	993

1 includes standardized drift net effort.

Appendix 10. Statistics of shovelnose sturgeon transmittered from 1989 - 1993 implanted with radio and/or sonic (S) transmitters.

Date	Implant location river mile	Radio/Sonic frequency	Transmitter type[1](weight(g))	Fish Weight (kg)	% loading	Total length (mm)	Fork length (mm)
8/8/89	1700	48.850	3	-	-	-	-
8/8/89	1700	48.870	3	-	-	-	-
3/24/90	1770	49.026	1	-	-	-	-
3/24/90	1770	49.051	1	-	-	-	-
7/30/91	1770	3335 (S)	3 (24)	0.771	3.6	640	-
7/31/91	1770	338 (S)	3 (24)	0.953	2.9	-	-
7/31/91	1770	257 (S)	3 (24)	-	-	-	-
7/31/91	1770	48.700/248	4 (39)	1.72	2.3	742	-
7/31/91	1770	48.720	4 (11)	0.68	1.6	602	-
7/31/91	1770	48.780	4 (11)	-	-	-	-
7/31/91	1770	48.800	4 (11)	-	-	-	-
8/6/91	69	48.560/22324	4 (73)	2.91	2.5	869	-
8/6/91	69	48.600/2525	4 (73)	3.09	2.4	919	-
8/7/91	69	48.620/2236	4 (73)	3.40	2.1	927	-
8/7/91	69	48.640/3342	4 (73)	3.09	2.4	914	-
8/8/91	1574	48.660/22234	4 (73)	3.09	2.4	917	-
8/8/91	1574	48.740/3333	4 (39)	1.77	2.2	856	-
9/4/91	1579	48.760/23233	4 (39)	2.63	1.5	940	861
10/9/91	11	48.680/2442	4 (73)	-	-	919	823
6/1/92	71	48.840/285	4 (64)[2]	3.49	1.8	1021	945
6/1/92	69	48.861/294	4 (64)[2]	3.20	2.0	886	823
6/1/92	71	48.921/357	4 (64)[2]	4.20	1.5	1039	947
6/2/92	71	48.821/276	4 (64)[2]	3.04	2.1	894	825
6/3/92	71	48.883/339	4 (64)[2]	3.78	1.7	910	878
6/3/92	71	48.902/438	4 (64)[2]	3.46	1.8	940	873
6/8/92	71	48.942/366	4 (64)[2]	2.90	2.2	868	803
9/28/92	1581	49.710	3 (40)	2.30	1.7	894	820
9/28/92	1581	49.790	3 (40)	2.70	1.5	856	787
5/27/93	6	48.551	2 (13)	2.40	0.5	851	777
6/93[3]		48.590	2 (13)	-	-	-	833

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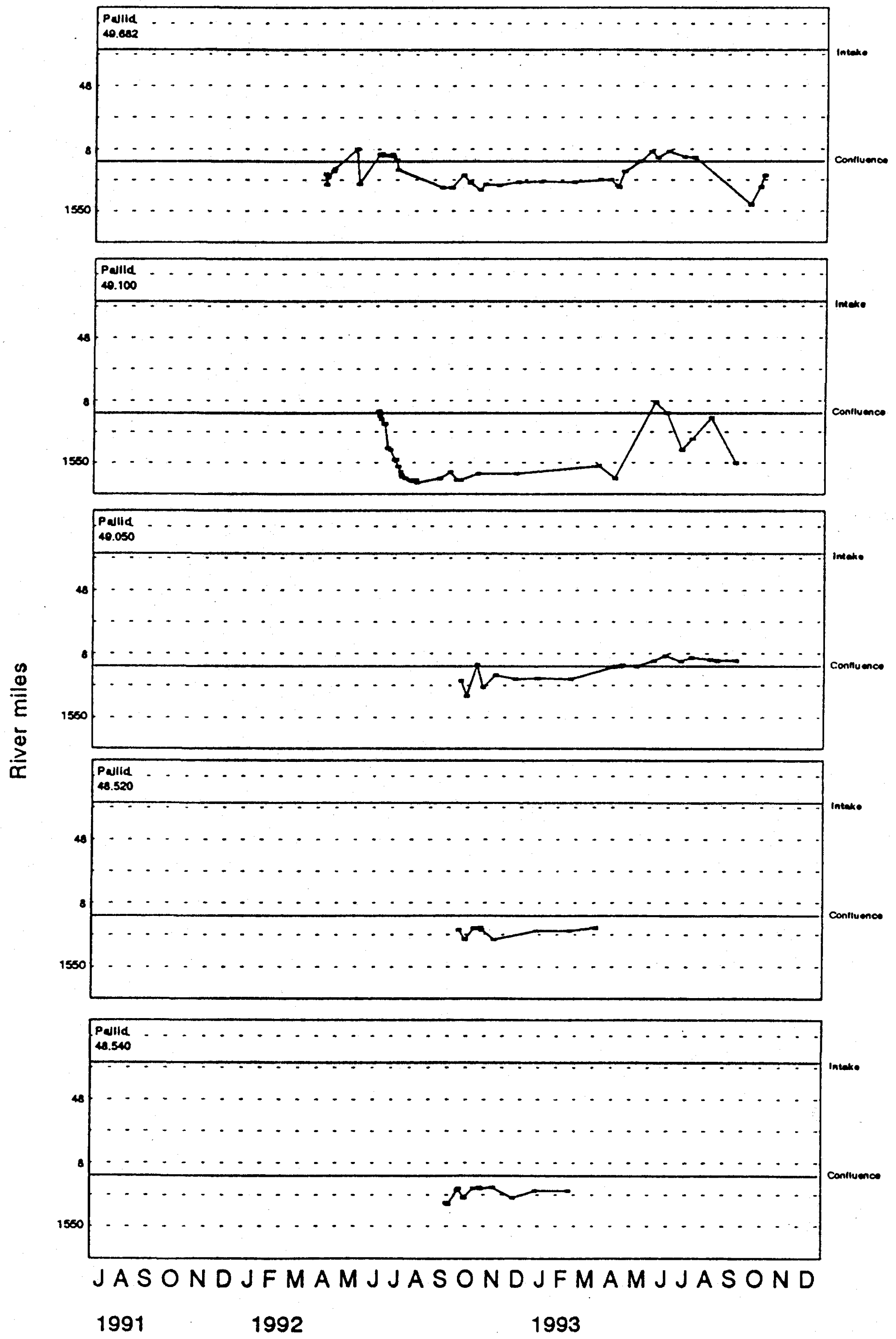
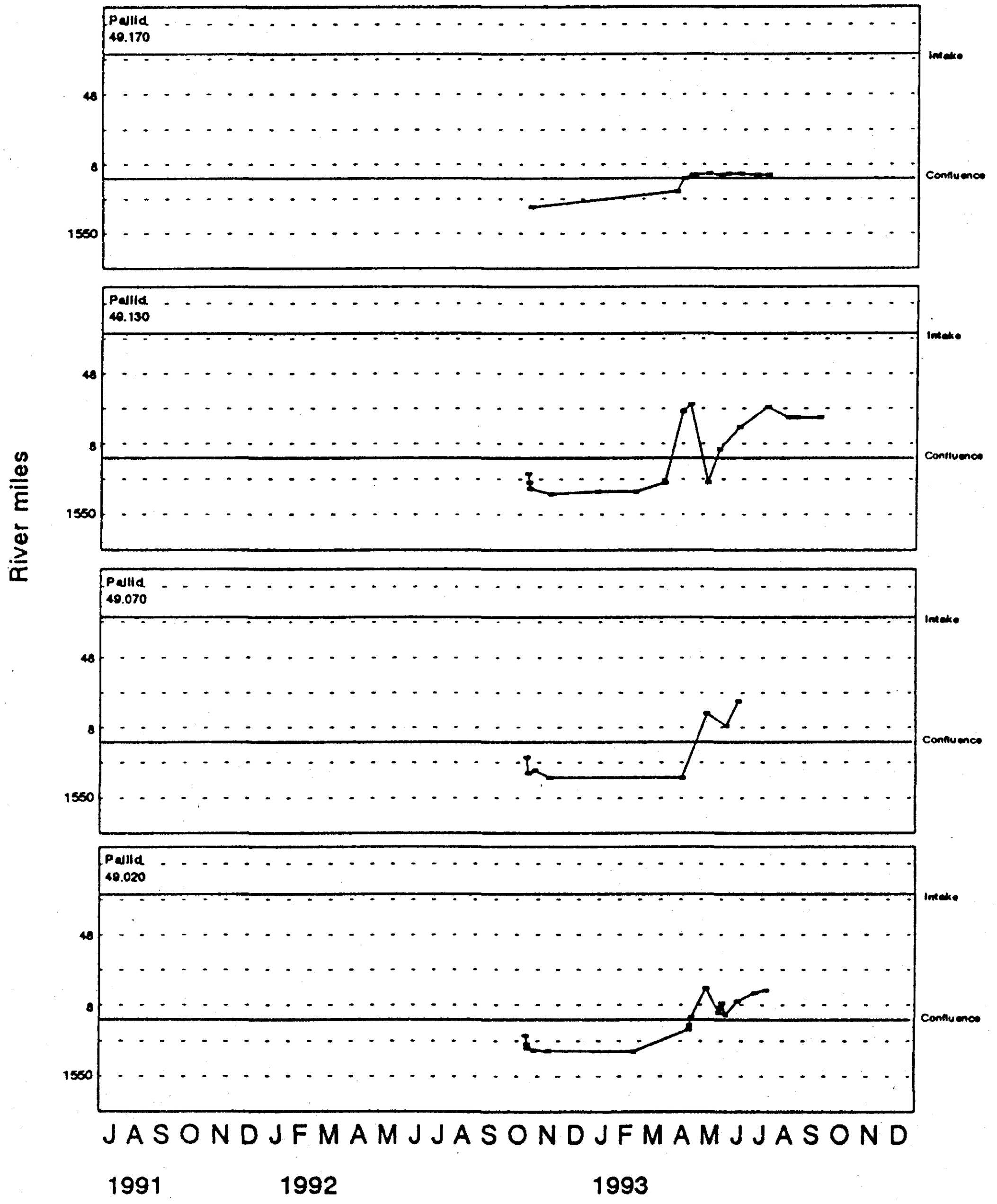
[1] See Table 3 for transmitter specifics.
[2] From Bramblett and White (1992)
[3] From Bramblett and White (1993)

