Fort Peck Flow Modification Biological Data Collection Plan

Summary of 2003 Activities

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Extended Abstract

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

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

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

Introduction

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

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

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

Study Area

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

Methods

Monitoring Component 1 - Water temperature and turbidity.

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

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

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

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

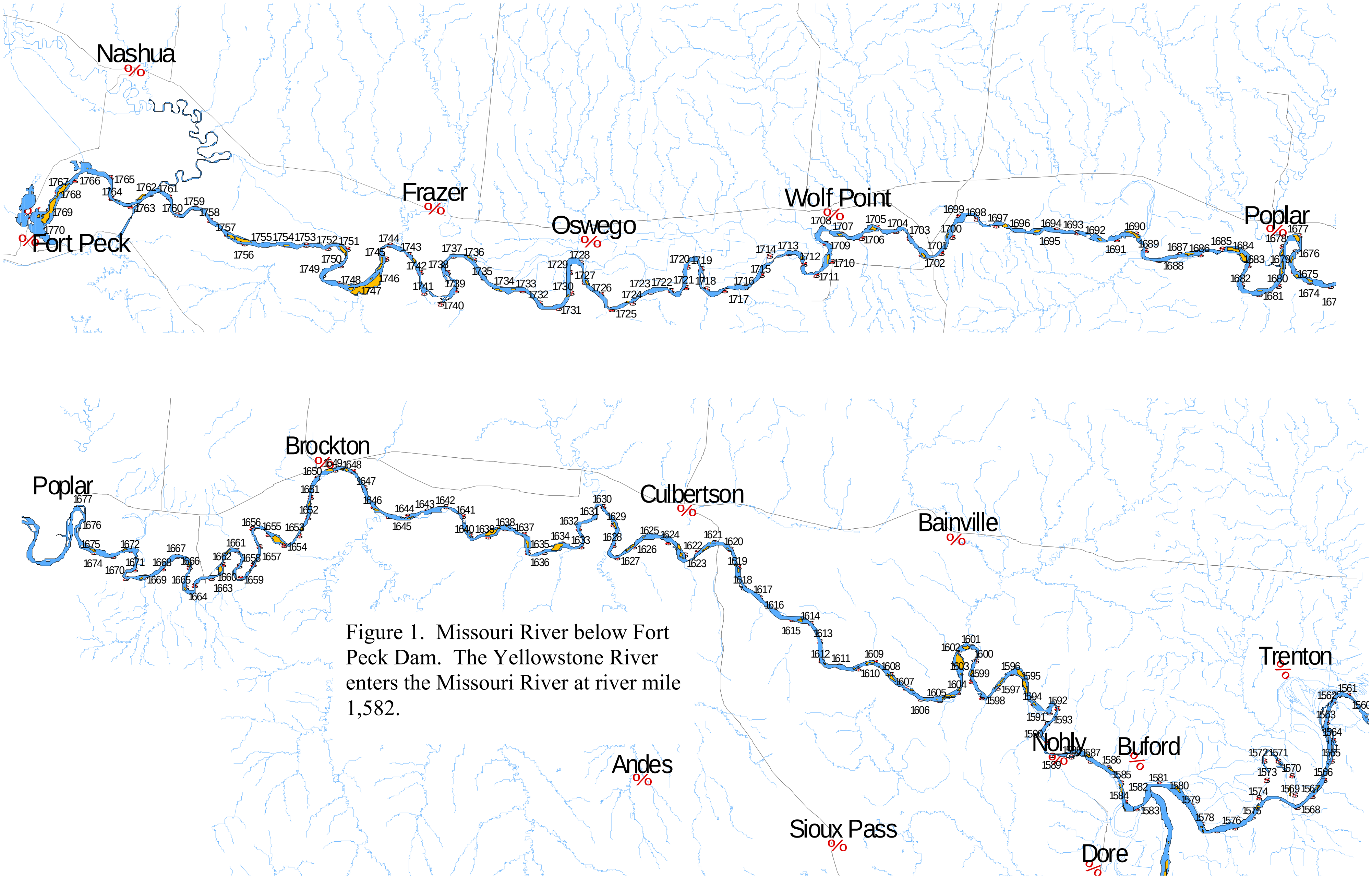


Figure 1. Missouri River below Fort Peck Dam. The Yellowstone River enters the Missouri River at river mile 1,582.

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

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

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

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

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

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

Monitoring Component 2 – Movements by pallid sturgeon.

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

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

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

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

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

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

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

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

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

Monitoring Component 4 – Larval Fish

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

Specific larval fish sampling protocols varied among sites and were dependent on site characteristics (Table 2). Two to five replicates were collected at the sites, where one replicate was comprised of four subsamples (two subsamples simultaneously collected on the right and left side of the boat at sampling locations near the left and right shorelines). At all sites except the spillway site, the left and right sampling locations corresponded to inside bend and outside bend locations at the mid-point of a river bend. The spillway channel had minimal sinuosity; therefore, samples did not reflect inside and outside bend locations. Only two replicates were available in the spillway channel (one replicate in both of the spillway channel pools), and three replicates were available at the site downstream from Fort Peck Dam. The full compliment of

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

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

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

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

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

Monitoring Component 5 – Young-of-year sturgeon

Sampling for young-of-year sturgeon was conducted with a benthic (beam) trawl between early August and early September 2003 in the Missouri River above the Yellowstone River confluence (i.e., ATC), Missouri River below the Yellowstone River confluence (i.e., BTC), and in the Yellowstone River. Four replicate sampling locations were established at each site (Table

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

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

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

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

Results and Discussion

Monitoring Component 1 - Water temperature and turbidity

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

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

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

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

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

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

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

Sample	Treatment	Logger mean	Logger minimum	Logger maximum	Logger range	Logger SD	Number of loggers
1	Cold	5.4	4.8	8.9	4.1	0.6	38
		5.3	4.8	5.9	1.2	0.3	37
2	Cold	6.4	5.6	9.3	3.8	0.6	38
		6.3	5.6	6.9	1.3	0.4	37
3	Cold	6.0	5.2	9.0	3.8	0.6	38
		5.9	5.2	6.5	1.2	0.3	37
4	Cold	5.4	4.9	8.7	3.8	0.6	38
		5.3	4.9	5.8	0.9	0.2	37
5	Cold	5.9	5.4	9.2	3.8	0.6	38
		5.8	5.4	6.4	1.0	0.2	37
6	Cool	19.4	17.8	19.7	2.0	0.3	38
		19.4	19.1	19.7	0.7	0.2	37
7	Cool	19.0	17.4	19.2	1.8	0.3	38
		19.0	18.6	19.2	0.7	0.1	37
8	Cool	18.6	17.3	18.9	1.6	0.3	38
		18.6	18.3	18.9	0.6	0.1	37
9	Cool	18.3	17.1	18.6	1.5	0.2	38
		18.3	18.0	18.6	0.6	0.1	37
10	Cool	18.0	17.0	18.2	1.3	0.2	38
		18.1	17.8	18.2	0.4	0.1	37
11	Cool	17.8	16.8	18.1	1.3	0.2	38
		17.9	17.6	18.1	0.4	0.1	37
12	Cool	17.7	16.7	17.9	1.3	0.2	38
		17.7	17.3	17.9	0.6	0.1	37
13	Cool	17.5	16.7	17.8	1.1	0.2	38
		17.5	17.2	17.8	0.6	0.1	37
14	Cool	17.4	16.5	17.6	1.1	0.2	38
		17.4	17.0	17.6	0.6	0.1	37
15	Cool	17.2	16.5	17.5	1.0	0.2	38
		17.2	16.8	17.5	0.6	0.1	37

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

Treatment	Sample	Group	Logger mean	Logger minimum	Logger maximum	Logger range	Logger SD	Number of loggers
Cold	1		7.2	6.6	13.0	6.4	1.1	31
			7.0	6.6	7.5	0.9	0.2	30
	2		7.1	6.6	13.0	6.4	1.1	31
			6.9	6.6	7.2	0.6	0.1	30
	3		7.2	6.7	13.2	6.5	1.1	31
			7.0	6.7	7.2	0.4	0.1	30
	4		7.3	6.7	13.3	6.6	1.1	31
			7.1	6.7	7.3	0.6	0.1	30
Cool	1		19.0	12.6	19.6	7.0	1.2	31
			19.3	18.8	19.6	0.8	0.1	30
	2		19.0	12.7	19.4	6.7	1.2	31
			19.2	18.8	19.4	0.6	0.1	30
	3		19.0	12.9	19.4	6.5	1.1	31
			19.2	18.8	19.4	0.6	0.1	30
	4		19.0	13.2	19.4	6.2	1.1	31
			19.2	18.8	19.4	0.6	0.1	30
	5		19.1	13.3	19.6	6.2	1.1	31
			19.3	18.9	19.6	0.6	0.1	30
Warm	1	1	24.4	13.0	26.0	12.9	2.7	21
			24.9	23.9	26.0	2.1	0.6	20
	2	1	23.1	12.9	24.5	11.6	2.4	21
			23.6	22.8	24.5	1.7	0.4	20
	3	1	22.3	12.9	23.3	10.4	2.2	21
			22.7	22.2	23.3	1.2	0.3	20
	1	2	26.4	25.1	27.1	2.1	0.8	5
	2	2	24.4	23.5	25.4	1.9	0.7	5
	3	2	23.3	22.7	24.0	1.3	0.5	5
	1	3	25.9	25.4	26.5	1.1	0.4	5
	2	3	24.3	24.0	24.6	0.6	0.2	5
	3	3	23.2	23.0	23.5	0.6	0.2	5

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

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

Influence of Milk River inflows on water temperature. Lateral differences in water temperature at some sites below Fort Peck suggested that Milk River inflows differentially influenced water temperatures on north and south bank locations due to incomplete lateral mixing. During 2003, the Milk River exhibited periods of increasing and decreasing flows primarily during mid-May, mid-June, and mid-July (Figure 2, 3, 4). Between May 1 and July 31, the difference in mean daily water temperature between north and south bank locations (north bank – south bank) was positively correlated with Milk River discharge at Nickels Ferry ($r = 0.70$, $P < 0.0001$, $N = 33$ days), Nickels Rapids ($r = 0.20$, $P = 0.06$, $N = 92$ days), Frazer Pump ($r = 0.66$, $P < 0.0001$, $N = 92$ days), Frazer Rapids ($r = 0.59$, $P < 0.0001$, $N = 92$ days), and Grand Champs ($r = 0.69$, $P < 0.0001$, $N = 92$ days. The maximum difference between water temperatures on the north and south bank locations declined from upstream to downstream and was 4.1^{o}C at Nickels Ferry, 2.6^{o}C at Nickels Rapids, 2.0^{o}C at Frazer Pump, 0.7^{o}C at Frazer Rapids, 0.6^{o}C at Grand Champs, and 0.4^{o}C at Wolf Point. Braaten and Fuller (2003) reported similar results for data collected during 2002, but the maximum differences observed between bank locations was slightly higher. Earlier studies in the Missouri River (Gardner and Stewart 1987; Yerk and Baxter 2001; Braaten and Fuller 2002; Kapuscinski and Baxter 2003) also showed similar results, and suggest that Milk River inputs most strongly influence lateral variations in water temperature during the spring and early summer when Milk River discharge is high and Missouri River water temperatures are cold.

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

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

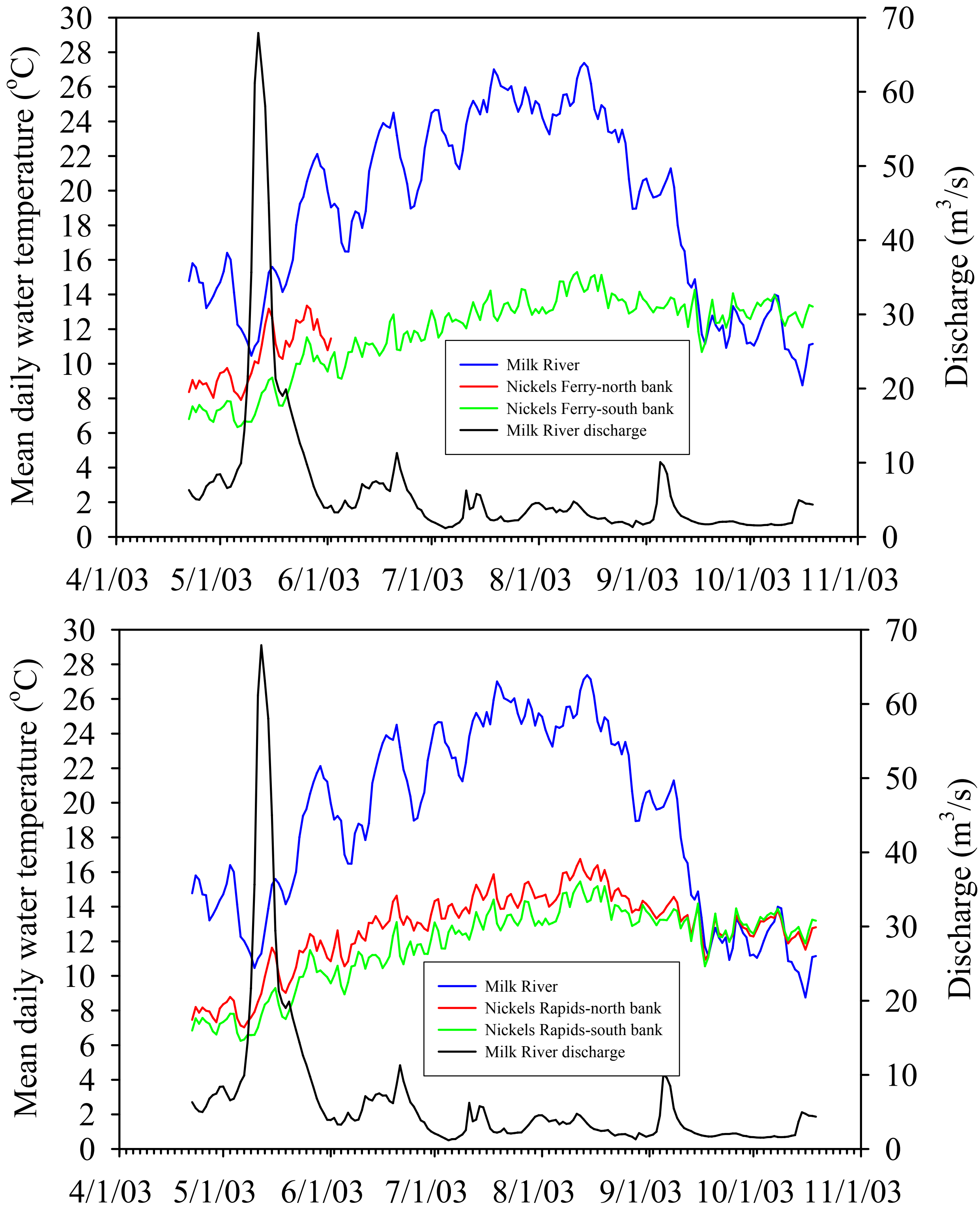


Figure 2. Water temperature profiles and discharge for the Milk River, and water temperatures profiles for the Missouri River at Nickels Ferry and Nickels Rapids during 2003.