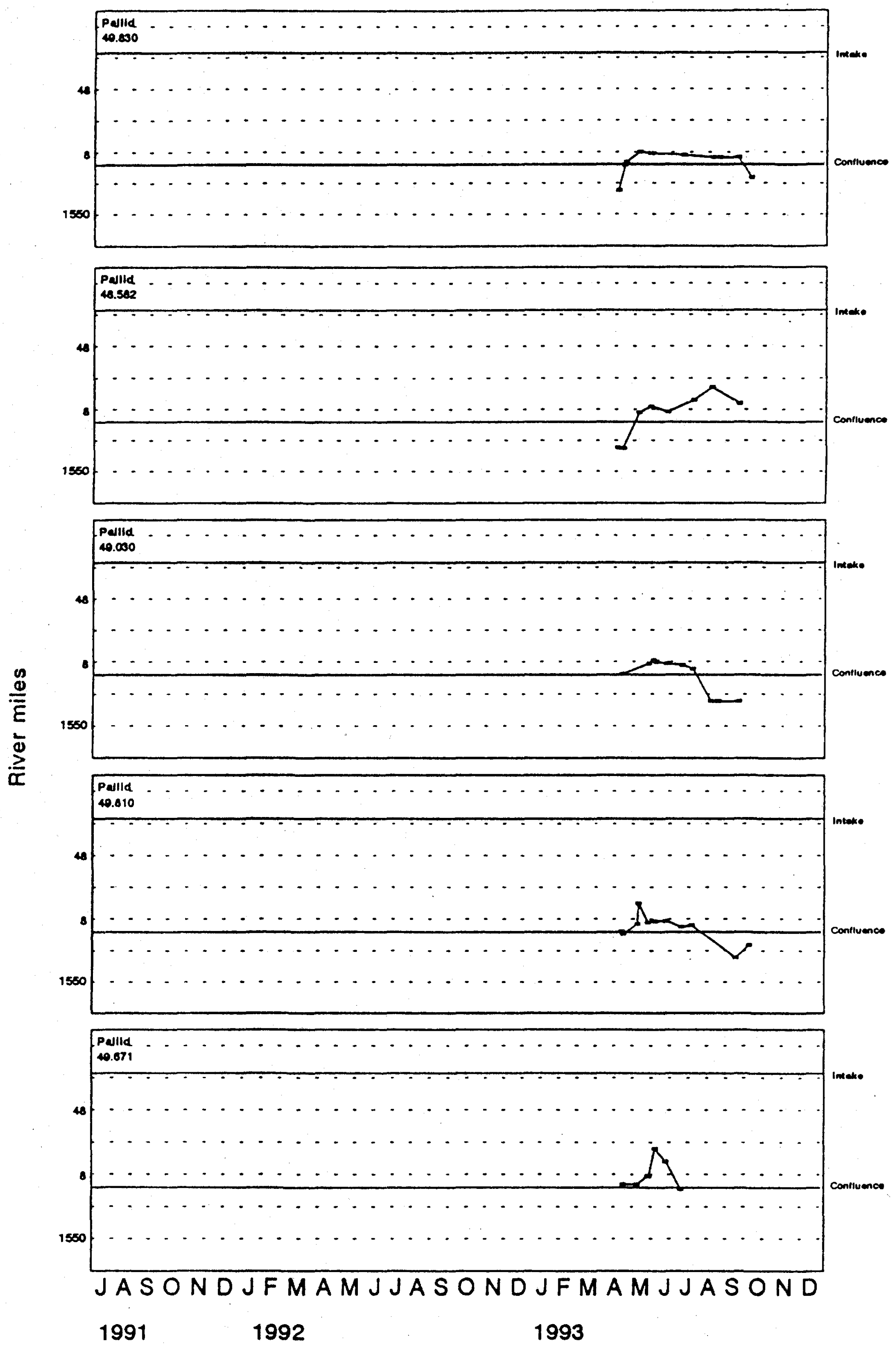
Appendix 11. Movement of radioed pallid sturgeon in the Yellowstone/confluence area.



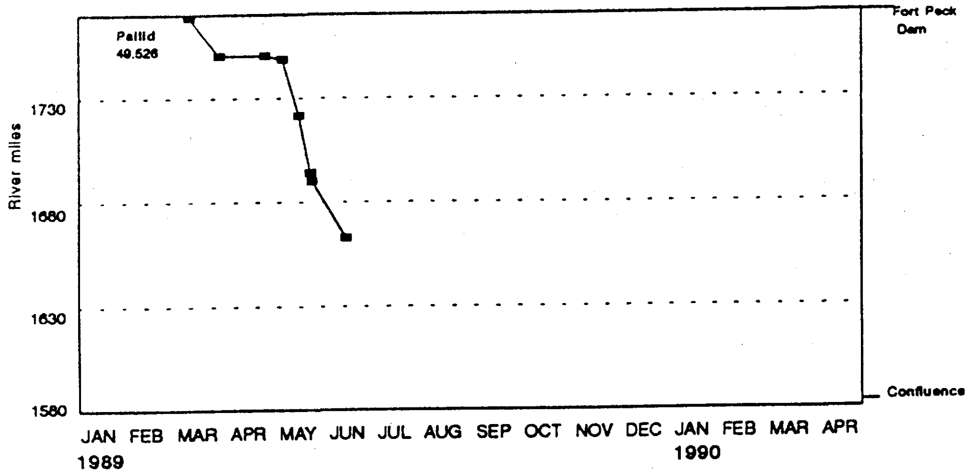
Appendix 11 continued. Movement of radioed pallid sturgeon in the Yellowstone/confluence area.

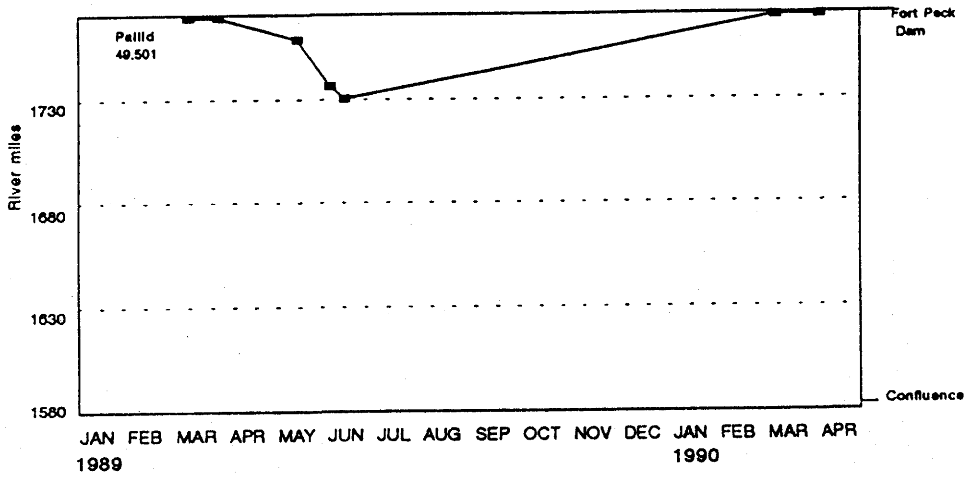


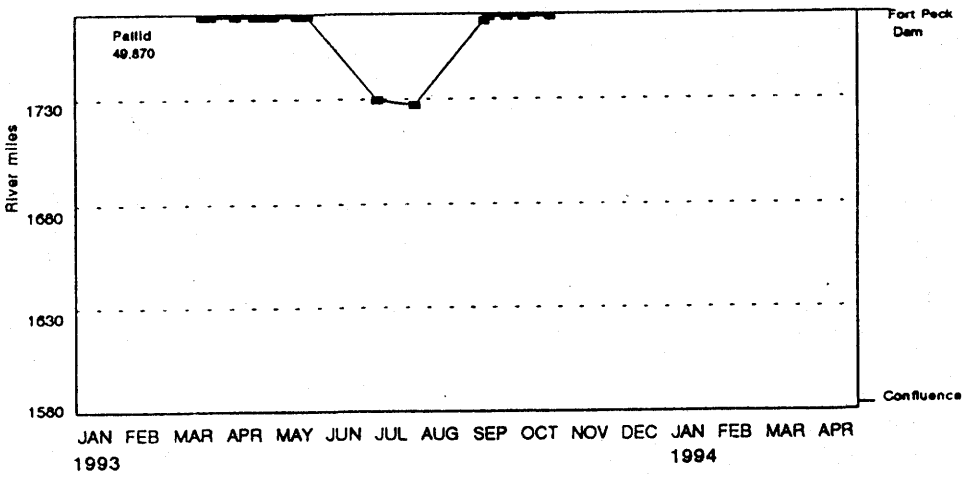
Appendix 11 continued. Movement of radioed pallid sturgeon in the Yellowstone/confluence area.