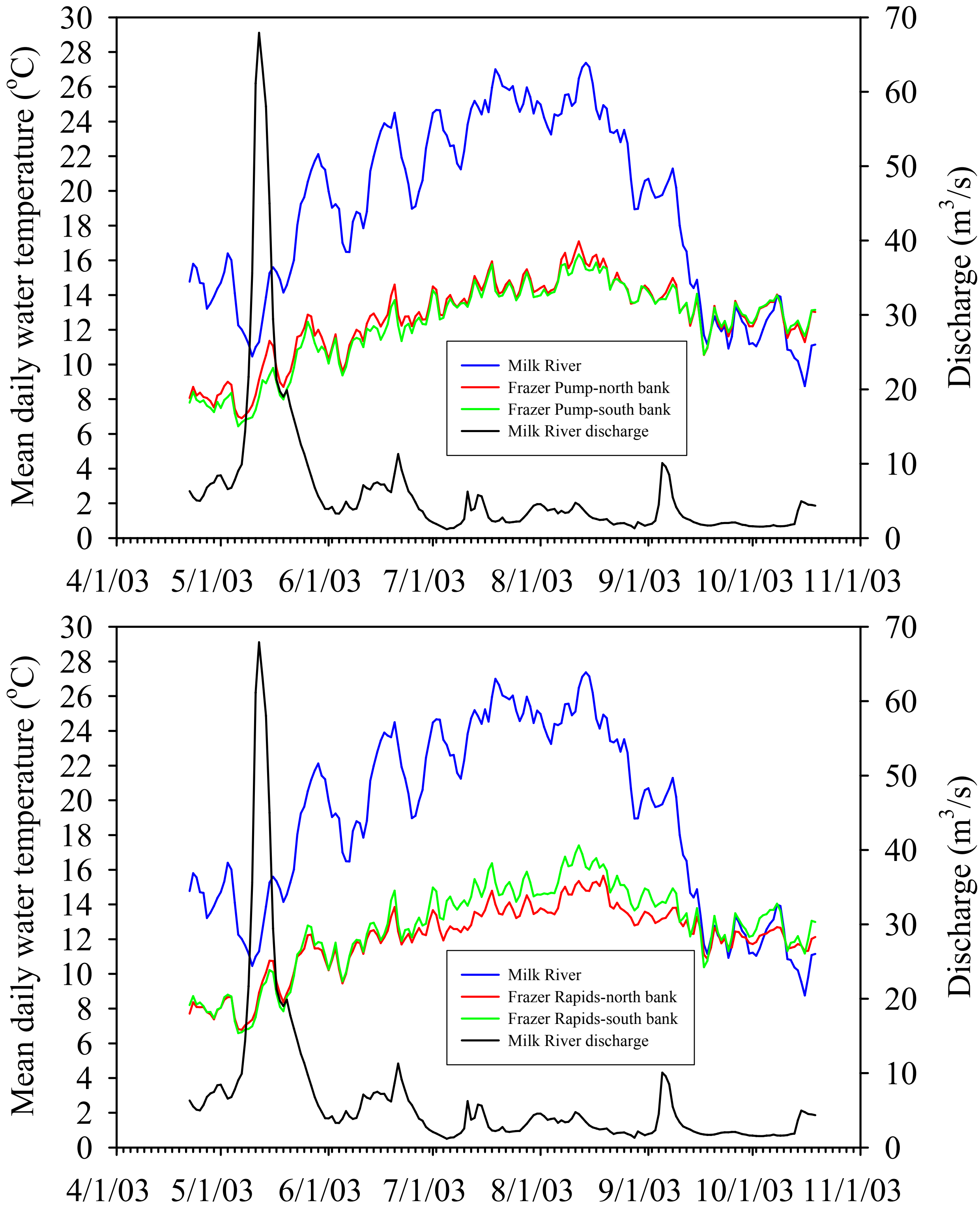
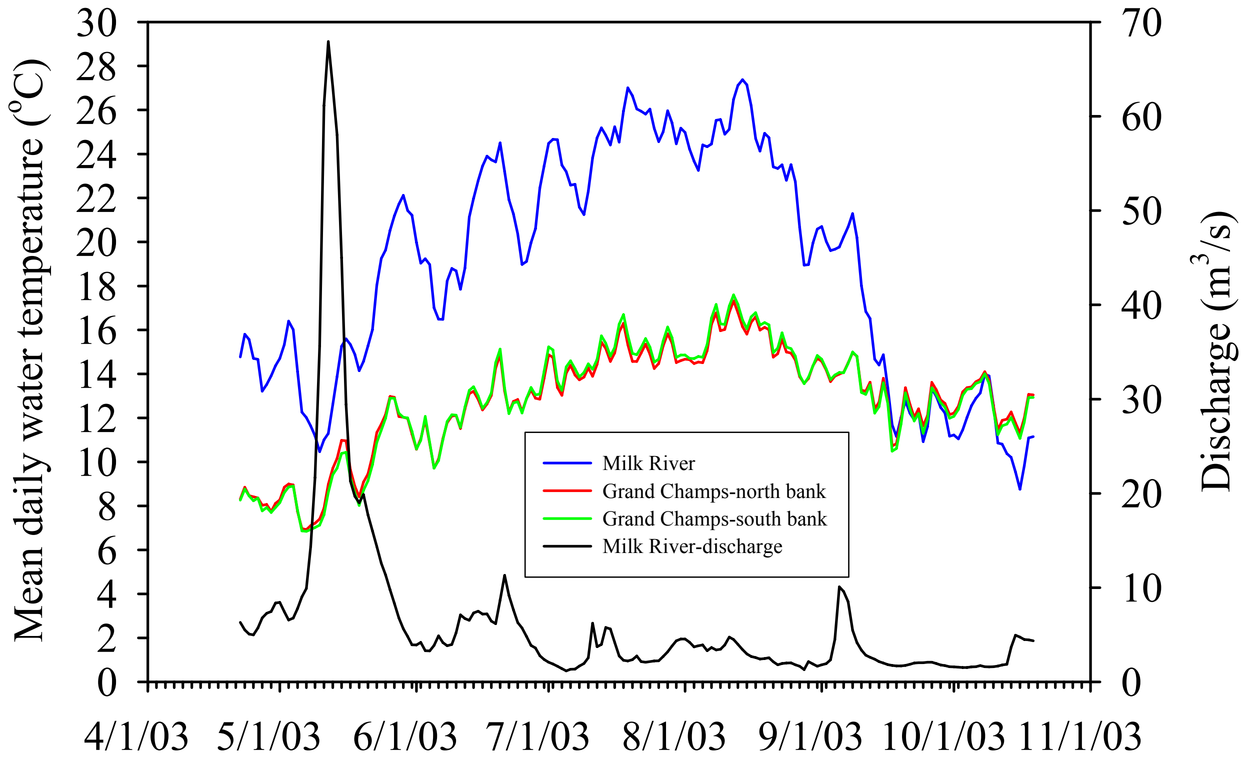


Figure 3. Water temperature profiles and discharge for the Milk River, and water temperatures profiles for the Missouri River at Frazer Pump and Frazer Rapids during 2003.



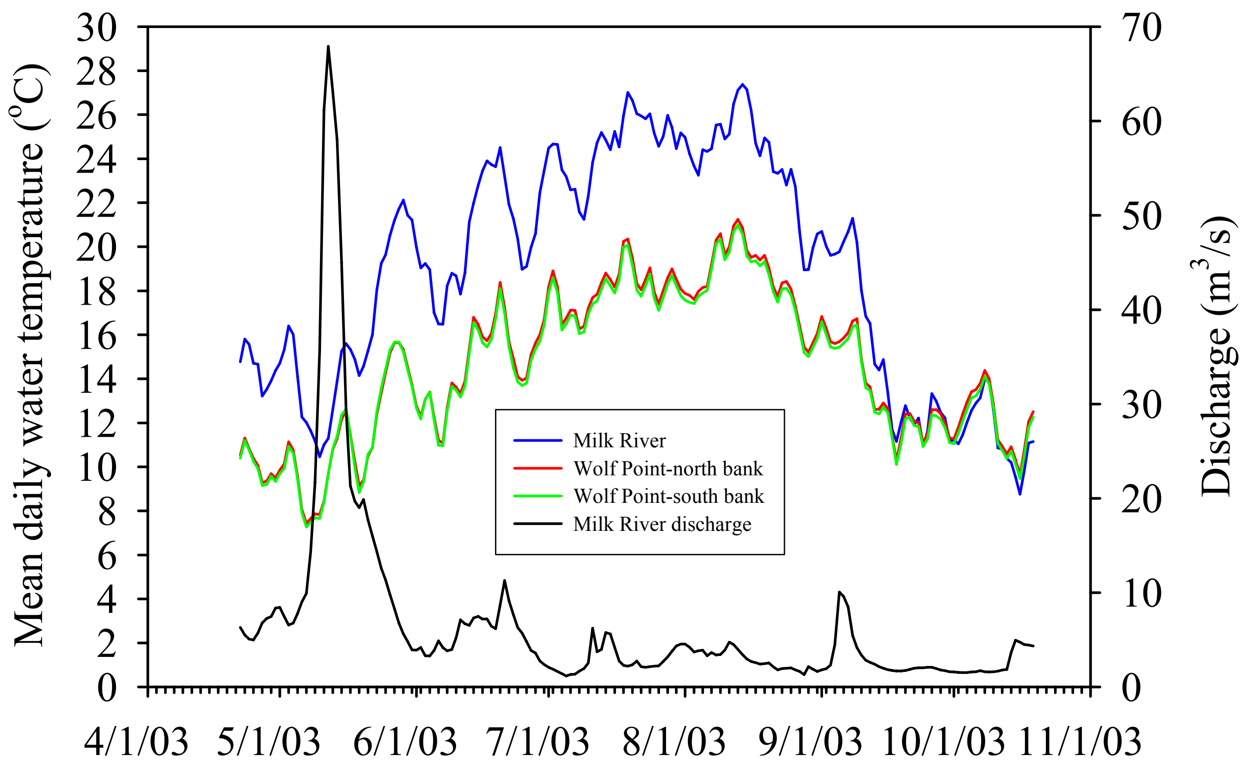


Figure 4. Water temperature profiles and discharge for the Milk River, and water temperatures profiles for the Missouri River at Grand Champs and Wolf Point during 2003.

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

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

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

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

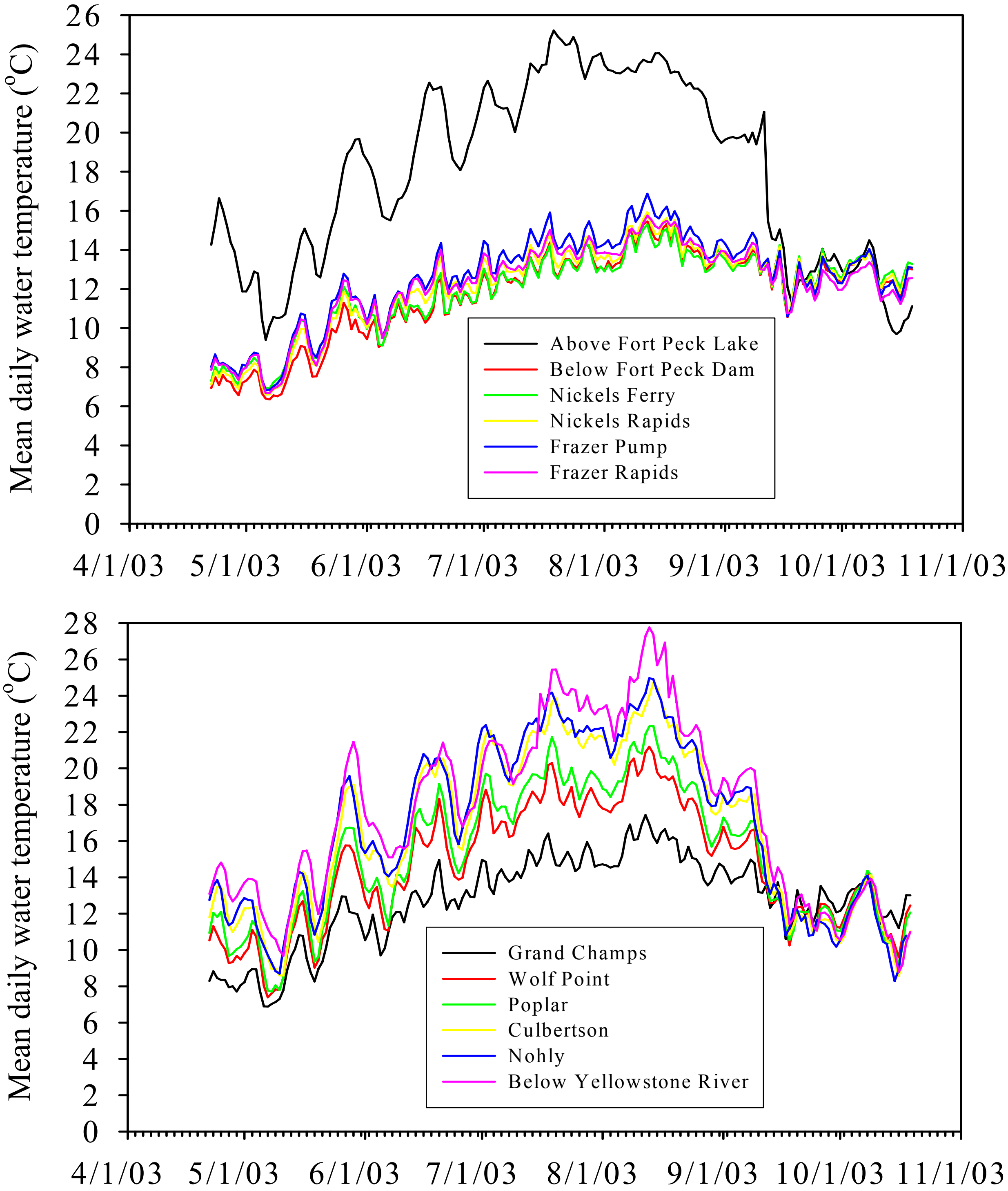


Figure 5. Mean daily water temperature (°C) at 12 sites on the mainstem Missouri River during 2003.

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

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

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

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

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

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

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

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

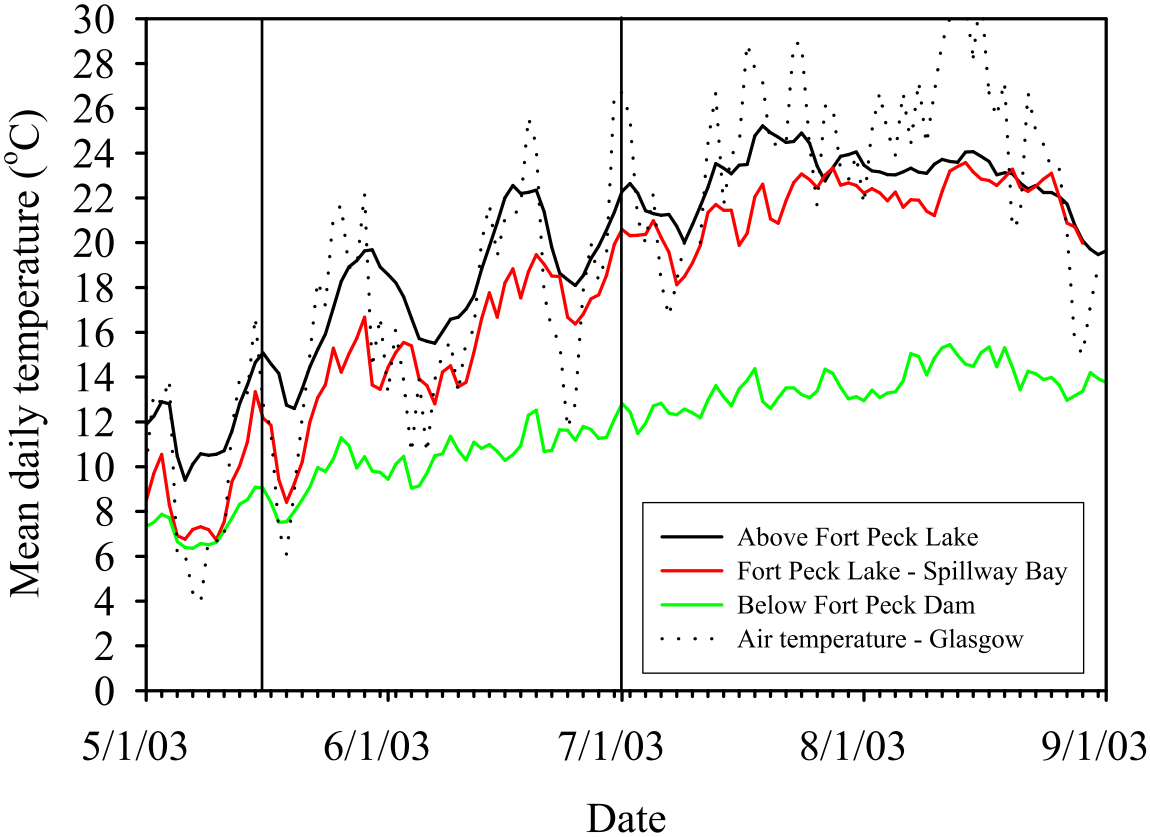


Figure 6. Mean daily water temperature at three sites (Missouri River above Fort Peck Lake, in the spillway bay, below Fort Peck Dam) and mean daily air temperature measured at Glasgow, Montana, during 2003. For reference, the vertical lines delimit dates when the proposed mini-test and full-test are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

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

Precision of turbidity loggers. Pre-deployment comparisons indicated there was no significant difference ($P = 0.66$) in mean turbidity among loggers in the low turbidity treatment (< 100 NTU), but mean turbidity differed significantly ($P < 0.0001$) among loggers in the medium turbidity treatment (200 – 500 NTU; Table 9). In the medium turbidity treatment, the Poplar logger recorded significantly lower ($P < 0.05$) mean turbidity than the Nohly and Yellowstone River loggers.

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

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

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

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

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

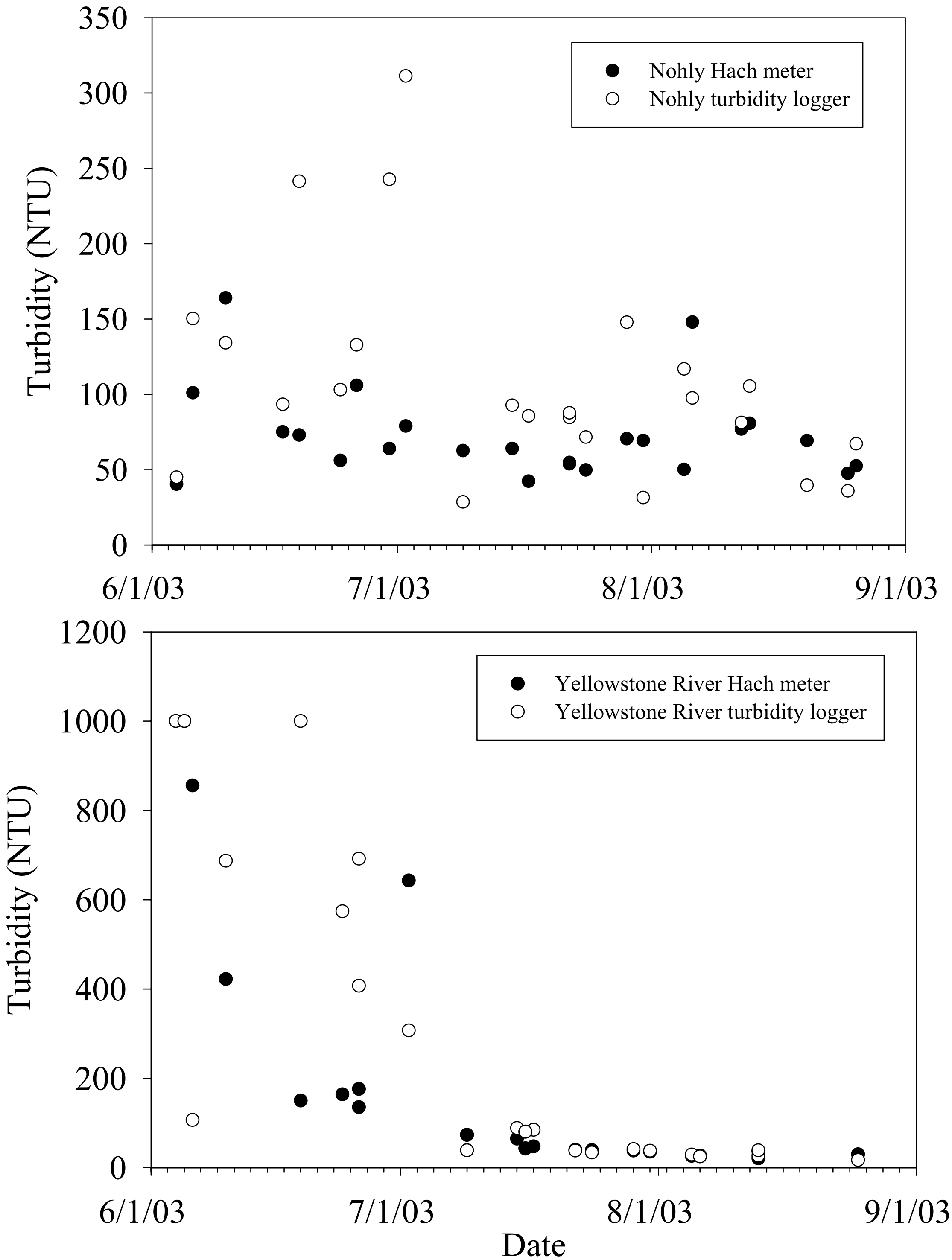


Figure 7. Hour-specific instantaneous turbidities (NTU) by date measured with a Hach meter during sampling activities and turbidity loggers at Nohly (upper panel) and in the Yellowstone River (lower panel).

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

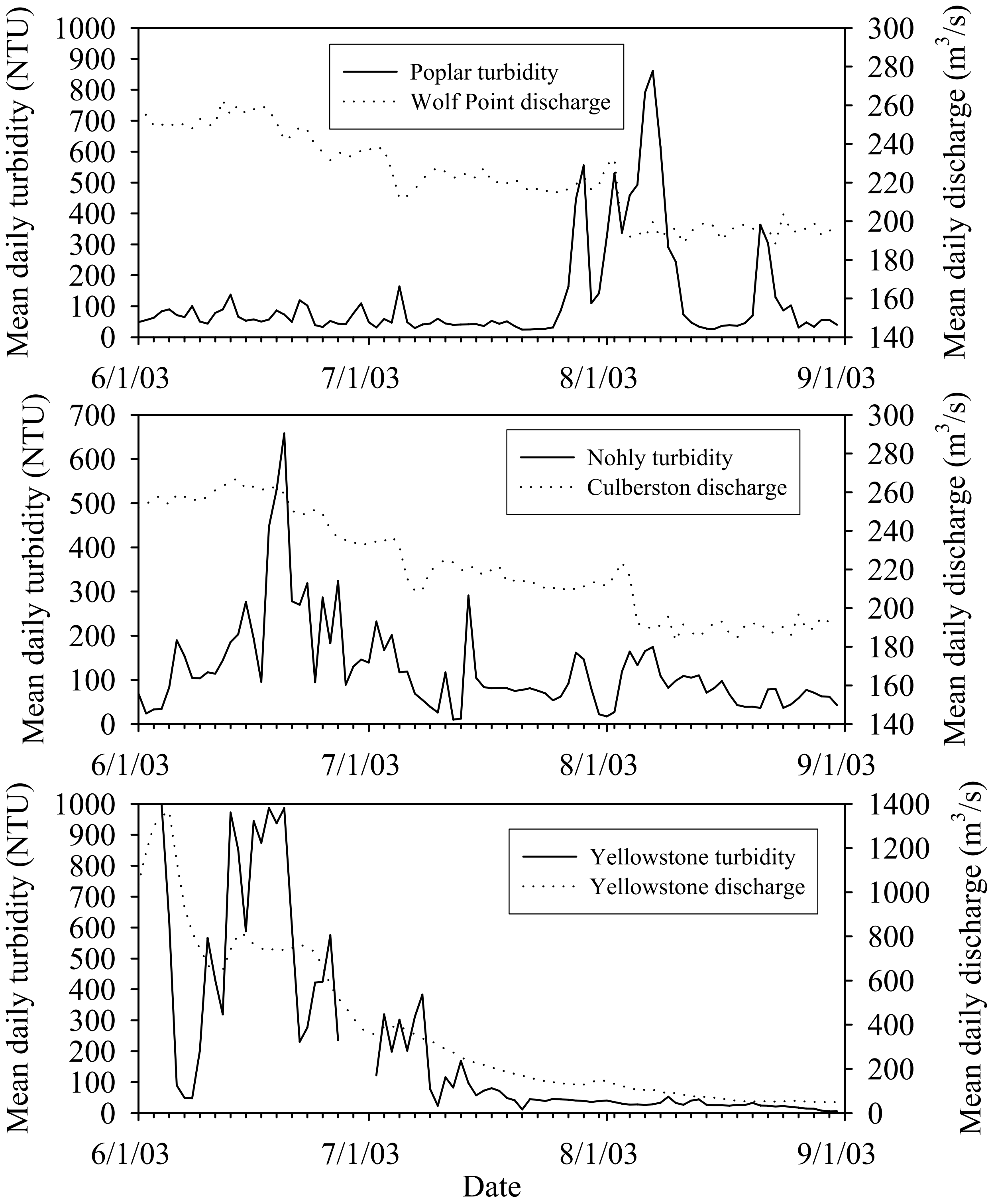


Figure 8. Mean daily turbidity (NTU; solid line) from turbidity loggers and discharge (m^3/s; dotted line) in the Missouri River near Poplar (upper panel), Nohly (middle panel), and in the Yellowstone River (lower panel) during 2003.

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

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

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

Monitoring Component 2 – Movements by pallid sturgeon

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

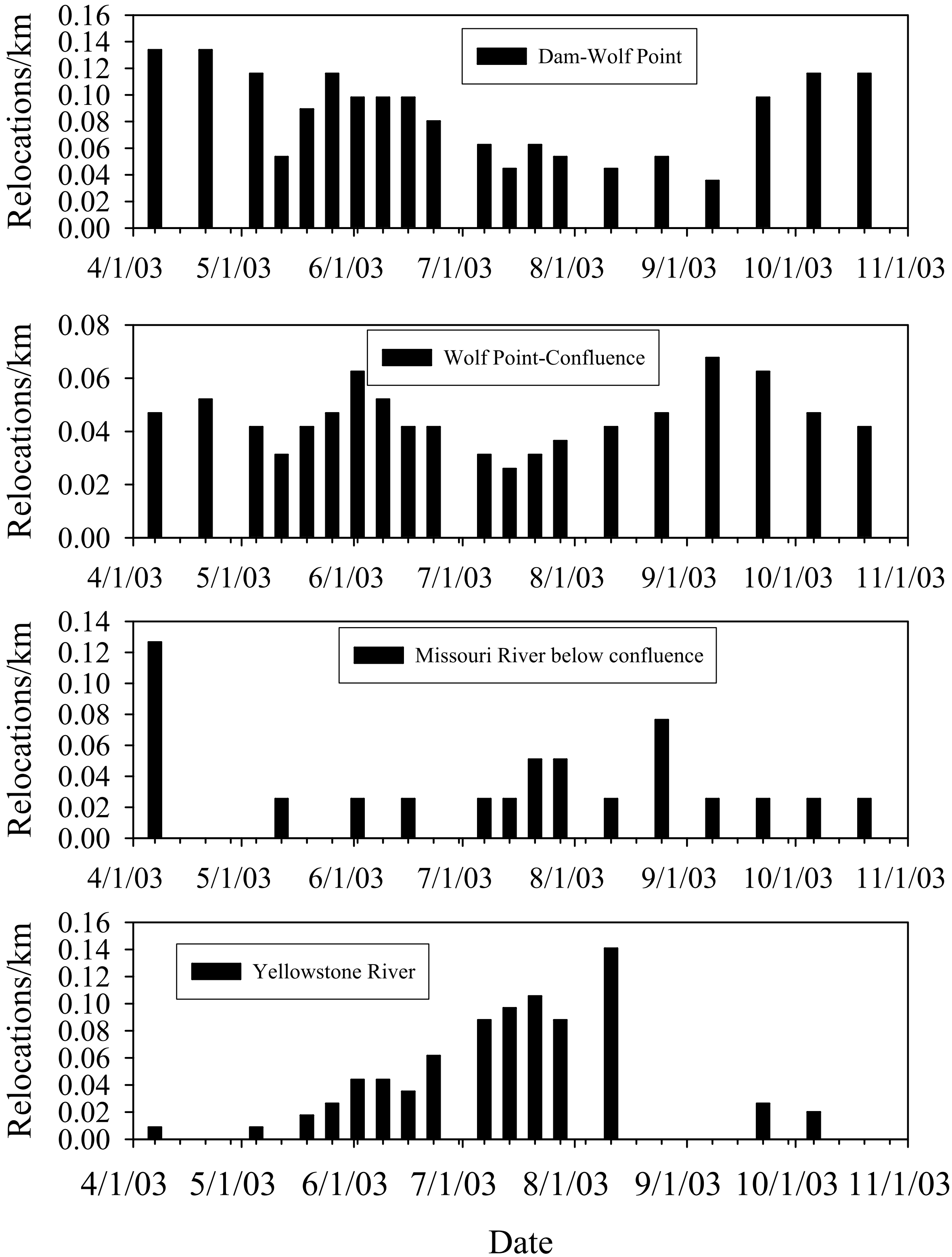


Figure 9. Number of blue sucker relocations per km in reaches of the Missouri River and Yellowstone River during 2003.

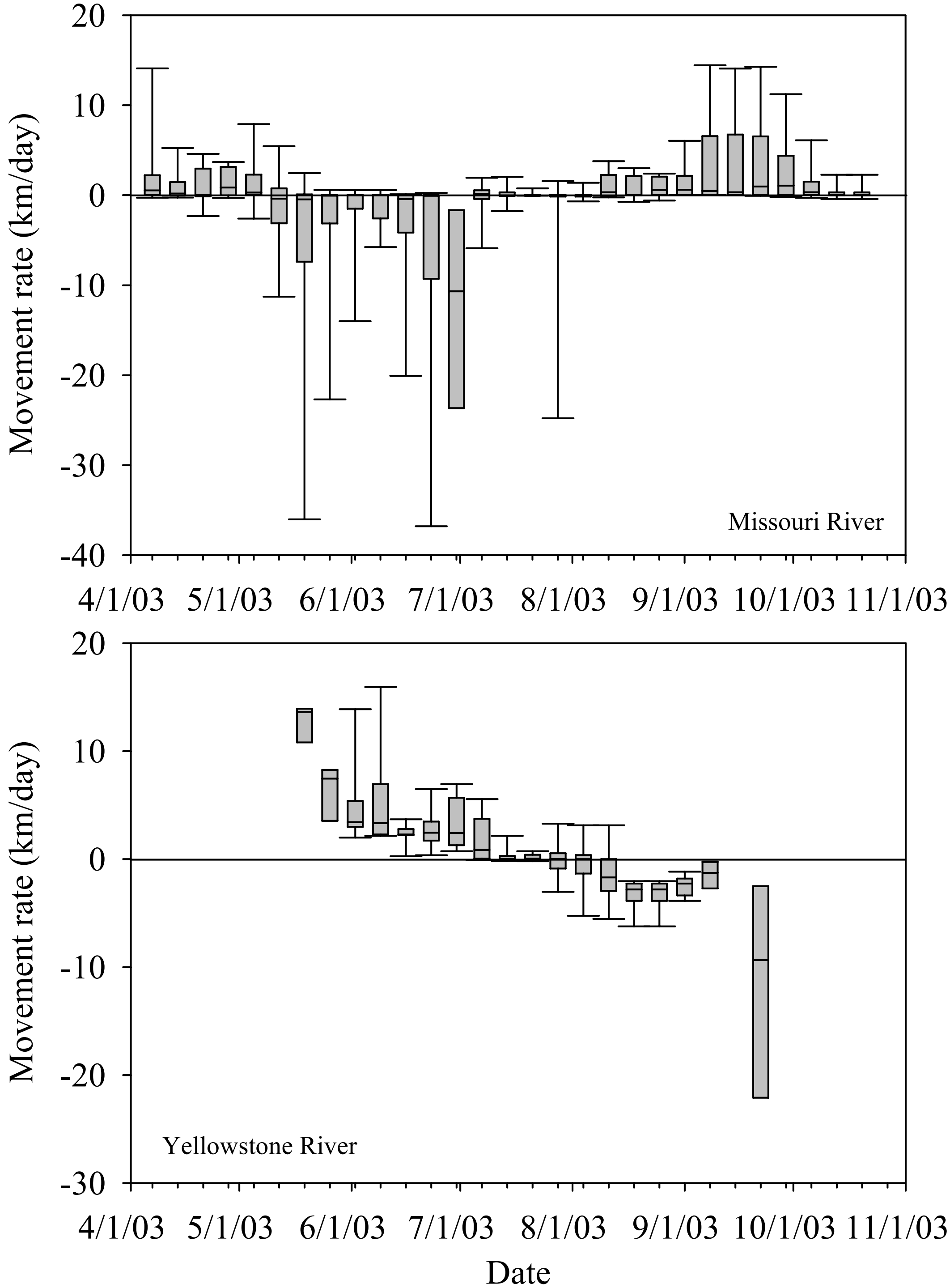


Figure 10. Box and whisker plots of net movement rates (km/day) of blue suckers in the Missouri River and Yellowstone River during 2003. Median movement rate is denoted as a line within the box. The box delimits 25th and 75th percentiles of the data, and whiskers delimit the 5th and 95th percentiles.

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

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

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

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

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

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

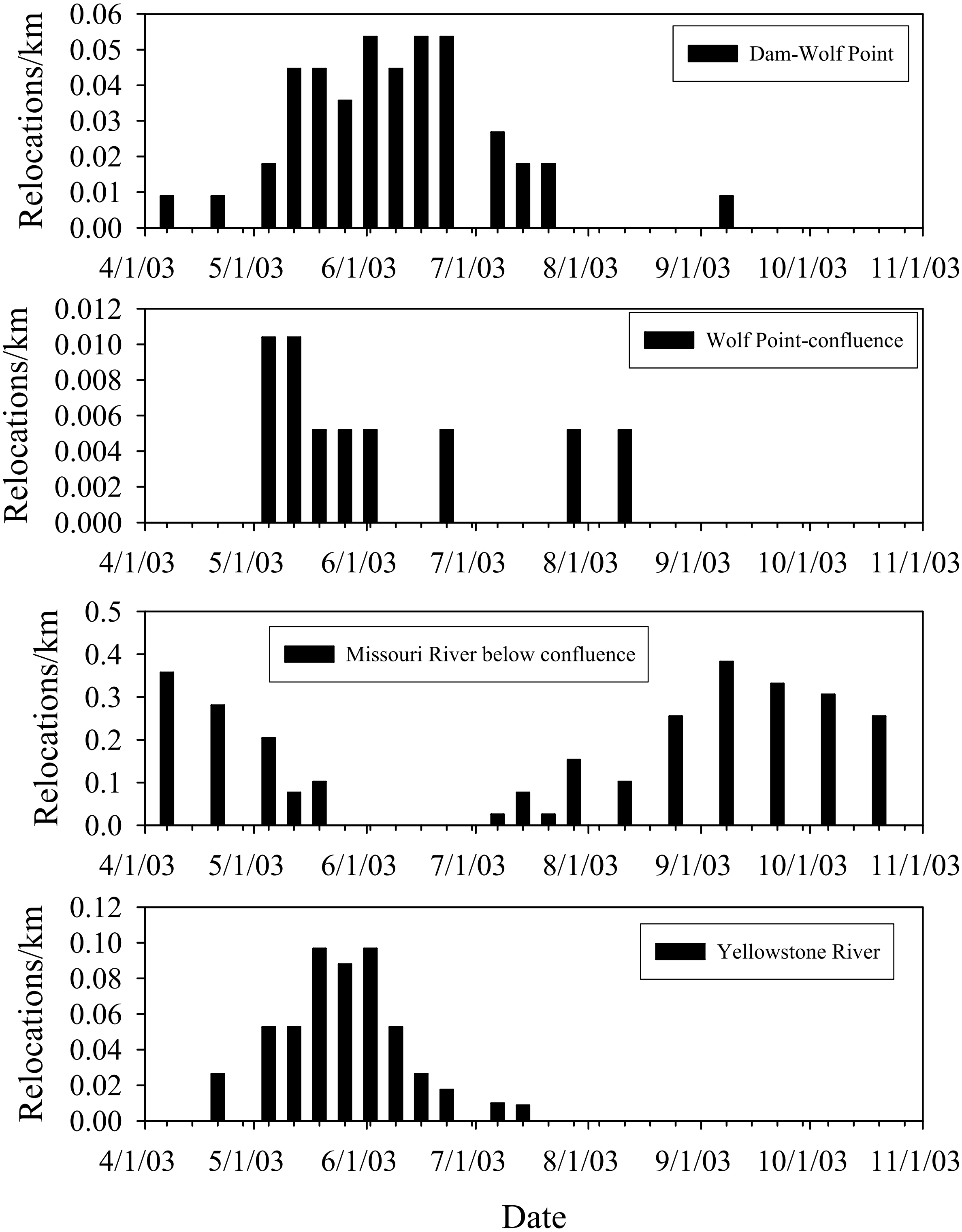


Figure 11. Number of paddlefish relocations per km in reaches of the Missouri River and Yellowstone River during 2003.

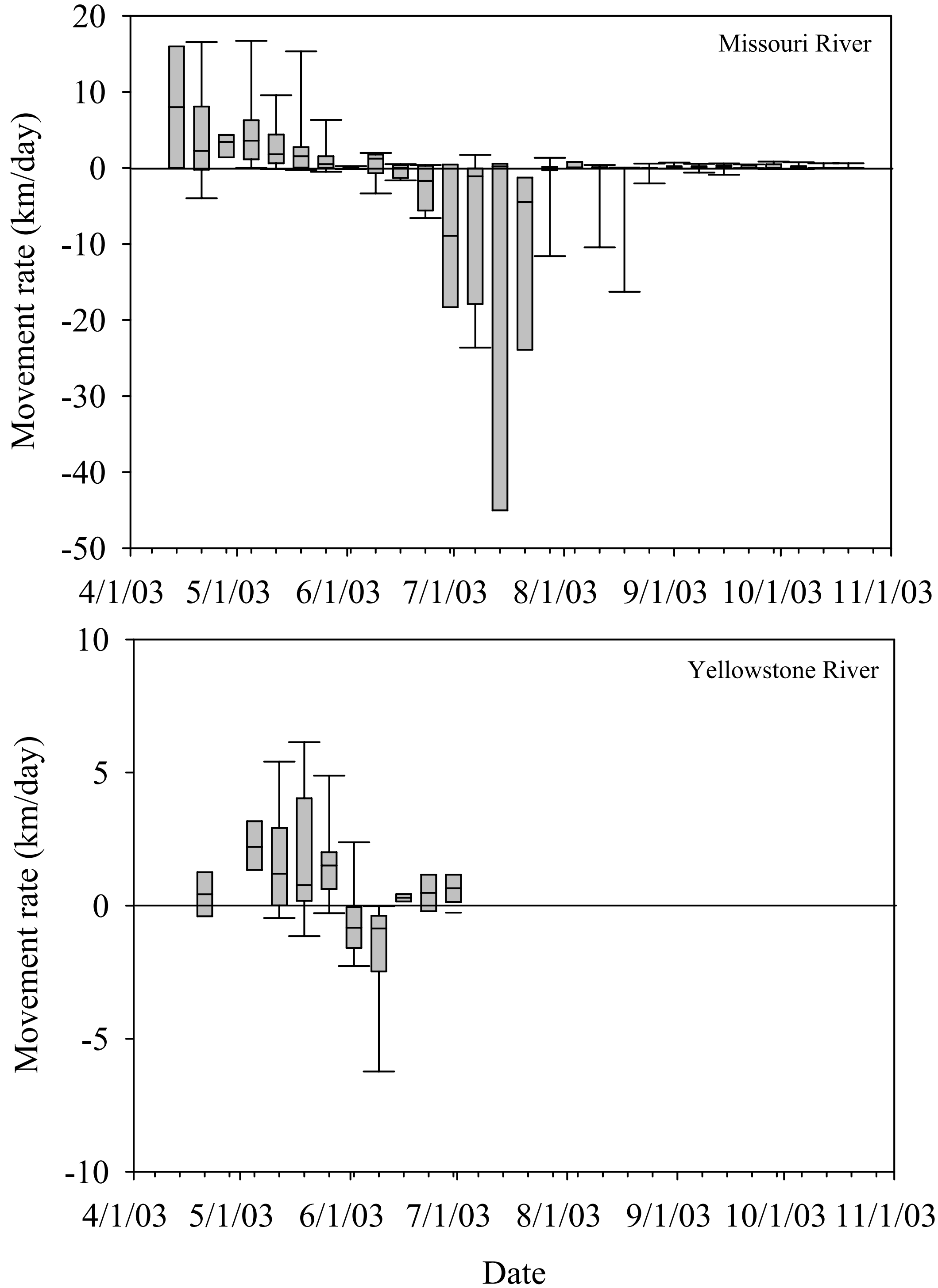


Figure 12. Box and whisker plots of net movement rates (km/day) of paddlefish in the Missouri River and Yellowstone River during 2003. Median movement rate is denoted as a line within the box. The box delimits 25th and 75th percentiles of the data, and whiskers delimit the 5th and 95th percentiles.