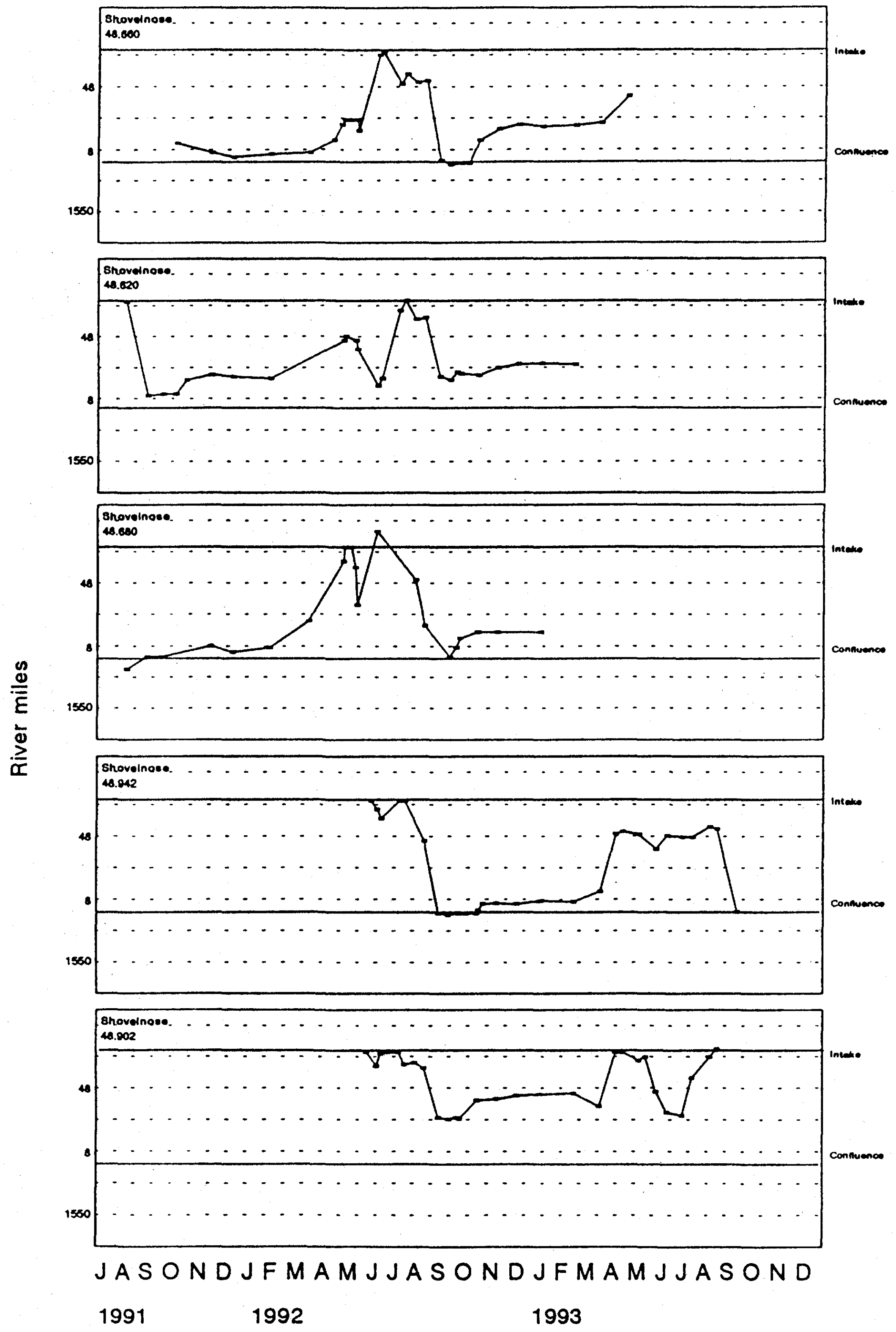
Appendix 12. Movement of radioed pallid sturgeon in the Fort Peck tailrace and in the Missouri above the confluence.