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

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

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

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

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

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

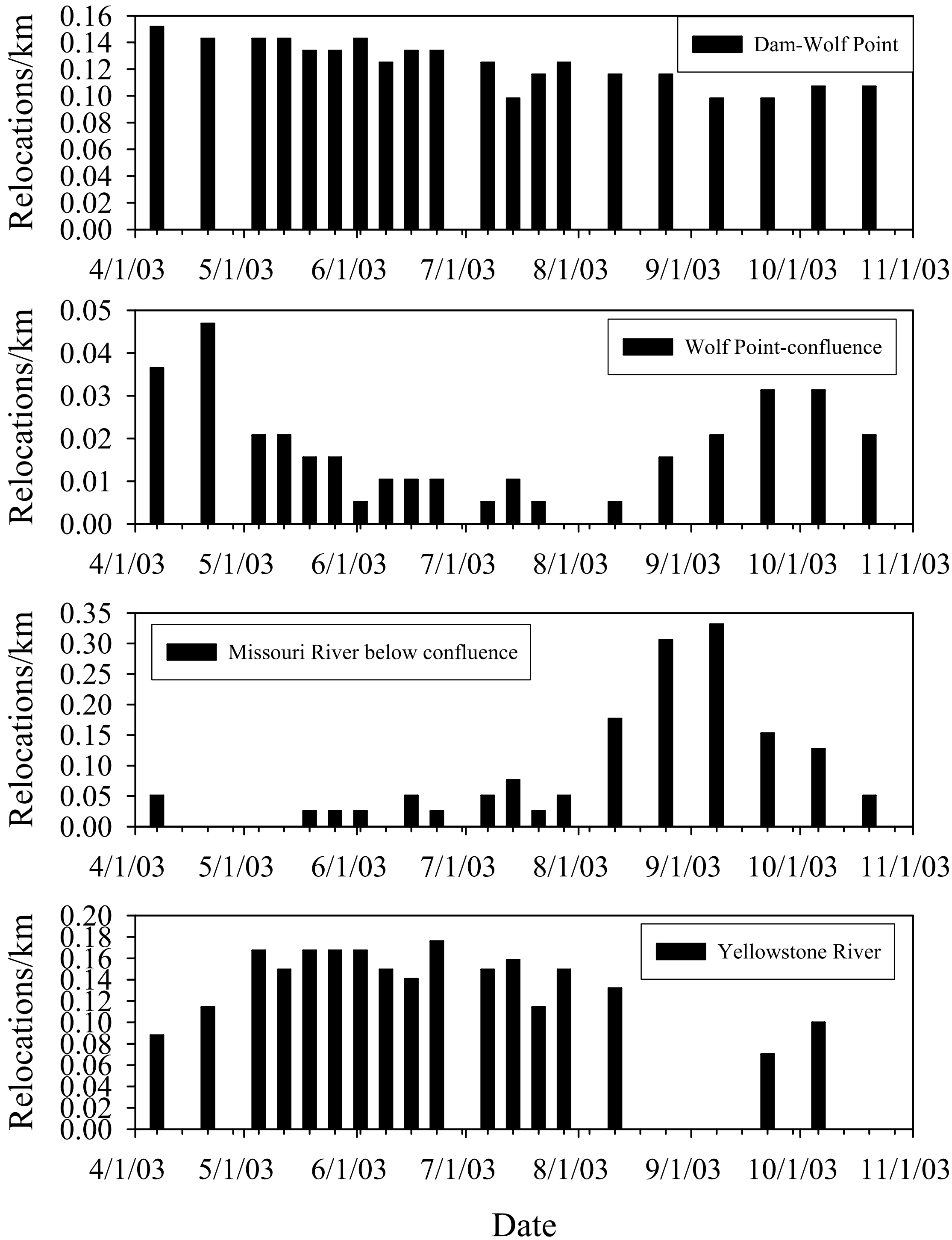


Figure 13. Number of shovelnose sturgeon relocations per km in reaches of the Missouri River and Yellowstone River during 2003.

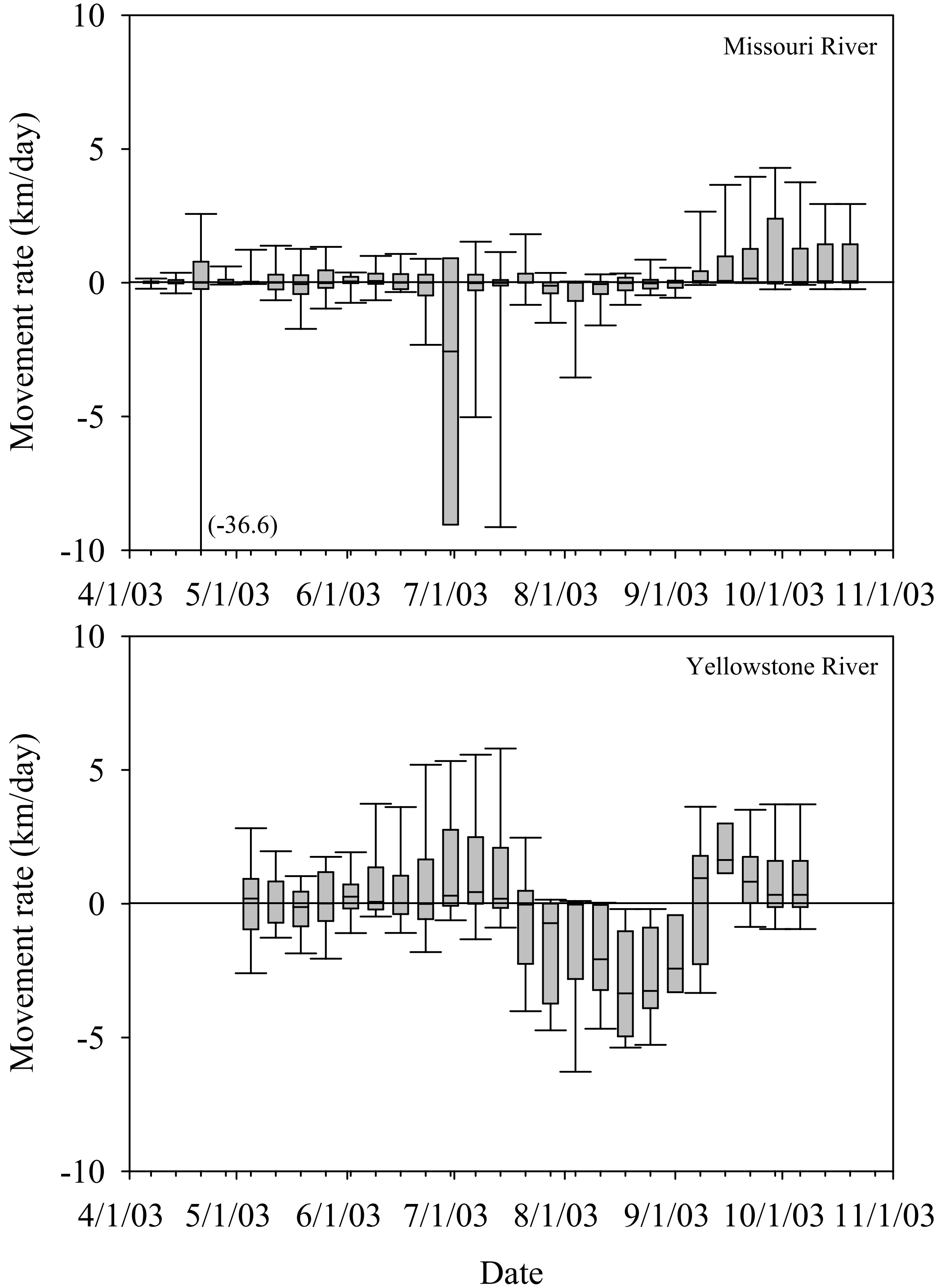


Figure 14. Box and whisker plots of net movement rates (km/day) of shovelnose sturgeon in the Missouri River and Yellowstone River during 2003. Median movement rate is denoted as a line within the box. The box delimits 25th and 75th percentiles of the data, and whiskers delimit the 5th and 95th percentiles.

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

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

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

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

Monitoring Component 4 – Larval Fish

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

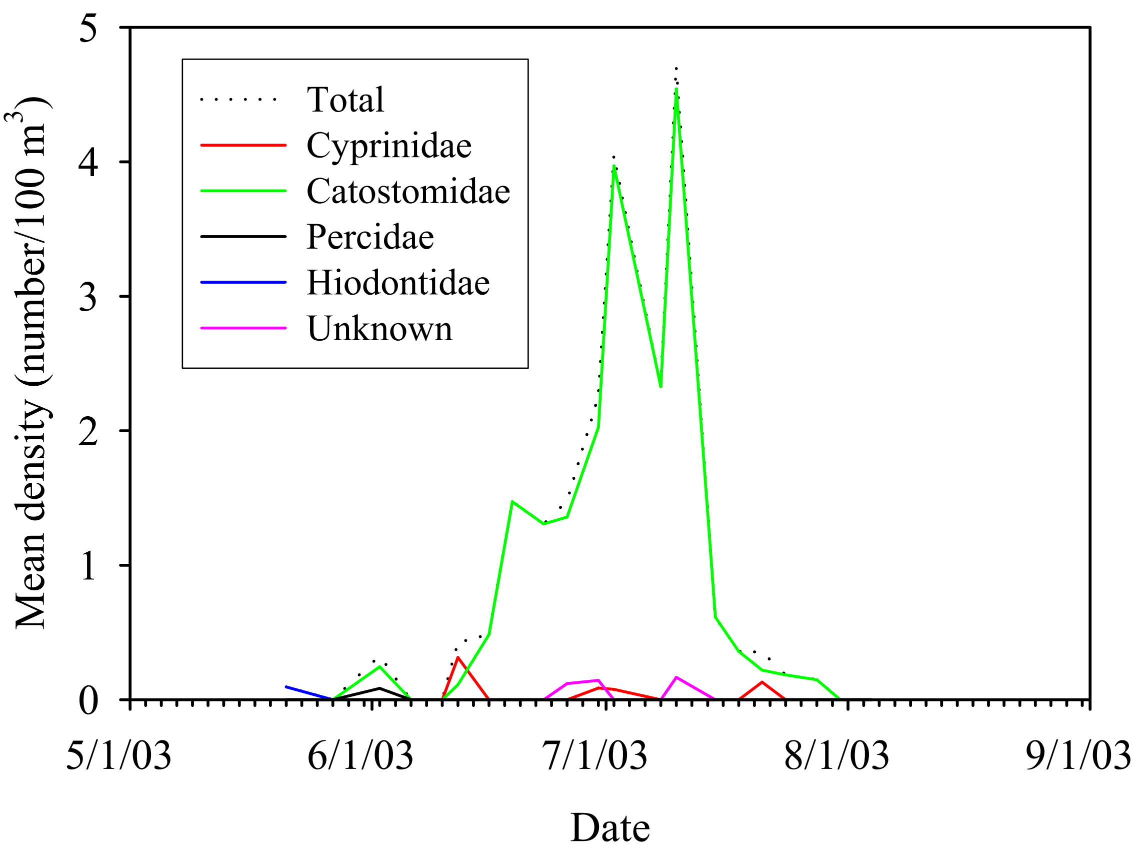


Figure 15. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Percidae, Hiodontidae, and unknown sampled in the Missouri River at the site downstream from Fort Peck Dam during 2003.

The larval fish community in the spillway channel exhibited four periods of elevated densities that were primarily attributed to Catostomidae abundance and to a lesser extent the abundance of Cyprinidae and Percidae (Figure 16). High densities in the spillway channel occurred on June 16 (mean = 8.56 larvae/100 m^3), June 19 (mean = 7.88 larvae/100 m^3) and July 8 (mean = 7.68 larvae/100 m^3) when Catostomidae composed 100% of the larvae sampled. Elevated densities also occurred on June 26 (mean density = 7.23 larvae/100 m^3) when Catostomidae composed 64% of the larvae, but Cyprinidae and Percidae also exhibited elevated densities. About 80% of the Cyprinidae sampled on June 26 was comprised of common carp larvae.

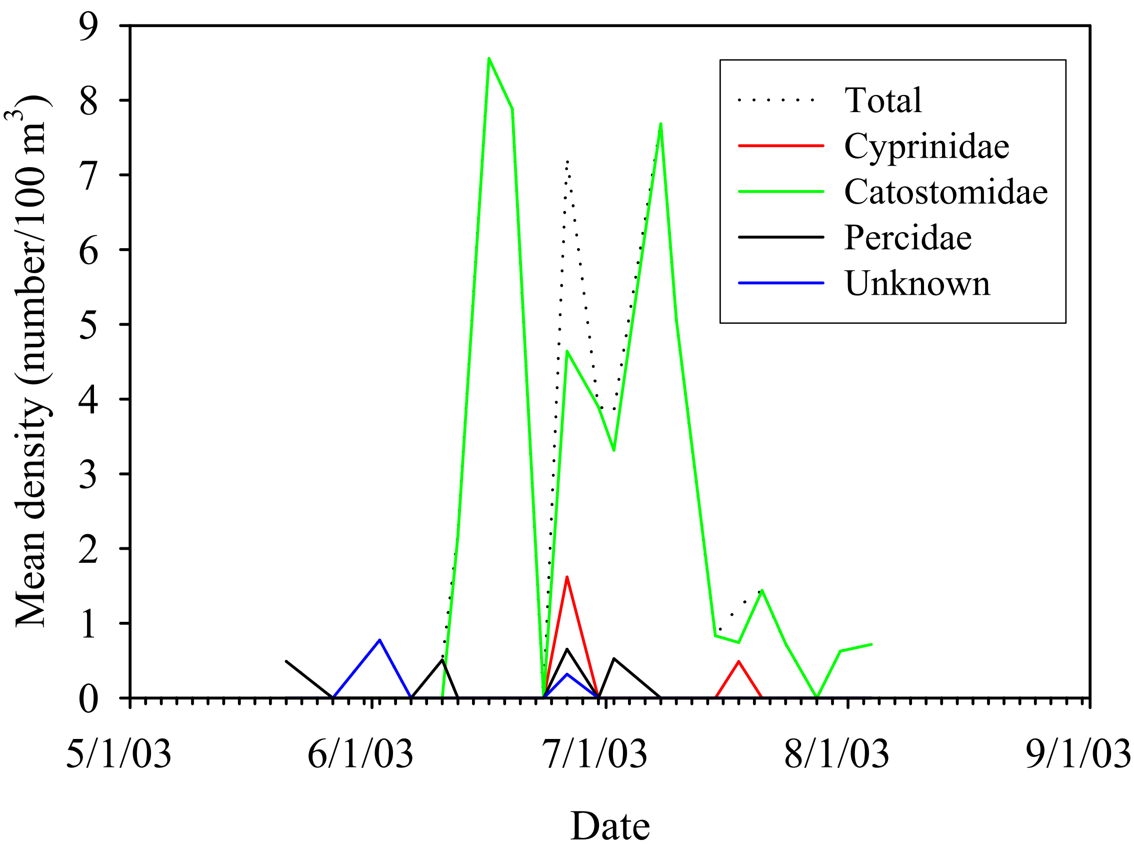


Figure 16. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Percidae, and unknown sampled in the Fort Peck spillway channel during 2003.