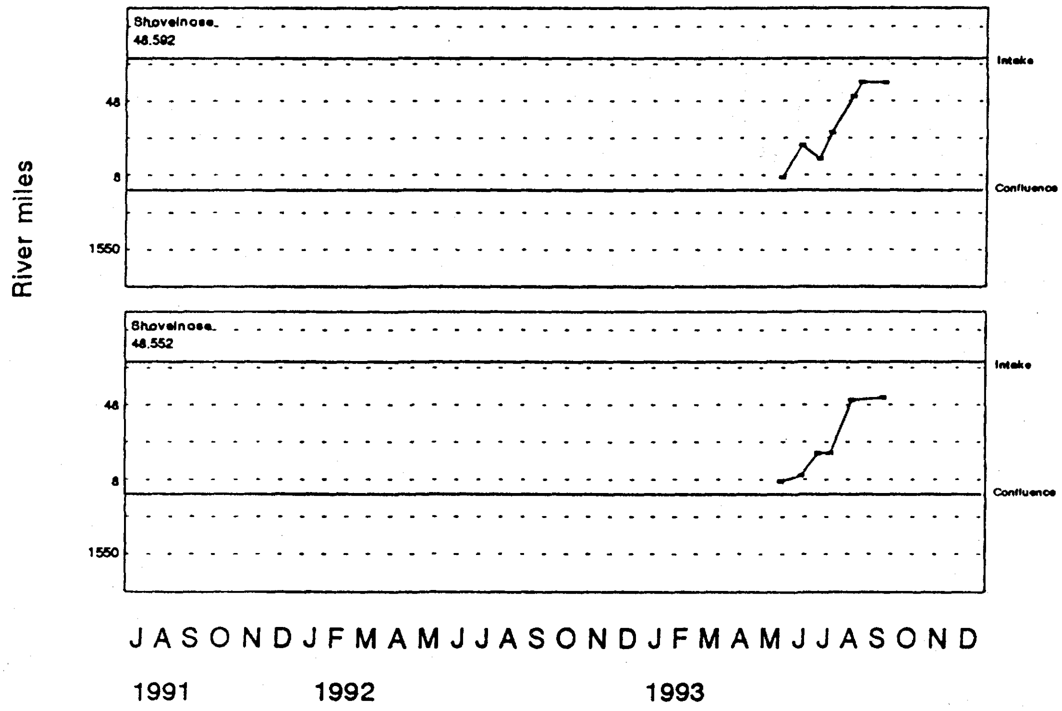




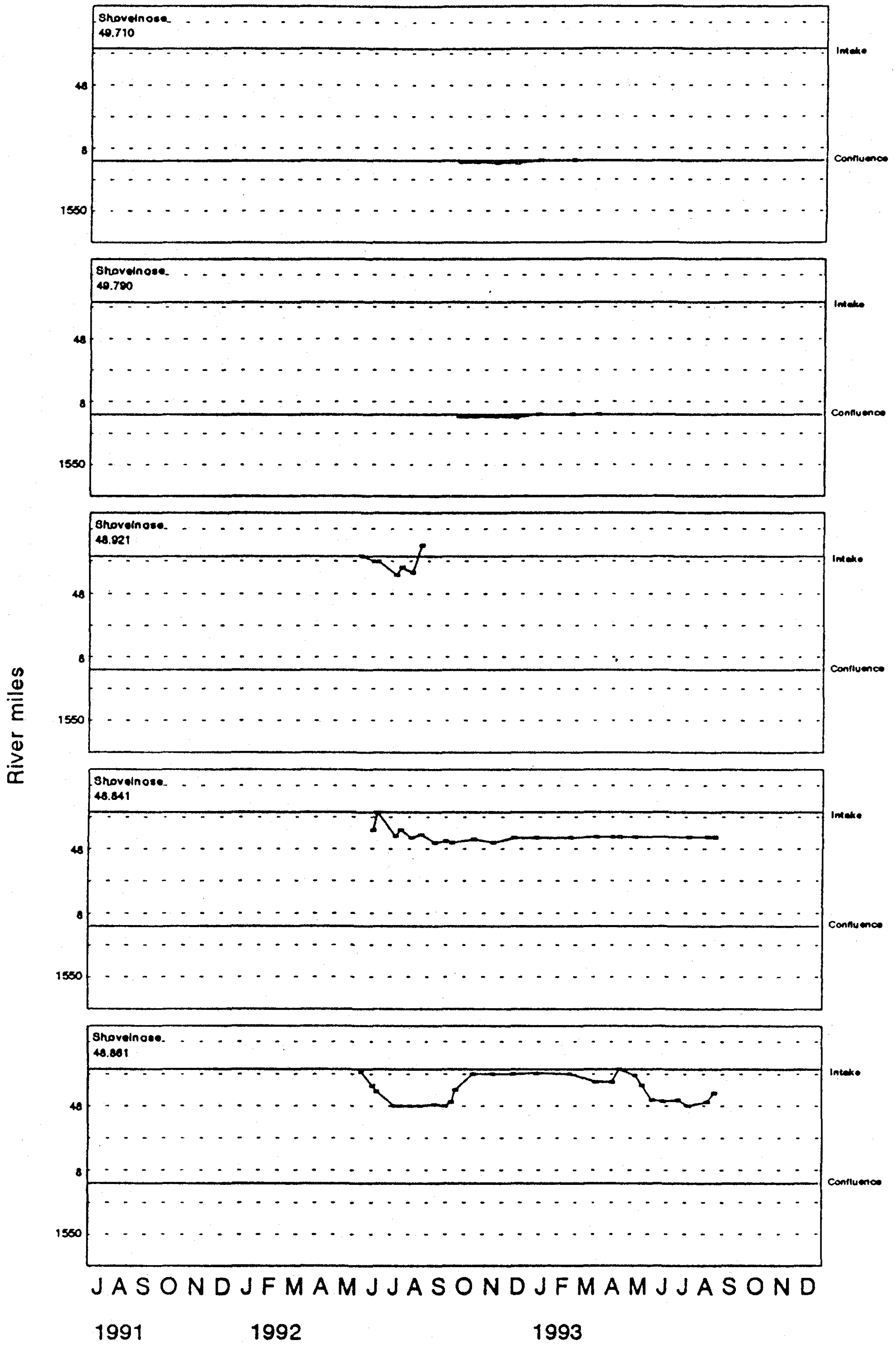
Appendix 13. Movement of shovelnose sturgeon in the Yellowstone/confluence area.



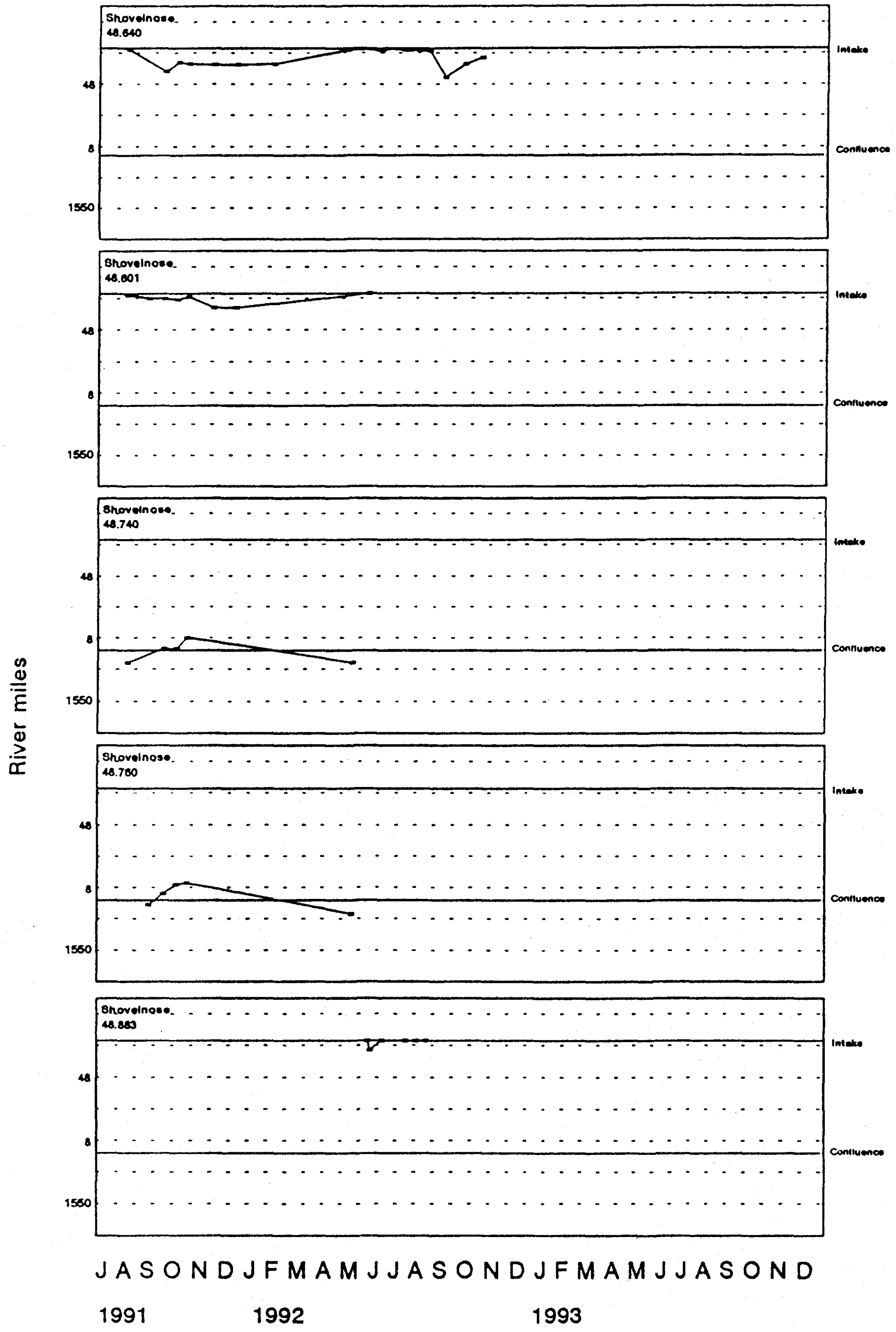
Appendix 13 continued. Movement of shovelnose sturgeon in the Yellowstone/confluence area.