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

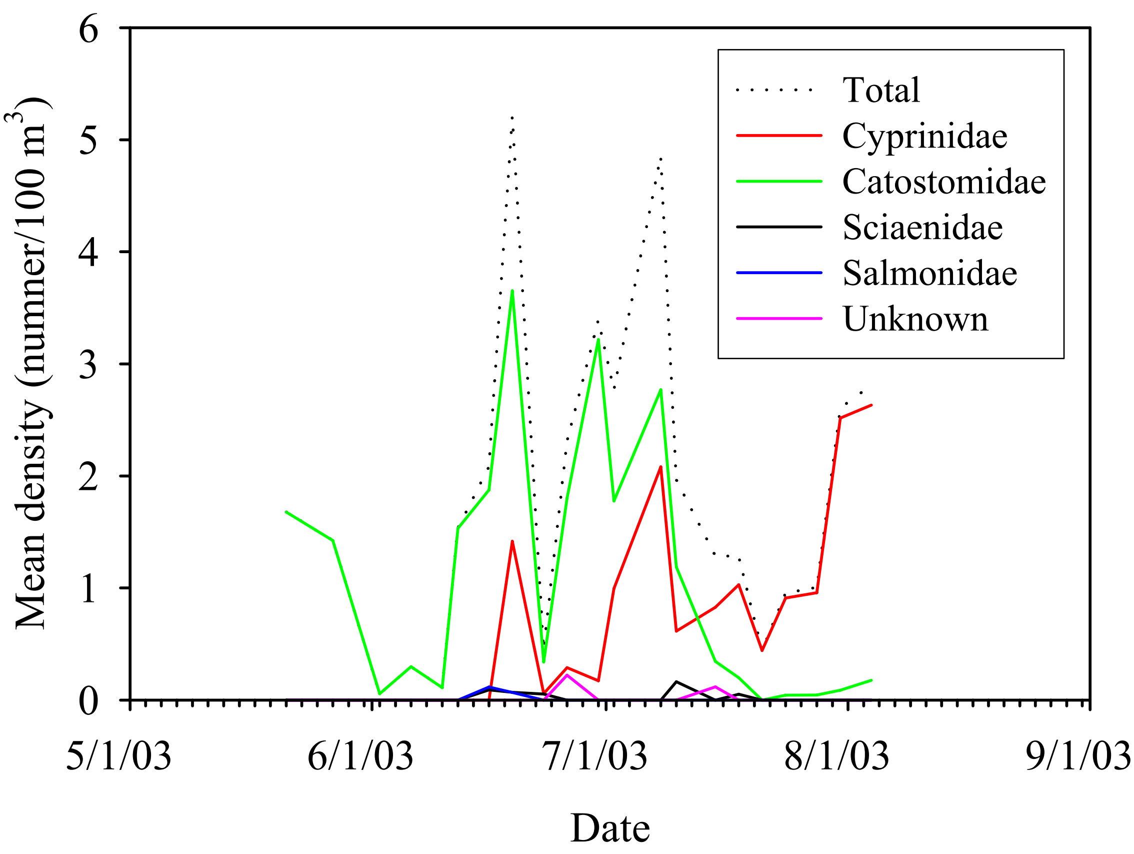


Figure 17. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Sciaenidae, Salmonidae, and unknown sampled in the Milk River during 2003.

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

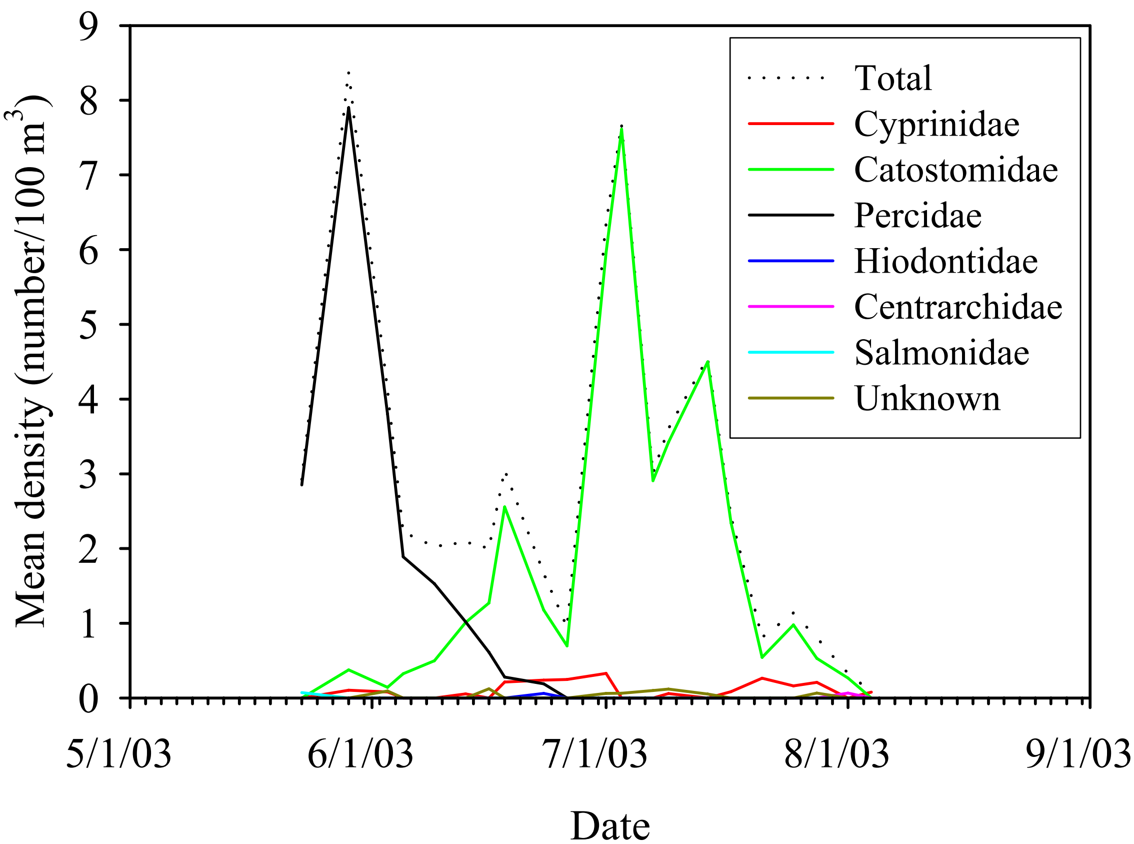


Figure 18. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Hiodontidae, Percidae, Centrarchidae, Salmonidae and unknown sampled in the Missouri River at Wolf Point during 2003.

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

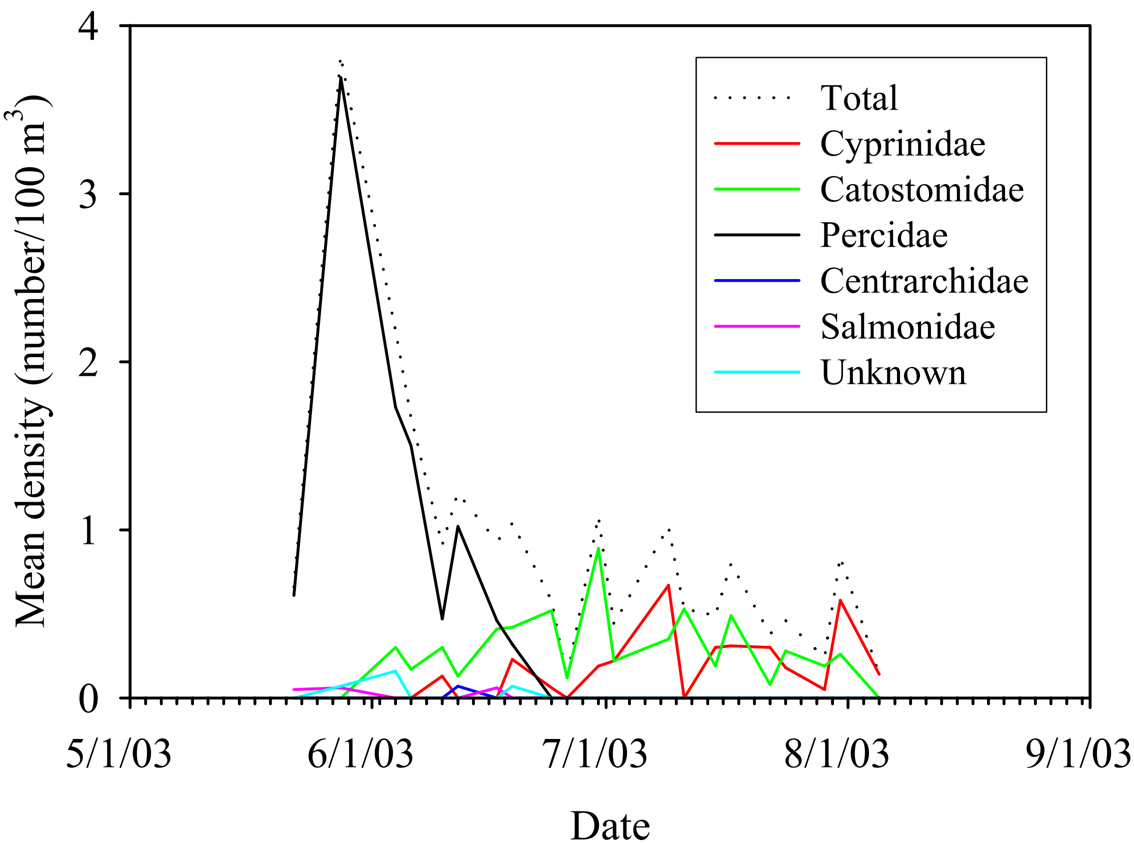


Figure 19. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Percidae, Salmonidae, Centrarchidae, and unknown sampled in the Missouri River near Nohly during 2003.

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

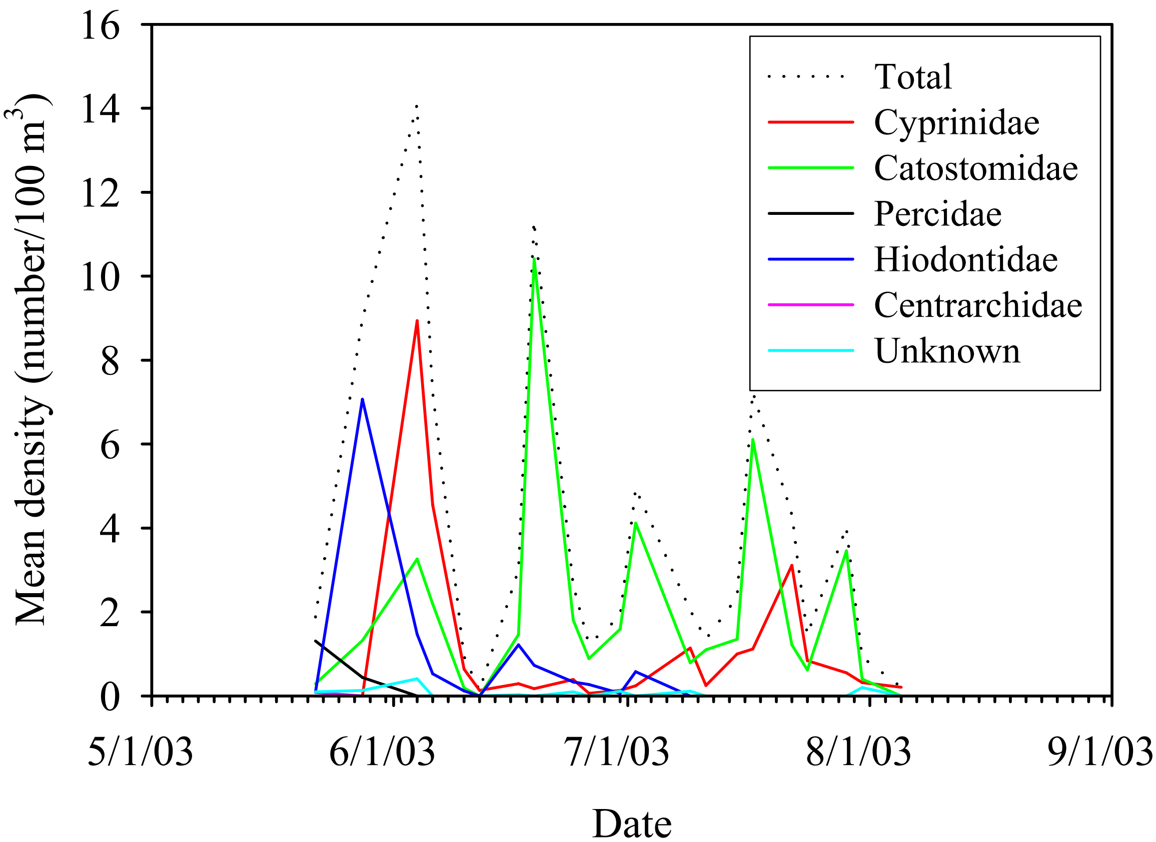


Figure 20. Mean density (number/100 m^3) by date of all larval fishes (Total), Catostomidae, Cyprinidae, Hiodontidae, Percidae, Centrarchidae, and unknown sampled in the Yellowstone River during 2003.

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

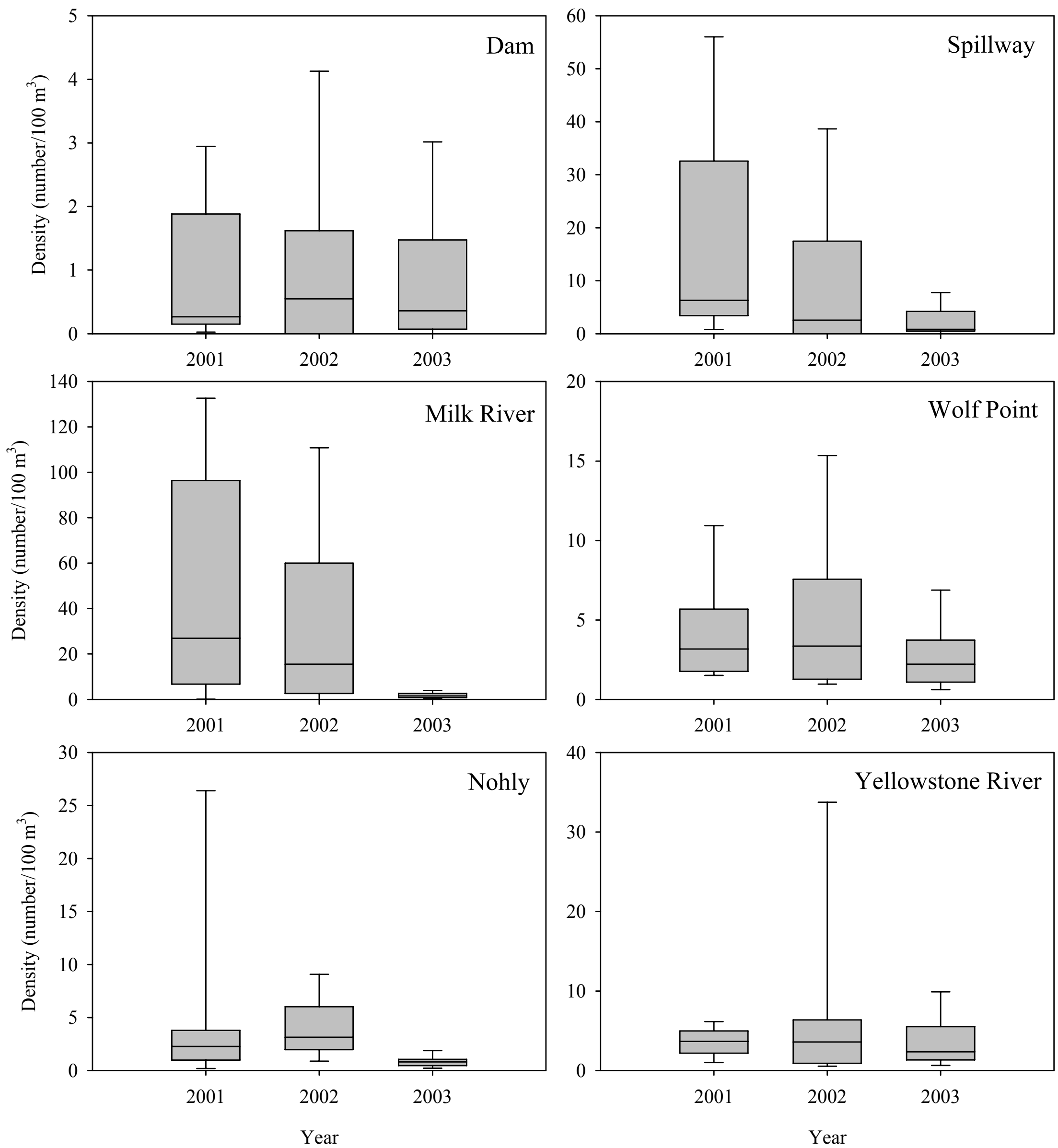


Figure 21. Box and whisker plots of total density (all taxa; number/100 m^3) of larval fishes sampled at six sites in 2001, 2002, and 2003. Boxes delimit the 25th and 75th percentiles of the data, lines within the boxes denote median density, and whiskers delimit the 5th and 95th percentiles.

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

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

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

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

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

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

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

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

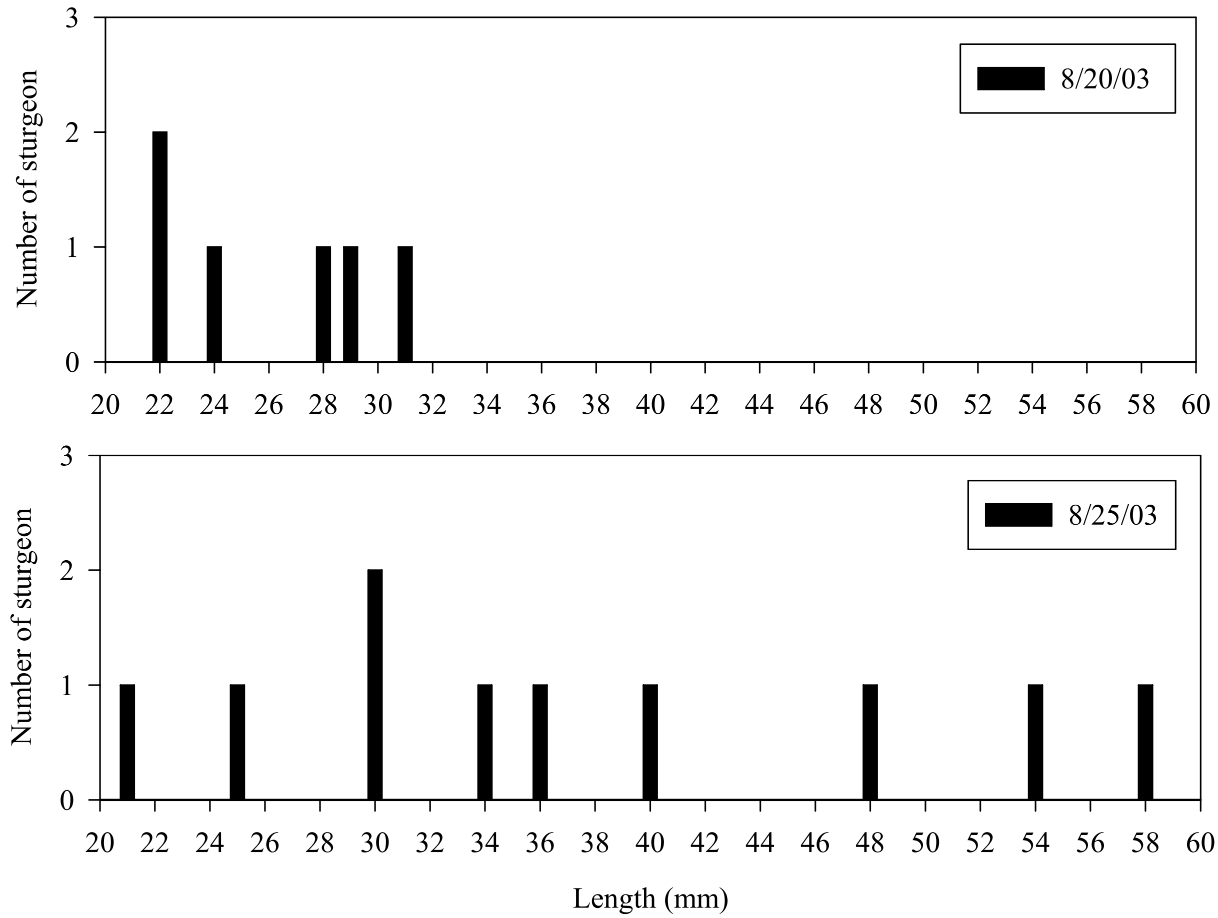


Figure 22. Length distributions of young-of-year sturgeon sampled during 2003 in the Missouri River above the confluence (ATC) of the Yellowstone River.