Appendix 13 continued. Movement of shovelnose sturgeon in the Yellowstone/confluence area.



Appendix 13 continued. Movement of shovelnose sturgeon in the Yellowstone/confluence area.



Appendix 14. Habitat measurements of pallid sturgeon taken during radio telemetry relocations in 1993.

Fish number	Month	Day	River mile	cfs	depth (m)	Velocity (m/s)			Secchi disk (cm)	Substrate
						Surface	Average	Bottom		
49.050	4	24	0.3	7940	1.4	0.70	0.64	0.62	2	SAND
	4	15	1582.0	14040	1.0	0.80	0.60	0.60	18	SAND
49.170	4	5	1574.5	16490	-	-	-	-	-	-
	4	15	0.5	6790	-	-	-	-	-	-
	5	12	2.5	16900	3.6	0.81	0.78	0.55	2	SAND
49.671	4	24	1.5	7940	-	-	-	-	-	SAND
	5	12	2.0	16900	3.0	0.88	0.84	0.80	5	SAND
49.682	4	7	1568.0	15550	1.4	0.60	0.37	0.37	8	SILT
	4	23	1575.5	14960	0.9	0.62	0.65	0.68	8	SAND
49.810	5	13	18.0	16300	4.9	-	-	-	2	SAND
49.830	4	25	2.0	7850	0.9	-	-	-	8	SAND
49.870	3	25	1769.5	4900	7.6	<0.01	<0.01	<0.01	610	-
	3	30	1769.5		10.4	<0.01	<0.01	<0.01	488	-
	4	9	1769.5	5900	10.4	<0.01	<0.01	<0.01	701	-
	5	24	1769.5	7300	11.3	<0.01	<0.01	<0.01	-	SAND
	7	28	1725.5	12600	2.0	0.68	0.60	0.47	2	SAND
	9	24	1769.5	3200	14.5	<0.01	<0.01	<0.01	148	-
	10	5	1769.5	3100	9.8	<0.01	<0.01	<0.01	165	-
	10	21	1769.5	3000	6.7	<0.01	<0.01	<0.01	204	-

Appendix 15. Average catch per seine haul (number) in 1993 by section.

Section	2	3	5	6	8	9	Total
# of hauls	2	3	3	4	3	8	23
Flathead chub	0.5	11.7	34.0	13.0	53.0	51.5	33.1
	(1)	(35)	(102)	(52)	(159)	(412)	(761)
Sturgeon chub	0.0	0.0	2.7	1.0	8.7	1.1	2.0
	(0)	(0)	(8)	(4)	(26)	(9)	(47)
Sicklefin chub	0.0	0.0	0.0	0.4	0.0	0.0	<0.1
	(0)	(0)	(0)	(1)	(0)	(0)	(1)
Shovelnose sturgeon	0.0	0.0	0.0	0.0	0.7	0.0	0.1
	(0)	(0)	(0)	(0)	(2)	(0)	(2)
Walleye/sauger	0.5	0.3	1.0	0.8	0.7	0.3	0.5
	(1)	(1)	(3)	(3)	(2)	(2)	(12)
Channel catfish	0.0	0.0	0.0	0.0	0.0	1.5	0.5
	(0)	(0)	(0)	(0)	(0)	(12)	(12)
Northern Pike	0.0	0.0	0.7	0.2	0.0	0.2	0.2
	(0)	(0)	(2)	(1)	(0)	(2)	(5)
Goldeye	0.5	0.0	0.3	0.0	1.0	1.1	0.6
	(1)	(0)	(1)	(0)	(3)	(9)	(14)
Emerald shiner	0.0	0.0	0.0	0.2	5.7	1.0	1.1
	(0)	(0)	(0)	(1)	(17)	(8)	(26)
Plains minnow	0.0	0.0	0.0	0.0	0.0	0.8	0.3
	(0)	(0)	(0)	(0)	(0)	(6)	(6)
Longnose dace	0.0	0.0	0.0	0.0	2.0	0.0	0.3
	(0)	(0)	(0)	(0)	(6)	(0)	(6)
White sucker	3.0	3.7	0.0	0.0	0.0	0.0	0.7
	(6)	(11)	(0)	(0)	(0)	(0)	(17)
Longnose sucker	0.0	0.0	3.0	0.0	0.0	0.1	0.4
	(0)	(0)	(9)	(0)	(0)	(1)	(10)
Shorthead redhorse	0.0	0.3	1.0	0.0	0.0	0.0	0.2
	(0)	(1)	(3)	(0)	(0)	(0)	(4)
River carpsucker	0.5	0.0	0.0	0.0	0.0	0.1	0.1
	(1)	(0)	(0)	(0)	(0)	(1)	(2)
Unknown	0.0	0.3	1.3	0.5	5.3	8.2	3.9
	(0)	(1)	(4)	(2)	(16)	(66)	(89)
Total fish	3.3	16.7	44.0	16.0	77.0	65.9	44.1
	(10)	(49)	(132)	(64)	(231)	(528)	(1014)
# species	5	4+	7+	6+	7+	10+	15+

Appendix 16. Fish species and number caught during drift netting at each standardized sampling station in 1993.

Species	Station 2	3	4	5	6	7	8	total
Shovelnose sturgeon	40	32	3	24	66	15	4	184
Goldeye	8	4	4	3	8	7	0	34
Channel catfish	1	0	1	7	5	12	0	26
Blue sucker	12	1	1	0	0	0	1	15
River carpsucker	1	4	0	1	1	7	1	15
Sauger	0	5	1	1	1	2	0	10
Walleye	0	1	0	0	1	1	0	3
Paddlefish	0	0	0	0	0	0	1	1
Smallmouth Buffalo	1	1	1	4	0	0	0	7
Bigmouth Buffalo	0	0	0	1	0	1	0	2
Shorthead redhorse	0	1	0	0	1	0	0	2
Longnose sucker	2	0	0	0	0	0	0	2
White sucker	1	1	0	0	0	0	0	2
Carp	0	0	1	1	0	1	0	3
Flathead chub	0	5	0	0	0	0	0	5
Total	66	55	12	42	83	46	7	311

Appendix 17. Shovelnose catch in the Missouri River, above the confluence during 1993 standardized sampling[1].

		Month						
Station		May	June	July	August	September	October	Total
2 Deep	#	8	26	3				37
	#/effort	2.7	6.5	0.8	-	-	-	3.4
	#/hour	25.0	61.9	9.4				35.2
2 Shallow	#	1	1	1				3
	#/effort	0.5	0.2	0.2	-	-	-	0.3
	#/hour	2.8	2.5	3.4				2.9
2 Average	#	9	27	4				40
	#/effort	1.8	3.4	0.5	-	-	-	1.9
	#/hour	13.5	32.9	6.4				19.0
3 Deep	#	2	6	3	0	0	8	19
	#/effort	1.0	1.5	0.8	0.0	0.0	2.0	0.9
	#/hour	10.0	13.3	9.3	0.0	0.0	24.0	9.0
3 Shallow	#	2	3	1	2	1	4	13
	#/effort	0.5	0.8	0.2	0.5	0.2	1.0	0.5
	#/hour	2.7	6.4	2.6	7.4	3.6	13.3	6.8
3 Average	#	4	9	4	2	1	12	32
	#/effort	0.7	1.1	0.5	0.2	0.1	1.5	0.7
	#/hour	9.3	9.8	4.7	3.5	1.6	19.0	8.0
4 Deep	#	1	0	0	0			1
	#/effort	0.2	0.0	0.0	0.0	-	-	0.1
	#/hour	2.4	0.0	0.0	0.0			0.6
4 Shallow	#	0	2	0	0			2
	#/effort	0.0	0.5	0.0	0.0	-	-	0.2
	#/hour	0.0	2.8	0.0	0.0			1.0
4 Average	#	1	2	0	0			3
	#/effort	0.1	0.2	0.0	0.0	-	-	0.1
	#/hour	1.2	1.7	0.0	0.0			0.8
Average of the Missouri above the Yellowstone River								
Deep	#	11	32	6	0	0	8	57
	#/effort	1.2	2.7	0.5	0.0	0.0	2.0	1.2
	#/hour	12.2	22.8	5.0	0.0	0.0	26.6	11.6
Shallow	#	3	6	2	2	1	4	18
	#/effort	0.3	0.5	0.2	0.2	0.2	1.0	0.4
	#/hour	3.0	3.8	1.7	3.3	3.3	13.3	3.7
Average	#	14	38	8	2	1	12	75
	#/effort	0.8	1.6	0.3	0.1	0.1	1.5	0.8
	#/hour	7.4	12.7	3.3	1.5	1.7	20.0	7.6

[1] One effort equals a standardized drift of approximately 370 m. When snagging occurred standardized drift sometimes involved 2 or more drifts.

Appendix 18. Shovelnose catch on the Yellowstone River during 1993 standardized sampling[1].

		Month						
Station		May	June	July	August	September	October	Total
6 Deep	#	0	0		4	2	4	10
	#/effort	0.0	0.0	-	1.0	0.5	1.0	0.7
	#/hour	0.0	0.0		14.8	6.2	12.0	9.1
6 Shallow	#	1	3		10	1	41	56
	#/effort	0.5	0.5	-	2.5	0.2	10.2	2.8
	#/hour	5.6	9.7		25.0	1.9	102.5	31.1
6 Average	#	1	3		14	3	45	66
	#/effort	0.2	0.5	-	1.7	0.4	5.1	1.9
	#/hour	2.7	8.1		20.9	3.5	61.6	22.0
7 Deep	#	0	1	0	0	2	1	4
	#/effort	0.0	0.5	0.0	0.0	0.5	0.2	0.2
	#/hour	0.0	7.7	0.0	0.0	5.3	3.0	2.2
7 Shallow	#	3	0	0	4	1	3	11
	#/effort	0.8	0.0	0.0	1.0	0.2	0.8	0.4
	#/hour	8.1	0.0	0.0	11.4	2.6	7.1	4.6
7 Average	#	3	1	0	4	3	4	15
	#/effort	0.4	0.1	0.0	0.5	0.4	2.0	0.3
	#/hour	4.6	1.6	0.0	5.7	3.9	5.3	3.5
8 Deep	#		0	0	0	1	0	1
	#/effort	-	0.0	0.0	0.0	0.5	0.0	0.1
	#/hour		0.0	0.0	0.0	5.6	0.0	1.2
8 Shallow	#		0	2	0	0	1	3
	#/effort	-	0.0	1.0	0.0	0.0	0.5	0.3
	#/hour		0.0	11.1	0.0	0.0	5.0	3.3
8 Average	#		0	2	0	1	1	4
	#/effort	-	0.0	0.5	0.0	0.2	0.2	0.2
	#/hour		0.0	5.7	0.0	2.0	3.1	2.3
Average for the Yellowstone River								
Deep	#	0	1	0	4	5	5	15
	#/effort	0.0	0.2	0.0	0.4	0.5	0.5	0.3
	#/hour	0.1	3.3	0.0	5.0	5.6	6.2	3.9
Shallow	#	4	3	2	14	2	45	70
	#/effort	0.7	0.2	0.3	1.4	0.2	4.5	1.2
	#/hour	6.7	3.3	3.3	15.5	1.7	45.0	13.7
Average	#	4	4	2	18	7	50	85
	#/effort	0.7	0.3	0.2	0.9	0.4	2.5	0.8
	#/hour	6.7	3.3	1.8	10.6	3.3	27.7	10.0

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[1] One effort equals a standardized drift of approximately 370 m. When snagging occurred standardized drifts sometimes involved 2 or more drifts.

Appendix 19. Shovelnose catch on the Missouri River and the average for all stations during 1993 standardized sampling[1].