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

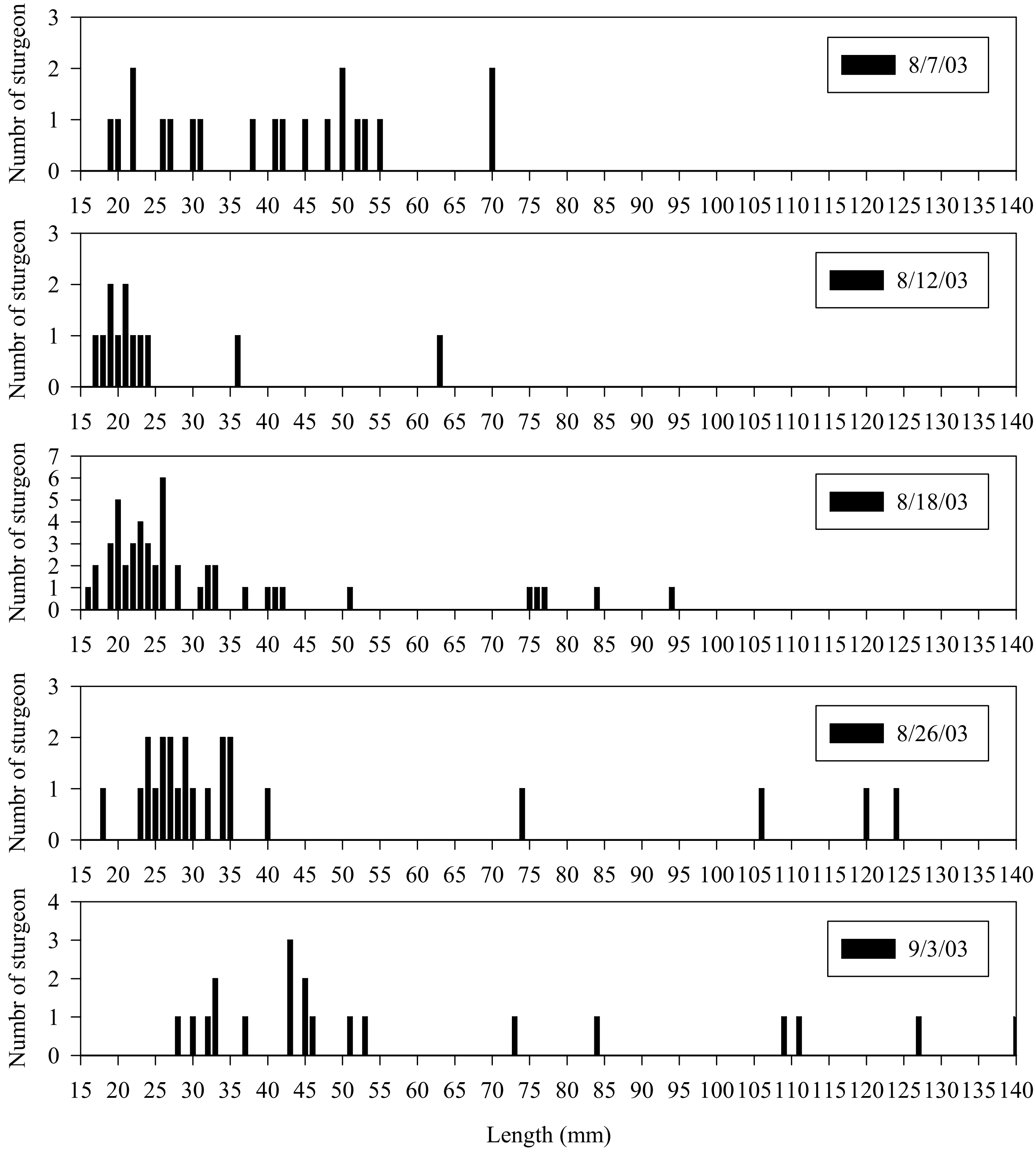


Figure 23. Length distributions of young-of-year sturgeon sampled during 2003 in the Missouri River below the confluence (BTC) of the Yellowstone River.

Related Activities

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

Activities for 2004

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

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Funding for this project was provided by the U. S. Army Corps of Engineers (Omaha District, William D. Miller and Kevin D. Mayberry, Project Managers). A special thanks is extended to Mark Drobish (USACE), William Miller (USACE), Tracey McKay (USACE), Bob Snyder (MTFWP), Ken McDonald (MTFWP), and Barb Golz (MTFWP) for administrative assistance necessary for securing the new 5-year contract. Personnel from the MTFWP involved in this project are commended for their quality performance in the field and laboratory: Nathan McClenning, William Waller, Landon Holte, Ryan Lott, Nik Anderson, Darrel Gackle, and Eric Dobbs. Mark Drobish and Brendan Waarvick (USACE) also periodically assisted in the field. Thanks are extended to Bill Gardner (MTFWP) for collecting water temperature data in the Missouri River above Fort Peck Lake, and to Fred Ryckman (North Dakota Game and Fish Department) for providing Yellowstone River water temperatures and periodic logistic support. Collaboration with Kevin Kapuscinski (MTFWP), Matt Baxter (MTFWP), Wade King (USFWS), and Ryan Wilson (USFWS) also contributed to progress on the project.

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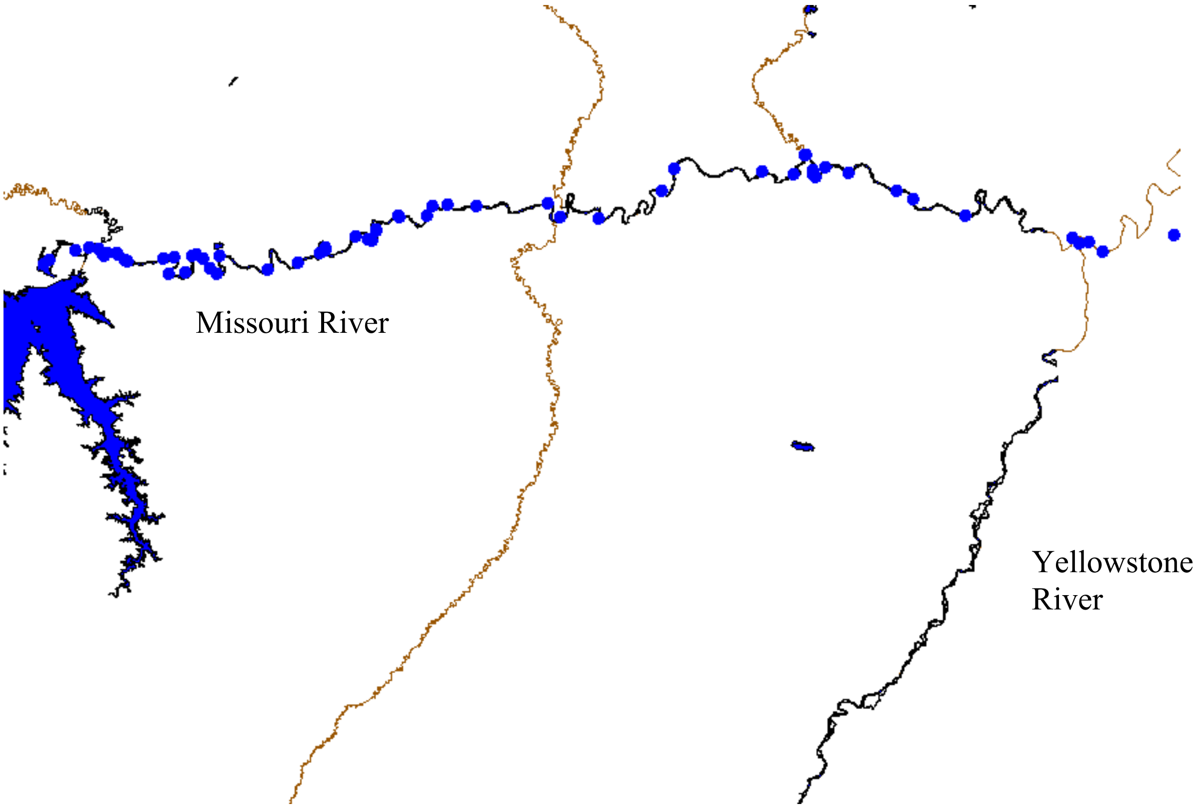
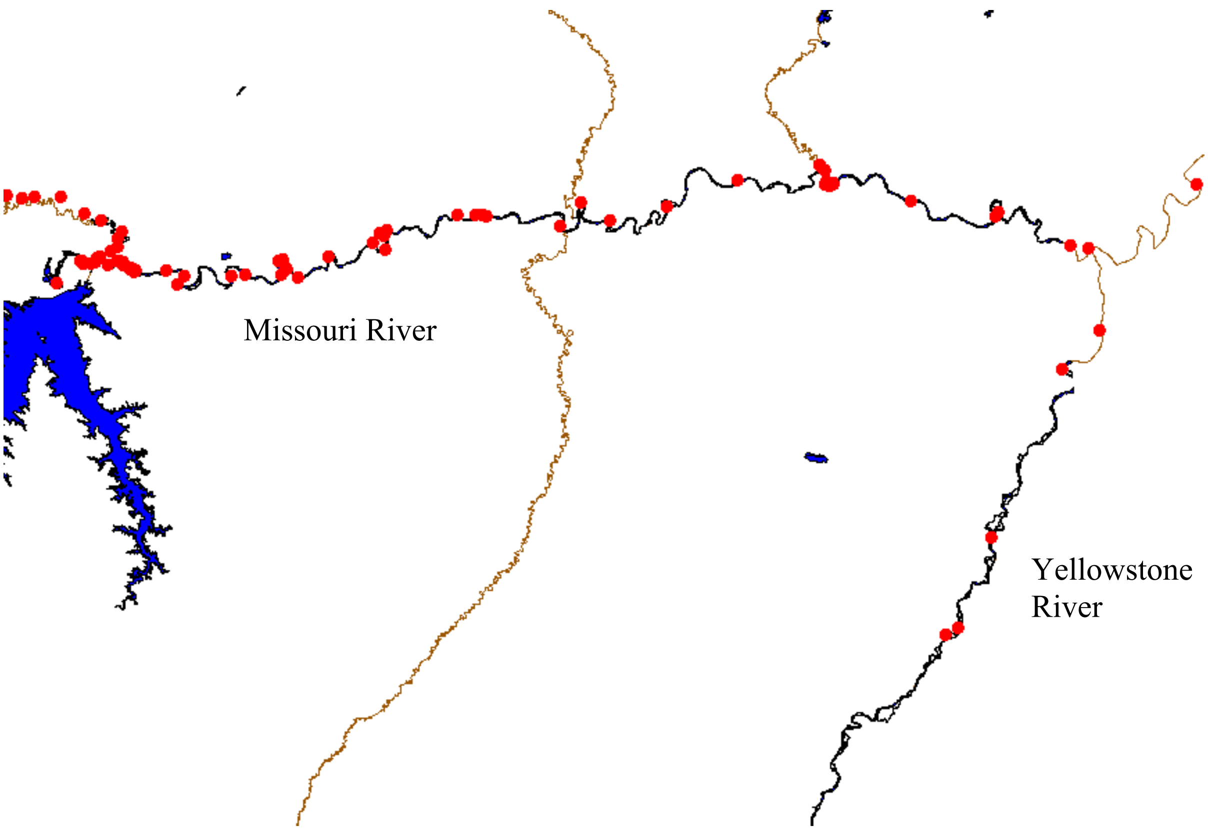
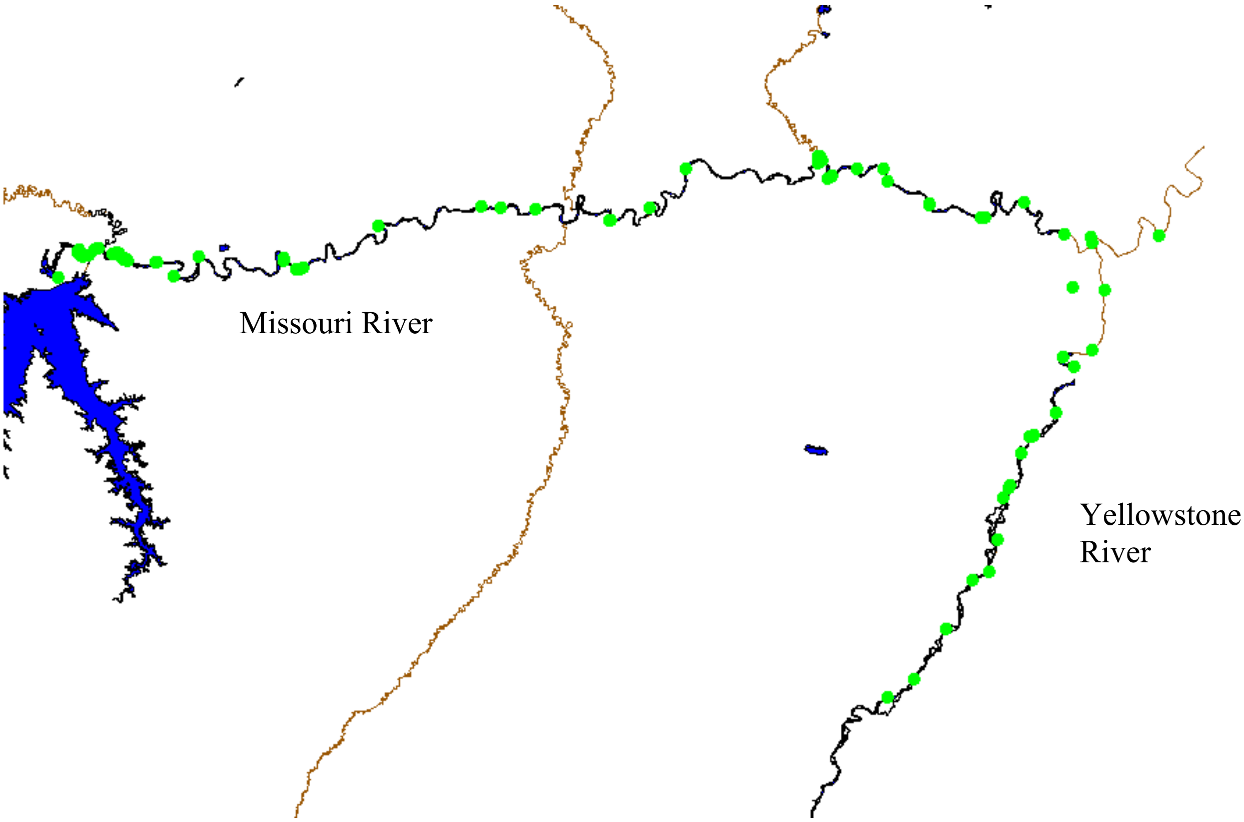
Appendix A. Map extent of blue sucker relocations during 2003.



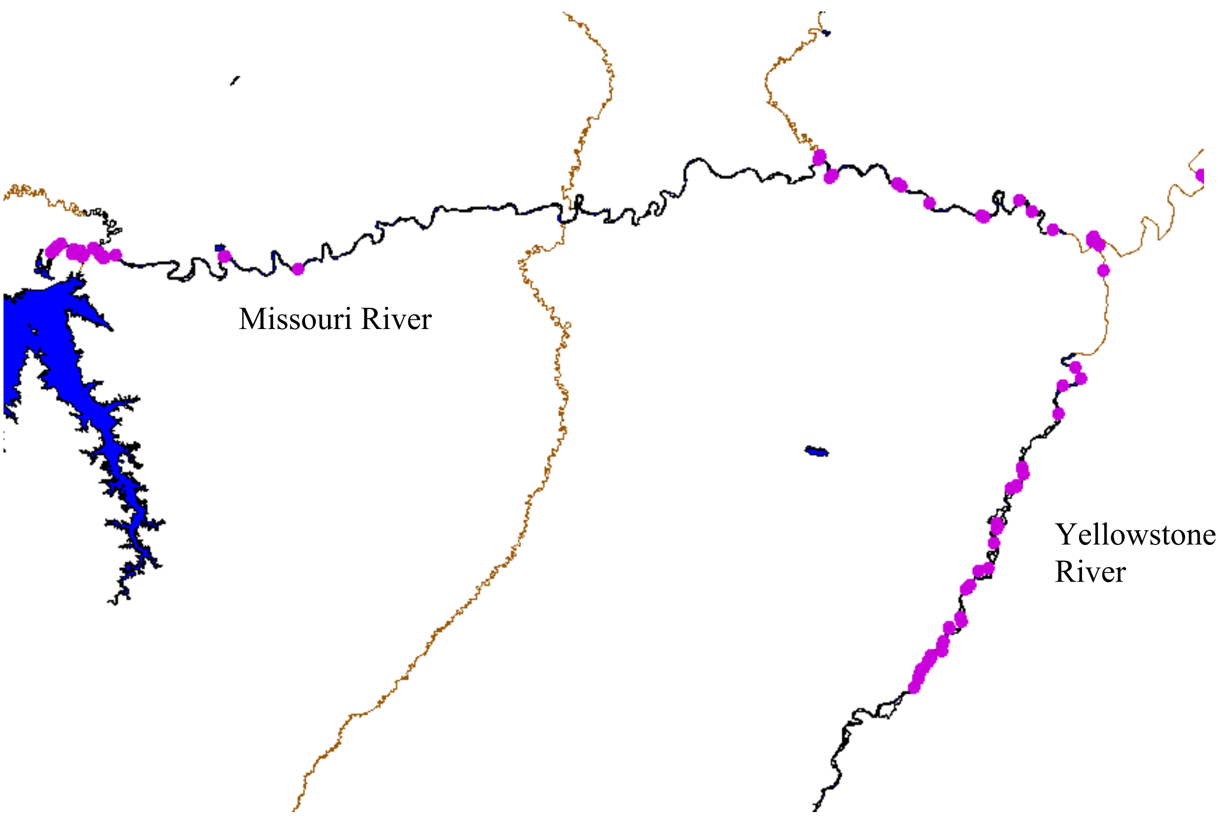
Appendix A.1. Blue sucker relocations in April 2003.



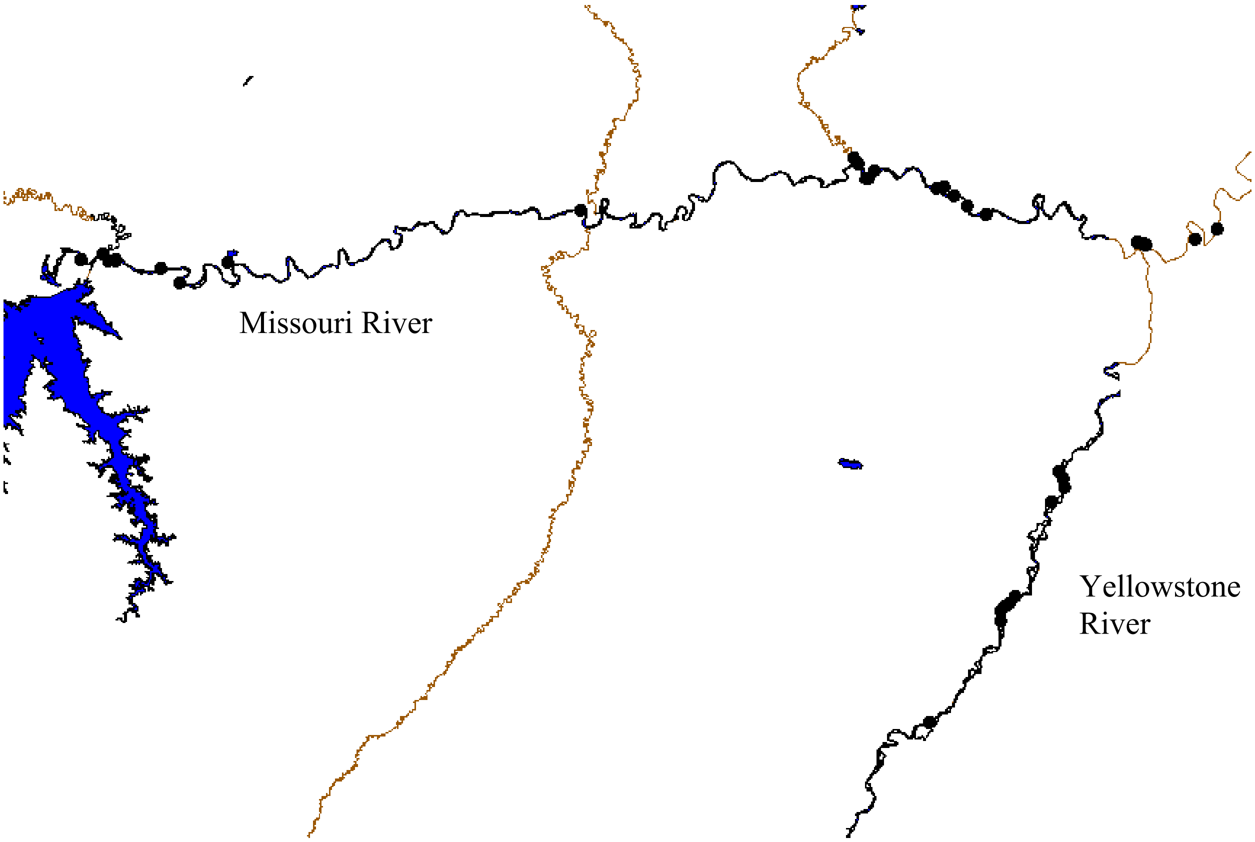
Appendix A.2. Blue sucker relocations in May 2003.



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

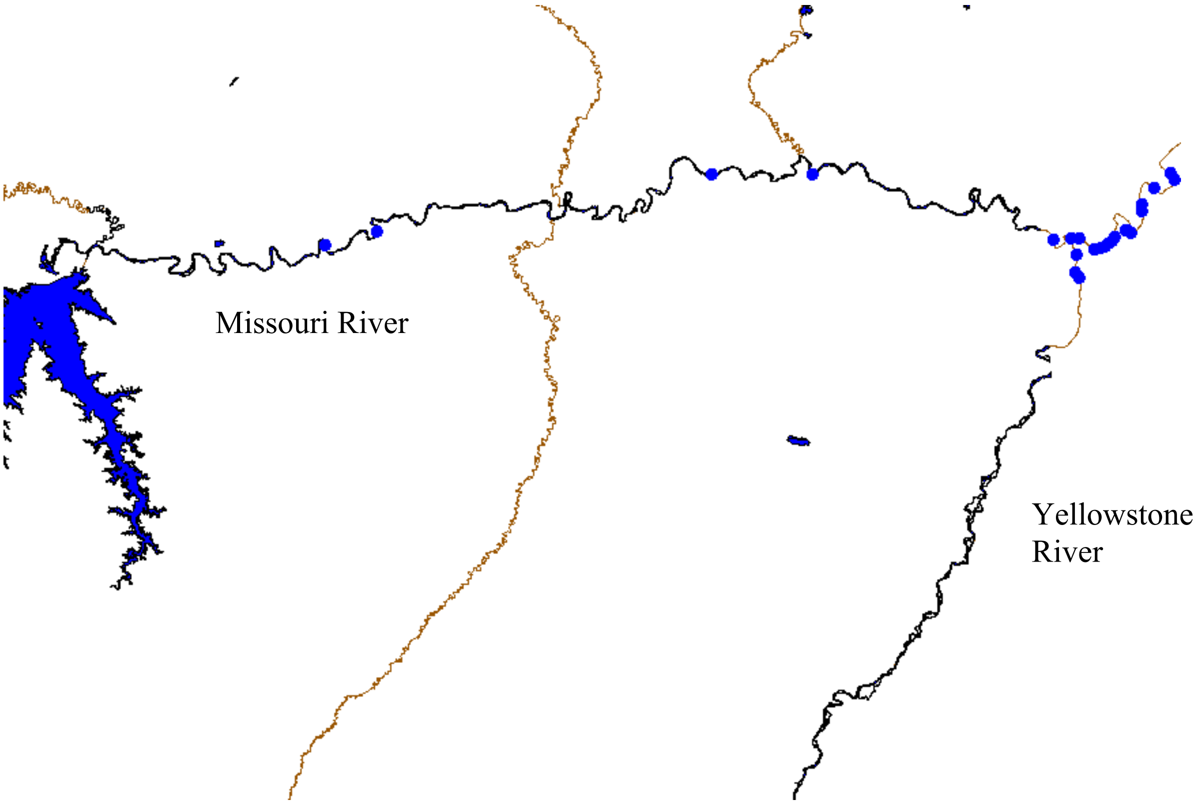


Appendix A.4. Blue sucker relocations in July 2003.

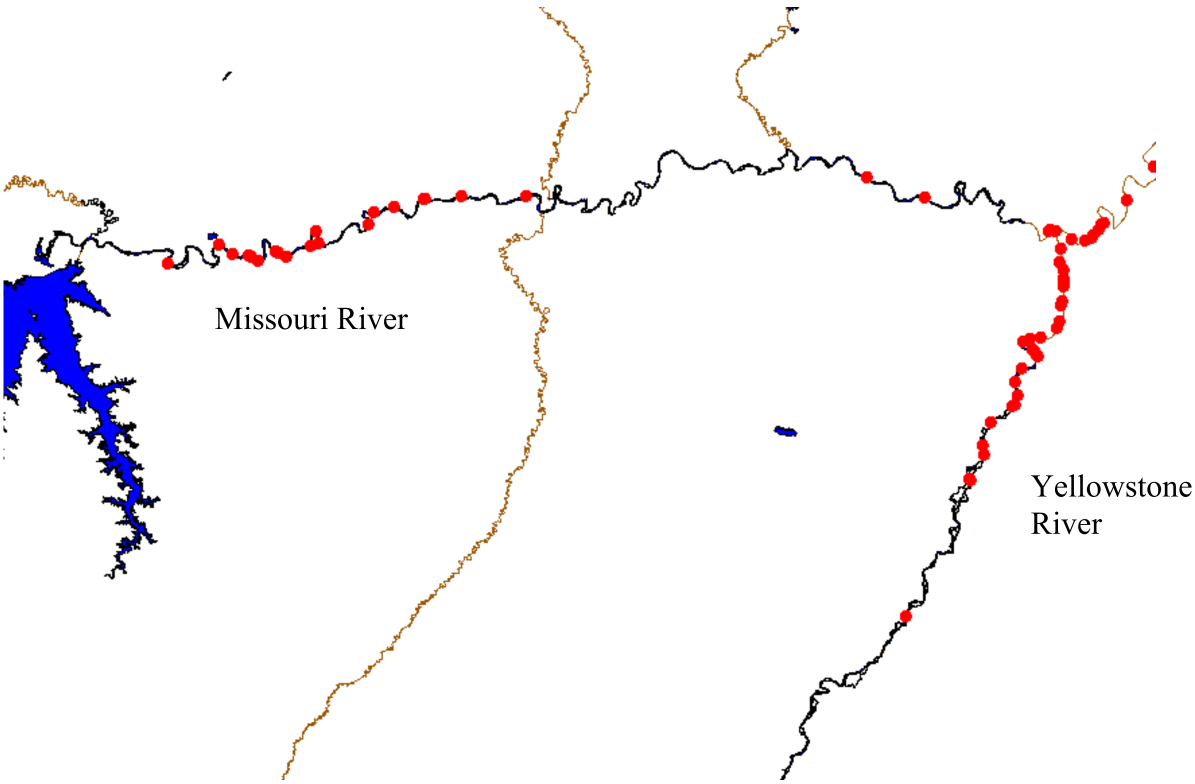


Appendix A.5. Blue sucker relocations in August 2003.

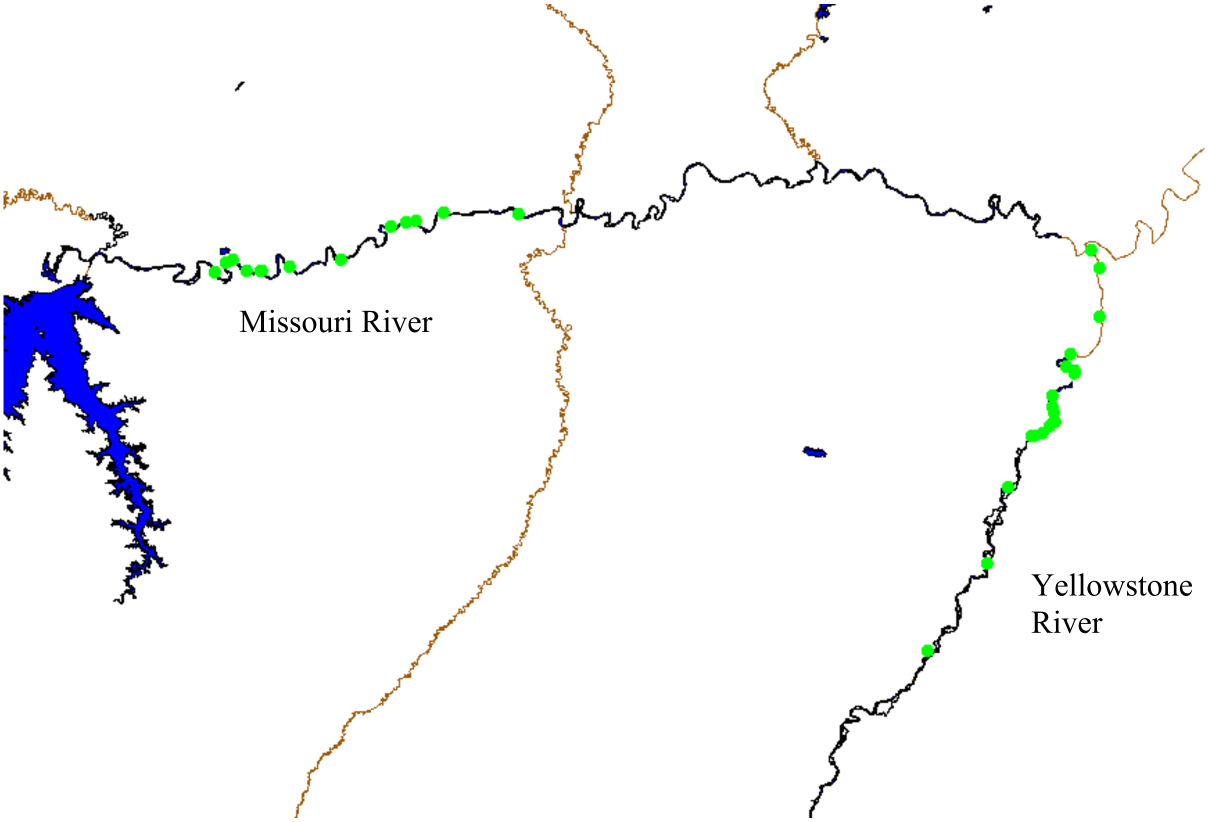
Appendix B. Map extent of paddlefish relocations during 2003.



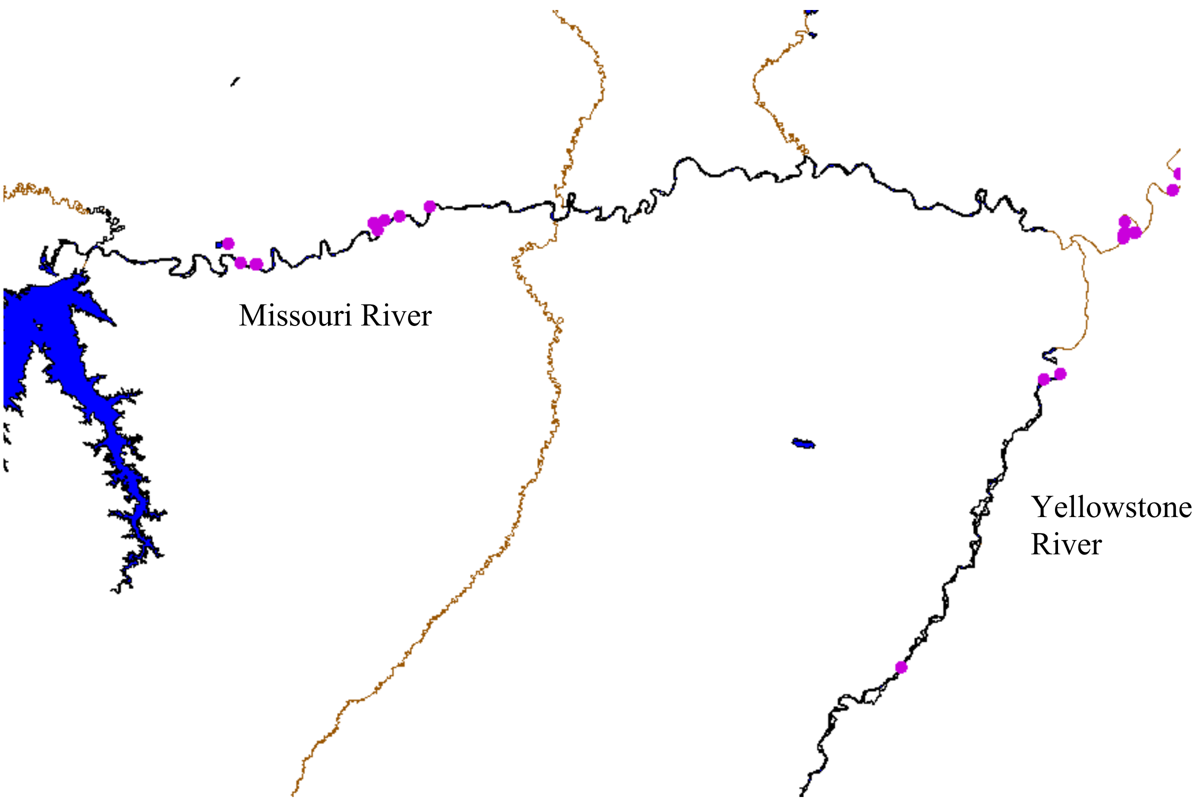
Appendix B.1. Paddlefish relocations in April 2003.



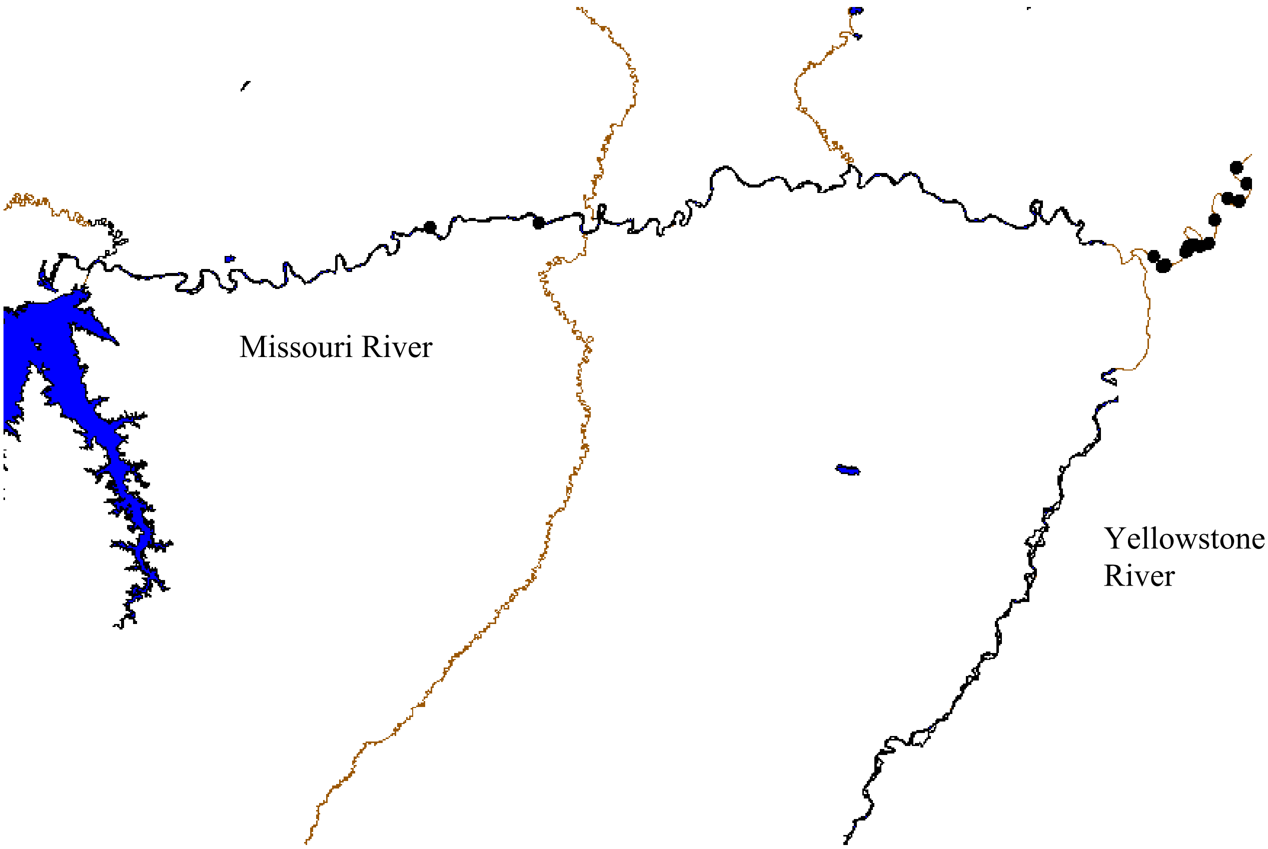
Appendix B.2. Paddlefish relocations in May 2003.