		Month						
Station		May	June	July	August	September	October	Total
5 Deep	#	0	0	1	0	1	0	2
	#/effort	0.0	0.0	0.2	0.0	0.2	0.0	0.1
	#/hour	0.0	0.0	3.1	0.0	3.0	0.0	1.1
5 Shallow	#	0	0	2	0	4	16	22
	#/effort	0.0	0.0	0.5	0.0	1.0	4.0	0.9
	#/hour	0.0	0.0	5.4	0.0	10.5	33.3	9.6
5 Average	#	0	0	3	0	5	16	24
	#/effort	0.0	0.0	0.4	0.0	0.6	2.0	0.5
	#/hour	0.0	0.0	4.4	0.0	6.9	20.8	5.8
Grand total (Missouri and Yellowstone combined)								
Deep	#	11	33	7	4	6	13	74
	#/effort	0.6	1.6	0.3	0.2	0.3	0.7	0.6
	#/hour	10.5	11.8	3.5	2.2	3.8	9.3	7.0
Shallow	#	7	9	6	16	7	65	110
	#/effort	0.4	0.3	0.3	0.7	0.4	3.6	0.8
	#/hour	3.7	4.5	2.8	8.4	3.7	36.1	8.9
Average	#	18	42	13	20	13	78	184
	#/effort	0.5	0.8	0.3	0.4	0.4	2.2	0.7
	#/hour	8.6	8.9	3.2	5.3	3.8	24.4	8.1

[1] One effort equals a standardized drift of approximately 370 m. When snagging occurred standardized drifts sometimes involved 2 or more drifts.

Appendix 20. Mean surface and bottom velocity (m/sec) at deep sites of standardized sampling stations by month.

Station		Month						
		May	June	July	August	September	October	Average
2	surface	0.65	0.69	0.60	-	-	-	0.65
	bottom	0.53	0.56	0.56	-	-	-	0.55
3	surface	0.55	0.62	0.71	0.88	0.71	0.57	0.67
	bottom	0.44	0.52	0.56	0.80	0.61	0.49	0.57
4	surface	0.83	0.71	0.76	0.75	-	-	0.76
	bottom	0.72	0.49	0.65	0.64	-	-	0.62
5	surface	1.20	1.25	1.20	0.80	0.82	0.77	1.01
	bottom	0.90	-	0.82	0.65	0.71	0.70	0.76
6	surface	0.90	-	-	1.40	0.92	0.91	1.03
	bottom	0.70	-	-	1.00	1.20	0.89	0.95
7	surface	1.02	1.20	1.07	0.82	0.63	0.69	0.90
	bottom	0.69	0.92	0.81	0.72	0.45	0.50	0.68
8	surface	-	1.80	1.10	0.93	0.82	0.74	1.08
	bottom	-	-	0.92	0.80	0.63	0.72	0.77
Average								
	surface	0.86	1.04	0.91	0.93	0.78	0.74	
	bottom	0.66	0.62	0.72	0.77	0.72	0.66	

Appendix 21. Mean surface and bottom velocity (m/sec) at shallow sites of standardized sampling stations by month.

Station		May	June	July	August	September	October	Average
2	surface	0.61	0.52	0.64	-	-	-	0.59
	bottom	0.43	0.40	0.37	-	-	-	0.40
3	surface	0.83	0.72	0.69	0.80	0.67	0.55	0.71
	bottom	0.70	0.52	0.52	0.69	0.59	0.49	0.58
4	surface	0.83	0.43	0.45	0.66	-	-	0.59
	bottom	0.64	0.30	0.34	0.58	-	-	0.46
5	surface	0.83	0.93	0.79	0.61	0.51	0.16	0.64
	bottom	0.70	0.82	0.67	0.55	0.60	0.22	0.59
6	surface	0.84	1.15	-	0.85	0.07	0.12	0.61
	bottom	0.64	0.82	-	1.74	0.03	0.17	0.48
7	surface	0.85	0.81	0.91	0.62	0.18	0.18	0.59
	bottom	0.55	0.53	0.93	0.52	0.22	0.15	0.48
8	surface	-	0.80	0.72	0.68	0.42	0.66	0.66
	bottom	-	0.60	0.72	0.60	0.36	0.60	0.58
Average								
	surface	0.80	0.76	0.70	0.70	0.37	0.33	
	bottom	0.61	0.57	0.59	0.61	0.36	0.32	0.51

Appendix 22. Mean monthly secchi disk depth (cm) of standardized sampling sites.

Station	Month May	June	July	August	September	October	Average
2	-	245	46	-	-	-	146
3	46	140	17	6	17	46	45
4	46	34	10	7	-	-	24
5	30	5	12	14	22	7	15
6	2	4	-	15	98	9	26
7	2	8	8	14	62	11	18
8	-	5	14	11	42	5	15
Average	25	63	18	11	48	16	

Appendix 23. Mean monthly temperature (°C) of standardized sampling sites.

Station	Month May	June	July	August	September	October	Average
2	7.2	9.4	14.4	-	-	-	10.3
3	8.9	10.4	16.1	17.2	16.1	12.4	13.5
4	17.4	14.7	17.2	22.2	-	-	17.9
5	16.1	17.2	16.1	22.2	12.2	7.8	15.3
6	17.8	16.7	-	22.9	12.8	8.5	15.7
7	16.8	17.2	15.9	22.2	12.8	8.9	15.6
8	-	15.6	16.1	25.0	12.8	7.9	15.5
Average	14.0	14.4	16.0	22.0	13.3	9.1	

Appendix 24. Mean monthly conductivity (μmhos/cm) of standardized sampling sites (corrected to 25° C).

	Month						
Station	May	June	July	August	September	October	Average
2	559	592	502	-	-	-	551
3	598	592	600	576	612	624	600
4	602	606	612	651	-	-	618
5	660	450	576	536	638	712	595
6	731	400	-	512	643	704	598
7	734	420	588	525	650	700	603
8	-	468	546	500	643	711	574
Average	647	504	571	550	637	690	

Appendix 25. Mean depth (m) at deep and shallow sites of standardized sampling stations by month.

		Month						
Station		May	June	July	August	September	October	Average
2	deep	2.3	2.9	2.9	-	-	-	2.7
	shallow	1.5	1.3	1.6	-	-	-	1.5
3	deep	2.2	2.6	2.5	2.8	3.0	2.5	2.6
	shallow	1.4	1.2	1.3	1.6	1.1	1.1	1.3
4	deep	2.9	3.5	3.7	2.6	-	-	3.2
	shallow	1.7	1.5	1.5	1.2	-	-	1.5
5	deep	4.5	6.2	5.4	3.9	3.1	3.4	4.4
	shallow	2.3	2.7	2.6	1.7	1.2	1.8	2.0
6	deep	3.4	4.8	-	2.9	2.8	3.0	3.4
	shallow	1.7	2.0	-	1.3	1.5	1.8	1.7
7	deep	3.1	4.4	4.6	2.7	2.2	2.5	3.2
	shallow	1.6	2.9	2.5	1.4	1.3	1.5	1.9
8	deep	-	4.8	4.6	3.6	2.6	3.2	3.8
	shallow	-	2.1	2.4	2.1	1.7	1.3	1.9
Average		3.1	4.2	4.0	3.1	2.7	2.9	3.3
	surface	1.7	2.0	2.0	1.6	1.4	1.5	1.7
	bottom							