Appendix B.3. Padllefish relocations in June 2003.

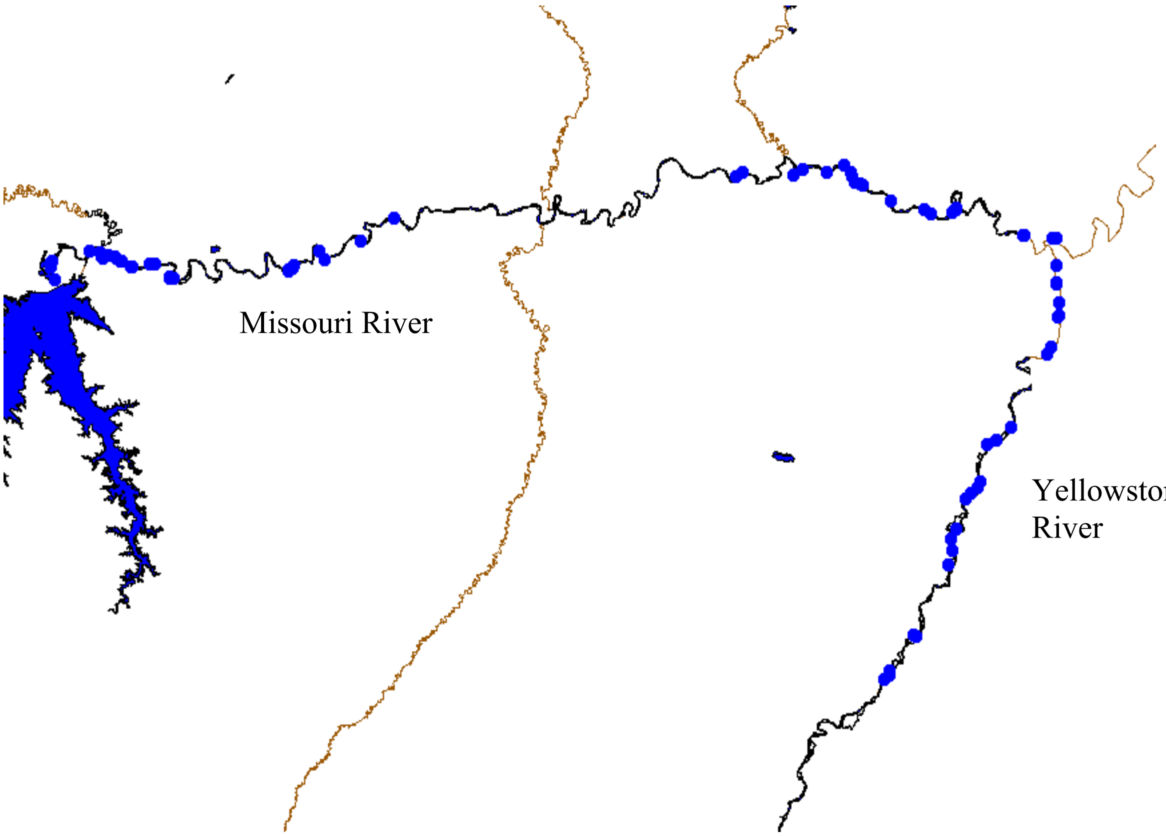


Appendix B.4. Paddlefish relocations in July 2003.

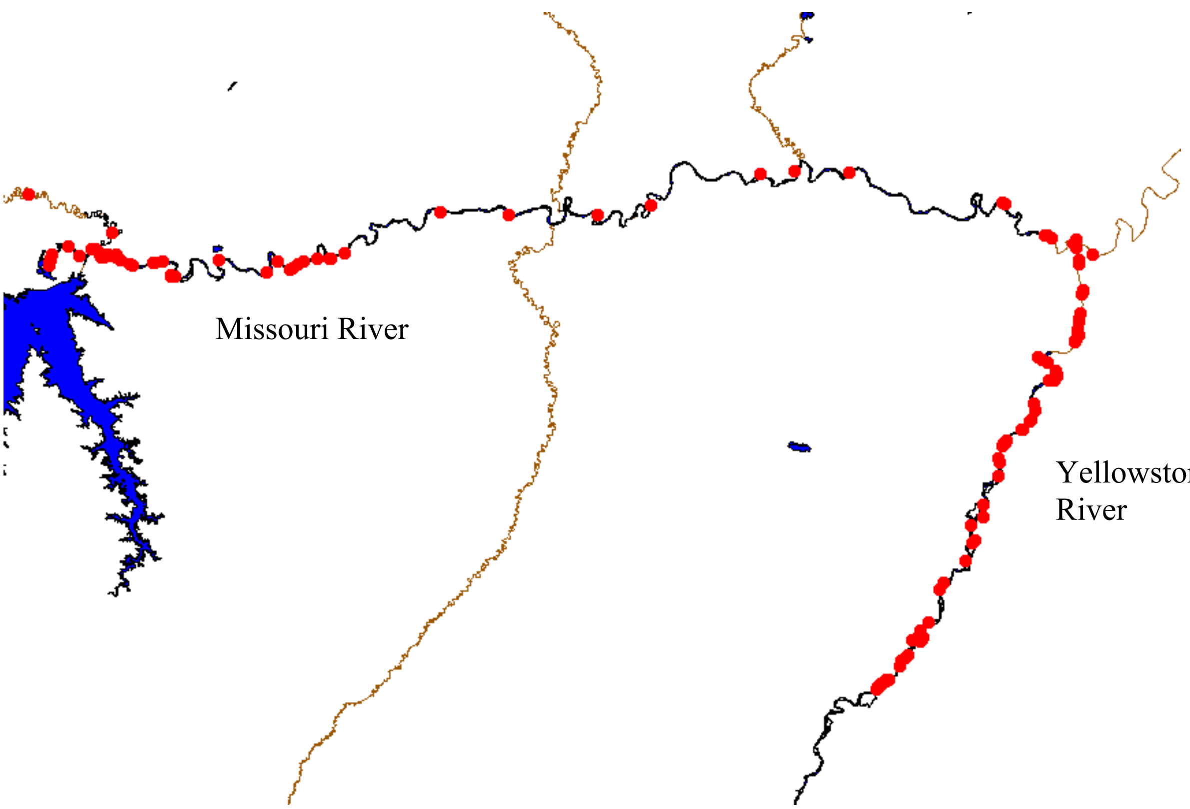


Appendix B.5. Paddlefish relocations during fall 2003.

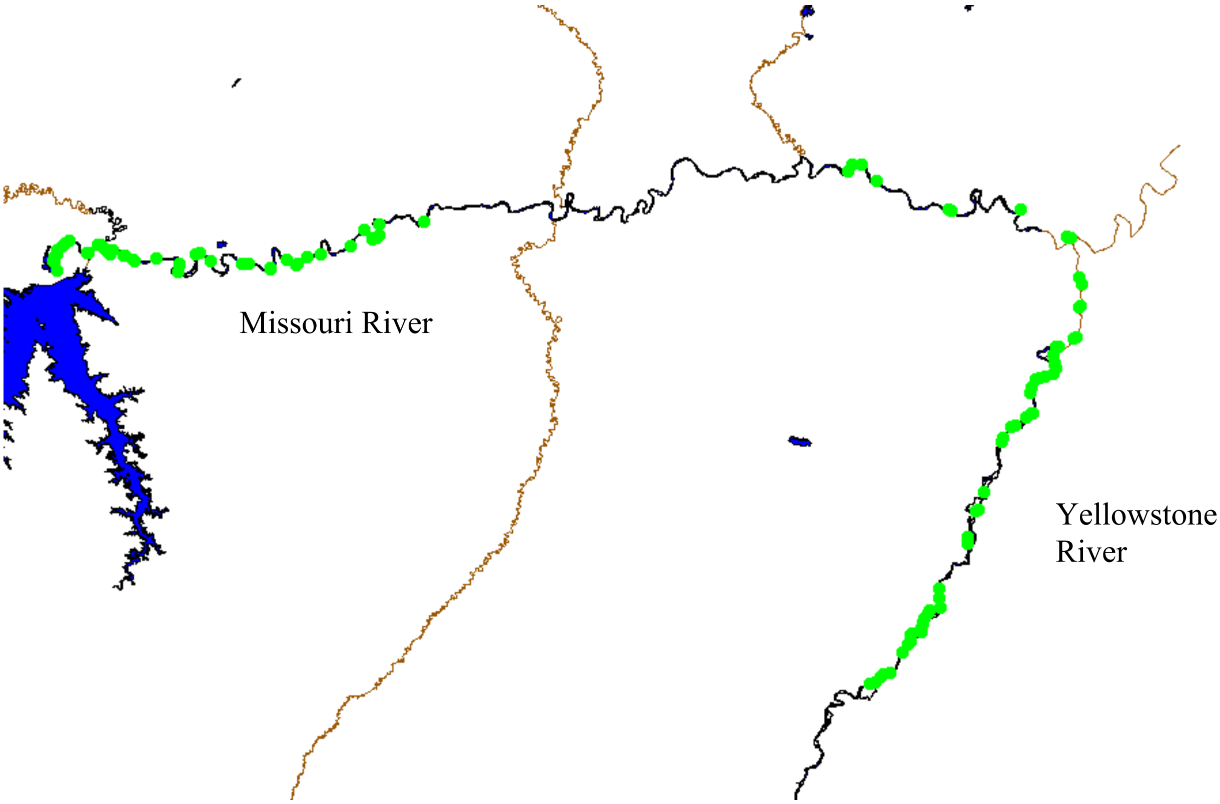
Appendix C. Map extent of shovelnose sturgeon relocations during 2003.



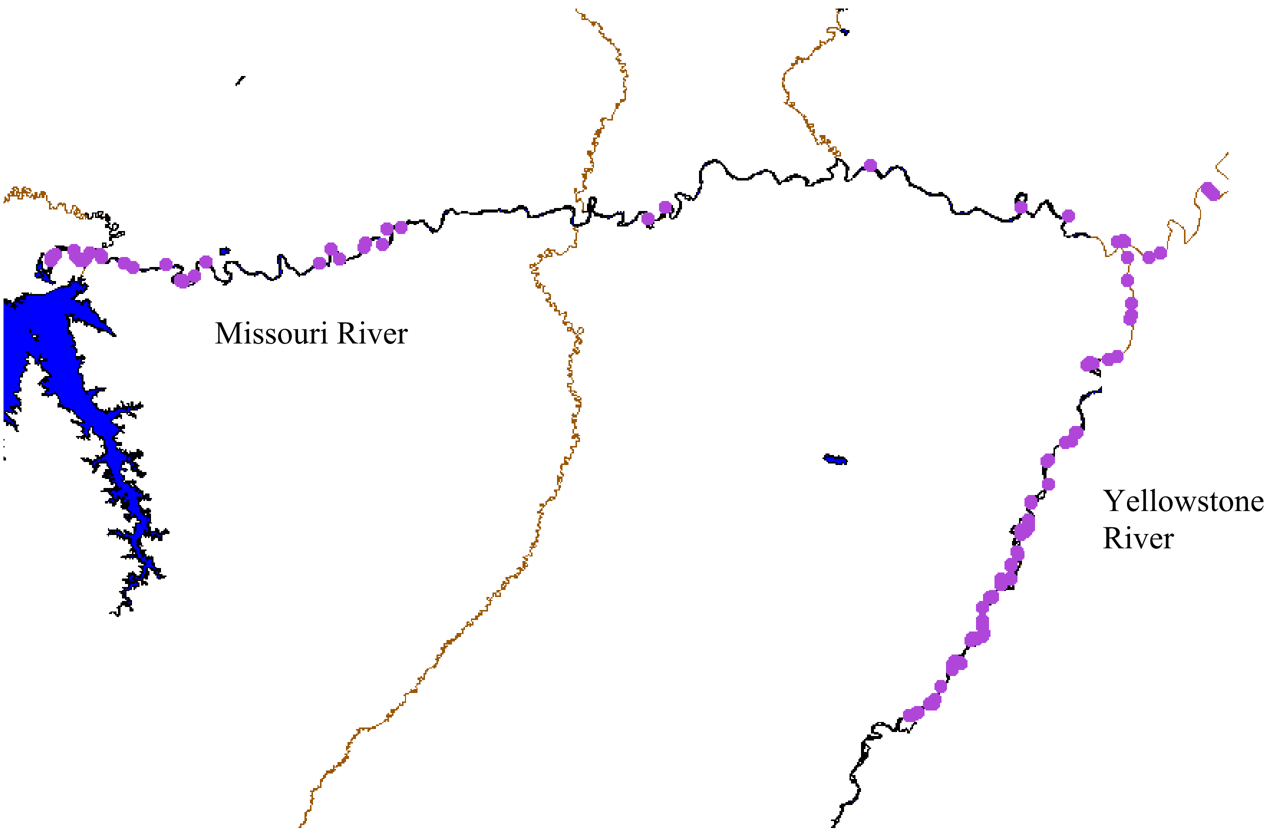
Appendix C.1. Shovelnose sturgeon relocations in April 2003.



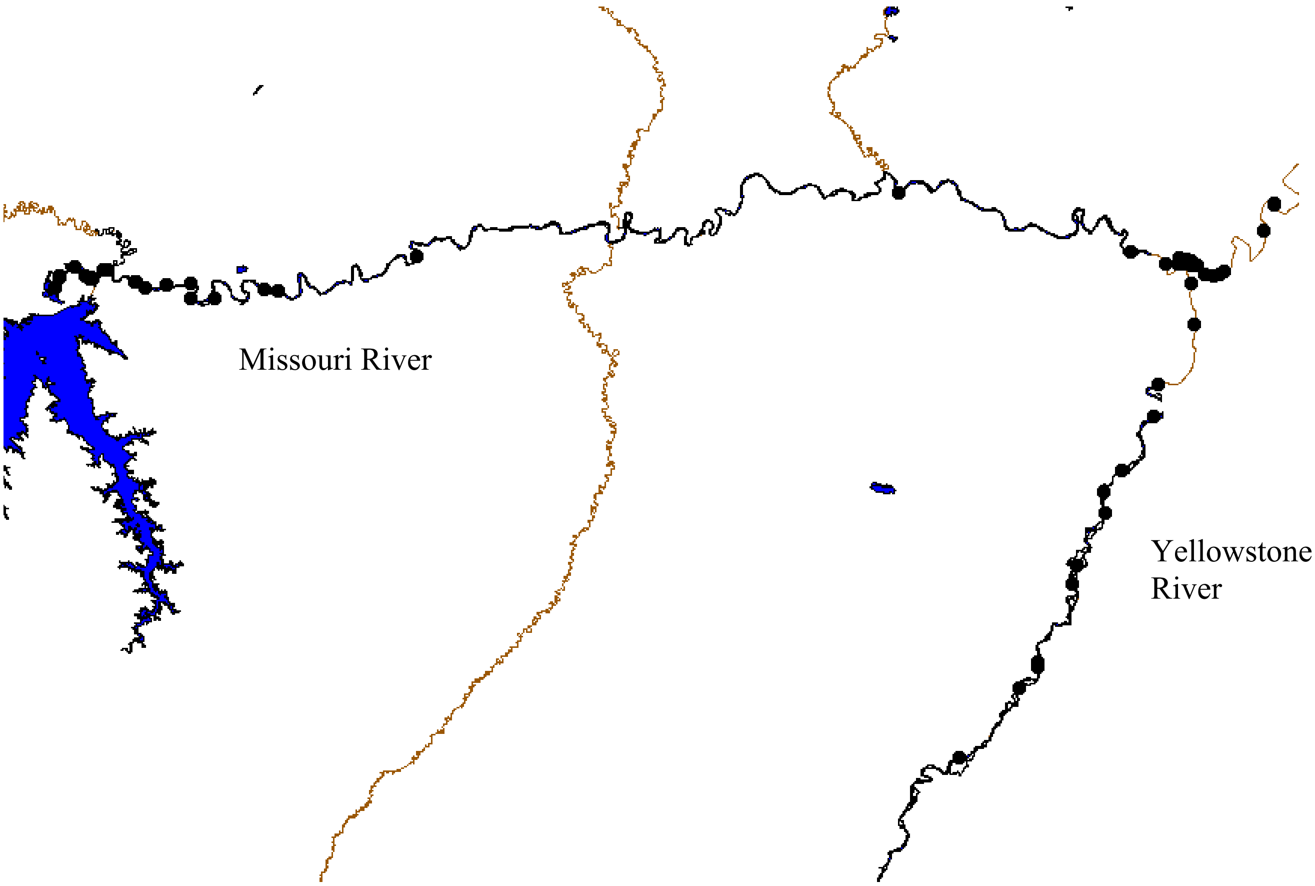
Appendix C.2. Shovelnose sturgeon relocations in May 2003.



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



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



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